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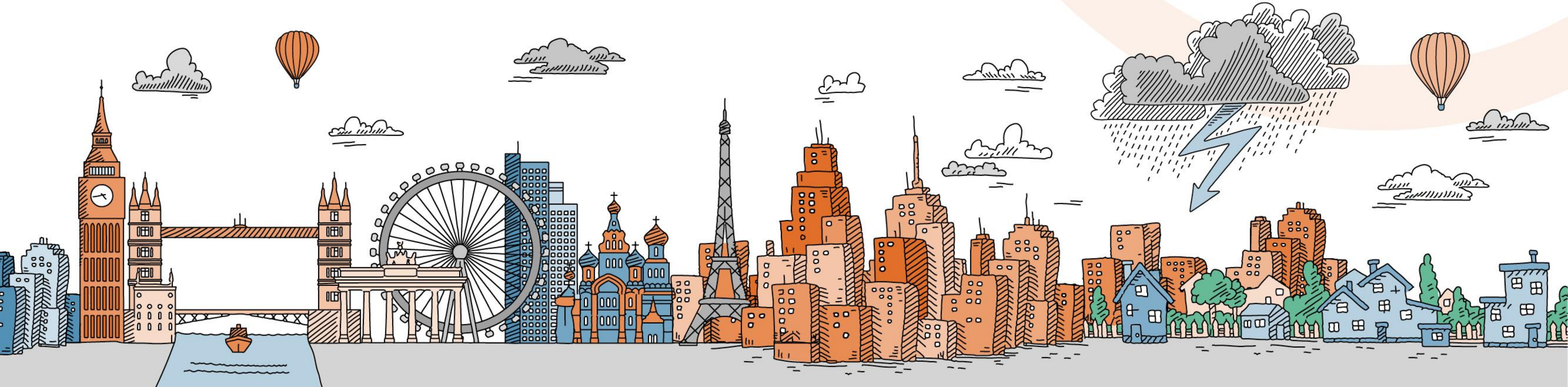
Teaching Life Cycle Assessment at the University of Manchester

Embedding life cycle thinking in engineering education

Dr Alejandro Gallego Schmid



The gap

STRONG RESEARCH PRESENCE

LIMITED CURRICULUM INTEGRATION

SKILLS GAP IN GRADUATES

Our approach

LCA not only as a tool (software, calculation & results)

Way of thinking (defining systems, trade-offs & supporting decisions)

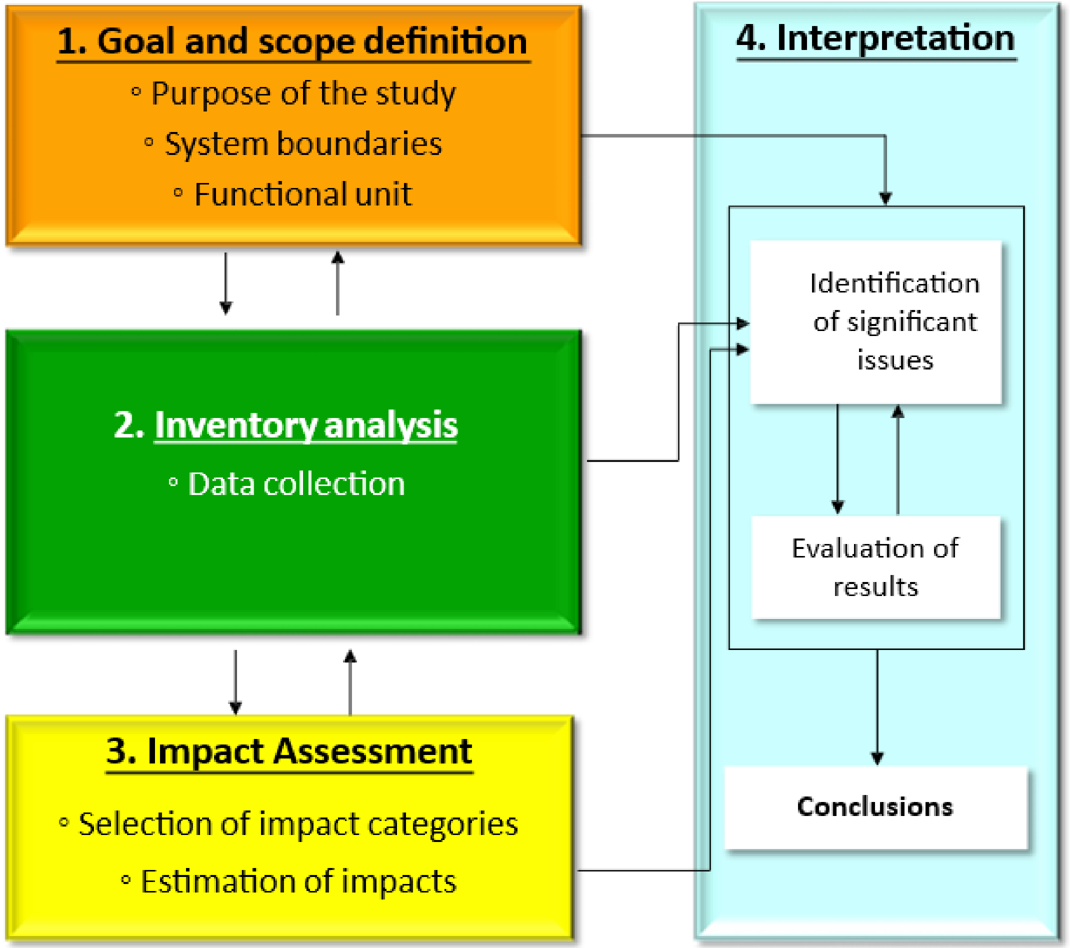
Not only results, but to develop judgement

Teaching design

- Lectures + tutorials
- Real-world case studies
- Problem-based learning

Lecture + tutorials: ISO standards

LCA methodology: ISO 14040/14044



GWP of CO_2 = 1
GWP of CH_4 = 34
GWP of N_2O = 265

Carbon footprint: results!

F.U. = 1.000.000 aluminium trays

			CO_2 eq. (kg/f.u.)
Stage 1: Raw material production			
Materials	Amount (kg/1000 trays)	Emissions (kg/kg material)	
Aluminium extraction	10	CO_2 = 9.4; CH_4 = 0.02	100,800
Stage 2: Production			
Energy	Amount (kWh/1000 trays)	Emissions (kg/kWh energy)	
Electricity, UK grid	0.017	CO_2 = 0.7; CH_4 = 0.04; N_2O =0.07	350
Natural gas, burned	0.030	CO_2 = 0.12; CH_4 = 0.003;	6.7
Transport	Amount (tkm/1000 trays)	Emissions (kg/tkm)	
Internal transport	0.1	CO_2 = 0.18; CH_4 = 0.07; N_2O =0.02	786
Stage 3: Distribution (external company)			
Transport	Amount (tkm/1000 trays)	Emissions (kg/tkm)	
External transport	2	CO_2 = 0.16; CH_4 = 0.004; N_2O =0.003	2182
Stage 4: Use: No associated impact , therefore zero GHG emissions			
Stage 5: Waste management			
	Amount (kg/1000 trays)	Emissions (kg/kg waste treated)	
Landfill	10	CO_2 = 0.02; CH_4 = 0.001	540

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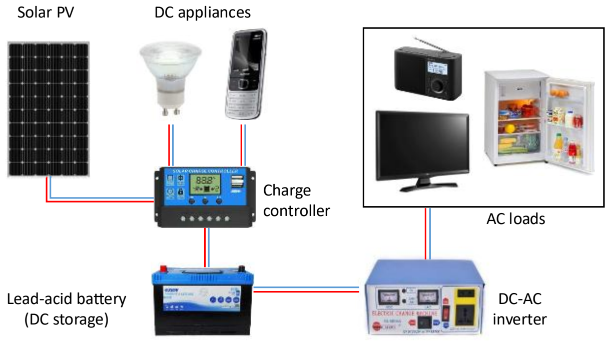
Real-world case studies: Research

Solar Home Systems, a Sustainable Development Tool?

Malawi Government target: 50% of households to own off-grid solar products by 2030

>2.5 million solar home systems



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Sustainability performance of each stage

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Below shows the results for an enhanced geothermal system – **ORC unit, stimulation required**

	Environmental ($g\ CO_2$ /kWh)	Economic (k€)	Social
Exploration	0.03	1,000	Low public acceptance rate (i.e. against exploitation)
Drilling & construction	9.6	31,740 (4.5 years)	Noise; Concerns on seismic risk &health impact; jobs creation
Operation & Maintenance	2.0	41,762.4 (for 30 years operation, including on-call team)	Creating jobs; boost local economy
Dismantling	-0.6*	2,548 (4-5 months)	Unknown

* Benefited from recycling of metals used in construction e.g. steel, aluminium

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Bioenergy in Indonesia: Environmental and Socio-Economic Implications

Dwica Wulandari

Final year PhD researcher

Dwica.wulandari@manchester.ac.uk

Real-world case studies: Industry

Real-world case studies: Cases

Activity 3: What transport option has the **highest** and the **lowest** carbon footprint (passenger-km)? **Why?**

- Plane (intercontinental)
- Plane (Europe)
- Rail (high speed)
- Rail (average)
- Bus (short distances)
- Coach (long distances)
- Tram
- Car (diesel)
- Car (gasoline)

Nexus transport & electricity

What is better **environmentally?**

Electric vehicle

Internal combustion vehicle (diesel/gas)

Other environmental impacts

Impacts (units)	Electric (EV)	Diesel (ICEV)	Gasoline (ICEV)
Terrestrial acidification (g SO_2 eq.)	0.84	0.79	0.89
Particulate matter formation (g PM_{10} e.q)	0.30	0.28	0.29
Terrestrial ecotoxicity (g 1,4-DCB eq.)	0.079	0.075	0.079
Fossil depletion (g oil eq.)	53	80	90
Photochemical oxidant formation (g NMVOC eq.)	0.42	0.68	0.61
Freshwater eutrophication (g P eq.)	0.18	0.052	0.054
Human toxicity (g 1,4-DCB eq.)	220	72	74
Freshwater ecotoxicity (g 1,4-DCB eq.)	3.5	1.5	1.5
Metal depletion (g Fe eq.)	56	30	30

Hawkins et al. (2013). Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles

Teaching design

- Lectures + tutorials
- Real-world case studies
- $\boxed{\text{Problem-based learning}}$

Problem solving: Coursework (previous)

- Theory (1 hour)
- Industrial perspective (1 hour)
- Overview CCaLC (Carbon Calculations over the Life Cycle of Industrial Activities)

Problem solving: Coursework (Day 1)

Carbon footprint production of a plastic water bottle with CCaLC

Preparation group presentation: results, improvements and potential problems

Problem solving: Coursework (Day 2)

- Deliver presentation:
  - results accuracy
  - novelty & feasibility of the ideas
  - environmental, economic & social aspects
  - timekeeping
  - fair participation by all group members

Problem solving: Coursework (Day 2)

Team A: light-weighting scenario & a bio-based material scenario

Team B: light-weighting scenario & a bio-based material scenario

Problem solving: Coursework (Day 3)

- Presentation: results, both scenarios, justification of favoured option & mitigation

- Team A & B debate the four scenarios & should agree on one final sustainable solution

Problem solving: Coursework (skills)

- Critical & systems thinking
- Communication (presentations & debate)
- Teamwork & social skills

LCA guide UG & MSc dissertation

- LCA concept
- Designed step-by-step use of CCalC
- Video

Step 4: Define transport between life cycle stages.

Transport links must be defined wherever materials or waste move between life cycle stages. Before doing this, make sure your **Production**, **Storage** and **Use** stages have been set up with their outputs defined. This keeps the mass balance consistent across the system.

To define transport, click the relevant "Transport" box - either at the Top level or within a specific production stage - to open the transport window (Figure 7). Select "Define Transport" and complete the form: choose the material or waste to be transported, select the ecoinvent database, specify the transport type, and enter the distance and quantity.

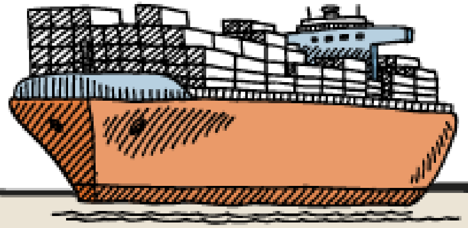
The default packing density value of one can remain unchanged, but it is worth calculating a realistic value where possible, as low-density products can have a significant effect on results. Use the data from Table 3. Click "Update" to confirm each entry.

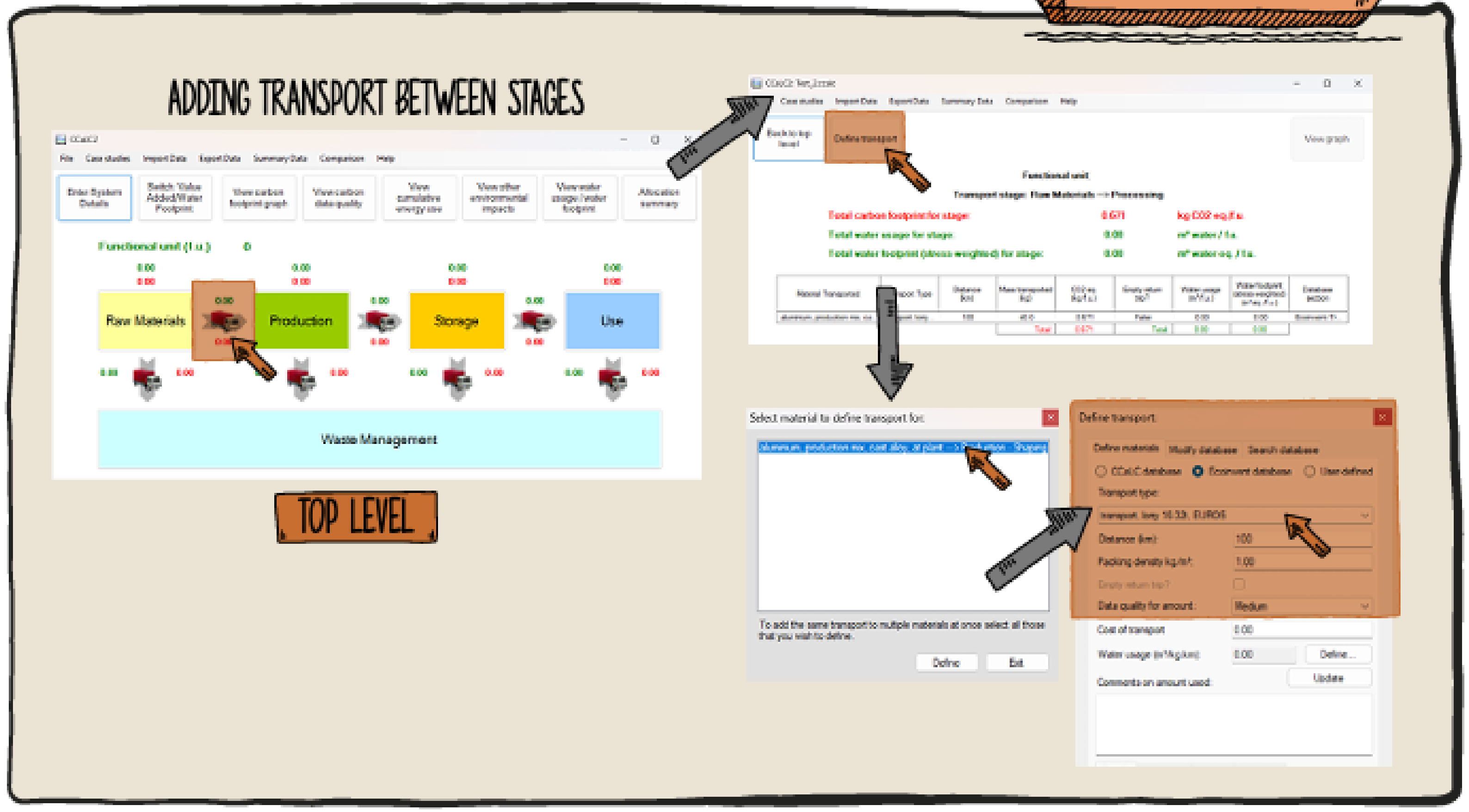
Step 5: Repeat for all transport flows.

Repeat the process above for every transport flow in the system. Note that transport defined within a production stage does not appear in the Top Level view, as this only shows movements between life cycle stages, but it is fully included in the results and reflected in the carbon footprint graphs.

Figure 7. Adding transport links in CCaLC2.

After defining the Production, Storage, and Use stages, click the "Transport" box, select "Define Transport", choose the material or waste, assign the database and transport type, and enter the distance and quantity. Click "Update" to confirm.





Conclusions

- LCA not only a tool, but a way of thinking
- Integration, practical application & connection to real-world challenges
- Combined with other skills

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Many thanks for your attention!