From fridge to fridge: polyol from recycling of PU foam wastes

Aldo Testa & Corrado Cecchini

Electrolux Italia SpA

Electrolux's commitment to sustainability

PLASTICS RECYCLING AWARDS EUROPE 2023 WINNER

HIPS – 15% of total appliance weight

First refrigerator with 70% recycled HIPS into inner liner launched in the market in 2022

Steel – 38% of total appliance weight

In 2025, 1,000 «Green steel» with 70% recycled steel used in Susegana

PU – 14% of total appliance weight

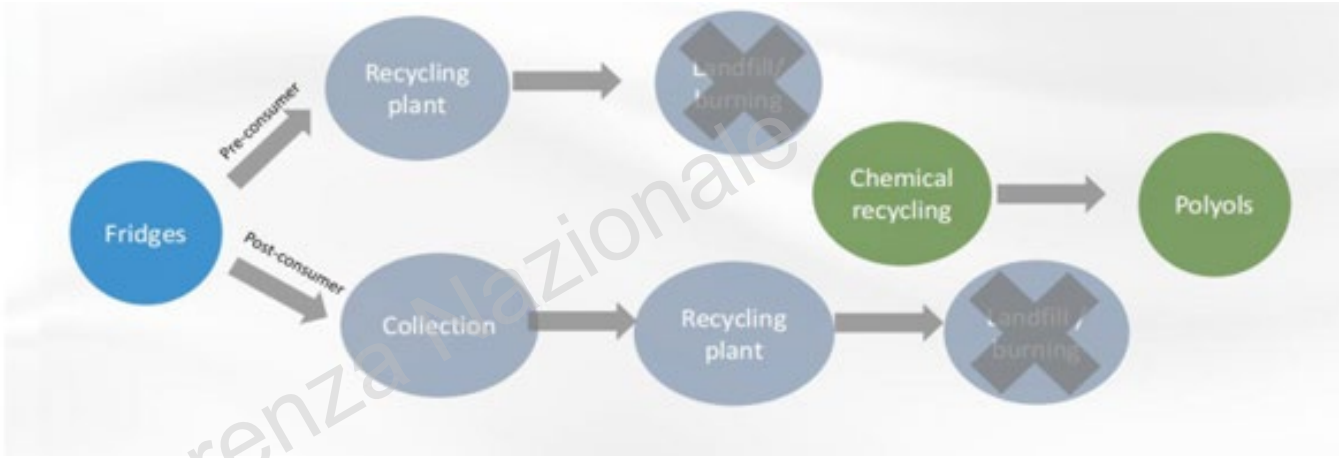
Chemical recycling to get back polyols and PMDI – Polyol from recycling

Background – Recycled Polyol production and potential business

PU FOAM

Automathed treatment
14% of total volumes

Composition
- 85-90% PU Foam
- 15-10% impurities



150KT recycled Foam = 600KT repolyol

1. Fridge production in China 90 million/year
2. Formal channel" recycle: 15 million/year
3. Unofficial channel" recycle: 20-40 million/year
4. " Idle at home" 5 million/year

Preliminary step: chemical compliance

Route	Reaction	Product	Note
alcoholysis	Temp: 150～200℃, Glycols	Polyols	Used in polyol blend

TUV certificate of analysis

Business Stream Products
Softlines

TÜVRheinland®
LGA

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Cologne, 28.11.2024

Test result: According to the kind and extend of tests performed no SVHC exceeding 0.1% have been detected in the present object.

tested by:

28.11.2024 X

Sachverständige(r)/Expert
Signiert von: Markus Clemens

tested by:

28.11.2024 X

Sachverständige(r)/Expert
Signiert von: Ralf Meier

Preliminary step: Life Cycle Analysis – CO_2 emissions -15%

Annex to certificate

Standard ISO 14040:2006, ISO 14044:2006

Certificate Registr. No. CO 50632640 0001

Report No. 70378829 001

Result:

Impact category	Unit	Total
Global warming (GWP100a)	kg CO_2 eq	3.65
Abiotic depletion	kg Sb eq	2.54E-05
Ozone layer depletion (ODP)	kg CFC-11 eq	1.08E-06
Acidification	kg SO_2 eq	1.73E-02
Eutrophication	kg PO_4 eq	1.27E-02
Photochemical oxidation	kg C_2H_4 eq	1.77E-03
Human toxicity	kg 1,4-DB eq	3.05

Polyol from fossil

Polyol from fossil

Annex to certificate

Standard ISO 14040:2006, ISO 14044:2006

Certificate Registr. No. CO 50632640 0002

Report No. 70378829 002

Result:

Impact category	Unit	Total
Global warming (GWP100a)	kg CO_2 eq	3.10
Abiotic depletion	kg Sb eq	1.93E-05
Ozone layer depletion (ODP)	kg CFC-11 eq	8.79E-07
Acidification	kg SO_2 eq	1.23E-02
Eutrophication	kg PO_4 eq	1.06E-02
Photochemical oxidation	kg C_2H_4 eq	1.40E-03
Human toxicity	kg 1,4-DB eq	2.37

Polyol from recycling

Polyol from recycling

Formulated polyol set-up

- As a baseline, a recipe of a formulated polyol used in Susegana and in Rayong and approved in Anderson was chosen. All those plants have adopted the multiple injection as foaming technology.
- The modification consists in replacing 15% of the polyols from fossil with the polyol from recycling
- The result obtained in this evaluation can be very likely applied to Rayong and Anderson plants as well.

- Content of recycled polyol: 15% in ”pure” polyol
- Content of recycled polyol: 6% in foam

Foam recipe used in production		Baseline	Recycled
Polyol	pbw	-	15
Polyol	pbw	100	85
PMDI	pbw	151	151
Cyclopentane	pbw	14.5	14.5
Content of polyol from fossil		37.7%	32%
Content of polyol from recycling		-	6%

Qualification path for a new formulated polyol

PILOT PLANT TRIAL

- Foam characterization
- Cabinet dimensions
- Reverse heat leakage

SMALL LINE TRIAL

- Foam characterization
- Cabinet dimensions
- Reverse heat leakage
- Post-assembly
- Energy consumption

PRESERIES OF SELECTED MODELS

- Energy consumption
- Fit, Feel, Finish evaluation by Quality

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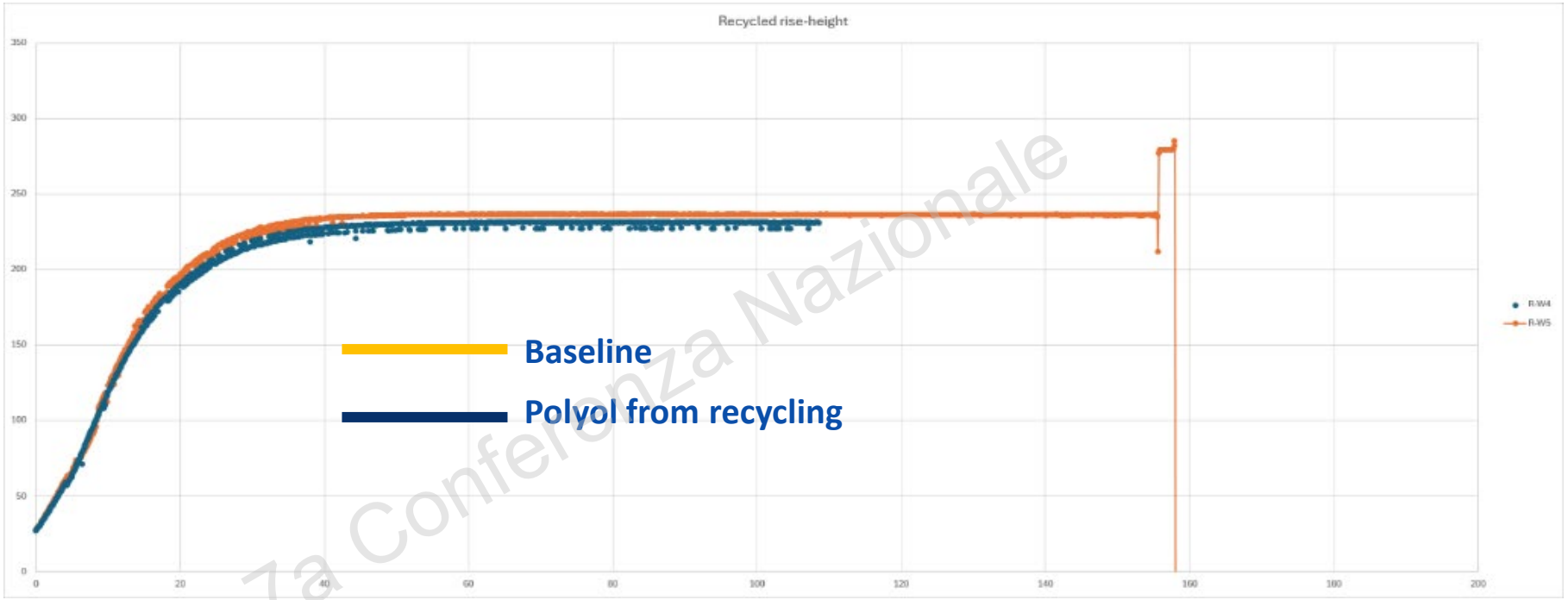
Rise curve comparison by Foamat equipment

25 cm diameter: 300 [g]



Rise curve and reaction parameters were recorded to generate data for future simulation of foaming process.

Baseline and polyol from recycling have the same behavior.

Trial at the PU foam lab of Susegana plant

		BASELINE	REC. POLYOL
Polyol	pbw	100	100
Cyclopentane	pbw	14.5	14.5
PMDI	pbw	151	151
Gel time	s	22-24	22-24
Free rise density	kg/m^3	21.5-22.0	21.5-22.0

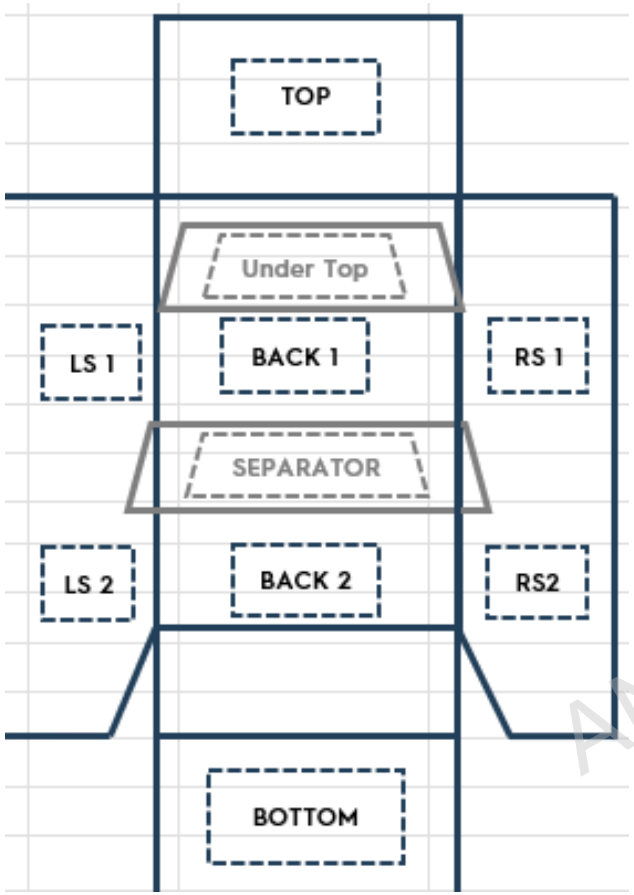
The chosen model:

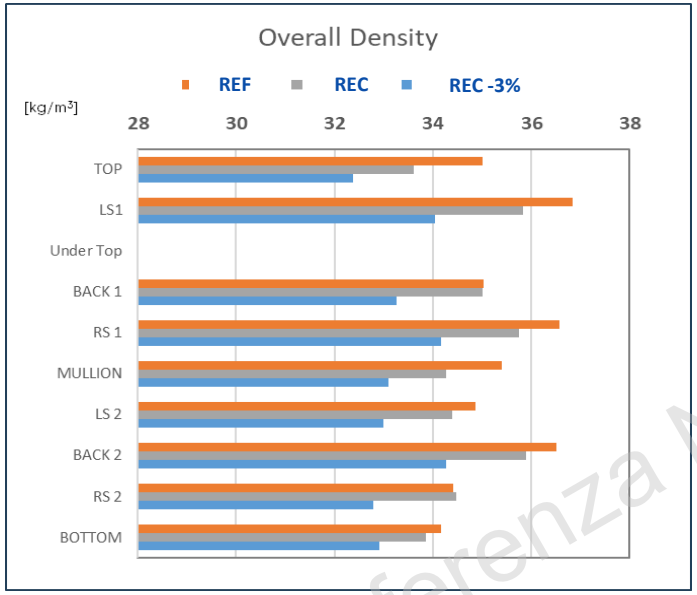
- **Bottom Freezer 1780**
- **Yearly production: > 200,000 unit – Susegana's "high-runner"**

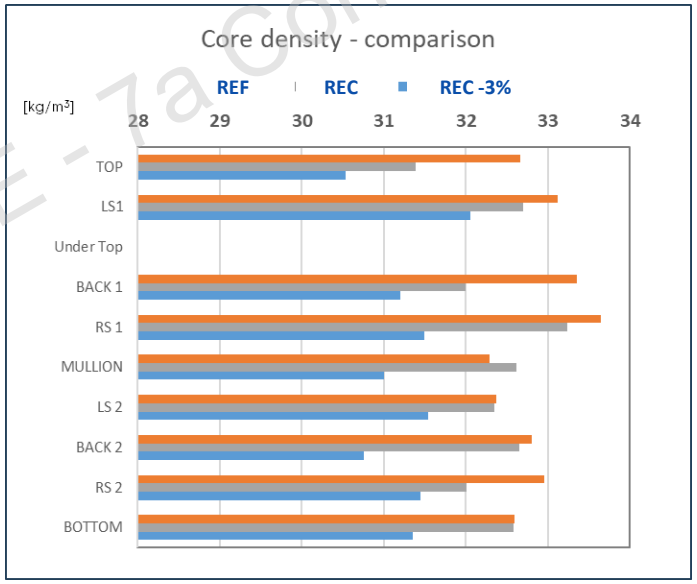
Foaming technology:

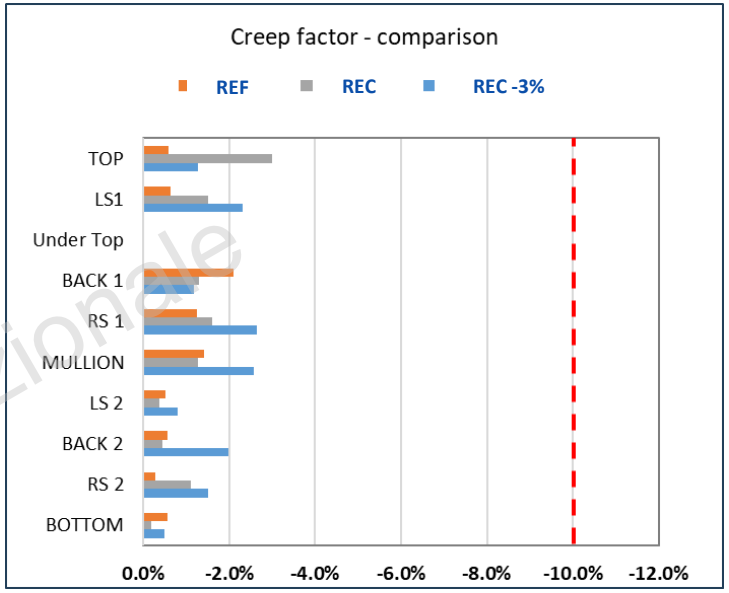
- **Cabinet position door down**
- **Multiple injection from the back**

Foam characterization







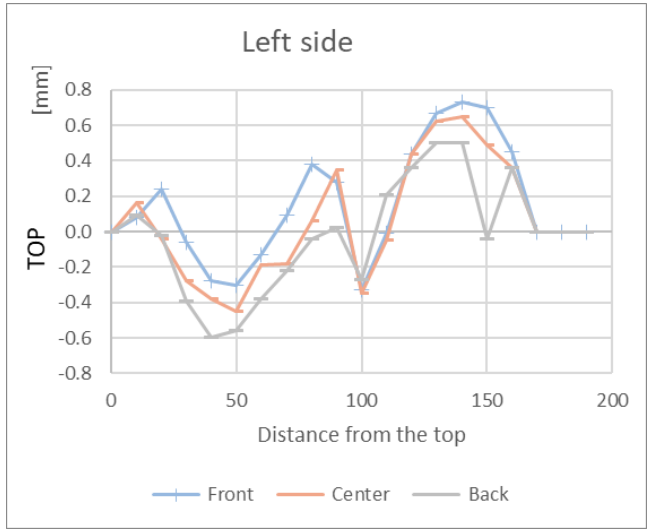


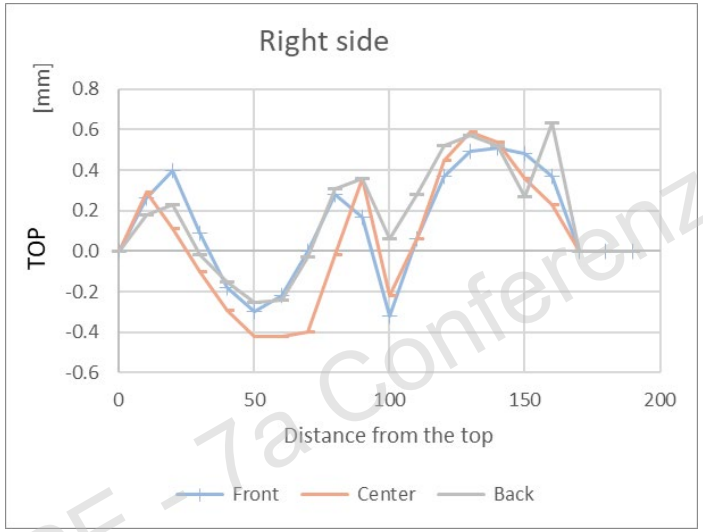
Foaming technology:

- **Cabinet position door down**
- **Multiple injection from the back**
- **Results:**
- **Both reference and polyol from recycling met the specification**
- **3% reduction of foam mass looks feasible with the polyol from recycling**

Evaluation of process-ability: demold time and foam adhesion

Demold time: deformation on cabinet side in spec at the standard demold time of 150 s



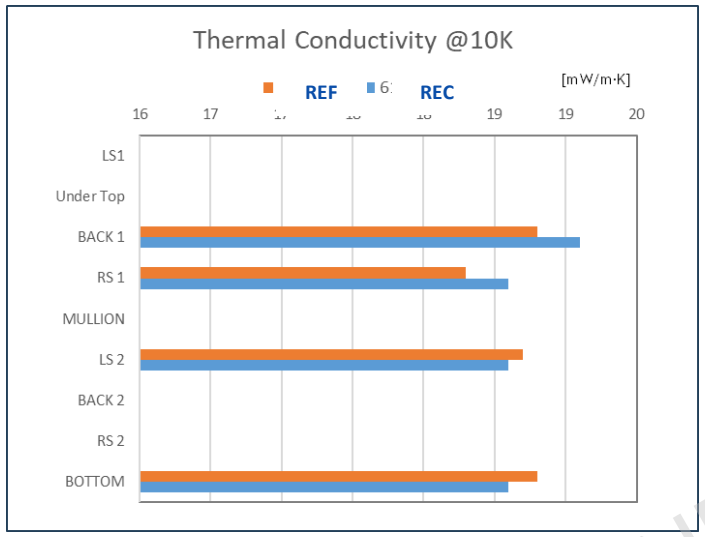


Acceptance limit, mm	1.5
Max deformation on the Left side, mm	0.73
Max deformation on the Right side, mm	0.63
Test result	PASSED

Foam adhesion: comparable to current production

Insulation properties: thermal conductivity @10°C and Reverse Heat leakage

Thermal conductivity vs baseline polyol



REVERSE HEAT LEAKAGE [W] – Internal method

	BASELINE		REC. POLYOL	
	Sample 1	Sample 2	Sample 1	Sample 2
Freezer	18.9	18.6	18.4	18.8
Fresh Food	50.5	49.3	50.4	50.6
Total	69.4	67.9	68.8	69.4
STD Dev.	0.7	0.8	0.6	0.6
Average	68.7		69.1	

Reverse Heat leakage: the gap vs the baseline is equivalent o +0.6%, well inside the test allowance

Next step: the small line trial planned in Q3 2026

PASSED

PILOT PLANT TRIAL

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SMALL LINE TRIAL

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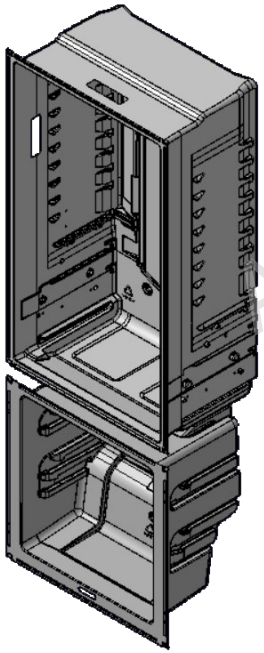
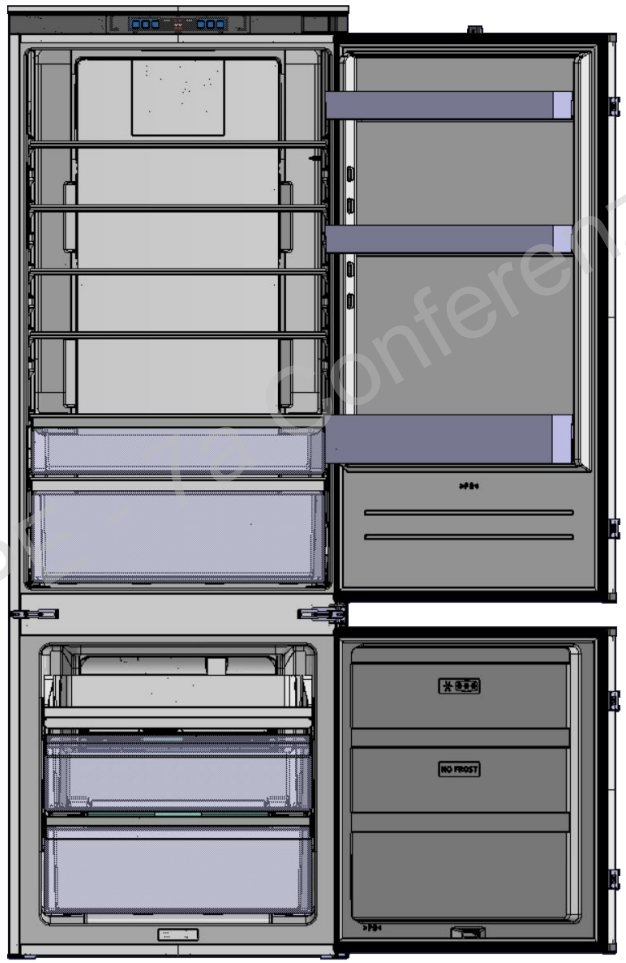
Business opportunity: design a “sustainability hero”

Polyol from recycling as a strategic contributor to our sustainability targets and as a marketing leverage to differenciate our product in the market.

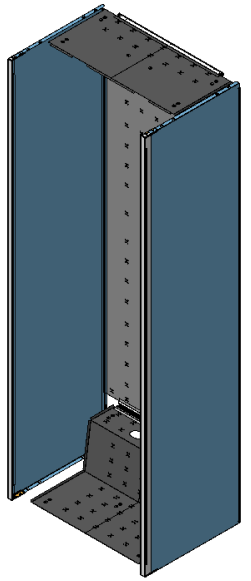
Energy

R-HIPS



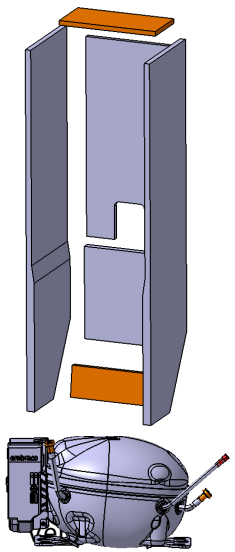


Green steel



Polyol from recycling

Approval ongoing



Conclusion

- The use of raw materials from recycling is one of the objectives pursued by Electrolux within the company strategy on Sustainability.

- Since 2022, domestic refrigerators and freezers with inner-liner containing 70% of HIPS from mechanical recycling are available in the European market and last year, the use of green steel has been implemented, bringing the content of recycled steel up to 70%.

- The third mainstream of materials from the end-of-life treatment of domestic refrigerators and freezers, the PU foam, has been approached through chemical recycling within a collaboration with preferred suppliers of PU chemicals.

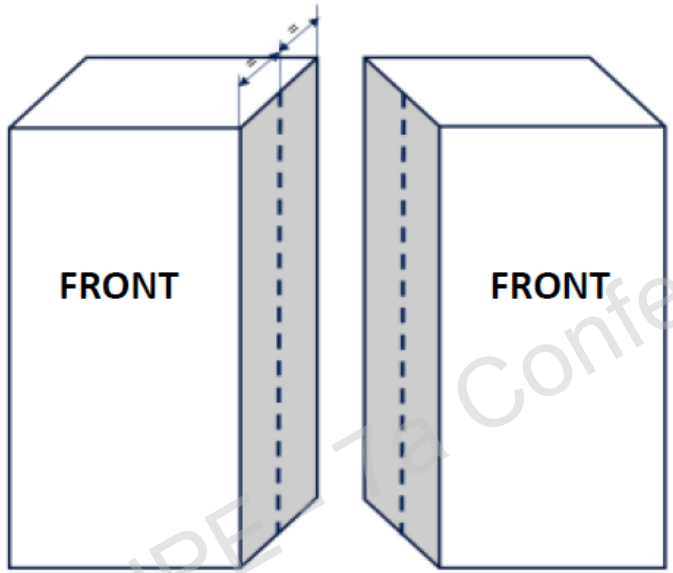
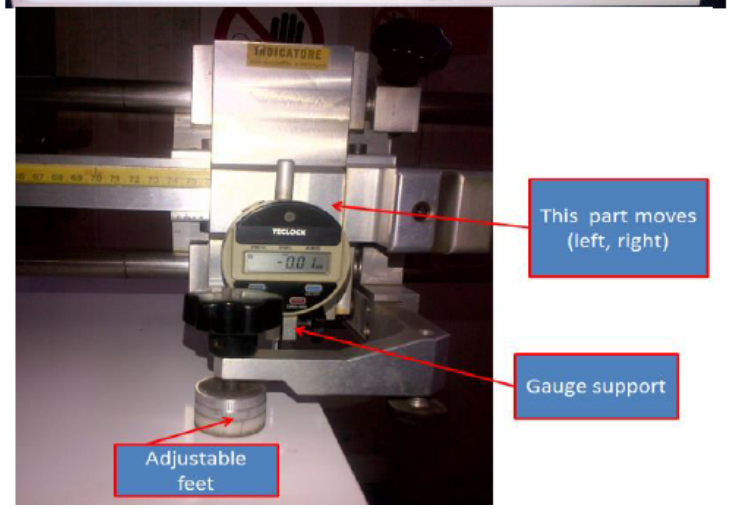
- The lab scale evaluation of a system containing a polyol from alcoholysis gave promising results and in short time an industrial trial will be planned to complete its approval. Tests to increase the content of recycled polyol have been planned.

- The availability of large volumes for a potential industrialization has been confirmed, providing the technical conditions for the eventual launch of a specific “green” model platform in the next future.

Thanks for your attention!

Electrolux

Measurement of cabinet side profile – Internal method

FOAMED CABINET BOW EFFECT	Planarity of each side of the Foamed cabient all along each side centerline: 	The BOW EFFECT shall be calculate on each side centerline on foamed cabinet. It must not exceed the **3 mm MAX** of deviation on each side of the cabinet, measured after 24 hours of stabilization of the foamed appliance Example of measuring tool:  

Reverse Heat leakage method

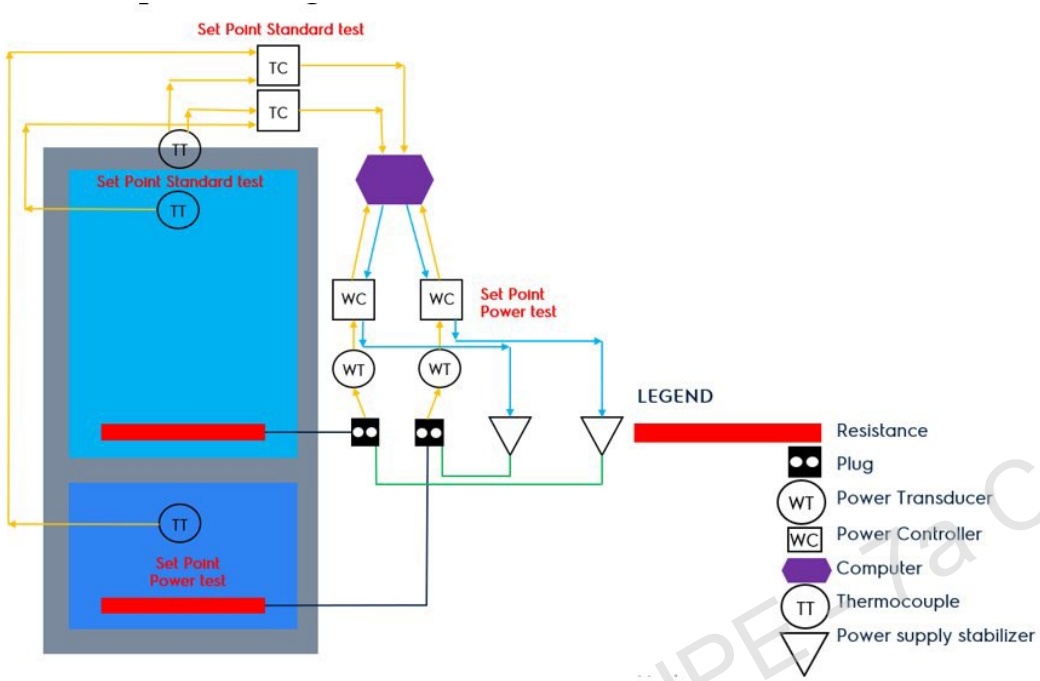


Figure 1. Control system scheme for RHL test

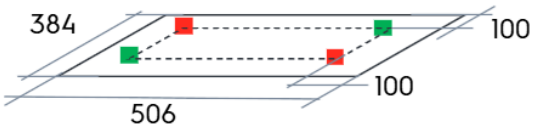
External wall thermocouple => center

Internal wall thermocouple=> center

Internal suspended thermocouple with metal head

Suspended control thermocouples with metal head

Controlled Variables: W
Set point(maximum 6): T1, T3, T5, T7, T9, T11



TC interne: n° 18
TC esterne: n° 6