FPCM-17

2026

John Summerscales

University of Plymouth

The 17th International Conference on Flow Processes in Composite Materials

30th June - 2nd July 2026 | The University of Sheffield, UK

McLaren SYENSQO GKN AEROSPACE IMDEA MATERIALES 50TH ANNIVERSARY

From Process Flows to Life Cycle Inventories:
why energy and mass flow inventories are essential for credible LCA of composite manufacturing.

John Summerscales, Badr Moutik
Alexandros Besinis, Jasper Graham-Jones, Richard Pemberton

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Sustainability

The Brundtland report (1987) suggested that **Sustainable Development** should be defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs"

Our Common Future
World Commission on Environment and Development, 1987

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Sustainability

We choose to define sustainability as a balance of

- technical, economic, environmental, social, and governance (TEESG), or
- performance, prosperity, planet, people and policy (F45P: fit for 5 purposes)

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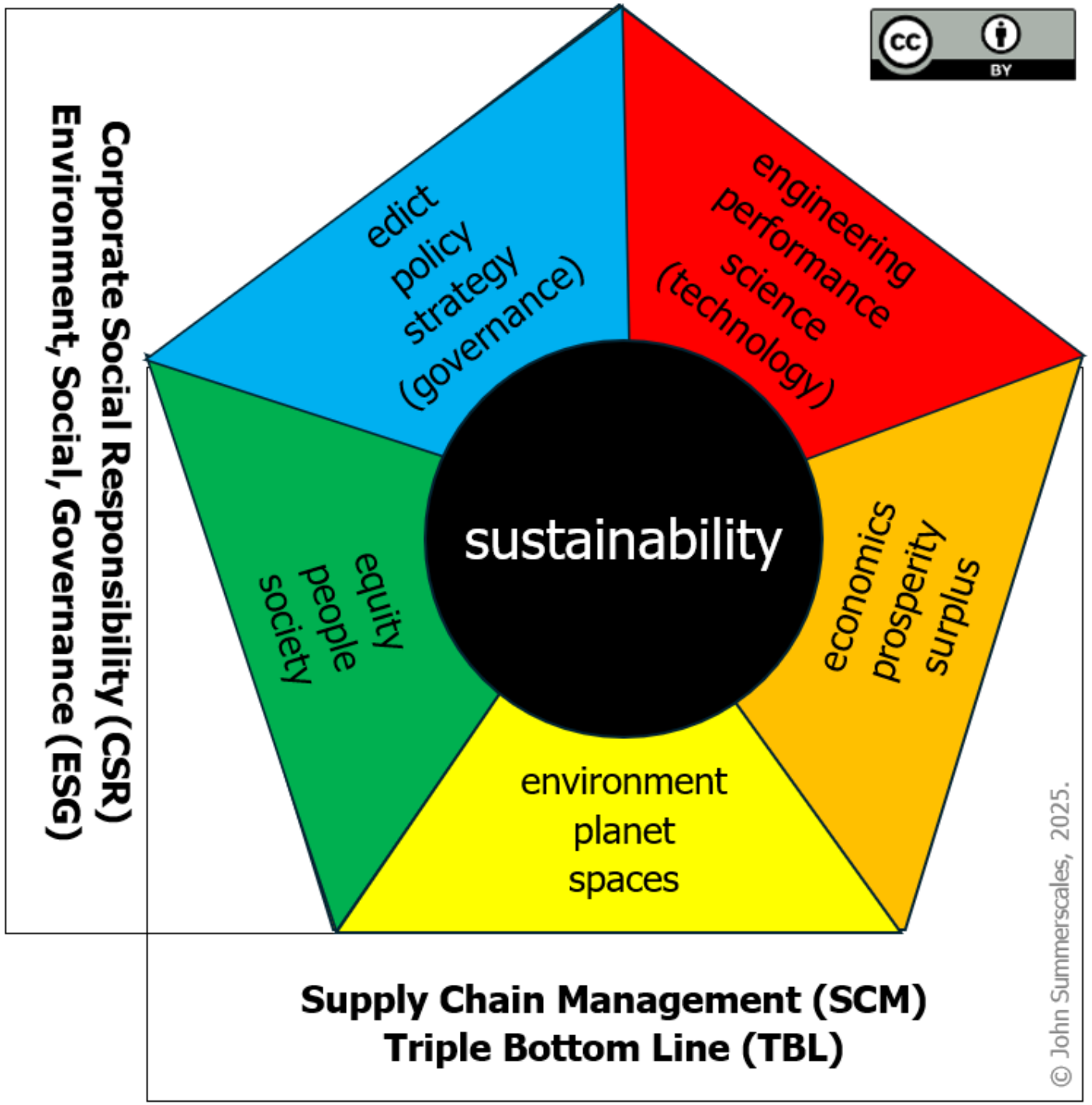

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Saving the planet

- leaving four elements of sustainability, now focus on the environmental issues

- United Nations hosts two major Conferences of the Parties (CoP)
  - Climate Change Conference
  - Biodiversity Conference

https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-cop

https://www.un.org/en/climatechange/un-biodiversity-conference

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Life Cycle Assessment (LCA)

- LCA is a quantitative tool for assessing and minimising potential environmental impacts of various entities through their entire life cycle
- LCA is **not** Life Cycle **Analysis**.

B Moutik, J Summerscales, J Graham-Jones, R Pemberton
Life Cycle Assessment research trends and implications: bibliometric analysis
Sustainability, 2023, 15(18), 13408

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Life Cycle Assessment (LCA)

- governed by International Standards
  Environmental management — Life cycle assessment
  - ISO 14040 principles and framework
  - ISO 14044 requirements and guidelines
- extended by e.g. ILCD
  International Life Cycle Data system

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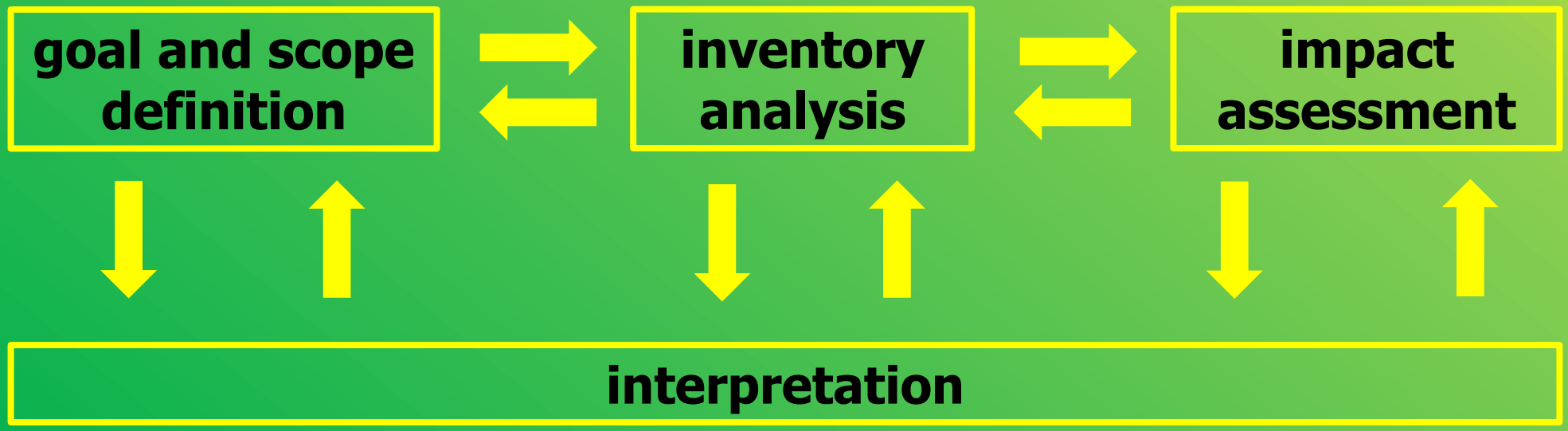
Four phases of an LCA



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goal and scope definition

- goal:
  - attributional LCA: describes a product system and its environmental exchanges, or
  - consequential LCA: describes how environmental exchanges of the system can be expected to change as a result of actions taken in the system.
- scope:
  - functional unit (FU): an impartial basis for assessment
  - system boundary

Rebitzer et al, Environment International, 2004
https://doi.org/10.1016/j.envint.2003.11.005

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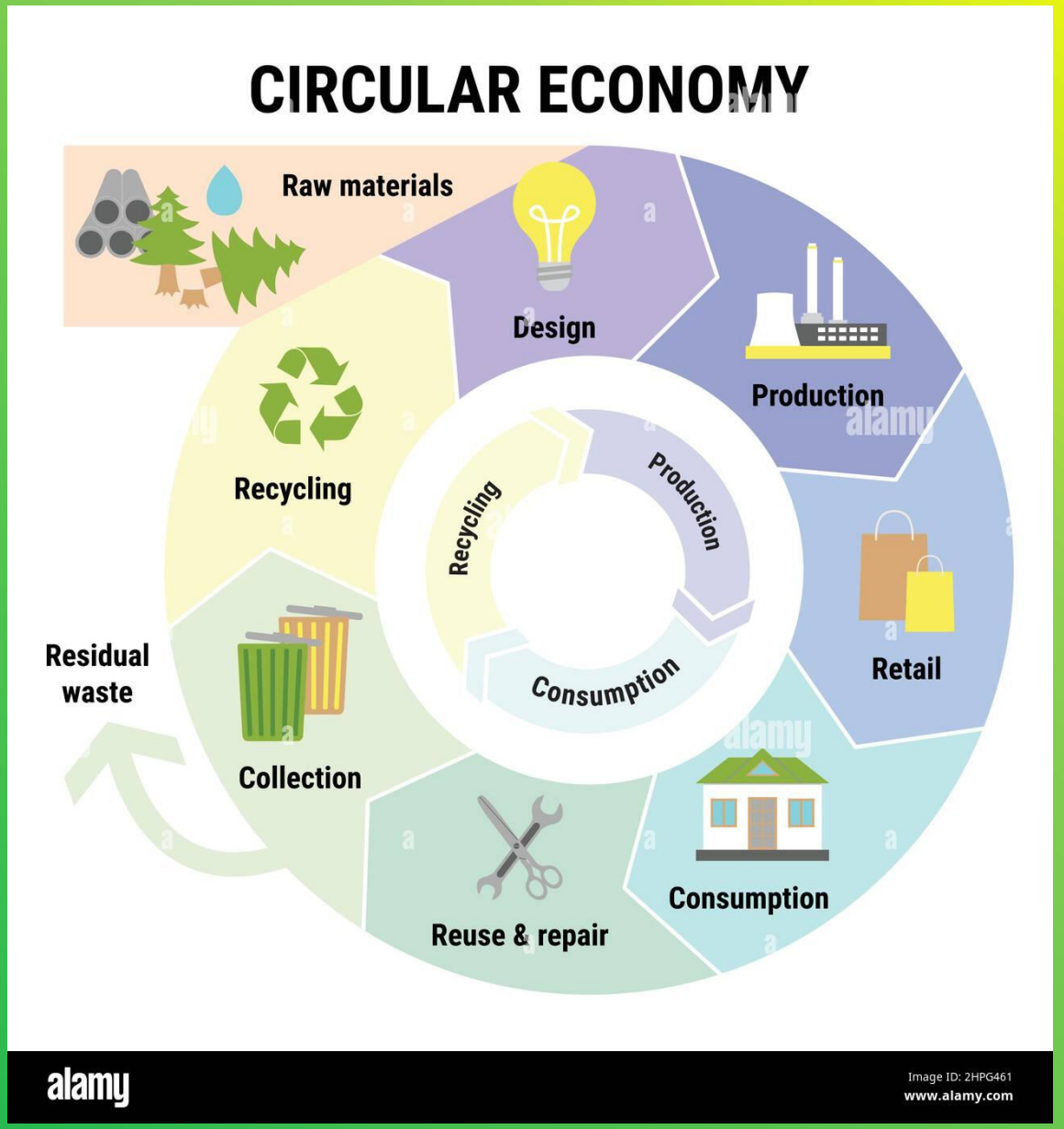
Energy and mass balance



https://www.alamy.com/circular-economy-infographic-sustainable-business-model-scheme-of-product-life-cycle-from-raw-material-to-design-production-consumption-reusing-image461346537.html

Must sensibly conserve energy and mass
… or explain why not.

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Inventory analysis

acquire data and calculate the respective sums of:

- emissions of substance x effect of substance
- quantity of resource/world reserve

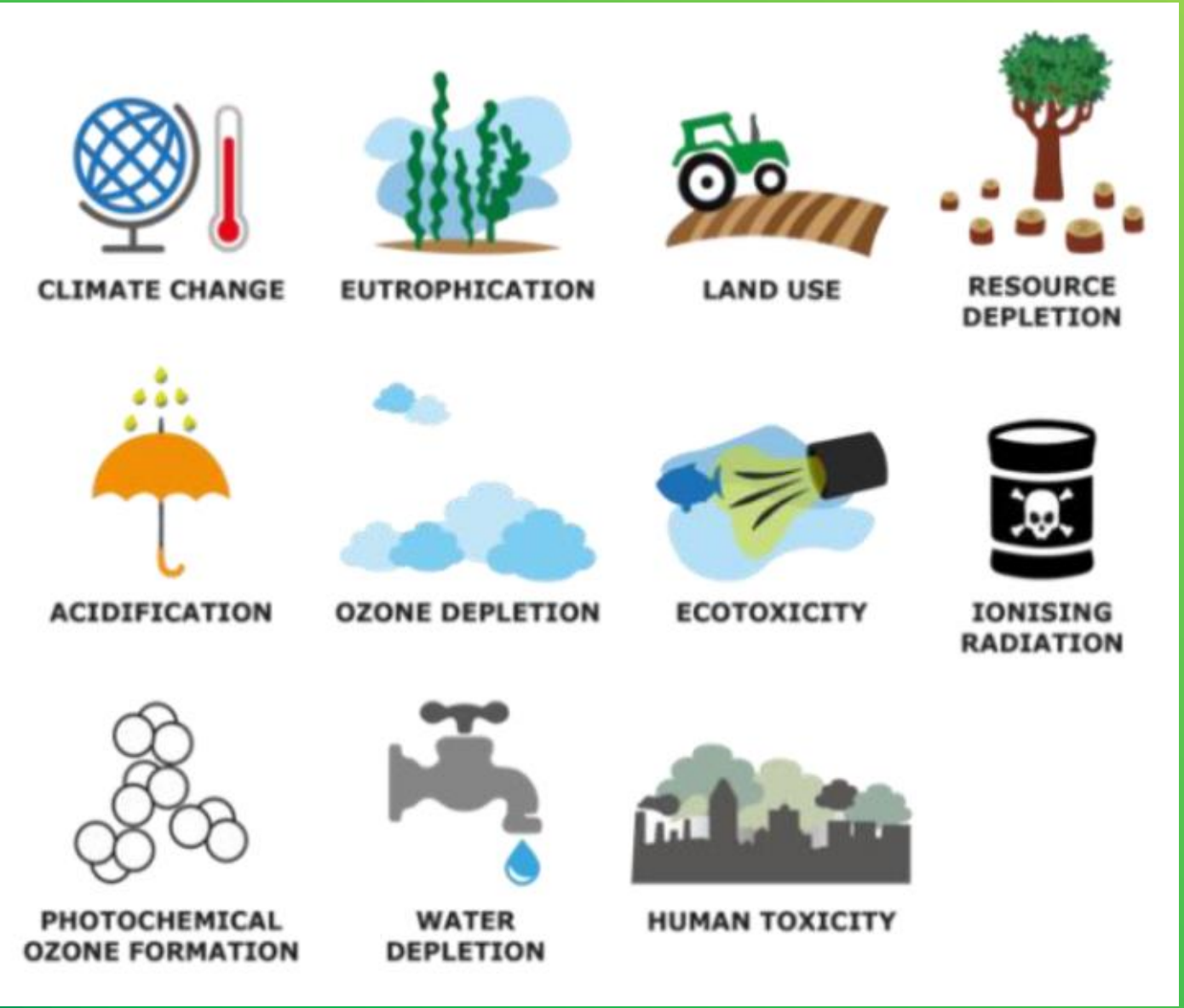
for each environmental impact to be assessed

Life Cycle Assessment (LCA):
Environmental Impact Classification Factors (EICF)

ISO/TR 14047:2003(E)	EICF (Azapagic et al)
Acidification	Acidification Potential (AP)
Ecotoxicity	Aquatic Toxicity Potential (ATP)
Eutrophication/Nitrification	Eutrophication Potential (EP)
Climate change	Global Warming Potential (GWP)
Human toxicity	Human Toxicity Potential (HTP)
Depletion of abiotic/biotic resources	Non-Renewable/Abiotic Resource Depletion (NRADP)
Stratospheric ozone depletion	Ozone Depletion Potential (ODP)
Photo-oxidant formation	Photochemical Oxidants Creation Potential (POCP)

A Azapagic, A Emsley and I Hamerton, Polymers, the Environment and Sustainable Development, John Wiley & Sons, March 2003, ISBN 0-471-87741-7.
A Azapagic and S Perdan (editors), Sustainable Development in Practice - Case Studies for Engineers and Scientists, Wiley, 2011. ISBN 978-0-470-71872-8.

Life Cycle Impact Assessment



https://eplca.jrc.ec.europa.eu/uploads/lifeCycleAssesment.png

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LCIA: ReCiPe

The ReCiPe model developed by Dutch RIVM now considered the international method for life cycle impact assessment (LCIA)

National Institute for Public Health and the Environment
Ministry of Health, Welfare and Sport

LCI data quality

temporal coverage

geographical coverage

technology coverage

completeness

sources of data

precision

consistency

uncertainty

representat-iveness

reproducibility

The pedigree matrix … doesn't encompass all critical data quality characteristics,
serving instead to semi-quantitatively address
certain areas to enhance data quality communication

Moutik et al, 2024
https://doi.org/10.1016/j.spc.2024.07.005

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proxies

- the material is not in the LCI datasets
- find an alternative
  with the least "distance"
  between the respective cases

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Cautionary tales ….

proxies

All natural fibres are equal, but some are less equal than others.

Asian jute

Aligned fibre

European flax

Woven fabric

Tractor

Fertiliser

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With apologies for paraphrasing George Orwell

proxies: embodied energy (MJ/kg)

- **jute** fibre cultivation 4-8
  (excluding field labour, retting and decortication)
- **flax** hackled fibre 12
  (French grown, French energy, mass allocation)
- **flax** fibre sliver 54
  (UK grown, UK energy, primary product allocation)
- **flax** fibre yarn 80
  (UK grown, UK energy, primary product allocation)
- **viscose** 169
  (regenerated cellulose fibre)

NPJ Dissanayake and J Summerscales
Life Cycle Assessment for Natural Fiber Composites
https://doi.org/10.1201/b16076-9

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Electrical energy in weaving

	Wh/kg		MJ/kg
open-end yarn spinning [1]	2541		9
ring yarn spinning [1]	3553		13
	Wh/m	**kJ/m**	**MJ/kg for 250 gsm**
general weaving [2]	450-550	1620-1980	6-8
air-jet loom [3]	1900	6840	27

values can vary based on
machine efficiency, fabric type, and production conditions.

[1] E Koç and E Çinçik, Fibres and Textiles in Eastern Europe, 2007, 15(4/63), 18-24.
[2] What is the energy profile of the textile industry?
https://oecotextiles.blog/2009/06/16/what-is-the-energy-profile-of-the-textile-industry/
but broken link to original source.
[3] MS Shripal, Specific energy consumption of air jet loom,
International Research Journal of Modernization in Engineering Technology and Science, August 2020,
2(8), 1468-1473.
https://www.irjmets.com/uploadedfiles/paper/volume2/issue_8_august_2020/3226/1628083127.pdf

Unsaturated polyester resin

"The system boundaries are displayed in Figure 1"?

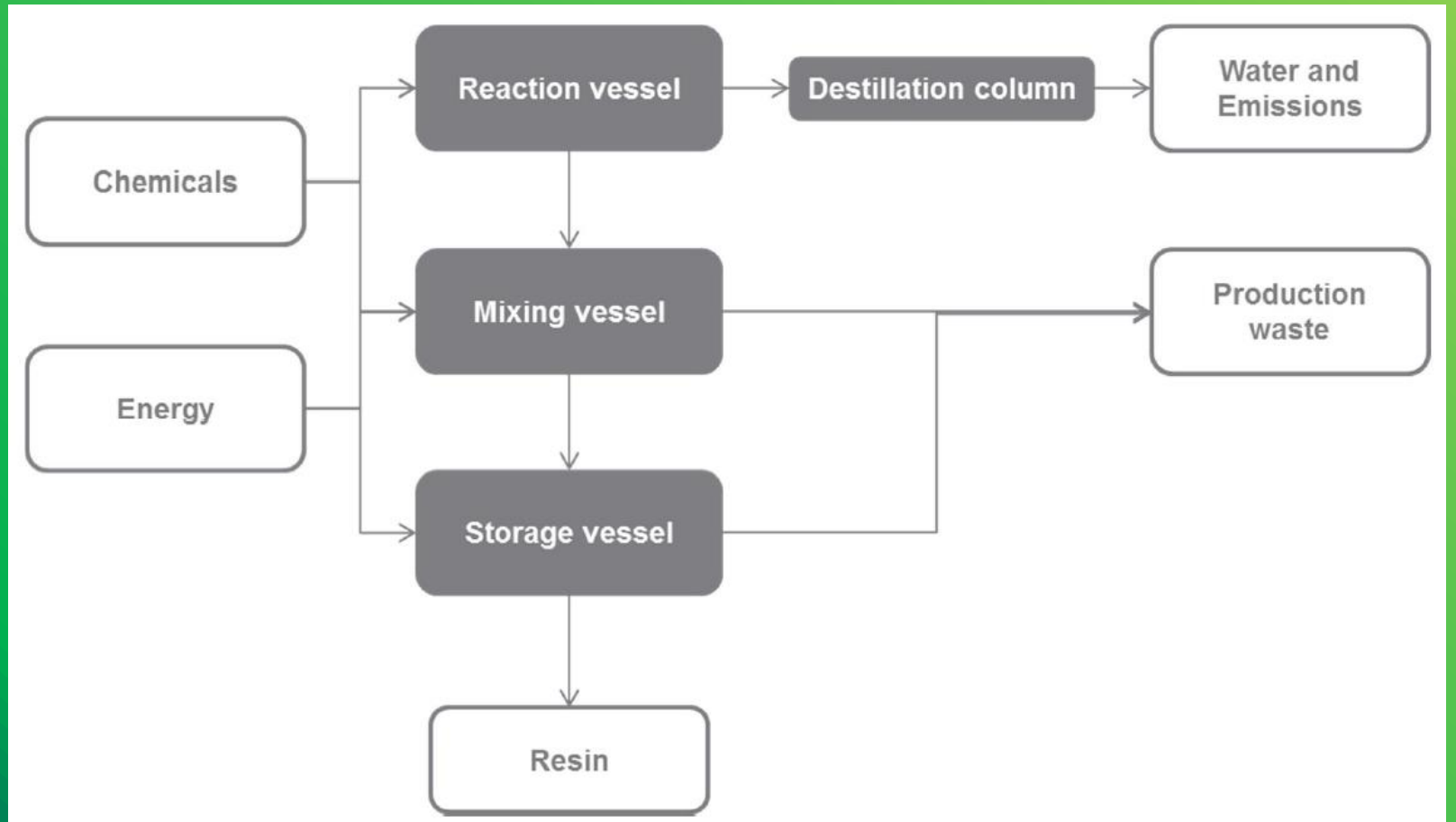

Figure 1 Schematic representation of the analyzed system

Eelco Rietveld and Sander Hegger with Lieke van Rossum (reviewer)
Life cycle assessment of four generic unsaturated polyester (UP) resins and one vinyl ester (VE) resins
Ernst & Young Accountants LLP, Rotterdam, The Netherlands, February 2014.

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Bio-based versus traditional polymer composites. a life cycle assessment perspective

- "major impact is associated to the epoxy resin [67%] while the impact due to the glass-fibers is [28%]"
- ecoinvent epoxy data is for base resin
- "hardener", "curing" *etc* not mentioned in paper.

https://doi.org/10.1016/j.jclepro.2014.03.017

The way forward

Every product should be accompanied by a
Life Cycle Inventory Data Sheet (El CIDs)
~ similar to Materials Safety Data Sheet (MSDS)
~ must be in a coherent system
~ industry will be reluctant to implement this!

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Conclusions

- LCA provides a coherent methodology for assessing environmental issues
- LCI data has some severe quality issues
- beware shortcuts in existing assessments
- **Life Cycle Inventory Data Sheet (El CIDs)**

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