

Improving the quality of recyclates

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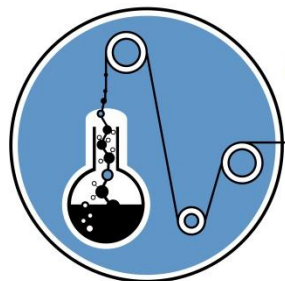
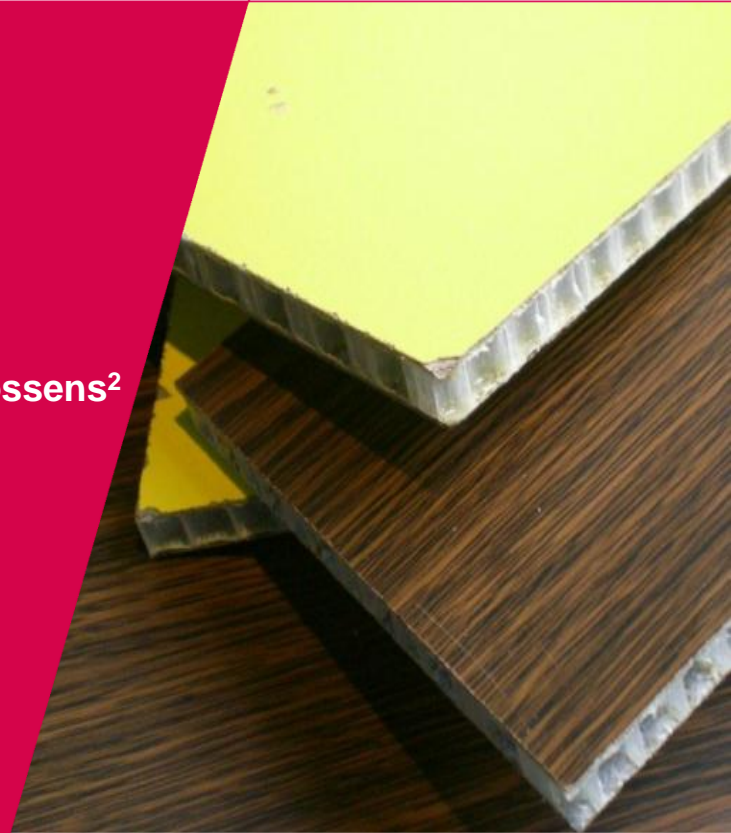
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SPM Laboratory
of Polymer
Materials
Mastering the Chain of Knowledge

TU / **e**

Technische Universiteit
Eindhoven
University of Technology

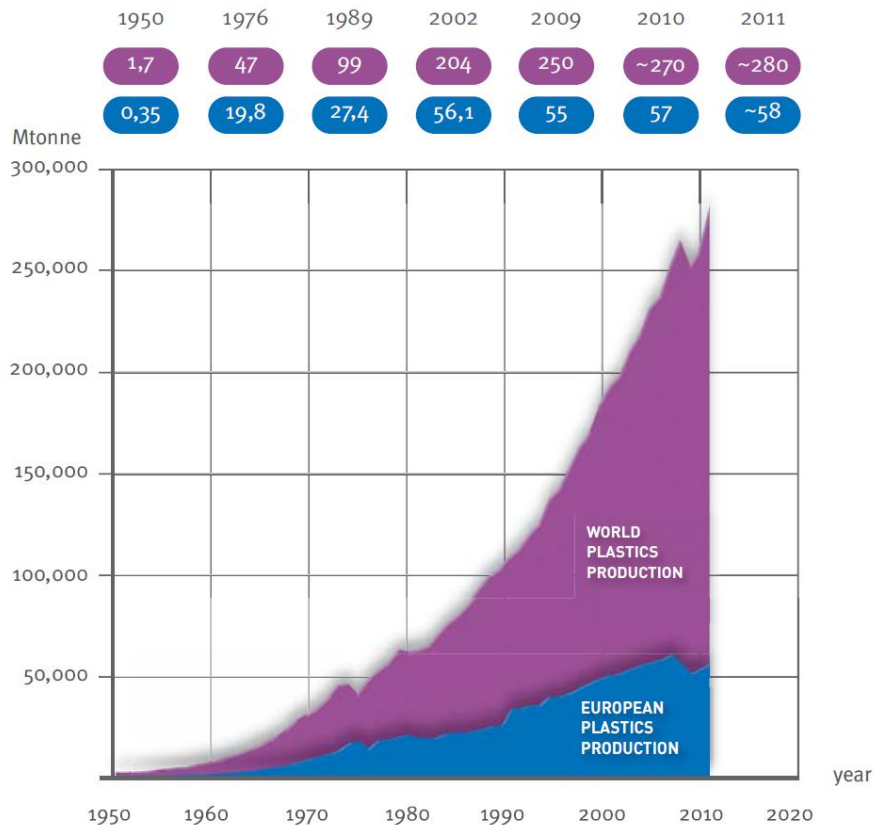
Where innovation starts

Outline

- **Introduction**
- **Objective and approach**
- **Starting materials**
- **Quality assessment recyclates**
 - **Compositional analysis**
 - **Mechanical properties**
- **Conclusions**
- **Outlook**
 - **PP: A case study**

Introduction

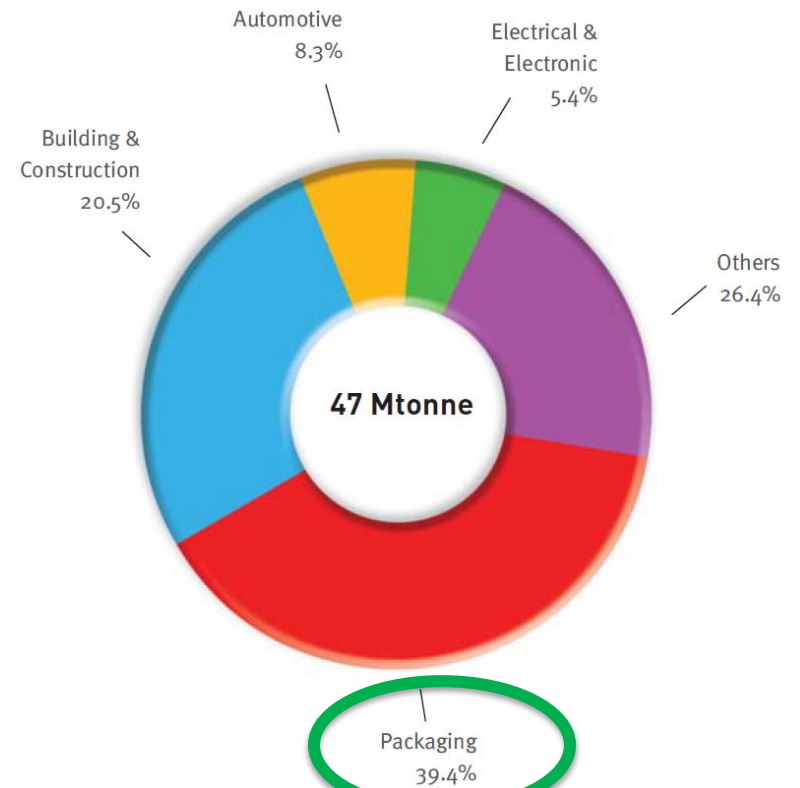
• Plastics production



Source: PlasticsEurope Market Research Group (PEMRG)

/ Chemical Engineering and Chemistry / Laboratory of Polymer Materials

Application sectors Europe



TU/e Technische Universiteit Eindhoven
University of Technology

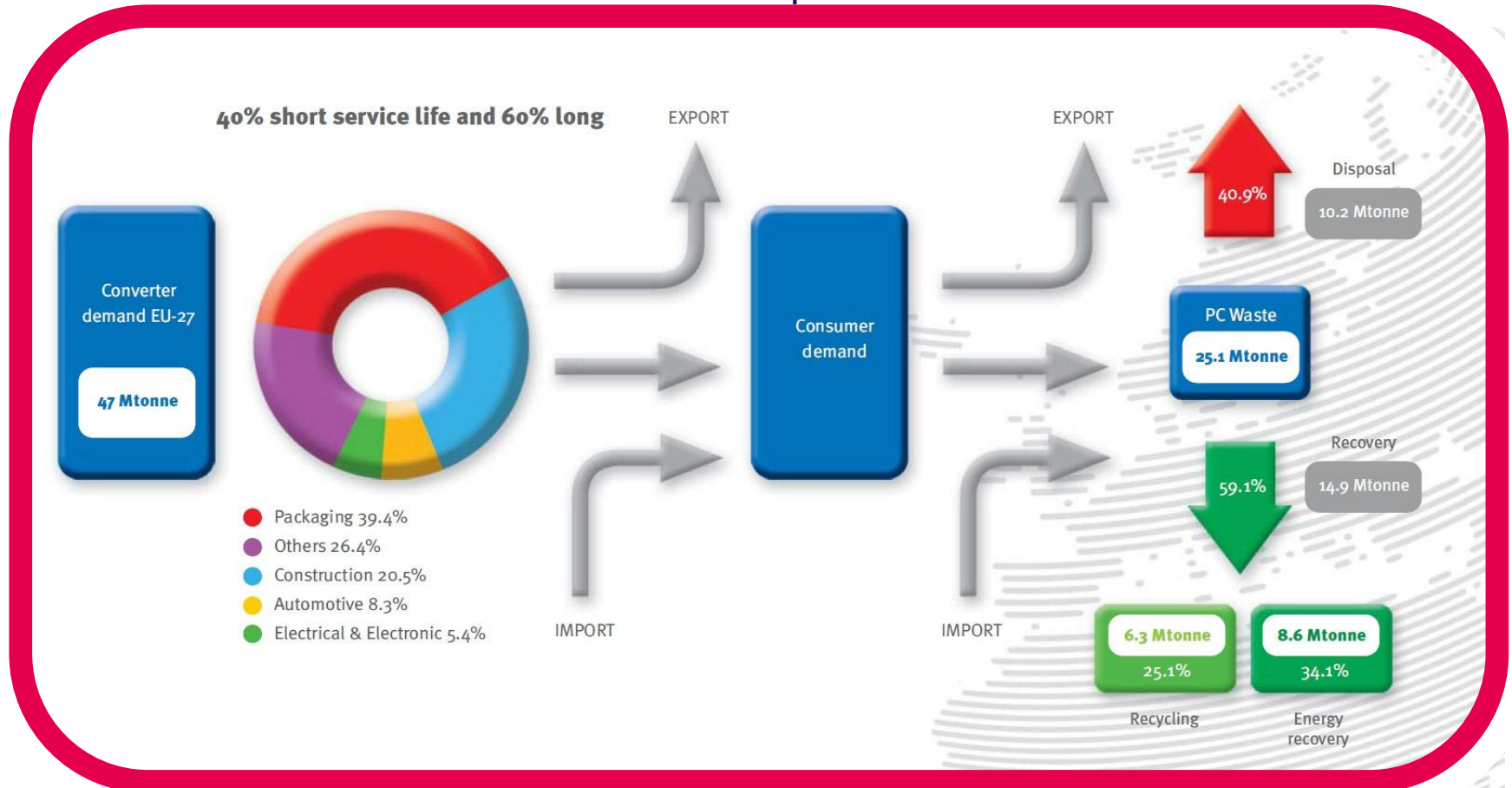
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Introduction

Europe



Source: PlasticsEurope Market Research Group (PEMRG)

Introduction

- **Mechanical recycling favourable option**
- **Current status: thick-walled products**
- **Developments in sorting technology**



Plastics recycling in the Netherlands

- Commingled collection
- Source-separation (pick-up and drop-off)

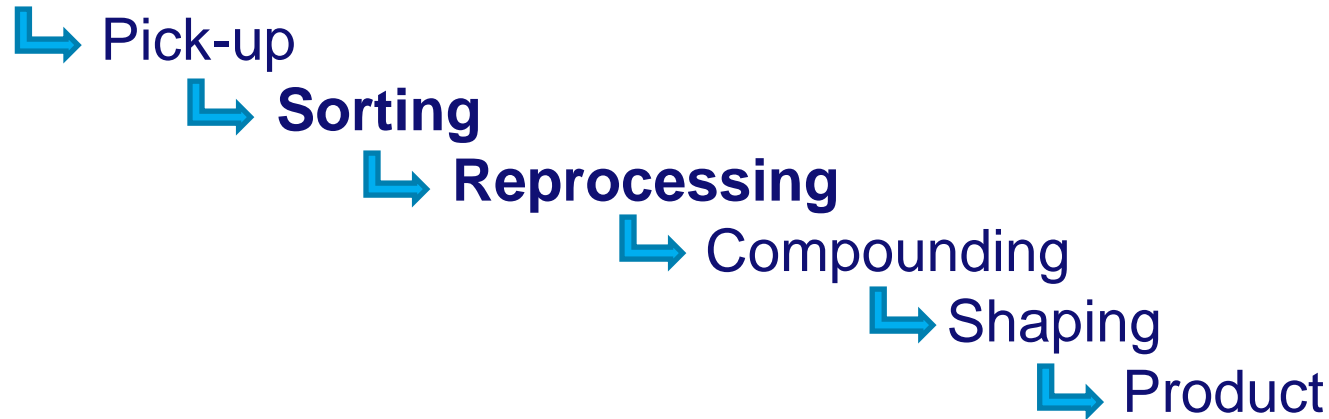


Objective

“To study the influence of sorting and reprocessing steps on the quality of recyclates”

Quality \equiv Composition & Performance

PPW



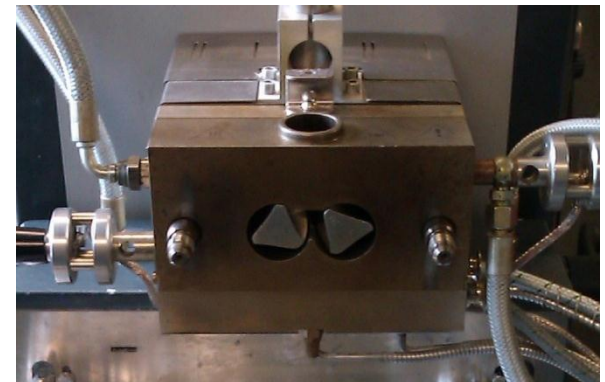
Approach (Composition)

1. **Compound** virgin blends of PE/PP in various compositions
2. Obtain **blend composition**
 - DSC
 - FT-IR spectroscopy
3. Construct **calibration lines**
 - Distinctive and abundant peaks
 - Choose on basis of 'best-fit'
4. **Test** method with recyclates
5. **Adapt** and **improve** methods

HDPE	iPP
100	0
97	3
94	6
80	20
60	40
50	50
20	80
6	94
3	97
0	100

Starting Materials

- **Virgin:** HDPE, i-PP
- **Recyclates** (~) well-defined materials
 - Source-separation (SS) and commingled collection (CC)
 - PE, PP, Film, PO Mix, Mixed plastics
 - SS: 2 collectors
 - CC: 3 collectors + 3 sorting facilities
- **Compounding:** Haake batch mixer

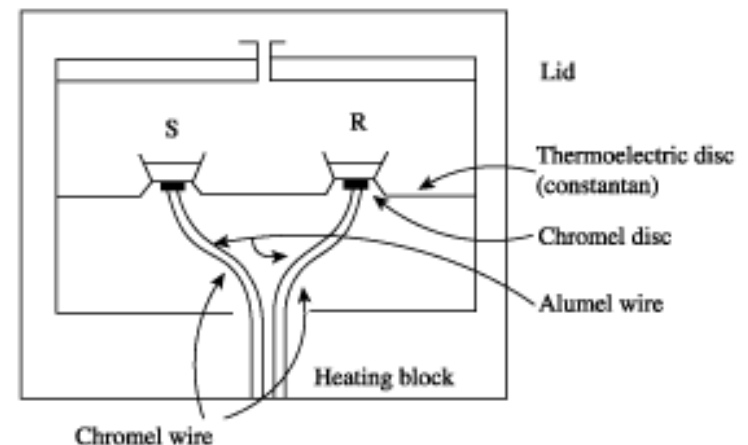


Code	Source	Origin	Main plastic	Additional separation steps
PE 1	CC	Collector 1, Facility 1	PE	
PE 2	CC	Collector 2, Facility 2	PE	
PE 3	CC	Collector 3, Facility 3	PE	
PE 4	SS	Collector 4	PE	
PE 5	SS	Collector 5	PE	Manual screening
PE 6	SS	Collector 5	PE	
Foil 1	CC	Collector 1, Facility 1	PE	Extensive hand-NIR sorting
Foil 2	CC	Collector 3, Facility 3	PE	
Foil 3	SS	Collector 4	PE	
Foil 4	SS	Collector 5	PE	Manual screening
Foil 5	SS	Collector 5	PE	
PP 1	CC	Collector 1, Facility 1	PP	
PP 2	CC	Collector 2, Facility 2	PP	
PP 3	CC	Collector 3, Facility 3	PP	
PP 4	SS	Collector 4	PP	
PP 5	SS	Collector 5	PP	Manual screening
PP 6	SS	Collector 5	PP	
PO 1	CC	Collector 1, Facility 1	PE, PP (rigids)	
PO 2	CC	Collector 3, Facility 3	PE, PP (flexibles)	
PO 3	CC	Collector 3, Facility 3	PE, PP (flexibles)	Centrifugation
PO 4	CC	Collector 3, Facility 3	PE, PP (rigids)	
PO 5	CC	Collector 3, Facility 3	PE, PP (flexibles)	Hot water washing
PO 6	CC	Collector 3, Facility 3	PE, PP (rigids)	Hot water washing
MP 1	CC	Collector 1, Facility 1	PE, PP, PET	
MP 2	CC	Collector 2, Facility 2	PE, PP, PET	
MP 3	CC	Collector 3, Facility 3	PE, PP, PET	
MP 4	SS	Collector 4	PE, PP, PET	

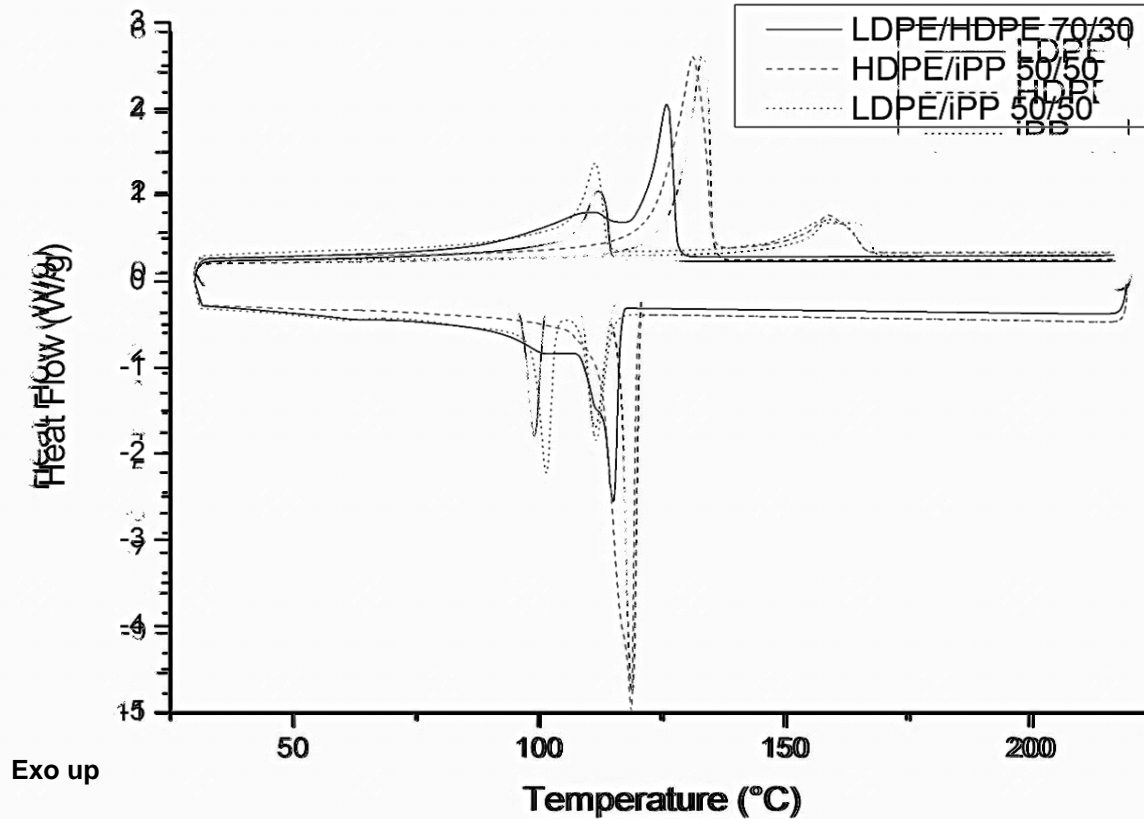
Compositional Analysis: DSC

Differential Scanning Calorimetry

- Phase transitions in semi-crystalline polymers
- LDPE, HDPE and i-PP show different melting and crystallization behaviour
- Often used in polymer science
 - Purity
 - Polymerization reactions
 - Thermal history
 - Degree of crystallinity
 - Etc.
- 1-10 mg sample size



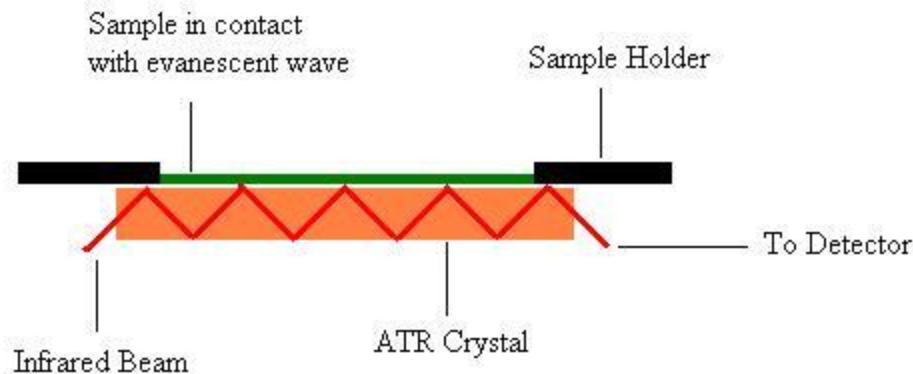
DSC Thermograms



Compositional Analysis: FT-IR

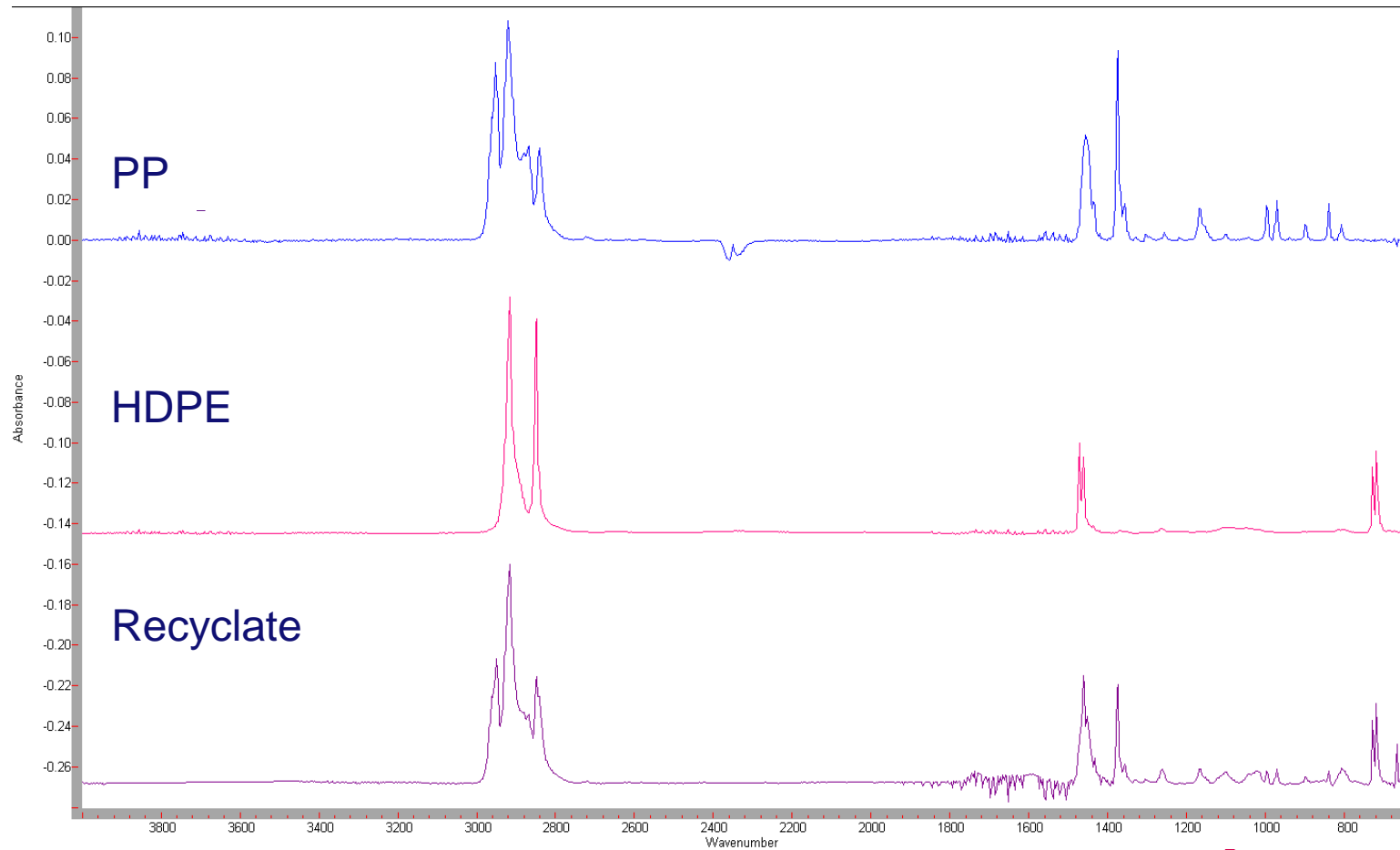
Fourier Transform InfraRed spectroscopy

- **ATR: Attenuated Total Reflectance Mode**
- **Molecular vibrations**
- **Spectra give fingerprint of polymer**



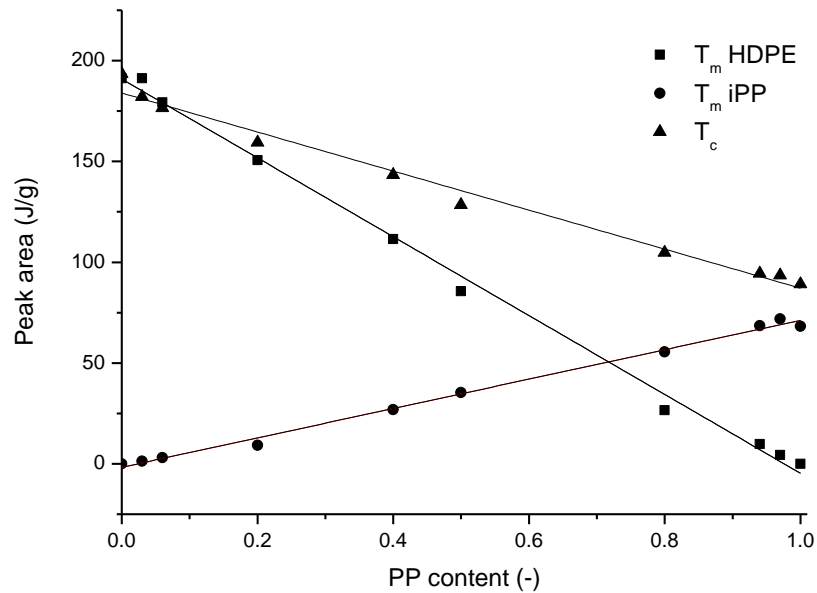
Schematic of a multiple reflection ATR system

FT-IR spectroscopy

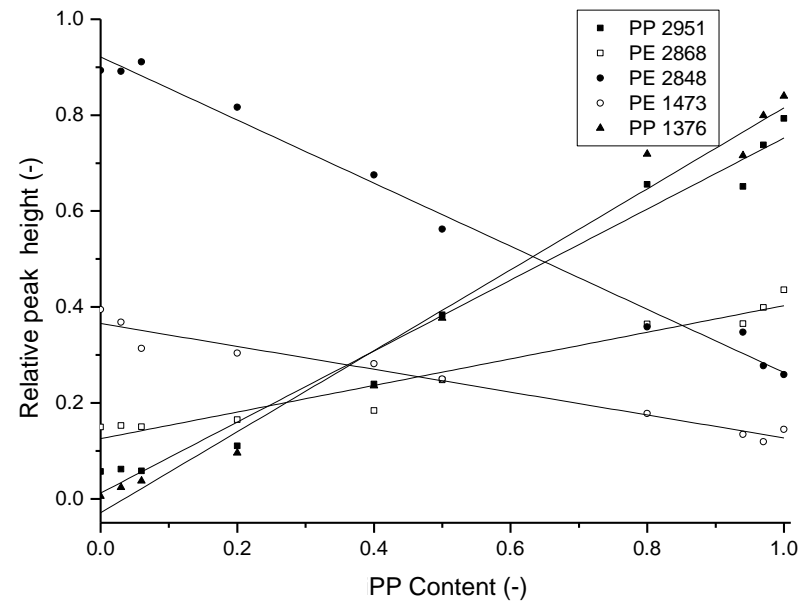


Calibration lines

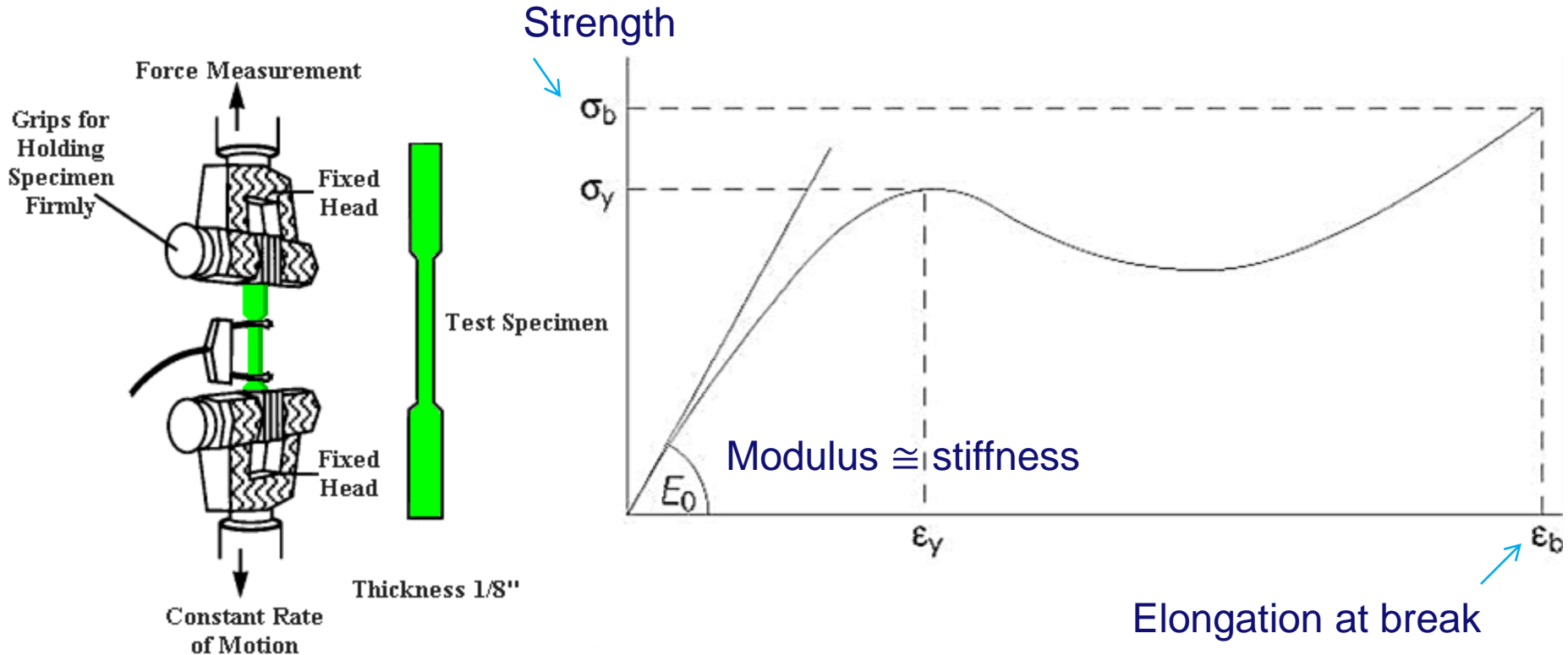
DSC



FT-IR



Mechanical Properties



Results

	Composition after sorting*			Composition after compounding		Mechanical properties	
	PE	PP	PET	IR	DSC	Strength (MPa)	ϵ at break (%)
				PP Content (-)			
PE average	0.93	0.05	0.02	0.11	0.10	24.7 ± 1.1	280 ± 164
Foil average	0.90	0.07	0.04	0.17	0.07	14.1 ± 2.1	170 ± 82
PP average	0.02	0.96	0.02	0.96	0.97	23.0 ± 1.8	12 ± 7
PO average	0.76	0.21	0.02	0.32	0.20	16.6 ± 1.9	97 ± 87
MP average	0.24	0.15	0.61	0.47	0.40	10.7 ± 2.6	13 ± 4
PO 2	0.85	0.13	0.01	0.23	0.15	13.1 ± 1.2	8 ± 3
PO 3 Centrifuge	0.85	0.13	0.01	0.19	0.17	14.7 ± 0.9	96 ± 107
Foil 4 Manual screening	0.89	0.05	0.06	0.17	0.08	12.4 ± 1.9	127 ± 172
Foil 5	0.89	0.05	0.06	0.15	0.09	12.5 ± 2.6	20 ± 8
PO 4	0.80	0.18	0.02	0.16	0.17	21.8 ± 3.9	176 ± 148
PO 6 Hot washing	0.82	0.15	0.02	0.16	0.11	20.2 ± 3.4	230 ± 204

- Sorting and compounding compositions match quite well
- Influence of additional sorting steps

*Source: Michael Jansen

Conclusions

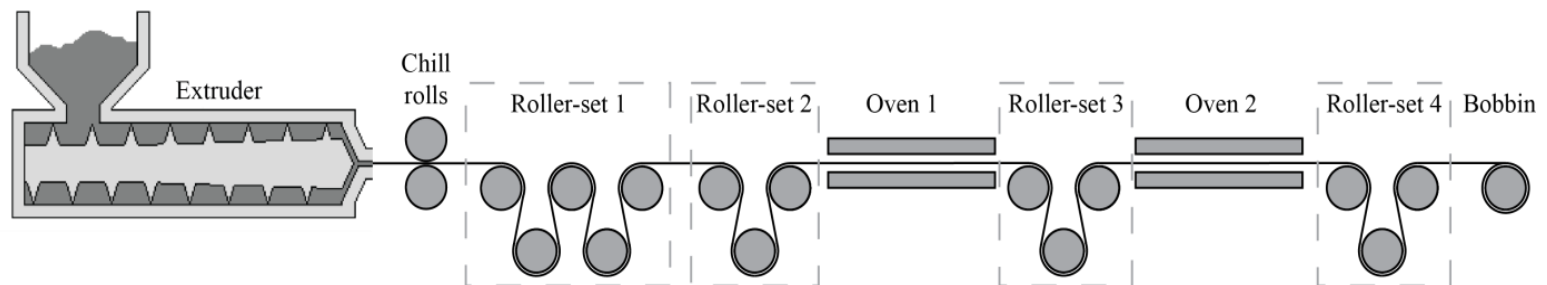
- **5-10 % plastic contamination in recyclates**
- **Which parameters in sorting and reprocessing influence the quality of recyclates?**
 - Hot washing
 - Additional manual sorting
 - Centrifugation
 - **No difference observed between commingled collection and source-separation**
- **Extensive sorting leads to properties approaching virgin plastics (PE, Film)**

Outlook

- **What does this study contribute to the field?**
 - **Structural improvements in recyclate quality**
 - **Exploration for high(er)-demanding applications**
- **PP: A case study**

PP: A case study

- **PP: versatile plastic, toughness**
- **Strength: 37 MPa, elongation at break ~800%**
- **PP Recyclate: 26 MPa, 30%** ☹️
- **Advanced processing method: solid-state drawing**



PP: A case study (2)

- **The results:**

	Modulus (GPa)	Strength (MPa)	Max. drawability (-)
Virgin	13.4	547	21
Recyclate	11.5	403	19

x16 😊

	Cost (€/ton)*	Strength (MPa)	Specific cost (€/MPa)
Virgin	941	547	1.72
Recyclate	627	403	1.55

*Source: www.alibaba.com, 21-11-2012

Questions

ONLY ONE EARTH



Thank you for your attention!