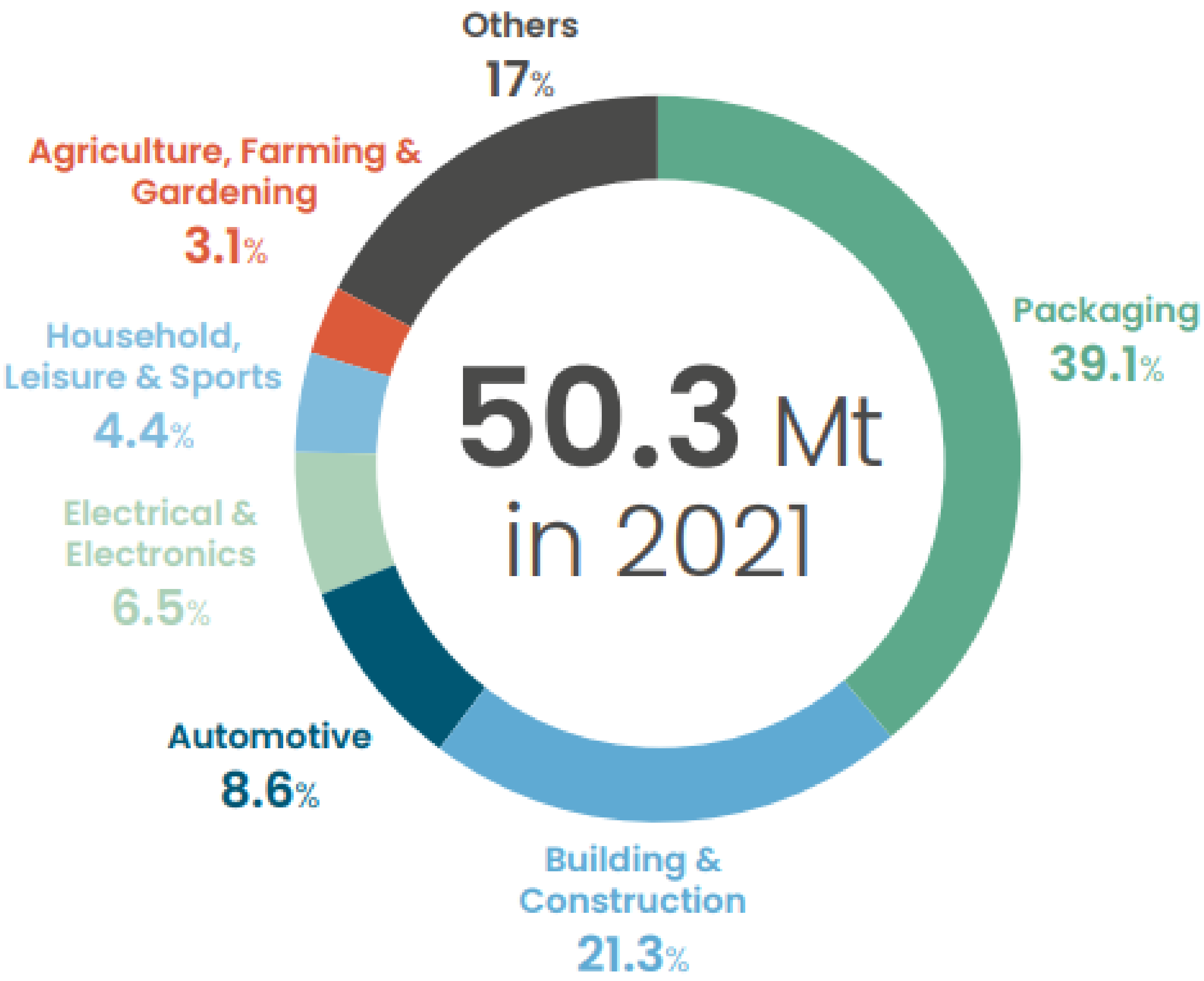
ONE-POT RECYCLING TECHNOLOGY OF POST-CONSUMER PLASTICS: DISSOLUTION AND INCREMENTAL POLYMERIZATION OF EXPANDED POLYSTYRENE WASTE

Domenico Zannini, Gabriella Santagata, Pierfrancesco Cerruti, Giovanni Dal Poggetto, Martino Di Serio, Riccardo Tesser, Rosa Turco

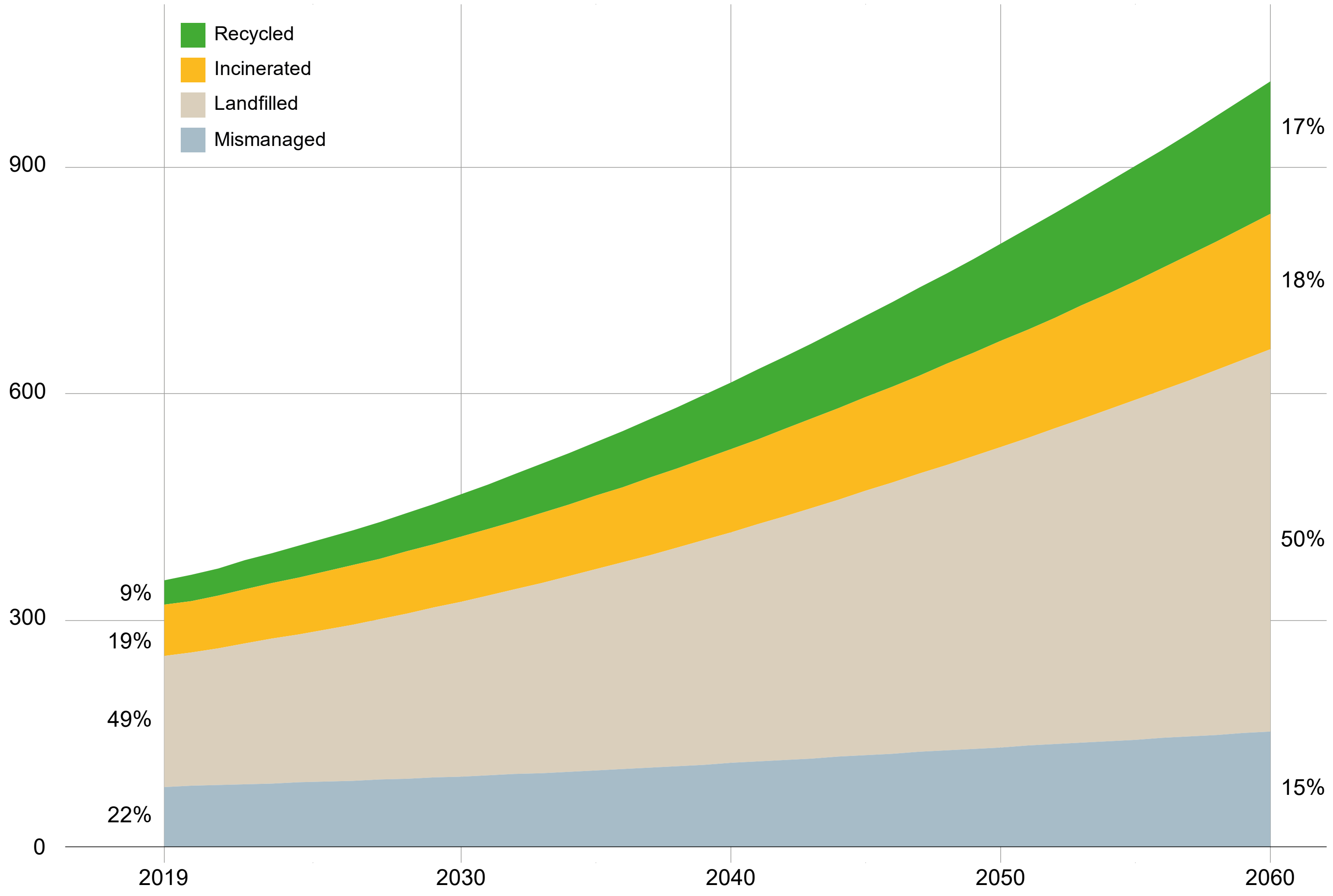
PLASTICS PRODUCTION



SOURCE: Plastics Europe Market Research Group (PEMRG) and Conversio Market & Strategy GmbH.

END-OF-LIFE OPTIONS OF PLASTICS

Plastic waste in million tonnes (left-hand axis) by waste management category, after disposal of recycling residues and litter collection.

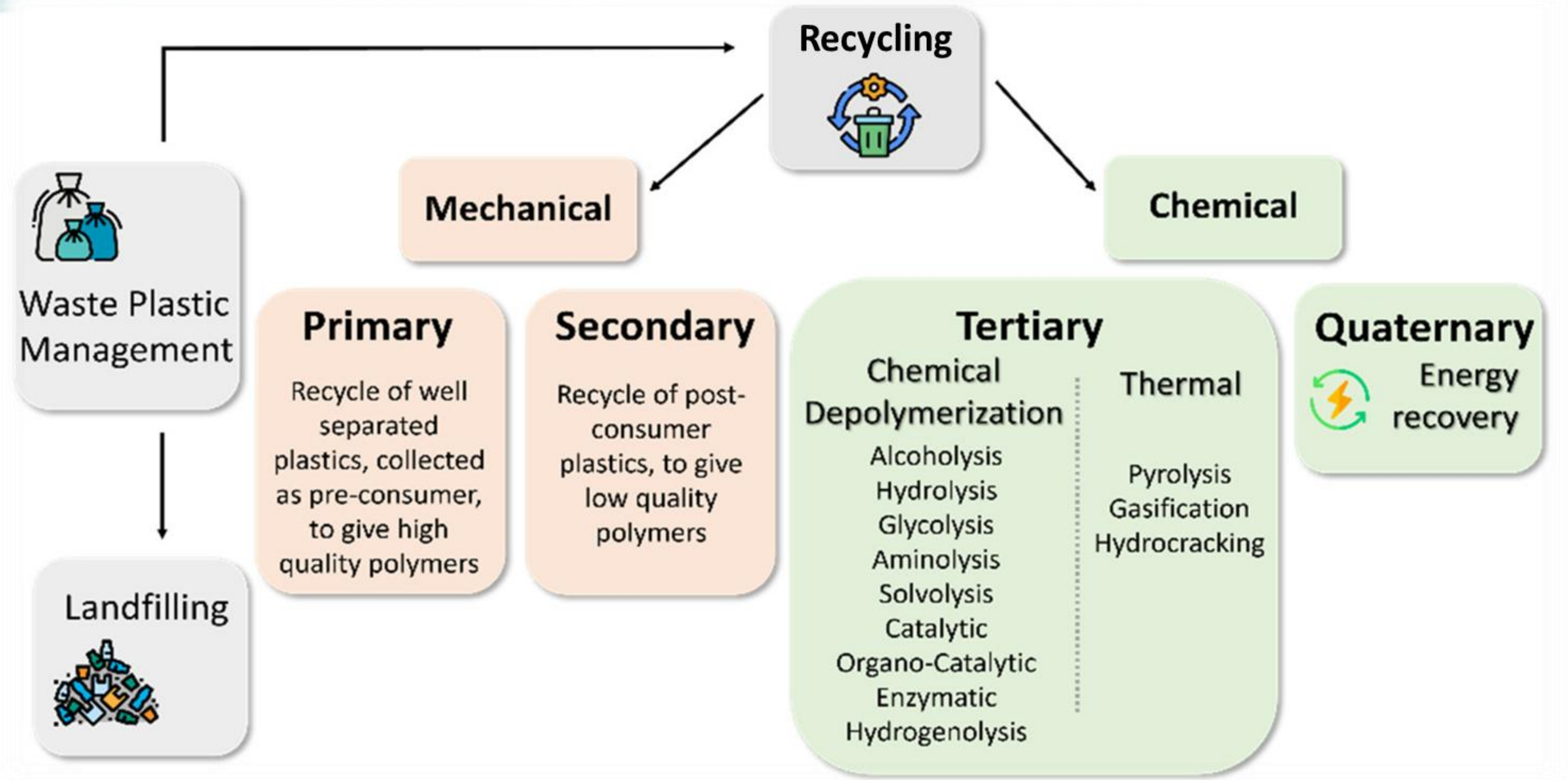


Source: OECD ENV-Linkages model.

ZERO LANDFILLING IS NEEDED TO ACHIEVE THE CIRCULAR ECONOMY OF PLASTICS

PLASTIC RECYCLING

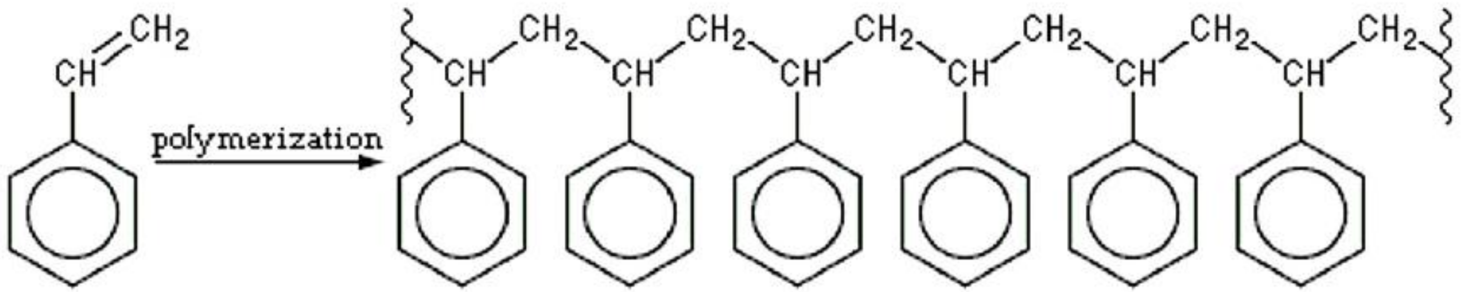
Today, mechanical recycling is the recycling process providing the highest quantities of recycled plastics. As a complement, different chemical recycling technologies have also been developed [1].



[1] V. Beghetto et al., Materials,14, 4782 (2021)

EXPANDED POLYSTYRENE (EPS)

- Low thermal conductivity (excellent insulation),flexible mechanical properties, good energy absorption (packaging).
- Low cost per volume/cost-effective, versatility in shapes, sizes and compatibility with a wide variety of materials.



styrene polystyrene

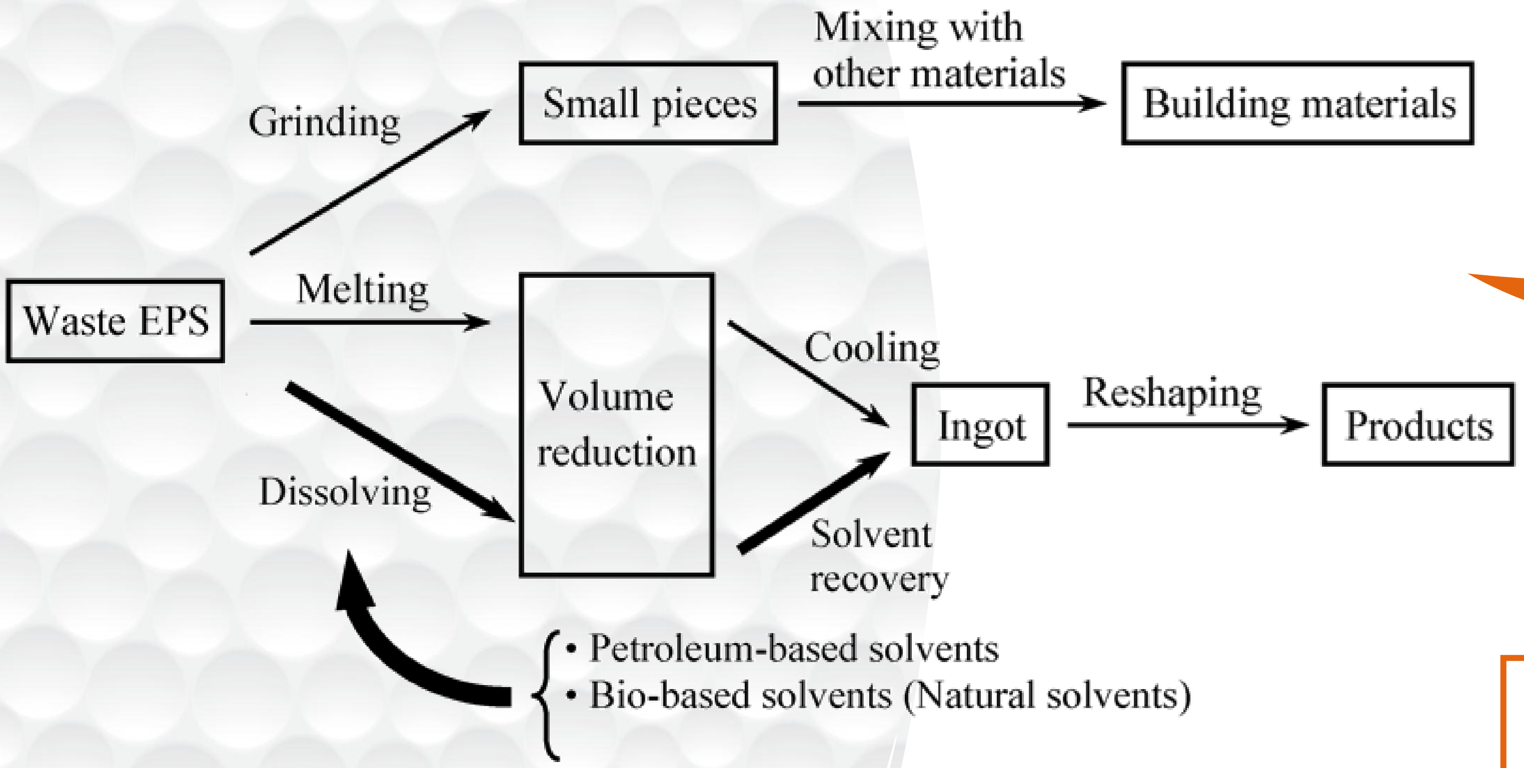
- Highly voluminous products taking up much space during transporting, major post-consumer waste product because of low rate of recycling.

Type of plastic	Total waste generation		Recovery					Disposal/ landfill Total	
			Total	Thereof mechanical recycling		Thereof energy recovery			
	in kt	in %	in kt	in kt	in %	in kt	in %	in kt	in %
EPS	140	8.0%	95	13	9.0%	83	59.0%	45	32.0%

http://www.conversio-gmbh.com/

EPS RECYCLING TECHNOLOGIES

– For the recycling of EPS, melting or solvent treatment are required to reduce the volume and to be reshaped subsequently [2].

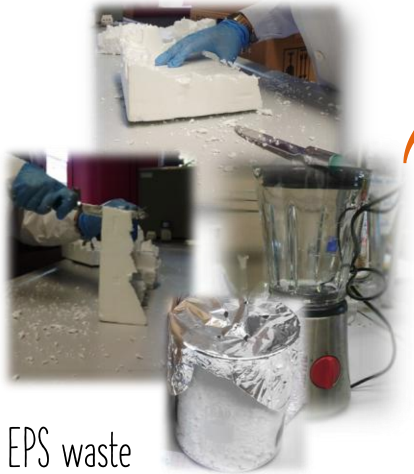


"One-Pot'' recycling technology

Dissolution in monomer
(*incorporation of EPS in styrene*)
+
Polymerization

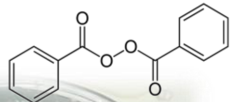
[2] G. D. Mumbach, et al, Polymer, 209 122940, (2020)

EXPERIMENTAL SET-UP



EPS waste

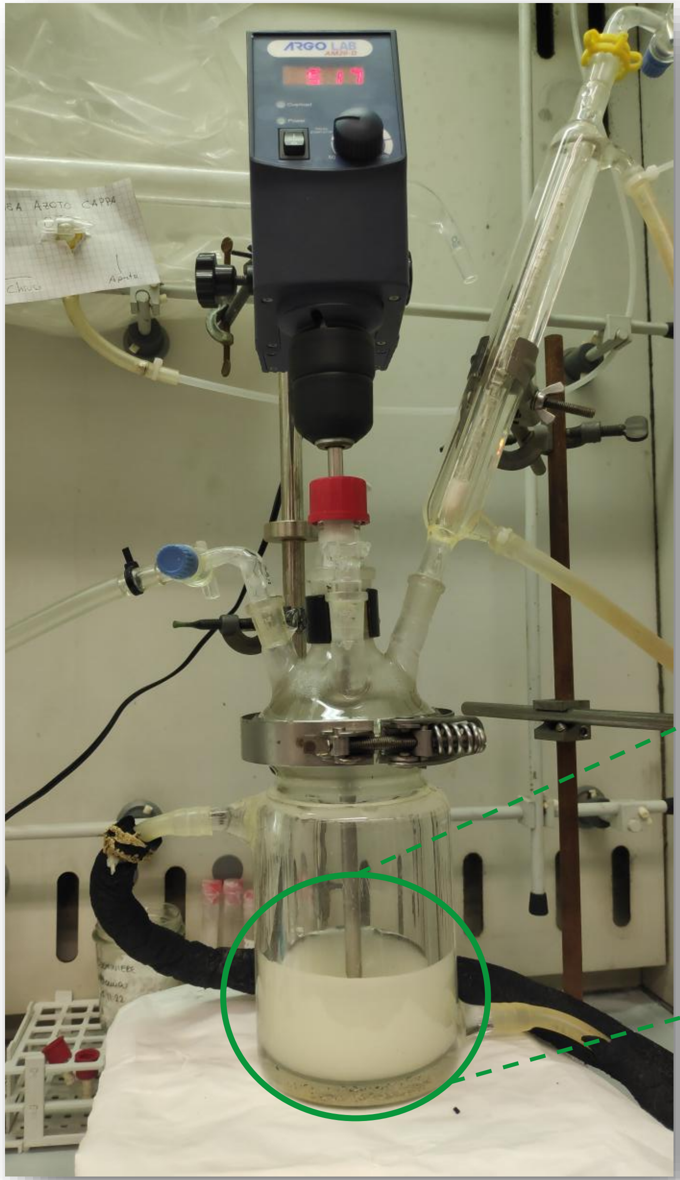
Benzoyl peroxide (BPO)



Dissolution EPS waste in styrene

Dispersing Polyvinyl alcohol (PVA) + H_2O

Suspension polymerization reaction



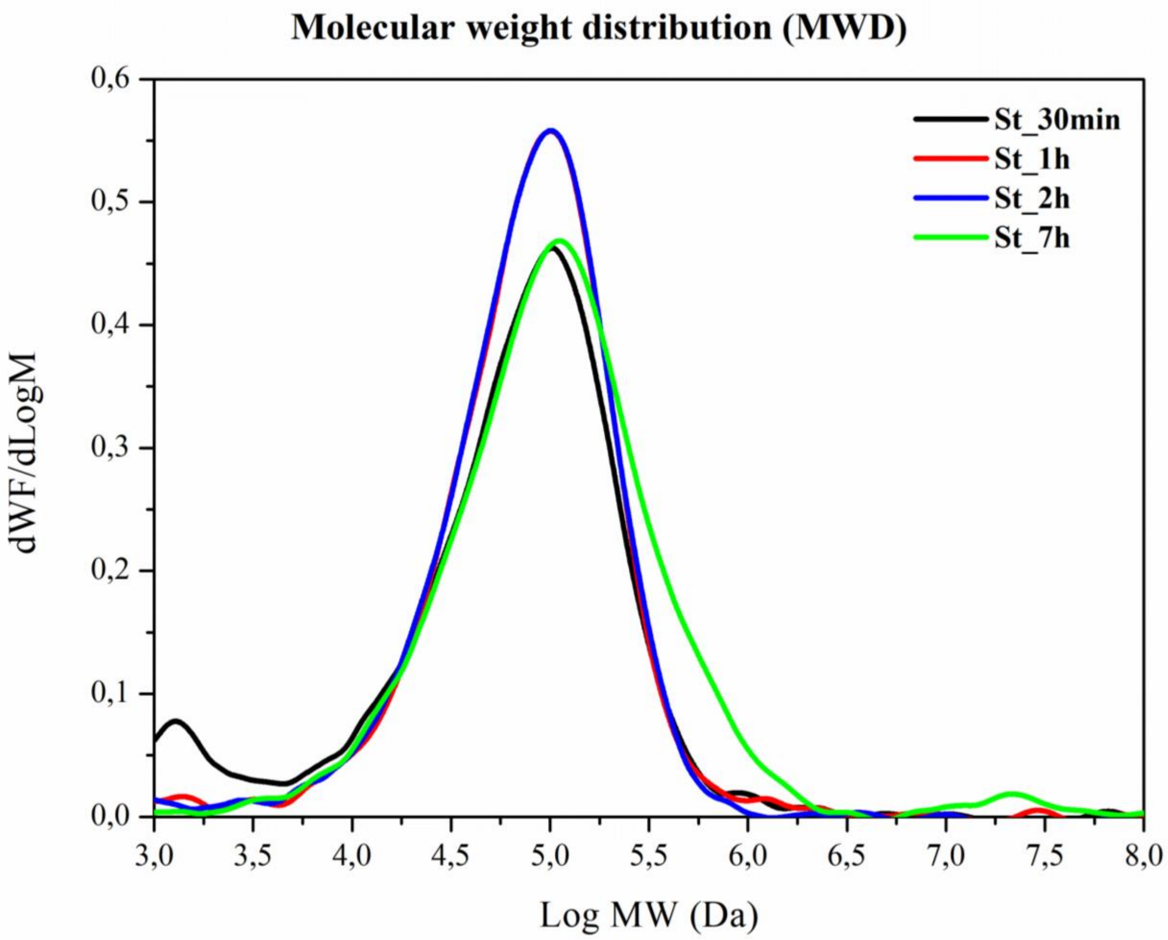
Beads of rPS new product

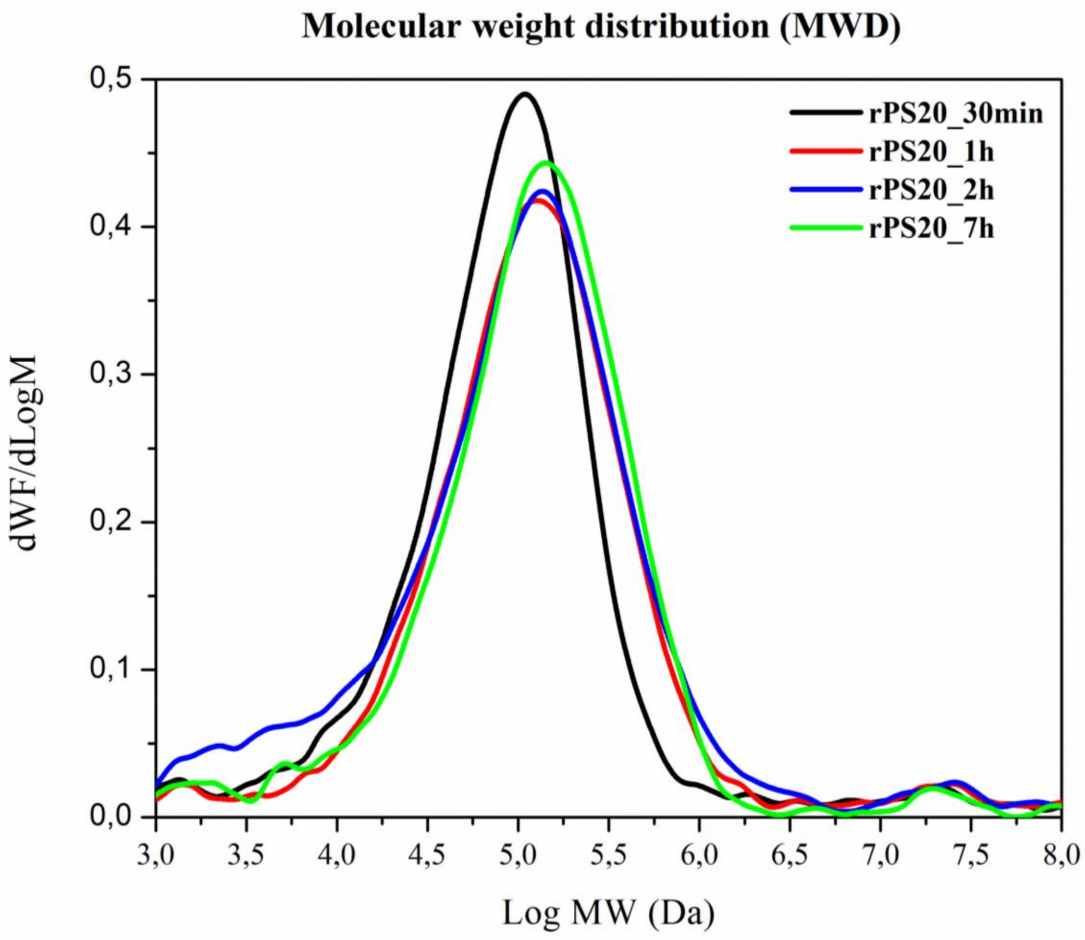
EXPERIMENTAL CONDITIONS

Samples	Styrene (St) (g)	wEPS (g)	BPO (g)	H_2O (g)	PVA (g)	Temperature (°C)	Time (h)
St_30min	33.6	-	0.0833	66.7	0.0833	90	0.5
St_1h	33.7	-	0.0833	66.7	0.0833	90	1
St_2h	33.5	-	0.0833	66.7	0.0833	90	2
St_7h	33.3	-	0.0833	66.7	0.0833	90	7
rPS20_30min	33.3	8.4	0.0833	66.6	0.0867	90	0.5
rPS20_1h	33.3	8.4	0.0833	66.7	0.0860	90	1
rPS20_2h	33.3	8.4	0.0833	66.8	0.0834	90	2
rPS20_7h	33.3	8.4	0.0833	66.9	0.0856	90	7

GPC RESULTS

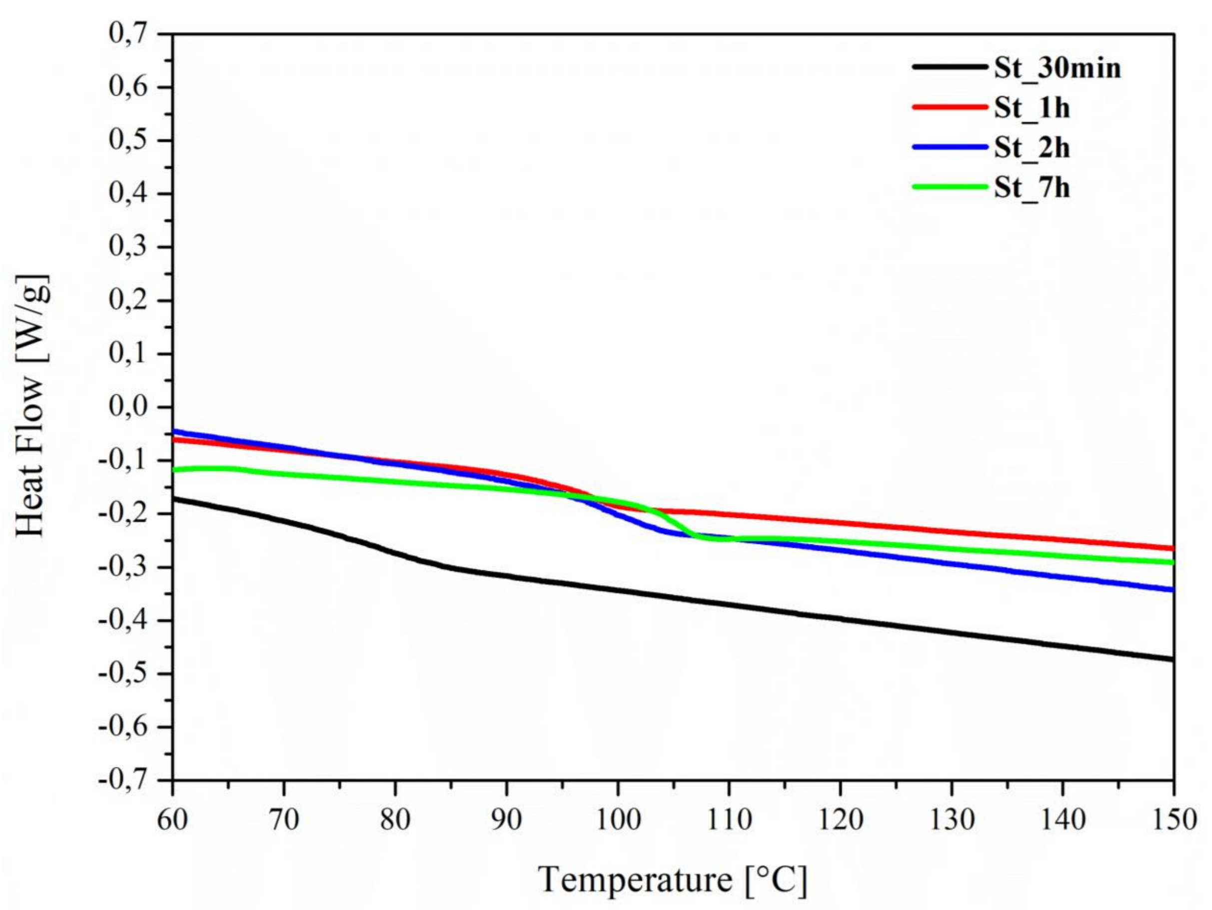
GPC results for rPS20 polymers show that as the reaction time increases, it is possible to note a slight shift of the molecular weight distribution curve towards higher values of molecular weight. In particular, no bimodal distributions are observed suggesting that styrene is able to polymerize quickly, reaching high M_w at low times.

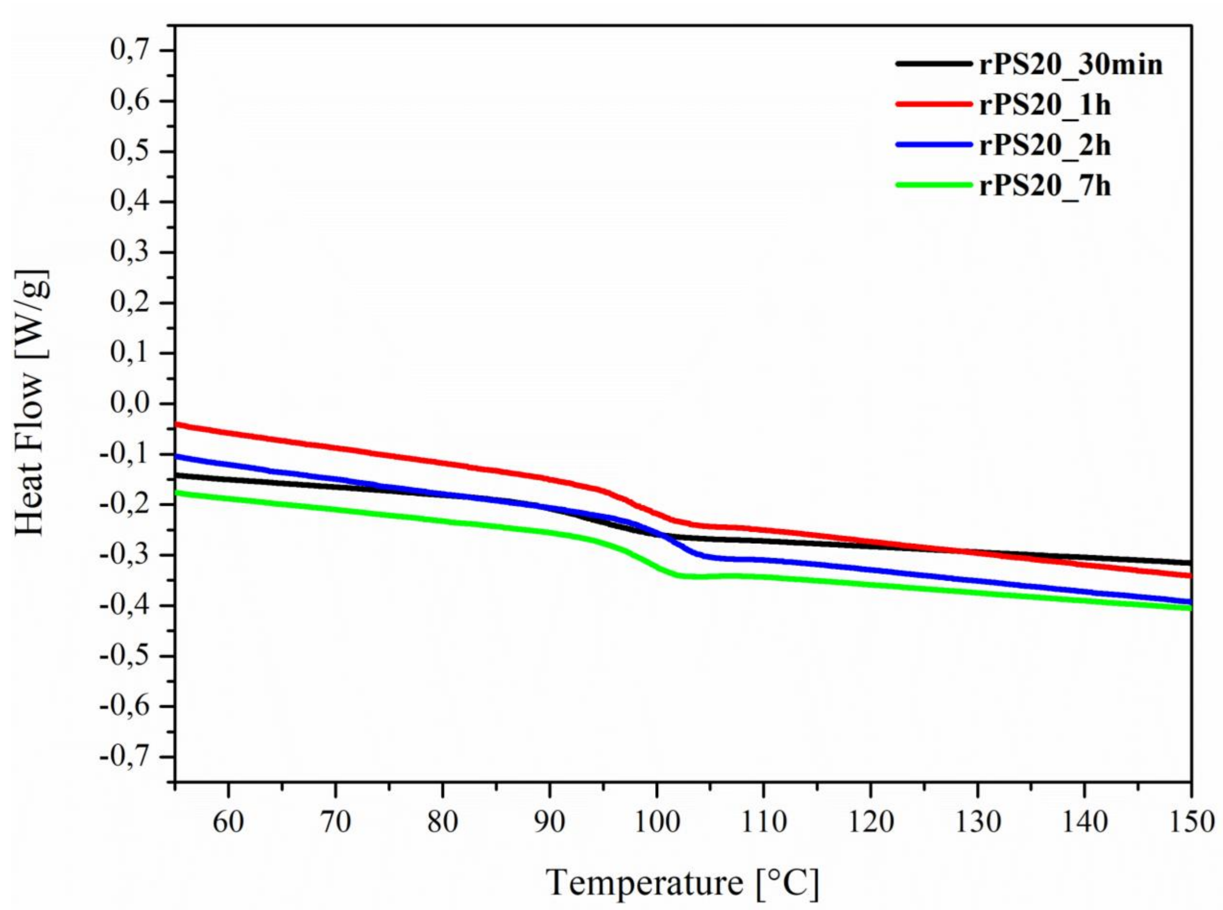




DIFFERENTIAL SCANNING CALORIMETRY (DSC)

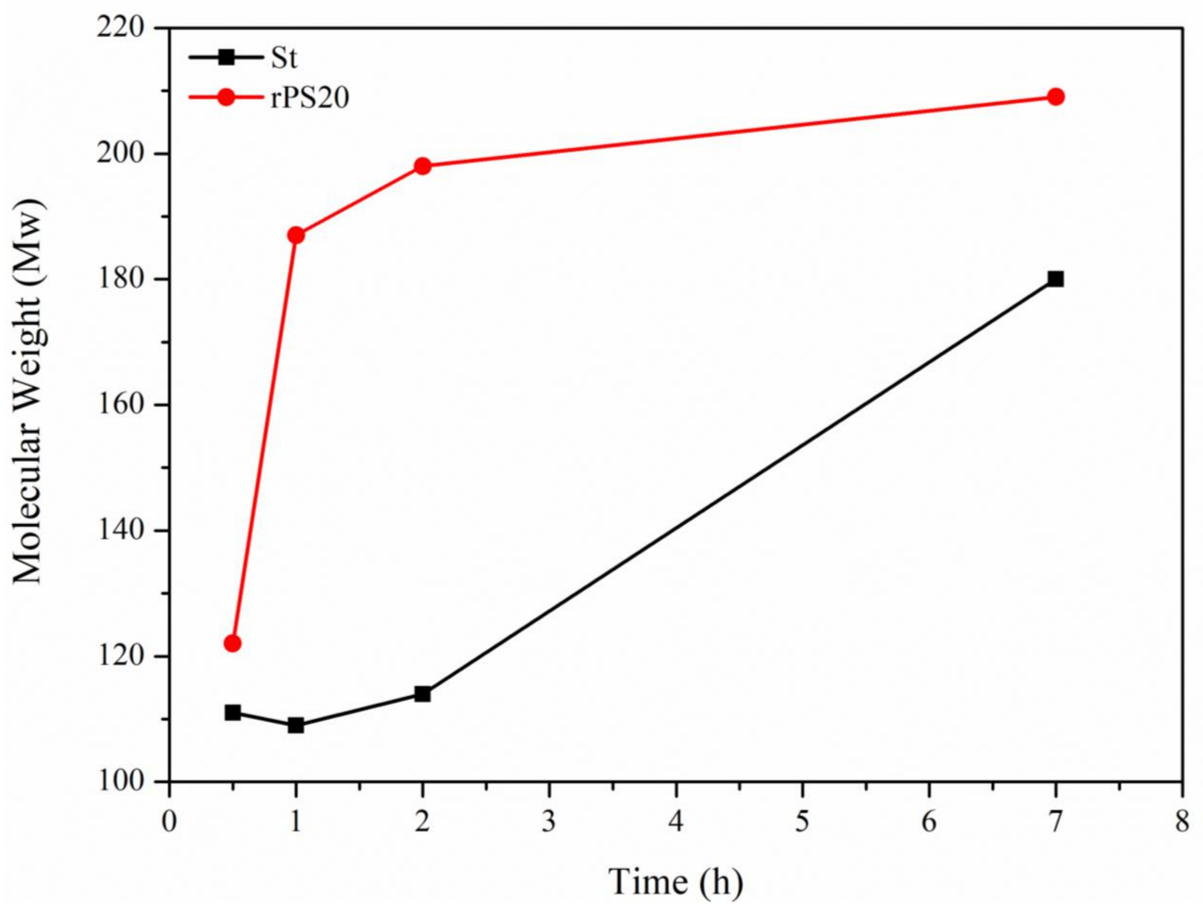
From the second heating ramp, it is possible to note that in the case of St, a sudden T_g increase occurred after 1h of polymerization, while the product of St_7h synthesis shows a mild increase of T_g values for higher reaction times. As regarding the rPS20 polymers, the increase in T_g values was more gradual.



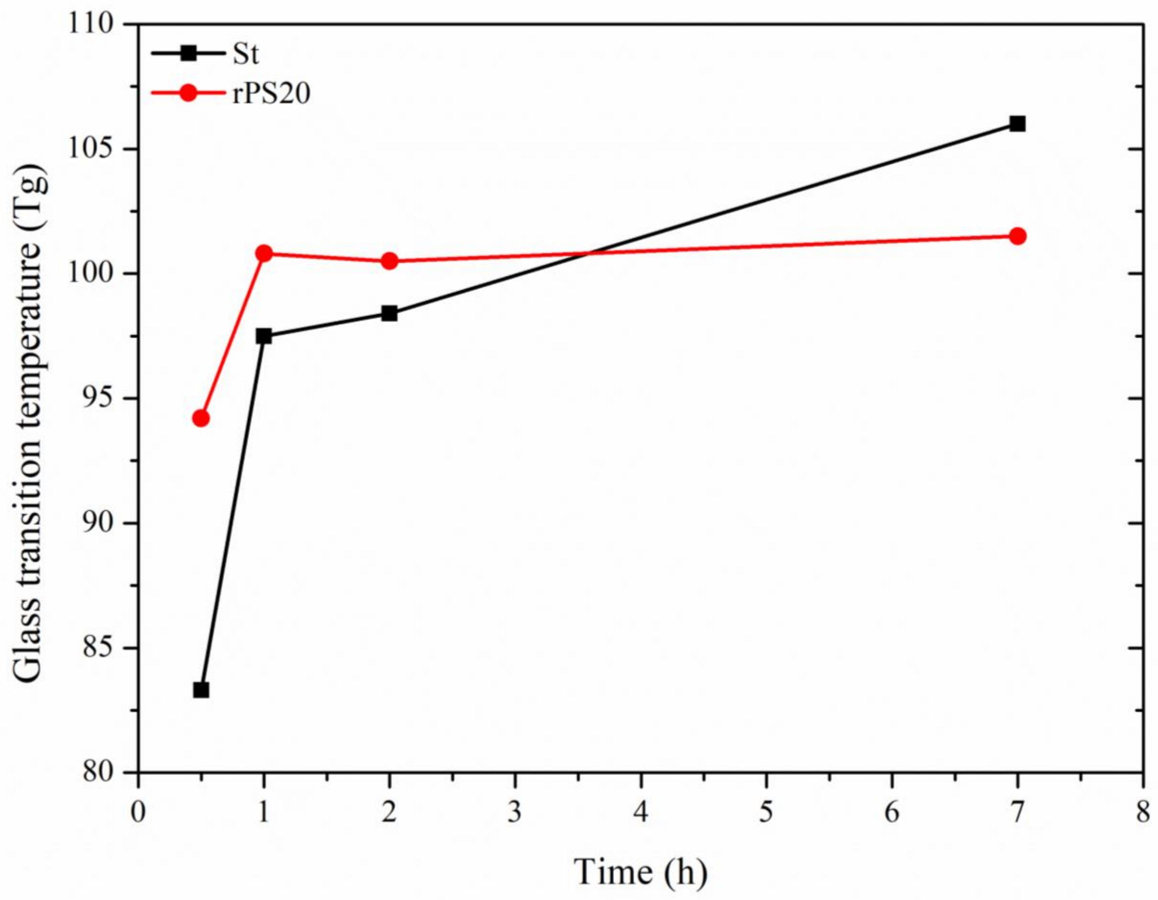


KINETICS GPC AND DSC RESULTS

In the case of the polymerization of neat St, an increase of molecular weight is observed only after 2h reaction.



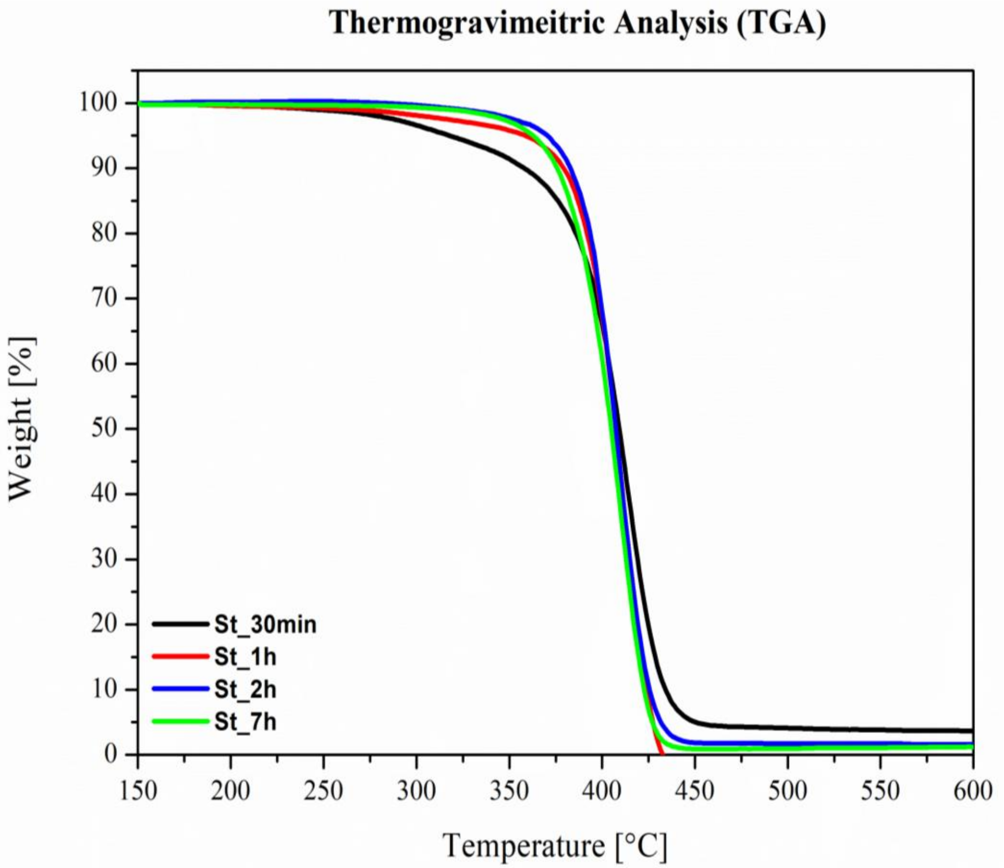
In the case study of the polymerization a sudden increasing of T_g after 1h due to the formation of polymers in the monomer solution.

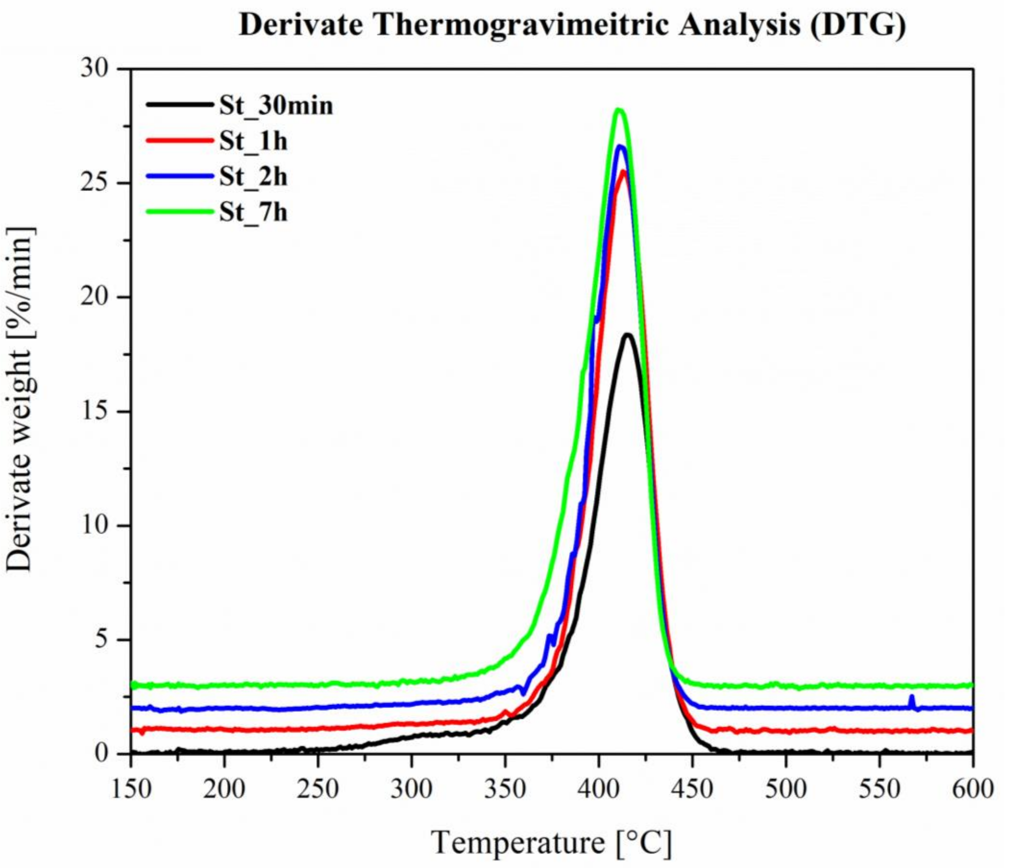


THERMOGRAVIMETRIC/DERIVATIVE (TGA/DTG)

Samples	$T_{10w\%}$ (°C)	T_{peak} (°C)
St_30min	358.1	413.3
St_1h	378.5	409.5
St_2h	382.6	409.7
St_7h	374.9	410.0

From the analysis of TGA/DTG, it is possible to note that the polymers with a lower molecular weight tend to thermally degrade easily.

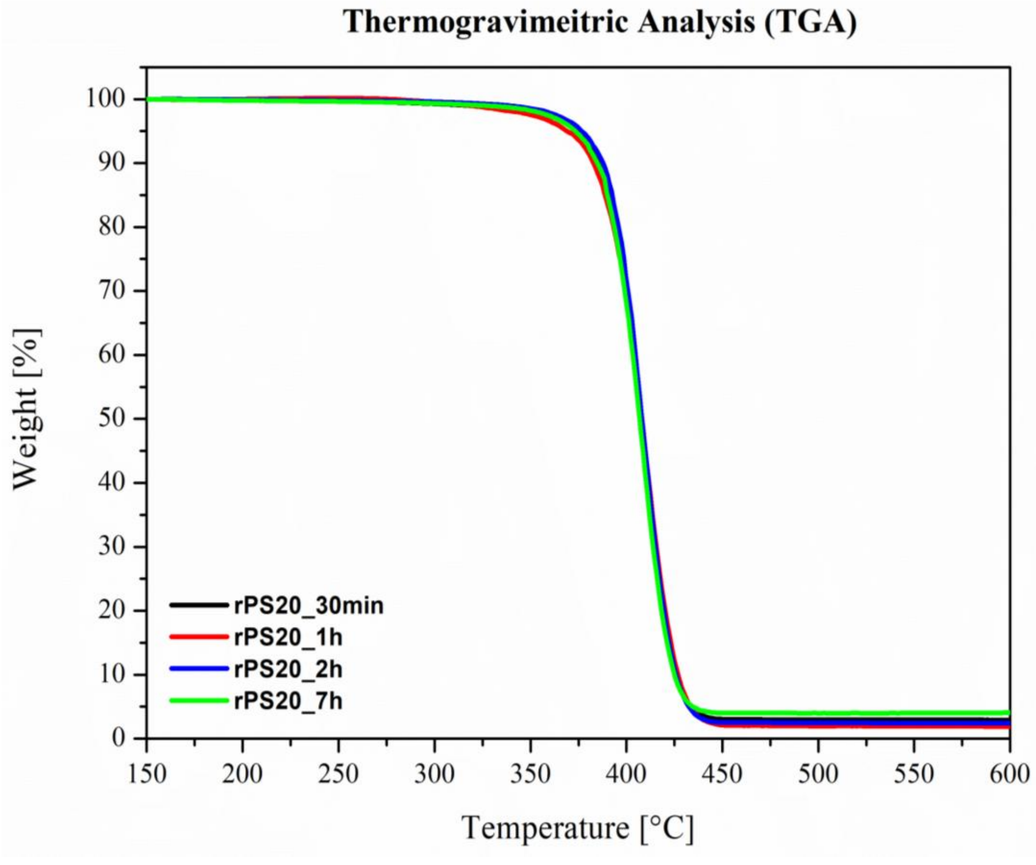


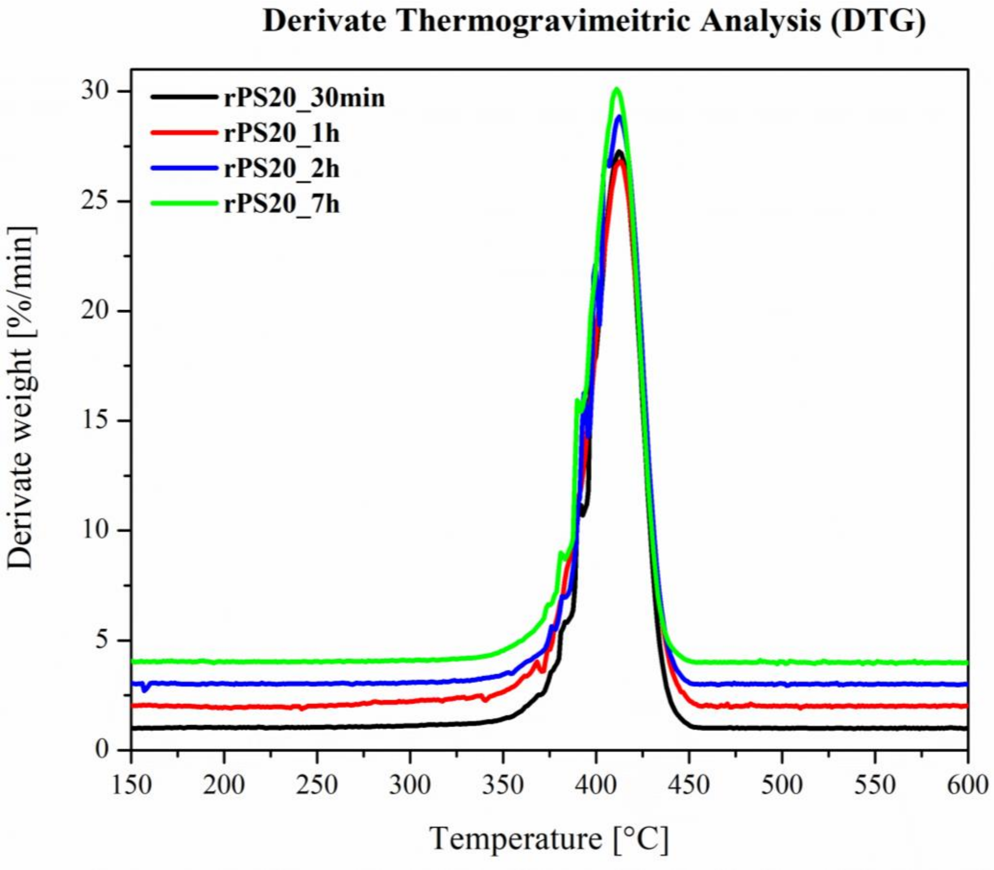


THERMOGRAVIMETRIC/DERIVATIVE (TGA/DTG)

Samples	$T_{10w\%}$ (°C)	T_{peak} (°C)
rPS20_30min	385.5	409.0
rPS20_1h	381.9	410.4
rPS20_2h	387.1	409.1
rPS20_7h	384.4	408.8

As regarding the rPS20 products, it is possible to evidence that the polymers show a value of the similar thermal stability with the same pattern degradation temperature.



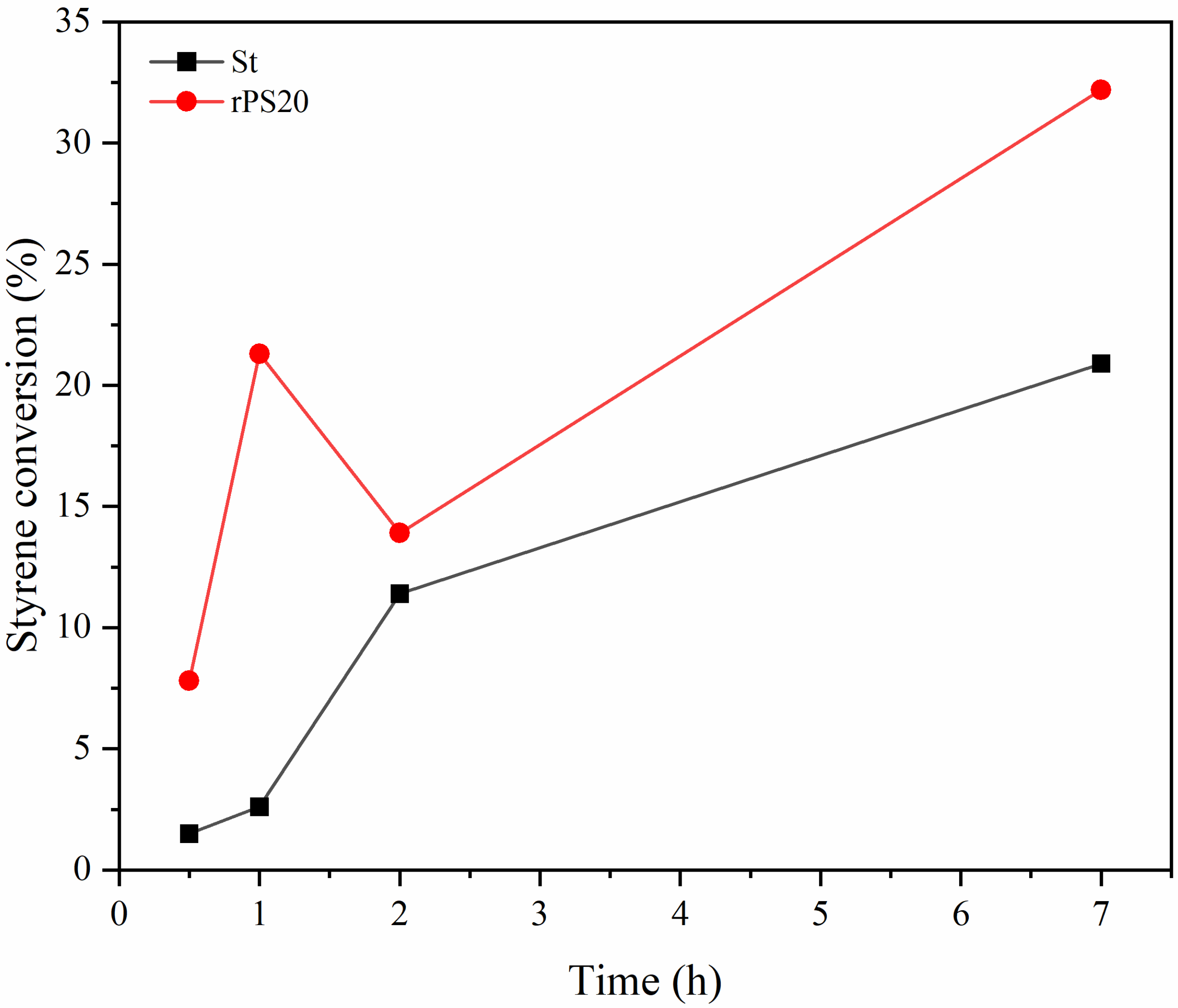


CONVERSIONE MONOMER

Samples	Styrene conversion (%)	Yield (%)
St_30min	1.5	1.5
St_1h	2.6	2.6
St_2h	11.4	11.4
St_7h	20.9	20.9
rPS20_30min	7.8	33
rPS20_1h	21.3	46.5
rPS20_2h	13.9	39
rPS20_7h	32.2	57.4

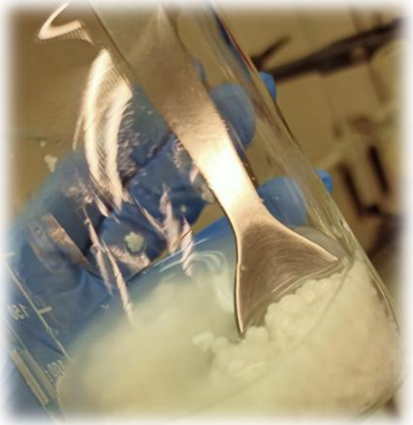
$$\text{Yield (\%)} = \frac{mass\ sample\ recovered\ (g)}{mass\ St\ loaded\ (g)} * 100$$

$$\text{St conversion(\%)} = \frac{[mass\ sample\ recovered\ (g) - ESP\ loaded\ (g)]}{mass\ St\ loaded\ (g)} * 100$$



CONCLUSIONS

I. This *"one-pot"* recycling technology could represent an important route for recycling of discarded polymer materials.



II. The presence of wEPS affects the kinetics of polymerization of styrene.

FUTURE PROSPECTS

MoDeSt

01

Evaluate the conversion degree of styrene at each reaction time.

02

Increase the amount of EPS waste recycled (up to 50% w/w), in order to evaluate how the amount of wEPS affect the polymerization kinetics and molecular weight (Mw) of the polymers.

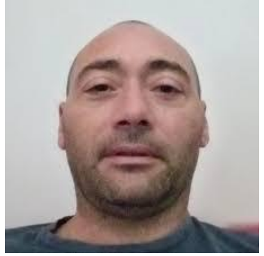
03

Characterization of structural, rheological, thermal and mechanical properties of the St polymers and the new polymers obtained by this recycling technology with different amounts of wEPS.

THANK YOU FOR THE KIND ATTENTION!

In memory of Dr. Mario Malinconico
IPCB-CNR

Dr. Gabriella Santagata
IPCB-CNR



Dr. Pierfrancesco Cerruti
IPCB-CNR

Dr. Giovanni Dal Poggetto
IPCB-CNR

Prof. Martino Di Serio
UNINA

Dr. Rosa Turco
UNINA/IPCB-CNR

Prof. Riccardo Tesser
UNINA

iPCB ISTITUTO PER I POLIMERI COMPOSITI E BIOMATERIALI
Consiglio Nazionale delle Ricerche

- Dr. Domenico Zannini
- domenico.zannini@unina.it
- domenico.zannini@ipcb.cnr.it

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

EPS CHARACTERIZATION

Sample	$T_{10w\%}$ (°C)	T_{peak} (°C)	T_g (°C)	M_n (kDa)	M_w (kDa)	M_w/M_n
EPS	50.0-128.0	409.0	104.3	77	207	2.7