The 57th International October Conference on Mining and Metallurgy
05 - 07 October 2026, Bor Lake, Serbia
https://ioc.irmbor.co.rs

DOI: 10.5937/IOC26353N Original Scientific Paper-Environmental Protection

FROM GLASS ART TO CLIMATE ACTION: A CARBON FOOTPRINT CALCULATOR FOR SUSTAINABLE STUDIO PRACTICE

Jelena Nikolić[1a], Dejan Molnar[2a], Hristina Mikić[3a], Đorđe Mitrović[2b], Veljko Savić[1b], Vladimir Topalović[1c], Snežana Grujić[4a]

[1]Institute for Technology of Nuclear and other Mineral Raw Materials, Franše d Eperea 86, 11000 Beograd, Serbia

[2]University of Belgrade, Faculty of Economics, Kamenička 6, 11000 Beograd, Serbia

[3]Institute for Creative Entrepreneurship and Innovation, Svetog Save 6, 35250 Paraćin, Serbia

[4]University of Belgrade, Faculty of Technology and Metallurgy, Karnegijeva 4, 11000, Beograd, Serbia

[1a] j.nikolic@itnms.ac.rs, https://orcid.org/0000-0002-9624-8865,
[2a] dejan.molnar@ekof.bg.ac.rs, https://orcid.org/0000-0002-6081-8141,
[3a] hristinamikic@gmail.com, https://orcid.org/0000-0003-3932-4398,
[2b] dorde.mitrovic@ekof.bg.ac.rs, https://orcid.org/0000-0002-1839-1105,
[1b] v.savic@itnms.ac.rs, https://orcid.org/0000-0002-8602-8260,
[1c] v.topalovic@itnms.ac.rs, https://orcid.org/0000-0002-4177-4649,
[4a] grujic@tmf.bg.ac.rs, https://orcid.org/0000-0002-9123-6830

Abstract

The artistic glass sector has received limited attention regarding greenhouse gas (GHG) emissions despite its reliance on energy-intensive processes. This study presents the development and validation of a GHG calculator designed to estimate the carbon footprint of artistic glass production and support sustainable material and energy choices. The calculator was tested using representative production scenarios. The results showed that replacing virgin raw materials with recycled glass (cullet) reduced the product carbon footprint by approximately fourfold. In addition, electricity generation significantly influenced emissions from electrically heated furnaces, with countries relying predominantly on renewable energy sources exhibiting approximately 2.5 times lower product carbon footprints than those with more carbon-intensive electricity mixes.

***Keywords**: GHG calculator, artistic glass, recycled glass, sustainability.*

1. INTRODUCTION

Glass art combines creativity, craftsmanship, and technical expertise while requiring considerable energy and material resources. Although the environmental impact of industrial glass manufacturing has been extensively investigated, greenhouse gas (GHG) emissions associated with artistic and small-scale glass production remain largely unexplored. Glass artists typically work in small studios using electric or gas-fired furnaces, where electricity consumption, raw material selection, and production practices strongly influence the carbon footprint of the final product [1,2].

Increasingly stringent environmental regulations and sustainability initiatives, including the European Green Deal, the GHG Protocol, ISO 14067, and the Product Environmental Footprint (PEF), promote transparent reporting of product-related GHG

emissions. As carbon footprint information becomes increasingly important for products placed on the market, glass artists face new challenges because most have limited experience with carbon footprint assessment and environmental reporting. Therefore, practical and accessible tools are needed to support sustainable decision-making. Carbon footprint calculators provide an efficient means of quantifying GHG emissions, identifying major emission sources, and comparing alternative production scenarios. In artistic glass production, they enable evaluation of the effects of energy consumption, raw material selection, transportation, recycling, and waste management on the overall carbon footprint [3-5].

To address these challenges, a dedicated GHG calculator, named the ArtGlass calculator, was developed for glass artists and small studios. The calculator provides a simple approach for estimating greenhouse gas emissions without requiring expertise in life cycle assessment or environmental accounting. Its modular methodology can be further expanded by incorporating additional emission sources, updated emission-factor databases, and region-specific datasets, and can also be adapted to larger-scale glass manufacturing facilities. This paper presents the development of the ArtGlass calculator and its application to representative production scenarios. The effects of furnace electricity consumption, national electricity generation mixes, and recycled glass utilization on the carbon footprint of glass art production are evaluated to identify practical opportunities for reducing greenhouse gas emissions.

2. EXPERIMENTAL

The study consisted of four stages. First, the ArtGlass carbon footprint calculator was developed based on a systematic assessment of materials, technologies, and production practices used by glass artists. Data were collected through questionnaires, interviews, and analysis of representative glassworking processes. The survey covered raw materials (commercial glass batches, natural raw materials, and recycled glass), processing techniques, furnace types, energy sources, transportation, waste management, electricity and fuel consumption, and production volumes. The calculator was developed using emission factors consistent with the GHG Protocol, including electricity and fuel consumption, raw material production, water supply, wastewater treatment, refrigerant leakage, and waste management. In the second stage, the calculator was evaluated for different electricity consumption scenarios representative of small electric furnaces, which are the most used melting equipment in artistic glass production. Specific electricity consumptions of 4, 6, 7, 8, and 10 kWh kg^{-1} of glass were considered to assess the influence of furnace utilization and operating efficiency [6]. The third stage investigated the effect of national electricity generation mixes by comparing countries with different shares of renewable and fossil-based electricity. Finally, the influence of recycled glass (cullet) was evaluated using glass batches containing 10, 25, 30, 40, and 50% cullet and compared with a scenario based on direct glass reshaping or decoration without remelting. All scenarios were evaluated to produce 10 kg of melted glass, while all parameters other than the investigated variable were kept constant.

3. RESULTS AND DISCUSSION

The ArtGlass carbon footprint calculator, developed within the European Union-funded project ‟Glassmaking Tradition Meets Innovation", provides glass artists and small studios with a practical tool for estimating greenhouse gas emissions associated with their activities. The calculator is freely available through the Creative Glass Serbia platform (https://creativeglassserbia.com/en/circular-glass-en/). It incorporates country-specific emission factors for Europe, the United States, and Canada, enabling carbon footprint calculations under different regional conditions. Users enter data on material consumption, energy use, waste generation, and other production parameters. Based on these inputs, the calculator automatically estimates the total carbon footprint and quantifies the contribution of individual emission sources. The generated report summarizes greenhouse gas emissions for a selected production period or production batch, helping users identify major emission hotspots and evaluate opportunities for reducing their environmental impact. The report can also be exported and saved in PDF format for documentation and future reference.

Electricity consumption during glass melting was identified as the dominant contributor to the carbon footprint of glass art production. Since most glass artists use small electric furnaces, the ArtGlass calculator was evaluated using five representative electricity consumption scenarios: 4, 6, 7, 8, and 10 kWh kg^{-1} of glass. To facilitate comparison among scenarios, the conservative operating condition (10 kWh kg^{-1} of glass), representing the highest carbon footprint under identical production parameters, was taken as the reference (100%), and the carbon footprints of the remaining scenarios were calculated as percentages relative to this value. These values represent optimistic (4 kWh kg^{-1}), typical (6–7 kWh kg^{-1}), and conservative (8–10 kWh kg^{-1}) operating conditions, reflecting differences in furnace utilization and heat losses. Figure 1 illustrates the relative carbon footprint for the evaluated electricity consumption scenarios, normalized to the conservative scenario (10 kWh kg^{-1} of glass), which was assigned a value of 100%. Under the optimistic scenario (4 kWh kg^{-1}), the carbon footprint is reduced by approximately 36% compared with the conservative scenario and by approximately 18% relative to the reference scenario (7 kWh kg^{-1}). These results demonstrate that improving furnace loading and operating efficiency is an effective strategy for reducing emissions. The optimistic scenario assumes a fully loaded furnace, minimized door opening, and an optimized melting schedule to reduce heat losses. Although these conditions are difficult to maintain in artistic glass production, they represent a realistic target for improving process sustainability.

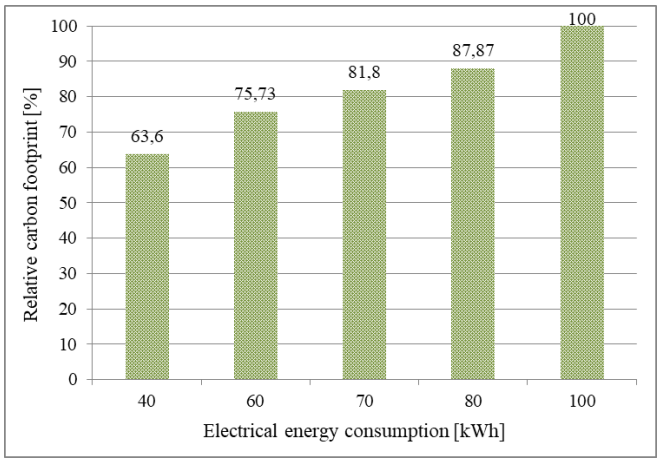


Figure 1. *Influence of specific electricity consumption (4–10 kWh kg⁻¹ of glass) on the carbon footprint of glass art production in Serbia*

The carbon footprint calculated by the ArtGlass calculator varied considerably among countries due to differences in the carbon intensity of electricity generation. Since electricity consumption during glass melting is the dominant source of greenhouse gas emissions, countries with a greater share of renewable or low-carbon electricity exhibited substantially lower carbon footprints than those relying on fossil fuels. Among the evaluated countries, Albania showed the lowest carbon footprint because its electricity is generated almost entirely from hydropower, followed by France, where nuclear power dominates electricity generation. Slovenia exhibited intermediate values, while Czechia produced higher emissions due to its continued dependence on coal.

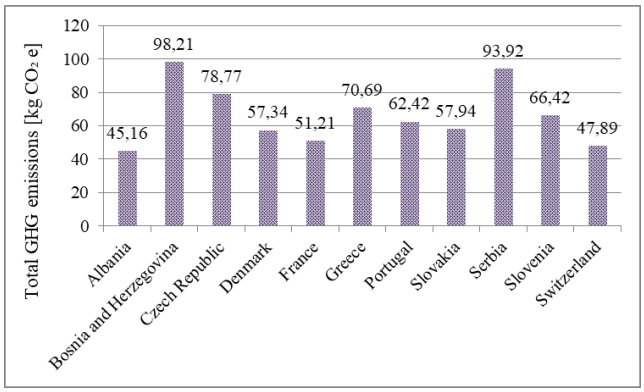


Figure 2. *Total greenhouse gas emissions for the production of 10 kg of glass in different countries with different electricity generation mixes*

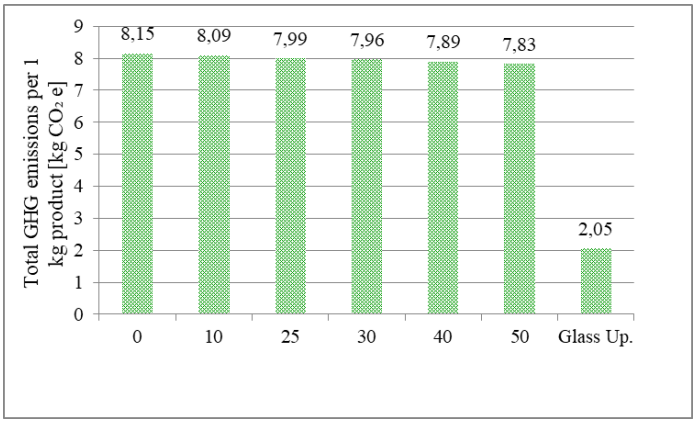


Figure 3. *Influence of recycled glass utilization and direct glass reuse without remelting on the carbon footprint of glass art production*

The highest carbon footprint was obtained for Bosnia and Herzegovina, with Serbia ranking slightly lower because both countries rely predominantly on lignite-fired power plants (Figure 2). These findings demonstrate that the environmental impact of glass art production depends not only on production efficiency but also on the carbon intensity of the national electricity grid. Consequently, identical production processes can generate substantially different greenhouse gas emissions depending on the country in which they are carried out.

The effect of recycled glass (cullet) on the carbon footprint was evaluated for Serbian conditions by considering glass batches containing 10, 25, 30, 40, and 50% cullet (Figure 3). The results indicate that increasing the recycled glass content leads to a reduction in greenhouse gas emissions; however, within the investigated range, the overall decrease in the carbon footprint is relatively modest. This is because electricity consumption during glass melting remains the dominant source of emissions and outweighs the benefits associated with replacing virgin raw materials with recycled glass. A much greater reduction was achieved when glass melting was eliminated entirely. In the scenario where recycled glass was directly reshaped or decorated without remelting, the calculated carbon footprint was approximately four times lower than that of conventional glass melting. These findings demonstrate that, while increasing the cullet content contributes to improved environmental performance, the greatest potential for reducing greenhouse gas emissions lies in artistic techniques based on the direct reuse of existing glass.

4. CONCLUSION

The ArtGlass carbon footprint calculator was developed as a practical tool for estimating greenhouse gas emissions associated with artistic glass production. The results identified electricity consumption during glass melting as the dominant source of emissions, with improved furnace utilization reducing the carbon footprint by up to 36%. The carbon footprint also varied significantly among countries due to differences in

electricity generation mixes. Increasing the recycled glass content in glass batches provided only a modest reduction in emissions, whereas direct reshaping or decoration of recycled glass without remelting reduced the carbon footprint by approximately fourfold. The developed calculator supports glass artists in evaluating and reducing the environmental impact of their work and provides a foundation for further development and application to larger-scale glass production.

ACKNOWLEDGEMENTS

This work was supported by the European Union under the project Grant Agreement No. 101174407 and the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia (Contract No. 451-03-33/2026-03/200023 and 451-03-34/2026-03/ 200135).

REFERENCES

[1] D. Molnar, J. Nikolić, H. Mikić, Dj. Mitrović, Book of Abstracts of ENERGY 2025, 14-17. april, 2025., Zlatibor, Serbia, p. 108-109.
[2] https://www.epa.gov/climateleadership/ghg-emission-factors-hub (25. 7. 2026.).
[3] Carbon price forecast 2030-2050: assessing market stability & future challenges. Enerdata, 2025, https://www.enerdata.net/publications/executive-briefing/carbon-price-projections-eu-ets.html (25. 7. 2026.).
[5] O. Palone, L. Mecucci, L. Cedola, G. Vanga, D. Borello., J. Clean. Prod., 570 (2026) 148702.
[6] E. Worrell, C. Galitsky, E. Masanet, W. Graus., Energy Efficiency Improvement and Cost Saving Opportunities for the Glass Industry, Berkeley Lab, Berkeley, 2008, p. 46-69.