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Lightweight, durable and sustainable composites

Do you want to know more about LCA of composite parts?



Circular economy:
Recycling GRP through applied LCA scenarios

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GRP Composites

GRP composites are used by a wide range of major **industrial sectors**

- construction,
- automotive,
- electronic,
- renewable energy, etc.

Production processes

- open mould techniques (i.e. laminating, hand lay-up, spray lay-up)
- closed mould processes (i.e. vacuum infusion, resin transfer moulding RTM)
- hot mould processes (i.e. bulk moulding compound BMC, sheet moulding compound SMC)
- continuous processes (pultrusion, centrifugal casting, filament winding)

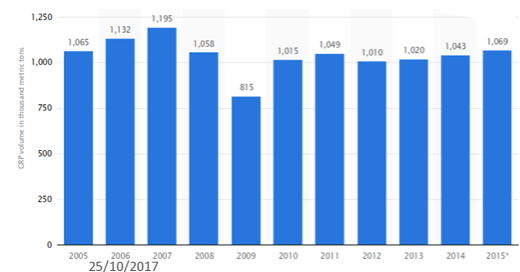
- + high specific strength and stiffness, good flexibility, high elastic module, good structural stability, acceptable price, good fatigue behaviour and low thermal expansion
- higher costs, lower temperature resistance or fire performance, more limited market approvals and design specifications as well as difficulty of recycling

Market Growth



- Modern turbines today have grown 100 times the size of those in 1980.
- Rotor surpassing 60 m in length.

Figure 4: Production volume of GRP in Europe (EU) from 2005 to 2015 (in thousand metric tons)



Source: The Statistics Portal [19]

Table 1: GRP waste volumes from windmill and automotive industries in Europe (in thousand metric tons)

	2000	2005	2010	2015
End of Life waste	111	170	212	251
Production waste	46	47	50	53
Total	157	217	262	304

Source: 1st European FRP-Recycling-Day
September 15, 2016 (data from 2006)



GRP Waste: To-do's

- A common EU target for **recycling** 65% of municipal waste by 2030;
- A common EU target for recycling 75% of packaging waste by 2030;
- A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030;
- A **ban on landfilling** of separately collected waste;
- Concrete measures to promote re-use and stimulate **industrial symbiosis** - turning one industry's by-product into another industry's raw material;
- Economic incentives for producers to put **greener products** on the market and support recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles).



- Thermosetting composite cannot be reshaped again by heating.
- Few standard formulations = higher variations in the properties and performance of the materials incorporating waste.
- Long life - estimated decommissioning time may be difficult to predict
- Limited logistics infrastructure (i.e. shredding)
- Lack of waste volume - there is not enough scrap

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GRP Waste - Methods

- landfilling,
- incineration,
- incineration with energy recovery,
- co-processing,
- mechanical and
- thermal processing,

- most used method
- the least preferred EU Waste Framework Directive
- Contaminate AIR / WATER / SOIL -> Humans and Wildlife

- emissions to atmosphere
- higher operating cost
- mineral ash to landfill!
- emission limits issues
- availability

- recovery of energy (heat, electrical)
- tolerate more contaminated scrap materials

- 2/3 cement production
- 1/3 incineration with energy recovery
- price
- formulation
- availability

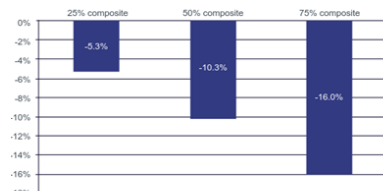
- best option for GRP (for emissions, chemicals)
- reducing size
- properties of the recyclate (open loop, close loop)
- availability

- Pyrolysis ~500C
- decomposition of composite
- recover fibres (carbon fibres)
- Solvolysis chemical recycling 350C
- decomposition and separation

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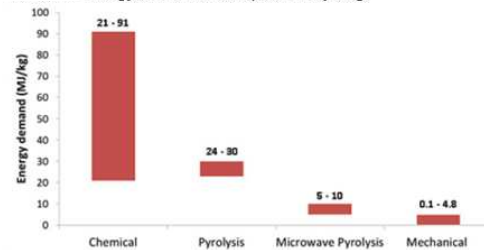
GRP/CRP Waste - Methods

Reduction of CO₂ footprint of clinker manufacturing (with glass reinforced composite regrind)



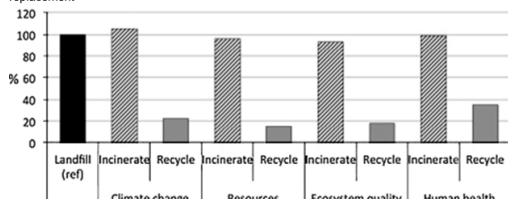
Source: EuCIA [31]

Energy demand in composite recycling:



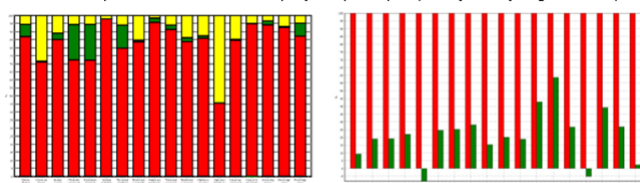
Source Composites UK [15]

Comparison of impacts from landfilling, incineration and recycling for the CF replacement



Source: Witik R.A. et al., [34]

Comparative results of carbon/epoxy composite part (solvolysis recycling vs. landfill).



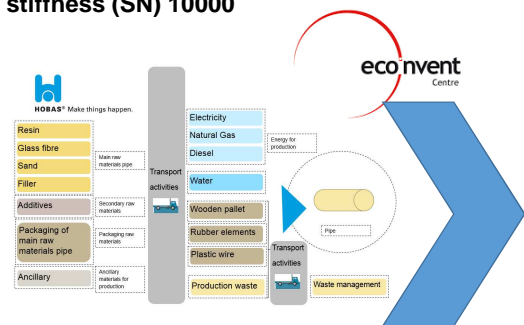
Source: Marion Princaud et. al. [35]

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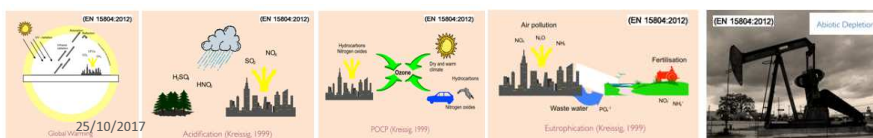
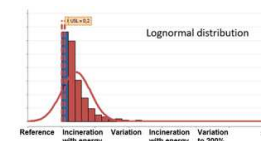
Study Case: GRP Applied Model

GRP Pipe with a nominal diameter (DN) 1000 mm, pressure class one PN 1 and a nominal stiffness (SN) 10000

EN 15804 Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products.

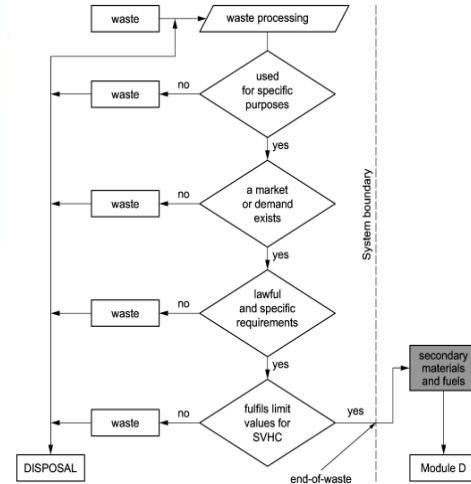
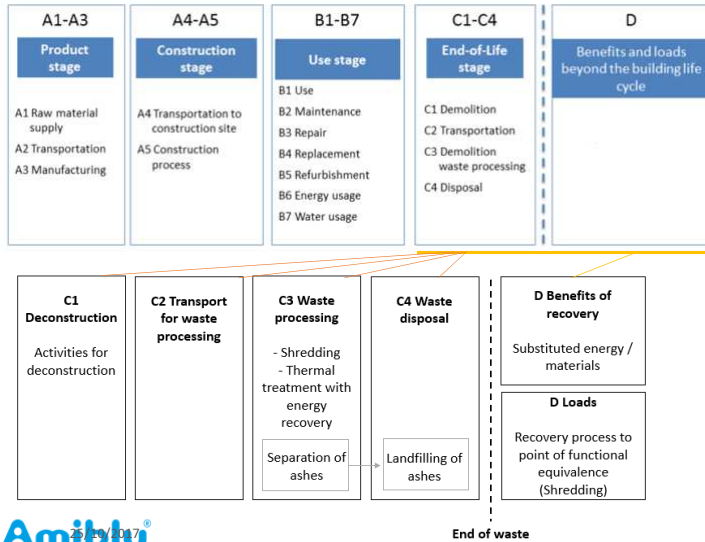


Advanced research



total renewable energy
 total non-renewable energy
 non-hazardous waste
 acidification potential
 GWP 100a
 eutrophication potential
 photochemical ozone creation (high NO_x POCP urban areas)
 depletion of abiotic resources

Methodology: Life Cycle Stages and Module D



Source: EN 15804

GRP Shredding

Reduction in size of GRP rests with available construction materials infrastructure (construction shredder) (2)



Source: courtesy of HOBAS

Reduction in size of GRP rests with available construction materials infrastructure (wood shredder) (3)



Source: courtesy of HOBAS

Typical available shredder capacity reaches its limits, when it comes to reducing pieces starting with dimensions of 50 x 50 cm, 3-10 cm thickness, 50 kg weight.

Thicker GRP rests

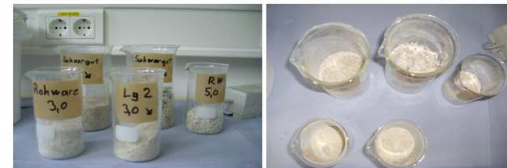


Source: courtesy of HOBAS

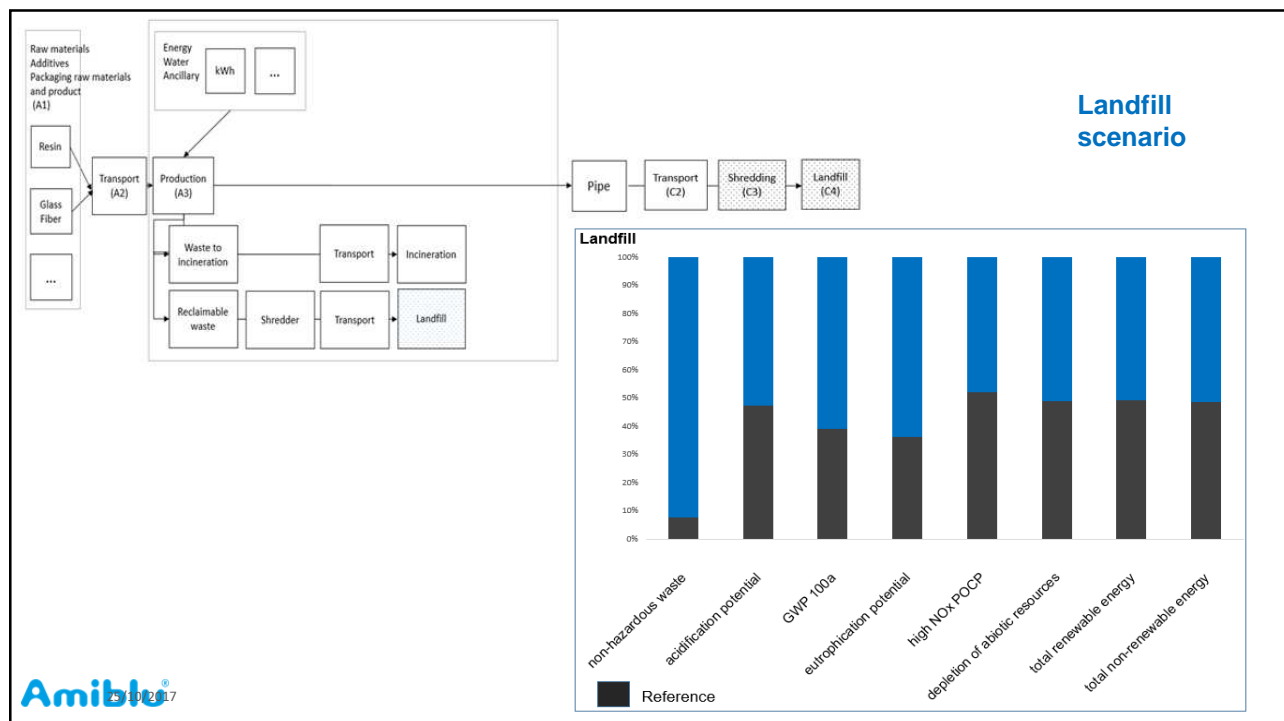
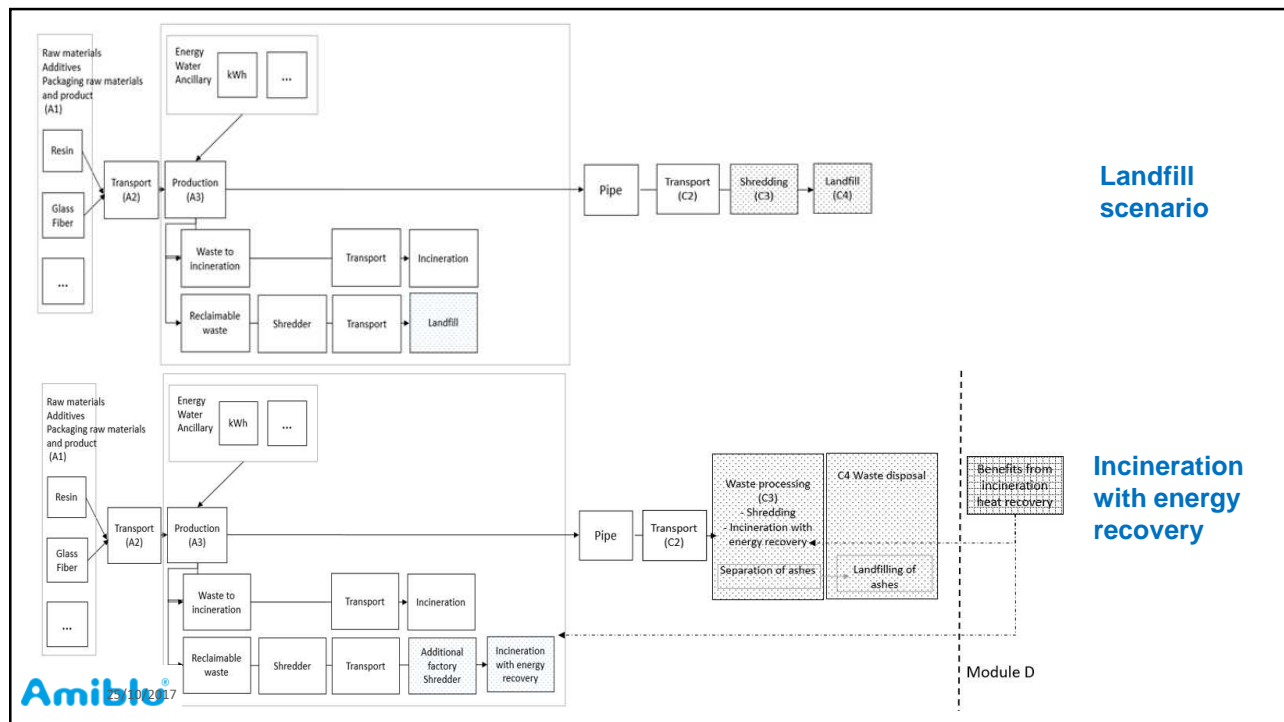
Reduction in size of GRP rests with available construction materials infrastructure (cross-flow shredder) (4)



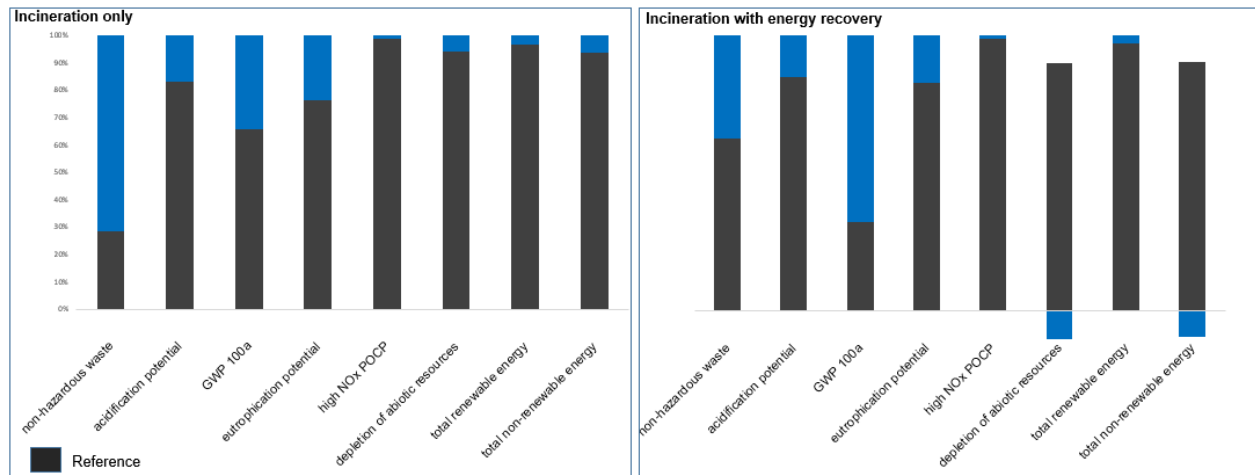
Source: MEWA [61]
Fine ground GRP



Source: courtesy of HOBAS

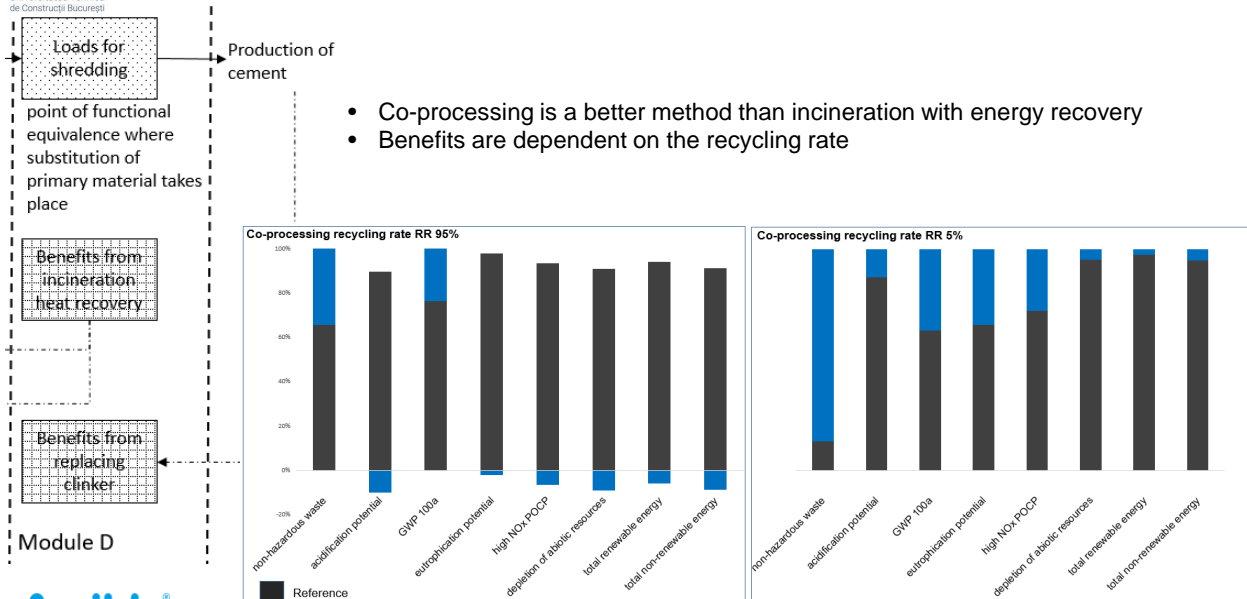


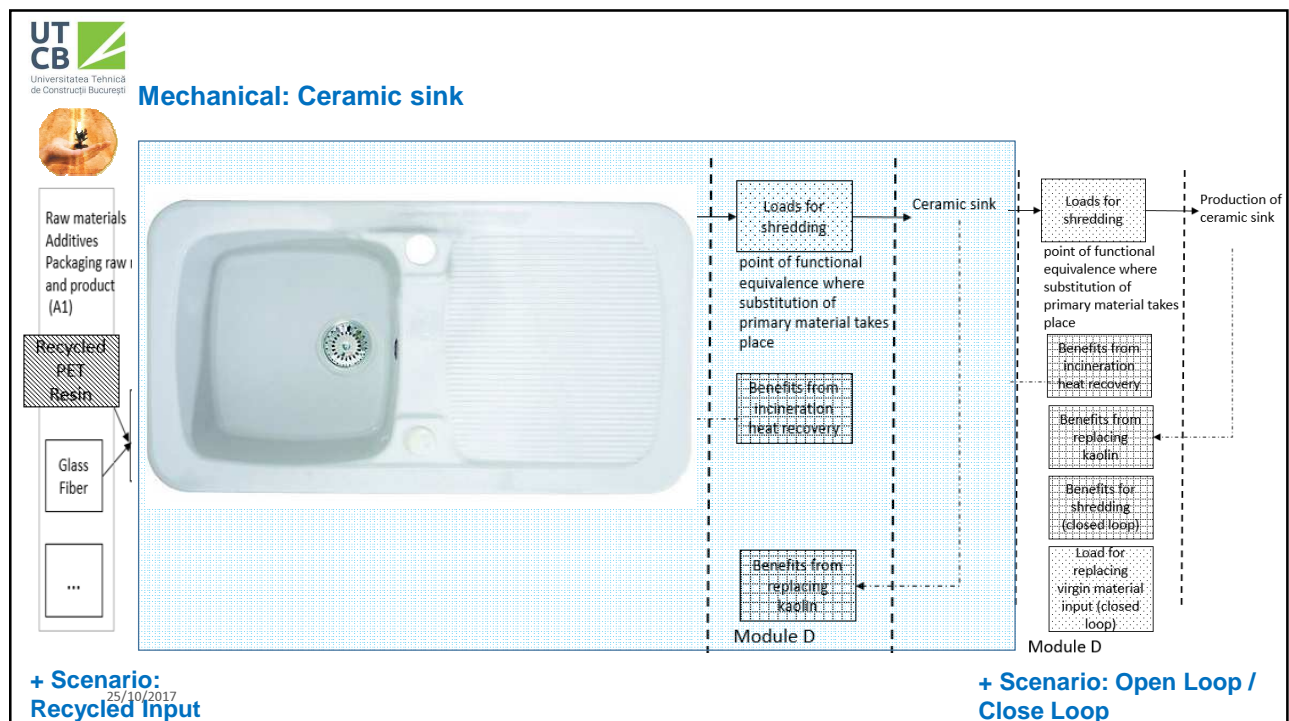
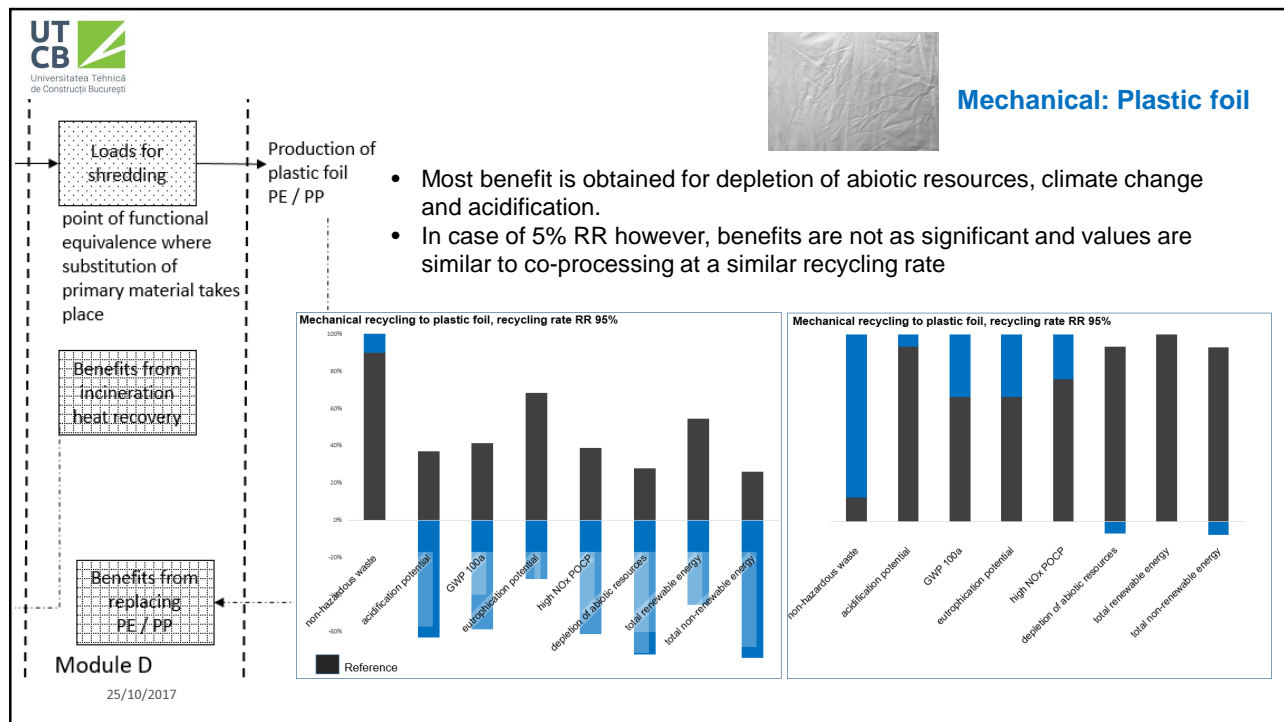
Incineration and incineration w. energy recovery

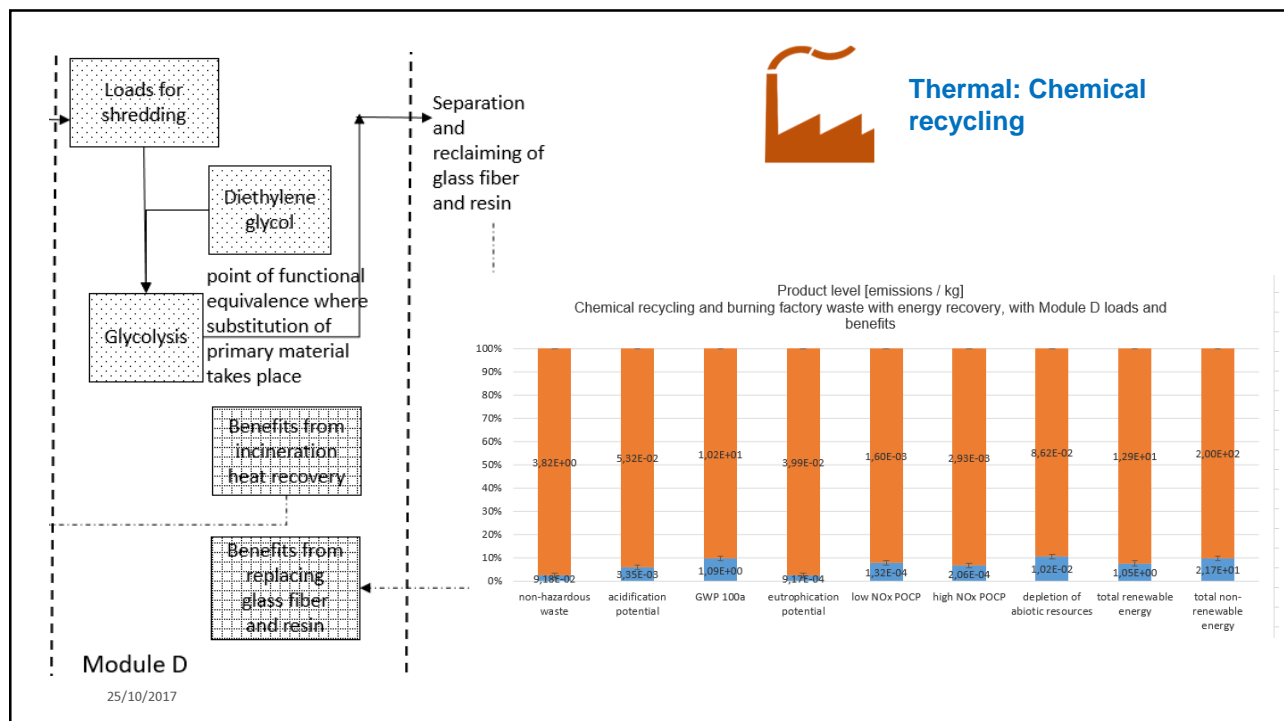
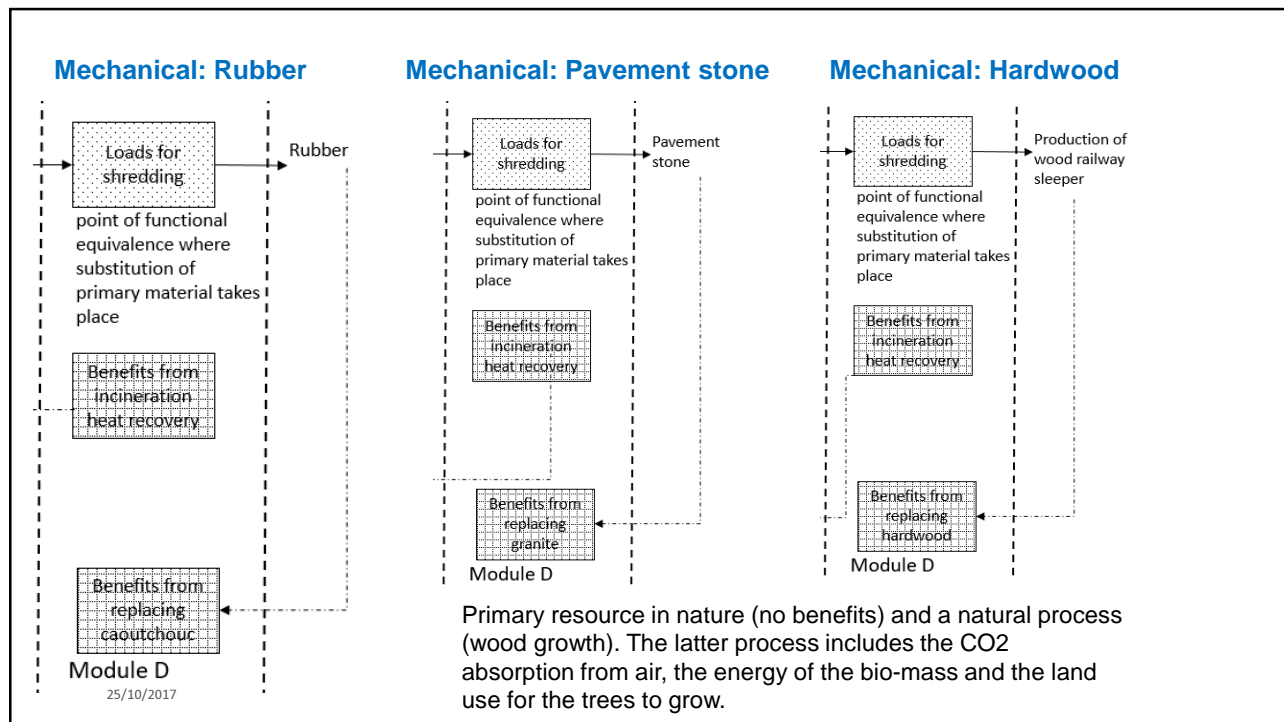


- In case of incineration, the amount of waste is reduced when compared to landfilling.
- Incineration with energy recovery performs better as compared with incineration only.
- Incineration still brings significant environmental burdens (trade-off).
- Benefits if waste is burnt as a direct replacement for coal, oil or gas.

Co-processing







Overview

RR = Recycling Rate OL CL= Open / Close Loop	Non-hazardous waste	GWP 100a	Depletion abiotic resource	Acidification	High NOx POCP	Eutrophication
Reference	9,18E-02	1,09E+00	1,01E-02	3,35E-03	2,05E-04	9,17E-04
Landfill	1,12E+0	1,70E+00	1,07E-02	3,73E-03	1,88E-04	1,61E-03
Incineration only	3,23E-01	1,66E+00	1,08E-02	4,03E-03	2,21E-04	1,20E-03
Incineration with energy recovery	1,47E-01	3,37E+00	9,04E-03	3,95E-03	2,08E-04	1,11E-03
Co-Processing RR 5% (a)	7,12E-01	1,72E+00	1,07E-02	3,84E-03	2,85E-04	1,40E-03
Co-Processing (a)	1,40E-01	1,42E+00	9,19E-03	2,97E-03	1,91E-04	8,98E-04
Plastic foil RR 5% (b)	7,11E-01	1,64E+00	9,49E-03	3,59E-03	2,70E-04	1,38E-03
Ceramic sink (c)	2,14E-01	1,14E+00	9,37E-03	3,08E-03	2,01E-04	8,07E-04
Railway wood sleeper (d)	1,25E-01	1,23E+00	1,06E-02	3,62E-03	2,17E-04	9,96E-04
Concrete block (e)	1,21E-01	8,94E-01	9,96E-03	3,08E-03	1,99E-04	8,88E-04
Ceramic sink OL CL (c)	1,21E-01	1,07E+00	9,41E-03	3,04E-03	1,90E-04	7,41E-04
Rubber (f)	1,21E-01	1,06E+00	9,31E-03	3,04E-03	1,89E-04	7,42E-04
Ceramic sink PET (c)	1,11E-01	9,18E-01	7,63E-03	2,51E-03	1,52E-04	6,53E-04
Plastic foil (b)	1,02E-01	-4,47E-01	-1,60E-02	-2,32E-03	-1,20E-04	4,96E-04
Chemical recycling (g)	3,82E+00	1,02E+01	8,62E-02	5,32E-02	2,93E-03	3,99E-02

Overview



Total non-renewable energy	Total renewable energy	
Reference	2,17E+01	1,05E+00
Landfill	2,29E+01	1,08E+00
Incineration only	2,31E+01	1,09E+00
Incineration with energy recovery	1,94E+01	1,08E+00
Co-Processing RR 5% (a)	2,29E+01	1,08E+00
Co-Processing (a)	1,96E+01	9,85E-01
Plastic foil RR 5% (b)	2,00E+01	1,05E+00
Ceramic sink (c)	1,97E+01	9,91E-01
Railway wood sleeper (d)	2,26E+01	-1,72E+01
Concrete block (e)	2,11E+01	9,90E-01
Ceramic sink OL CL (c)	1,98E+01	1,01E+00
Rubber (f)	1,96E+01	9,88E-01
Ceramic sink PET (c)	1,93E+00	6,55E-01
Plastic foil (b)	-3,98E+01	1,79E-01
Chemical recycling (g)	2,00E+02	1,29E+01



Thank you!

- CO₂ Emissions saved in the city of Warsaw
- Benefits of recycled and bio raw materials
- B2B Industry projects
- Recyclability

Net Benefit

Net benefit impact indicator = Yield * Amount * [RR * (Ev' - Er') - RC * (Ev - Er)], where

- RR = Recycling rate at the end-of-life (EoL stage)
- Ev' = Impacts of substituted virgin material production (EoL stage) (credit)
- Er' = Impacts connected to the recycling processes from beyond the system boundary (after the end-of waste state up to the point of functional equivalence)
- RC = Recycled content (product stage)
- Ev = Impacts of virgin material production (product stage)
- Er = Impacts connected to the recycling processes from beyond the system boundary of the life cycle that generated the waste flow (after the end-of waste state)

$$E = (1 - R1) \times Ev + R1 \times Q_{Sin}/Q_{Pin} \times E^{Sv} + R2 \times (E_{recyclingEoL} - E'v \times Q_s/Q_p) + R3 \times (E_{ER} - LHV \times X_{ER,elec} \times E_{SE,elec} - LHV \times X_{ER,heat} \times E_{SE,heat}) + (1 - R2 - R3) \times ED$$

Input primary material

Output recycle

Output waste

Input secondary material

Output recovered energy



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Assumptions for scenario calculation

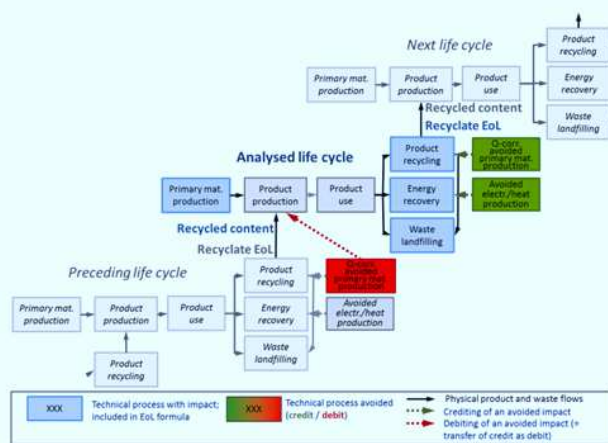
Parameter	Unit	Remarks
Recycling rate (RR)	95%	A relatively high rate is allocated; it is considered that losses through processing or transport activities at EoL are limited to 5% (this is the indicative, potential rate).
	5%	As alternative, a low 5% rate is calculated for selected scenarios (co-processing and plastic foil).
Rest of waste to RR	55%	Landfill share.
	45%	Incineration share.
Recycled content (RC)	5%	A low level is allocated due to literature research indicating difficulties to re-integrate GRP recylate to the original product. The percent may be considered ambitious for pipes, but 5% was preferred to be able to determine an impact in the calculation.
Efficiency of the incineration process	90%	Typical rate for process efficiency.
Yield of functional equivalence	85%	Estimated, the substitution of primary material by the secondary material is not 1 to 1.
Calorific value GRP waste	12 MJ/kg	As per literature research.
Distance to the incineration plant / landfill / recycling plant	300 km	Estimated distance to the incineration plant / landfill / recycling plant.

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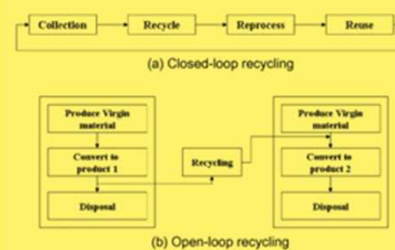
Figure 28: LCA processes, credits and debits



Source: Wolf et. al. [97].
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Further clarifications

Figure 29: Closed-loop and open-loop



Source: Belgian Building Research Institute [98]

Substitution factor may be approached from different perspectives: yield (i.e. 1kg steel scrap produces less than 1kg secondary steel) and value correction factor (i.e. secondary plastic can only be used in lower grade applications - "downcycling")

Recycling rate, Recycled content