

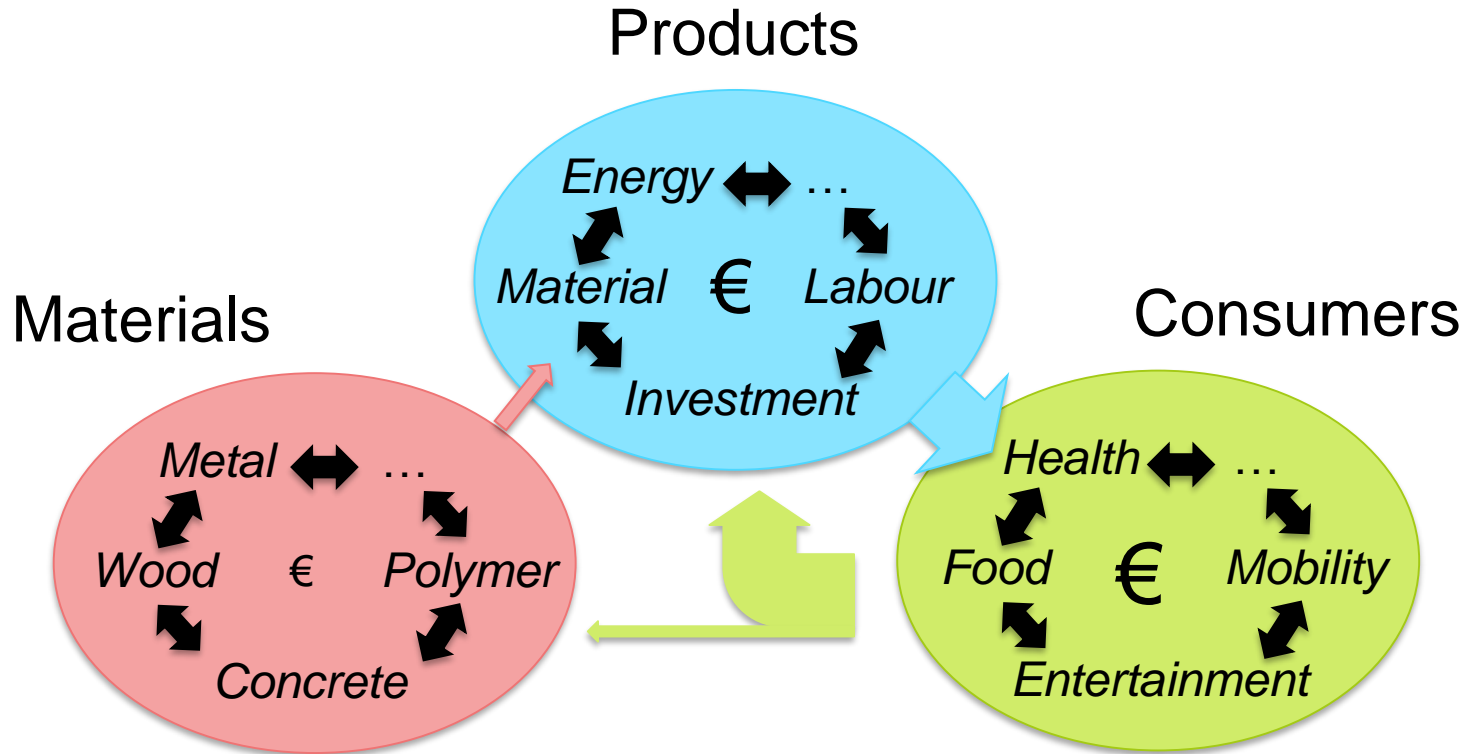
Materials Separation, and the Recycling of Concrete

Resources & Recycling,

Faculty of Civil Engineering and Geosciences, Delft University of Technology

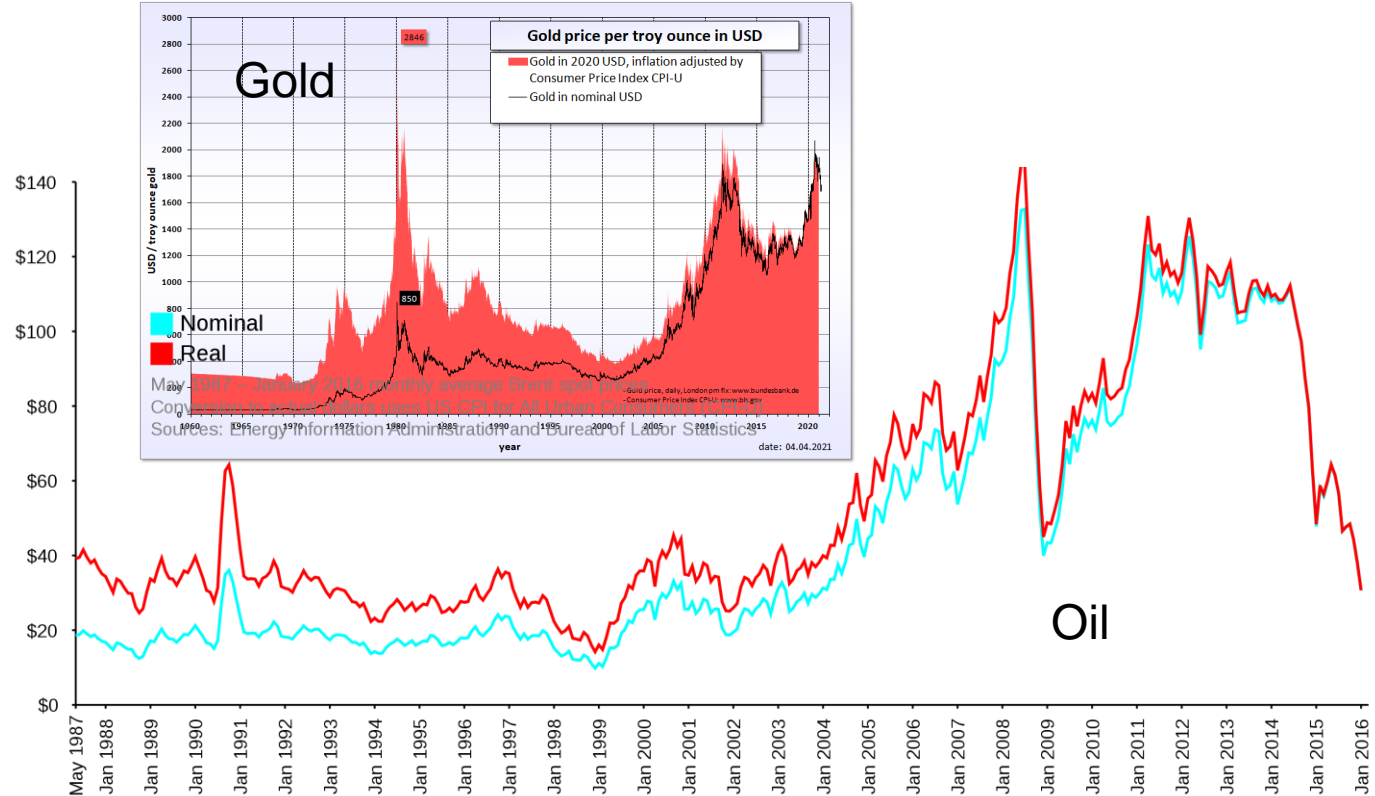
Raw Materials

Raw materials sector: small in €, large in stress



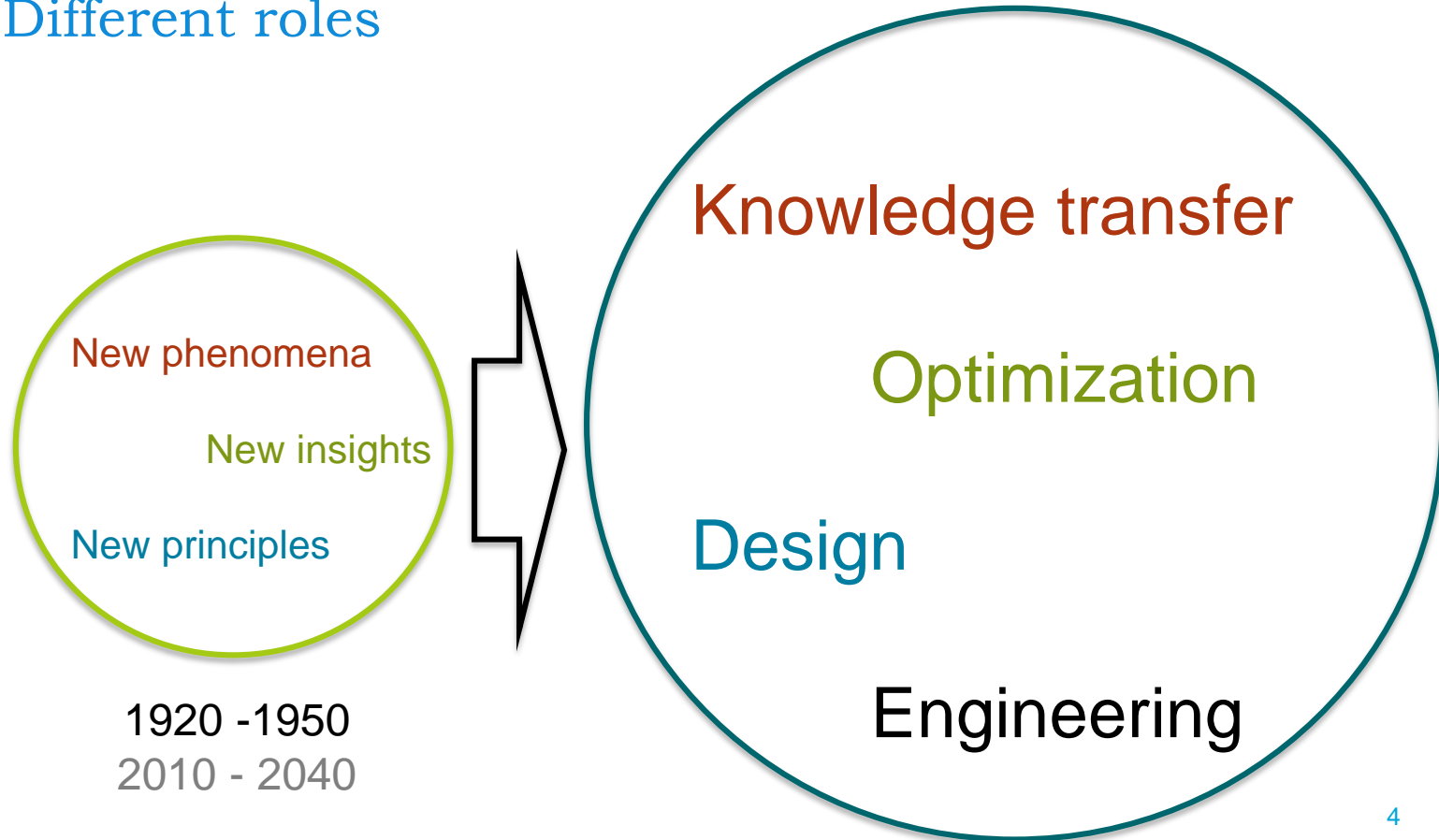
Raw Materials

Raw materials sector: small in €, large in stress



Relief from hard or from soft science?

Different roles



So: how bad is it?

Areas of change

Primary resources	Waste
Granular particles	All shapes
Complexity : 2-3 mat.s	>1000 materials
Demand-driven specs	Waste-driven specs
Tailings acceptable	Tailings not acceptable
Always wet	Sometimes dry
Breakeven 30 years	Breakeven 9-16 months

Mathematics

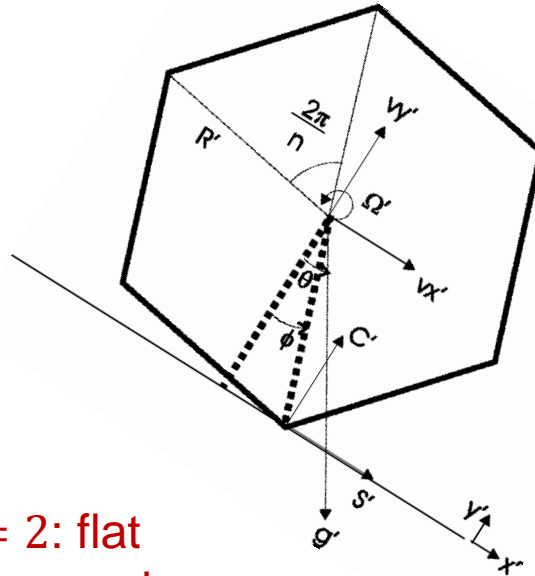
Physics

Economics

Generalized particle shape

Universal equations of motion in contact with slopes

$$\text{Shape } \bar{\phi} = \frac{\pi}{2n}$$



$N = 2$: flat

$N = \infty$: sphere

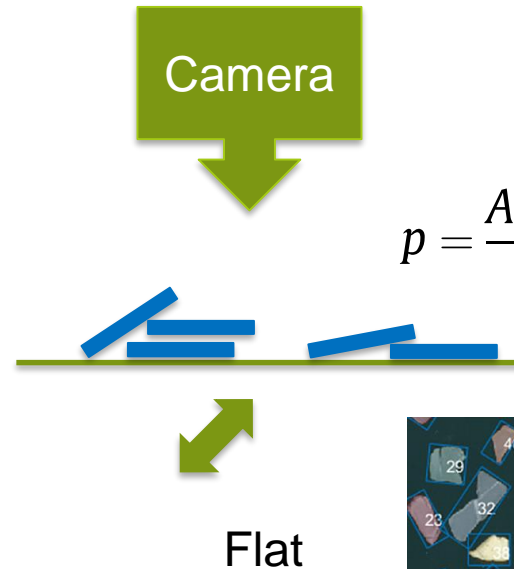
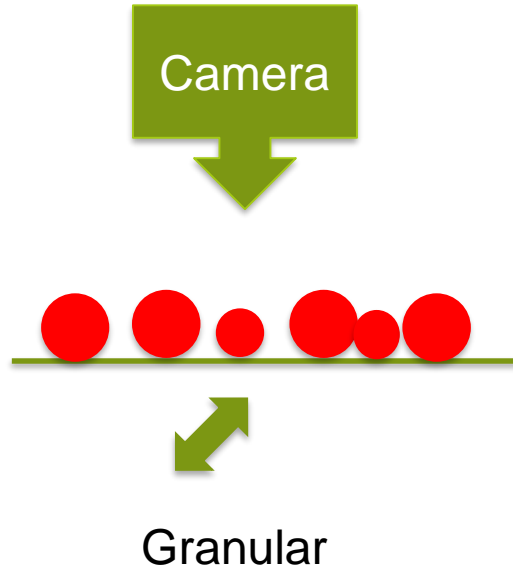
$$\begin{aligned} \dot{v}_x &= (v_{x2} - v_{x0}) / \Delta t \\ &= \frac{\cos^2 \bar{\phi} \sin \theta - \sin \bar{\phi} \cos \bar{\phi} \cos \theta}{2} \end{aligned}$$

$$\begin{aligned} \dot{\Omega} &= (\Omega_2 - \Omega_0) / \Delta t \\ &= \frac{\sin \bar{\phi} \cos \theta - \cos \bar{\phi} \sin \theta}{2I_c} \end{aligned}$$

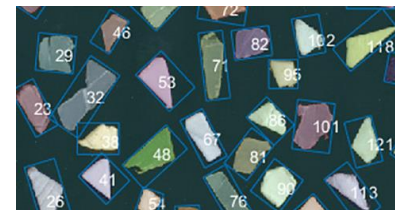
$$\mu > \frac{\sin \theta + \sin \bar{\phi} \cos \bar{\phi} \cos \theta + \sin \theta \sin^2 \bar{\phi}}{\cos \theta + \cos \theta \cos^2 \bar{\phi} + \sin \bar{\phi} \cos \bar{\phi} \sin \theta}$$

Generalized particle shape

Flat particles do not spontaneously form mono-layers

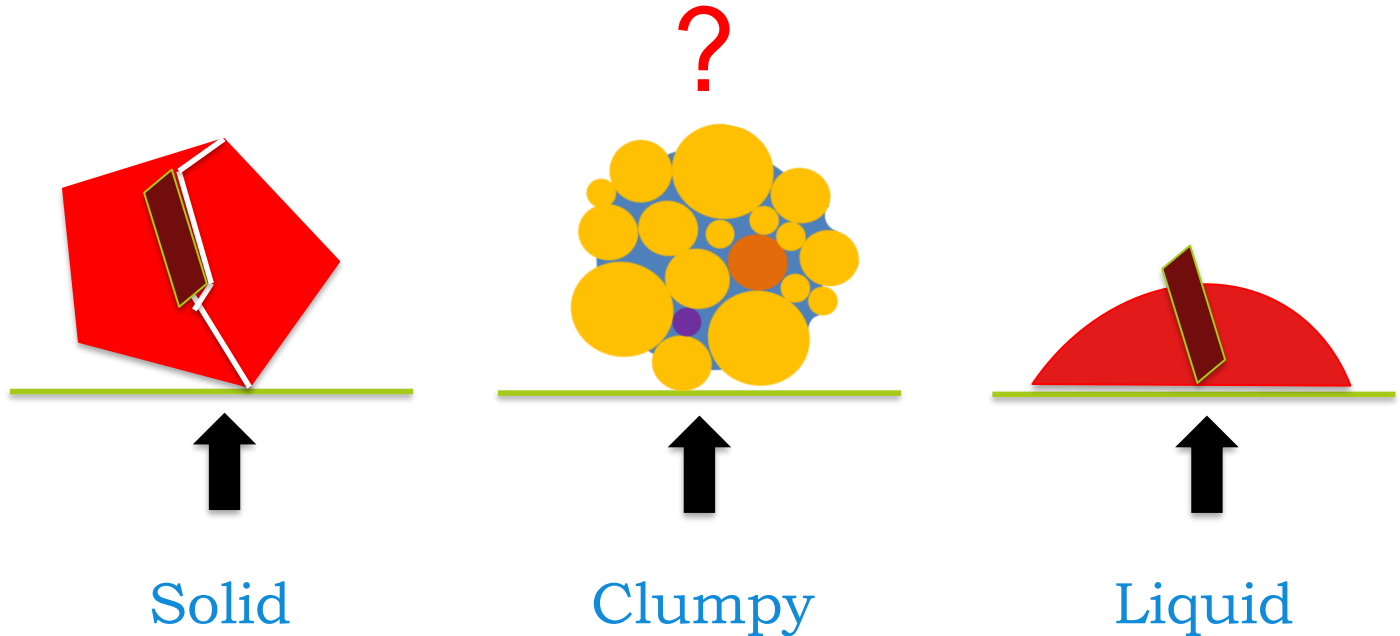


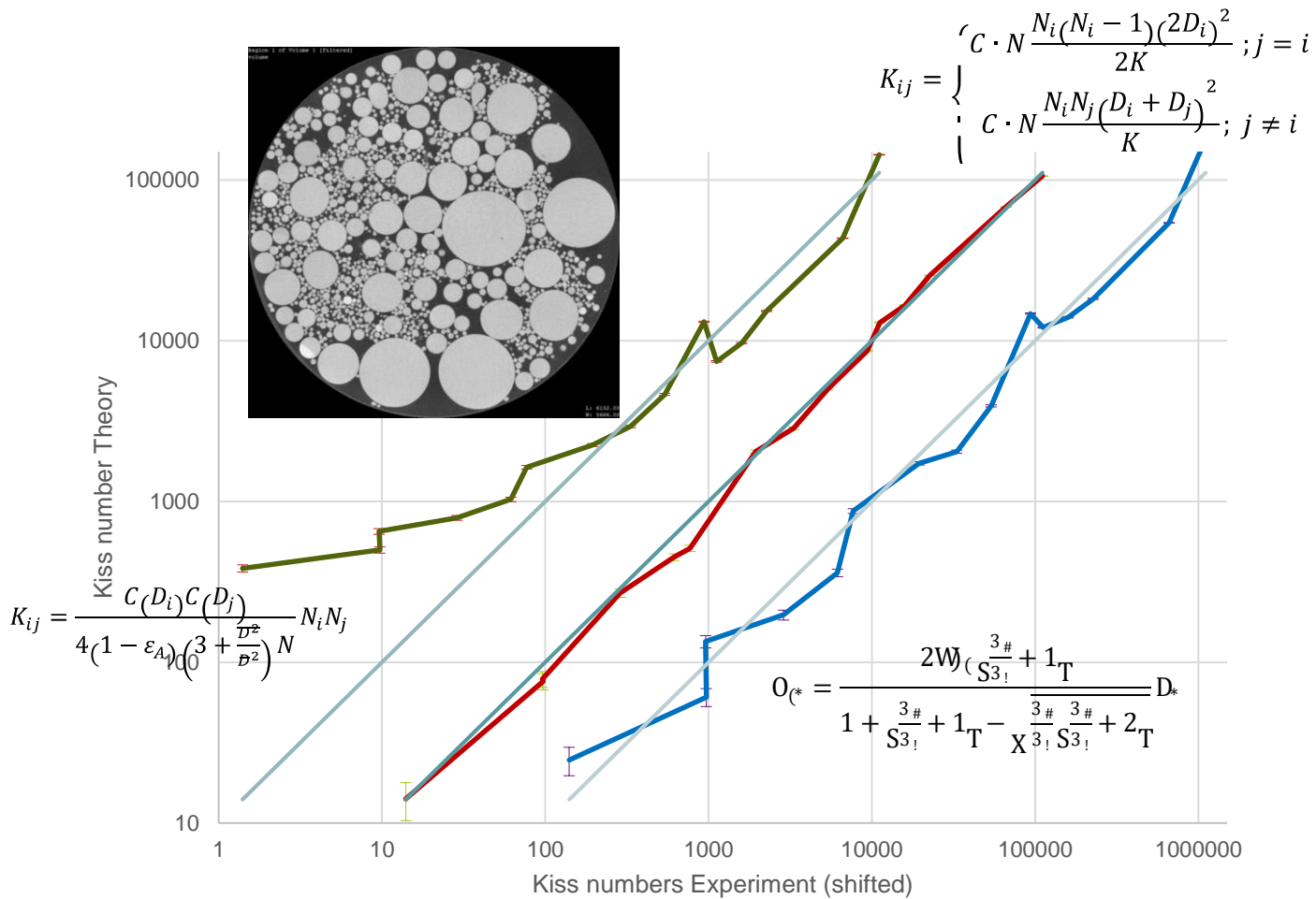
$$p = \frac{A + A' + PP' / 2\pi}{A_{\text{plane}}}$$



Liberation from composites

Clumpy state: between liquid and solid





Liberating metals from moist fine wastes

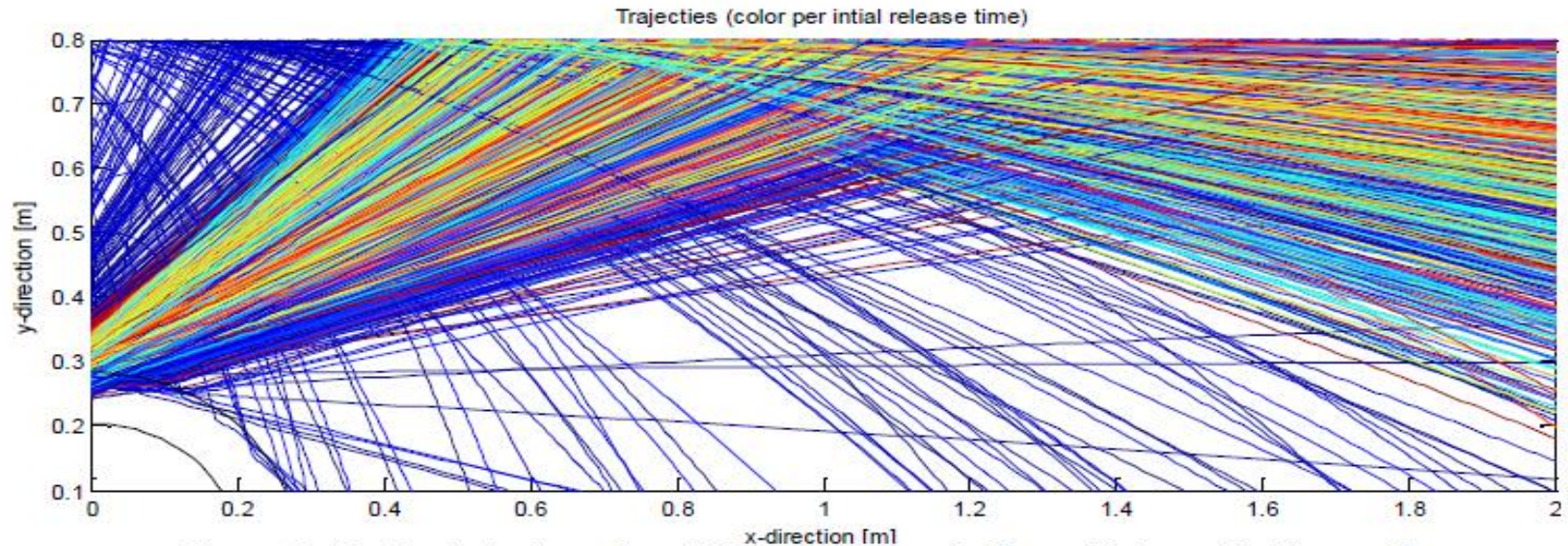


Figure 5.19: Trajectories of particles before and after collision with the roof

Physics of jet formation/evolution

Spinout company: Inashco

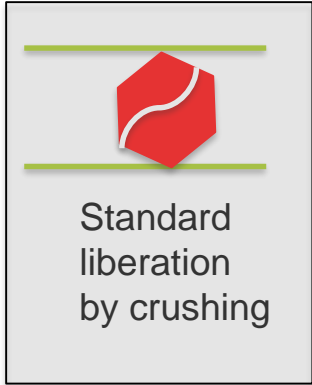
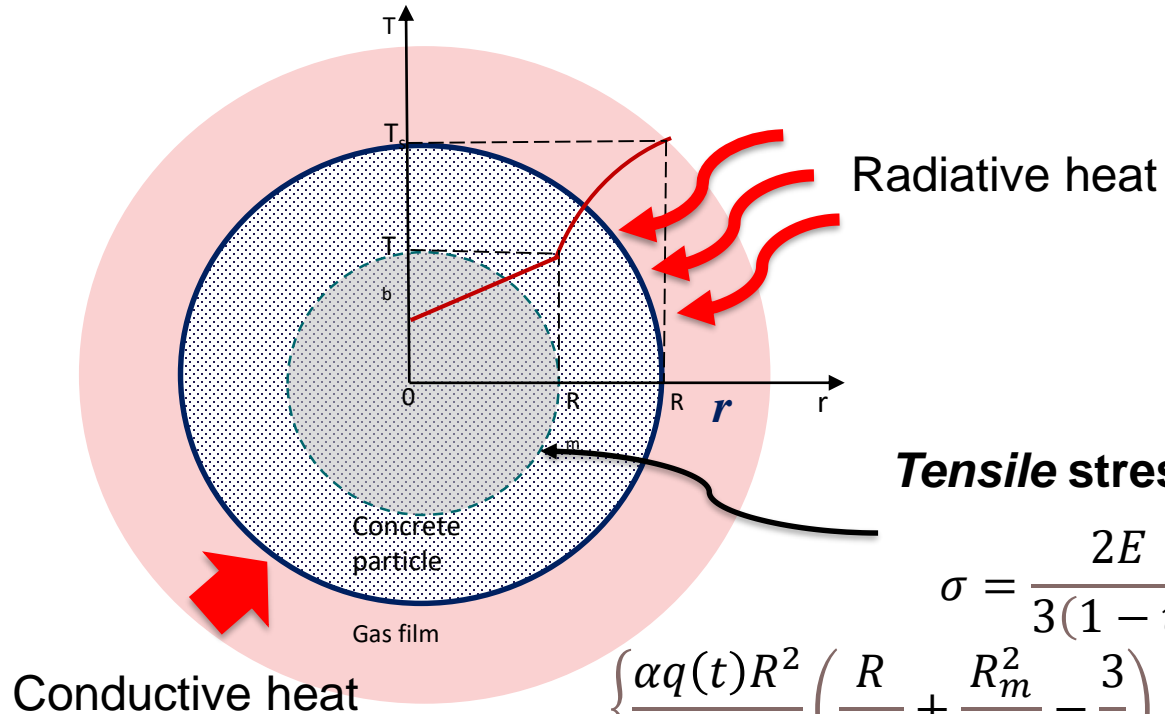
Ashes from household waste



ME 9 (2009) - ME 430 (2021)
Share value

Liberation by a heat shock

Spalling of concrete into cement paste dust and sand



Tensile stress peak

$$\sigma = \frac{2E}{3(1-\nu)}$$

$$\left\{ \frac{\alpha q(t) R^2}{\lambda_c A(t) R} \left(\frac{R}{R_m} + \frac{R_m^2}{2R^2} - \frac{3}{2} \right) - \mu m_0 \left(1 - \frac{R_m^3}{R^3} \right) \right\}$$

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EU 2021 Award: C2CA Technology

Recycling of concrete

The 2021 Innovation Radar Prize has been awarded

Overall 'Grand Prix'
winner



MetGen from Finland was the overall 'Grand Prix' winner of the 2021 Innovation Radar Prize for their game-changing bio-based solution to replace petrochemical wax-based solutions currently used in cardboard packaging boxes.

Category winner
'Disruptive Tech'



Winner of the 'Disruptive Tech innovation' category was Kypo from Czechia for their open source cybersecurity training platform that addresses Europe's cybersecurity skills gap.

Category winner
'Sustainability Tech'



The winner for 'Innovative Sustainability Tech' was C2CA Technology from the Netherlands (a spinoff of TECHNISCHE UNIVERSITEIT DELFT) who have developed a system for recycling construction material and so reduce greenhouse gas emissions.

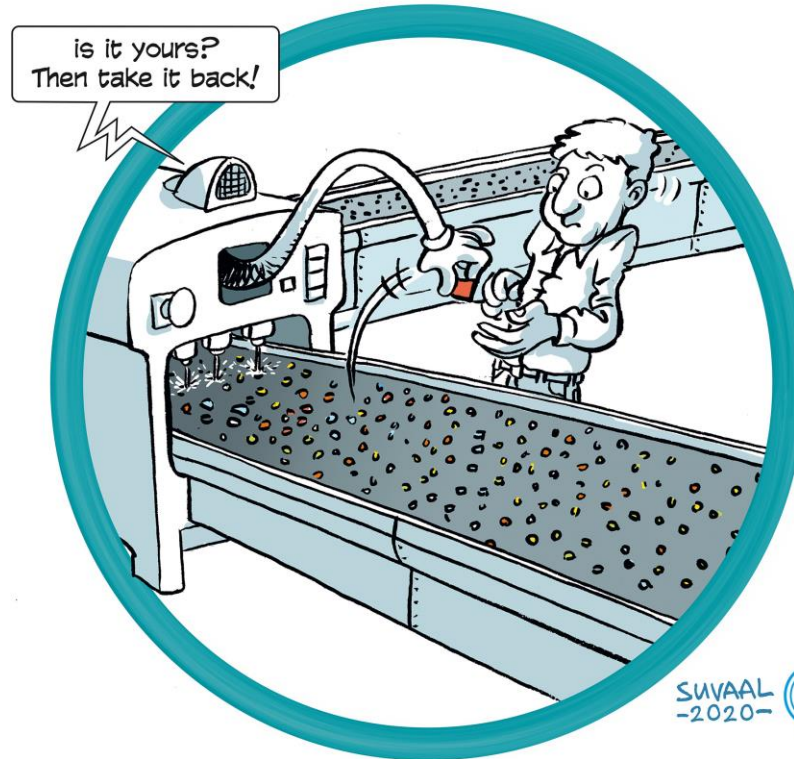
Category winner
'Health Tech'



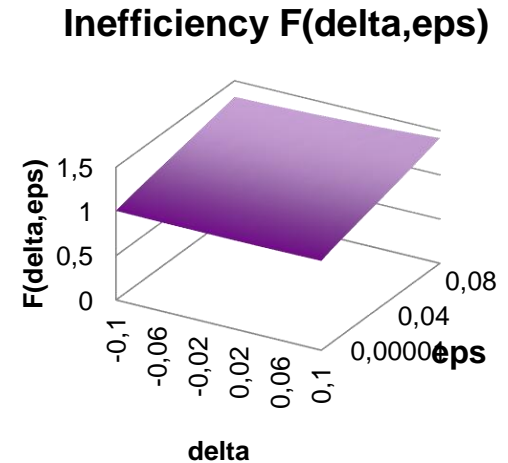
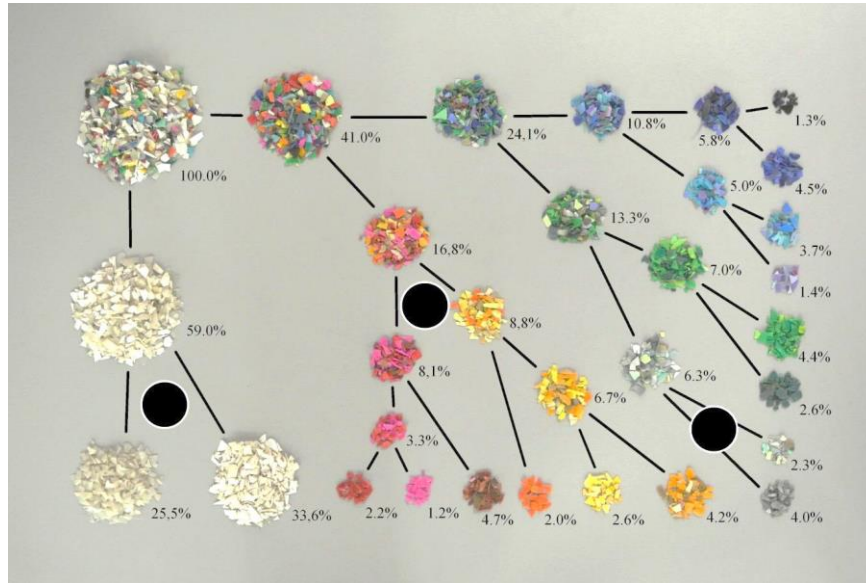
The winner for 'Innovative Health Tech' category was React4Life from Italy for their organ-on-chip solution that accelerates development of new drugs.

Demand-driven recycling

The extreme solution: returning directly to manufacturer



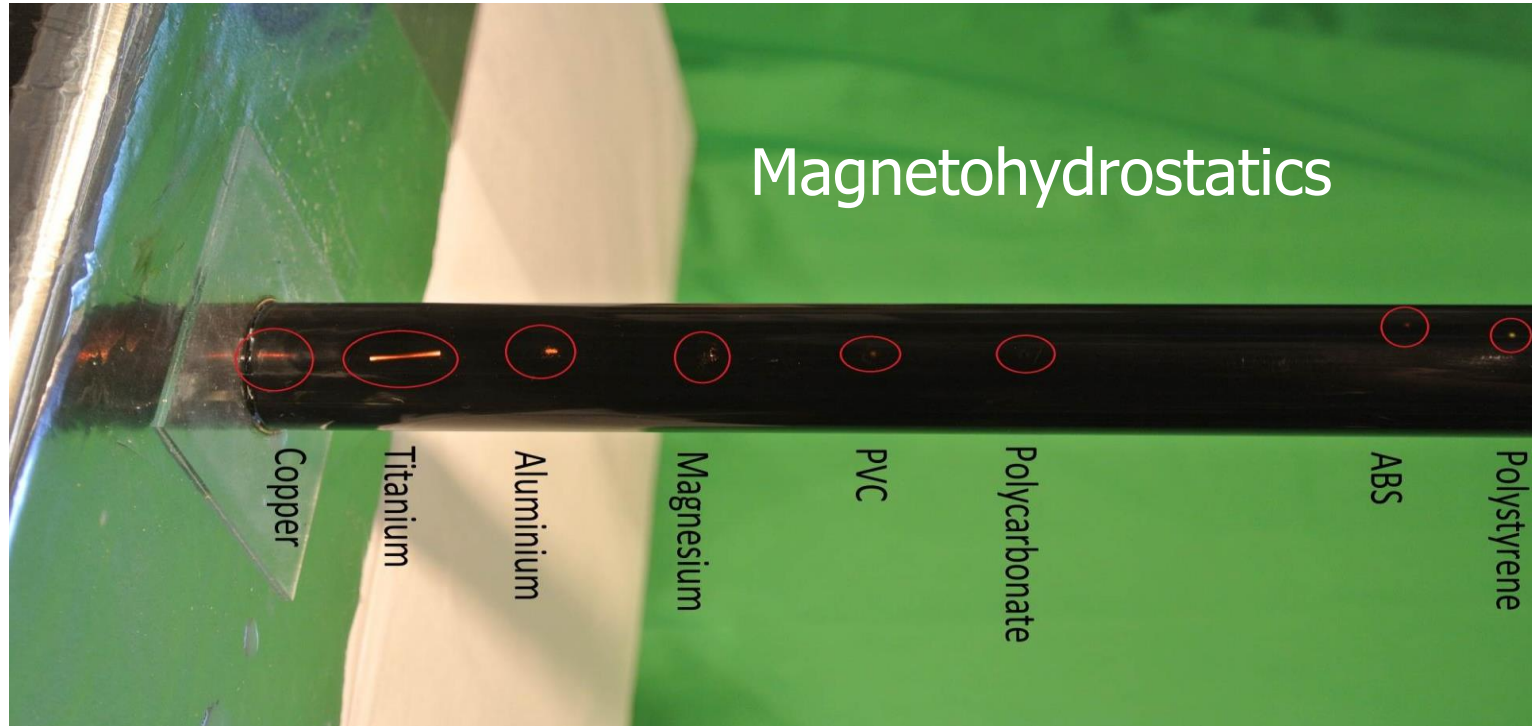
Complexity vs Process Cost



$$\text{Process cost} > F(\delta, \epsilon) C \sum_{i=1}^N c_i^k \log\left(\frac{1}{c_i}\right)$$

Fundamental limit from math: we do not know how to do it!

Spinout Umincorp: sorting into many



Plastic Recycling Amsterdam (PRA)

Questions?