Dan-iso A/S

Insulating & Saving Energy

PURrecy

Sustainable insulation products

Dan-iso A/S provides technical insulation for district heating, cooling, the wind turbine industry, and construction – as well as for the oil, offshore, and marine industries. A reliable and innovative partner since 1986.

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Why?

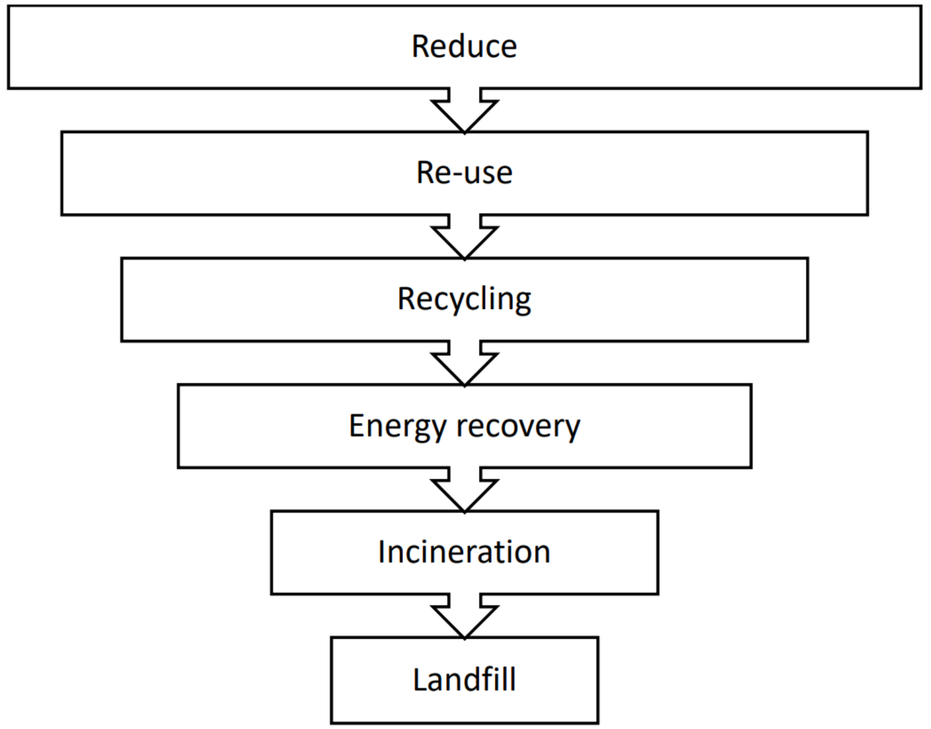
- A significant amount went to waste
- We should be able to address this issue
- Too much valuable material to simply burn

What have we done so far?

- Raw materials
- Production residues
- Product end-of-life

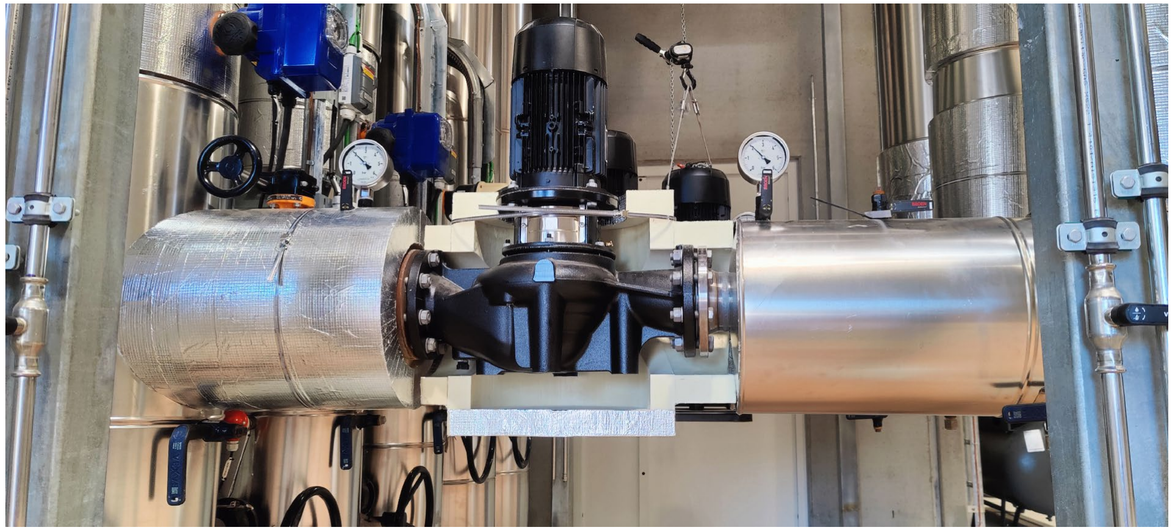
How can we improve?

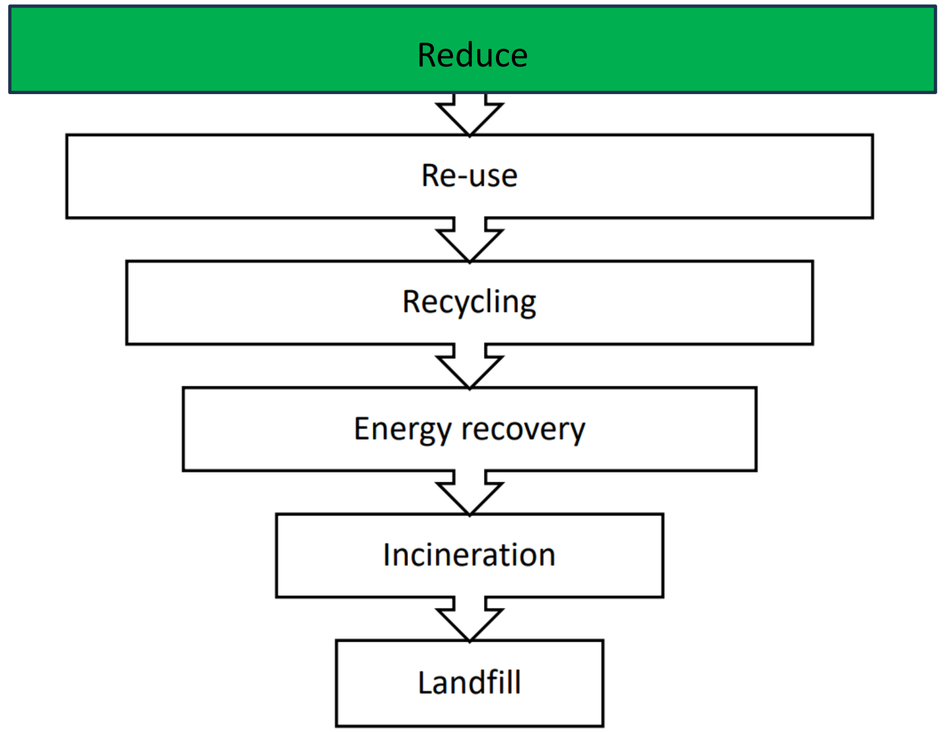
- What is recommended for waste management?
- EU Directive 2008/98/EC: Prevention, recycling, reuse, energy recovery, disposal
- The Waste Hierarchy (Lansink's Ladder)



Current practices

- Focus on high-efficiency and optimized production to minimize waste
- Ensuring the production of high-quality products that are designed to have a long lifespan before, reducing the need for frequent replacements



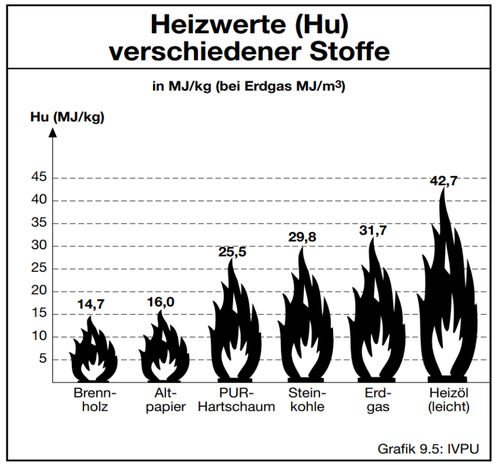


Sustainable PUR

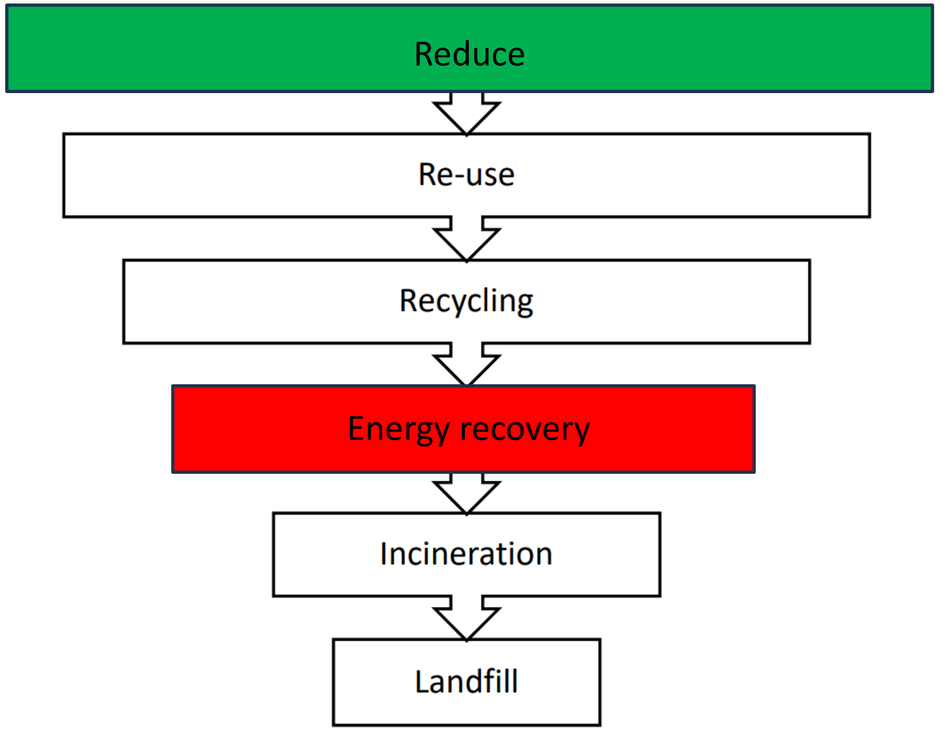
- PUR waste is particularly challenging to recycle.
- Until approximately 20 years ago, the consensus was that incineration and energy recovery were considered best practices.

'The European PU industry, specially for rigid PU foam, consider the recovery of energy from scrap material PUR foam from construction and demolition waste to be the best disposal option as laid down in various posoisition papers [71, 72]'

Source: Zevenhoven, 2004, Treatment and Disposal of Polyurethane Wastes: Options for Recovery and Recycling

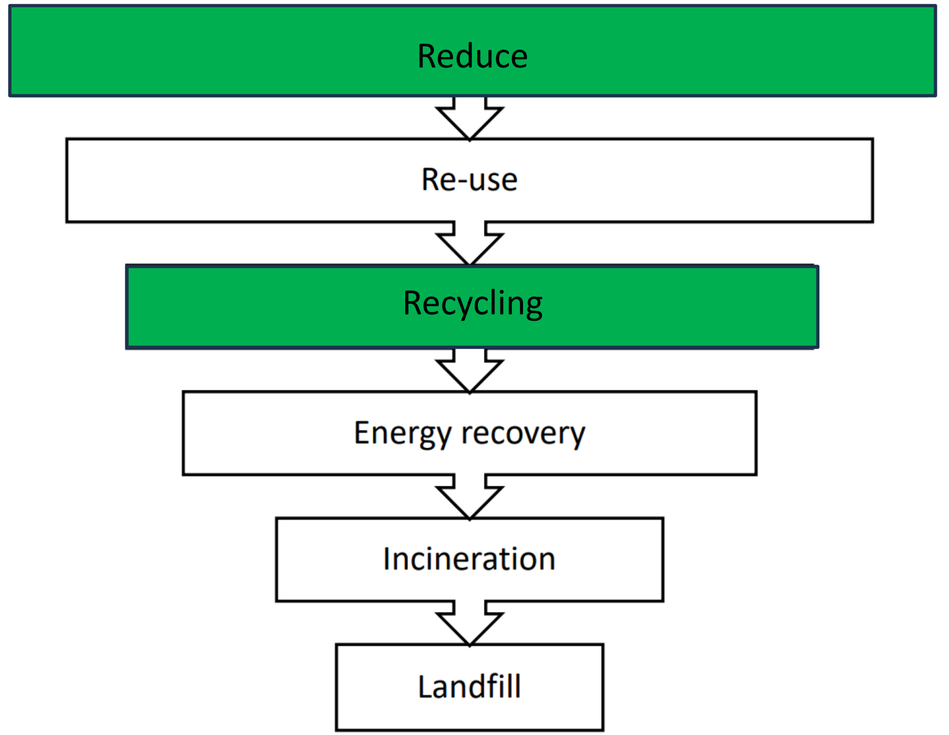


Calorific values of PUR foam compared with other energy sources



Our goal with the project

- We are already doing a lot to reduce material consumption, but
- We aim to increase recycling.

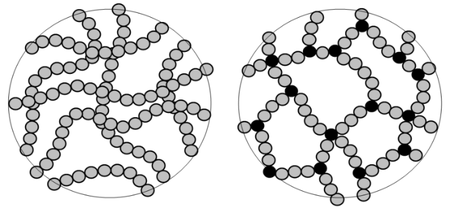


Our Requirements

- We must be able to use our own waste
- It must be profitable
- It must be a real green solution
- Processes must be kept in-house
- Keep it simple!

Which way to go?

- PUR foams cannot be recycled using conventional methods.
- Thermosets contain strong crosslinks that prevent recycling.
- Four main strategies for recycling
- Which one should we choose?
- The low-hanging fruit.



Thermoplastic Thermoset

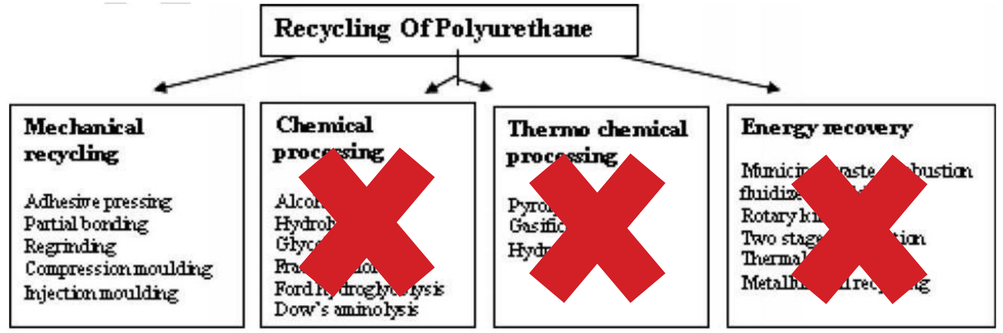
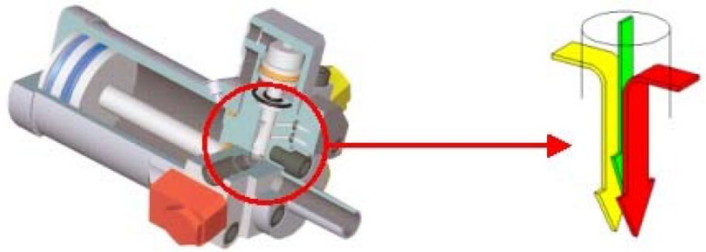


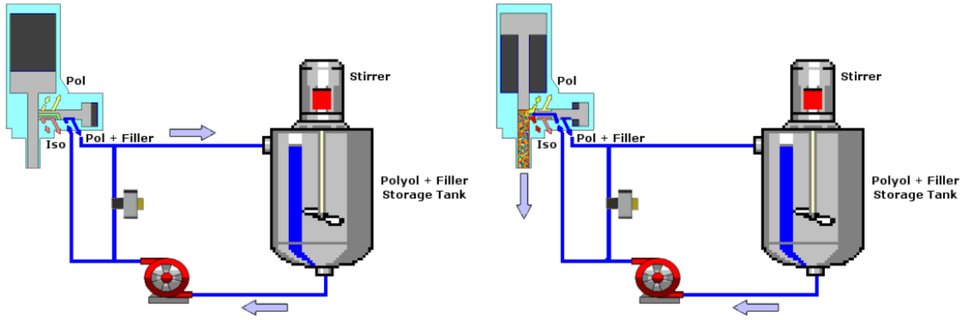
Fig. 1. Overview of options for polyurethane recycling [16].

Have others tried?

- Several examples can be found in the open literature.
- Cannon Afros and Mobius Technologies have developed machine prototypes for this purpose.



Picture 7 - Cannon FPL /3 Mixing Head with High Efficiency Axial Components Mixing



Picture 8 – Cannon prototype filler injection kit layout showing recycling and pouring phases

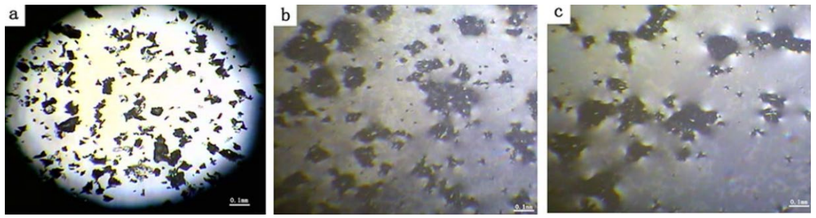
CONCLUSIONS

The results obtained show that recycled PU powder can be used in moulded car seats at levels of up to 7% on the overall foam weight. Mobius selected this level as it was demonstrated in earlier trials that at such a level, the mechanical and physical properties of the moulded foam parts were not significantly affected and seat foams were still meeting the specific OEM specifications for car seats.

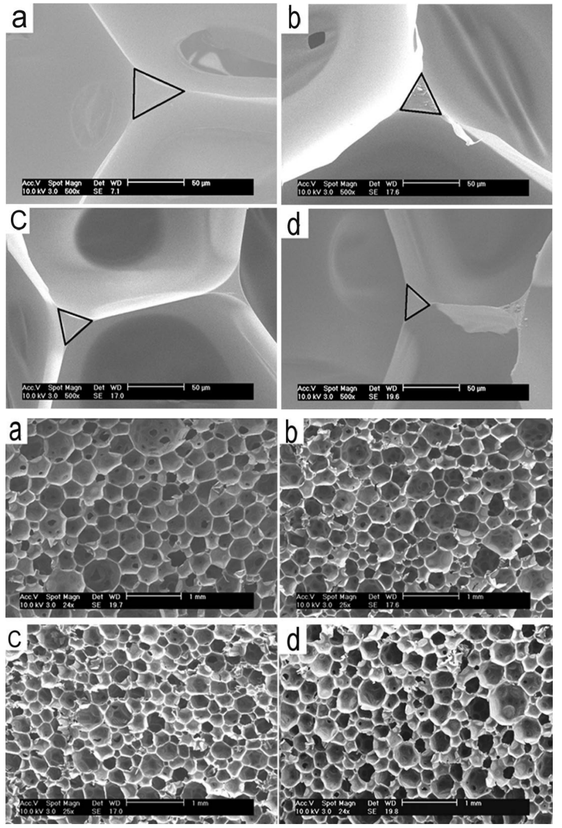
Kilde: ANDREOLLI, STEFANO & CHARIATI, CHRISTIAN & BERTHEVAS, PAUL & VILLWOCK, ROBERT. (2015). Innovative Filler Injection System for Powdered Recycled Urethane.

Have others tried?

- Yang et al. (2013) reached up to 15% recycled powder material in a rigid foam (Fudan University, Shanghai)
- Good properties at 5% and 10% powder content
- Reaching 15% requires several extra processes and additives



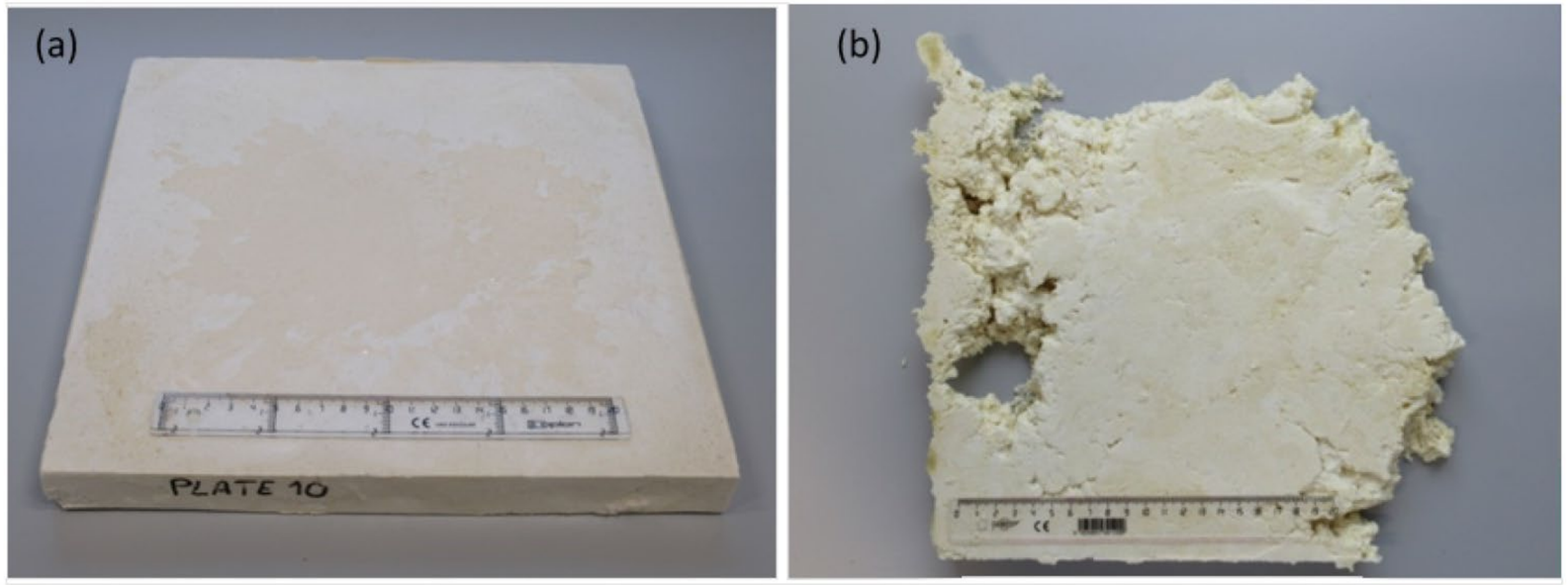
Dispersion of particles in polyol



Foam structure with various contents of recycled material

Have others tried?

- Aranberri et al. (2022) reached up to 5% with good results
- They recommend op to 3% for best results
- A maximum of 3 to 10% is mentioned by most sources
- A few sources cite op to 15% recycled material, but this requires expensive and complicated processes
- Dan-iso saw this as a challenge worth taking



(**a**) Plates of rigid polyurethane foams with 3 wt% and (**b**) 10 wt% of recycled polyurethane foam powder.

[Aranberri et al. 2022]

Preliminary Experiments

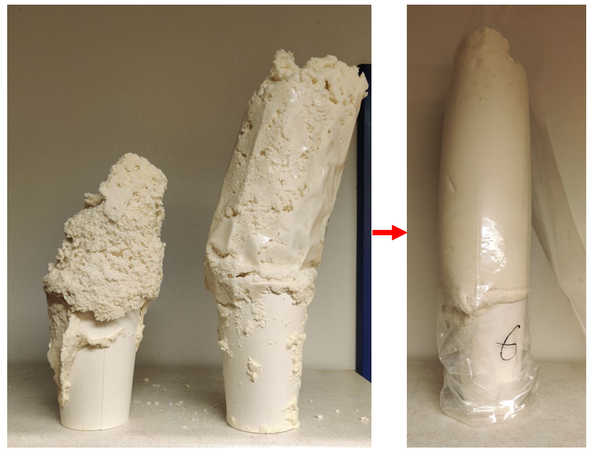
- Even with low quantities of PUR powder the liquid becomes very viscous
- This poses a big challenge to existing machinery
- Not so easy (after all)

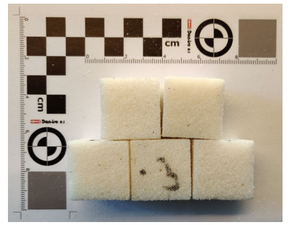
Sample	Polyol	Polyol/ PPU5wt%	Polyol/ PPU10wt%	Polyol/ PPU15wt%
Viscosity (mPa s)	1900	3400	5480	>10,000

Viscosity of polyol with PUR powder - [Yang et al. 2013]

Incremental Development

- Small quantities of recyclate to begin with
- (2-3%)
- Slow but steady progress to 25% and beyond
- Always with a focus on production
- The goal was always a marketable product



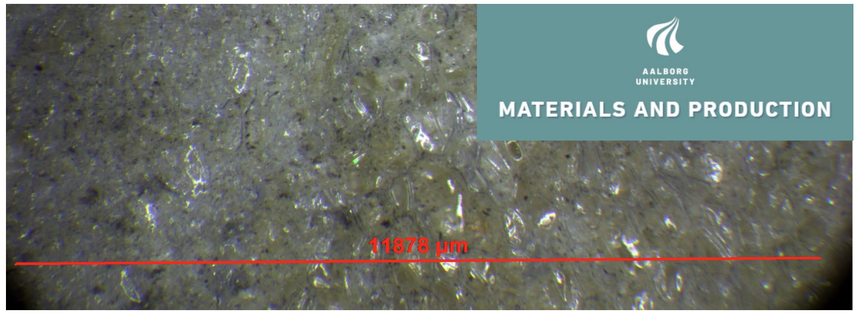


Identification of Key Parameters

Input parameters:
- Blowing agents
- Mixing methods
- Particle surface
- Particle size
- ...

Material properties:
- Density
- Compressive strength
- Lambda
- Stiffness
- ...

Production parameters:
- Interaction with different mold shapes
- Interaction of processes with our own machinery
- Extra processes that require implementation
- ...



Where is Dan-iso?

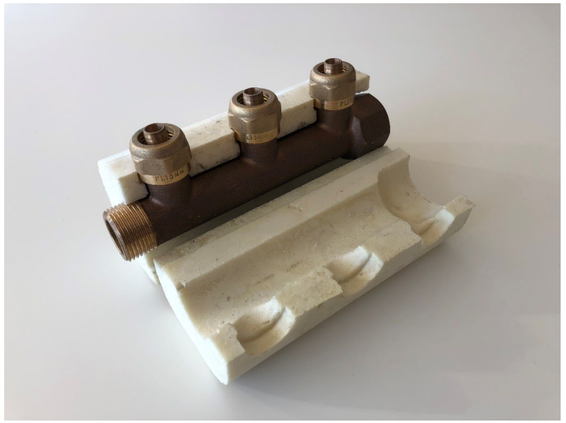
Two tracks

Track 1: 40% to 45% recycled material

Pros:
High content of recycled material
Requires few new processes
Can be implemented in our existing production line
Good compressive strength
Material utilization ~95%
Cons:
Lambda values raise a bit (2-3mW/m·K)
Cosmetic differences compared to virgin foam

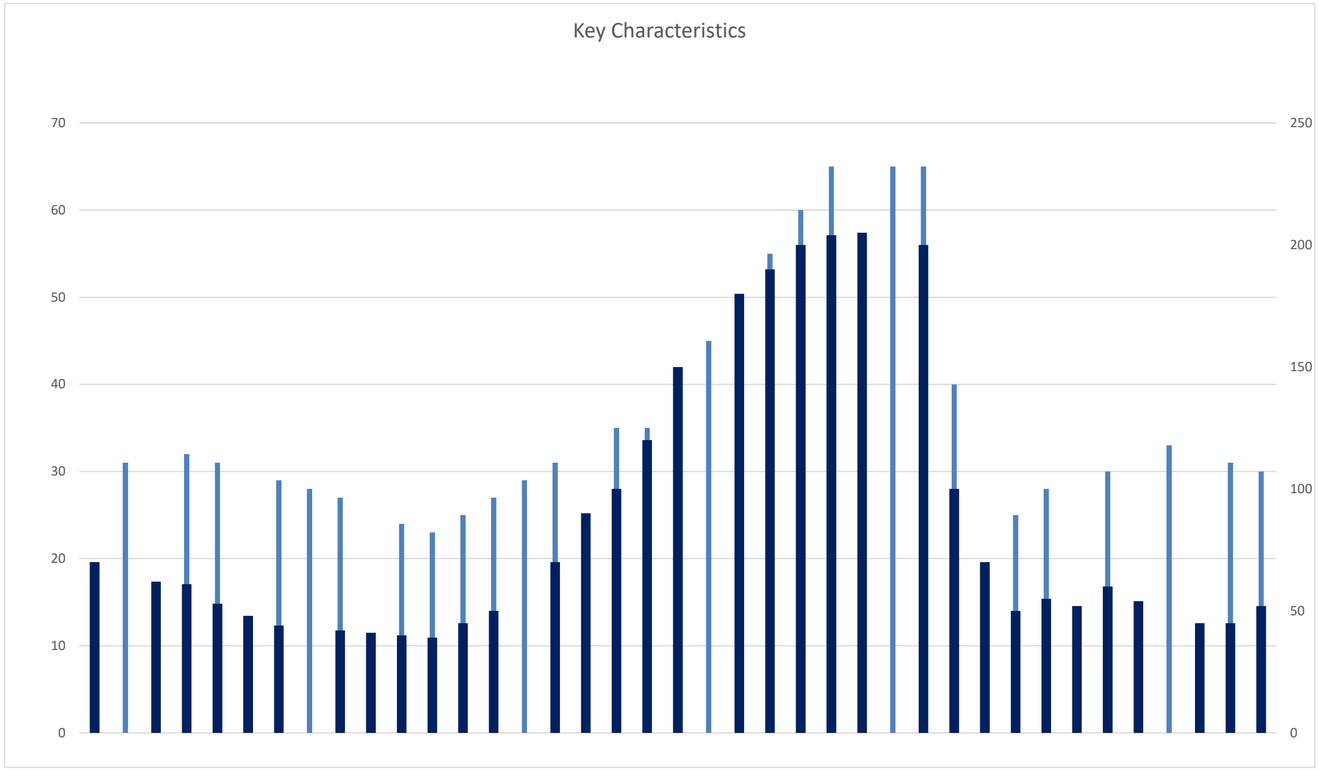
Track 2: 23% to 27% recycled material

Pros:
Really good insulation
Some measurements show slightly better values than pure foam (1-2mW/m·K)
Very flexible with respect to different geometries
Material utilization ~97%
Cons:
Reduction of compressive strength compared to virgin foam
Requires several new processes
Required the development and testing of new machinery and processes



Why Two Tracks?

- The sweet spots of both properties coincide
- Other properties, such as compressive strength, top also at these ”sweet-spots”
- “Something” happens around there



Why Right There?

For small particles,

- We see a very uniform distribution of the particles
- The characteristic surface of the particles “fits” the cell structure
- This results in good foaming
- Particles in the liquid phase are well dispersed

Pore structure of 15% sample

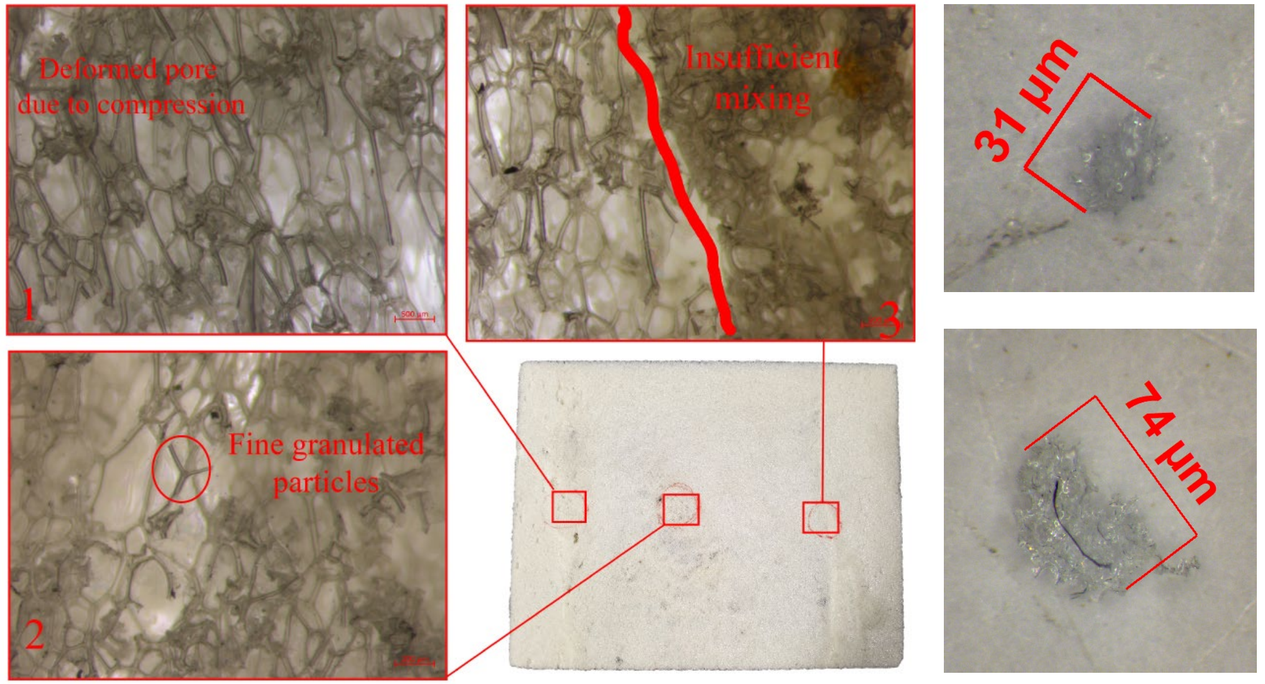
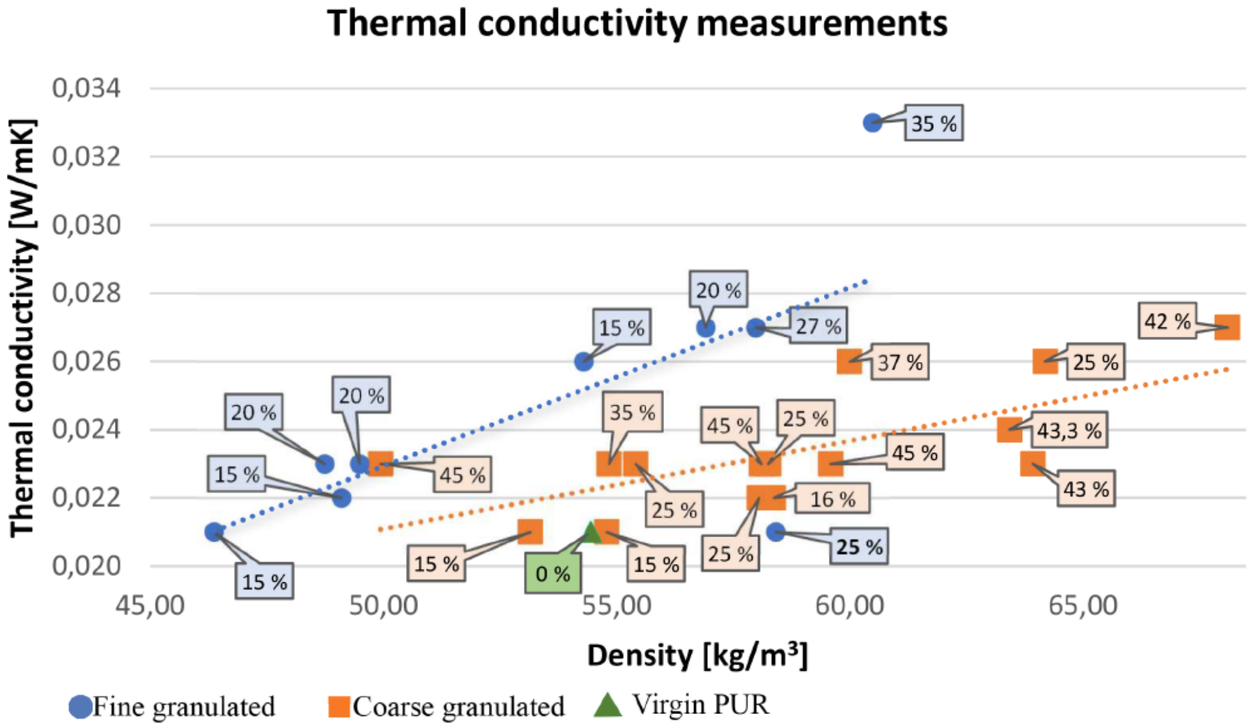


Figure G.2. Fine granulated 15% sample

Microscopic structure of foam with 15% recyclate

Detailed parametric study

- The mechanical and thermal properties at different recycling percentages and production techniques have been studied.
- With the latest production techniques, we achieve exceptional insulation values with up to 25% recycled content.



Preliminary EPD

- A preliminary EPD has been undertaken un cooperation with Aalborg University.
- The EPC shows considerable improvements compared to standard PUR

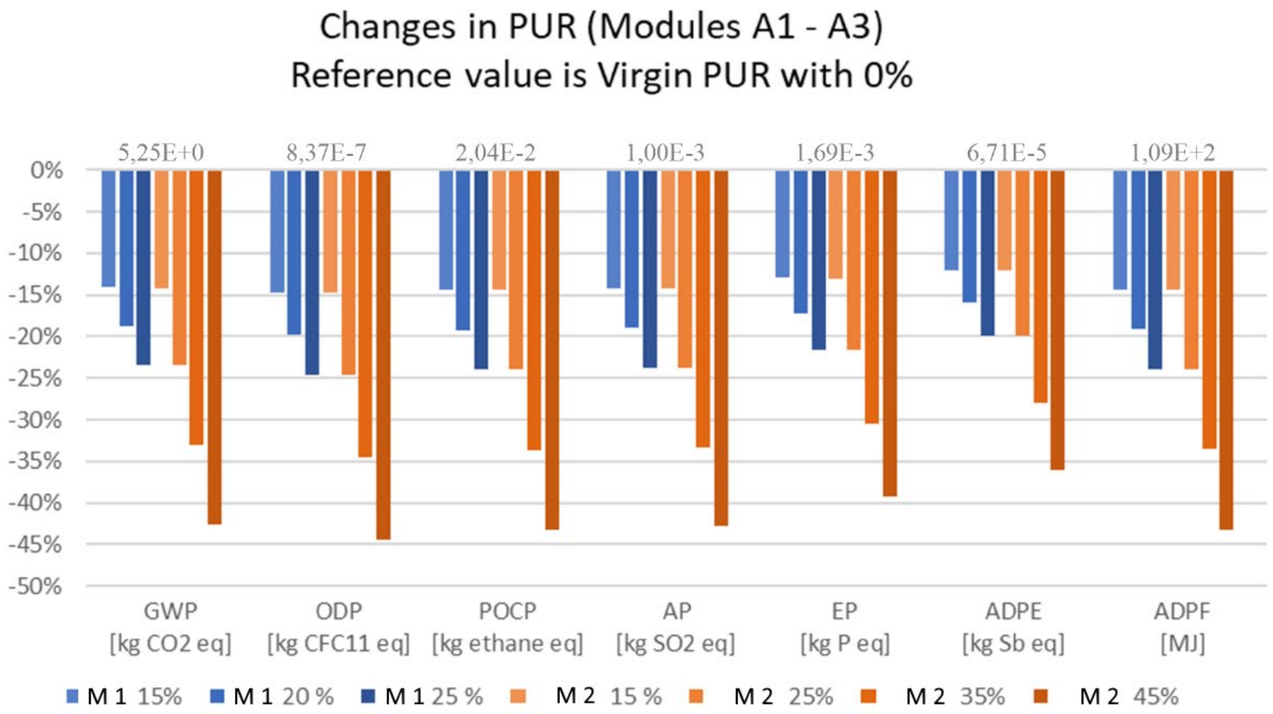
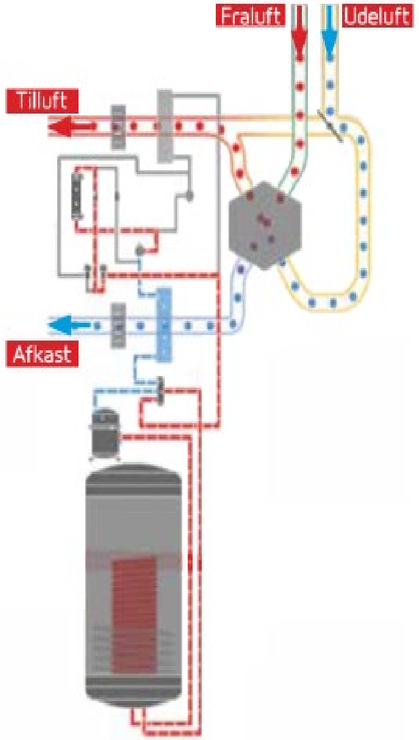


Figure G.3. Changes in PUR (Modules A1 - A3)

What's Next?

- Acquire a deeper understanding in order to increase the percentage of recycled material
  - *Continue along both paths*
- Explore practical applications
  - *Project with AAU Build (DHW and energy expenditures)*
- Examine sustainability
  - *Project with AAU Build on material LCA*
- We have two stable processes - must be automatized



Circular Products