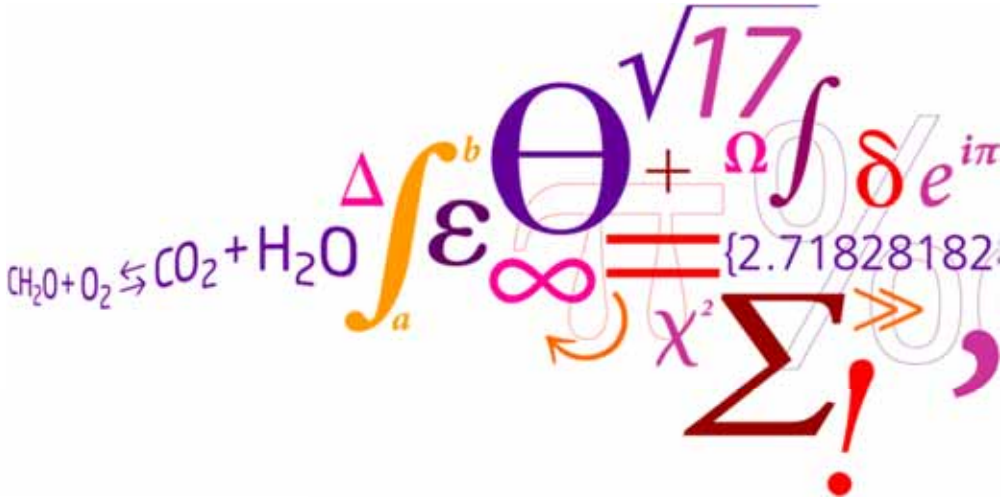
Technical University of Denmark DTU

What is the Difference between Biogenic and Fossil CO_2?

Thomas F. Astrup



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Background and content

- Increasing focus on fossil carbon emissions from waste incineration within recent years
- Uncertainties related to emissions affect national CO_2 inventories and “sustainability” of WtE (for DK uncertainties corresponds to about 1 % of total emissions)
- Still confusion about how to account CO_2 emissions consistently

- How to properly account biogenic and fossil CO_2 from WtE facilities?
- What is the importance of uncertainties in CO_2 emissions for WtE facilities?

Carbon in waste

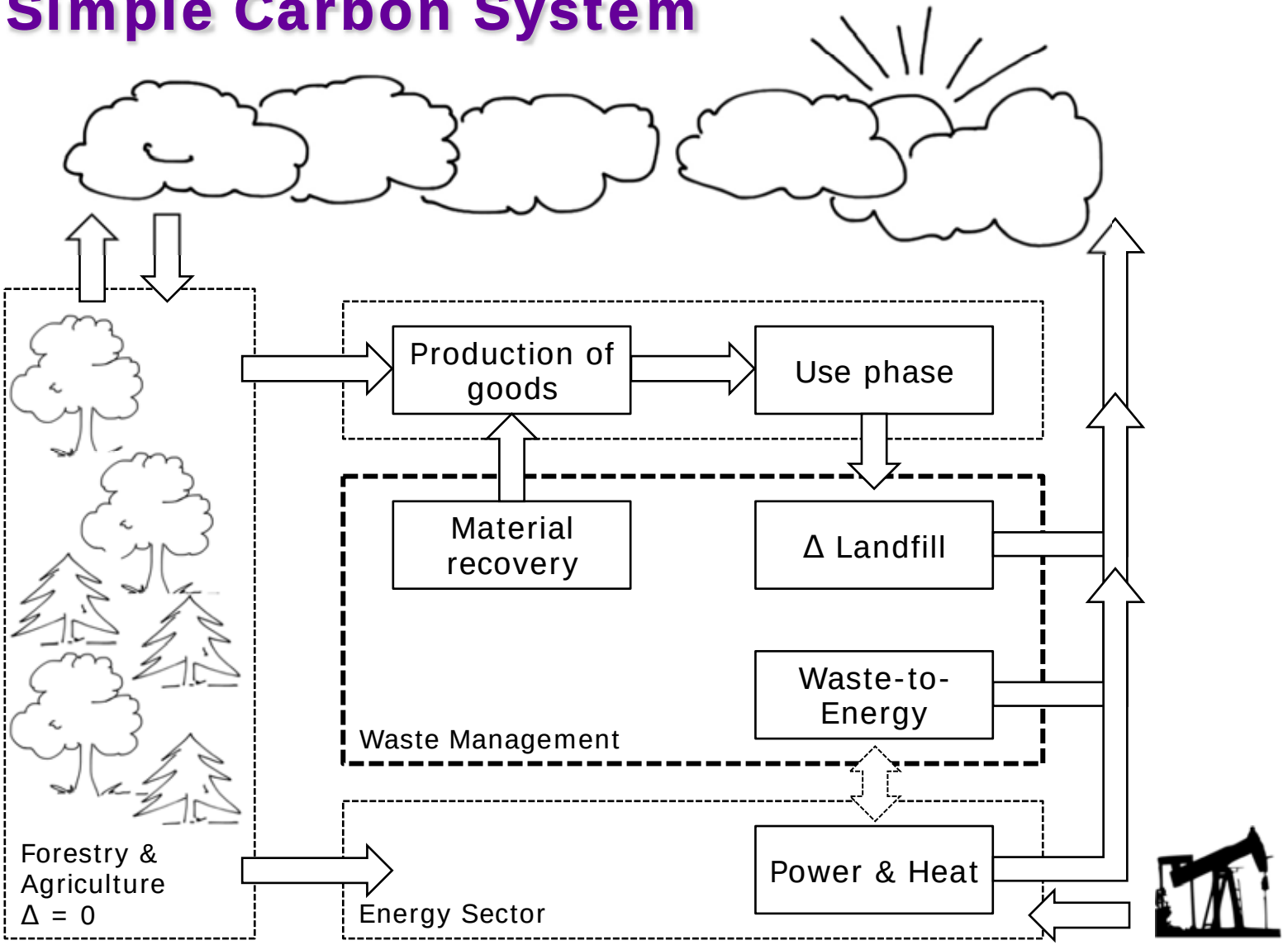
Biogenic carbon: plant materials which have been growing "recently", CO_2 part of a “natural” cycle:

- Food
- Wood
- Paper
- Cotton

Fossil carbon: plant materials which have been growing "millions of years" ago, CO_2 would not otherwise have been released

- Plastic
- Oil
- Coal

Simple Carbon System



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Based on: Christensen, Gentil, Boldrin, Larsen, Weidema, Hauschild (2009)

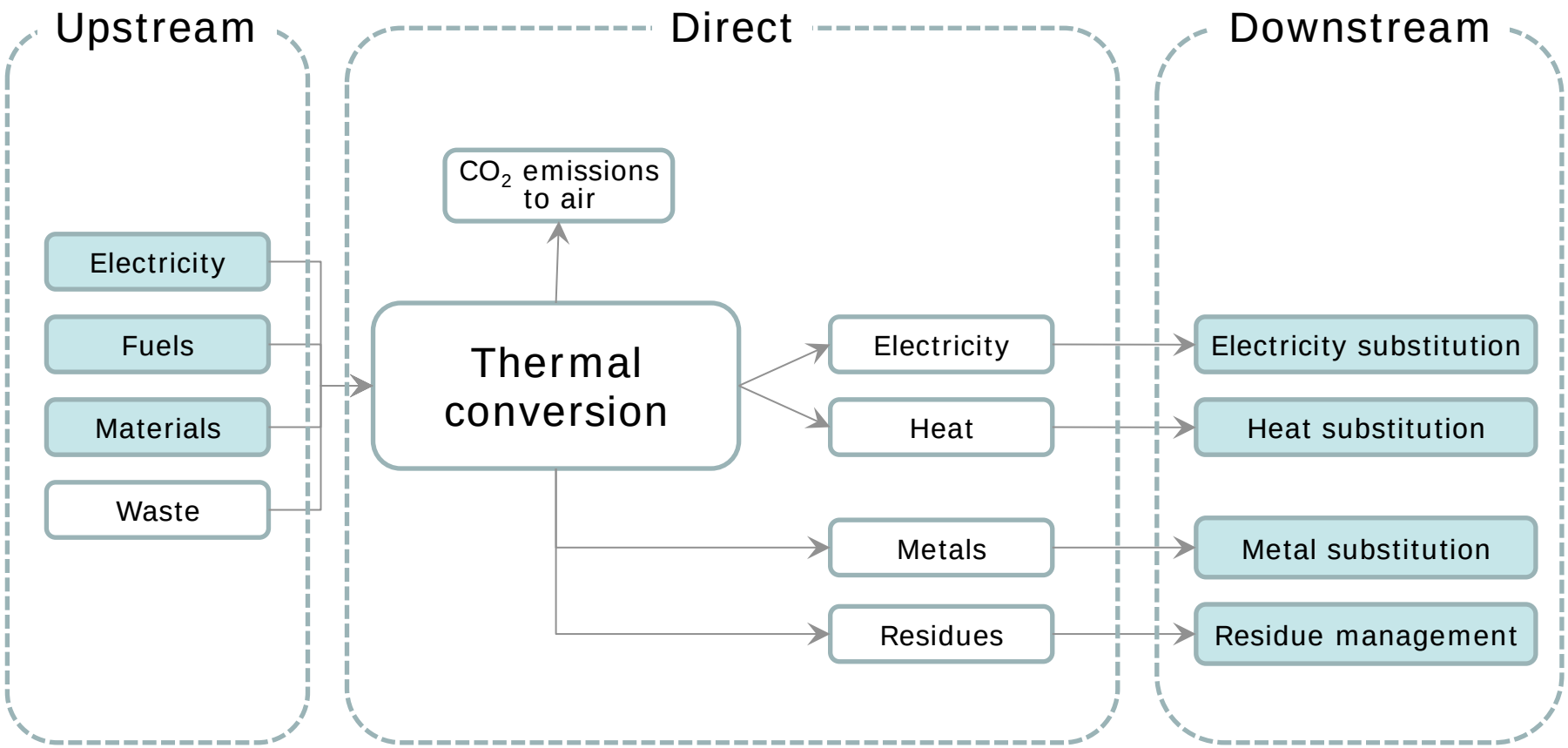
Accounting principles

	C to air		C sequestration		Energy substitution		Constrained Biomass resource?	
	Biogenic	*Fossil*	*Biogenic*	*Fossil*	*Biogenic*	*Fossil*	*No*	*Yes*
A)	0	1	-1	0	0	-1	0	-1
B)	1	1	0	0	-1	-1	1	0

1 = counted, 0 = not counted, -1 = subtracted, “constrained biomass resource” indicates whether saved biomass fuels are considered lost and naturally decomposed (No), or assumed to off-set fossil fuel consumption (Yes)

Based on: Christensen, Gentil, Boldrin, Larsen, Weidema, Hauschild (2009)

Waste-to-Energy: CO_2 system perspective



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Astrup, T.; Møller, J.; Fruergaard, T. (2009): Incineration and co-combustion of waste: accounting of greenhouse gases and global warming contributions. *Waste Management & Research*, 27, 789-799.

CO_2-accounting example: incineration

[Approach A, constrained biomass]

Upstream	Direct	Downstream
82 kg CO_2-eq/tonne waste	**370 kg CO_2-eq/tonne waste**	**-1094 kg CO_2-eq/tonne waste**
(kg CO_2-eq/tonne waste) Provision of: • Electricity : 75 • Oil: 0.3 • Flue gas cleaning: 7	(kg CO_2-eq/tonne waste) Emission of: • Fossil CO_2 (oil): 3 • Fossil CO_2 (waste): 367 • Biogenic CO_2 (waste): 0	(kg CO_2-eq/tonne waste) Substitution of: • Electricity: -517 • Heat: -558 • Metals -25 • Residues: +0.5
Included (pr. tonne waste) • Electricity: 75 kWh • Oil: 0.5 kg • $CaCO_3$: 3 kg • NaOH: 1 kg • NH_3: 1.5 kg	Included (pr. tonne waste) • Oil: 1 kg • Fossil C in waste: 100 kg • Biogenic C in waste: 200 kg	Included (pr. tonne waste) • Electricity (20 %): 517 kWh • Heat (75 %): 7000 MJ • Iron 13 kg • Aluminium 0.5 kg • Residues: 50 kg
Not included • Transport • Pre-treatment • Plant construction • Dioxin cleaning	Not included • Plant construction • Emissions from stored waste • Emissions of trace gases	Not included • Transport

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CO_2-accounting example: incineration

[Approach A, un-constrained biomass]

Upstream	Direct	Downstream
82 kg CO_2-eq/tonne waste	**370 kg CO_2-eq/tonne waste**	**-536 kg CO_2-eq/tonne waste**
(kg CO_2-eq/tonne waste) Provision of: • Electricity : 75 • Oil: 0.3 • Flue gas cleaning: 7	(kg CO_2-eq/tonne waste) Emission of: • Fossil CO_2 (oil): 3 • Fossil CO_2 (waste): 367 • Biogenic CO_2 (waste): 0	(kg CO_2-eq/tonne waste) Substitution of: • Electricity: -517 • Heat: -0 • Metals -25 • Residues: +0.5
Included (pr. tonne waste) • Electricity: 75 kWh • Oil: 0.5 kg • $CaCO_3$: 3 kg • NaOH: 1 kg • NH_3: 1.5 kg	Included (pr. tonne waste) • Oil: 1 kg • Fossil C in waste: 100 kg • Biogenic C in waste: 200 kg	Included (pr. tonne waste) • Electricity (20 %): 517 kWh • Heat (75 %): 7000 MJ • Iron 13 kg • Aluminium 0.5 kg • Residues: 50 kg
Not included • Transport • Pre-treatment • Plant construction • Dioxin cleaning	Not included • Plant construction • Emissions from stored waste • Emissions of trace gases	Not included • Transport

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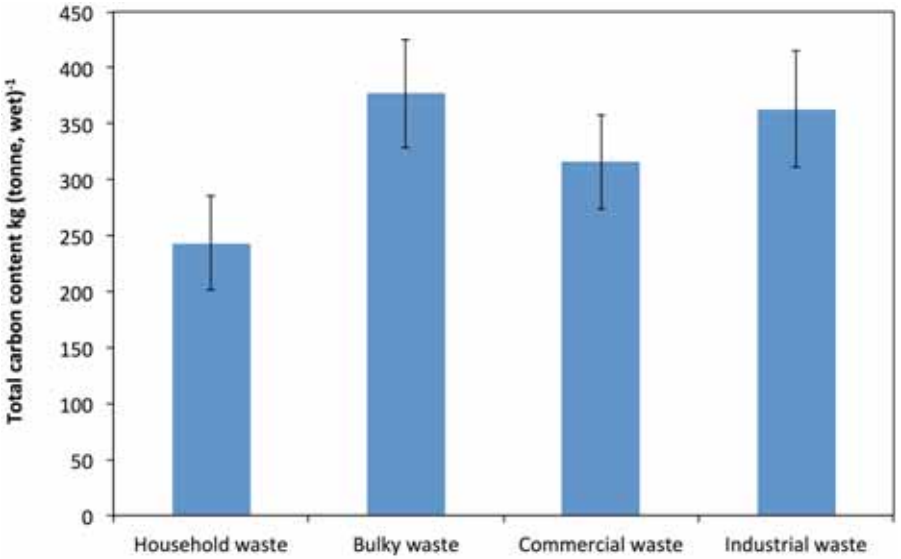
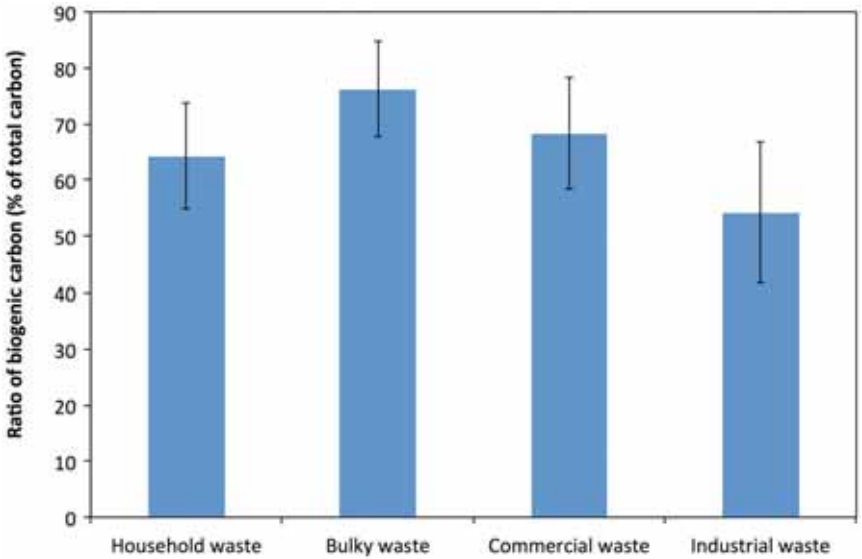
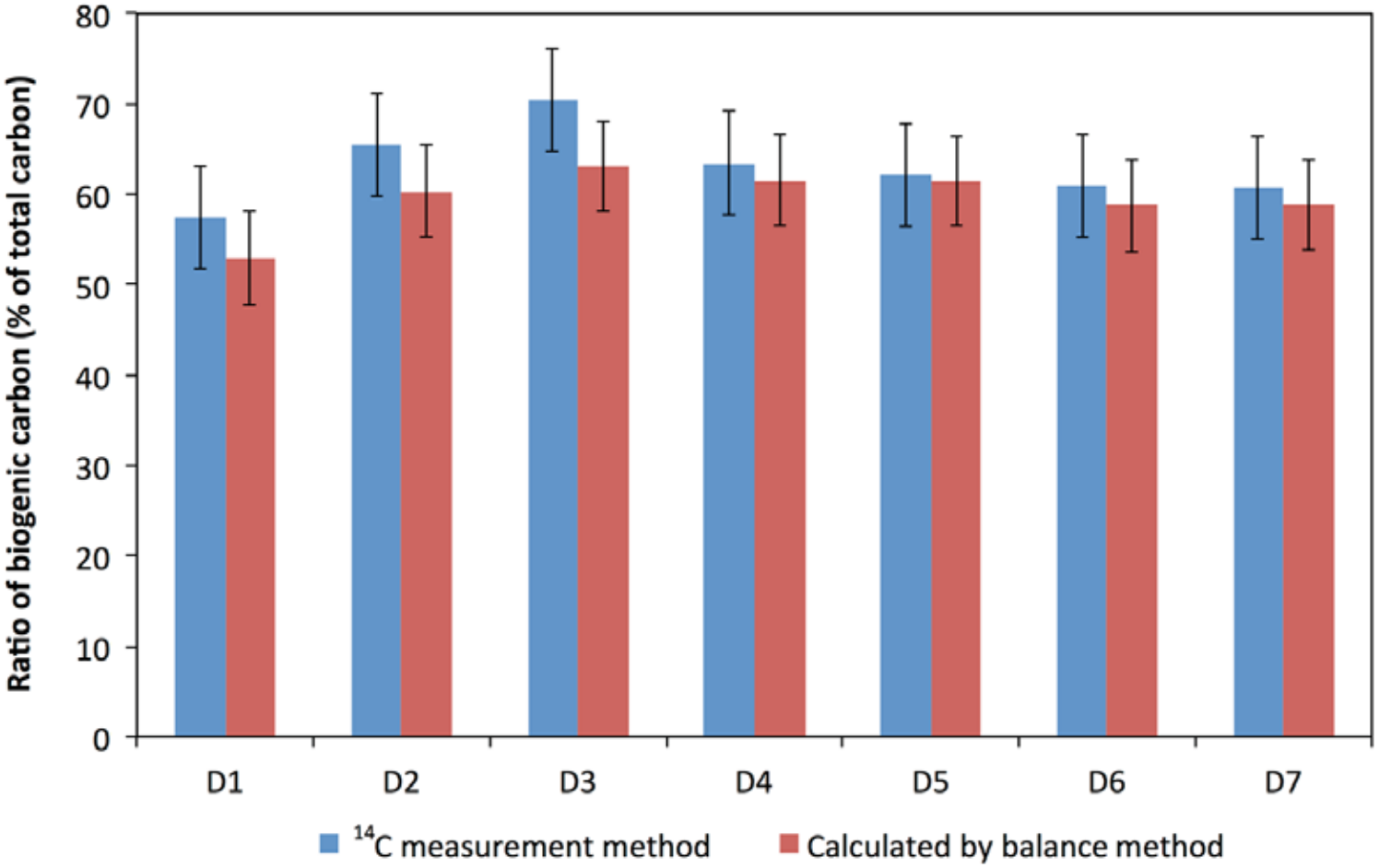
Importance of carbon in Waste

- Systematic accounting of CO_2 in waste needed, and
- Consistent ranking of alternatives can be obtained with both accounting principles
- Carbon contents in waste are uncertain due to the heterogeneity of waste materials





Experimental data: normal operation



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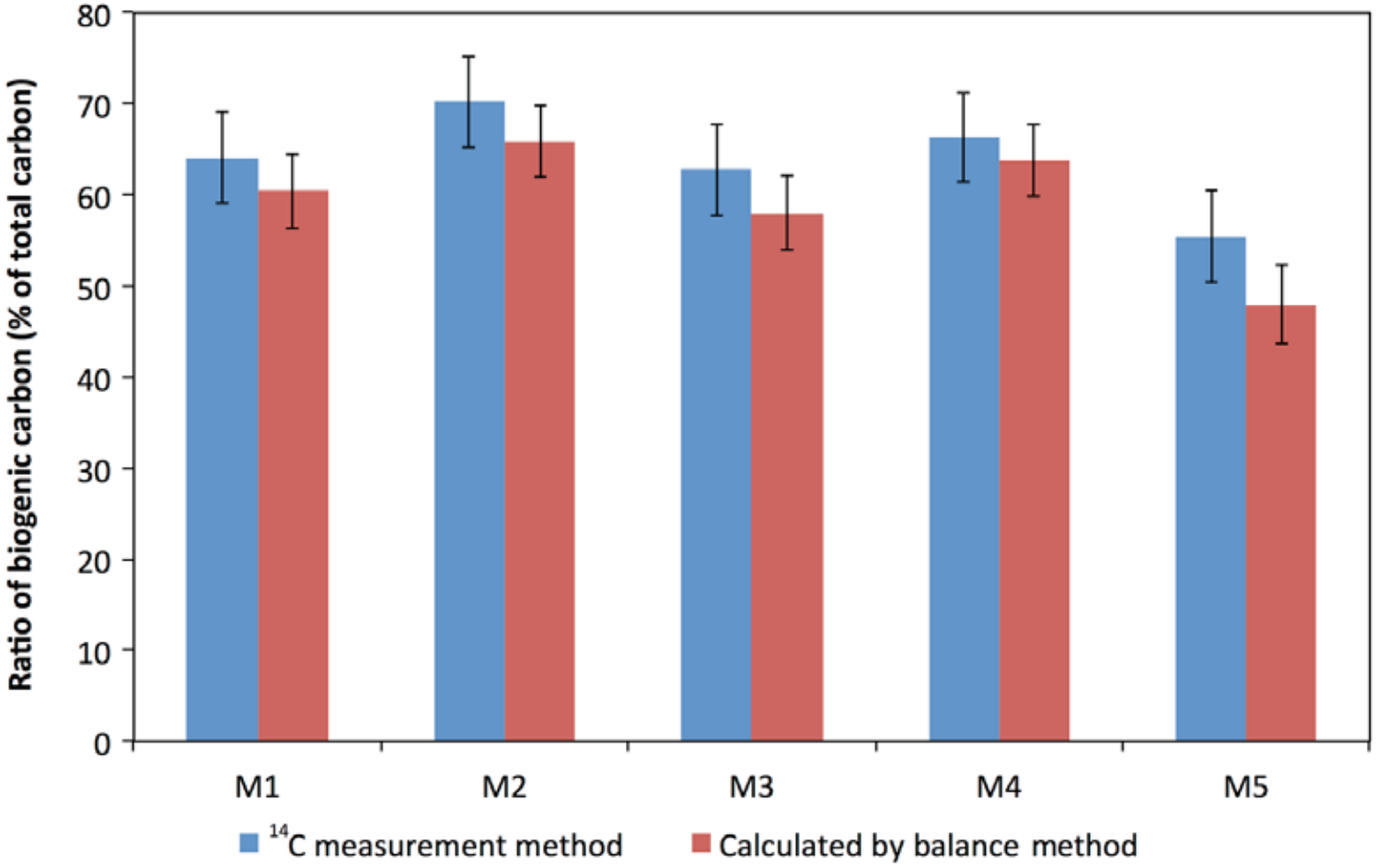
Larsen, A.W.; Fuglsang, K.; Pedersen, N.H.; Fellner, J.; Rechberger, H.; Astrup, T. (2013): Biogenic carbon in combustible waste: Waste composition, variability and measurement uncertainty. *Waste Management & Research,* 31(10), S56-S66.

Experimental data: controlled variations in waste input



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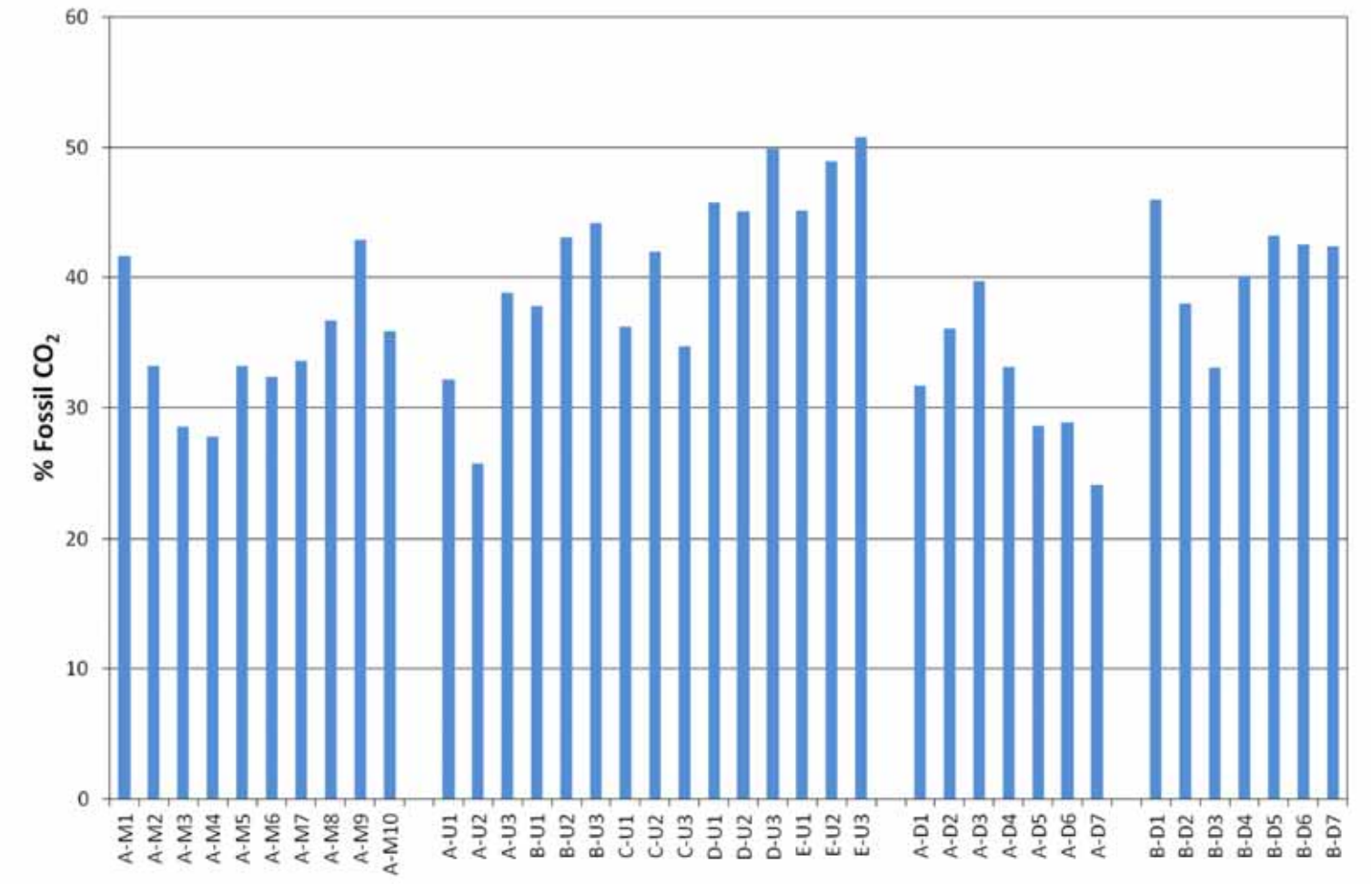
Fossil carbon emission variations over time



Fuglsang, K.; Pedersen, N.H.; Larsen, A.W.; Astrup, T. (2013). Measurement of variations in biogenic and fossil CO2 from Danish waste incinerators using long-term sampling of CO2 and 14C determination. *In press by Waste Management & Research*.

CO_2-accounting example: incineration

[Approach A, constrained biomass]

Upstream	Direct	Downstream
82 kg CO_2-eq/tonne waste	**322-487 kg CO_2-eq/tonne waste**	**-1094 kg CO_2-eq/tonne waste**
(kg CO_2-eq/tonne waste) Provision of: • Electricity : 75 • Oil: 0.3 • Flue gas cleaning: 7	(kg CO_2-eq/tonne waste) Emission of: • Fossil CO_2 (oil): 3 • Fossil CO_2 (waste): 319-484 • Biogenic CO_2 (waste): 0	(kg CO_2-eq/tonne waste) Substitution of: • Electricity: -517 • Heat: -558 • Metals -25 • Residues: +0.5
Included (pr. tonne waste) • Electricity: 75 kWh • Oil: 0.5 kg • $CaCO_3$: 3 kg • NaOH: 1 kg • NH_3: 1.5 kg	Included (pr. tonne waste) • Oil: 1 kg • Fossil C in waste: 87-132 kg • Biogenic C in waste: 54-68 kg	Included (pr. tonne waste) • Elelctricity (20 %): 517 kWh • Heat (75 %): 7000 MJ • Iron 13 kg • Aluminium 0.5 kg • Residues: 50 kg
Not included • Transport • Pre-treatment • Plant construction • Dioxin cleaning	Not included • Plant construction • Emissions from stored waste • Emissions of trace gases	Not included • Transport

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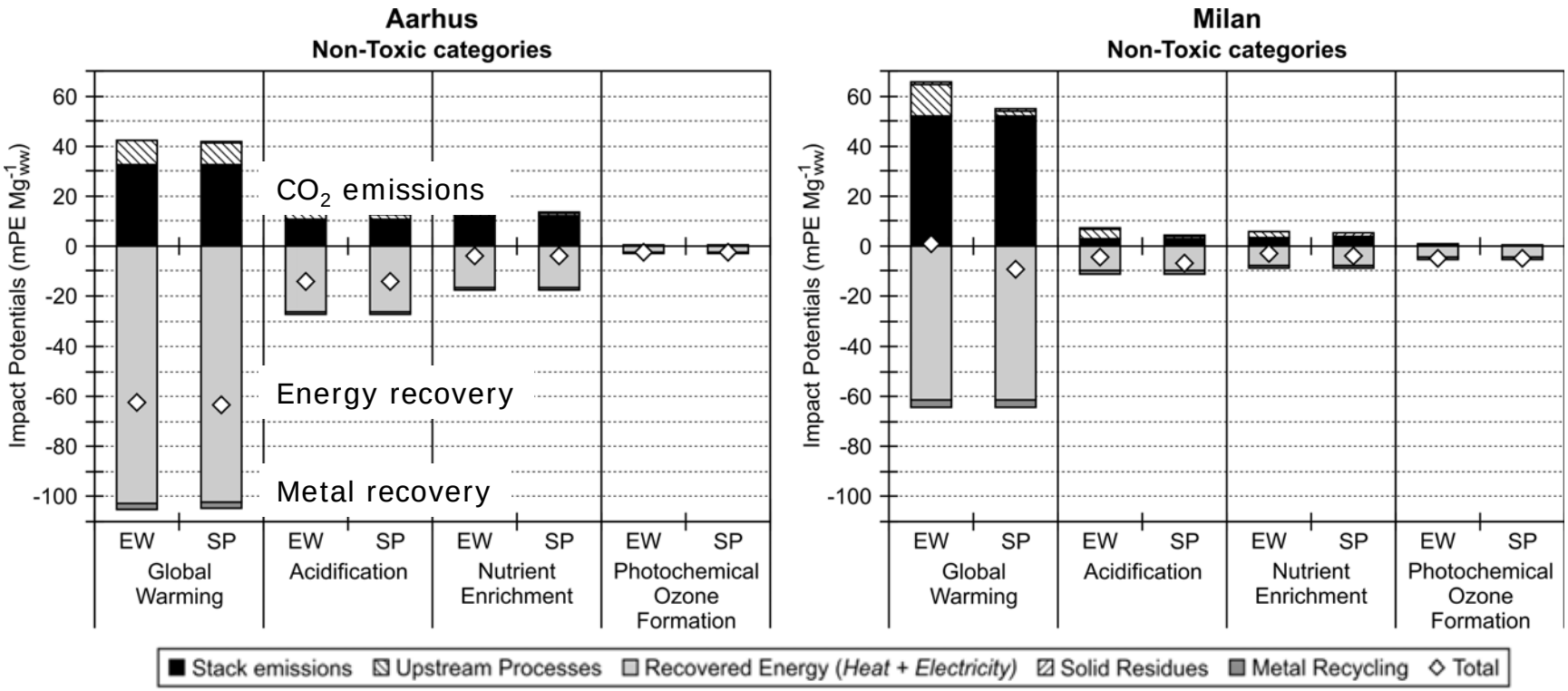
Importance for environmental impact assessments



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Turconi, R.; Butera, S.; Boldrin, A.; Grosso, M.; Rigamonti, L.; Astrup, T. (2011): Life cycle assessment of waste incineration in Denmark and Italy using two LCA models. Waste Management & Research, 29(10), S78-S90.

Key messages

- CO_2 accounting principles are often unclear
- Two correct principles: provides different numerical results, but consistent ranking between waste alternatives
- Significant variations in fossil carbon emissions from WtE facilities:
  - Observed variations between 56-71 % biogenic carbon
  - Uncertainty on observations about: 6-10 % (95 % conf.)
- Waste collection and source segregation systems may be important for CO_2 emissions
- Discussions of CO_2-emissions from Waste-to-Energy: Remember a system level perspective!

Larsen, A.W.; Astrup, T. (2010): CO2 emission factors for incineration of household waste and the influence of source separation of recyclable materials. W*aste Management*, 31, 1597-1605.

Larsen, A.W.; Fuglsang, K.; Pedersen, N.H.; Fellner, J.; Rechberger, H.; Astrup, T. (2013): Biogenic carbon in combustible waste: Waste composition, variability and measurement uncertainty. *Waste Management & Research,* 31(10), S56-S66.

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Thanks for your attention