# Absolute Zero: challenges and opportunities in construction

Cyrille Dunant London, March 2020







Emissions in context

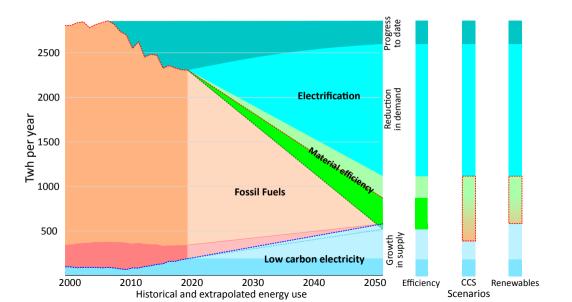
Material Utilisation in Construction

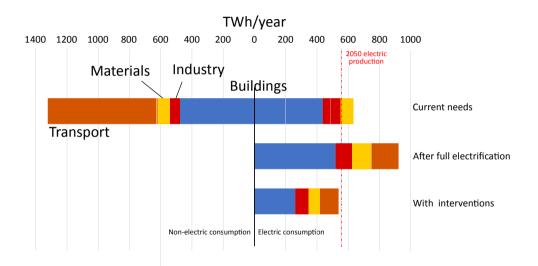
Role of the Layout

Better buildings design?

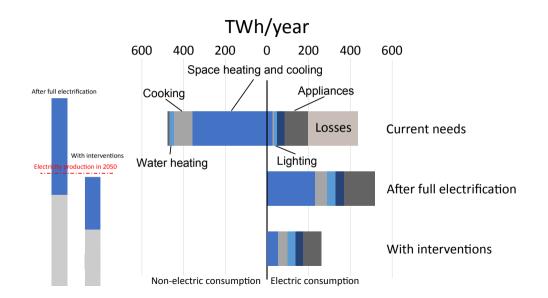
### Emissions in context

#### The big picture

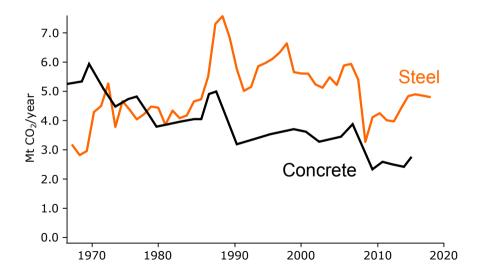




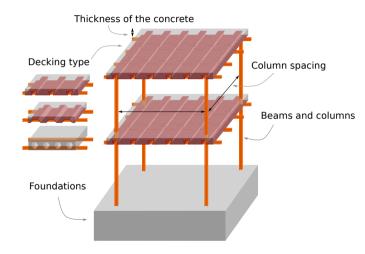
#### The energy budget



#### Process emissions — steel and cement scaled by $CO_2$



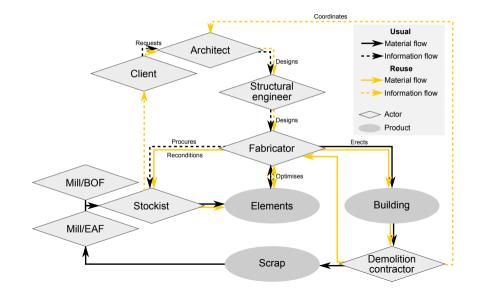
- Overall layout
- Grid spacing
- floor heights
- Serviceability
- Loads
- Type of frame
- Type of decking



- Developers value flexible space
- Architects look at function and æstethics
- General contractors will take the project and coordinate actors
- Structural designers look at structural solutions and construction details
- Other contractors will finish the details and do the actual construction

As you go down that list, consideration of value gives place to consideration of costs

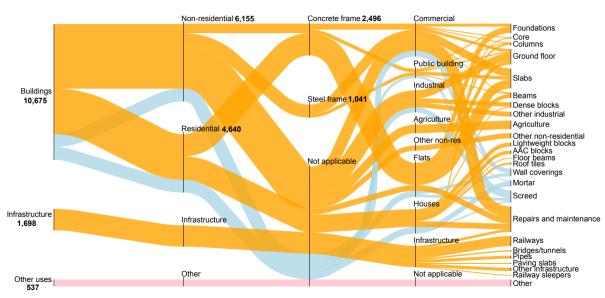
#### Coordination — steel reuse as an example



## Material Utilisation in Construction

- 1. MC Moynihan, JM Allwood Proceedings of the Royal Society A, 2014
- 2. CF Dunant et al. Resources Conservation and Recycling, 2018
- 3. W Shanks et al.— Resources Conservation and Recycling, 2019

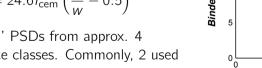
#### Where cement (and steel) goes

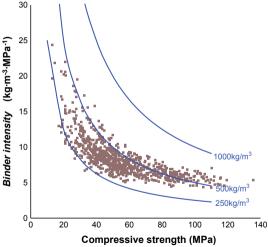


- Concrete strength depends on
  - 1. Cement composition
  - 2. Water/cement Ratio
  - 3. Aggregate PSD
- $\blacksquare \frac{w}{c}$  can be lowered using admixtures
- Using an 'optimal' PSD

$$f_c = 24.6 f_{\rm cem} \left(\frac{c}{w} - 0.5\right)$$

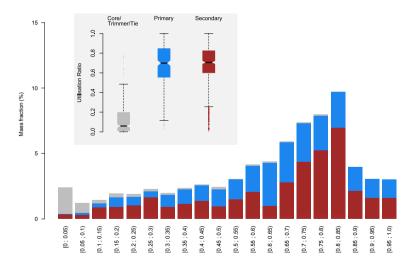
• 'Optimal' PSDs from approx. 4 aggregate classes. Commonly, 2 used



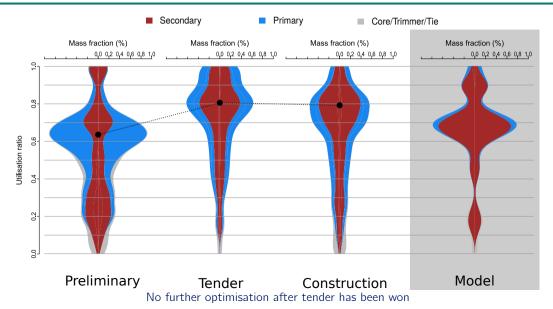


- BL Damineli et al. Cement & Concrete Composites, 2010
- 2. J Bolomev, Travaux, 1935

- Drop-off for UR > 0.8
- Long tail suggests important role of spans
- Cores/Trimmers/Ties?



#### The optimisation process



#### Options for material saving

Application

Floor slabs Ground floor   45 %   6<													
Repairs and maintenance 72 %   Screeds 62 %   Rallway bridges and tunnels 70 %   Beams 40 %   Agriculture 70 %   Foundations 66 %   Other (unknown) 82 %   Other industrial 70 %   Columns 82 %   Finishings 72 %   Mortar 82 %   Other Pipes 72 %   Post tensioning 72 %   Post tensioning 72 %   Post tensioning 72 %   Post tensioning 72 %   Other industrial Calcined clay + limestone   Reducing cement content of concrete 85 %   Reducing cement content of concrete 85 %   AC blocks Construction waste   Columa state 71 %   Optimised construction 72 %   Optimised construction 72 %   Optimised construction 72 %   Timestone 72 %   Optimised construction 72 %   Optimised construction 72 %   Time 72 %   T		Floor slabs				1			4	5 %			
Screeds 82 % 70 %   Railway bridges and tunnels 70 % 70 %   Agriculture 70 % 70 %   Agriculture 70 % 70 %   Foundations 70 % 70 %   Other (unknown) 82 % 66 %   Other industrial 70 % 70 %   Columns 70 % 70 %   Finishings 70 % 70 %   Mortar 70 % 70 %   Other industrial 70 % 70 %   Columns 82 % 82 %   Finishings 9 Post tensioning 72 %   Post tensioning 72 % 72 %   Post tensioning 72 % 72 %   Post tensioning 72 % 72 %   Colorshuction waste 85 % 86 %   Colorshuction waste 72 % 71 %   Colorshuction 72 % 72 %   Gother day + Imestone 72 % 72 %   Optimised construction 72 % 72 %   Optimised construction 72 % 72 %   Tool 1200 1000 800 600 400 200 0		Ground floor							5	i0 %			
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Press 72 %   Dense blocks Precast systems   Lightweight blocks Reducing cement content of concrete   Roof tiles Calcined clay + limestone   AAC blocks Construction waste   Paving slabs Optimised construction   Railway sleepers 72 %   1400 1200 800 600 400 200 0 200 400 600 800		Finishings							8	2 %			
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Roof tiles   Calcined clay + limestone   72 %     AAC blocks   Construction waste   85 %     Core   71 %   72 %     Paving slabs   Optimised construction   72 %     Floor beams   72 %   72 %     Railway sleepers   1400   1000   800   600   400   200   0   200   400   600   800		Dense blocks		,					8	15 %			
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Core   71 %     Paving slabs   Optimised construction   72 %     Floor beams   72 %   72 %     Railway sleepers   1400   1000   800   600   400   200   400   600   800		Roof tiles		Calcined of	clay + limes	tone			7	2 %			
Paving slabs   Optimised construction   72 %     Floor beams   72 %   72 %     Railway sleepers   72 %   72 %     1400   1200   1000   800   600   400   200   0   200   400   600   800		AAC blocks		Constructi	ion waste				8	15 %			
Floor beams   72 %     Railway sleepers   72 %     1400   1200   1000   800   600   400   200   400   600   800		Core							7	1 % 📕			
Railway sleepers   72 % II     1400   1200   1000   800   600   400   200   400   600   800		Paving slabs		Optimised	constructio	n							
1400 1200 1000 800 600 400 200 0 200 400 600 800									7	2 %			
		Railway sleepers									 		
			1400	1200	1000	800	600	400	200	-	400	600	800

Optimising construction only a partial solution

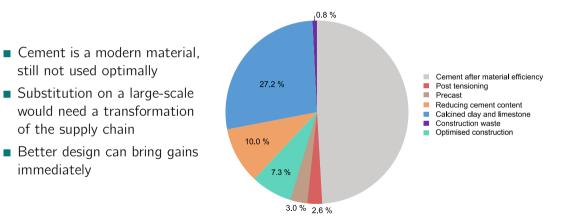
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Application

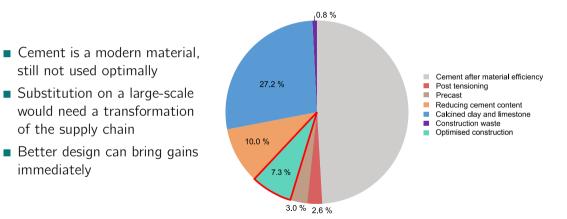
	Floor slabs				1				45 %				
	Ground floor								50 %				
	Repairs and maintenance								72 %				
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	Railway bridges and tunnels								70 %				
	Beams								40 %				
	Agriculture								70 %				
	Foundations								66 %				
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Infrastructure	Other industrial								70 %				
rast	Columns								42 %				
	Finishings								82 %				
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	Lightweight blocks		Reducing	cement cor	ntent of con	crete			85 %				
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		1400	1200	1000	800	600	400	200	0 Mass	200 (kt)	400	600	800

Optimising construction only a partial solution

#### Design is the first thing to improve



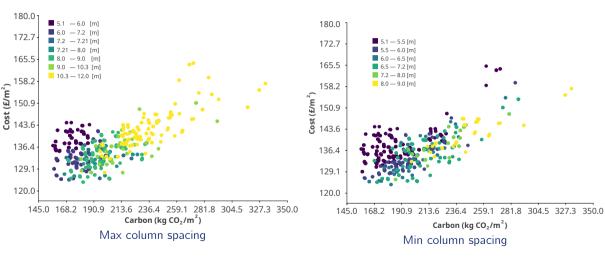
#### Design is the first thing to improve



## Role of the Layout

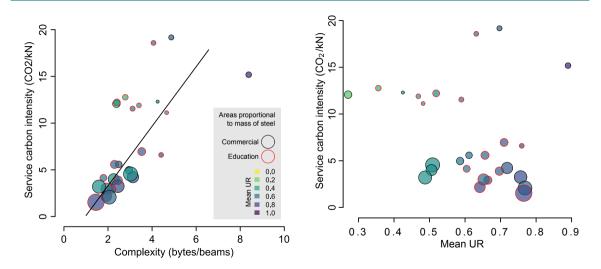


#### Choosing a grid



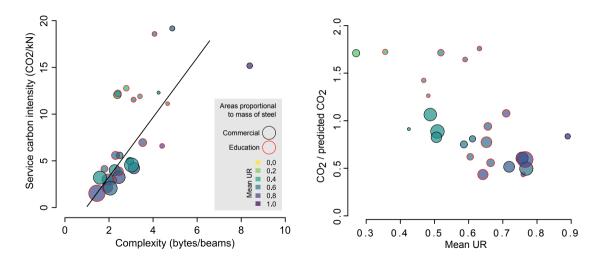
Grid choice can double carbon for only 30% more cost

#### Optimisation and complex layouts



Extra CO<sub>2</sub>: optimisation  $\frac{1}{3}$ , design  $\frac{2}{3}$ 

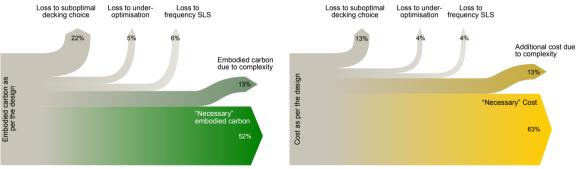
#### Optimisation and complex layouts



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#### Choosing the decking

- Deckings are not optimal (it's the best you can do, picking 1 of 2000 options)
- The carbon impact is similar to the choice of the grid
- The choice is made early and typically not revised.



Changes in designs can save both money and embodied CO<sub>2</sub>

## Better buildings design?



■ 5-10% of extra embodied carbon due to under-optimisation



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- $\blacksquare$  15% of extra embodied carbon due to the layout



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- $\blacksquare$  15% of extra embodied carbon due to the layout

- The same things are likely true for initial massing choices
- Poor planning/craftsmanship causes the same thing in cement mix design



Thank you

Special thanks to:

## PRICE&MYERS

And to all the Use Less Group and Resource Efficiency Collective