CIRCULAR FOAM

D 5.3 Results of successful simulations for one ofthe applications (as a fridge) without optimization

Author:

Corrado Cecchini, Aldo Teste, Florian Hupka, Dariusz Niedziela, Sebastian Hänisch, Yann Spiesschaert

Date: 19 January 2026

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 10103684

Technical References

Project Acronym	**CIRCULAR FOAM**
Project Title	Systemic expansion of regional CIRCULAR Ecosystems of End-of-Life FOAM
Project Coordinator	Dorota Pawlucka, Covestro Deutschland AG dorota.pawlucka@covestro.com
Project Duration	October 2021 – September 2025 (48 months)

Deliverable No.	5.3
Dissemination Level[1]	PU
Work Package	WP5: Demonstration of the use of recycled materials in applications and evaluation
Task	5.3: Results of successful simulations for one of the applications (as a fridge) without optimization
Lead Beneficiary	UNI
Contributing Beneficiaries	COV, ELUX, FHG
Due Date of Deliverable	30.07.2025

[1]PU-public, CO-confidential, only for members of the consortium (including the Commission Services), EU-SEC-classified information: SECRET UE (Commission Decision 200/444/EC)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101036854

Executive Summary

The raw materials coming from the recycling technologies developed in this project were able to be used in the production of r-polyol and r-pMDI. However, upscaling of the production process for r-pMDI met with several delays, resulting in a limited availability of r-pMDI for application testing. Therefore, a strategic pivot was made to not produce a real refrigerator cabinet, but to simulate the filling of one using data generated in the project. The simulations were then used to compare PU chemicals from recycling with the conventional ones based on fossil-feedstock. The simulations were made using software developed by the Fraunhofer Institute.

In this context, an Electrolux Genesi range refrigerator, produced in Susegana, Italy, with high energy efficiency (B European class) was used as the cabinet of choice to perform the simulations on. To obtain the filling simulations several steps had to be taken. First the foam rise, based on the hand-mixed data of fossil and recycled foams was simulated to tune the software.

Following this, PU foam was prepared by industrial mixing (high pressure technology) and the required rise curve and kinetic and thermodynamic parameters were recorded. These data were used to simulate the filling of the insulation cavity of the chosen refrigerator to further tune the software. Then the hand mixed foam data from fossil chemicals was utilized to simulate the filling of the insulation cavity to align the simulation data between hand mixed foams and industrial mixed foams.

Lastly, the filling of the insulation cavity using the data of hand mixed foams from recycled chemicals was performed.

In all simulations a successful filling of the cabinet was obtained, with slight differences that aligned with the expected process characteristics. The recycled foam simulations demonstrate their capability to effectively fill the cabinet geometry and their potential to be used on an industrial scale.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101036854

Disclaimer

Any dissemination of results must indicate that it reflects only the author's view and that the Agency and the European Commission are not responsible for any use that may be made of the information it contains.

Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101036854

1 Introduction

The project "CIRCULAR FOAM - Systemic expansion of territorial CIRCULAR Ecosystems for end-of-life FOAM" will develop and demonstrate technological steps required to achieve circularity of plastics in post-consumer applications, using the example of rigid PU foams used as insulation in refrigerators and construction.

The overall objective of Work Package 5 (WP5) is to demonstrate the use of recycled materials in applications and to evaluate their performance. In task 5.2 the recycled materials obtained from the process of WP4 and WP5 task 5.1 were tested in the formulation typical for appliance foams by Covestro and Electrolux.

Initially, task 5.3 and thus deliverable 5.3 was based on the production of a refrigerator cabinet with recycled raw materials. However, as the available quantities of polyol and pMDI from recycling were not enough to enable foaming real scale refrigerator cabinets and doors, as originally planned, the decision was taken to strategically pivot and work through simulations to compare PU chemicals from recycling with the conventional ones based on fossils. The data generated in Task 5.2 was then used as a basis for the simulations. This task was carried out by Electrolux in strong collaboration with Covestro, who provided the chemicals, and with the Fraunhofer Institute, who ran simulations of PU foaming process.

The comparison was based on the following steps:

1. Preparation of PU foams with chemicals from fossil and from recycling by hand-mix and recording of their rise curve and the main kinetic and thermodynamic parameters using the Foamat equipment.
2. Simulate the foam rise to tune the software developed by the Fraunhofer Institute.
3. Preparation of PU foam from fossil by industrial mixing (high pressure technology), recording rise curve and kinetic and thermodynamic parameters.
4. Select a real refrigerator cabinet produced on the manufacturing line and simulate the filling of its insulation cavity to tune the software.
5. Simulate the filling of the insulation cavity of the selected refrigerator cabinet using the data of hand mixed foam from fossil chemicals. This step allowed to align foams produced by hand mixing and by industrial mixing.
6. Simulate the filling of the insulation cavity of the selected refrigerator cabinet using the data of hand mixed foams from recycled chemicals.

In the following chapter the results obtained in all the above steps are presented and discussed.

2 Results

Step 1 and 2. Figure 1 shows the rise curves of fossil and recycling based foams obtained by hand mix; the continuous lines are the experimental recording, while the dotted lines is the simulated rise. Curves are perfectly overlapping.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101036854

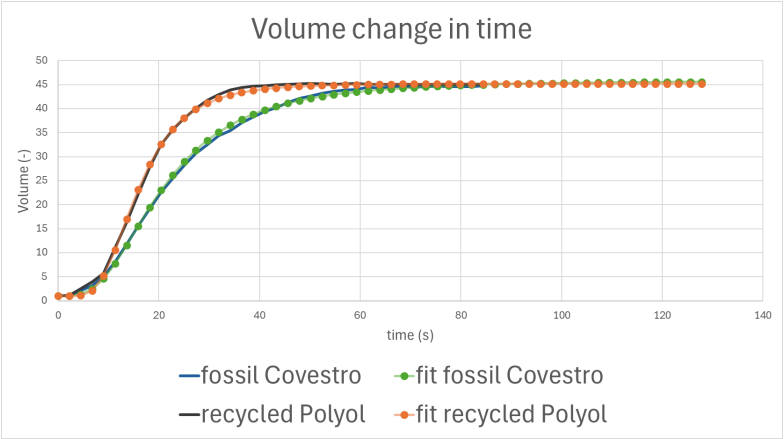

FIGURE 1 RISE CURVES OF FOAMS BASED ON FOSSIL AND RECYCLED POLYOL

The foam obtained with recycled polyol shows shorter reaction times; according to Covestro, this behaviour is due to the presence of some impurities which work as "catalysts" of the polymerization reaction. More effective purification and finer tuning of the catalysts in the recipe could close this gap in an eventual industrial application.

Step 4 and 5. Figure 2 shows the picture of the selected refrigerator cabinet after steel facings were peeled off. It is a Built In refrigerator belonging to the Electrolux Genesi range, produced in Susegana, Italy, with high energy efficiency (B European class).

FIGURE 2 ELECTROLUX MODEL 17CBMNV0D

This cabinet is foamed in the production line applying the following process parameters:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101036854

- Injection P1: 1.066 kg over 1.3325 s
- Injection position P2: 1.603 kg over 2.00375 s
- Injection output: 0.8 kg/s
- Wall temperature: 45°C
- Injected material temperature: 20 °C
- Specific weight of injected reaction mixture 1228 kg/m³
- Initial pressure 1 bar

The simulation was based on a mesh size of 2191607 elements and venting holes were modeled as permeable walls.

The result of the simulation can be seen in Figure 3.

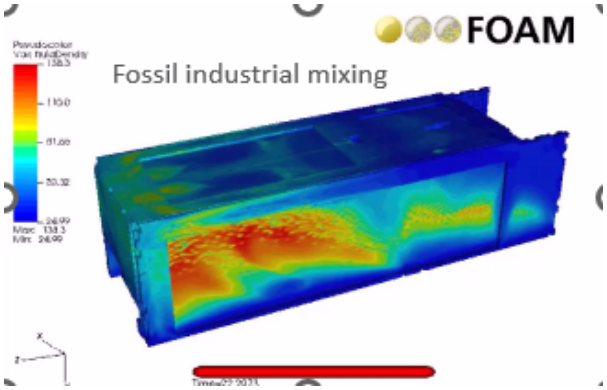

FIGURE 3 SIMULATION OF CABINET FILLING WITH FOSSIL PU CHEMICALS WITH INDUSTRIAL MIXING

The simulation of the cavity filling was repeated using the data of foam characterization related to fossil chemicals and hand mixing; result is presented in Figure 4.

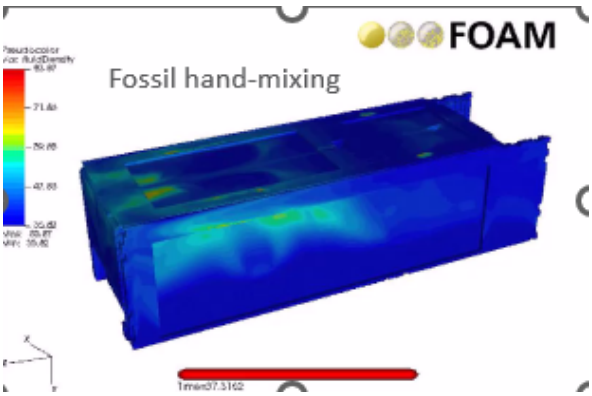

FIGURE 4 SIMULATION OF CABINET FILLING WITH FOSSIL PU CHEMICALS WITH HAND MIXING

In both cases, the cavity was filled without voids. Colours indicate foam density in the different cavity areas, and the difference is due mainly to the different reactivity. Indeed, industrial mixing provides higher energy to the system, and this reflects in shorter reaction times and a slightly different flow behaviour in the cavity.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101036854

Step 6. The baseline for the comparison with fossil PU chemicals is now defined and the filling of the refrigerator cavity can be simulated using the data of the hand mixed foams. Figures 5 and 6 show the result of these simulations.

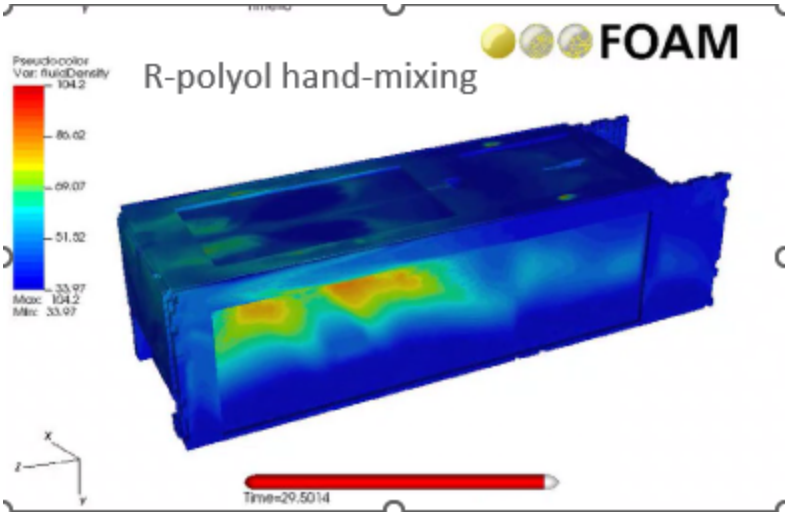

FIGURE 5 SIMULATION OF CABINET FILLING WITH POLYOL FROM RECYCLING WITH HAND MIXING

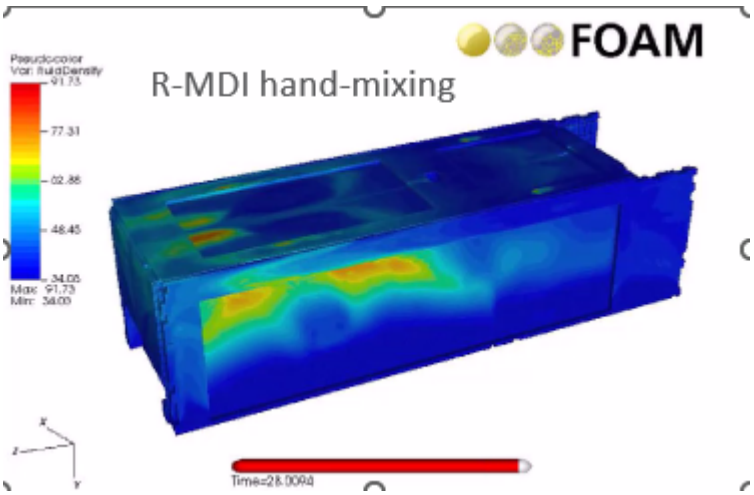

FIGURE 6 SIMULATION OF CABINET FILLING WITH PMDI FROM RECYCLING WITH HAND MIXING

In both cases the cavity was well filled, without foam voids. Moreover, the colors, indicating foam density, are very similar to the ones of the Figure 4 related to PU chemicals from fossil.

The simulation provides a further parameter, the value of the gas pressure, which indicates the area where the 4 foam flows coming from the pour holes meet. In all the cases the meeting point takes place in the bottom part of the back side of the cabinet; this is an additional confirmation of the equivalence between PU chemicals from recycling and from fossil.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101036854

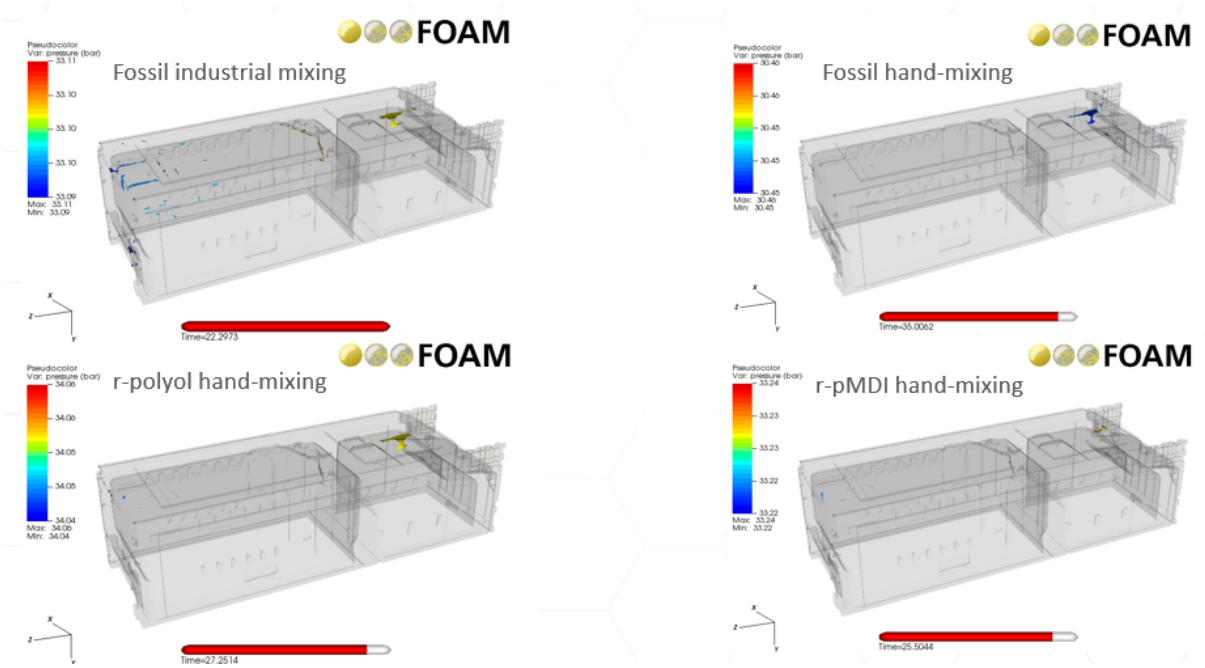

FIGURE 7 SIMULATION OF CABINET FILLING – GAS PRESSURE GRAPHS

3 Conclusion

- A comparative analysis between fossil foams produced through industrial mixing and manual hand-mixing has been conducted.
- Both mixing approaches successfully achieve cabinet filling, with foam behaviour differences aligned with expected process characteristics.
- Simulations of recycled foams demonstrate their capability to effectively fill the cabinet geometry.
- Recycled foams exhibit promising potential for industrial-scale application, subject to successful validation through dedicated production trials

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101036854