Waste Management and Climate: Accounting of GHG Emissions and Savings

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UBA, Berlin June 2012

DTU Environment
Department of Environmental Engineering

Outline

- Which contributions and which savings?
- GHG accounting in waste management: 4 types
- Determining factors in GHG counting
  - 1. Boundaries: Upstream-Operation-Downstream: Transparence needed
  - 2. Boundaries: Reference level
  - 3. Characterization factors: Be specific – methane and bound-C are critical
  - 4. Waste management data:
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    4.2 CO2 fossil from incineration
    4.3 CH4 and N2O from composting and biofilters
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    4.5 CH4 capture and utilization in landfils (not shown)
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    5.1 Energy substitution
    5.2 Material substitution
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Which contributions?

Direct GHG contributions: CO_2-fossil, methane (CH_4) and dinitrogenoxide (N_2O) + a few other (SF6,..)

- Combustion of fuels in vehicles and machinery
- Emissions of methane (CH_4) from landfills, anaerobic digestion and composting
- Emissions of CO_2-fossil from incineration of plastic, textiles etc. containing C-fossil
- Emissions of dinitrogenoxide (N_2O) from biological processes, e.g. composting

Which savings?

Indirect saving in GHG contributions: CO_2-fossil, methane CH_4, dinitrogenoxide N_2O from what we avoid to produce plus bound C-biogenic:

- Energy recovery (electricity, heat, fuels) from MBT-plants/RDF/SRF, incineration, anaerobic digestion and landfill gas utilization
- Recycling of materials is often energy saving when compared to production from virgin materials
- Recycling of nutrients is often energy saving when compared to production of commercial fertilizers
- Binding of C-biogenic in soils and landfills

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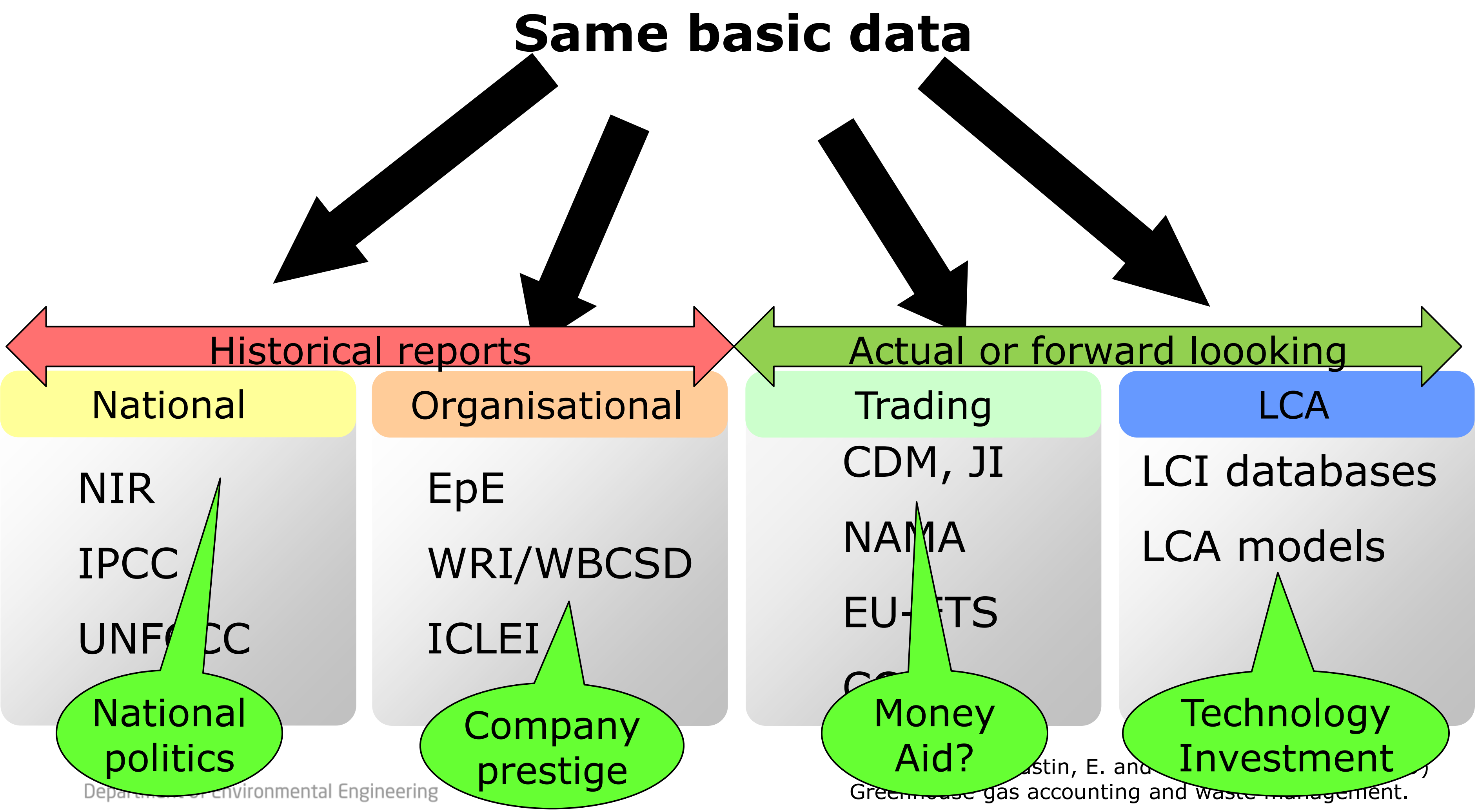
GHG accounting in waste management



…astin, E. and … Greenhouse gas accounting and waste management. Waste Management & Research, 27, 696-706.

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1. Boundaries and basic data: UOD table

- The GHG-account of a waste management technology depends per tonne of waste on:
  - indirect up-stream: the use of electricity, materials and the provision of fuels
  - direct emissions from the facility: fuel combustion, process emissions etc.
  - indirect down-stream: the substitutional value of the out-puts
- In Waste Management & Research (2009, Vol. **27**, p.696-836) each technology is described:

Indirect: Upstream	Direct: Operation/ Waste	Indirect: Downstream
GWF (kg CO_2-eq./tonne ww):	GWF (kg CO_2-eq./ton vv):	GWF (kg CO_2-eq./ tonne ww):
GWF (kg CO_2-eq./ tonne ww): ▪Xxx ▪Xxx ▪Xxx	GWF (kg CO_2-eq./ton vv): ●Xxx ●Xxx ●Xxx	GWF (kg CO_2-eq./ tonne ww): ▪ Xxx ▪Xxxx ▪Xxx
Accounted (unit/ tonne ww) : ▪Xxxxx ▪ Xxxx ▪ Xxxx	Accounted (unit tonne ww /): ▪ Xxx ▪ Xxxx ▪ Xxxx	Accounted (unit/ tonne ww): ●Xxx ●Xxx ●Xxx
Not accounted: Xxxx ▪Xxxx	Not accounted: ▪ Xxxxx	Not accounted: ▪ Xxxxxxx

Example: MRF for iron metal recovery

Indirect: upstream	Direct: waste management	Indirect: downstream
GWF (kg CO_2-eq. tonne^{-1} ww): 6 to 45.8	GWF (kg CO_2-eq. tonne^{-1} ww): 6.8	GWF (kg CO_2-eq. tonne^{-1} ww): –560 to –2360
GWF (k… ne^{-1} ww): • P… 1.3 (GWP = 1) • … 44.5	GWF (kg CO… ww): • Com… ab cranes: 6.8 (G…	GWF (kg CO_2-eq…): • Reprocess… production of 980… to –2360 (GWP…
…n	A… • … es: 2.5 L … nting):	Accou… • Re… ap
…tures and	• … al … d other	Not a… • Lo… to sm… • Tran… nent plant… • Treatme… al

U

Low to moderate

O

Low to moderate

D

High to very high

Net = U + O + D (negative value)

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2. Boundaries: reference levels

- Common reference: No waste management: preferred
- Some countries –e.g. Australia - it is common to use the landfill as the reference: complicates comparison

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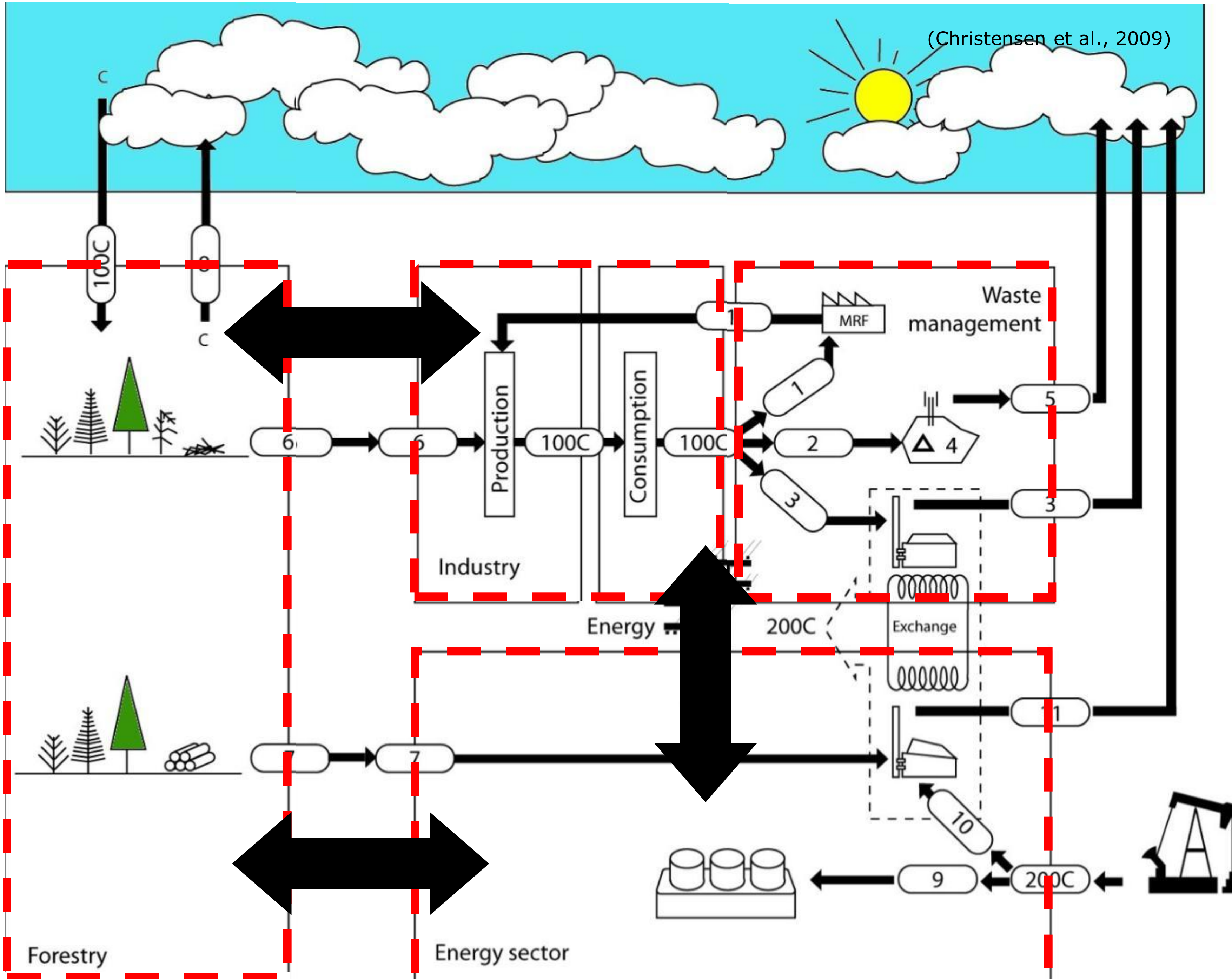
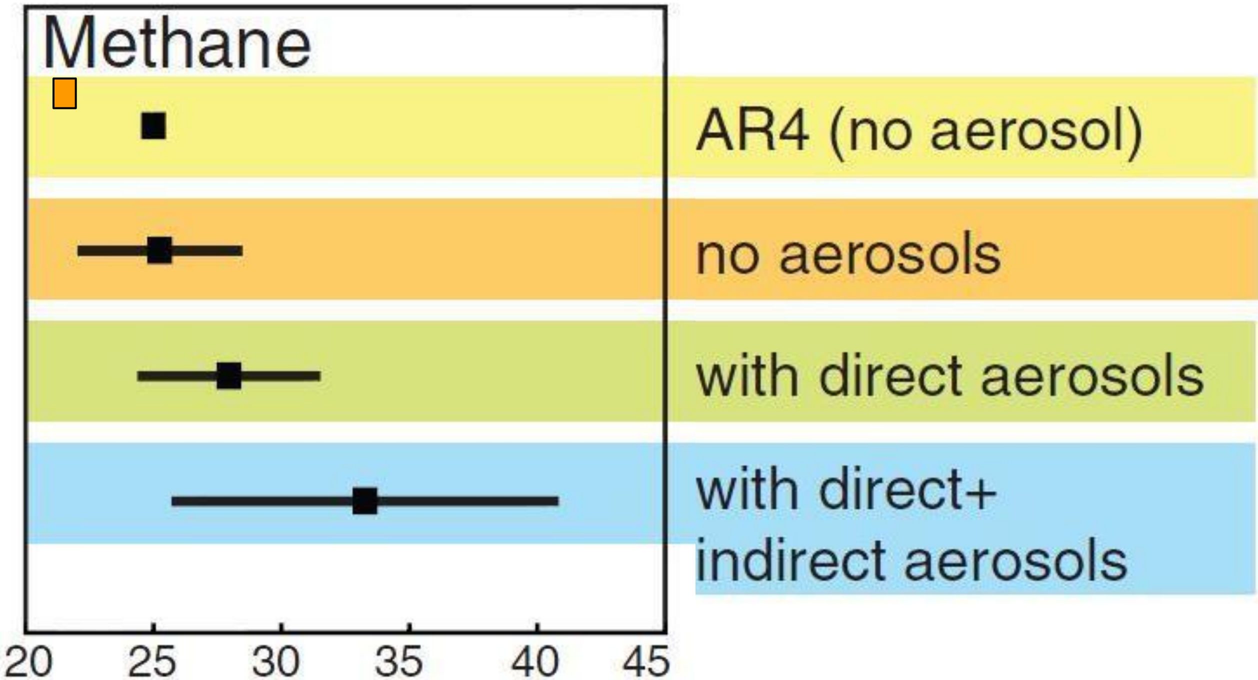
3. Characterization Factors

- IPCC: 6 substances, 3 substances dominate
- GHG counting:
  - o C-fossil emitted as CO_2: GWP = 1 Kg CO_2-eqivalents/ kg CO_2
  - o C-fossil bound: GWP = 0
  - o C-biogenic emitted as CO_2: GWP = 0
  - o C-biogenic bound: - 3.67 Kg CO_2-eqivalents/ kg C bound
  - o avoided C-fossil emitted as CO_2: GWP = -1 Kg CO_2-eqivalents/kg CO_2
  - o avoided C-biogenic emitted as CO_2: GWP = 0
  - o release of bound C-biogenic: 3.67 Kg CO_2-eqivalents/ kg C released
- CH_4 (see next) and N_20 (298 times CO_2)
- Occasionally SF_6, CFCs
- Critical: CO_2-biogenic, CH_4 and C-bound



(Christensen et al., 2009)
C
100C
8
C
Waste
management
MRF
1
5
2
4
3
6
100C
100C
Production
Consumption
Industry
Energy
200C
Exchange
11
7
10
9
200C
Forestry
Energy sector

CH_4 Characterization factor: 100 year



1kgCH_4=25 kgCO_2-eq up to 40kgCO_2-eq. or even higher if a shorter time horizon is applied

Shindell *et al.* 2009, Science

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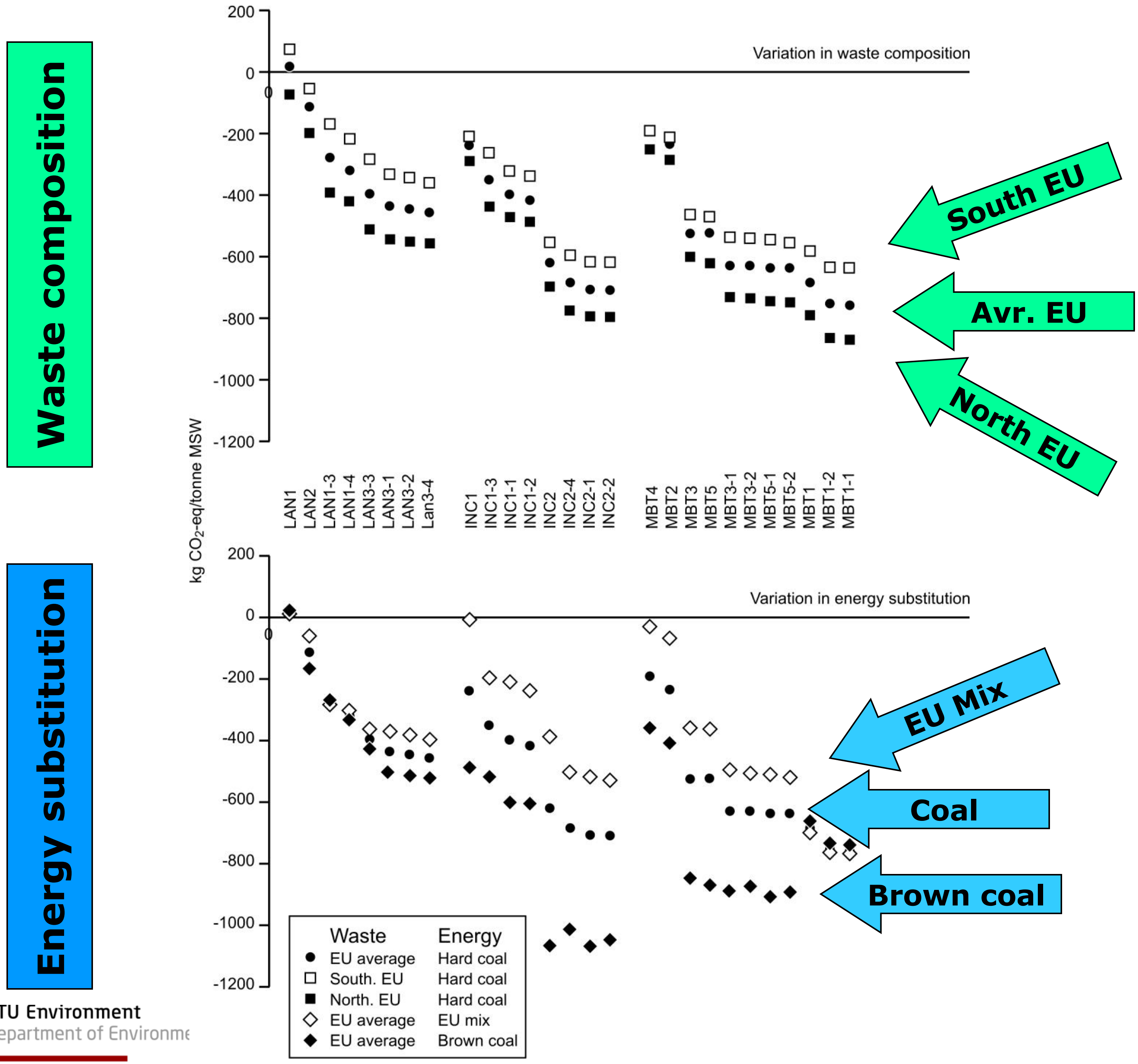
Waste composition
Energy substitution
Variation in waste composition
Variation in energy substitution
kg CO_2-eq/tonne MSW
200
0
-200
-400
-600
-800
-1000
-1200
LAN1
LAN2
LAN1-3
LAN1-4
LAN3-3
LAN3-1
LAN3-2
Lan3-4
INC1
INC1-3
INC1-1
INC1-2
INC2
INC2-4
INC2-1
INC2-2
MBT4
MBT2
MBT3
MBT5
MBT3-1
MBT3-2
MBT5-1
MBT5-2
MBT1
MBT1-2
MBT1-1
South EU
Avr. EU
North EU
EU Mix
Coal
Brown coal
Waste Energy
EU average Hard coal
South. EU Hard coal
North. EU Hard coal
EU average EU mix
EU average Brown coal

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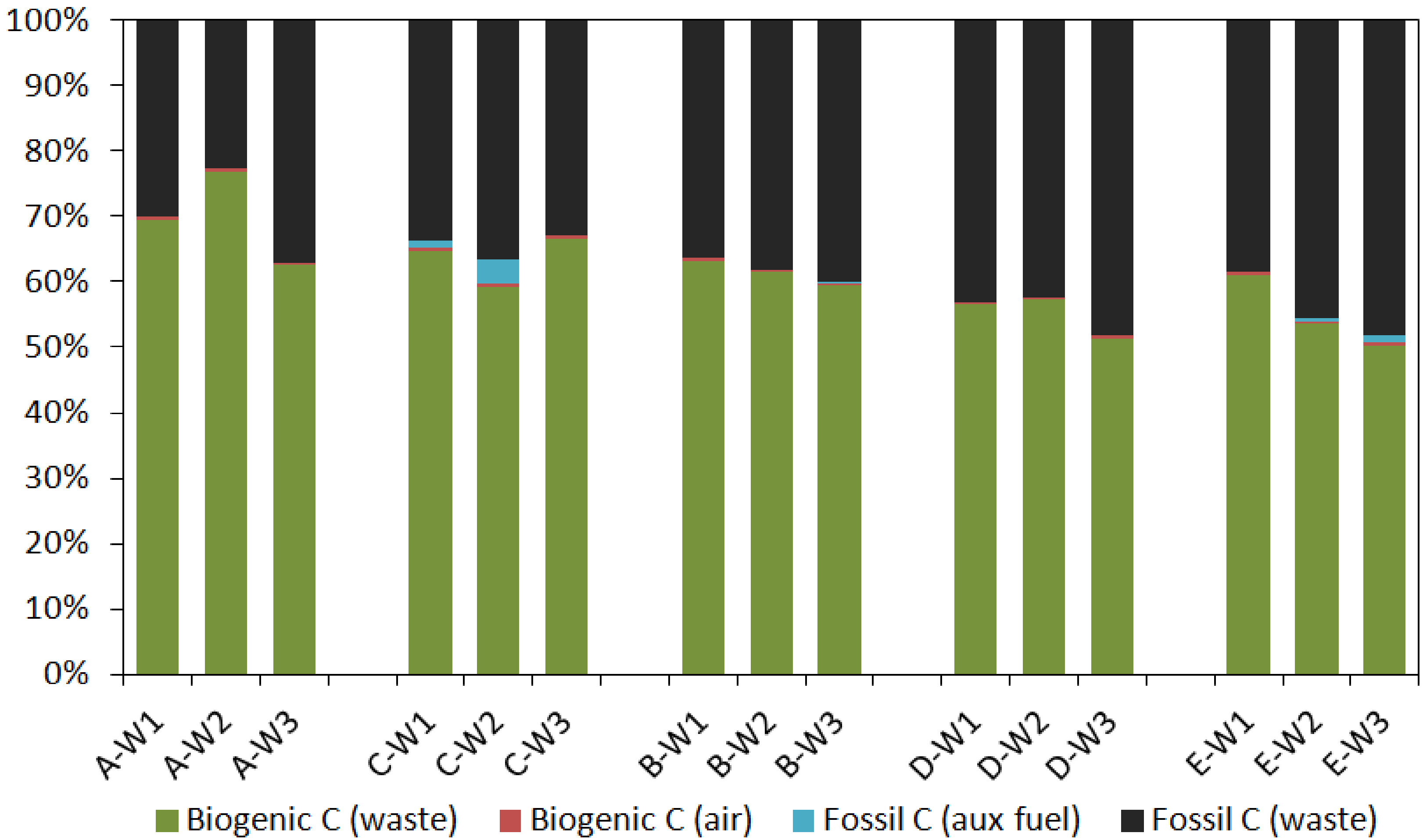
Waste incineration: National CO_2 inventories: CO_2 emission factors

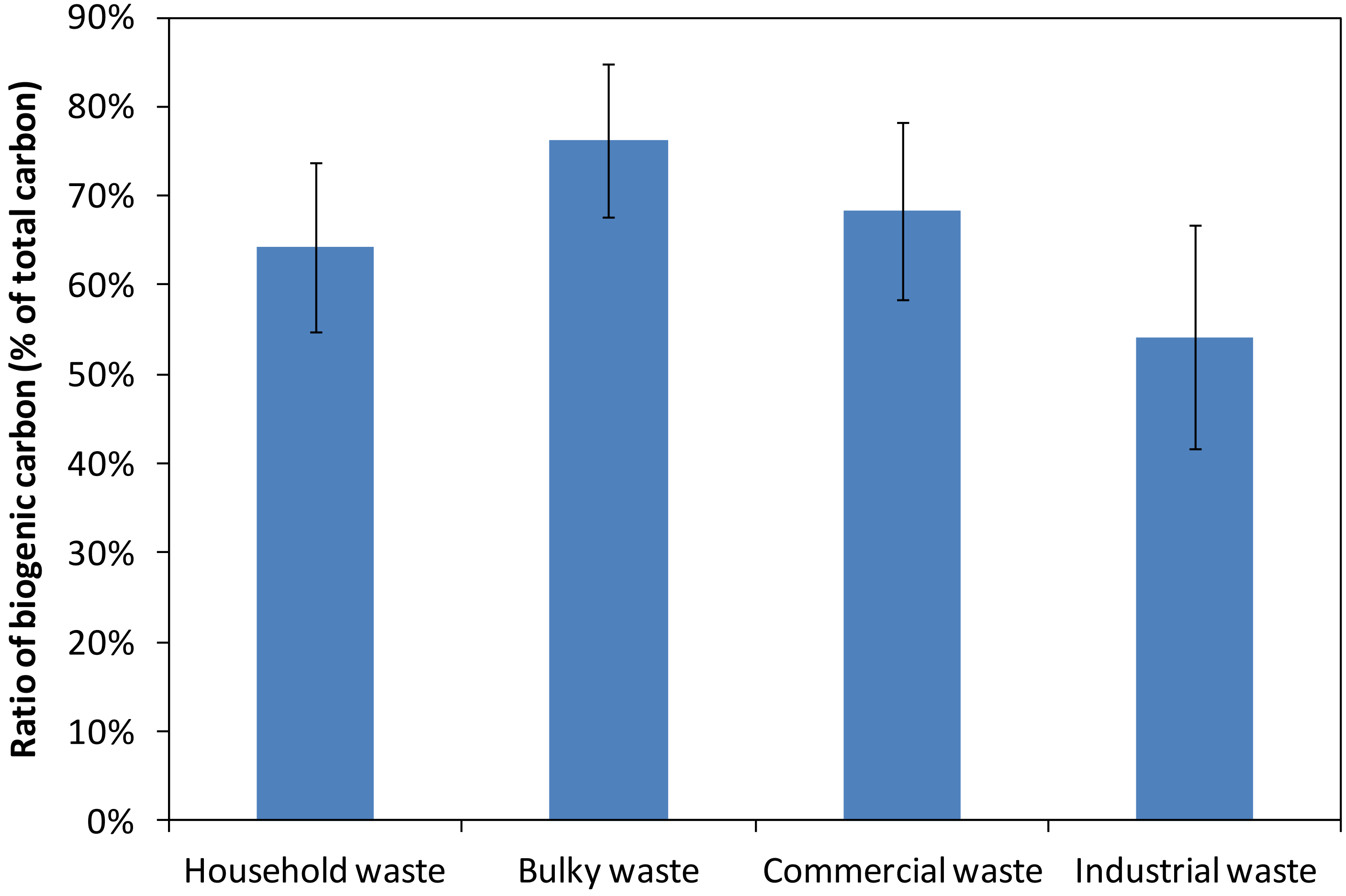
	kg CO_2/GJ
Germany	91.5
The Netherlands	73.6
France	54.7
Austria	48.9
Switzerland	45
Great Britain	41
Finland	31.8
Sweden	25
Norway	24
Denmark	17.6 **---> 32.5** **---> 37**

Data are based on National IPCC reports, Survey done by NERI (Denmark) around 2009

Waste incineration:
C14 method: 5 plants over 3 weeks



Waste incineration:
C14 method: 1 plant and 4 waste types



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Larsen, A.W.; Fuglsang, K.; Pedersen, N.H.; Fellner, J.; Rechberger, H.; Astrup, T. (2012): Importance of variability in waste composition for determination of fossil carbon emissions from waste incineration. Manuscript

Waste incineration: Emission factors and carbon contents

		A*	B	C	D	E
LHV	GJ/tonne	10.6	11.0	9.7	11.1	11.0
Fossil carbon ratio	% C total	30.8	38.4	35.2	44.7	44.5
Total Carbon	kg C/tonne	274	310	255	327	341
Fossil Carbon	kg C/tonne	84	119	90	146	152
Emission factor (fossil CO_2)	kg CO_2/GJ	29	40	34	48	51
Emission factor (fossil CO_2)	kg CO_2/tonne	309	438	327	537	556

*) Based on monthly samples, one sample excluded due to lack of operational data from plant.

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Composting:
GHG from home composting (90% food waste)

Emissions of CO_2, CH_4, N_2O and CO expressed in kg g^{-1} ww (as given in Andersen et al., 2010a) and as percent of total C and N emissions respectively, for home composting of organic kitchen waste (OHW) during 1 year.

Unit	Gaseous emissions							
	EF[a] (kg Mg^{-1} ww)				Percent of total C (or N) emissions (%)			
	CO_2	CH_4	N_2O	CO	CO_2	CH_4	N_2O	CO
1	252	4.2	0.45	0.10	81	3.7	5.5	0.05
2	240	3.7	0.39	0.09	92	3.9	4.6	0.06
3	209	0.8	0.36	0.08	78	0.8	4.3	0.05
4	236	1.0	0.55	0.13	95	1.1	6.3	0.08
5	177	0.4	0.30	0.08	51	0.3	2.8	0.04
6	189	0.6	0.32	0.07	83	0.7	5.1	0.05

[a] EF, emission factor

Times 25 + **Times 298** = **170 kg CO2 equiv./ t**

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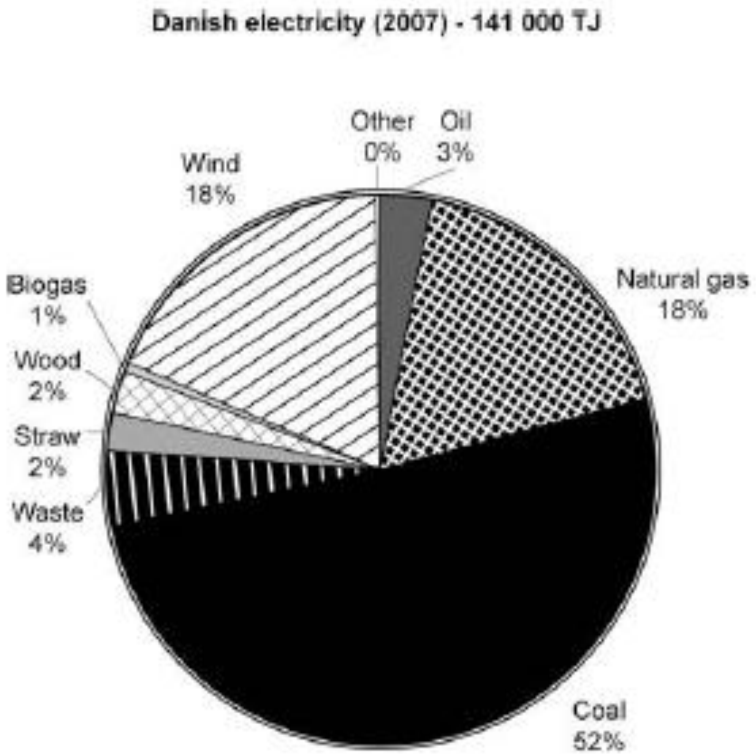
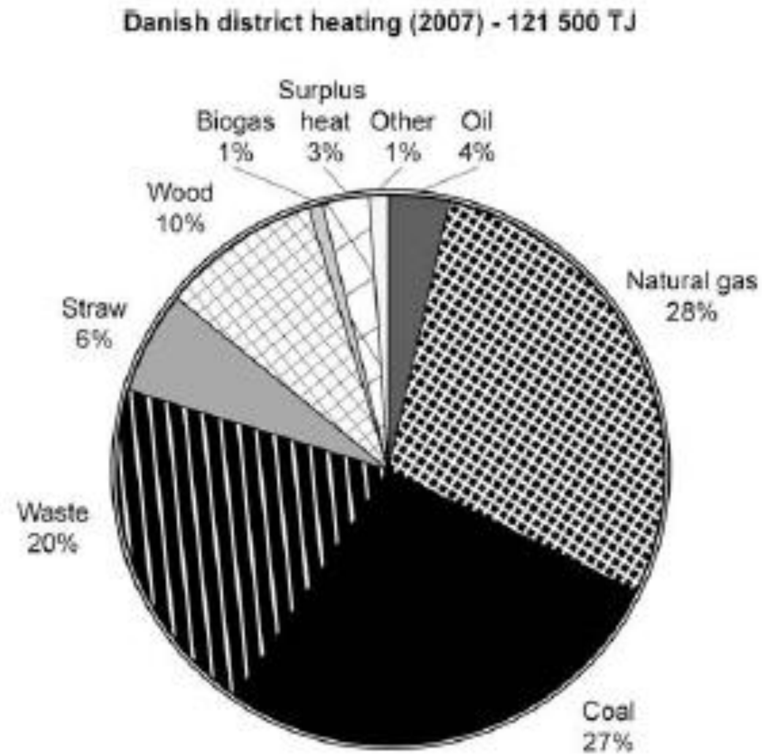
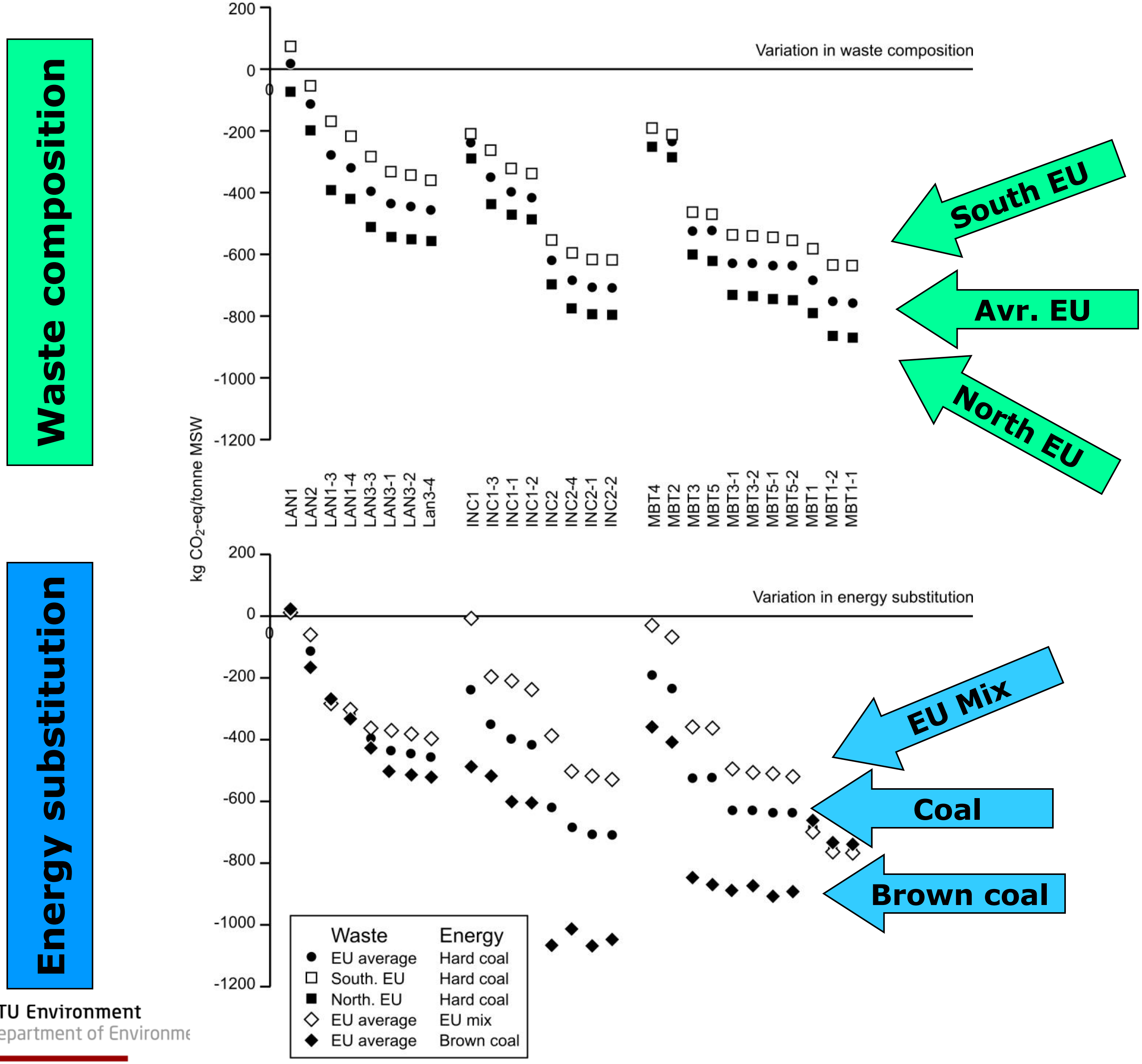
Energy substitution:
Average or marginal? Which marginal?





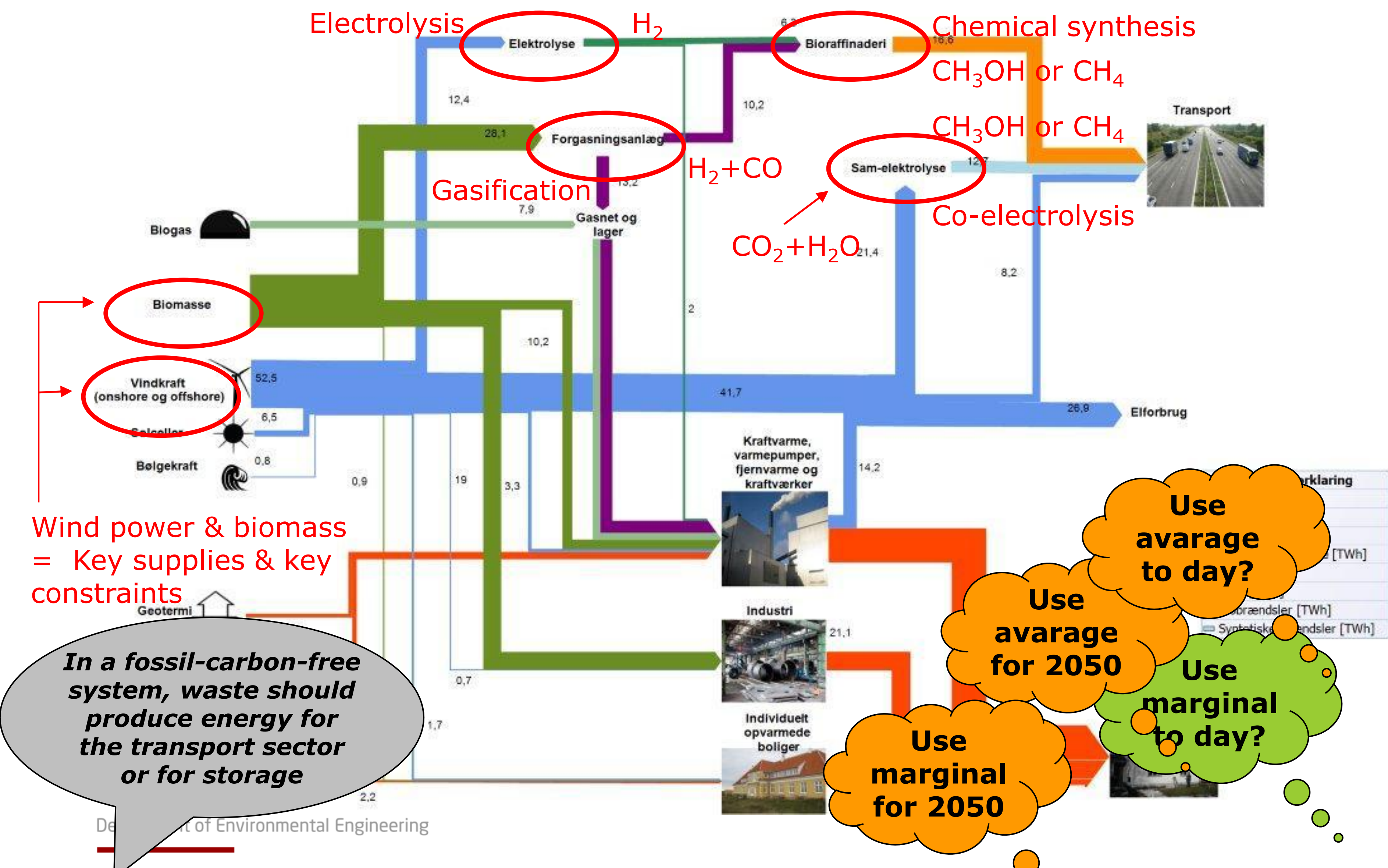
T Fruergaard, T H Christensen & T Astrup (2010):
Energy recovery from waste incineration
Assessing the importance of district heating networks.
Waste Management, **30**, 1264-1272



Waste composition
Energy substitution
kg CO2-eq/tonne MSW
Variation in waste composition
Variation in energy substitution
South EU
Avr. EU
North EU
EU Mix
Coal
Brown coal
LAN1
LAN2
LAN1-3
LAN1-4
LAN3-3
LAN3-1
LAN3-2
Lan3-4
INC1
INC1-3
INC1-1
INC1-2
INC2
INC2-4
INC2-1
INC2-2
MBT4
MBT2
MBT3
MBT5
MBT3-1
MBT3-2
MBT5-1
MBT5-2
MBT1
MBT1-2
MBT1-1
Waste Energy
EU average Hard coal
South. EU Hard coal
North. EU Hard coal
EU average EU mix
EU average Brown coal

Danish energy 2050: 100 % renewable

CEESA research project, Wenzel et al



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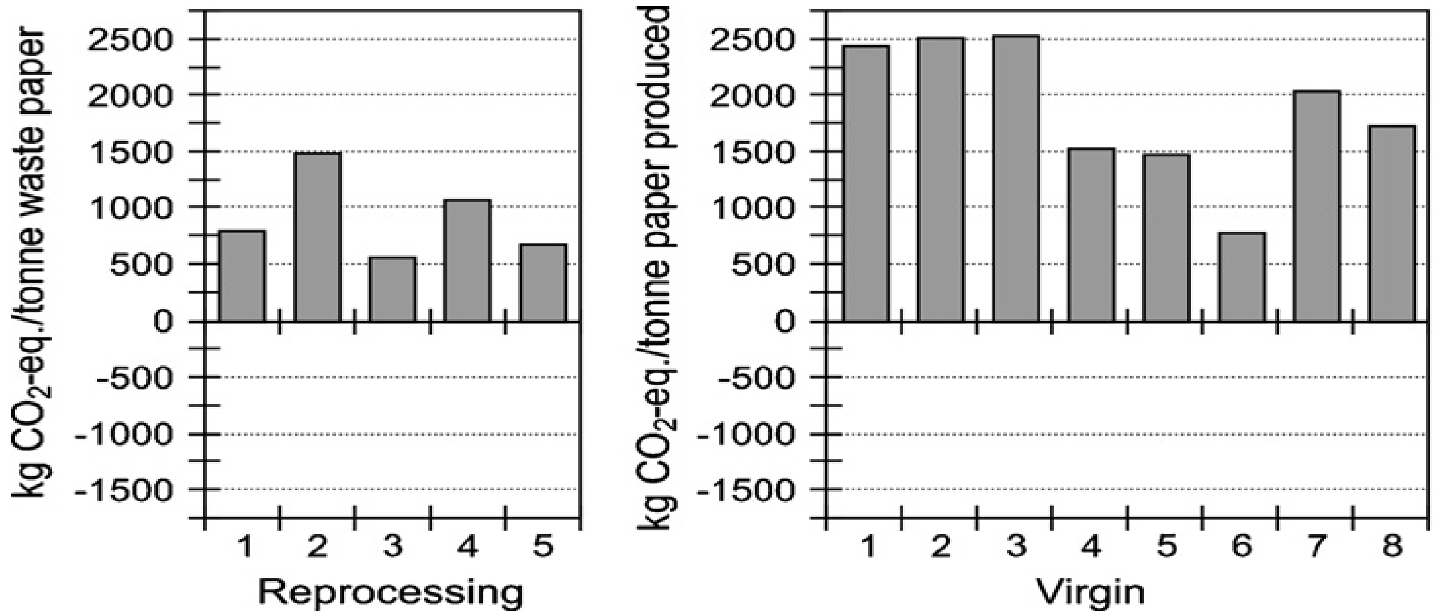
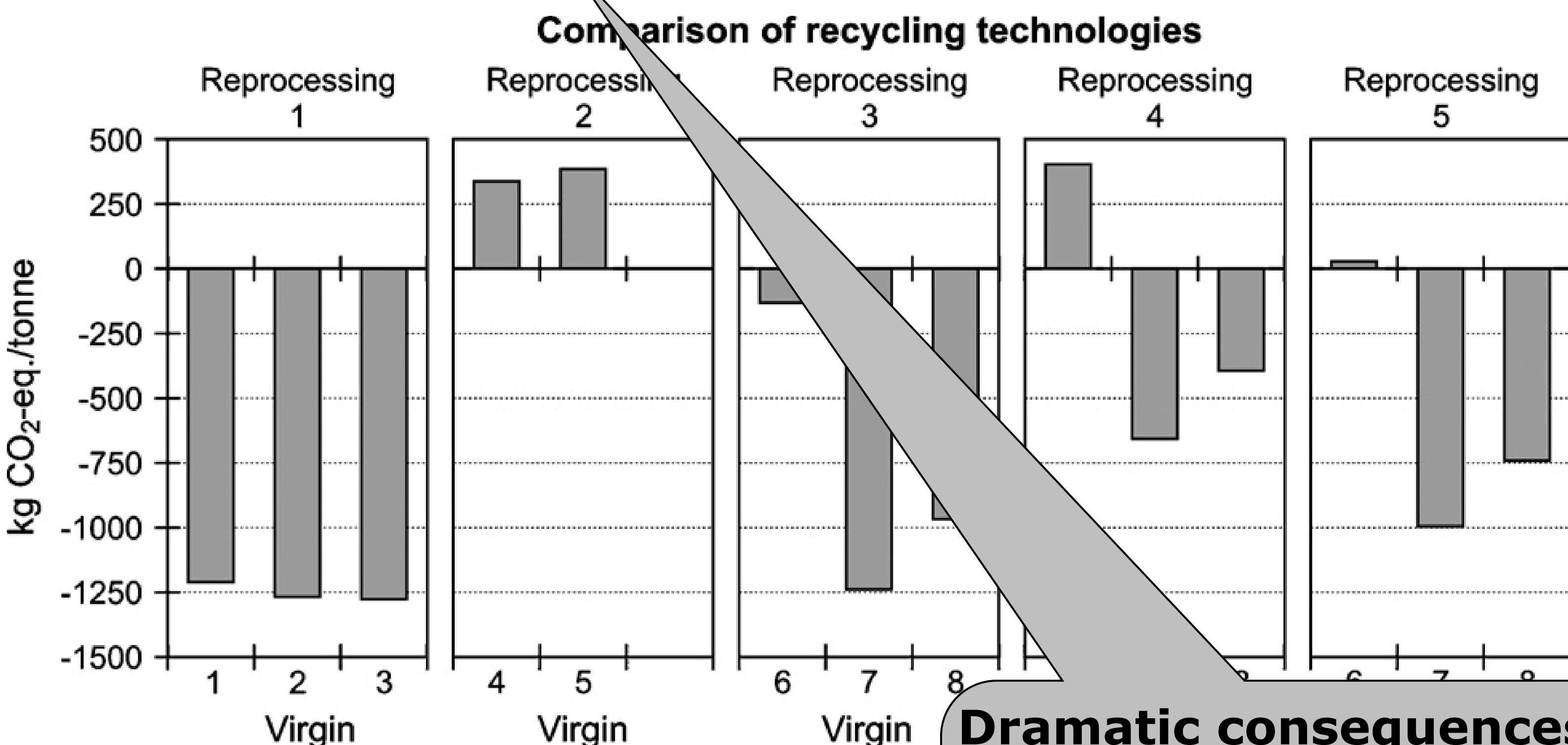
Paper recycling: Reprocessing – A ● virgin-processing



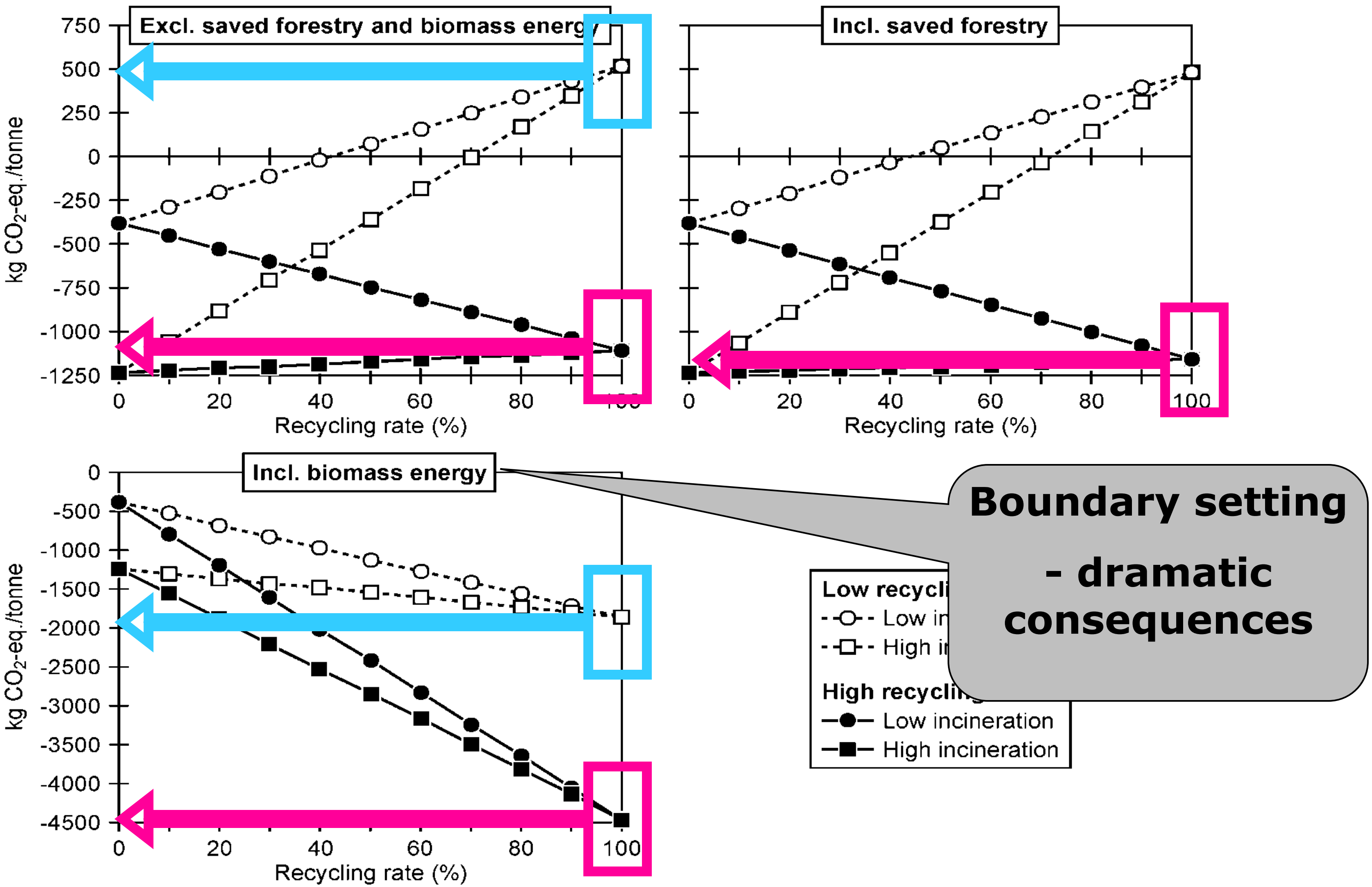
Paper recycling:
Reprocessing – A ● virgin-processing = ?



Dramatic consequences:

- **Market conditions**
- **Often no link between reprocessing and virgin**

Boundaries: Cascading - paper



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Exchange with material production: Example private use of compost