Environmental and economic assessment of demountable composite beams

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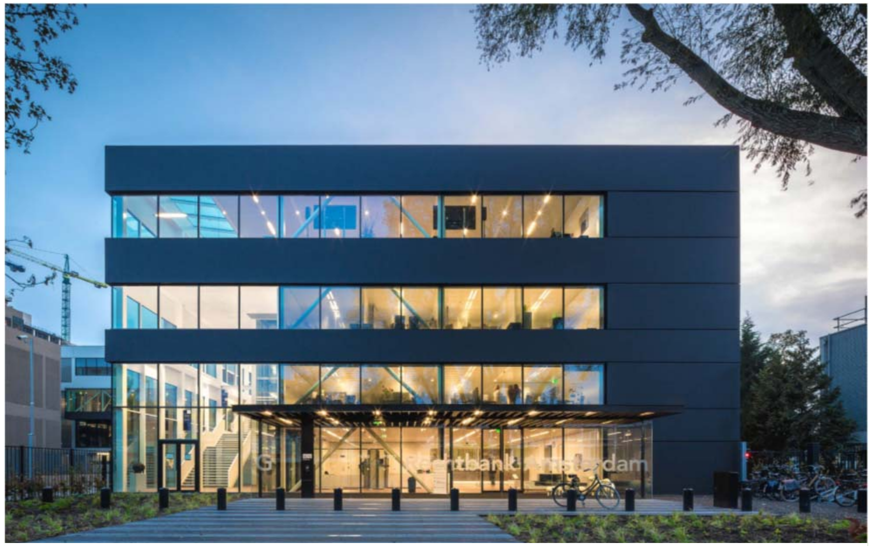
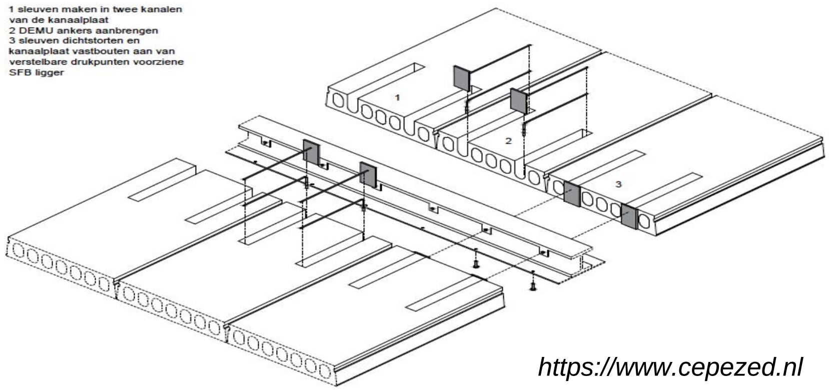
- Sustainability Bouwen met Staal
- Managing director MRPI (EPD's)

Objective WP

- Compare different structural forms
  - o weight of materials per m^2 floor area
- Assess environmental impact
  - o different structural forms
  - o reusing composite steel structures
  - o design for deconstruction and reuse of composite steel structures
- Assess cost
  - o design for deconstruction and reuse of composite steel structures

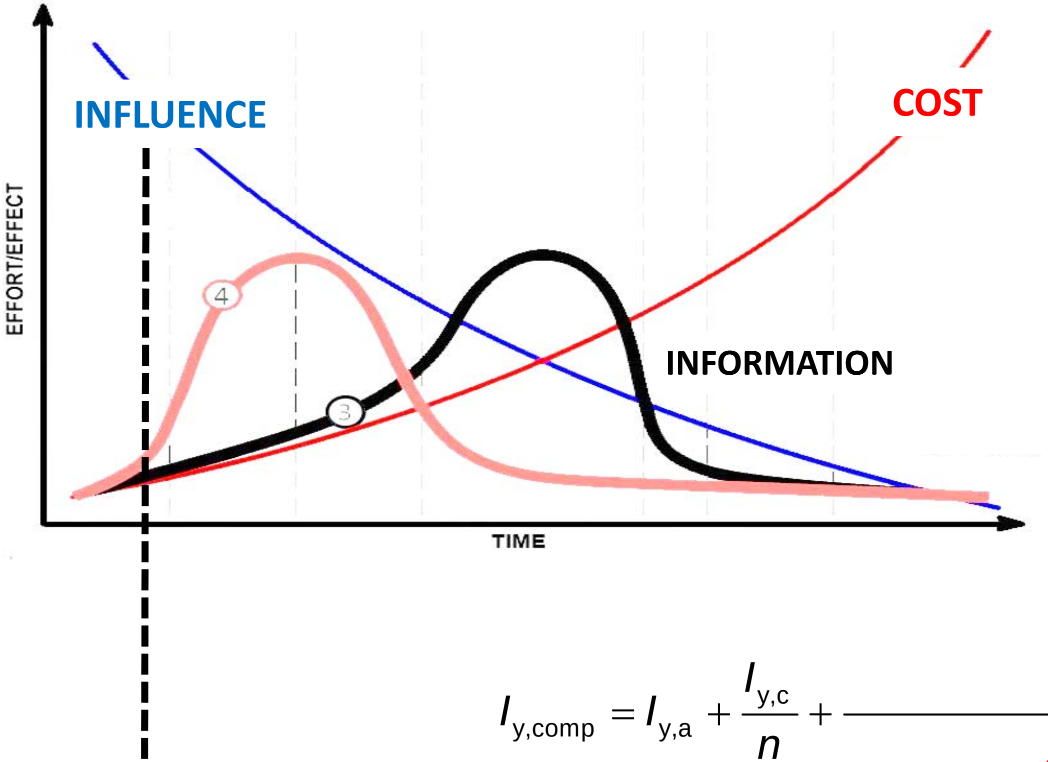
For typical mid-rise office buildings.





https://www.cepezed.nl

Demonstrate REDUCE knowledge to designers



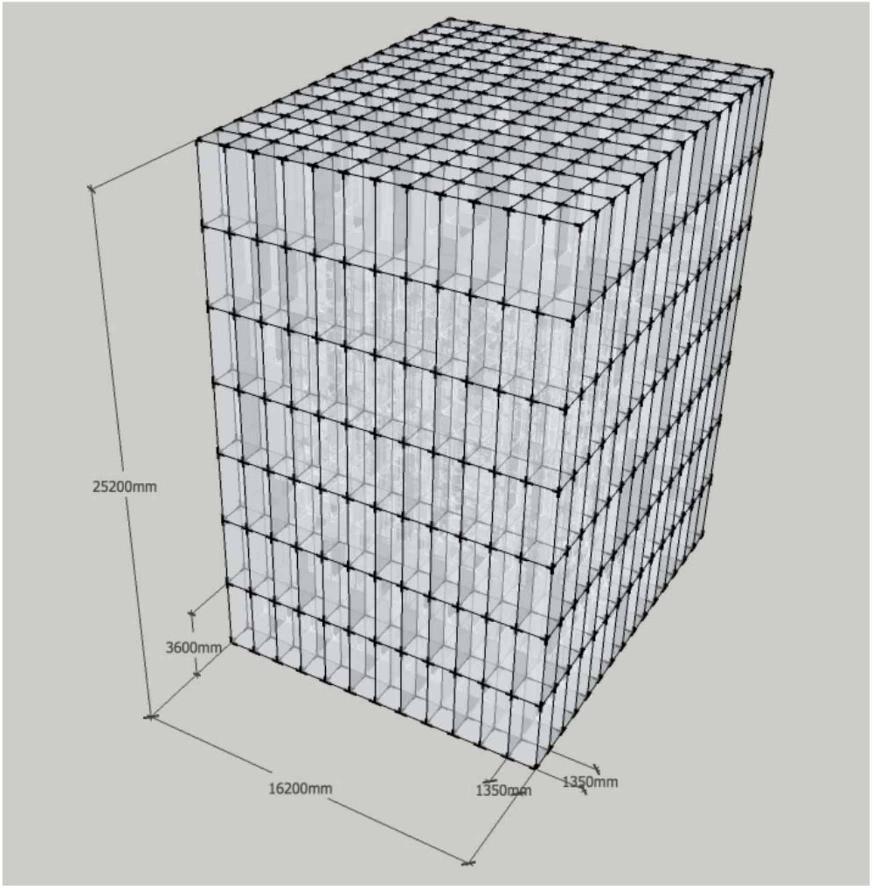
Information ideally available for the designer is unfortunately only available later ….

$$I_{y,comp} = I_{y,a} + \frac{I_{y,c}}{n} + \frac{b_{eff} h_c A_a}{n A_a + b_{eff} h_c \left[1 + \left(\frac{\pi}{L} \right)^2 \frac{E_a s_{sc,eq}}{k_{sc}} A_a \right]} \left(h_p + 0.5 h_c + y_s \right)^2$$

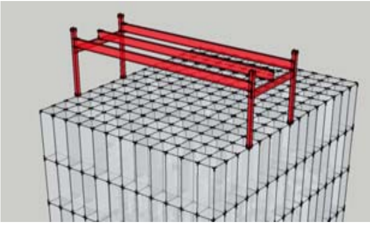
Office building (REDUCE)

- Assessment based on slice through the building
- Results normalised to 1 m^2 floor area

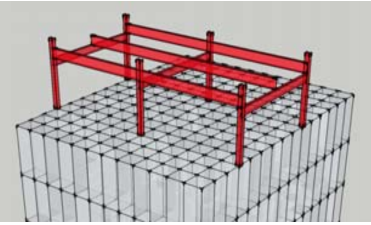
Reference building	
Lifespan	50 years
Width	16,2m
Grid	1,35m x 1,35m
Storey height	3,6m
Number of storeys	7



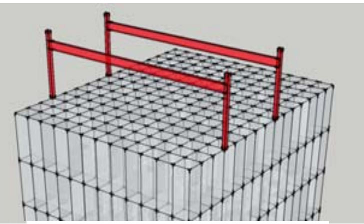
Structural forms & Material properties



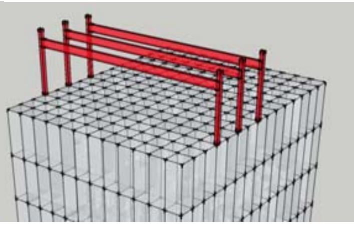
system 1A/7A: 16,2x5,4



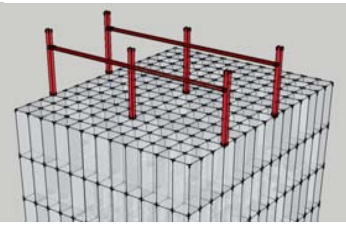
system 1B/7B: 8,1x8,1



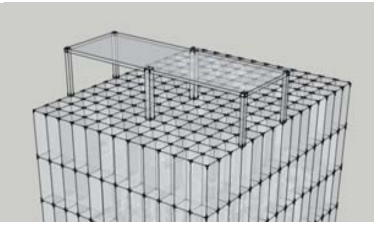
system 2/4: 16,2x6,75



system 3: 16,2x2,7



system 5: 8,1x6,75



system 6: 8,1x5,4

Structural forms	
1a	Long-span composite decking
1b	Short-span composite decking
2	Hollow core, composite
3	Composite decking, non composite
4	Hollow core, non-composite
5	**Slimfloor, non-composite hollow core**
6	In-situ concrete
7a	Long-span **demountable** composite decking
7b	Short-span **demountable** composite decking

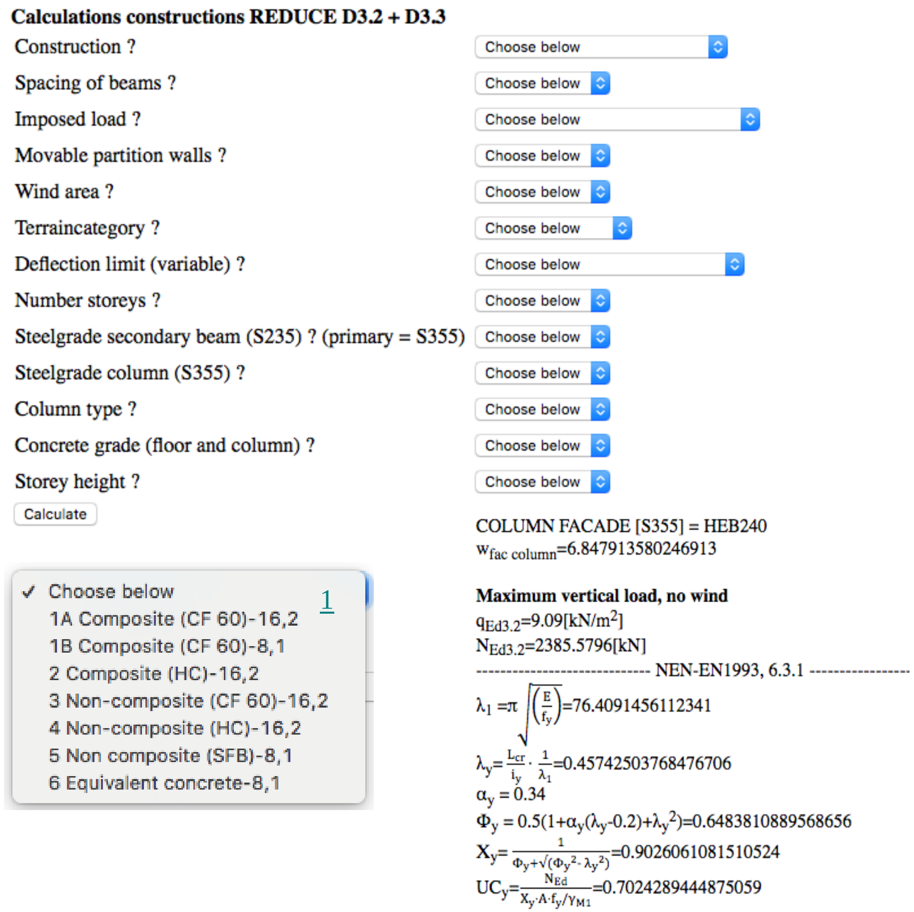
Material	Element	Material specification
Steel grade	Column	S355
	Beam (primary)	S235
	Beam (secondary)	S355
	Decking	S390
Concrete grade	Composite decking	C30/37 (on site)
	column (on-site)	C30/37
	deck (on-site)	
Reinforcement	Bars & nets	B500
Fire protection	Column	25mm calcium silicate boards =
		3,6m x 0,025 x (4x0,3) x 850 kg/m^3 = 92kg/column
	Beam (primary/secondary)	1,5mm intumescent paint =
		0,8m^2/m^2 floor area = 1,2 kg /m^2 floor area

Loading & design

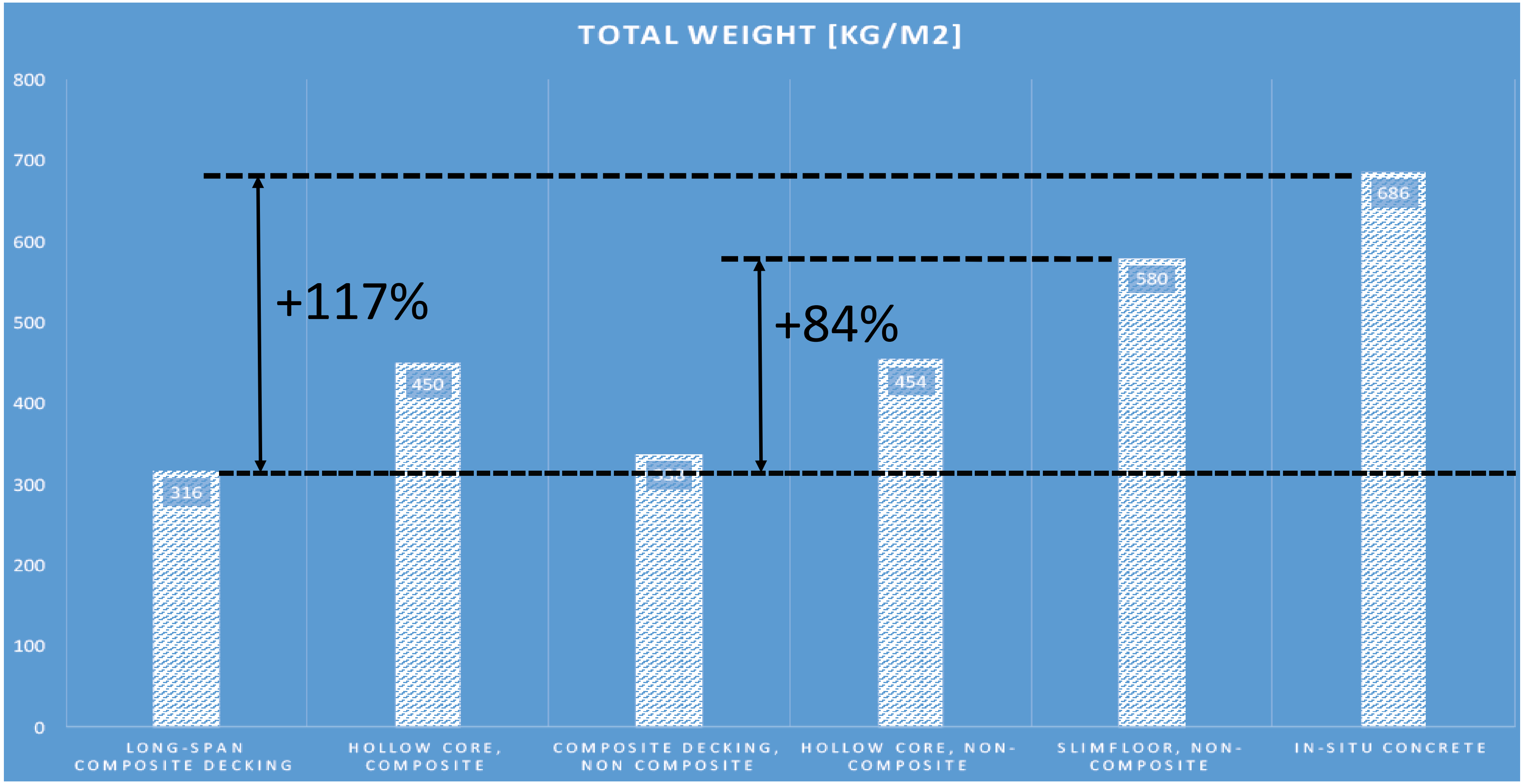
Loadings

Imposed loading	2,5 kN/m^2
Partition walls	1 kN/m^2
Snow	0,56 kN/m^2
Windload	Dutch NA
Deflection limit (total load)	1/250L_{rep} (floor span)

- No rules of thumb
- Design to relevant Eurocode (0-4) and Dutch NA



Weight comparison – frame and floor



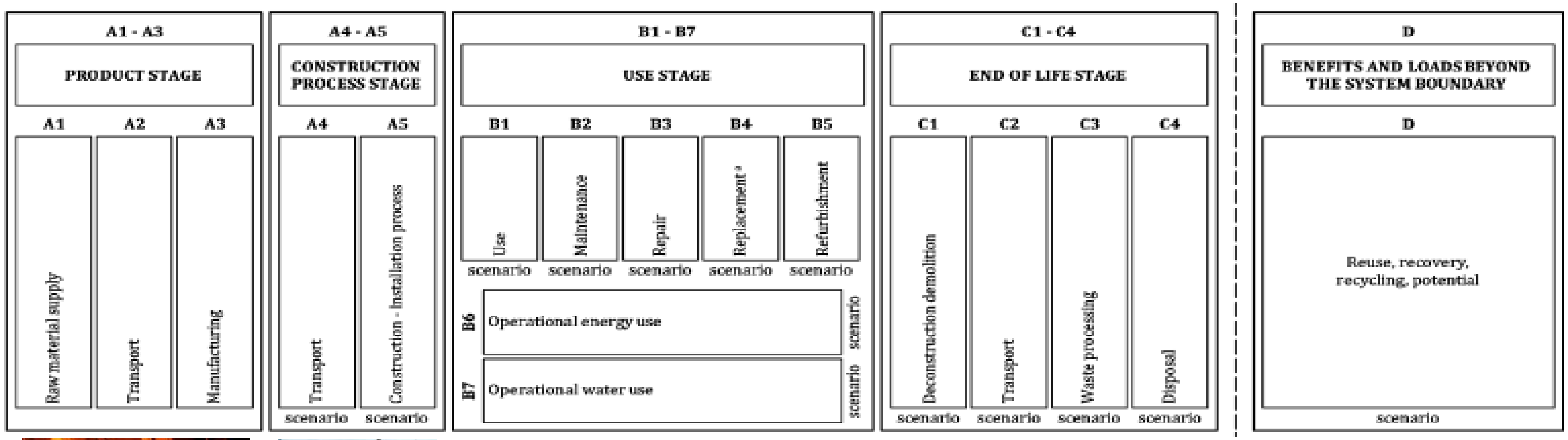
Scope of environmental assessment

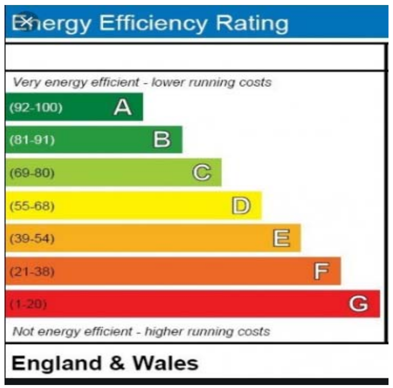
- Frame and floors

- Structural materials:
  - o Structural steel
  - o In-situ concrete
  - o Precast concrete
  - o Steel decking
  - o Mesh and rebar
  - o Screed
  - o Intumescent coating
  - o Fire protection boards

- Global warming potential only (carbon footprint)
- GWP data
  - o Published EPD
  - o Information held by SCI
- Modular approach according to EN 15804

CEN/TC350 Modular approach





Modules included and sources impacts

- A1-A3 included for all materials
- A4 included: transport impacts (average UK)
- A5 excluded – insufficiently detailed information available
- B excluded – in-use impacts not relevant to scope of assessment
- C included: impacts*

Module D:

- Other materials than steel: impacts*
- For steel based on methodology (presentation Michael)

$$\sum_i (M_{MRout|i} - M_{MRin|i}) \cdot \left(E_{MRafterEoWout|i} - E_{VMSubout|i} \cdot \frac{Q_{R\,out}}{Q_{Sub}}\Big|_i\right)$$

** Based on PE International (now Thinkstep) study, see steelconstruction.info*

Two reuse scenarios

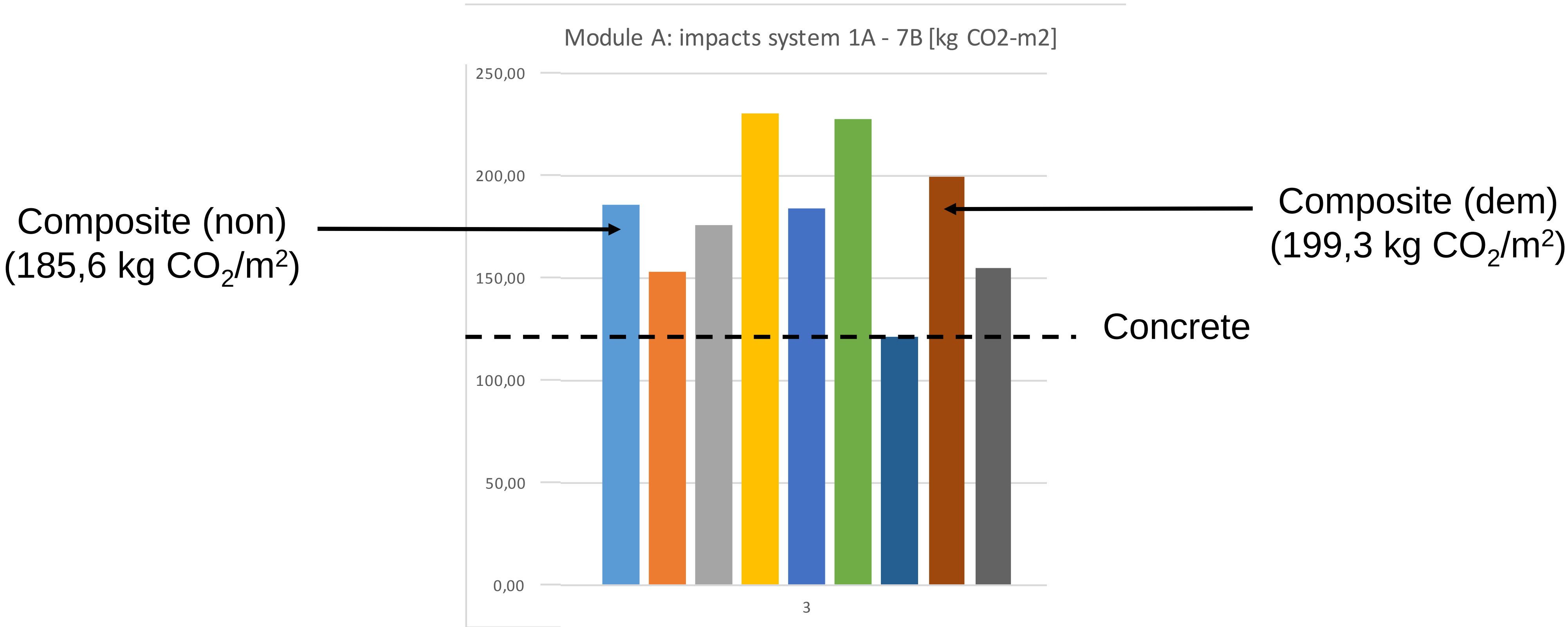
Reuse today

Future reuse

Reflected in Module A1-A3

Reflected in Module D

Reuse today (Module A)

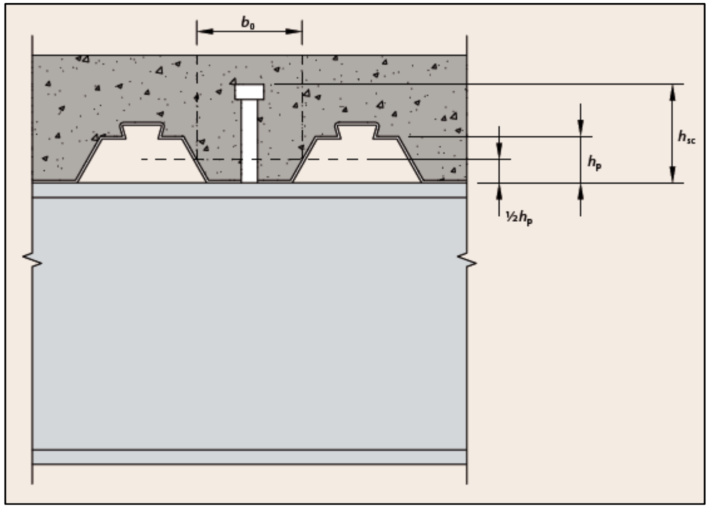


Steel: Average mix (UK)

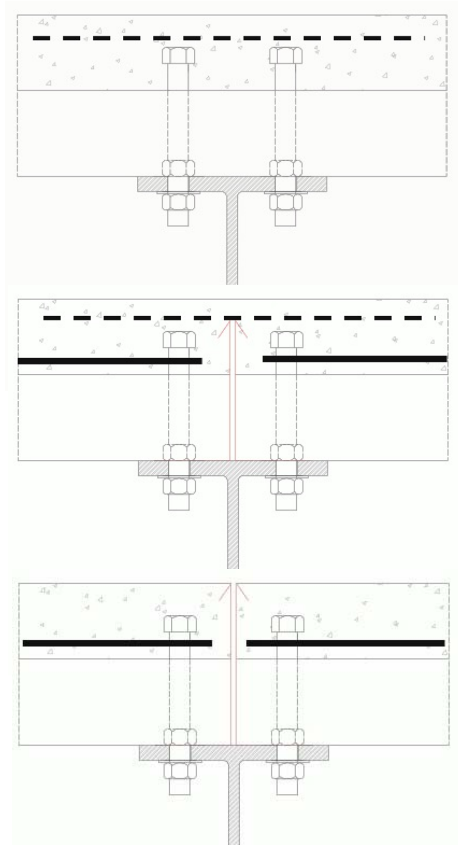
Future reuse: demountable systems REDUCE in detail

Demountable composite system (REDUCE)

Conventional composite system



Through-deck welded shear studs (WS)
Non-demountable



Continuous

Partial depth edge trim
Pre-defined cut-lines

Full depth edge trim

End-of-life scenarios (Module D)

- Scenario E1 - 95% recycling of structural steel – reflecting current practice
  - Crushing of floor slab
  - Recycling of decking and rebar

- Scenario E2 – 90% reuse of structural steel; 10% recycled
  - Crushing of floor slab
  - Recycling of decking and rebar

- Scenario E3 – 90% reuse of structural steel; 10% recycled
  - 90% of floor slabs recovered and reused

Future reuse (Module D)

EN15804 Module	A [kg CO_2/m^2]	C [kg CO_2/m^2]	D [kg CO_2/m^2]			A+C+D [kg CO_2/m^2]		
Structural form			E1	E2	E3	E1	E2	E3
1A Long-span composite decking	185,6	5,35	-62,3			128,6		
7A Long-span **demountable** composite decking	199,3	5,75	-67,5	-96,6	-134,0	137,6	108,7	71,7
6 In-situ concrete	121,5	4,38	-14,2			111,7		

Conclusions:

1- Concrete has lowest impact Module A (average Mix)

2- Module C (End-of-Life) impacts are small

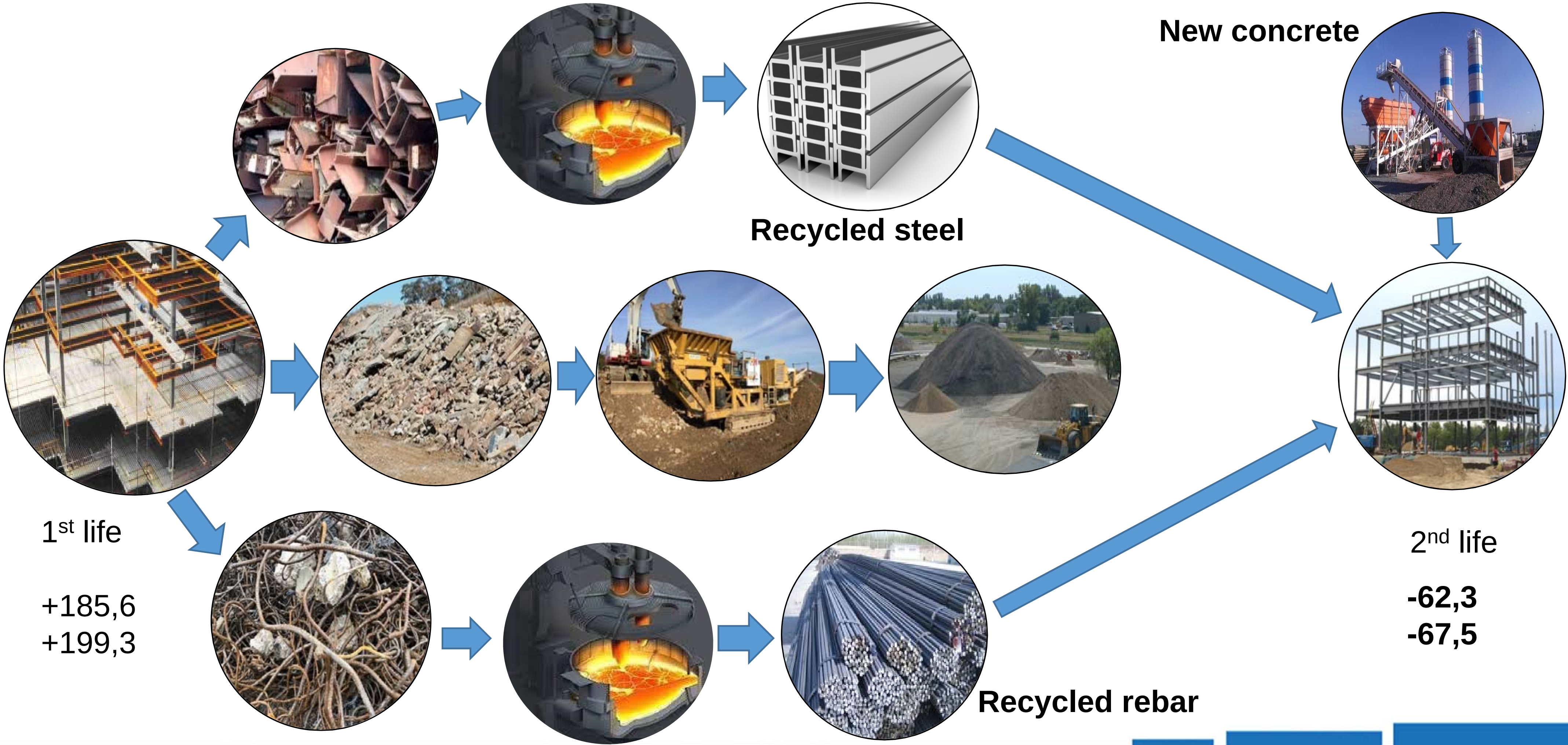
3- 7A has slightly greater Module A impact (larger section + edge trims)

4- Module D benefits for steel in E1 (recycling) larger than for concrete

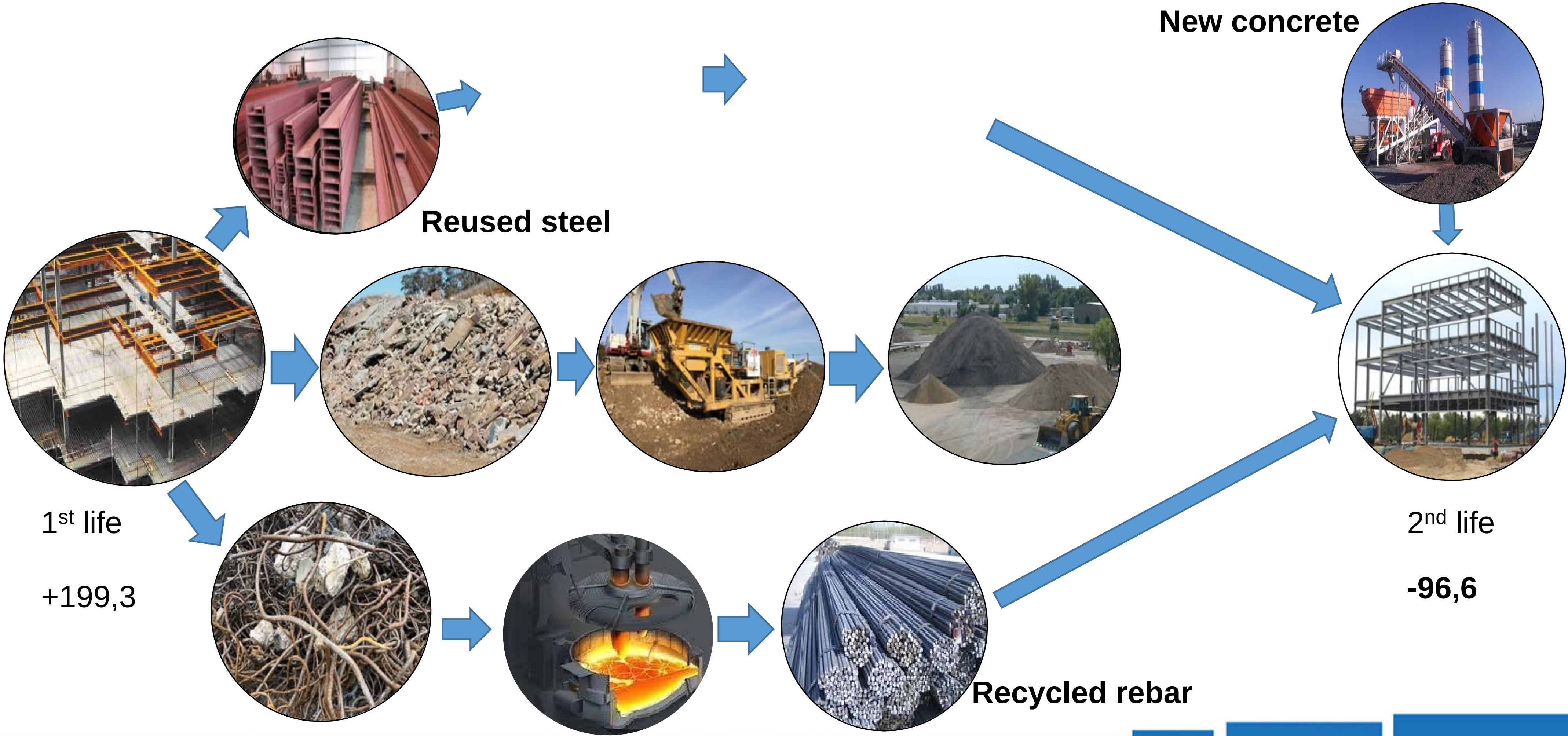
5- Scenarios E2 and E3 show additional benefits for reusing steel and reusing steel and floor slab

6- Aggregating shows concrete has lowest impact under scenario E1 but the demountable options have lower impacts under E2 and significantly lower under E3

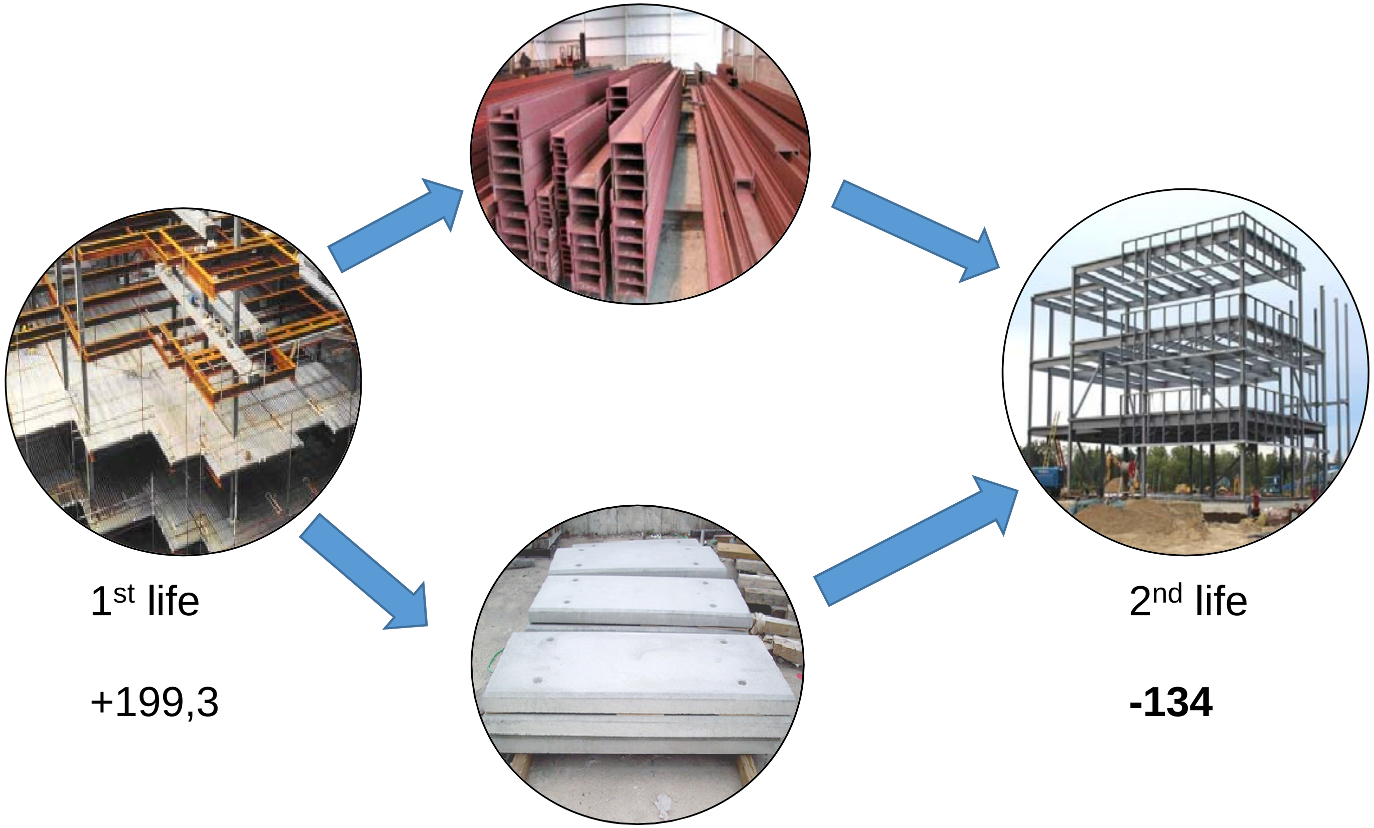
Current 95% recycling scenario (E1)



Reuse only steelwork (E2)



The Holy Grail of REDUCE



<u>Module D</u>

-67,5 (100% = E1)
-96,6 (+43% = E2)
-134 (+99% = E3)

Reuse the steelwork and the concrete slabs !

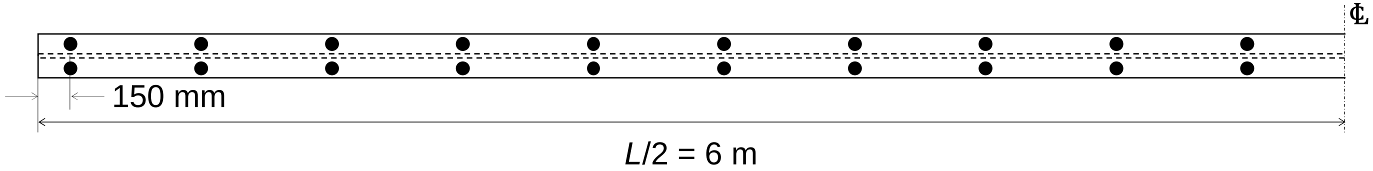
Relative costs of demountable shear connectors*

	Costs	
Steelwork	2000	€/t
Decking	40	€/m^2
Fire protection	25	€/m^2
Concrete	25	€/m^2
A193 mesh	10	€/m^2
A393 mesh	20	€/m^2
Welded shear studs (WS)	3	€/p
Demountable shear connectors (DSC)	8	€/p

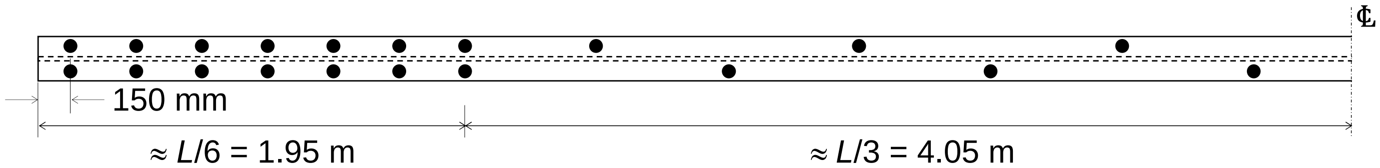
€ Demountable shear connector ~ 2,7€ Welded shear connector

*M. Lawson: REDUCE D3.2 & A. Girao-Coelho: REDUCE D7.2

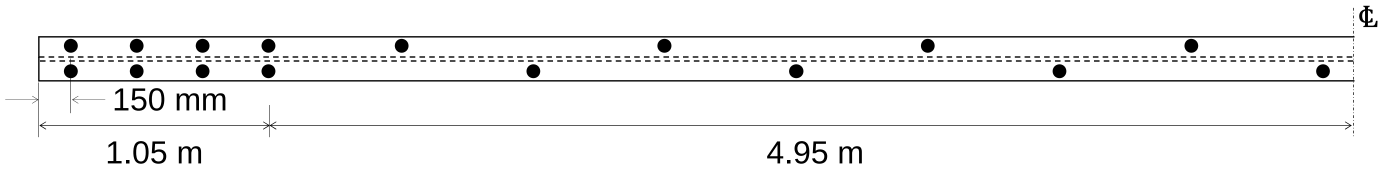
Reduce demountable shear connectors*



Arr1 WS/DSC: Uniform distribution (40 connectors)



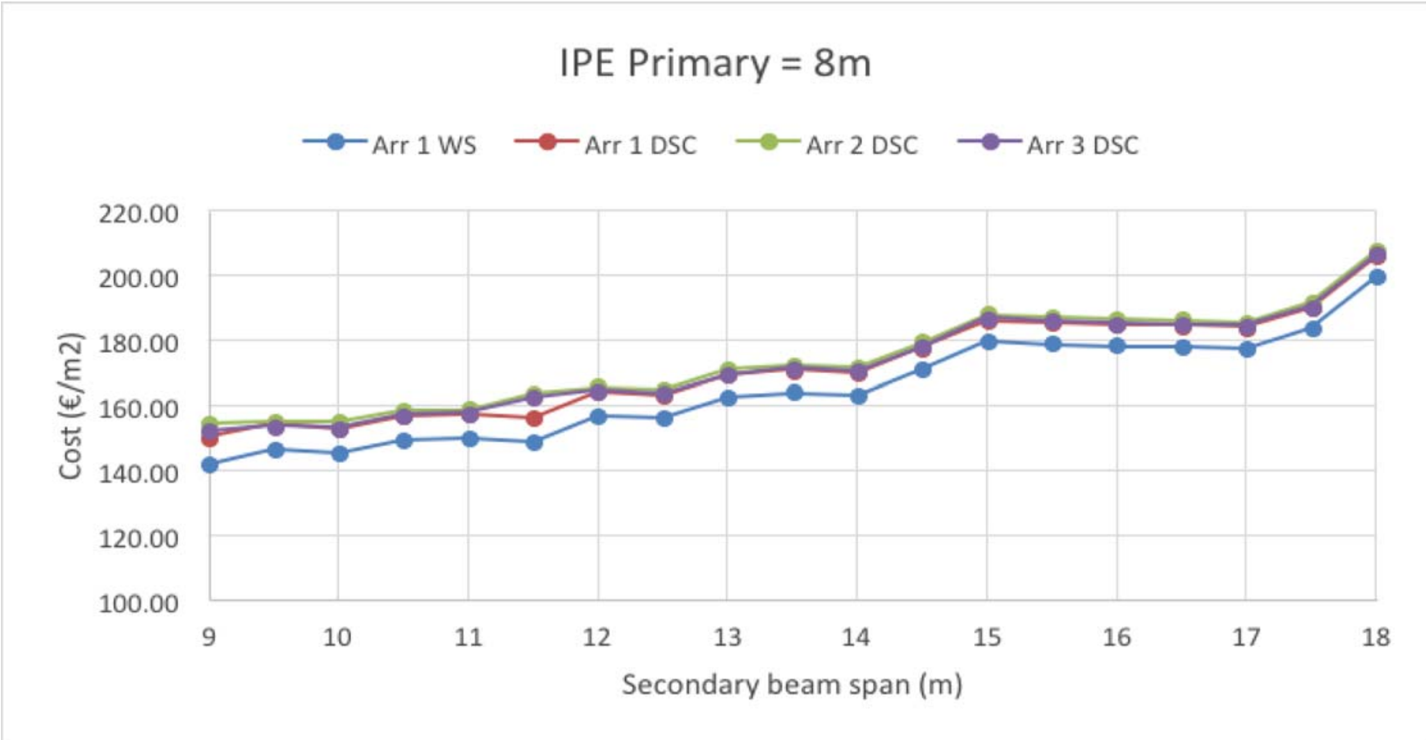
Arr2 DSC: Spacing for the sixth span (40 connectors)



Arr3 DSC: Spacing for the twelfth span (32 connectors)

*A. Girao-Coelho: REDUCE D7.2

Costs structural system [€/m^2]



	Arr1 WS	Arr1 DSC	Arr2 DSC	Arr3 DSC
Relative costs	100%	+6,1%	+5,2%	+4,6%

Conclusions

- In situ concrete weighs +117% compared to long span composite decking;
- In situ concrete has lowest GWP on Module A (Production, average mix);
- Module C (End-of-Life) impacts are small;
- Module D, Scenario E3: reuse structural steel **and slab** leads to significant lower GWP impact;
- Costs system with demountable shear connectors **+5%** compared to system with welded shear connectors;

Thank you !

1821: to propel the USS Constitution by manpower