

Welsh Composites Centre



Environmental Impact of Composites

Cris Arnold & Sue Alston
Swansea University





Outline of webinar

- Introduction: the potential environmental benefits and impacts of composites
- How “green” is it really?
 - Use of Life Cycle Assessment (LCA)
- Biocomposites
- End-of-life issues with composites



Environmental downsides of composites

Complex materials production

Material (per kg)	Greenhouse gas emissions	Overall Environmental Impact
Carbon fibre	100	100
Glass fibre	5.1	4.7
Epoxy resin	13.6	11.9
Steel	3.6	3.1
Aluminium	14.3	15.2



Environmental downsides of composites



Process impacts

- Energy use
- Solvent release during processing
- Consumables & cleaning



Harder recycling of some composites than with metals / thermoplastics





Environmental benefits of composites

- Mainly in use phase
- Lower weights lead to fuel savings in aerospace and automotive sectors





Environmental benefits of composites

- Construction sector
- Refurbishment possible rather than rebuilding
- Faster construction / less disruption / less transport





Environmental benefits of composites

- ✚ Energy sector
- ✚ Improved efficiency of renewable energy generation which may not be possible without composites





Environmental benefits of composites

- Increased lifetime
- Less maintenance / corrosion treatments
- Metal matrix and ceramic matrix composites allow higher temperature combustion processes and hence better fuel efficiency



**So, how do we assess the
overall environmental
performance?**







Life Cycle Assessment

- ✘ A method of analysing and quantifying the environmental impact of a product, process or activity.
- ✘ Can be applied to almost any situation
- ✘ Has rapidly developed over the last 15 years
- ✘ Covered by International Standards (ISO 14040 & 14044)



So – how green is my composite?

Some figures*:

 Carbon Fibre / Epoxy	100%
 Sheet Moulding Compound (Short Glass Fibres/Polyester/Filler)	74%
 Hemp / Polyester	73%
 Woven Glass Fibre / Polyester	67%

Job done! ???

- But what do they mean?

* BRE/Net Composites “Green Guide to Composites”



Stages of LCA



Initiation

- Defines what the LCA covers and why we're doing it, assumptions made



Inventory Analysis

- Often termed life cycle inventory
- Quantitative list of everything measurable i.e. all inputs and outputs



Impact Assessment

- Calculates the effects of the Inventory on the environment

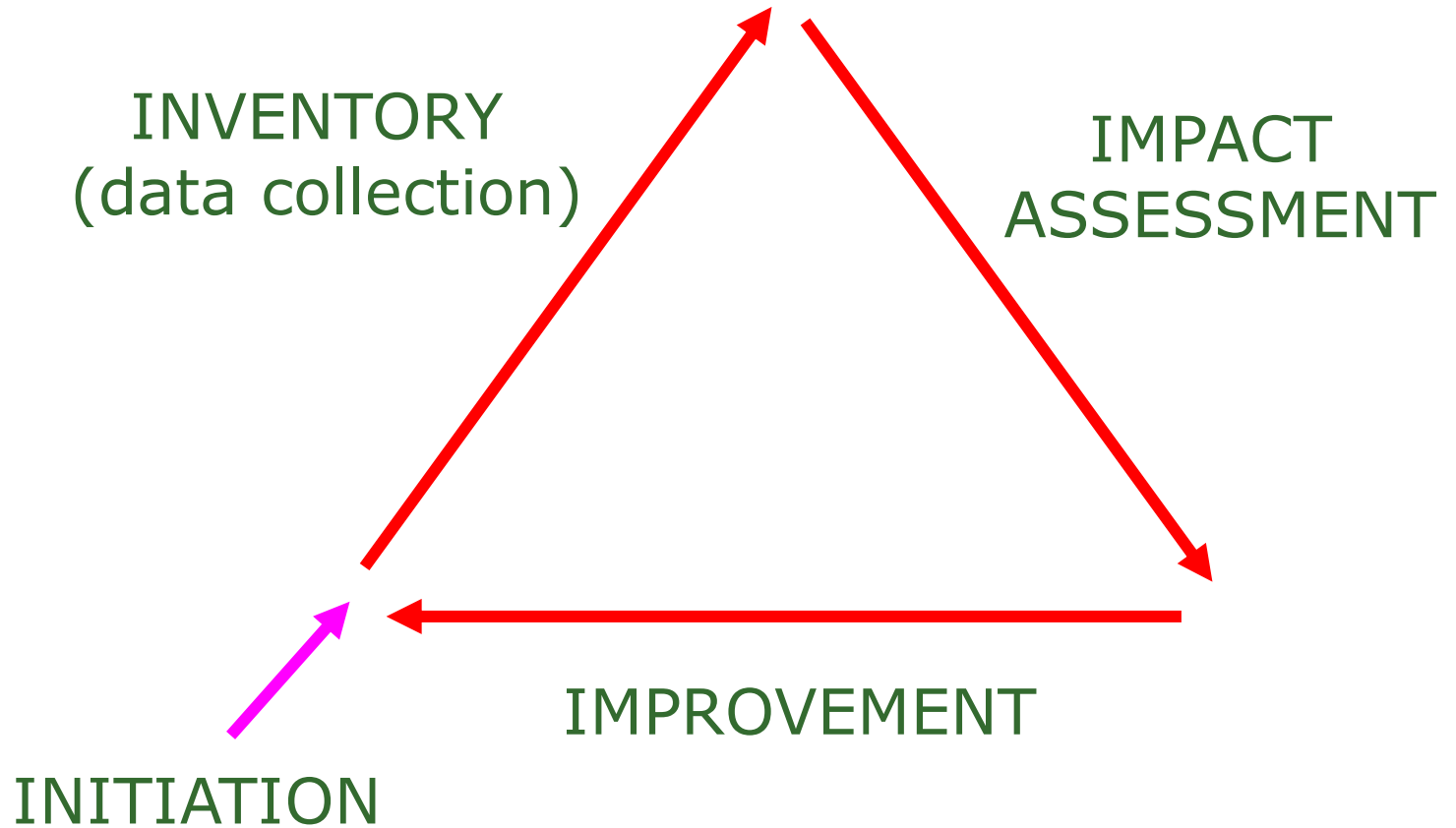


Improvement

- Uses the results to improve the process



Stages of LCA





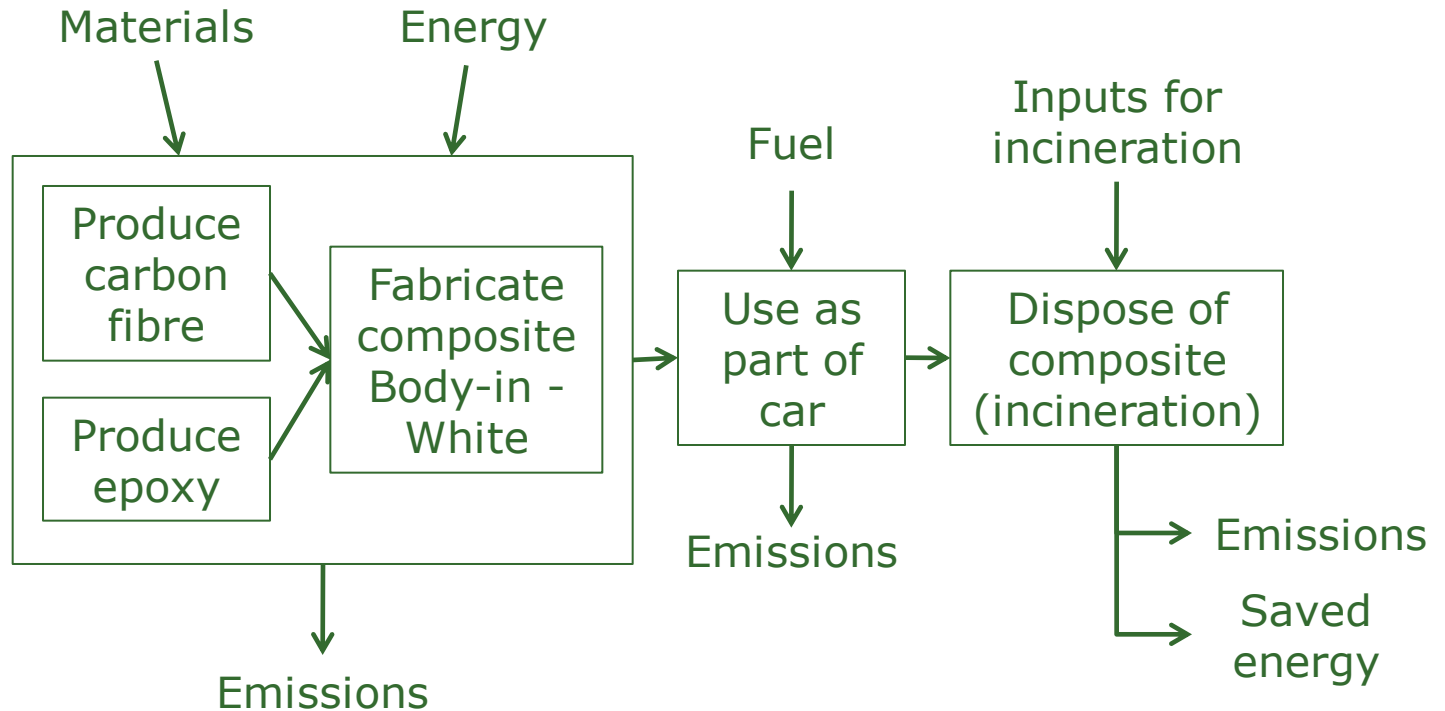
LCA - Initiation

- First we need to define the “system” we are looking at.
- Often that will be “cradle to grave” i.e. from raw materials through manufacturing and use to disposal.
- To illustrate LCA procedures, we will look at a “Body in White” (BIW) – the basic vehicle structure – for a small car, made of either carbon fibre composite or steel.
- Data is based on Duflou et al, 2009 [1]



LCA - Initiation

 An overview is shown in the process flow:





LCA - Initiation

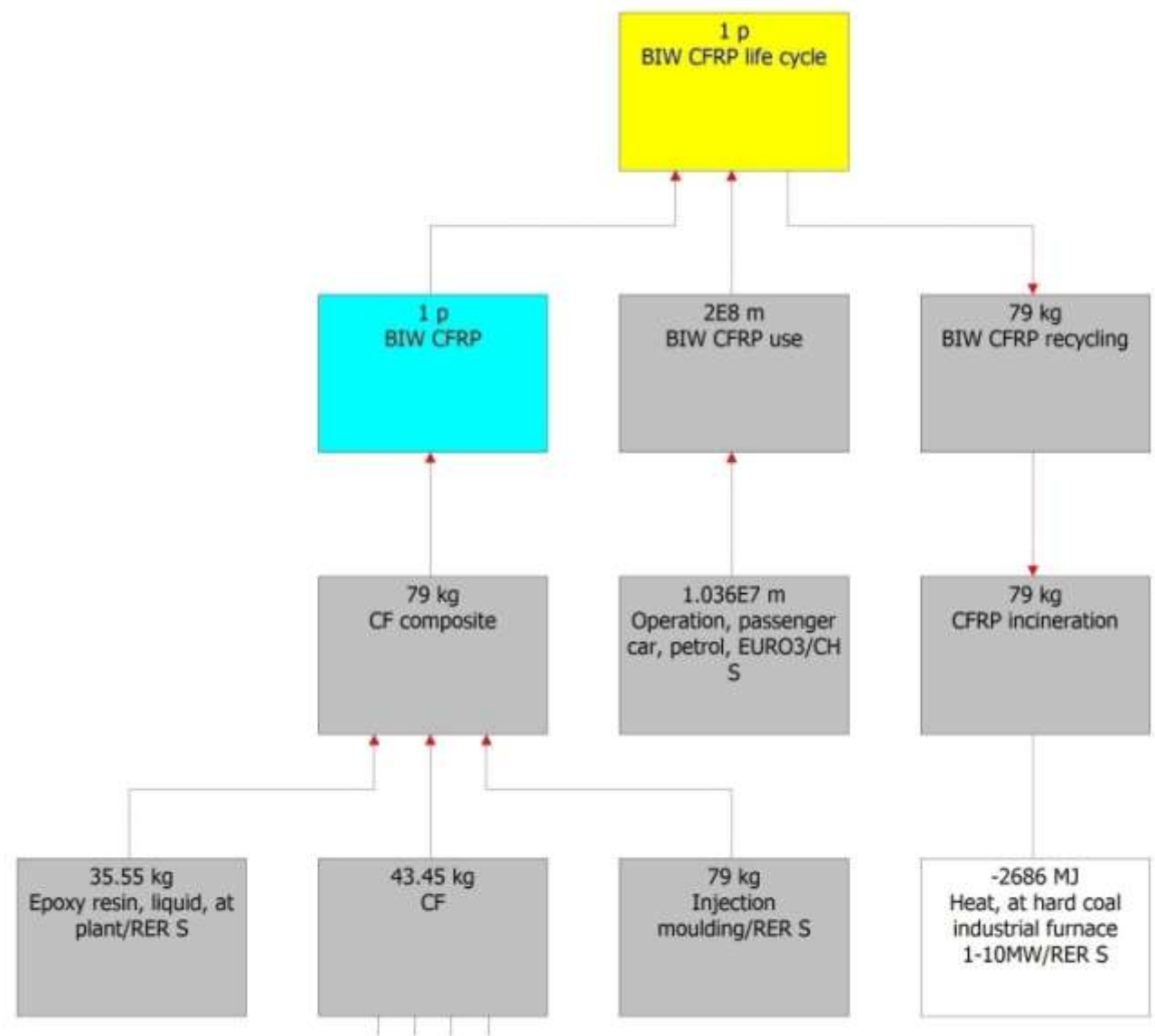
- ✚ LCA is often used to make comparisons
- ✚ What are we going to compare with what?
- ✚ e.g. 1 tonne of steel vs 1 tonne of composite?
- ✚ Or a bridge, designed to carry 40 tonne lorries for a 50 year lifetime, made of steel vs one made of composite?
- ✚ In this example, we take the Body in White, driven during use for 200000km, as our “functional unit”.



LCA - Inventory

- Next we need to itemise all the inputs and outputs of the system we are looking at.
- This is built up in parts, and can be done more easily using a software package. This example is built using Simapro 7.
- e.g. for a composite BIW we might have a “tree” that looks like...

LCA - Inventory





LCA - Inventory

- Then for each process in the tree we can add in its part of the inventory.
- At the lower levels we can use data from established databases e.g. "ecoinvent" from the Swiss Centre for Life Cycle Inventories.
- These can be very detailed, e.g. for epoxy ...

LCA - Inventory

D:\Simapro\Professional; Webinar - [Copy material process 'Epoxy resin, liquid, at plant/RER S']

File Edit Calculate Tools Window Help

Documentation Input/output Parameters System description

Products

Known outputs to technosphere. Products and co-products

Name	Amount	Unit	Quantity	Allocation %	Waste type	Category	Comment
Epoxy resin, liquid, at plant/RER S	1	kg	Mass	100 %	not defined	Chemicals\Organic	Europe
(Insert line here)							

Known outputs to technosphere. Avoided products

Name	Amount	Unit	Distribution	SD ^{^2} or 2*SD Min	Max	Comment
(Insert line here)						

Inputs

Known inputs from nature (resources)

Name	Sub-compartment	Amount	Unit	Distribution	SD ^{^2} or 2*SD Min	Max	Comment
Aluminium, 24% in bauxite, 11% in crude ore, in ground	in ground	0.0012746	kg	Undefined			
Anhydrite, in ground	in ground	0.000013001	kg	Undefined			
Barite, 15% in crude ore, in ground	in ground	0.00041564	kg	Undefined			
Basalt, in ground	in ground	0.0000010968	kg	Undefined			
Borax, in ground	in ground	0.0000000000	kg	Undefined			
Bromine, 0.0023% in water	in water	0.0000000000	kg	Undefined			
Cadmium, 0.30% in sulfide, Cd 0.18%, Pb, Zn, Ag, In, in ground	in ground	0.0000000019	kg	Undefined			
Calcite, in ground	in ground	0.73511	kg	Undefined			
Carbon dioxide, in air	in air	0.00087903	kg	Undefined			
Carbon, in organic matter, in soil	in ground	0.0000000030	kg	Undefined			
Chromium, 25.5% in chromite, 11.6% in crude ore, in ground	in ground	0.0000019068	kg	Undefined			
Chrysotile, in ground	in ground	0.0000000012	kg	Undefined			
Cinnabar, in ground	in ground	0.0000000001	kg	Undefined			
Clay, bentonite, in ground	in ground	0.0001584	kg	Undefined			
Clay, unspecified, in ground	in ground	0.0094146	kg	Undefined			
Coal, brown, in ground	in ground	0.21036	kg	Undefined			
Coal, hard, unspecified, in ground	in ground	0.36303	kg	Undefined			
Cobalt, in ground	in ground	0.0000000000	kg	Undefined			
Colemanite, in ground	in ground	0.0000000274	kg	Undefined			
Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in g	in ground	0.0000001299	kg	Undefined			

Swansea University

LCA - Inventory

S D:\Simapro\Professional; Webinar - [Copy material process 'Epoxy resin, liquid, at plant/RER S']

S File Edit Calculate Tools Window Help

Documentation Input/output Parameters System description

Water, unspecified natural origin/m3	in water	0.019209	m3	Undefined				
Water, well, in ground	in water	0.000023175	m3	Undefined				
Wood, hard, standing	biotic	0.000000365	m3	Undefined				
Wood, primary forest, standing	biotic	0.000000000	m3	Undefined				
Wood, soft, standing	biotic	0.0000010025	m3	Undefined				
Wood, unspecified, standing/m3	biotic	0.00000304	m3	Undefined				
Zinc, 9.0% in sulfide, Zn 5.3%, Pb, Ag, Cd, In, in ground	in ground	0.0000010432	kg	Undefined				
Zirconium, 50% in zircon, 0.39% in crude ore, in ground	in ground	0.000000000	kg	Undefined				
(Insert line here)								
Known inputs from technosphere (materials/fuels)								
Name	Amount	Unit	Distribution	SD^2 or 2*SDMin	Max	Comment		
(Insert line here)								
Known inputs from technosphere (electricity/heat)								
Name	Amount	Unit	Distribution	SD^2 or 2*SDMin	Max	Comment		
(Insert line here)								
Outputs								
Emissions to air								
Name	Sub-compartment	Amount	Unit	Distribution	SD^2 or 2*SDMin	Max	Comment	
1,4-Butanediol	high. pop.	0.000000000	kg	Undefined				
1-Pentanol	high. pop.	0.000000000	kg	Undefined				
1-Pentene	high. pop.	0.000000000	kg	Undefined				
2-Aminopropanol	high. pop.	0.000000000	kg	Undefined				
2-Propanol	high. pop.	0.0000000001	kg	Undefined				
Acenaphthene		0.000000000	kg	Undefined				
Acetaldehyde	high. pop.	0.000000004	kg	Undefined				
Acetaldehyde	low. pop.	0.000000000	kg	Undefined				
Acetaldehyde		0.0000000169	kg	Undefined				
Acetic acid	high. pop.	0.0000000025	kg	Undefined				
Acetic acid	low. pop.	0.000000000	kg	Undefined				
Acetic acid		0.0000000022	kg	Undefined				
Acetone	high. pop.	0.0000000005	kg	Undefined				
Acetone	low. pop.	0.000000000	kg	Undefined				
Acetonitrile	low. non.	0.000000000	kn	Undefined				

Swansea University

LCA - Inventory

S D:\Simapro\Professional; Webinar - [Copy material process 'Epoxy resin, liquid, at plant/RER S']

S File Edit Calculate Tools Window Help

Documentation Input/output Parameters System description

Cadmium	low. pop.	0.000000002	kg	Undefined
Cadmium	low. pop., long-term	0.000000000	kg	Undefined
Cadmium	stratosphere + trop.	0.000000000	kg	Undefined
Cadmium		0.000000001	kg	Undefined
Calcium	high. pop.	0.0000000941	kg	Undefined
Calcium	low. pop.	0.0000000051	kg	Undefined
Calcium	low. pop., long-term	0.000000125	kg	Undefined
Carbon dioxide, biogenic	high. pop.	0.004533	kg	Undefined
Carbon dioxide, biogenic	low. pop.	0.006097	kg	Undefined
Carbon dioxide, biogenic		0.00001196	kg	Undefined
Carbon dioxide, fossil	high. pop.	5.904	kg	Undefined
Carbon dioxide, fossil	low. pop.	0.0017778	kg	Undefined
Carbon dioxide, fossil	stratosphere + trop.	0.000000002	kg	Undefined
Carbon dioxide, fossil		0.020617	kg	Undefined
Carbon dioxide, land transformation	low. pop.	0.0000001002	kg	Undefined
Carbon disulfide	high. pop.	0.0000005	kg	Undefined
Carbon disulfide	low. pop.	0.000000122	kg	Undefined
Carbon disulfide		0.000000000	kg	Undefined
Carbon monoxide, biogenic	high. pop.	0.0000009702	kg	Undefined
Carbon monoxide, biogenic	low. pop.	0.0000003573	kg	Undefined
Carbon monoxide, fossil	high. pop.	0.0022016	kg	Undefined
Carbon monoxide, fossil	low. pop.	0.0000037479	kg	Undefined
Carbon monoxide, fossil	stratosphere + trop.	0.000000000	kg	Undefined
Carbon monoxide, fossil		0.000073167	kg	Undefined
Carbon-14	low. pop.	0.000089071	kBq	Undefined
Cerium-141	low. pop.	0.000000002	kBq	Undefined
Cesium-134	low. pop.	0.000000000	kBq	Undefined
Cesium-137	low. pop.	0.000000001	kBq	Undefined
Chloramine	high. pop.	0.000000000	kg	Undefined
Chlorine	high. pop.	0.000006063	kg	Undefined
Chlorine	low. pop.	0.000000000	kg	Undefined
Chlorine	low. pop., long-term	0.000000004	kg	Undefined
Chlorine		0.000000000	kg	Undefined

Swansea University

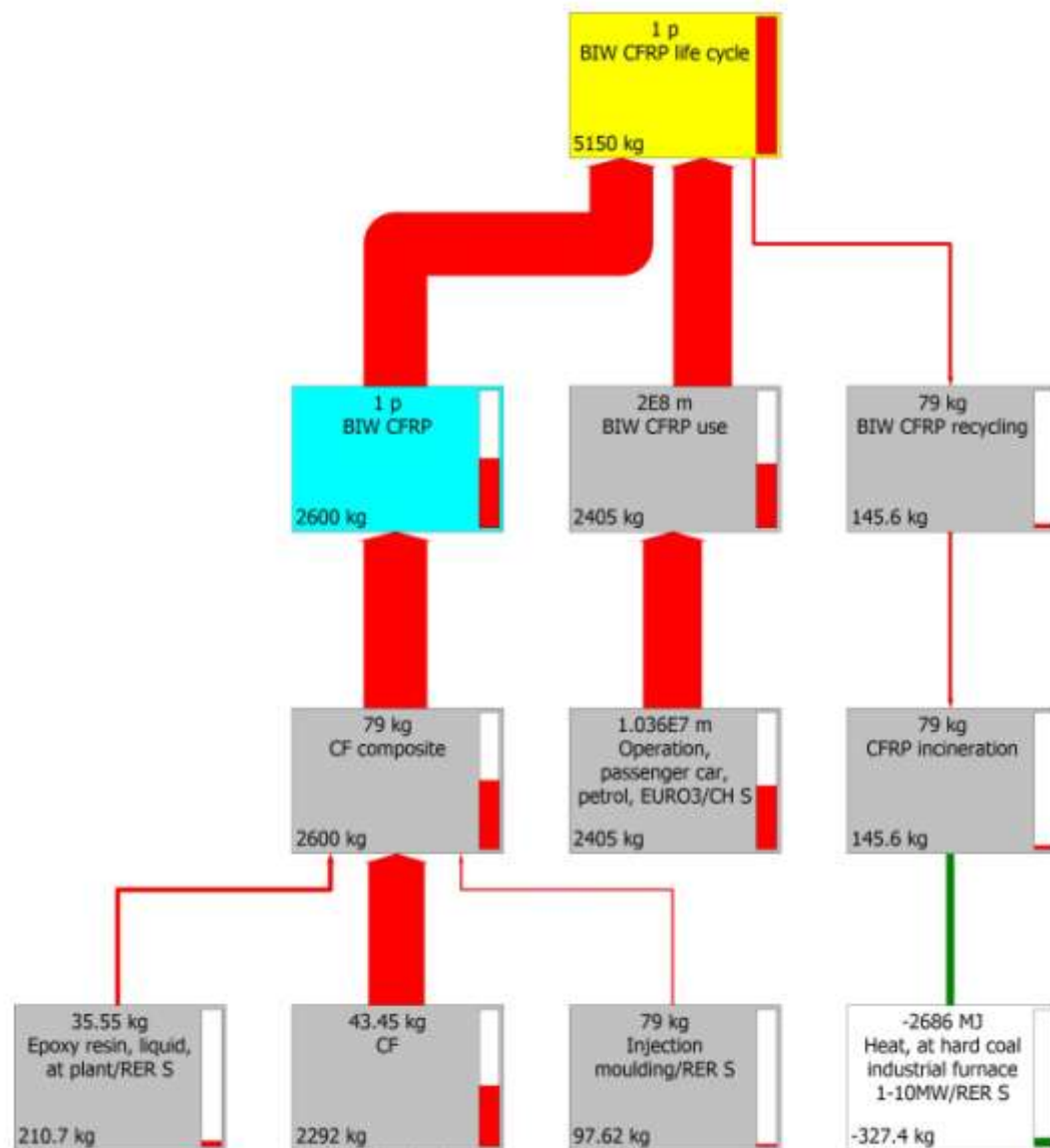


LCA - Inventory

- ✚ ... and many more pages.
- ✚ At the end of this we have a complete inventory for the whole system.
- ✚ We can re-draw the “tree” of processes in terms of a specific substance, giving a total figure for that substance for the whole system.
- ✚ For example for the carbon fibre BIW we have carbon dioxide emissions:



LCA - Inventory - CO₂





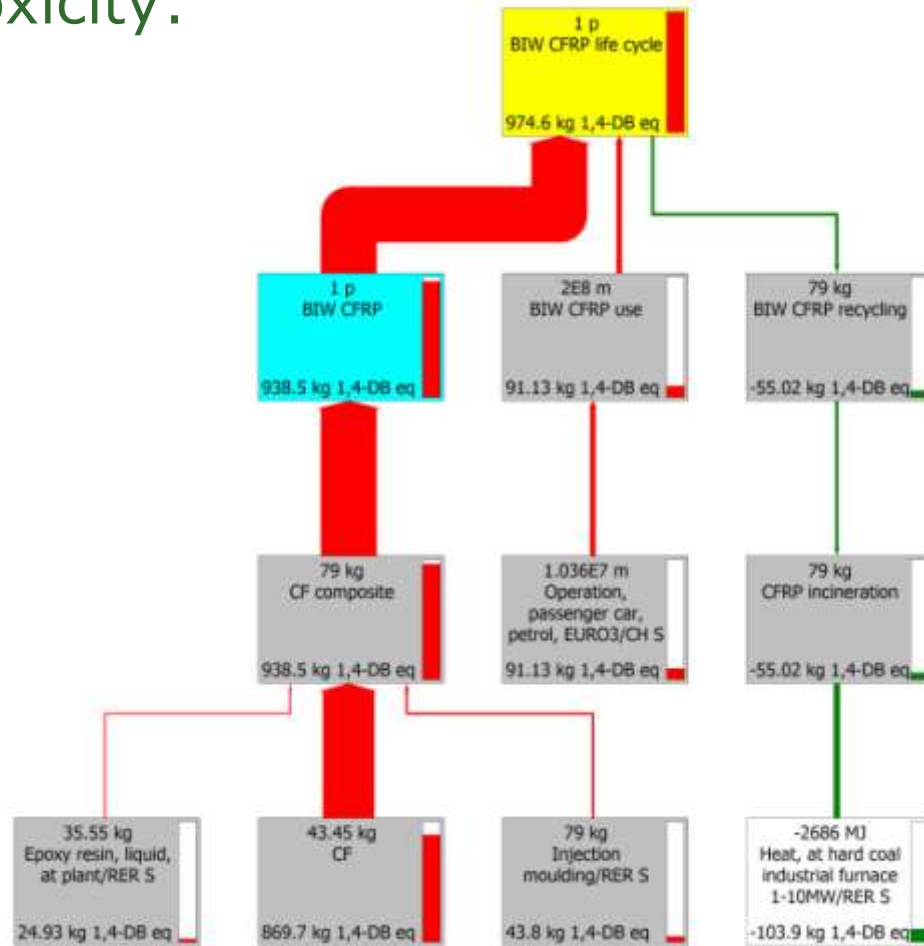
LCA – Impact Assessment

The impact of the substances in the inventory can be classified into categories such as:

- ✚ Climate change
 - ✚ Ozone depletion
 - ✚ Human toxicity
 - ✚ Photochemical oxidant formation
 - ✚ Particulate matter formation
 - ✚ Ionising radiation
 - ✚ Terrestrial acidification
 - ✚ Freshwater and marine eutrophication
 - ✚ Terrestrial and aquatic ecotoxicity
 - ✚ Land occupation and transformation
 - ✚ Water depletion
 - ✚ Metal depletion
 - ✚ Fossil depletion
- these are taken from the “ReCiPe” method which is used in this example

LCA – Impact Assessment

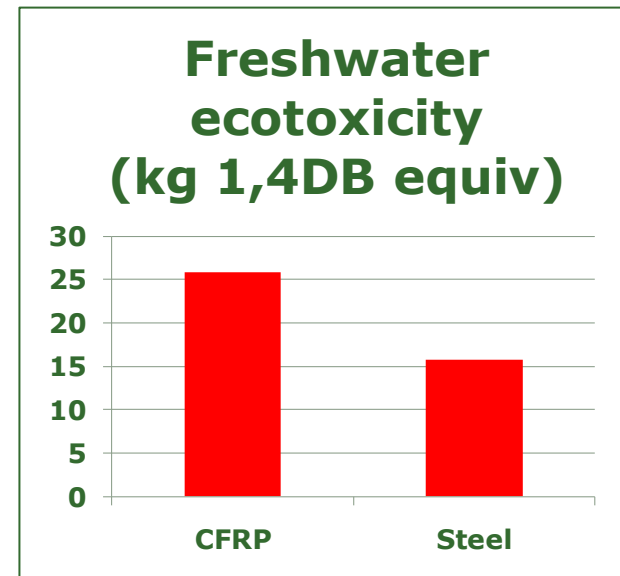
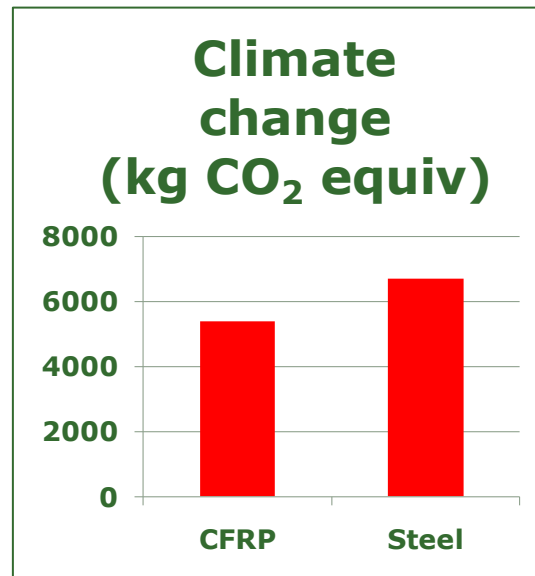
Now we can re-draw the “tree” of processes in terms of a specific impact, giving a total figure for that impact for the whole system, e.g for human toxicity:





LCA – Impact Assessment

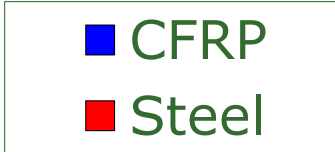
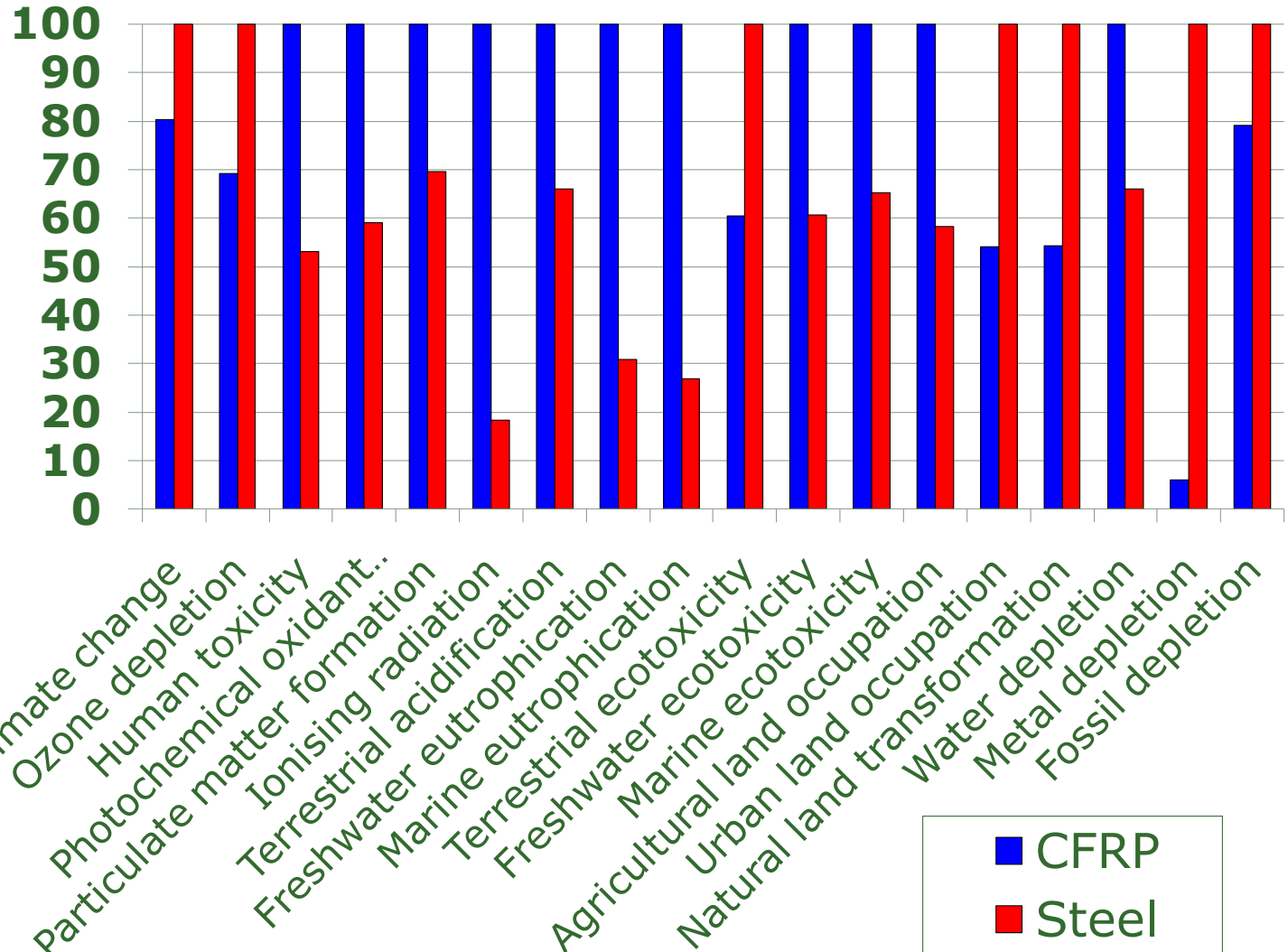
- These impacts can then be compared for a number of systems.
- Each category has an impact in different units, e.g. climate change might be in “kg CO₂ equiv”, ecotoxicity in “kg 1,4-dichlorobenzene equiv”
- Example





LCA – Impact Assessment

To put the data on the same chart we have to use percentages:



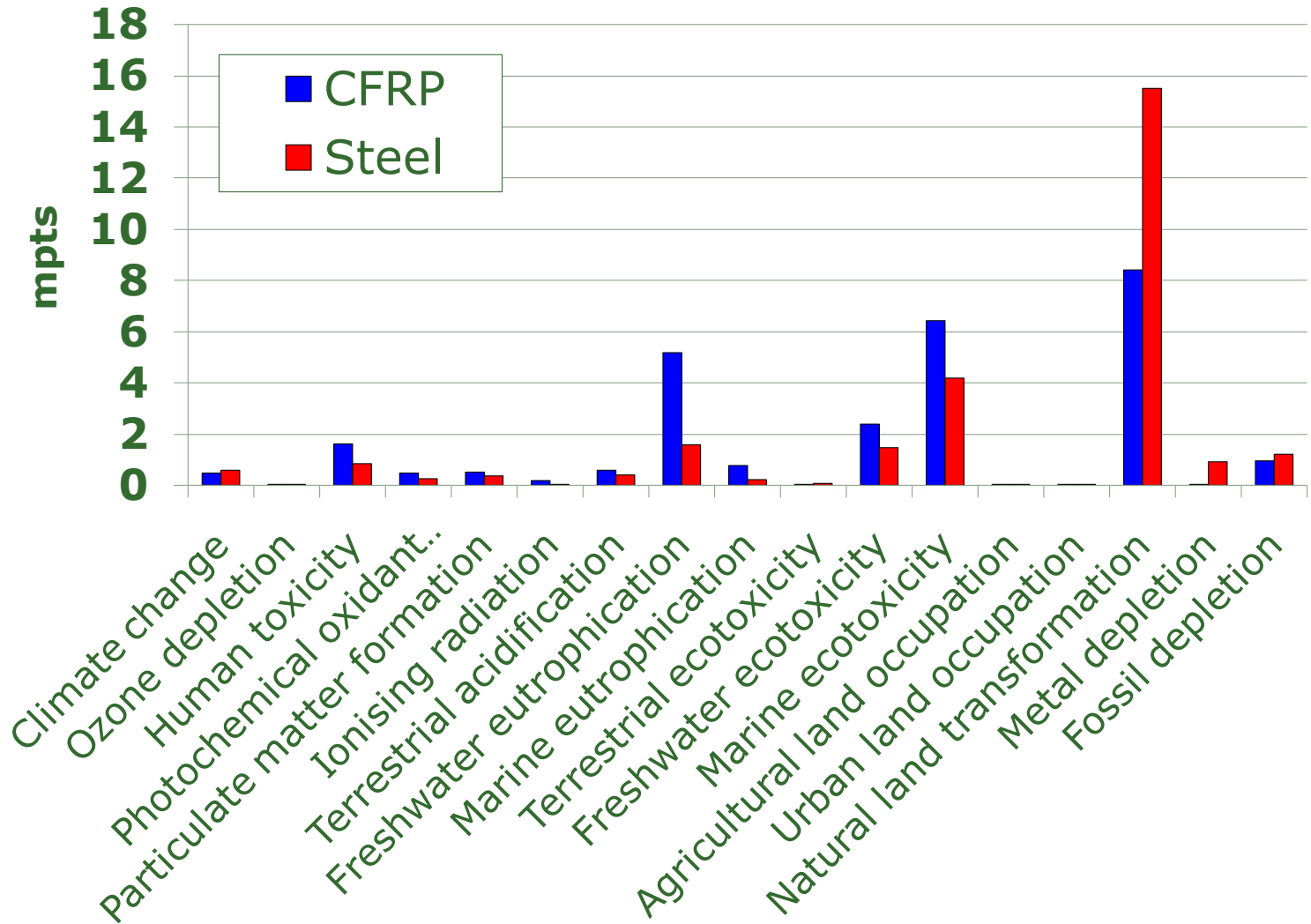


LCA – Impact Assessment

- ✖ This is good for looking at specific effects, but doesn't provide a way of getting an overall picture – how do the categories relate to each other?
- ✖ To enable some sort of comparison between categories, the figures are “normalised”.
- ✖ A common way of doing this is to divide the impact for each category by the total annual impact of one individual on that category.
- ✖ The results are expressed in “ecopoints” or, more often, milli-ecopoints (mpts).
- ✖ The same results, normalised ..



LCA - Impact Assessment





LCA – Impact Assessment

- ✖ This still leaves some judgement to be made.
- ✖ Compared to an average person, the most significant impact of the BIW is on land transformation, whilst the effect on climate change is comparatively small. But which is really more significant?

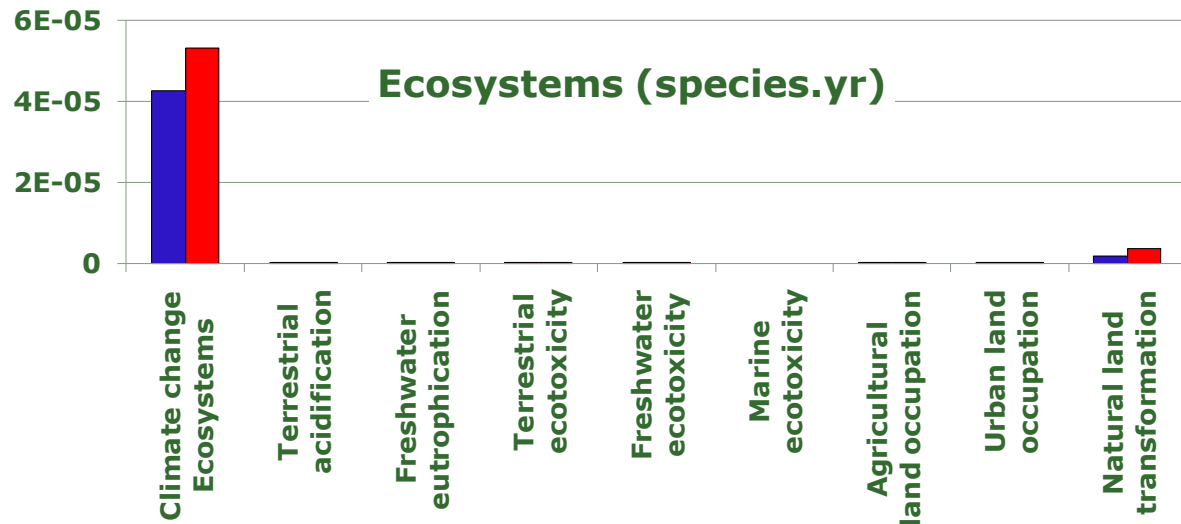
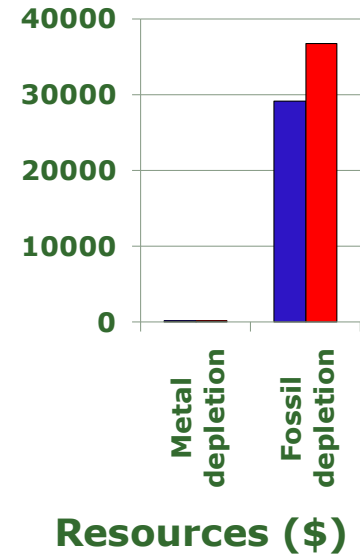
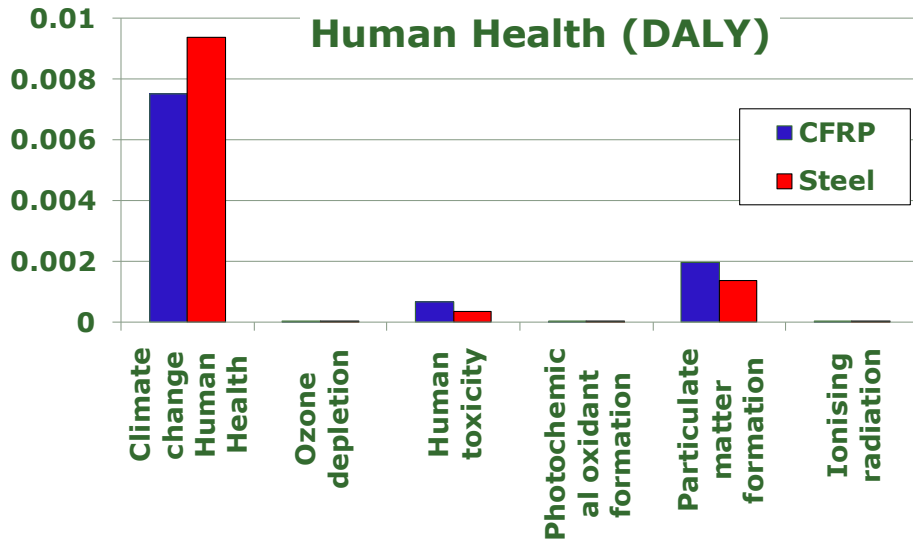


LCA – Impact Assessment

- One option is to group the impacts we have (“mid-point categories”) into bigger categories (“end-point categories”), and express all the impacts in one end-point category in the same units.
- Examples of end-point categories are
 - **Human Health** – Disability adjusted life years (DALY)
 - **Ecosystems** – Potentially disappeared fraction of species over the years the effect lasts (species.yr)
 - **Resources** – Increasing cost of extraction (\$)
- These calculations have more uncertainty but can help with analysis
- Some effects may fall into more than one category e.g. climate change



LCA - Impact Assessment



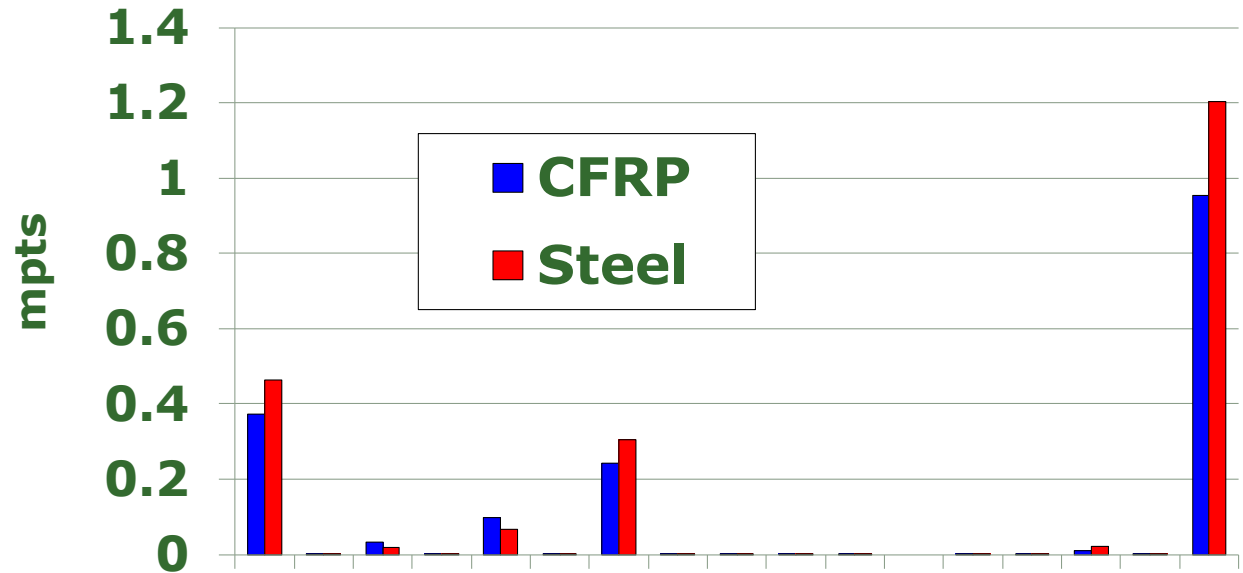


LCA – Impact Assessment

- Instead of normalising each individual impact, we now normalise by end-point category.
- So e.g. for Human Health we divide all the impacts by the number of DALYs an average person causes in a year.
- This means the relative sizes of impacts within each end-point category won't change, just the relation between end-point categories.
- Normalised like this we get ..



LCA - Impact Assessment



Climate change
Human Health
Ozone depletion
Human toxicity
Photochemical oxidant..
Particulate matter formation
Climate change Ecosystems
Terrestrial acidification
Freshwater eutrophication
Terrestrial ecotoxicity
Freshwater ecotoxicity
Marine ecotoxicity
Natural land occupation
Urban land occupation
Agricultural land occupation
Metal depletion
Fossil depletion



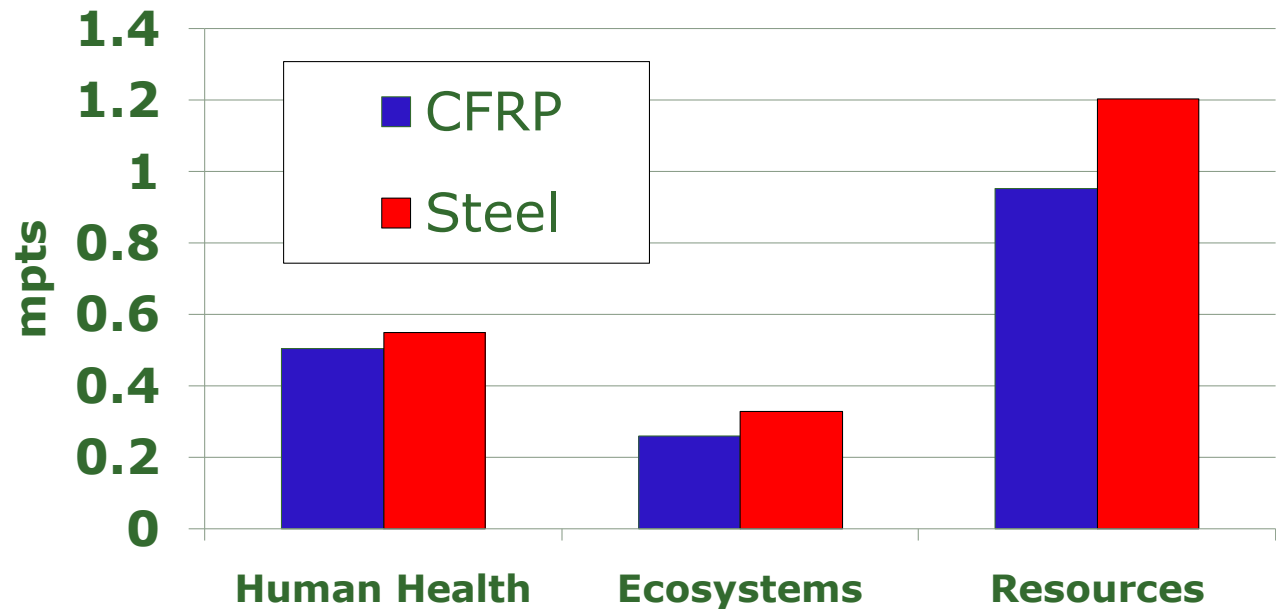
LCA – Impact Assessment

- ✖ This gives a different picture – it turns out the actual effect of land transformation is quite small.
- ✖ The most significant impacts are
 - **Human Health** – climate change then particulate matter formation
 - **Ecosystems** – climate change
 - **Resources** – Fossil depletion
- ✖ For the 3 largest mid-point categories, the steel BIW has the worse impact.



LCA – Impact Assessment

- The 3 end-point categories can still not be combined, but we can add the mid-point impacts within each one.

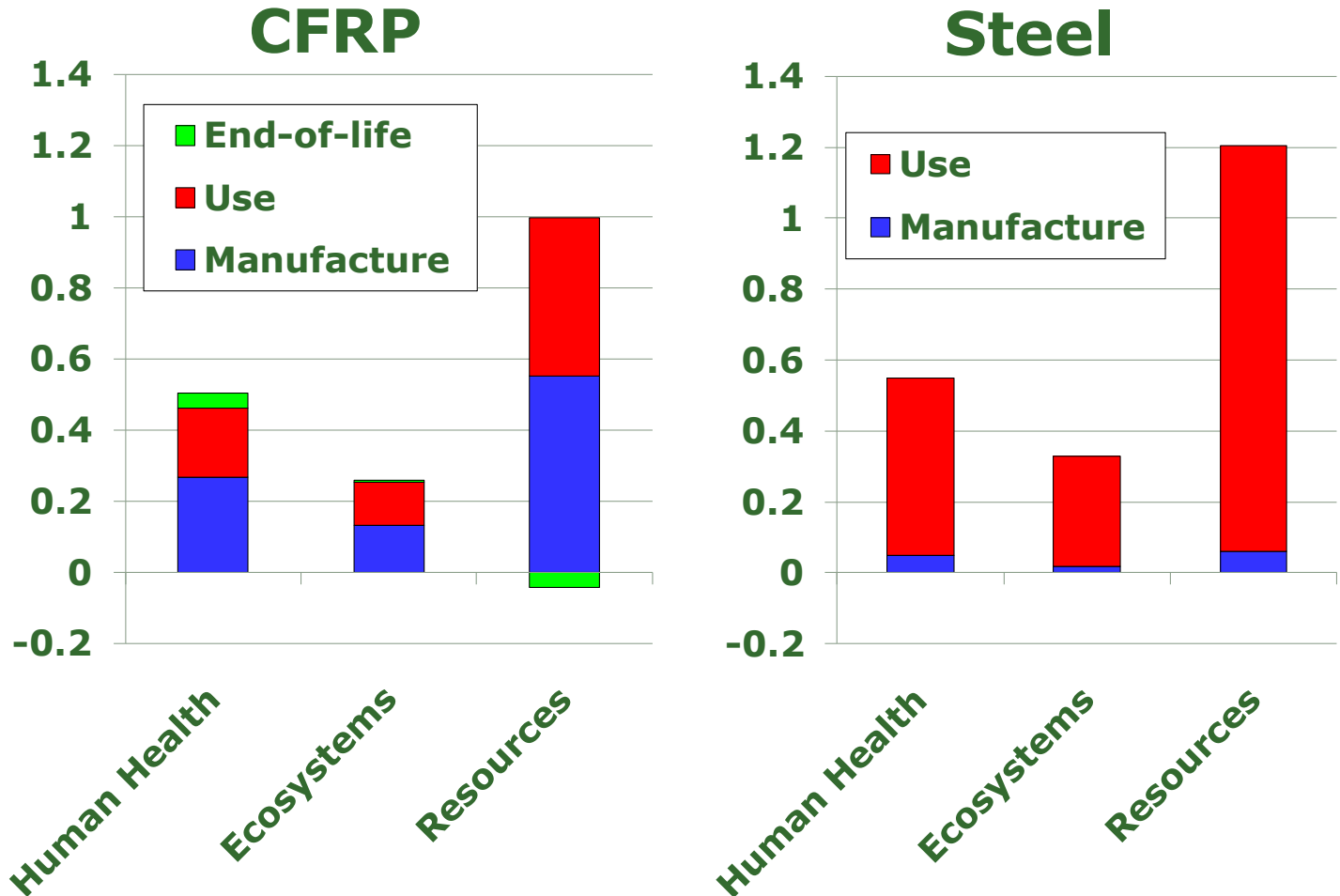


- Overall, in each end-point category, the steel BIW has the greater impact.



LCA - Impact Assessment

We can also look at the breakdown between different parts of the life cycle.

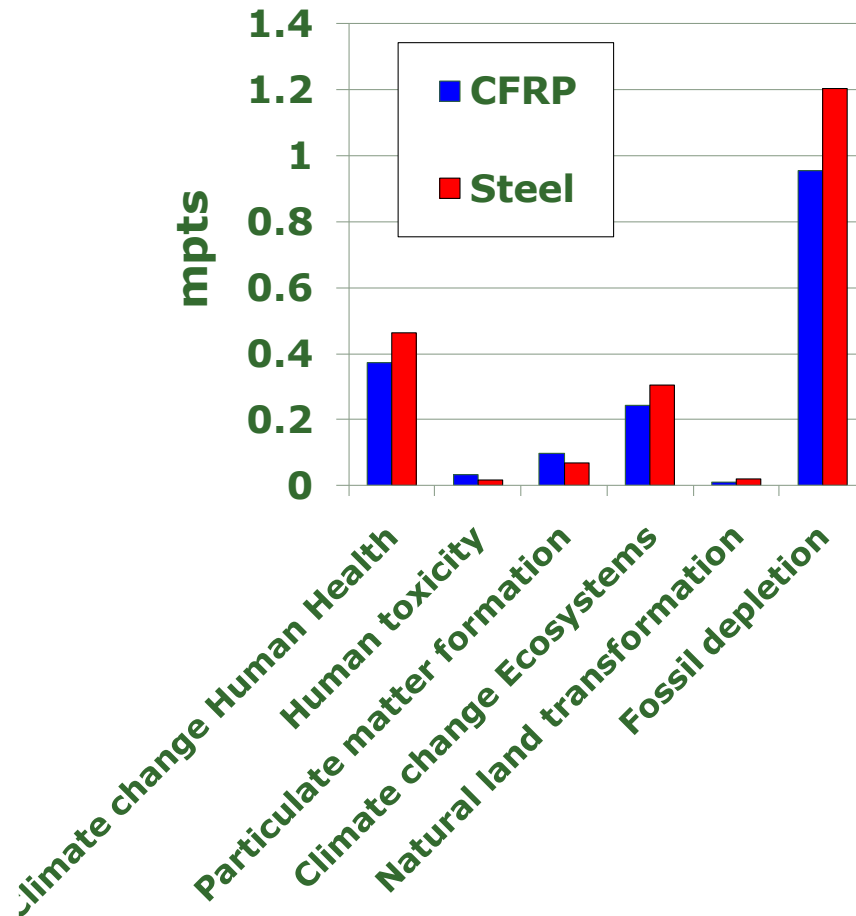




LCA – Impact Assessment



The example we have used here gives the same comparison in all three categories – that the steel BIW has a higher impact. So a single figure would be reasonably representative.

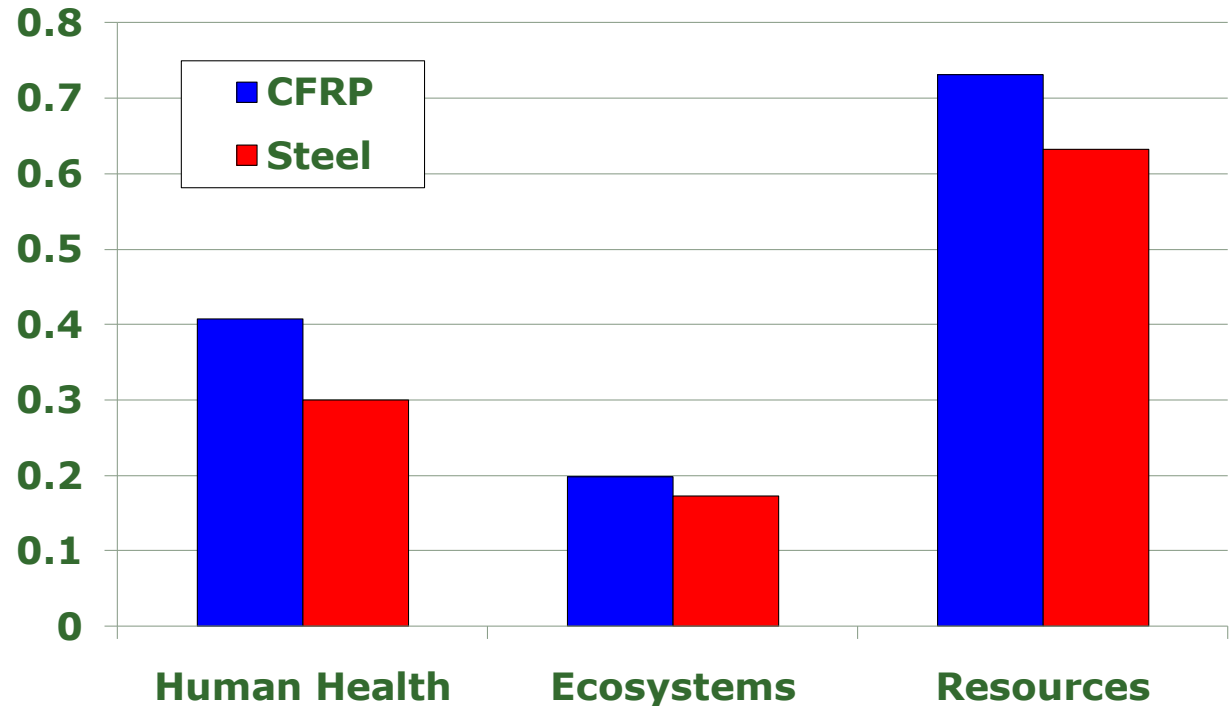


This assumes that climate change and “peak oil” are high priorities – if you believed otherwise then the CFRP BIW would have a higher impact.



LCA - Impact Assessment

- Finally, how does the result depend on the "functional unit" we chose?
- These are the results if the vehicle is driven for 100000 km instead of 200000 km.





Dangers of LCA

- ✘ Can easily create good-looking graphs from unrealistic data
- ✘ Can choose assessment methods to give desired outcome
- ✘ Incorrect avoided impacts can dominate results
- ✘ Need to ensure fair comparisons and independent scrutiny



Benefits of LCA

- Enables systems to be compared on a consistent basis
- Identifies relative importance of different stages
- Allows identification of best improvement options
- Determines sensitivity of results to data & assumptions

Green Guide to Composites

Produced by BRE
& NetComposites

Undertook LCA for
composite
materials &
processing



© BRE & NetComposites

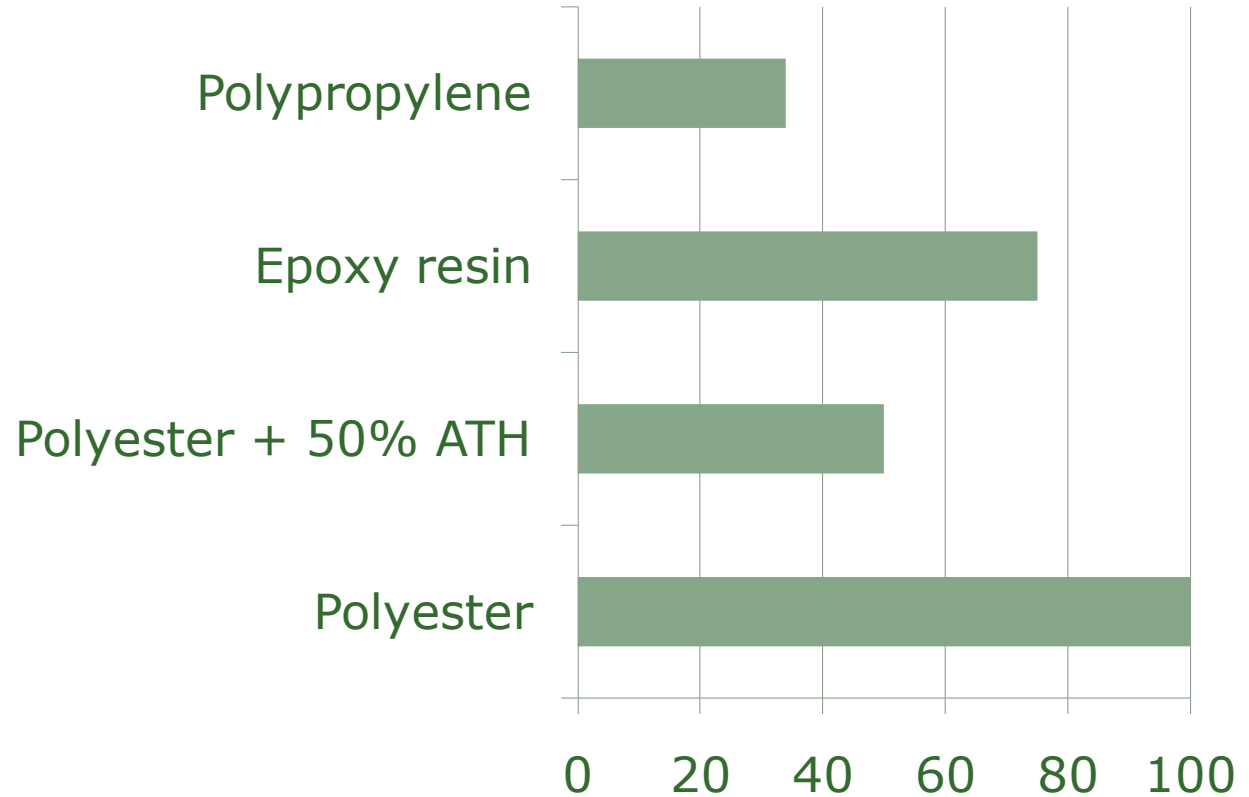


Green Guide - Weighting

Climate Change	38.0%
Fossil Fuel Depletion	12.0%
Ozone Depletion	8.2%
Human Toxicity to Air	7.0%
Waste Disposal	6.1%
Water Extraction	5.4%
Acid Deposition	5.1%
Eutrophication	4.3%
Ecotoxicity	4.0%
Summer Smog	3.8%
Minerals Extraction	3.5%
Human Toxicity to Water	2.6%

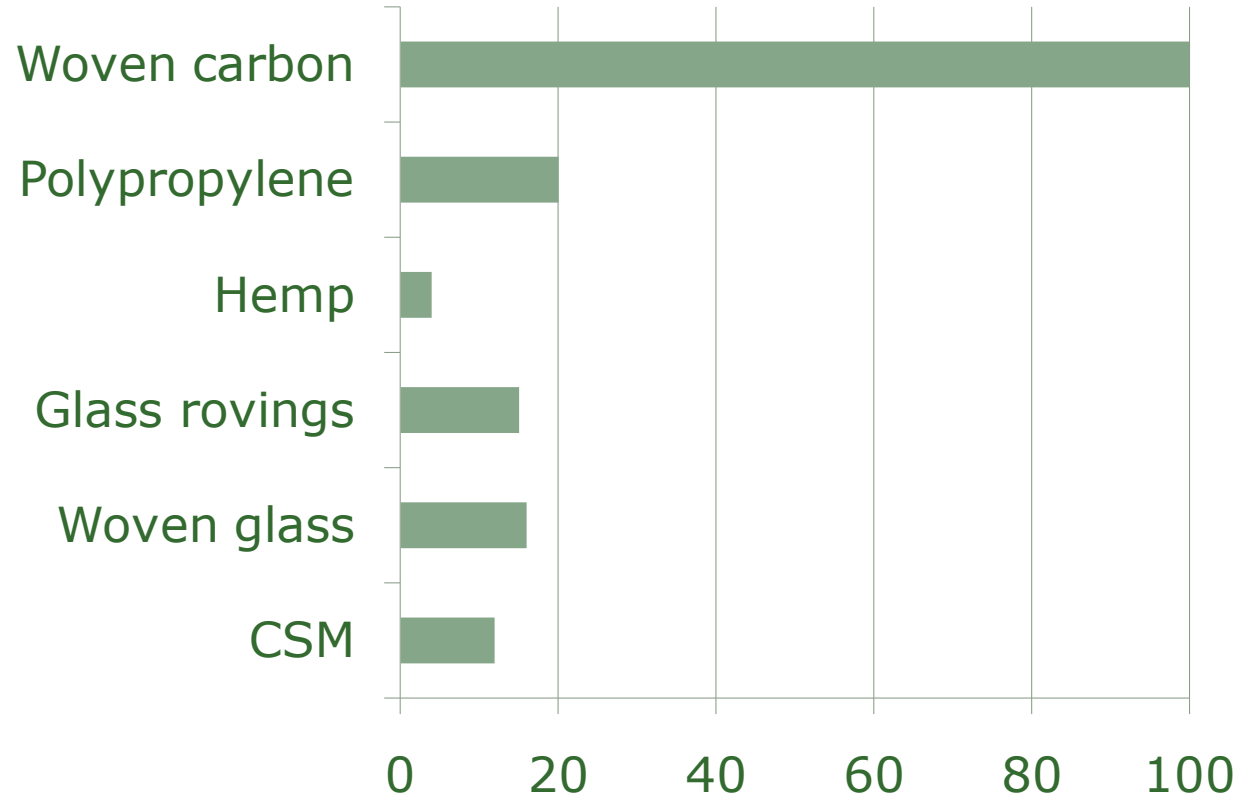


Green Guide – Matrix impact



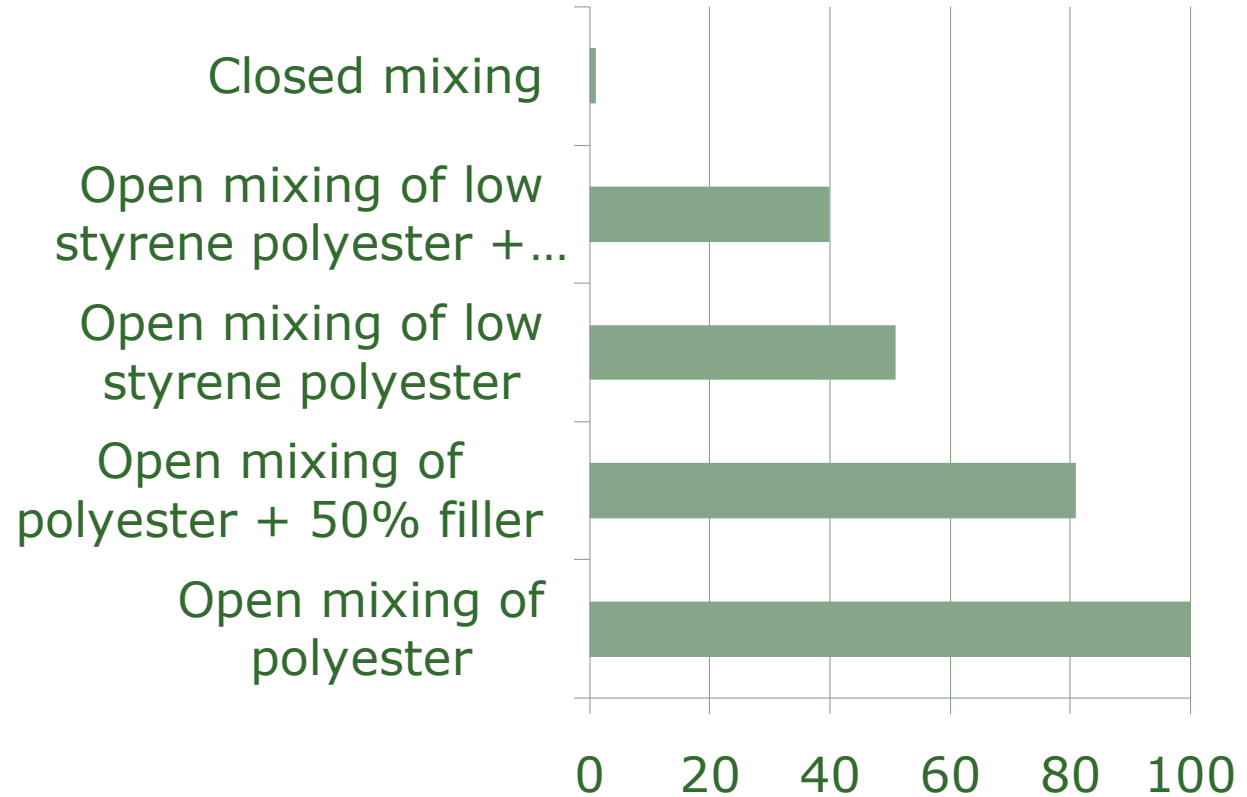


Green Guide – Fibre impact



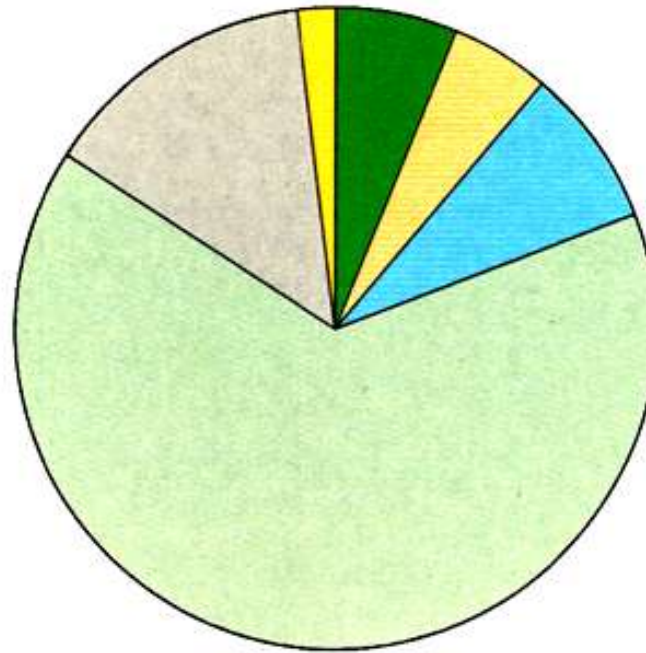


Green Guide – Polyester Mixing



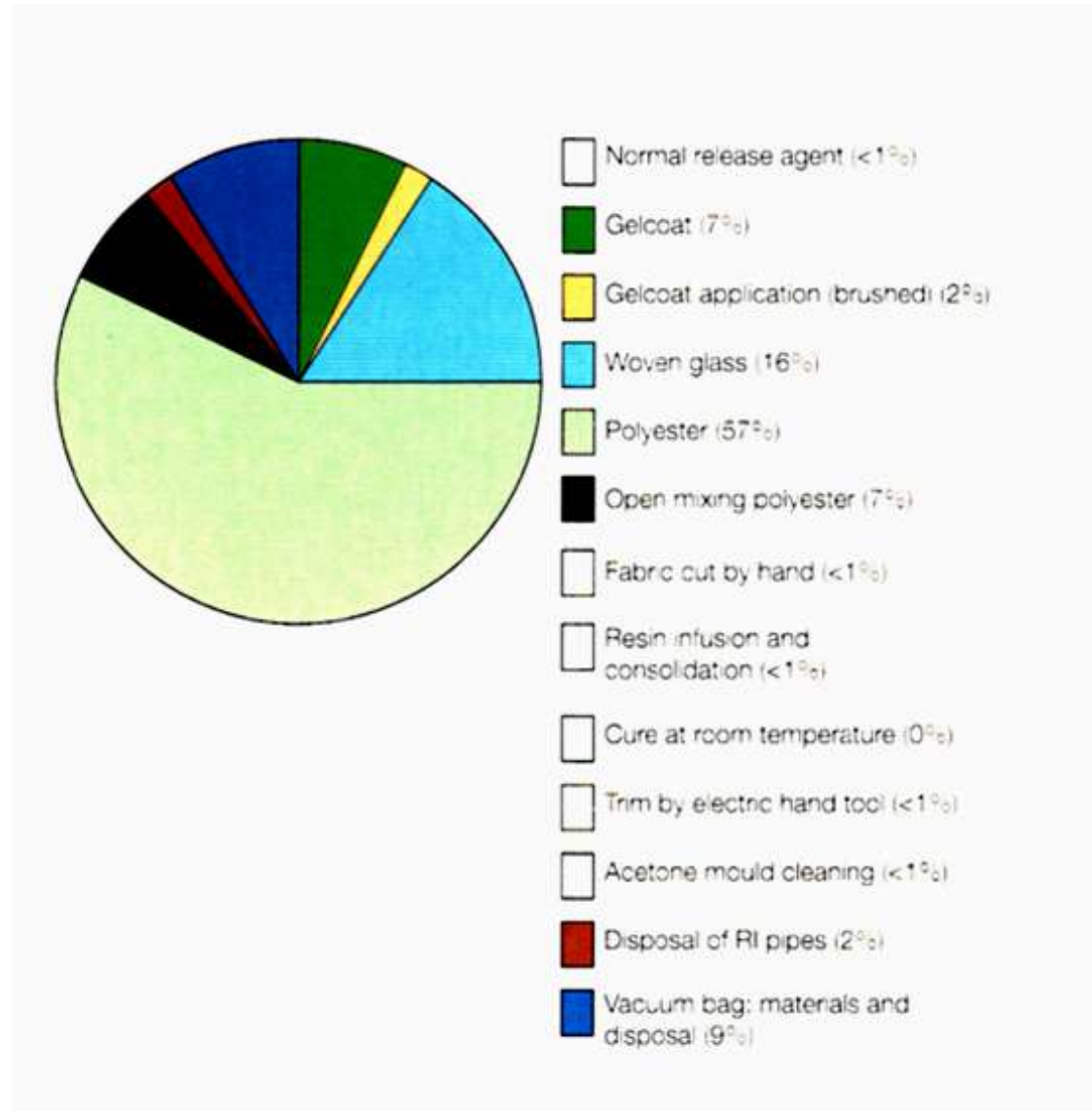


Green Guide – Spray-up

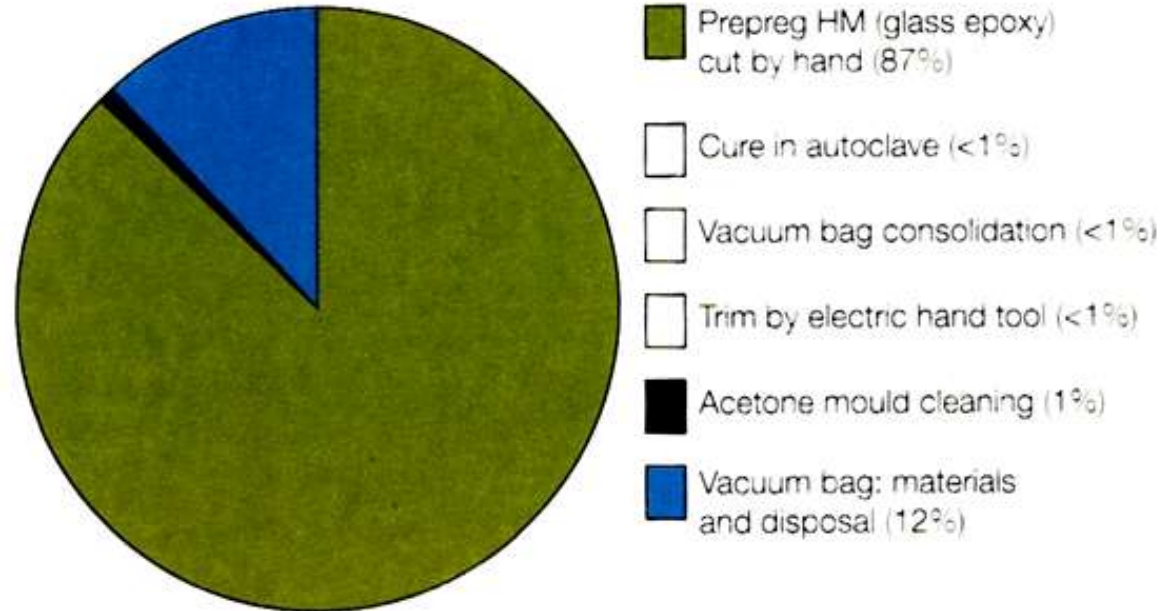


- Normal release agent (<1%)
- Gelcoat (6%)
- Uncontrolled spraying of gelcoat (5%)
- Glass rovings (8%)
- Polyester (62%)
- Closed mixing (<1%)
- Uncontrolled spraying of polyester (14%)
- Consolidate with roller (2%)
- Cure at room temperature (0%)
- Trim by electric hand tool (<1%)
- Acetone mould cleaning (<1%)

Green Guide – Hand lay-up



Green Guide – Autoclave



Flat Sandwich Panel 1m x 8m

A generic component measuring 1m x 8m with a 25mm thick core, having a panel bending stiffness equivalent to a sandwich panel with a 4mm thick chopped strand mat skin. For the pultrusion process the component is modelled with ribs instead of the core material used in other processes. This component is designed to be representative of large-scale applications such as bridge decks and marine structures.



Process	Material Choice	Environmental Indicators											Social Indicators		
		Summary Environmental Rating	Climate Change	Fossil Fuel Depletion	Ozone	Human Toxicity	Waste Disposal	Water Extraction	Acid Deposition	Ecotoxicity	Eutrophication	Summer Smog	Minerals Extraction	Risk Score	Remuneration
Vacuum Bag Moulding	CSM/Polyester	E	C	E	A	E	D	A	B	D	A	E	B	C	E
RTM	Woven Glass/Polyester	B	C	C	A	B	E	A	B	B	A	A	C	B	E
Resin Infusion	Woven Glass/Polyester	C	B	C	A	C	D	A	B	C	A	B	C	B	C
Autoclave Moulding	Glass/Epoxy Prepreg (hot melt)	A	B	A	A	A	D	B	B	C	B	A	C	A	B
Pultrusion	Woven glass and glass rovings/Polyester +CaCO ₃ filler	A	A	A	A	B	B	A	A	A	A	C	C	B	A
Hand Lay-Up	CSM/Polyester	E	C	E	A	E	D	A	B	D	A	E	C	C	E
	Woven Glass/Polyester	C	B	C	A	C	D	A	B	C	A	C	C	B	E
	Hemp/Polyester	E	B	D	A	E	A	A	B	D	B	E	A	C	E
	CSM/Polyester +50% CaCO ₃ filler	C	A	B	A	C	D	A	A	B	A	D	E	D	E
	CSM/Polyester +50% ATH filler	D	B	C	B	C	E	A	C	E	A	D	E	D	E
	CSM/Low styrene (LS) polyester	E	C	E	A	E	D	A	B	D	A	C	C	C	E
	CSM/LS polyester +50% CaCO ₃ filler	B	A	B	A	C	D	A	A	B	A	C	E	D	E
	CSM/LS polyester +50% ATH filler	C	B	C	B	C	E	A	C	E	A	C	E	D	E
	Woven Glass/Epoxy	B	C	A	A	A	E	C	C	C	C	A	C	B	E
	CSM/Epoxy	C	E	B	A	B	E	E	E	E	E	A	D	C	E
	Woven Glass/LS polyester +50% CaCO ₃ filler	A	A	A	A	B	D	A	A	B	A	B	D	C	E



Biocomposites

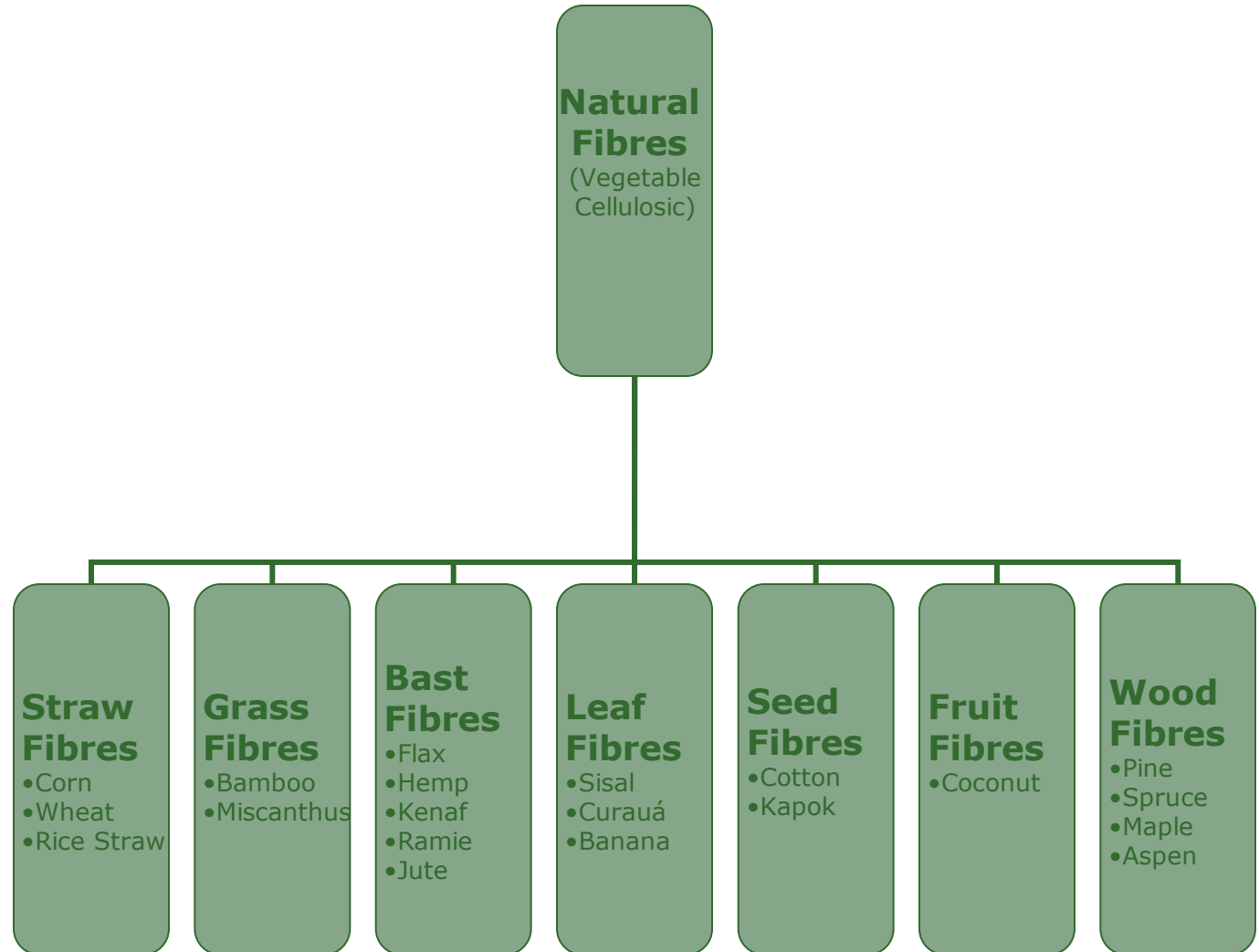
Natural Fibre Composites

- Initial work looked at natural fibres as reinforcement in traditional matrices
- A large number of products use milled natural fibre as a particulate reinforcement, adding stiffness but little strength
- More recently, the boom in biopolymers and bioresins has allowed biocomposites to target products which are 100% biological in origin





Natural Fibre Types





Natural Fibres are Composites!

Bast Fibres



Bast fibres have a high cellulose content

Their cell walls are very thick to provide strength to the stem of the plant

	Cellulose	Hemicellulose	Lignin	Pectin	Wax	Moisture Content
Flax	71	18.6-20.6	2.2	2.3	1.7	10.0
Hemp	70.2-74.4	17.9-22.4	3.7-5.7	0.9	0.8	10.8



Commercially Important Natural Fibre Sources

Fibre	Main Countries	Origin	World Production 2004 (tonnes)
Wood	Numerous (>10,000 species)	Stem	1,750,000,000
Bamboo	China (>1250 species)	Stem	10,000,000
Jute	India, Bangladesh	Stem	2,861,000
Kenaf	India, China	Stem	970,000
Coir	India, Vietnam, Sri Lanka	Fruit	931,000
Flax	China, Europe	Stem	830,000
Sisal	Brazil, Kenya	Leaf	378,000
Ramie	China	Stem	249,000
Hemp	China, Europe	Stem	214,000
Abaca	Philippines, Ecuador	Leaf	98,000
Agave	Columbia, Cuba, Mexico	Leaf	56,000



Bast Fibre Extraction



Harvesting



Retting

- Pond retting
- Dew retting
- Enzymatic retting



Breaking or
scutching



Cleaning and
drying

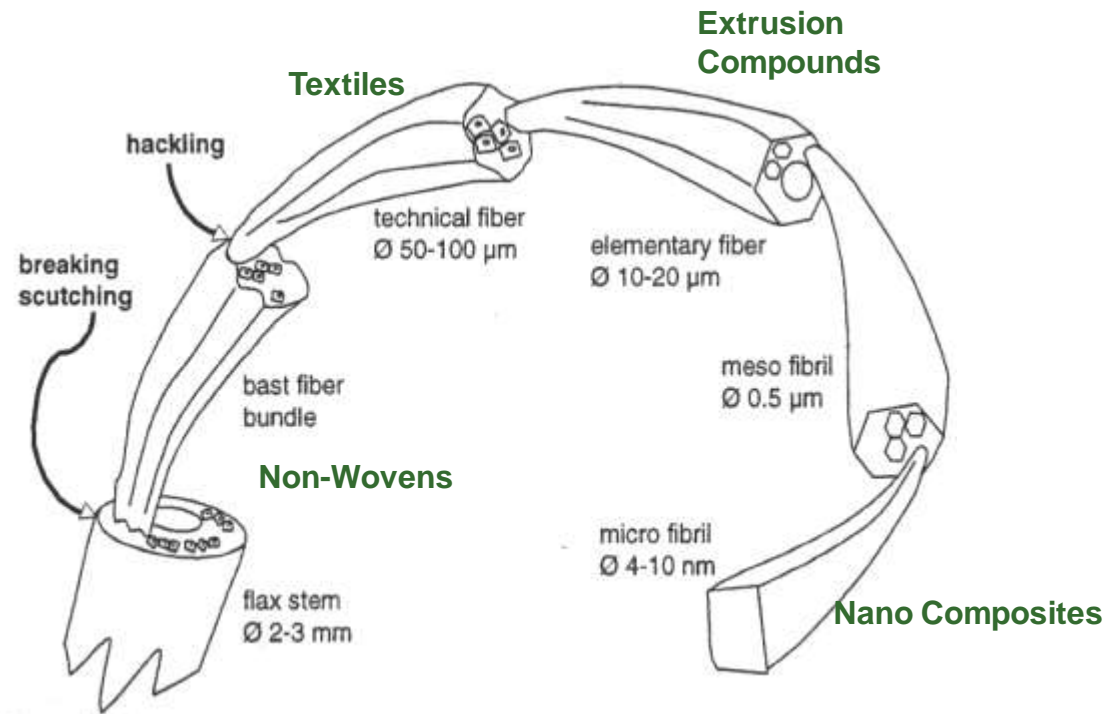


Carding



Bast is Best

- Natural task to stabilise plant
- Good mechanical properties
- Low density
- Used as reinforcements in lightweight composite parts



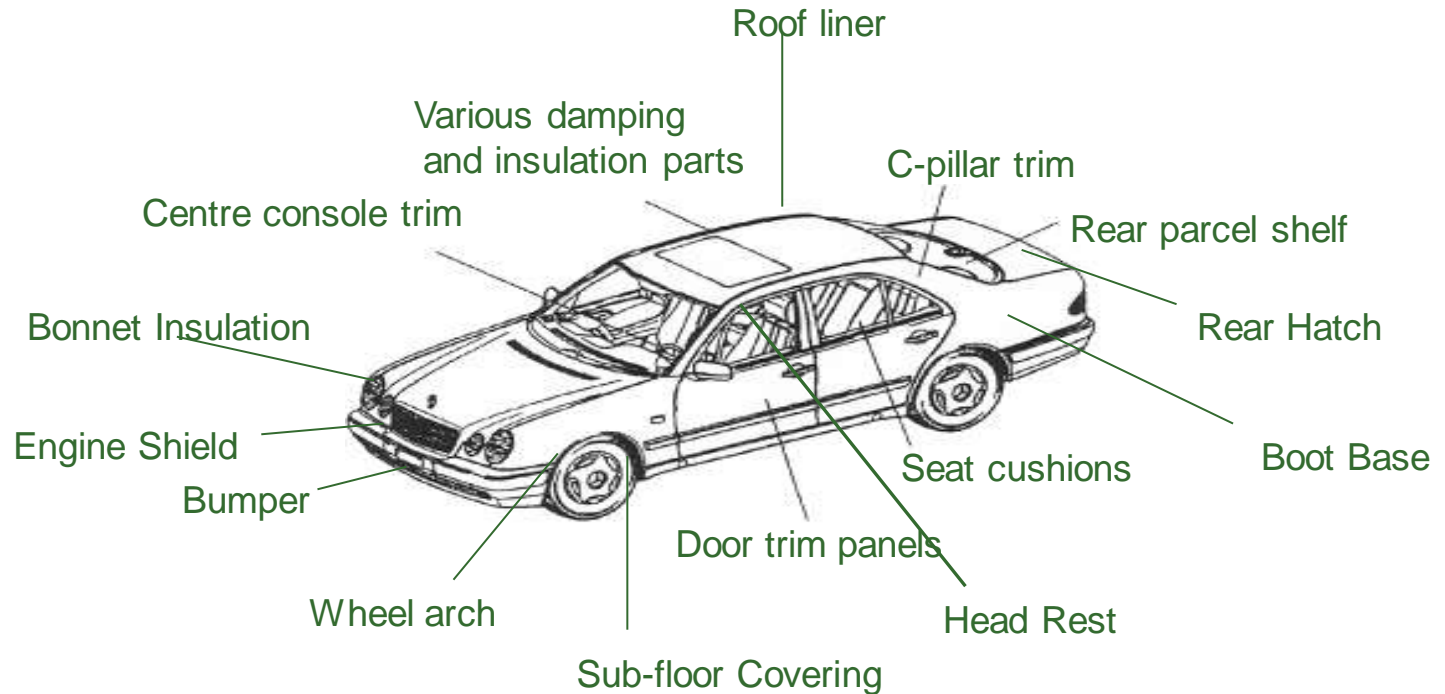


Properties of Natural Fibres

Property	E-glass	Flax Fibre	Hemp Fibre
Diameter [μm]	8-14	5-40	10-50
Density [g/cm^3]	2.56	1.5	1.4
E-modulus [GPa]	76	27.6	35
Tensile Strength [GPa]	1.4-3.5	0.4-1.1	0.7
Elongation to Fracture [%]	1.8-3.2	2.7-3.2	1.6
Specific E-modulus [$\text{GPa}/\text{g}/\text{cm}^3$]	30	18.4	25
Specific Tensile Strength [$\text{GPa}/\text{g}/\text{cm}^3$]	0.5-1.3	0.4-1.1	0.5

Example 1

Thermoplastic NFC panels in the automotive sector



Audi, BMW, Daimler Chrysler, Fiat, Ford, Mercedes Benz, Peugeot, Renault, Rover, SAAB, Seat, Toyota, Vauxhall, Volkswagen, Volvo

Example 1

Thermoplastic NFC panels in the automotive sector

Front door liners	1.2-1.8 kg
Rear door liners	0.8-1.5 kg
Boot liners	1.5-2.5 kg
Parcel shelves	Up to 2 kg
Seat backs	1.6-2.0 kg
Sunroof interior shields	Up to 0.4 kg
Head rests	Approx 2.5 kg

Audi, BMW, Daimler Chrysler, Fiat, Ford, Mercedes Benz, Peugeot, Renault, Rover, SAAB, Seat, Toyota, Vauxhall, Volkswagen, Volvo

Example 1

Thermoplastic NFC panels in the automotive sector



Audi, BMW, Daimler Chrysler, Fiat, Ford, Mercedes Benz, Peugeot, Renault, Rover, SAAB, Seat, Toyota, Vauxhall, Volkswagen, Volvo

Example 2

100% bio-derived SMC panel

- Vegetable oil based epoxy resin
 - PTP® from Biocomposites And More GmbH
- Production of sheet moulding compound (SMC) with hemp fibre
- Demonstration project in Germany to form bus panels





End-of-Life options



Recycling



- Thermoset-based composites can't be recycled
- Thermoplastic composites can but granulation leads to short fibres
- Can be ground and used as filler, but this gives large degradation in properties



Thermal reprocessing

- Controlled heat treatments can remove resin from carbon fibres
- Pyrolysis / incineration can be used to generate useful fuels, feedstocks and electricity



End-of-Life options



Biodegradation

- Possible with bio-composites
- Most will be tailored for long lifetimes, so may only break down in specific conditions





Summary

- Composites often have more environmental impacts on production and disposal than more conventional materials
- In many cases, these are offset by benefits in use due to the lower weight / improved performance of composites
- To quantify these issues LCA methods can be used
- Biocomposites can lead to reduced impacts in materials manufacture

Welsh Composites Centre



Thank-you for your attention

