Carbonated Manufactured Aggregates: Current Status and Future Direction

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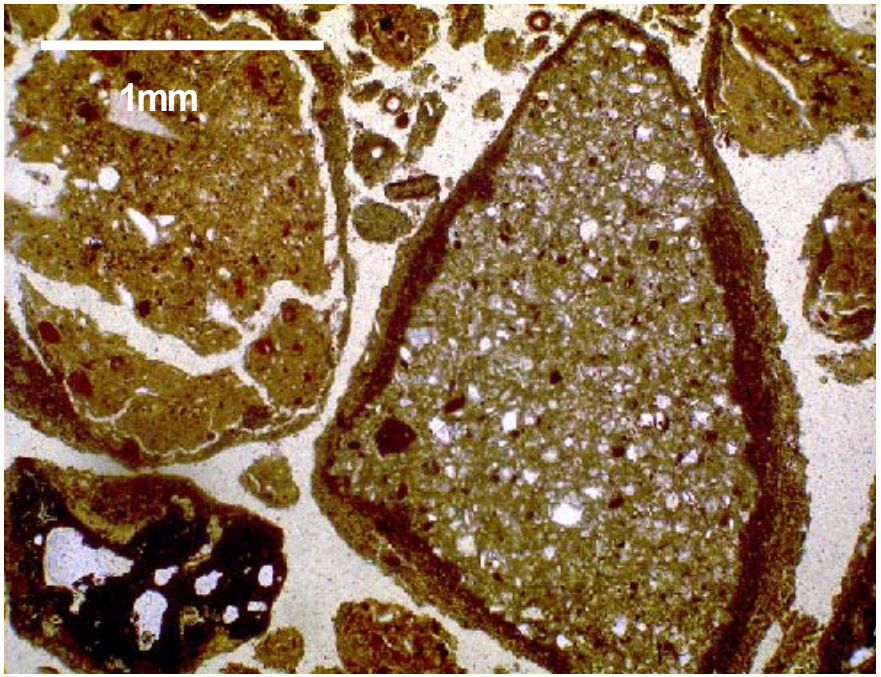
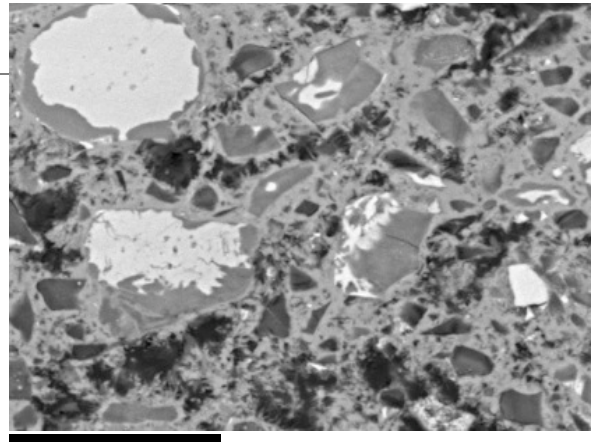
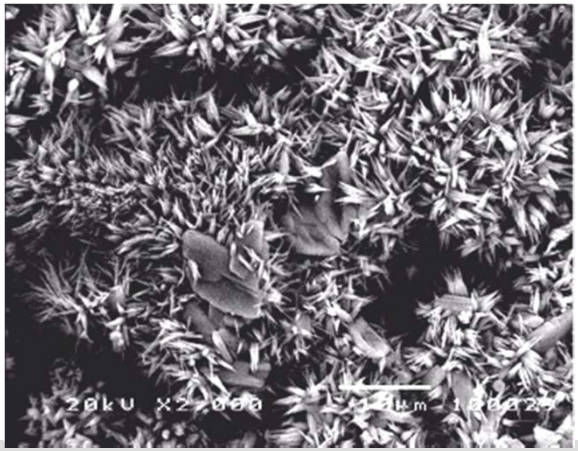
History – accelerated carbonation of contaminated soil/haz-waste ‘poisoning’ of s/s (ca. 2000)

Trial carbonation of contaminated soil



Original research on metal poisoning of stabilised/solidified waste

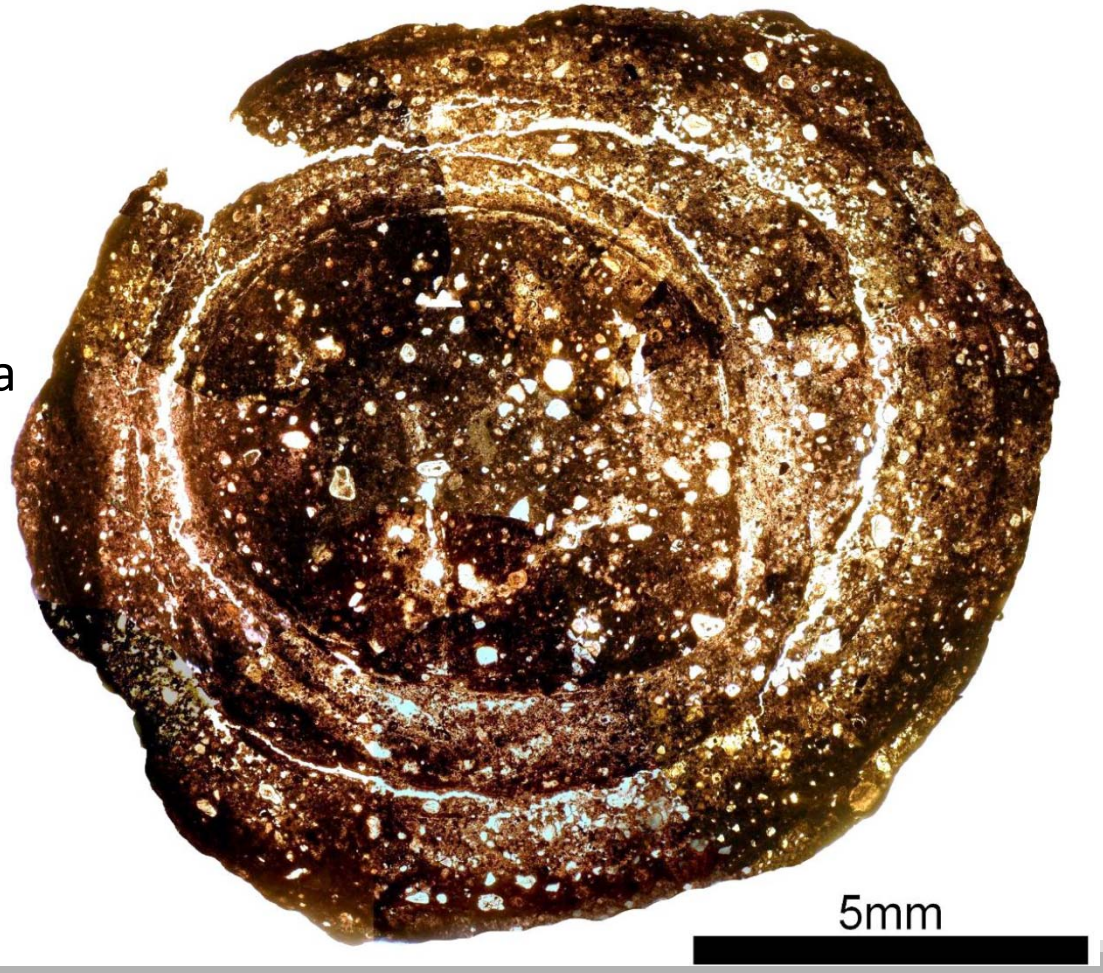




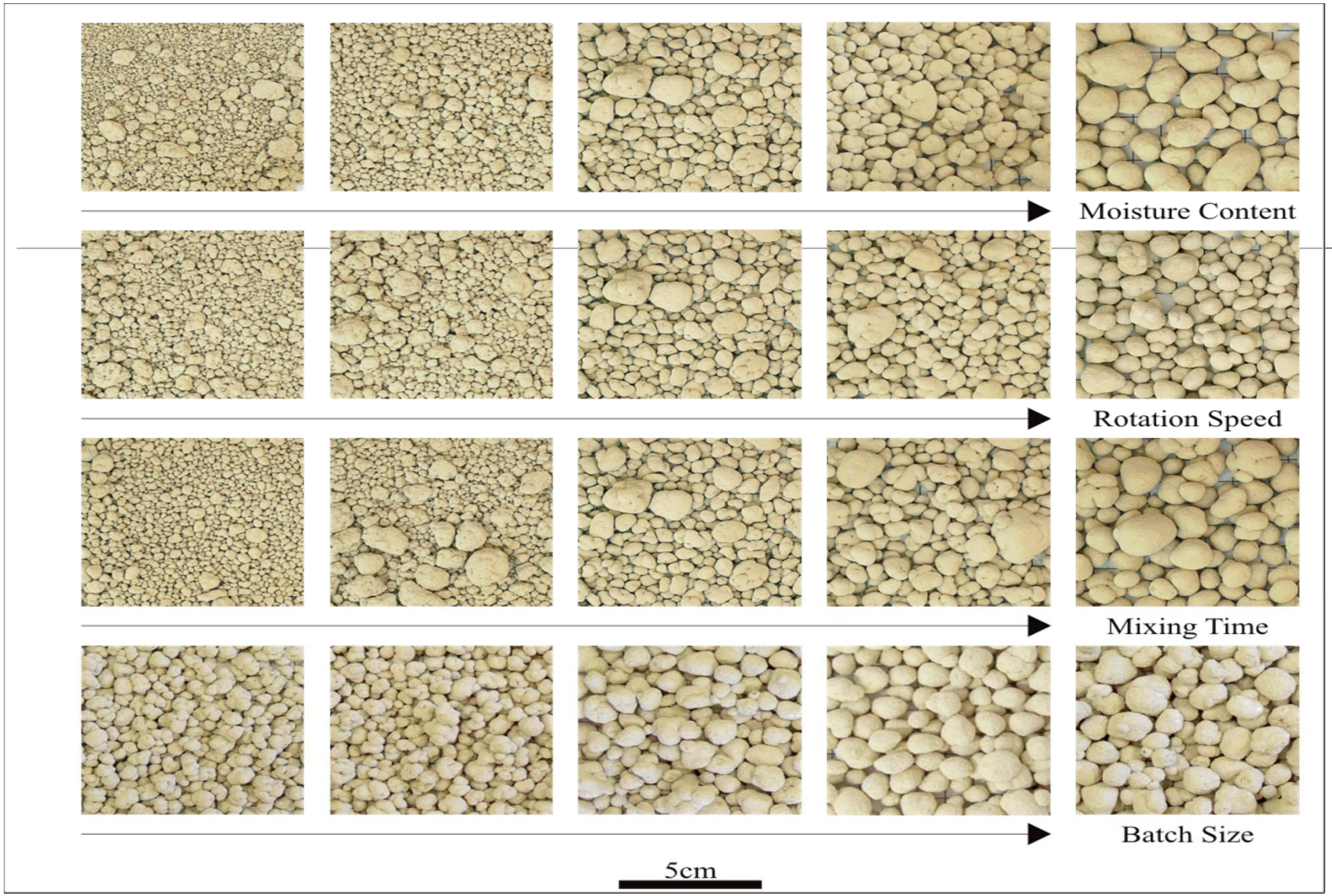
Demonstration at the Olympic Park, 2010

Carbonated aggregate

The aggregate structure is analogous to a Pisolith: displays a growth pattern



Transmitted light photo-micrograph


Moisture Content
Rotation Speed
Mixing Time
Batch Size
5cm

Requirements for ‘End of Waste’

- A product that is ‘fit for purpose’
- A demonstrable market need (contracts)
- Demonstrable management of risks/agreed specification
- A replacement for virgin stone

If any of the above are not met, then waste status remains

Manufactured carbonated aggregates

- 5 years of commercial use (with small and multinational companies)
- 2 UK plants, 5 by ca. 2021 (ca. 500kt/yr), with EoW for construction blocks
- Carbonated aggregates are also suitable for:
  - pipe bedding
  - sub-base for roads, geotechnical fill,
  - ready-mix concrete
  - no fines screed etc.
  - higher value (e.g. porosity controlled) products can also be manufactured

- CO_2 'content' would be increased, if the cost of CO_2 was lower

Is waste treatment focused, but 'know-how' is transferable to mineralisation of geo-materials

Leaching performance

(Leaching in accordance with EN 12457 in mg/kg, bdl = below detection limit)
(Max = Specification agreed with the Environment Agency)
(Aver = Average levels for **C8Agg**)

	Sb	As	Ba	Cd	Cr	Cu	Pb	Mo	Ni	Se	Zn
Max	0.06	0.5	50	0.04	1.5	0.15	0.5	1.0	0.4	0.1	3.5
Aver	bdl	0.05	17	bdl	0.5	bdl	0.1	0.2	0.03	0.06	0.26

Aggregate stocks at Carbon8 Aggregates plant in Suffolk

Different wastes and their aggregated products

Aggregates for blocks

Material Properties				
Particle size		0 - 15	mm	
Dry loose bulk density	Minimum	950	kg/m^3	EN 1097
	Maximum	1100	kg/m^3	EN 1097
Particle density	Oven dried	1.94	kg/m^3	EN 1097
Crushing Resistance	Typical value	6.6	N/mm^2	EN 13055
	Minimum value	5.2	N/mm^2	EN 13055
Moisture content as delivered	Typical value	8	%	
Water absorption	Typical value	18.8	%	EN 1097
Water soluble chloride	Typical value	4.2	%	EN 1744
Water soluble sulfate	Typical value	0.1	%	EN 1744
Total sulfate (as SO_3)	Typical value	1.78	%	EN 1744
Resistance to Attrition (Los Angeles)	Typical value	39	%	EN 1097
Magnesium sulphate soundness	Typical value	30.1	%	EN 1097
Drying shrinkage	Typical value	0.021	%	EN 1367

Ready Mix Concrete

Material Properties				
Particle size		4 - 16	mm	
Dry loose bulk density	Minimum	950	kg/m^3	EN 1097
	Maximum	1100	kg/m^3	EN 1097
Particle density	Oven dried	1.94	kg/m^3	EN 1097
Crushing Resistance	Typical value	6.6	N/mm^2	EN 13055
	Minimum value	5.2	N/mm^2	EN 13055
Moisture content as delivered	Typical value	8	%	
Water absorption	Typical value	18.8	%	EN 1097
Water soluble chloride	Typical value	4.2	%	EN 1744
Water soluble sulphate	Typical value	0.1	%	EN 1744
Magnesium sulphate soundness	Typical value	30.1	%	EN 1097
Drying shrinkage	Typical value	0.021	%	EN 1367

Pre-cast concrete

Material Properties				
Particle size		4 - 16	mm	
Dry loose bulk density	Minimum	950	kg/m3	EN 1097
	Maximum	1100	kg/m4	EN 1097
Particle density	Oven dried	1.94	kg/m5	EN 1097
Crushing Resistance	Typical value	6.6	N/mm2	EN 13055
Moisture content as delivered	Typical value	8	%	
Water absorption		18.8	%	EN 1097
Water soluble chloride		4.2	%	EN 1744
Water soluble sulphate		0.1	%	EN 1744
Resistance to attrition (Los Angeles)		48	%	EN 1097
Magnesium sulphate soundness		30.1	%	EN 1097
Drying shrinkage		0.021	%	EN 1367

No-Fines Concrete

No fines base		
Dry density	1436	kg/m^3
Weight per sq m at 100mm thick	143.6	kg
System: 100mm base and 15 mm topping		
Dry density	1510	kg/m^3
Weight per sq m	173.7	kg
Kg of CO_2 per sq m	11	kg

Where are we now?

- Carbonated aggregates are fit for purpose and meet BS EN standards (EoW is an issue)
- A range of materials properties and new applications are possible (incl. high value products)
- EoW is NOT consistently applied across the EU and the process is not ‘transportable’
- CO_2 is not cheaply available – limits use and application
- The construction industry is largely conservative in nature
- No market advantage for low-CO2 embodied construction products (is price driven)
- Mt/yr of CO2 can be mineralised in waste in EU (incentives are not in place, to do this)

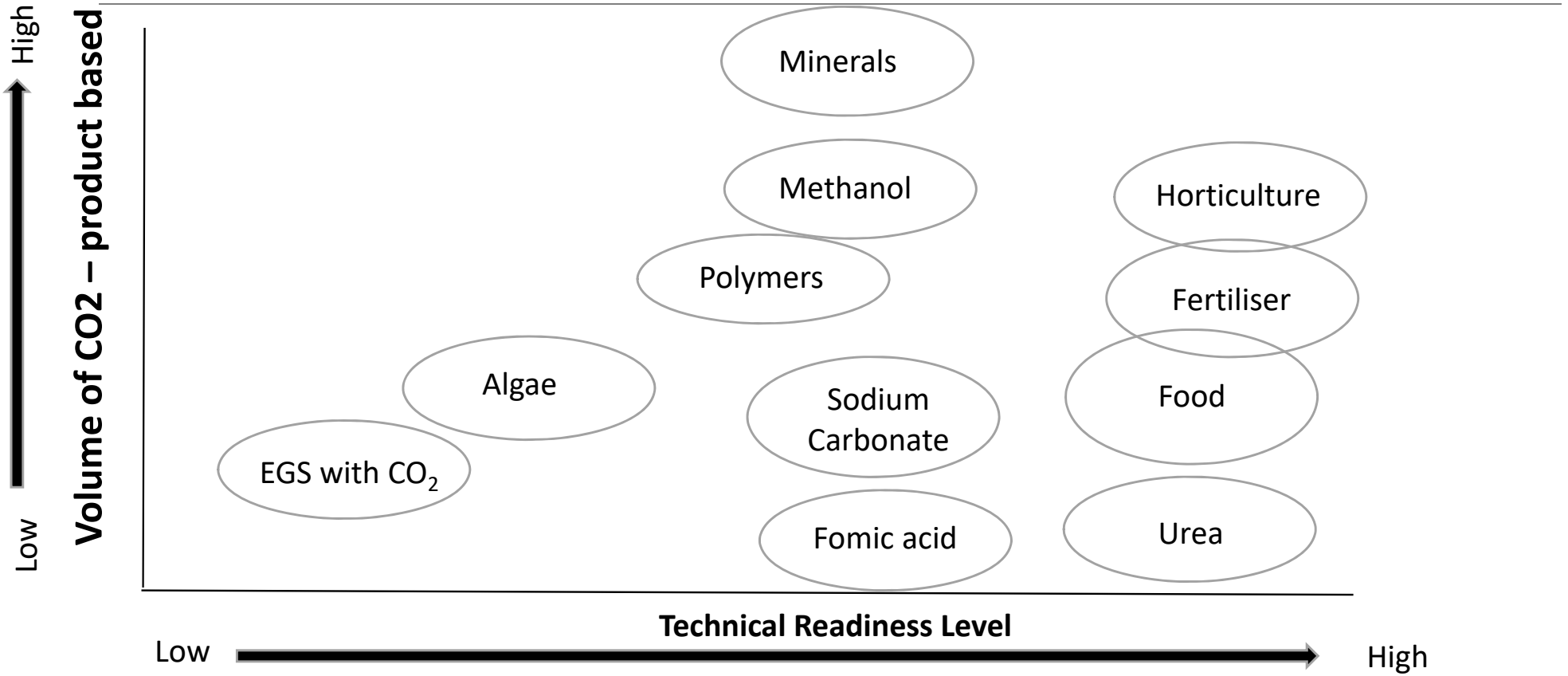
DeConto and Pollard, Nature 53, pp. 591. doi:10.1038/nature17145

‘End of Waste’ status across EU countries*

Country	Is EoW Possible?	Legislation
Italy	Yes (?)	Decree of 5-2-88
France	Yes (?)	Decree 602
Switzerland	No	Ordinance for the Environment and Water protection
Spain	Yes	Article 5 of law 22/2011 (No criteria defined)
Ireland	Yes	Article 28 of law 126/2011 (No criteria)
Belgium	Yes Yes No status	Flanders (Material decree 2011; Decision VLAREMA 2012) BX City (Brussels Waste 2012) (No criteria) Wallonia (Waste 2012; transposing Directive 98/2008)
Netherlands	Yes	Various (WMB1979; IMPL 2011; IENM/BSK-2015/18222 (criteria for recycled aggregates only)
Denmark	No	WFD not transposed
Germany	Yes	Article 6, KrWG, waste stream-specific

* results of a ‘quick’ survey of selected countries WFD = waste framework directive

Comparison with other CO_2 transformation technologies



Further development needs

- A level regulatory ‘playing field’ in EU for EoW (via the Single Market Act?)
- A review of materials standards for products made from waste (solid/gaseous) to enable cross-cutting through EN standards
- Harmonisation of landfill pricing/taxes in member states
- Route to low cost capture and delivery of CO_2 from point sources
- Public awareness campaign of benefits of CCU (develop a ‘culture’)
- Carbon pricing, to further encourage utilisation of CO_2 as a feedstock
- An embodied carbon marking scheme


Carbon8
Imagine.....capturing this much carbon dioxide every year