DTU Management Engineering
Quantitative Sustainability Assessment

Toward a parsimonious life cycle based Alternatives Assessment (LCAA)

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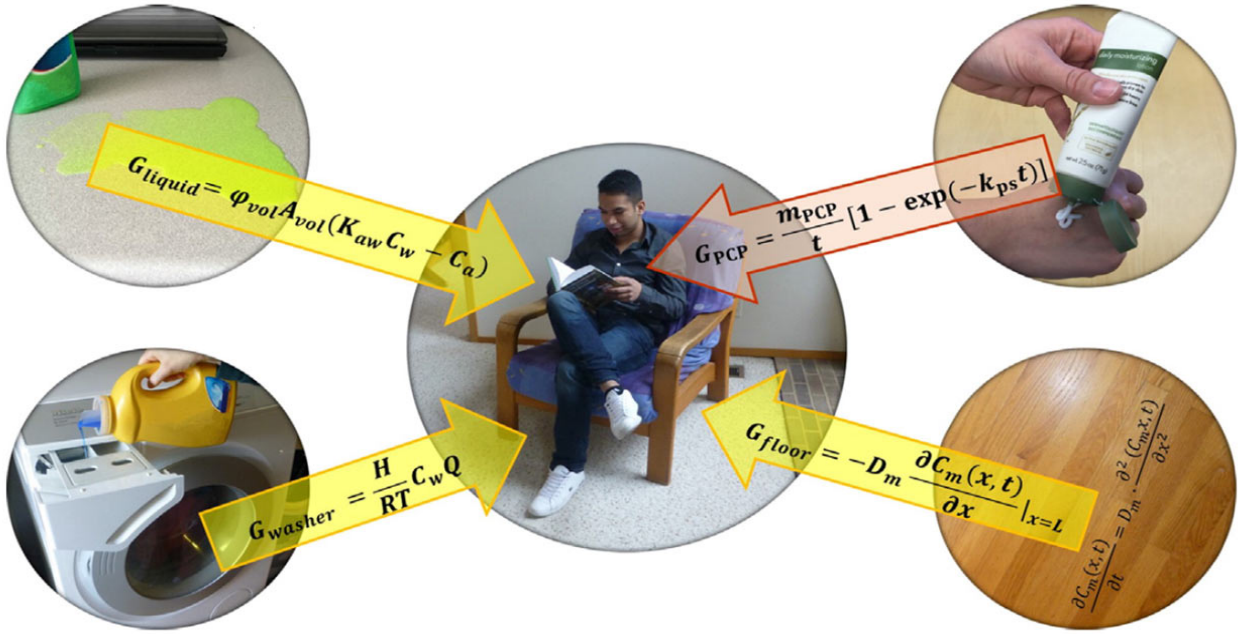
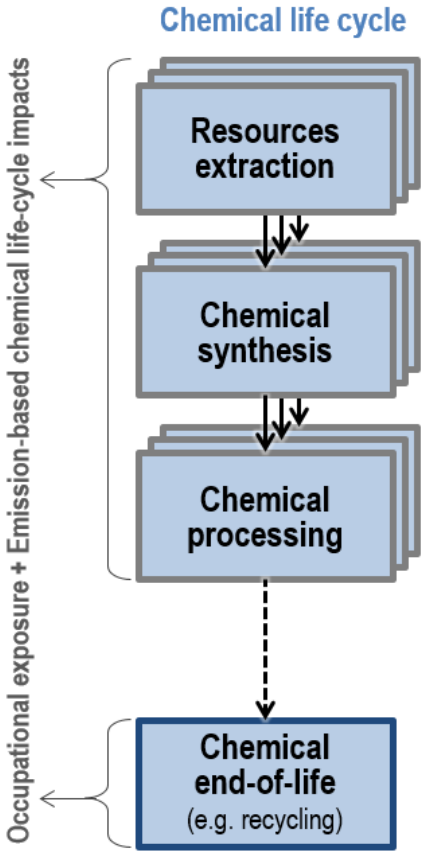


About life cycles



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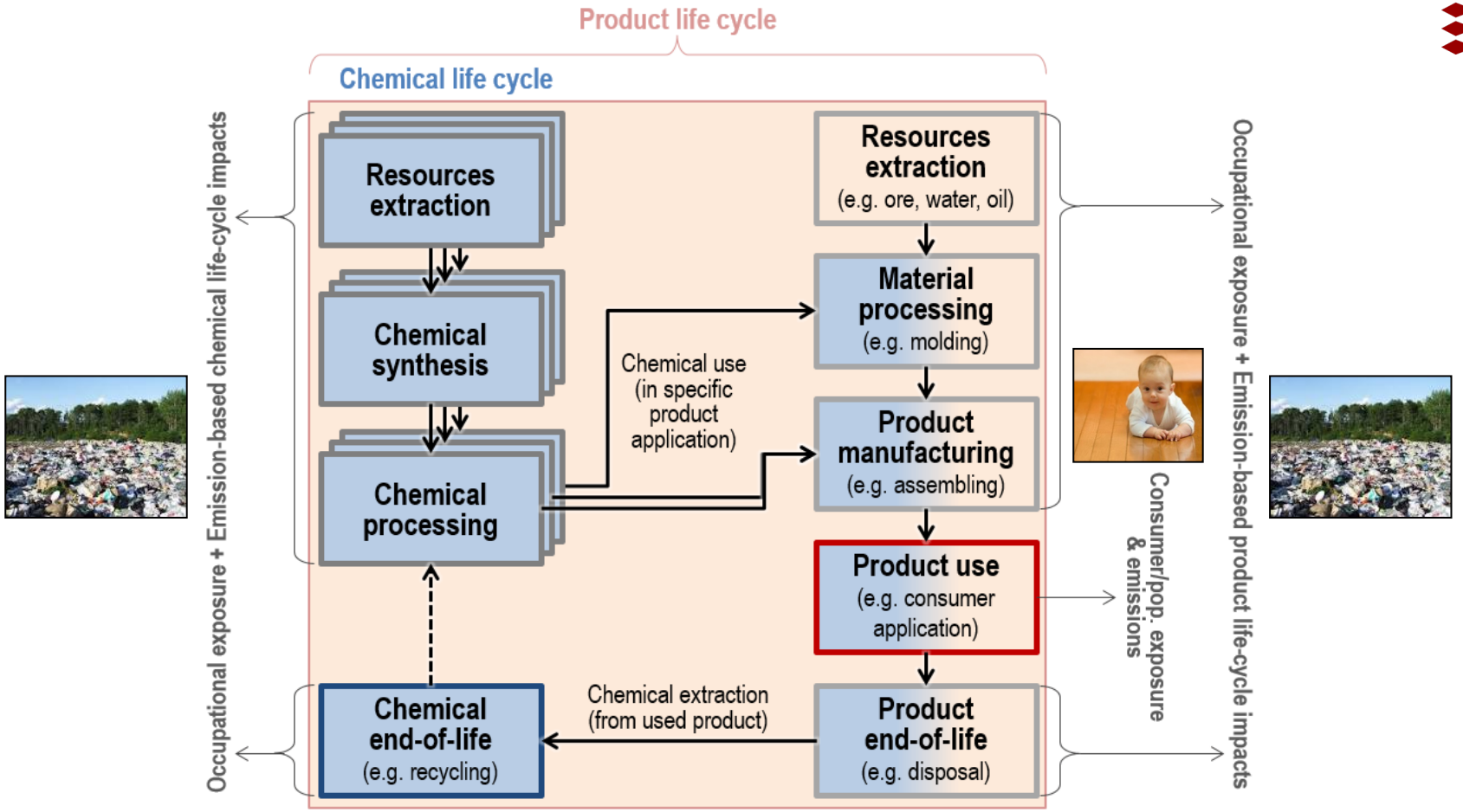
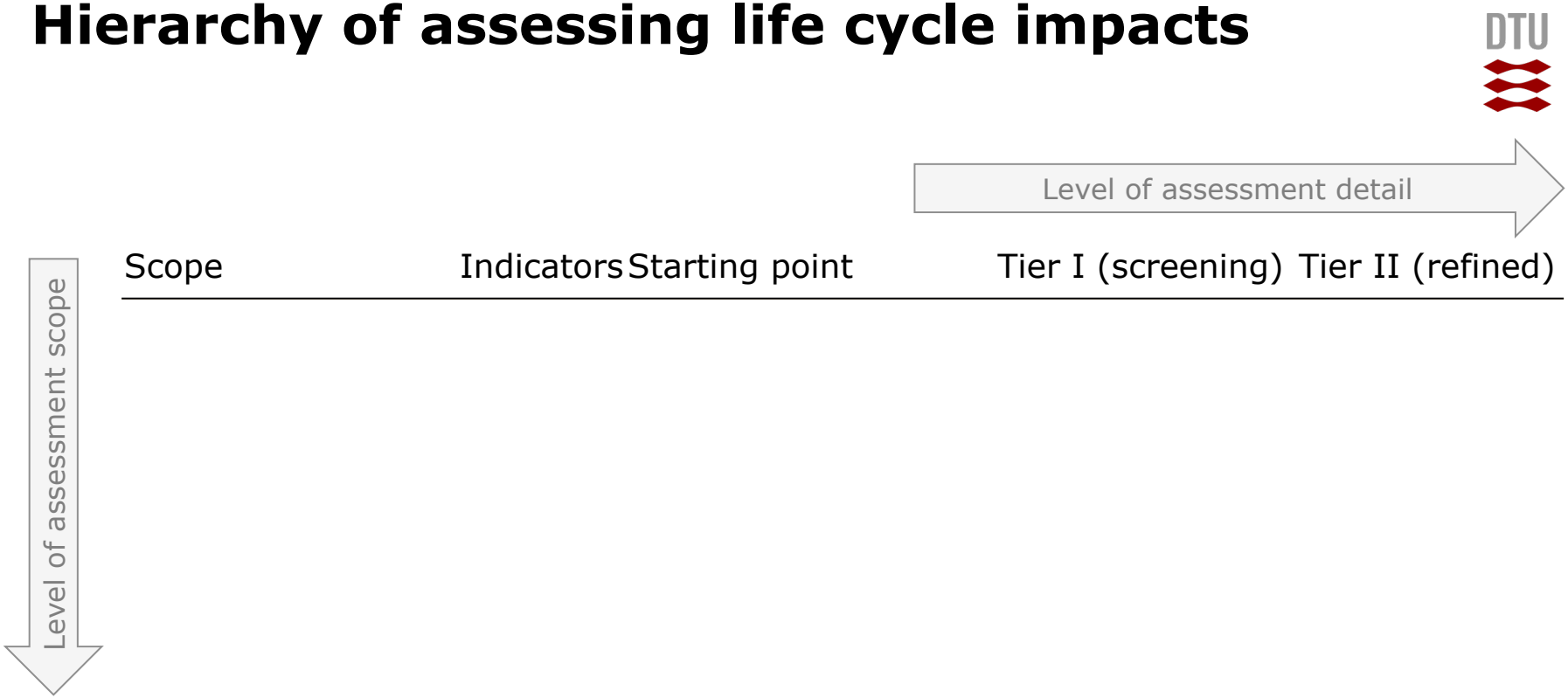


Hierarchy of assessing life cycle impacts

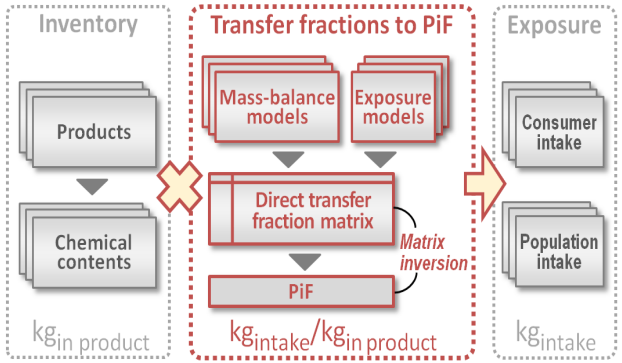


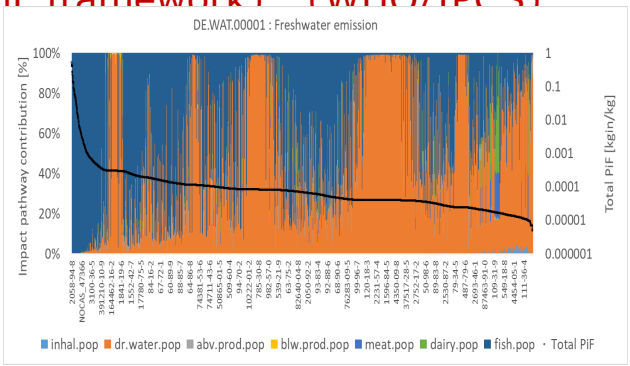
Level 1: Chemical substitution stage

Level of assessment detail

Level of assessment scope

Scope	Indicators	Starting point	Tier I (screening)	Tier II (refined)
Substitution routes/effects **stage**	User toxicity, ecotoxicity	Chemical mass in product	Exposure/hazard (PiF framework)	Main (WHO/IPCS)



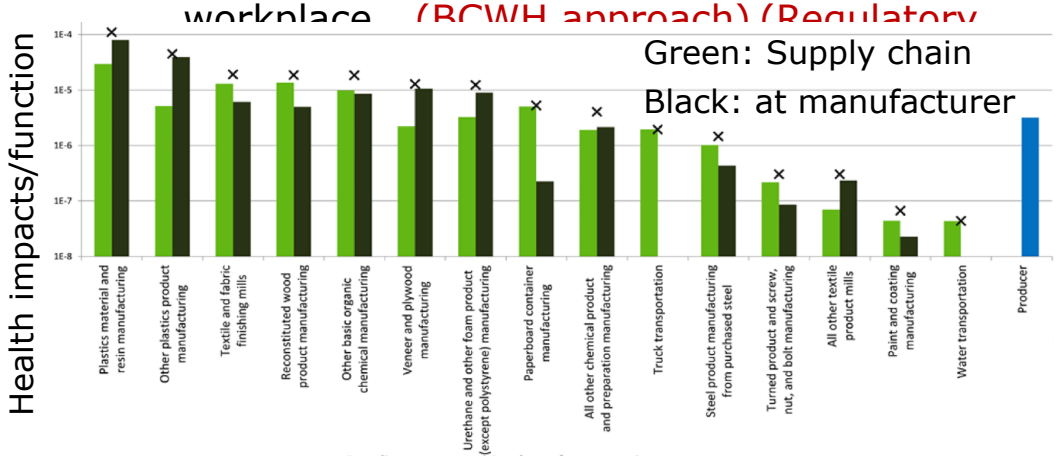


Level 2: Chemical supply chain

Level of assessment detail

Level of assessment scope

Scope	Indicators	Starting point	Tier I (screening)	Tier II (refined)
Substitution routes/effects **stage**	User toxicity, ecotoxicity	Chemical mass in product	Exposure/hazard (PiF framework)	Main (WHO/IPCS)
Chemical supply chain	Occupational toxicity	Chemical at workplace	Worker hours	Quantitative risk (BCWH approach) (Regulatory tools)

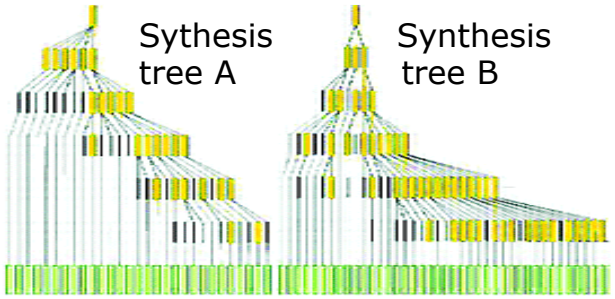


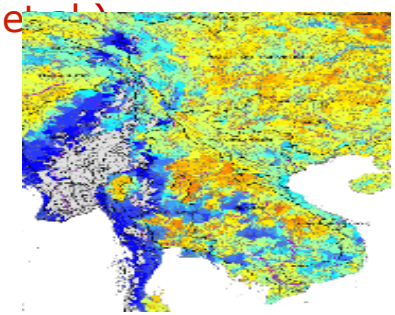
Level 3: Chemical life cycle (excl. use)

Level of assessment detail

Level of assessment scope

Scope	Indicators	Starting point	Tier I (screening)	Tier II (refined)
Substitution	User toxicity,	Chemical mass	Exposure/hazard	Main
routes/effects				
stage	ecotoxicity	in product	(PiF framework)	(WHO/IPCS)
Chemical	Occupational	Chemical at	Worker hours	
	Quantitative risk			
supply chain	toxicity	workplace	(BCWH approach)	(Regulatory
tools)				
Chemical	(Eco)toxicity,	Env. emissions,	Far-field screening	
	Spatial modeling			
life cycle	energy, water	res		
	(Pan			





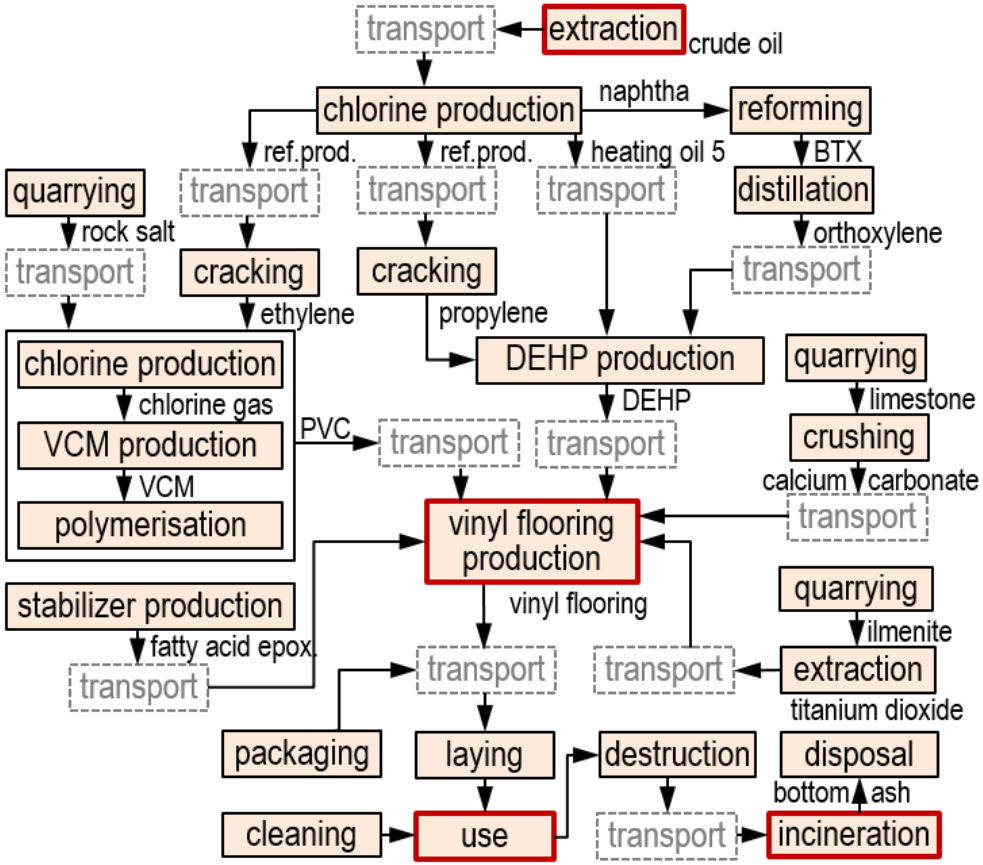
Level 4: Full product application life cycle

Level of assessment detail

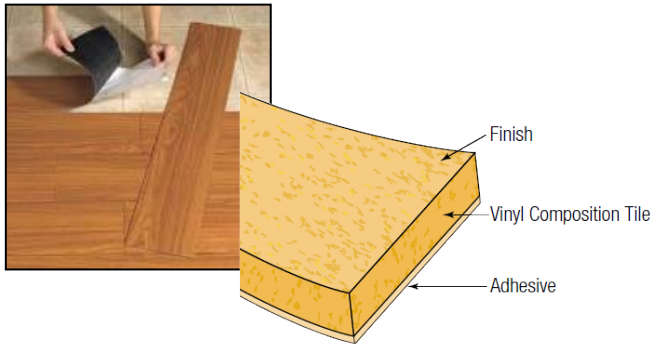
Level of assessment scope

Scope	Indicators	Starting point	Tier I (screening)	Tier II (refined)
Substitution	User toxicity,	Chemical mass	Exposure/hazard	Main
routes/effects				
stage	ecotoxicity	in product	(PiF framework)	(WHO/IPCS)
Chemical	Occupational	Chemical at	Worker hours	
	Quantitative risk			
supply chain	toxicity	workplace	(BCWH approach)	(Regulatory
Chemical	(Eco)toxicity,	Env. emissions,	Far-field screening	
tools)	Spatial modeling			
life cycle	energy, water	resources use	(EGIP, USEtox et al.)	
	(Pangea)			
Product life	Climate, health,	Env. emissions,	Far-field screening	
	Full LCA			
cycle	ecosyst., res.	resources use	(ecoinvent, GLAM)	
	(own			

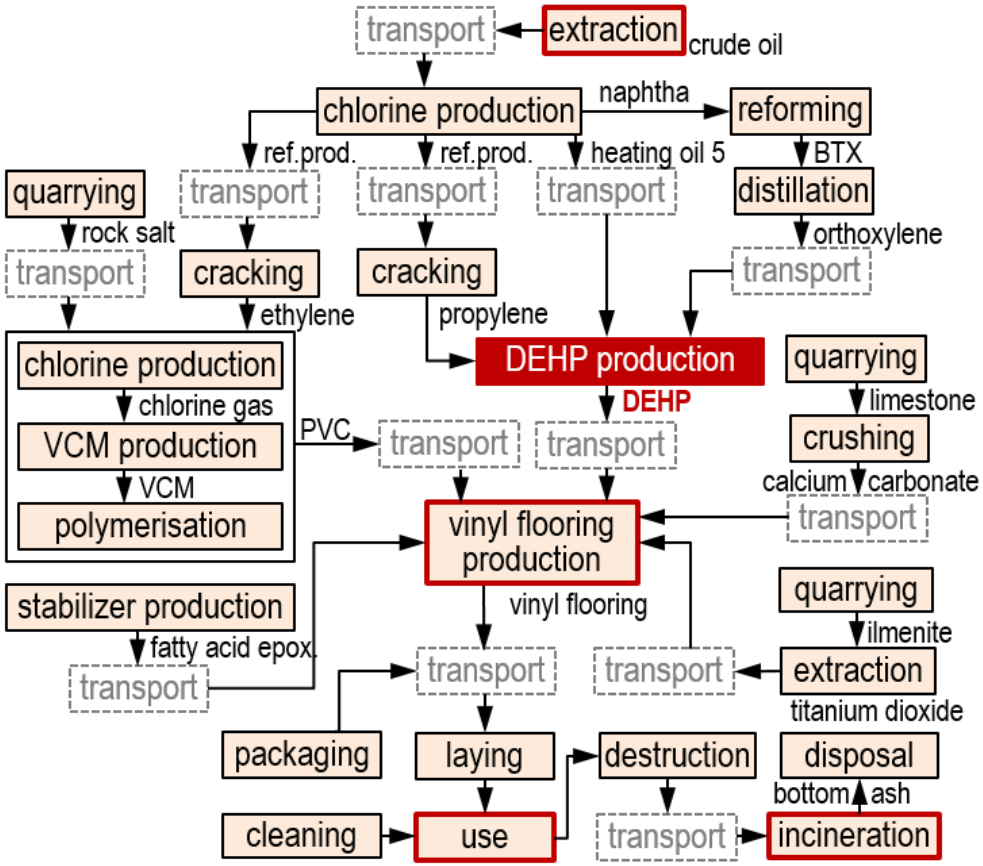
Getting real: Life cycle of flooring incl. DEHP



[Jönsson et al. 1997 Build Environ 32: 245-255]



Level 1: Substitution stage & chemical function



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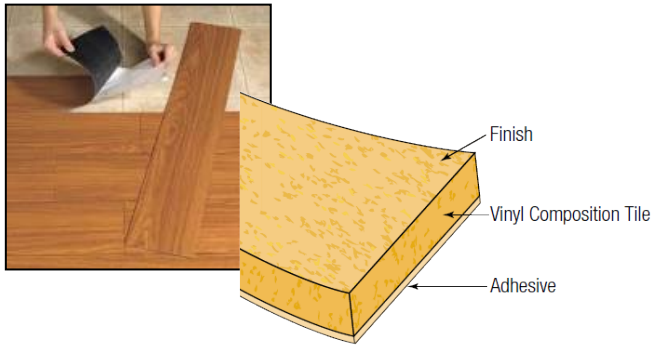
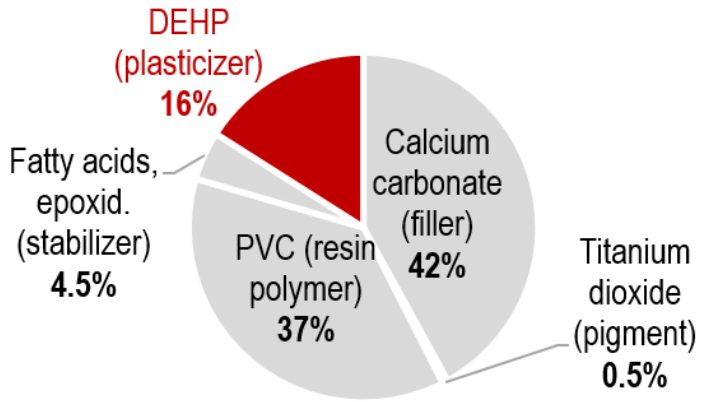
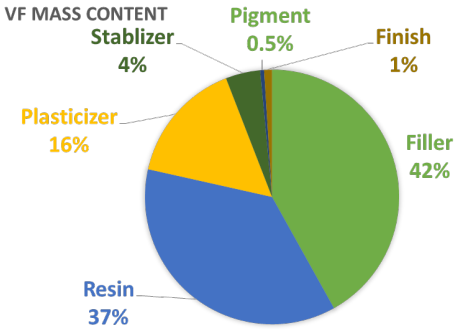
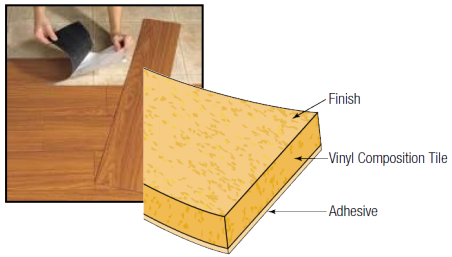




Levels 2-4: Chemical and product impacts



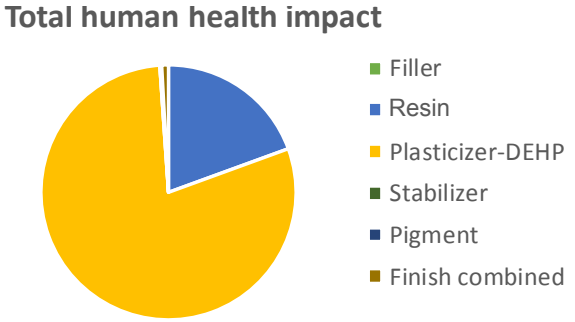


Looking at single alternative:

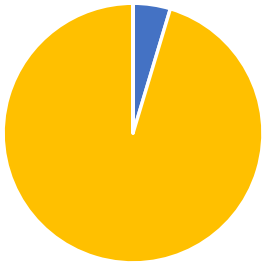
DIHP vs DEHP : –21% human health

–59% ecotoxicity

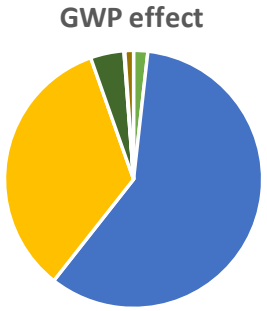
–3.7% global warming



Cradle to gate toxicity: 0.4%
Cradle to gate $PM_{2.5}$: 3.6%
Use phase consumer tox: 96.0%

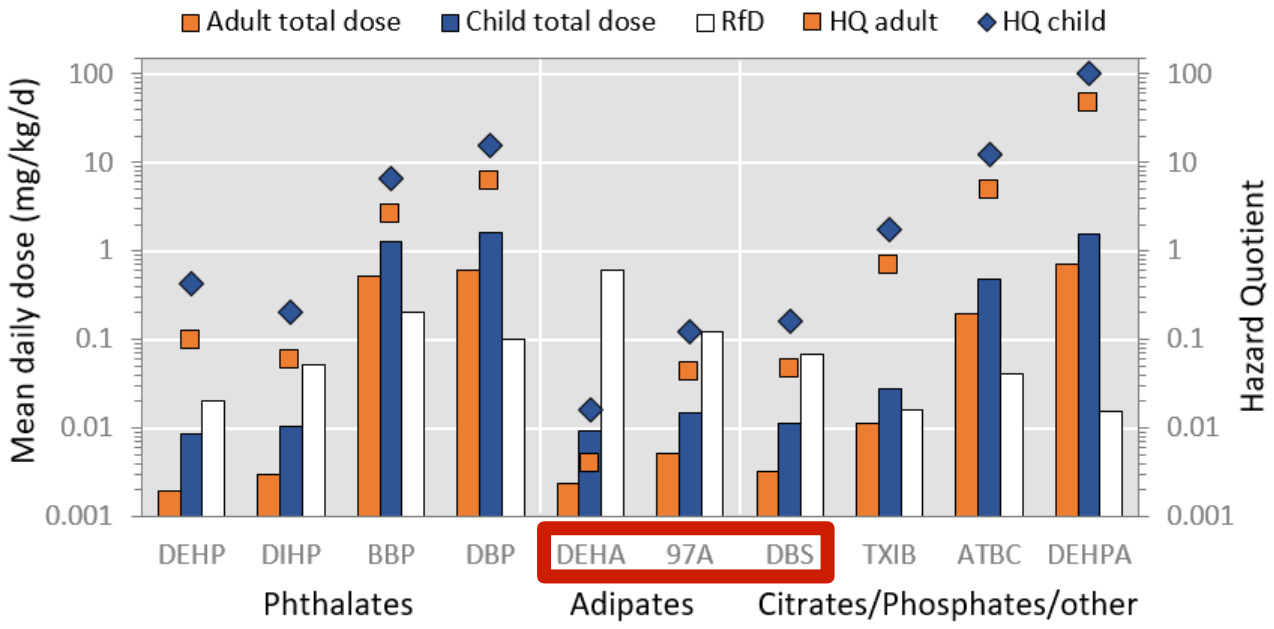


Cradle to gate: 16%
Use & disposal phase: 84%

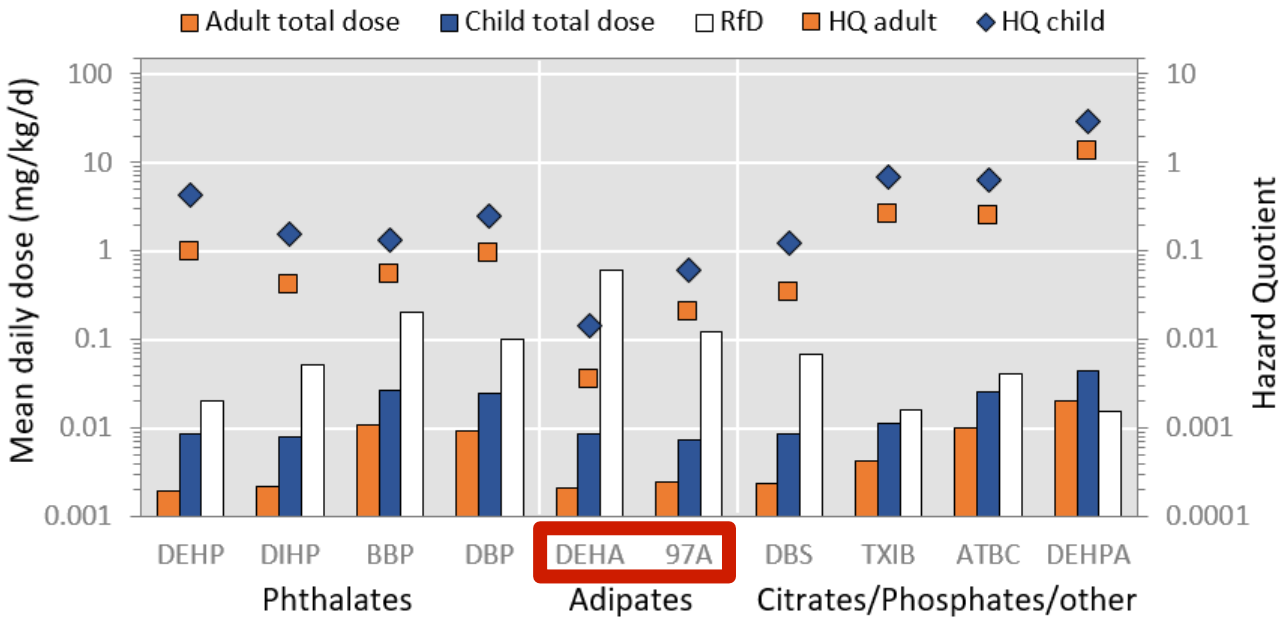


Cradle to gate: 100%

Looking at multiple alternatives (first 50 days)



Looking at multiple alternatives (15 years use)



→ Toxicity information alone not sufficient

→ Different exposure pathways matter (dermal gaseous inhalation, dust ingestion)

→ Measured material-air partitioning coefficient for phthalate alternatives in addition to toxicity data

Take-Home Messages

1) Hazard, exposure and life cycle impacts can be consistently aligned

→ Quantitative high-throughput methods are becoming available

→ Assumptions can be aligned and models harmonized

2) Define substitution based on chemical function

→ Relevance of production application (e.g. phthalate: plasticizers & solvents)

→ Chemical contribution to product mass defines assessment focus

3) Two refinement tiers to inform about environmentally viable alternatives

→ **Tier 1**: cover all (!) chemicals (e.g. QSARs for 800K chemicals) – data gaps are no excuse!

→ **Tier 2**: data hierarchies and increasing level of spatialization

THANK YOU!

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