University of Padova – Department of Industrial Engineering

Master Degree in Chemical and Process Engineering

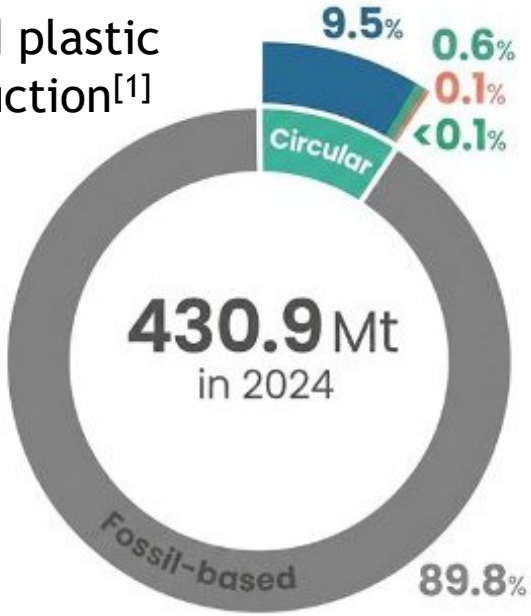
Comparison of different solvolysis processes for the chemical recycle of rigid polyurethane foams

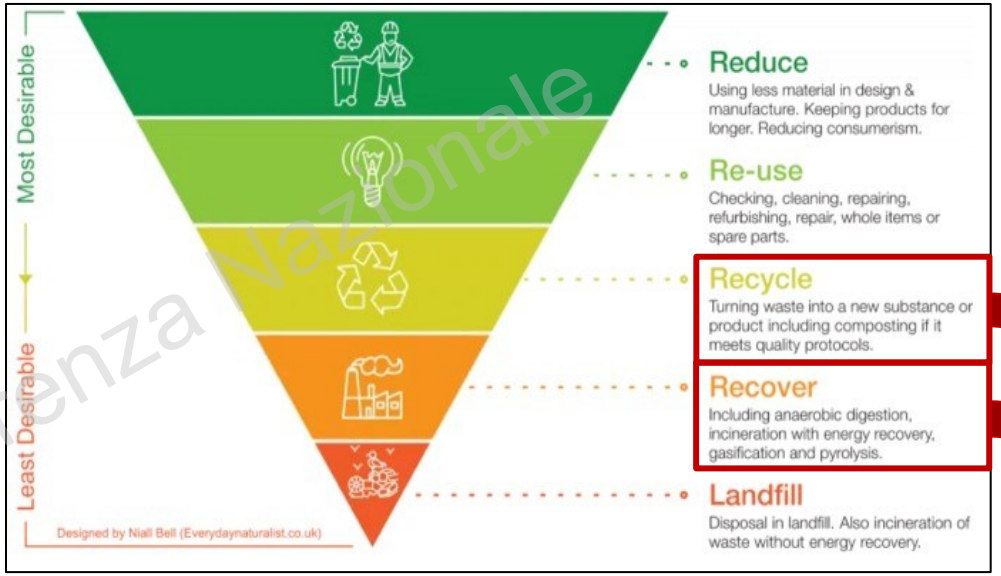
Roma, 07/05/2026

Alessandro Bonato

INTRODUCTION

World plastic production[1]





Pollution of air, lands and seas

↓

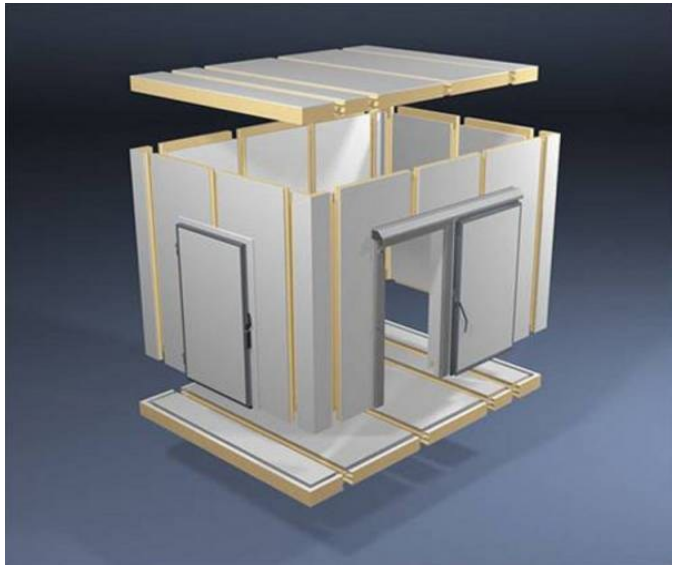
Need to recycle

THERMAL VALORIZATION: the most used one

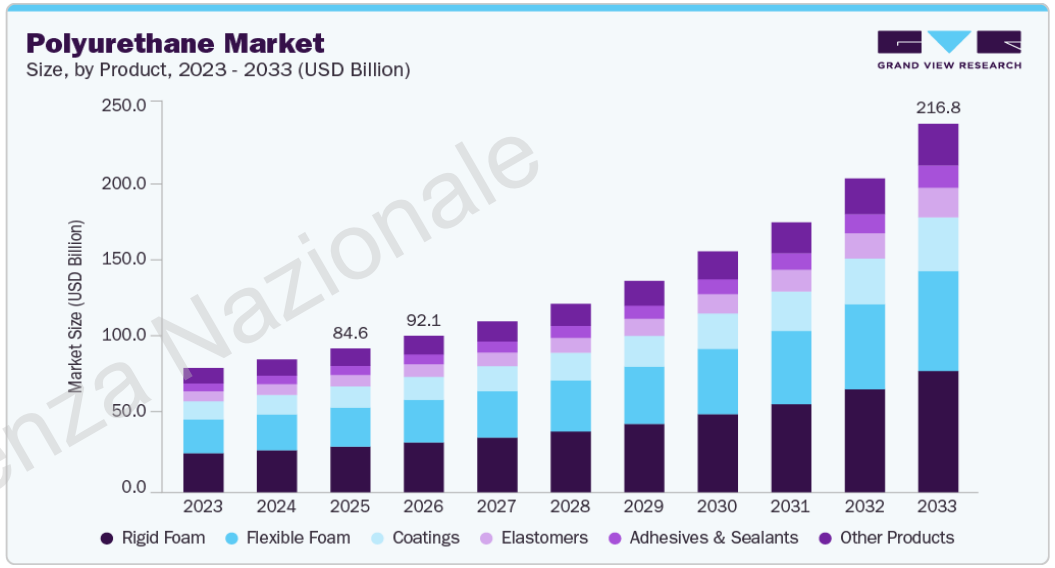
CHEMICAL RECYCLING: **glycolysis**, **aminolysis**, hydrolysis, acidolysis, phosphorolysis, etc

[1] "Plastics the Fast Facts 2025, Global and European plastics production and economic indicators", October 2025, Plastics Europe AISBL.

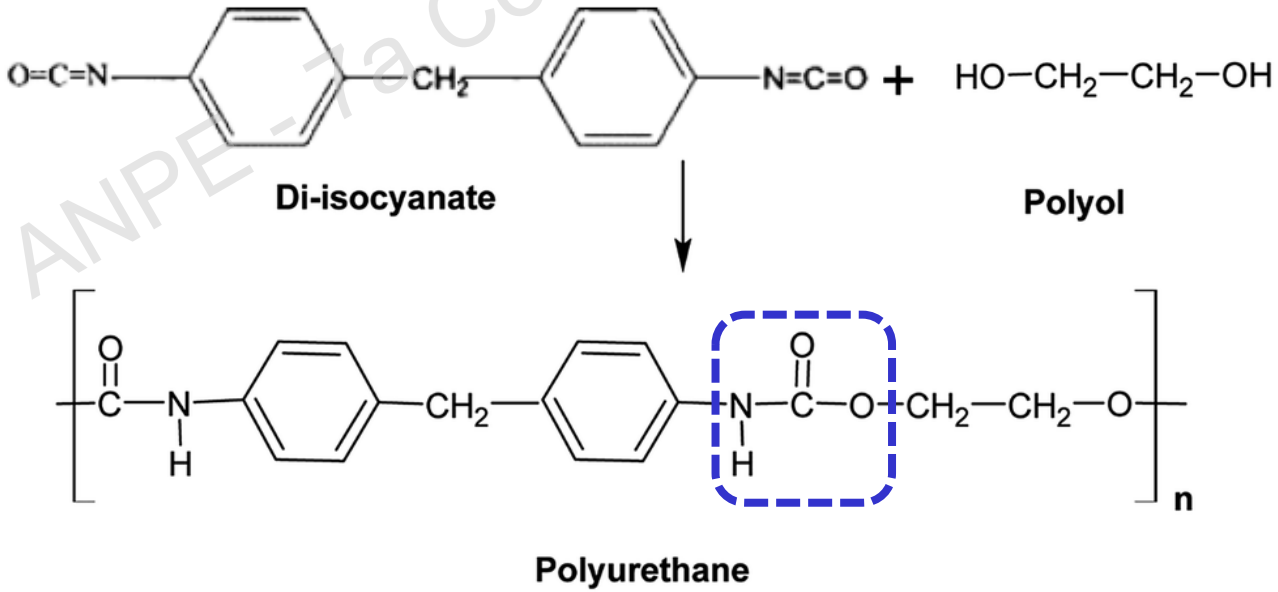
POLYURETHANE



Rigid PU panels for thermal insulation



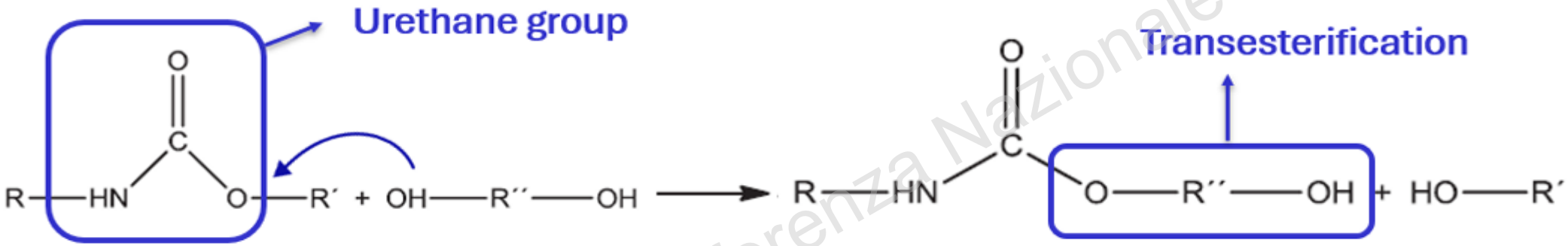
PU market[2]



[2] Grand View Research, "Polyurethane Market Size, Share & Trends Analysis Report"

GLYCOLYSIS PROCESS

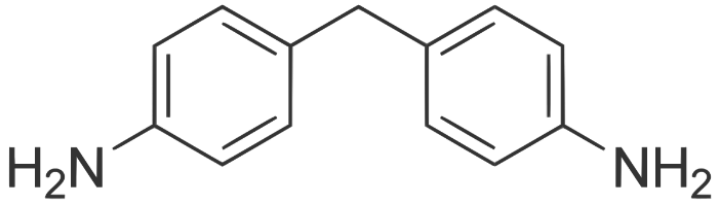
TRANSESTERIFICATION of the urethane group using a glycol and a suitable catalyst at 210 °C



polyurethane glycol Recovered polyols

Wanted characteristics:

- Low MDA content (<1000 ppm)
- Low viscosity (<10000 cP)

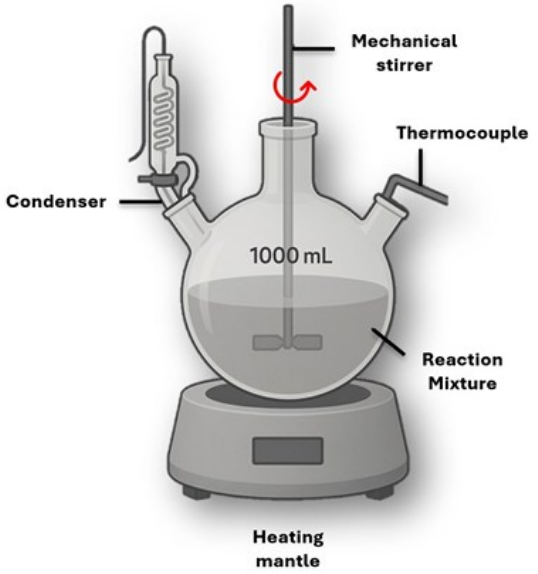


4,4'-methylene dianiline (MDA)

Variables:

- PU/glycol
- Type of glycol
- Catalyst type and amount

GLYCOLYSIS TESTS



Rigid PU scraps

DPG + cat

Glycolyzed product

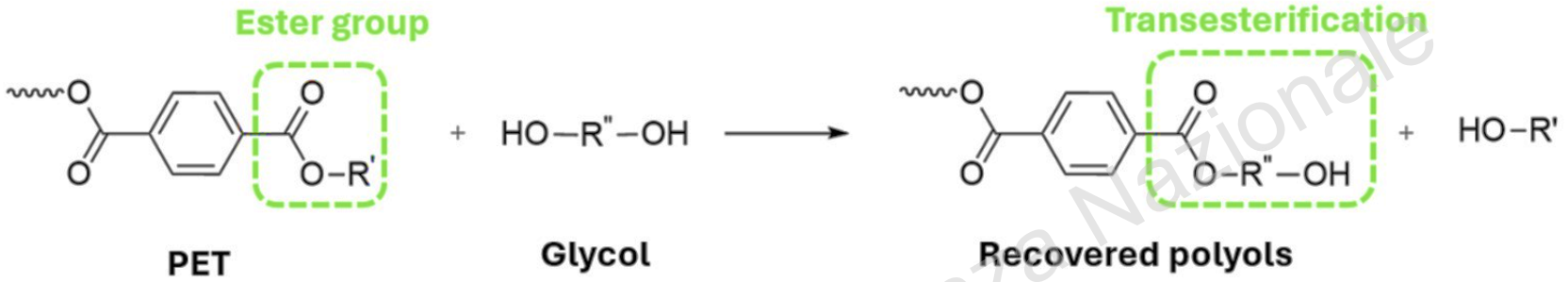
Problems:

- MDA content
- Viscosity
- Amount of catalyst

Test	Catalyst	mmol Cat/100 g waste	4,4' MDA [ppm]	Viscosity [cP]
GL1	KOAc	30	12893	10900
GL2	KOAc	50	21739	5400
GL3	TBT	50	5078	63500
GL4	Sn(Oct)2	50	23667	3900
GL5	Sn(Oct)2	25	8689	10500

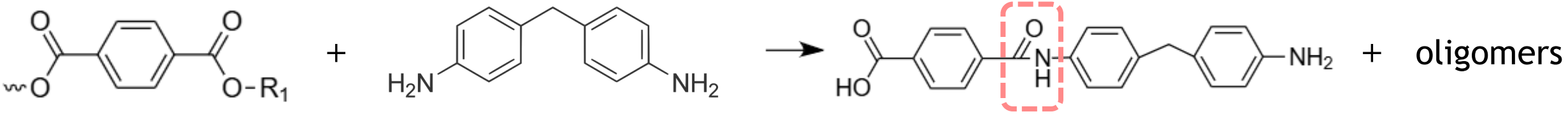
GLYCOLYSIS OF PET

TRANSESTERIFICATION of the ester group of PET using a glycol and a suitable catalyst at 210 °C



Pros:
- PET is another scrap
- No formation of amine
- React with MDA

TRANSESTERIFICATION of PET with MDA forming a compound with an amide group



GLYCOLYSIS WITH PET AND PU

Rigid PU scraps

PET scraps

Glycol + KOAc

Glycolyzed product

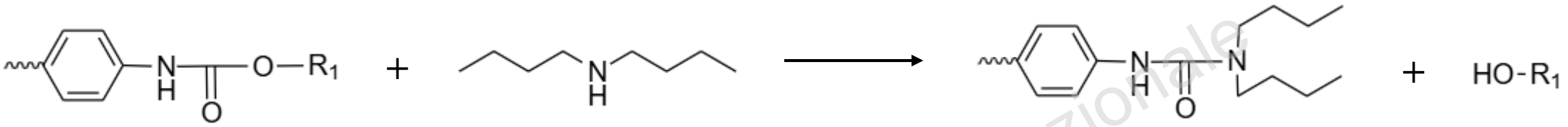
Problem:

- MDA content is still high

Test	PU/PET [%]	Solvent	Reaction time [h]	MDA [ppm]	Viscosity [cP]
GLmix1	25/25	DPG	4	4000	8040
GLmix2	30/20	DPG	3	5400	5400
GLmix3	30/20	DPG	4	3900	5800
GLmix4	30/20	DEG	4	5600	6000

AMINOLYSIS AND TWO-STEP REACTION SCHEME

Aminolysis of polyurethane using DBA at 165 °C



Polyurethane | Secondary Amine | Polyurea | Polyol

TWO-STEP REACTION BLOCK SCHEME

FIRST STEP: PET

- DEG
- KOAc
- PET

Fast glycolysis at 220 °C

SECOND STEP: PU

- T↓ to 165 °C
- Amine
- PU

Aminolysis at 165 °C

TWO-STEP REACTION WITH PET AND PU

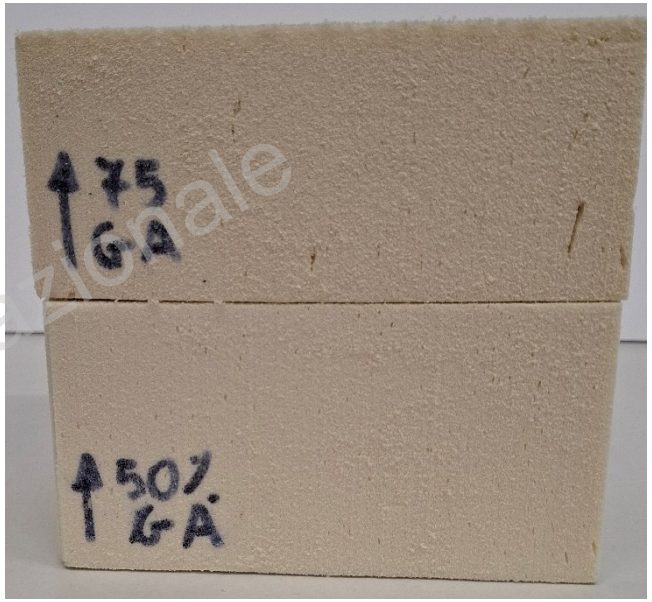
Pros:

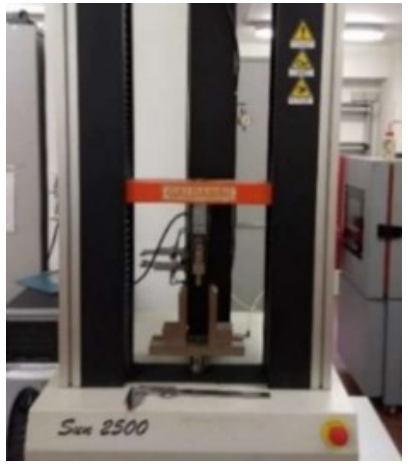
- Lowest formation of MDA
- Lowest viscosities
- Less catalyst than glycolysis
- Lower T than mixed glycolysis
- More scraps than aminolysis
- Less amine than aminolysis

Test	PET/PU/ DEG/Amine [%]	KOAc [mmol /100 g waste]	Glycolysis time [min]	Aminolysis time [h]	MDA [ppm]	Viscosity [cP]
G+A1	20/30/40/10	15	30	4	950	8500
G+A2	20/30/43/7	2.5	60	6	397	7000
G+A3	**25/25/43/7**	**5**	**45**	**4.5**	**437**	**5000**
G+A4	30/25/38/7	5	40	4.5	/	13000
G+A5	25/30/38/7	5	40	4.5	/	26500

RIGID FOAMS PRODUCTION

	Ref	25%GA	50%GA	75%GA	100%GA
RF551 [g]	100	75	50	25	0
RP [g]	**0**	**25**	**50**	**75**	**100**
CAT 1 [g]	1.5	1.5	1.5	1.52	1.5
CAT 2 [g]	0.4	0.4	0.4	0.4	0.4
SILICONE [g]	2	2	2	2	2
H_2O [g]	1.5	1.2	1.08	0.81	0.59
C5 [g]	8.74	9.89	10.42	10.96	12.43
Iso MDI [g]	160.86	158.92	157.4	155.6	158.75
Cream time [s]	25	30	30	27	32
Gel time [s]	115	102	85	91	183
Tack free time [s]	153	143	116	128	285
Density [kg/m^3]	35.45	36.85	36.46	37.03	38.36

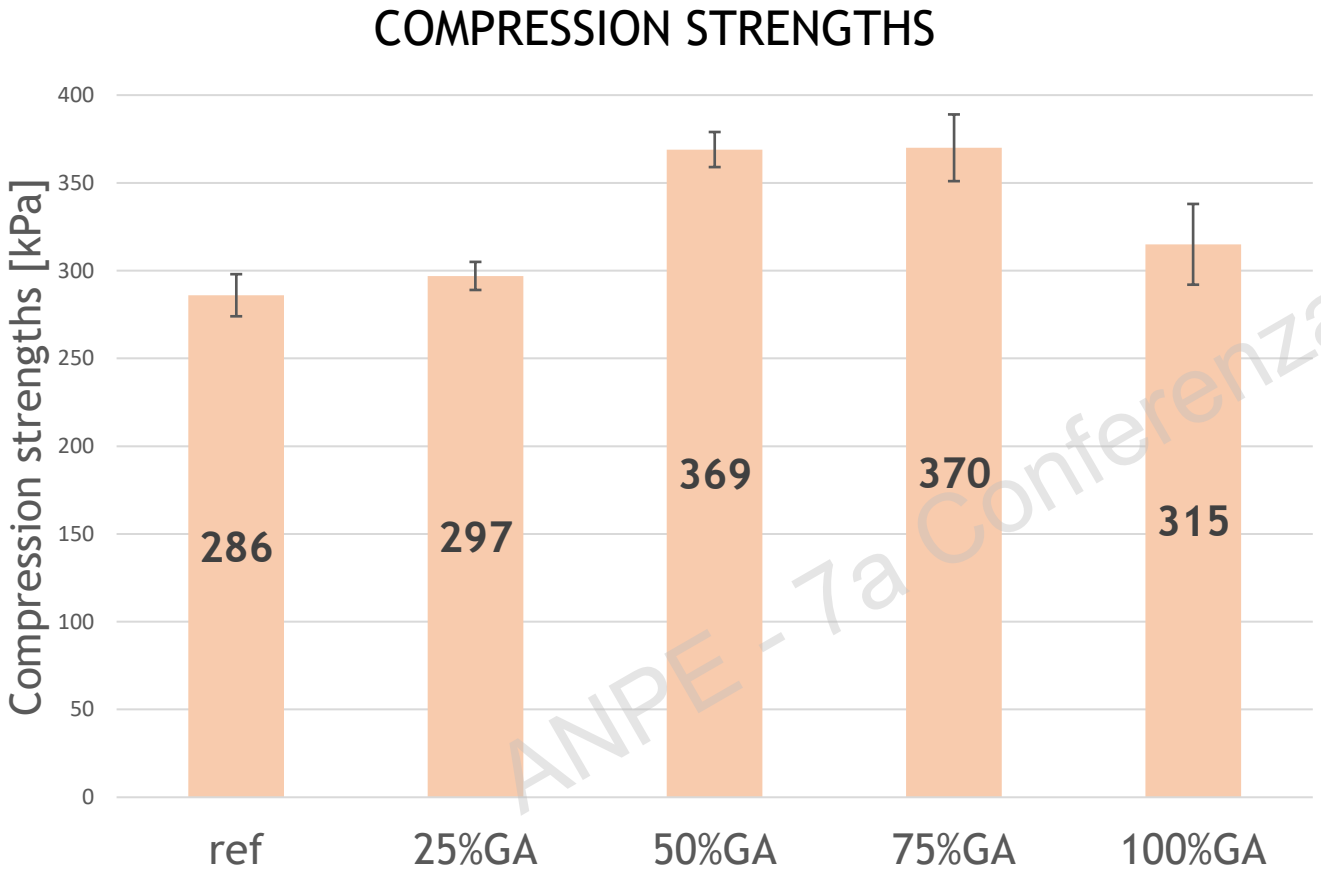


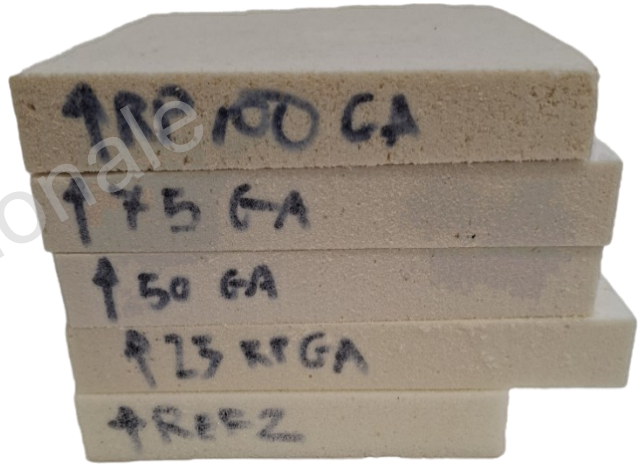


Dynamometer

Thermal conductometer

RIGID FOAMS PRODUCTION





THERMAL CONDUCTIVITY

Foam	k [mW/m K]
Ref	25.52
25%GA	23.35
50%GA	22.14
75%GA	22.83
100%GA	28.29

CONCLUSIONS

PAST

Problem of MDA content

PRESENT

New recycling method with 2 scraps → Final polyol with good characteristics that allows to obtain foams with excellent compression and insulating properties

FUTURE

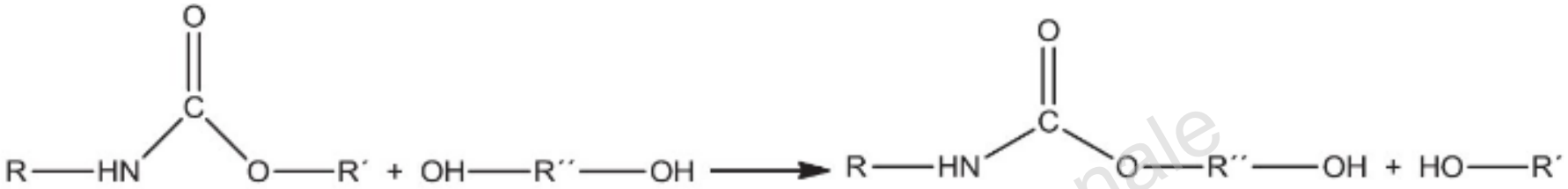
Industrial scale-up

LCA and economic analysis

THANK YOU FOR THE ATTENTION

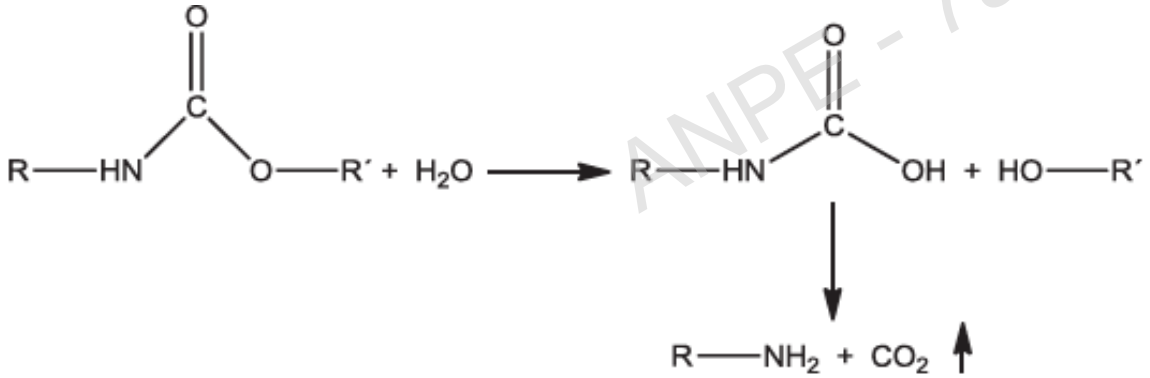
APPENDIX – REACTIONS INVOLVED DURING GLYCOLYSIS

Glycolysis of PU



Glycolysis of polyurea

Hydrolysis of PU and polyurea



APPENDIX - DEAMINATION WITH 2-EHGE