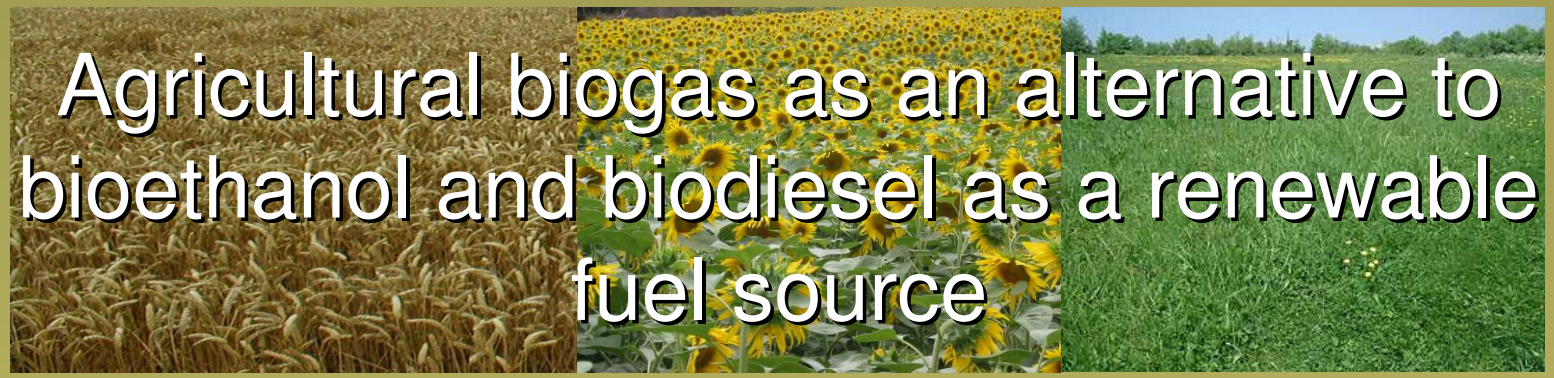

Agricultural biogas as an alternative to bioethanol and biodiesel as a renewable fuel source

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Biogas - Explosive Potential!

20th November 2006

South Somerset District Council

University of Southampton

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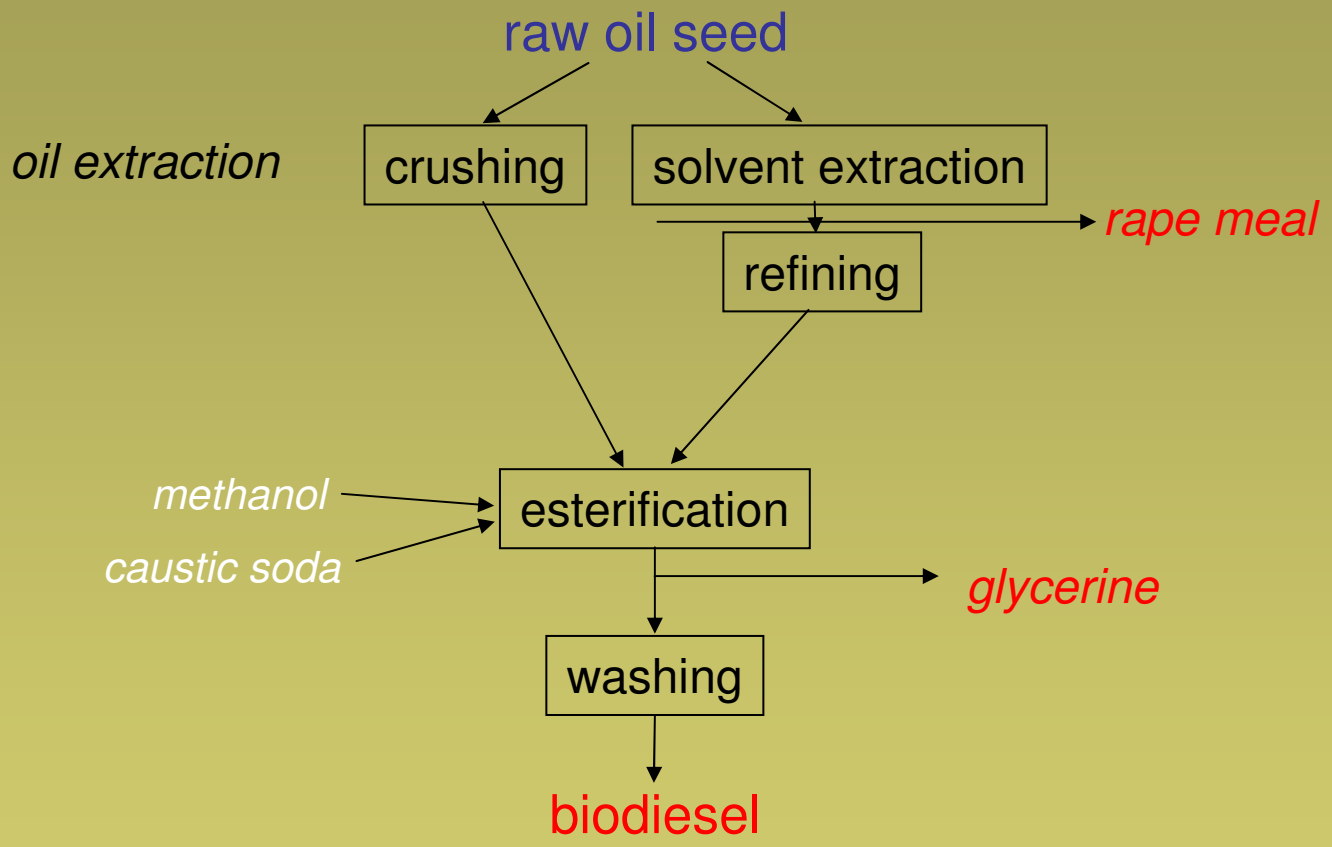
Outline

- renewable biomass based fuels
- crops as fuel sources
- energy balances
- fuel uses
- the CO_2 cycle
- conclusion

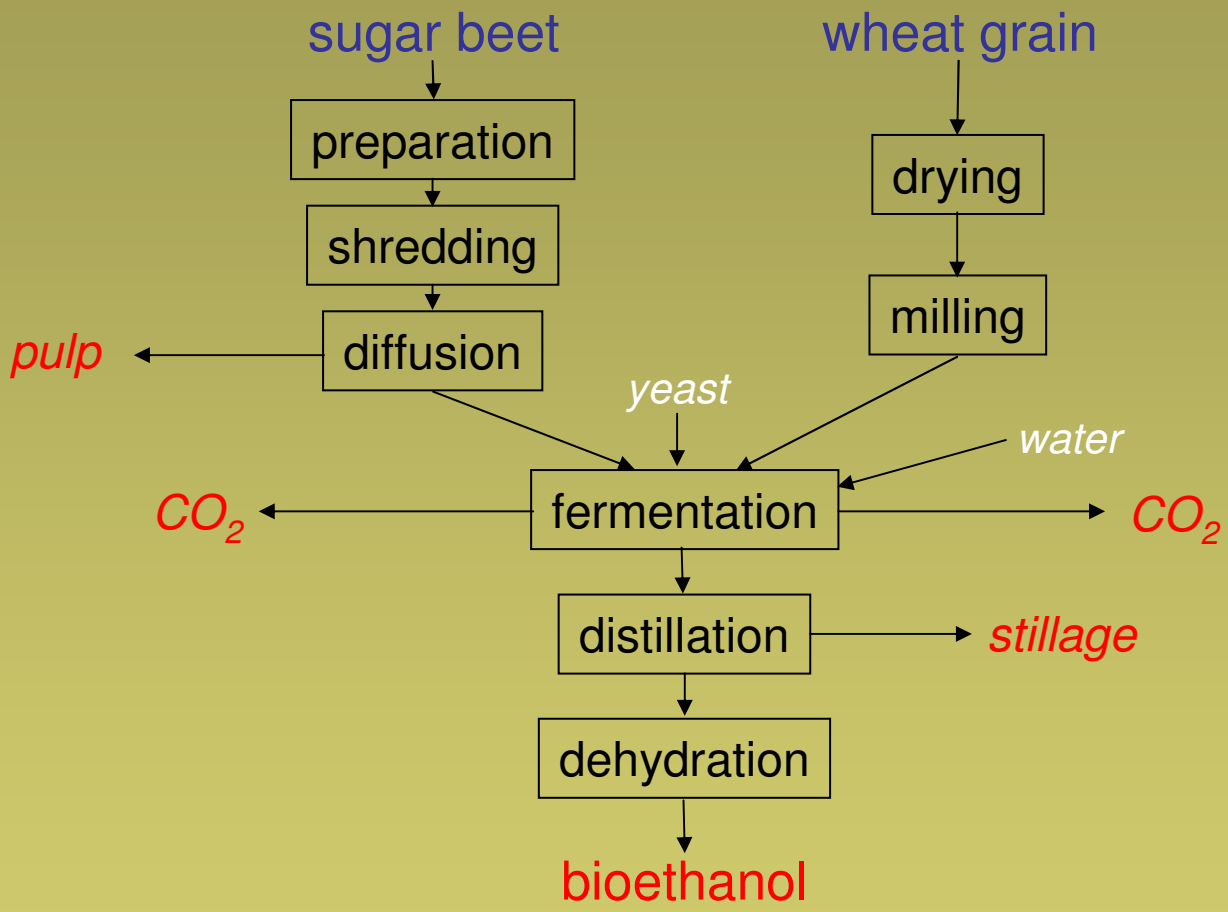
Renewable biomass fuels

- Bioethanol
- Biodiesel
- Biogas
- *Combustion*

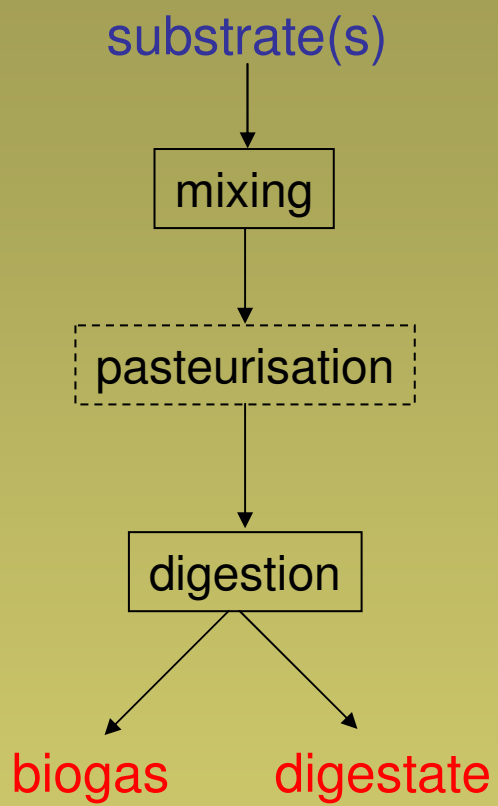
Biodiesel – process



Bioethanol – process



Biogas - process



Inputs and outputs

	inputs	*outputs*	*by-products*
biodiesel	crop, methanol	biodiesel	glycerine, meal,
bioethanol	crop	bioethanol	CO_2, stillage
biogas	crop, crop wastes, slurry etc.	biogas, digestate	

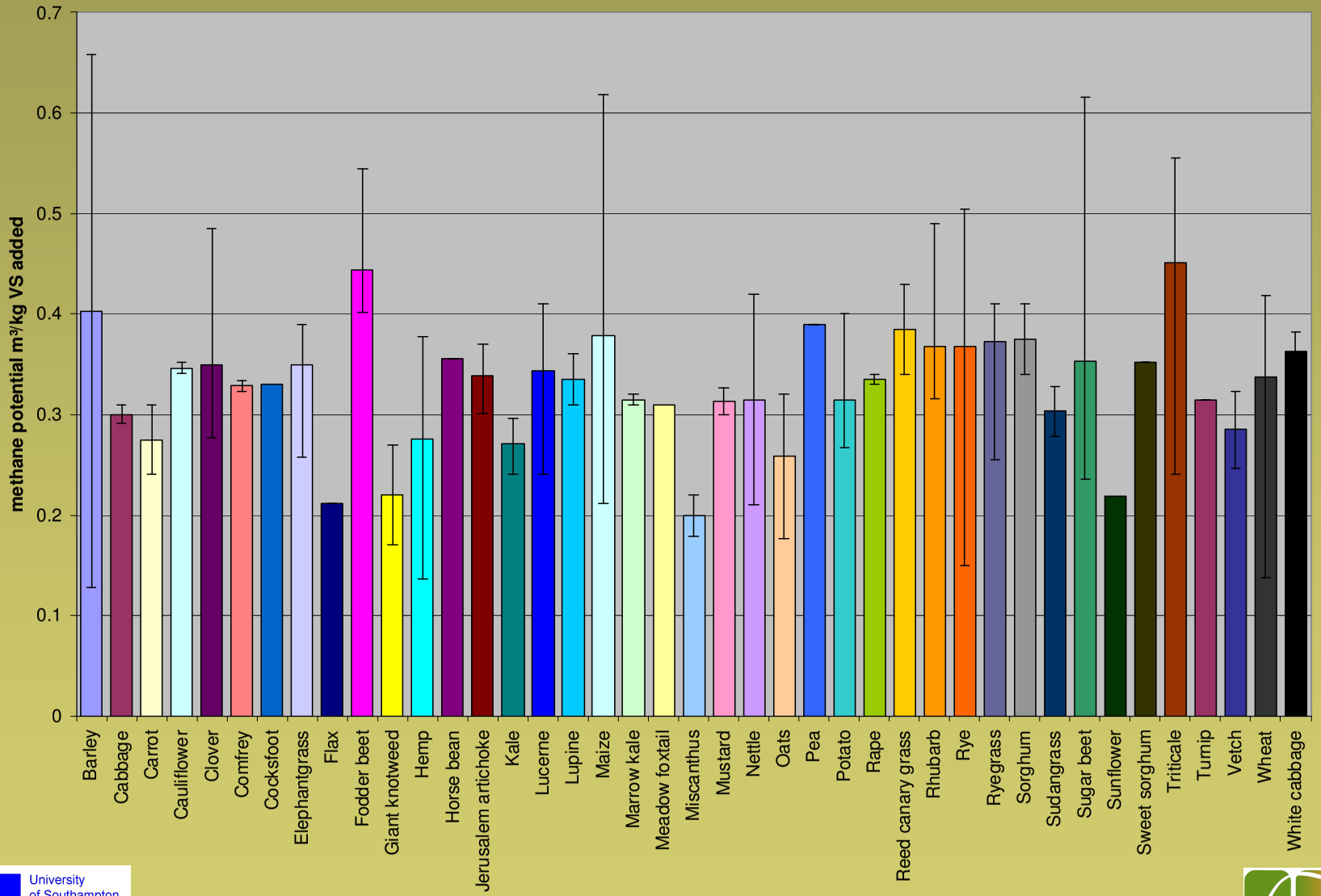
Feedstocks for biofuel production

- for biodiesel
  - oilseed rape
  - sunflower
  - linseed
  - soya
  - peanut
- for bioethanol
  - wheat
  - sugar beet
  - maize
  - sugar cane
  - *lignocellulosic material*
- for biogas
  - crops
  - agricultural wastes
  - green waste

Potential crops for biogas -

- Barley
- Cabbage
- Carrot
- Cauliflower
- Clover
- Elephant grass
- Flax
- Fodder beet
- Giant knotweed
- Hemp
- Horse bean
- Jerusalem artichoke
- Kale
- Lucerne
- Lupin
- Maize
- Marrow kale
- Meadow foxtail
- Miscanthus
- Mustard
- Nettle
- Oats
- Pea
- Potato
- Rape
- Reed canary grass
- Rhubarb
- Ryegrass
- Sorghum
- Sugar beet
- Triticale
- Turnip
- Verge cuttings
- Vetch
- Wheat

Potential methane yields



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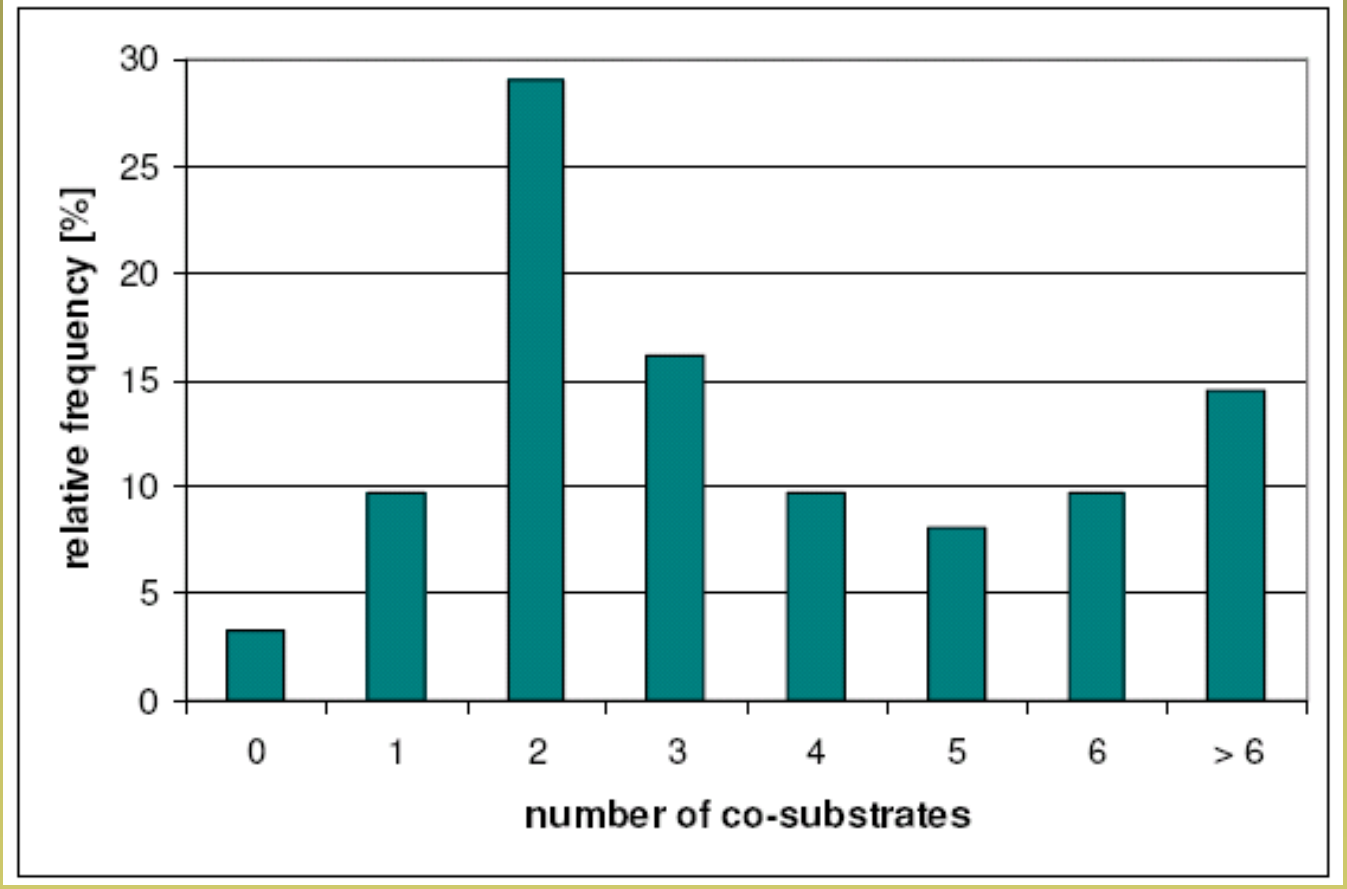
Agricultural substrates commonly used for anaerobic digestion

- Silage maize
- Maize corn
- Grass silage
- Pig slurry
- Cattle slurry

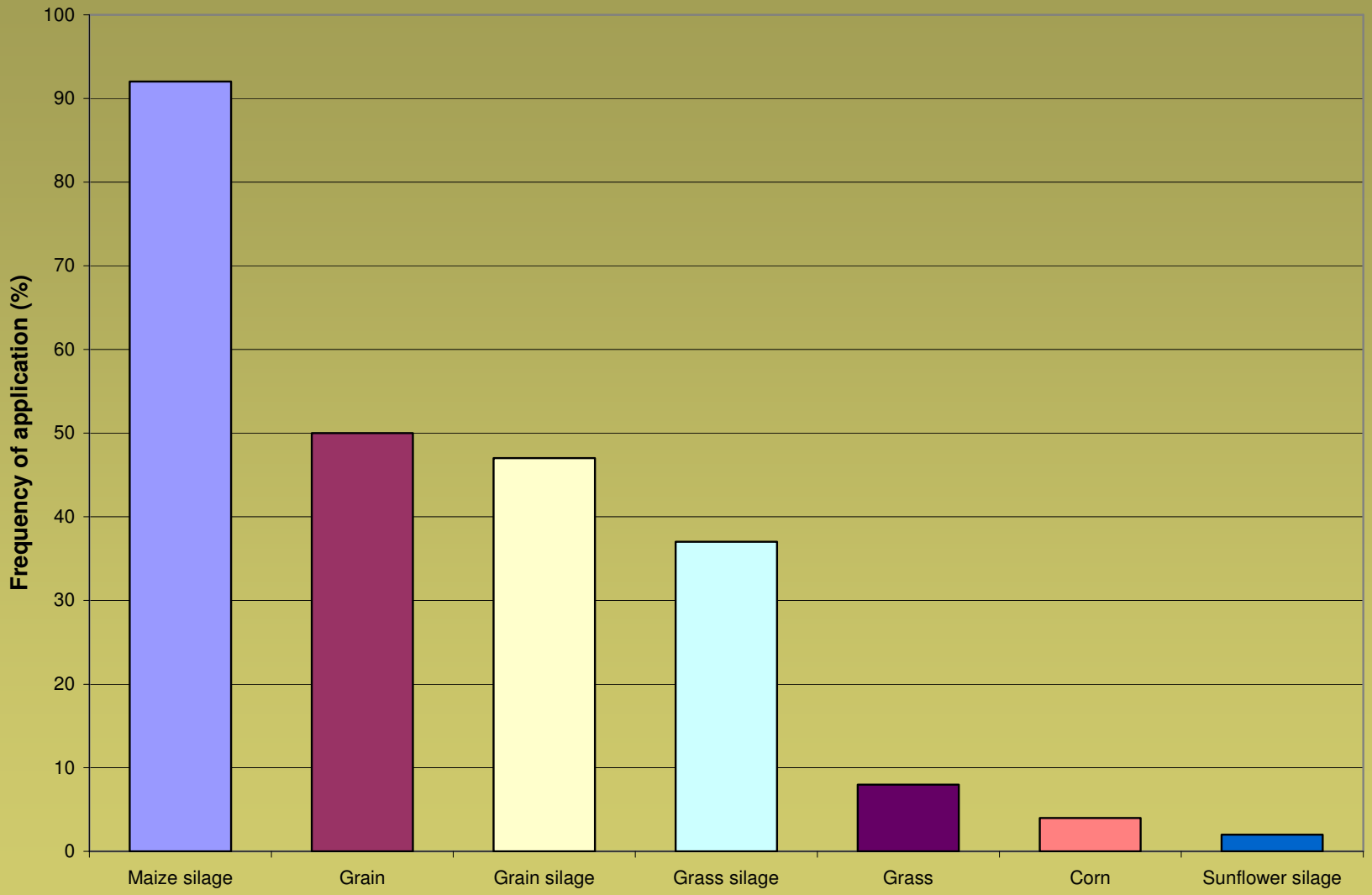
- *often used as co-substrates*

Number of applied co-substrates in modern biogas plants (Germany)



Weiland, P., Rieger, C. & Ehrmann, T. (2003) Evaluation of the newest biogas plants in Germany with respect to renewable energy production, greenhouse gas reduction and nutrient management. *Future of Biogas in Europe II,*. Esbjerg.

Crop based digestion in Germany



Weiland, P. (2006) report to the 5th meeting of the IEA Bioenergy Task 37

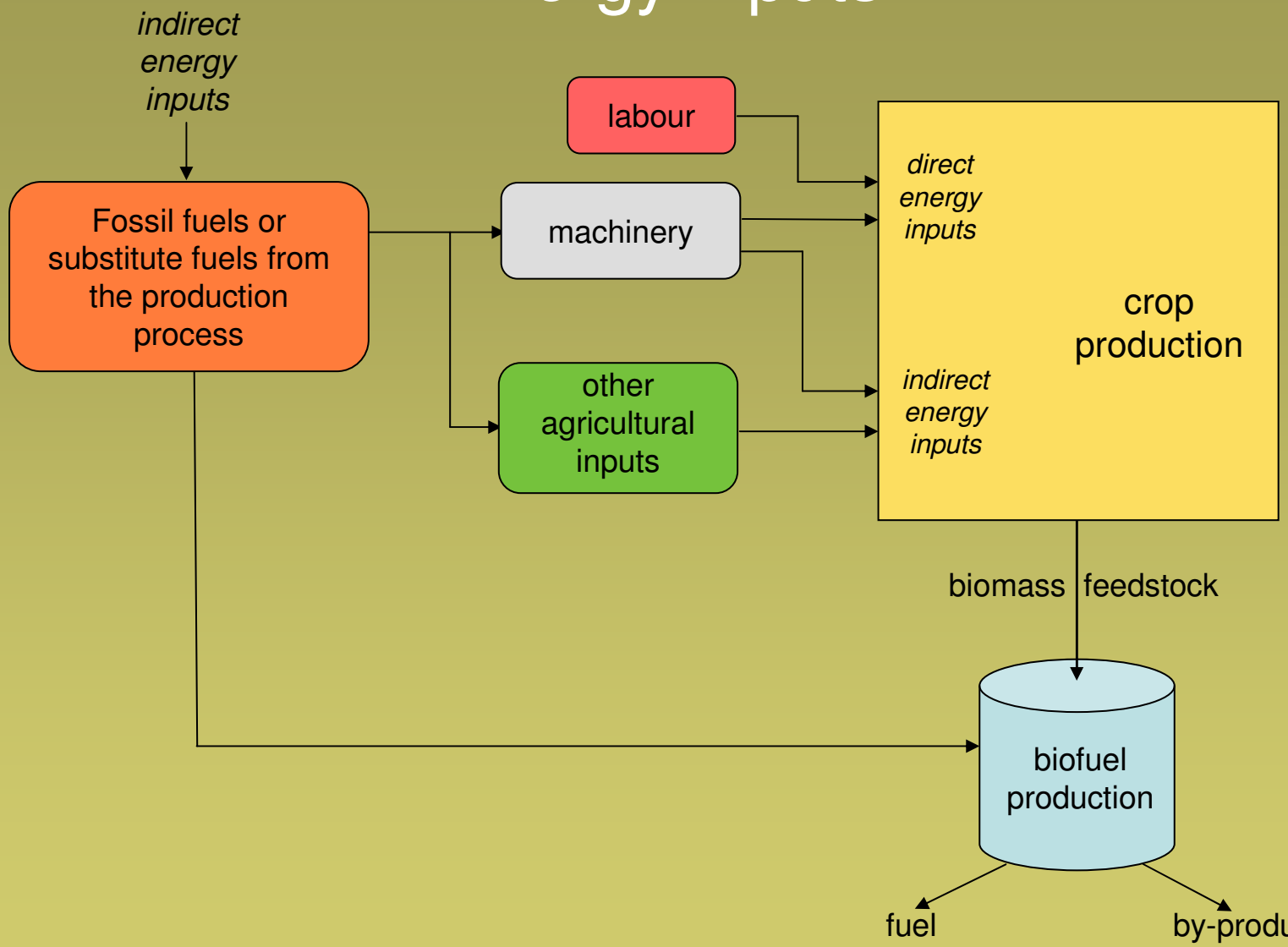
Scales of production

- Farm based - (farmer can produce most of the feedstock to produce fuel for own use plus a little extra)
- Medium sized - (input material sourced from a number of farms, can supply farmers and excess which can be sold)
- Large scale - (1000s of tonnes of input material – commercial enterprises).

Energy balance

- Inputs / outputs
- Direct energy
- Indirect energy
- Energy balance
- Energy ratio

Energy inputs



Direct and indirect energy

- Direct energy
  - consumption of energy directly in the production process - includes:
    - fossil fuels
    - labour
- Indirect energy
  - energy which has been used in producing something then used in the production process - includes:
    - fertiliser
    - pesticides / herbicides
    - machinery

Direct & indirect energy inputs

	energy input type	
operation/input	direct	indirect
cultivation	fuel	equipment
fertiliser	application fuel	production, application equipment
harvest	fuel	equipment
fuel		production and transport
processing	heat, power	construction
product distribution	fuel	transport equipment

Example energy comparisons

crop	OSR seed (1,2)	wheat grain (1,2)	sugar beet (2)	wheat grain	sugar beet	maize
fuel produced	biodiesel	bioethanol	bioethanol	biogas		
fertiliser (N kg ha^{-1})	180 -195	150 -195	147	150	147	150
crop yield (t DM ha^{-1})	2.9 - 3.8	6.9 - 7.7	11.5	6.9	11.5	12.6
energy for crop production (GJ t^{-1}DM)	3.2 - 4.4	1.7 - 1.8	1.04	1.9	1.04	1.2
energy for processing (GJ t^{-1}DM)	3.2 - 4.6	1.9 - 6.6	3.6	0.9	0.9	0.9
energy of fuel produced (GJ t^{-1}DM)	13.9 -14.4	8.8 - 9.6	10.2	13.6	12.4	9.3
net energy produced (GJ t^{-1}DM)	6.35 - 9.5	1.3 - 5.1	5.6	10.9	10.5	7.2
output/input ratio	*1.8 - 2.9*	*1.2 - 2.4*	*2.2*	*4.9*	*6.4*	*4.4*
net energy produced (GJ ha^{-1})	**10 - 18**	**10 - 35**	**64**	**70**	**115**	**89**

1) Richards, I. R. (2000) *Energy balances in the growth of oilseed rape for biodiesel and of wheat for bioethanol.*, British Association for Bio Fuels and Oils (BABFO), Levington Agriculture Report.
2) Elsayed, M. A., Matthews, R. and Mortimer, N. D. (2003) *Carbon and Energy Balances for a Range of Biofuels Options*, School of Environment and development, Sheffield Hallam University, B/B6/00784/REP.

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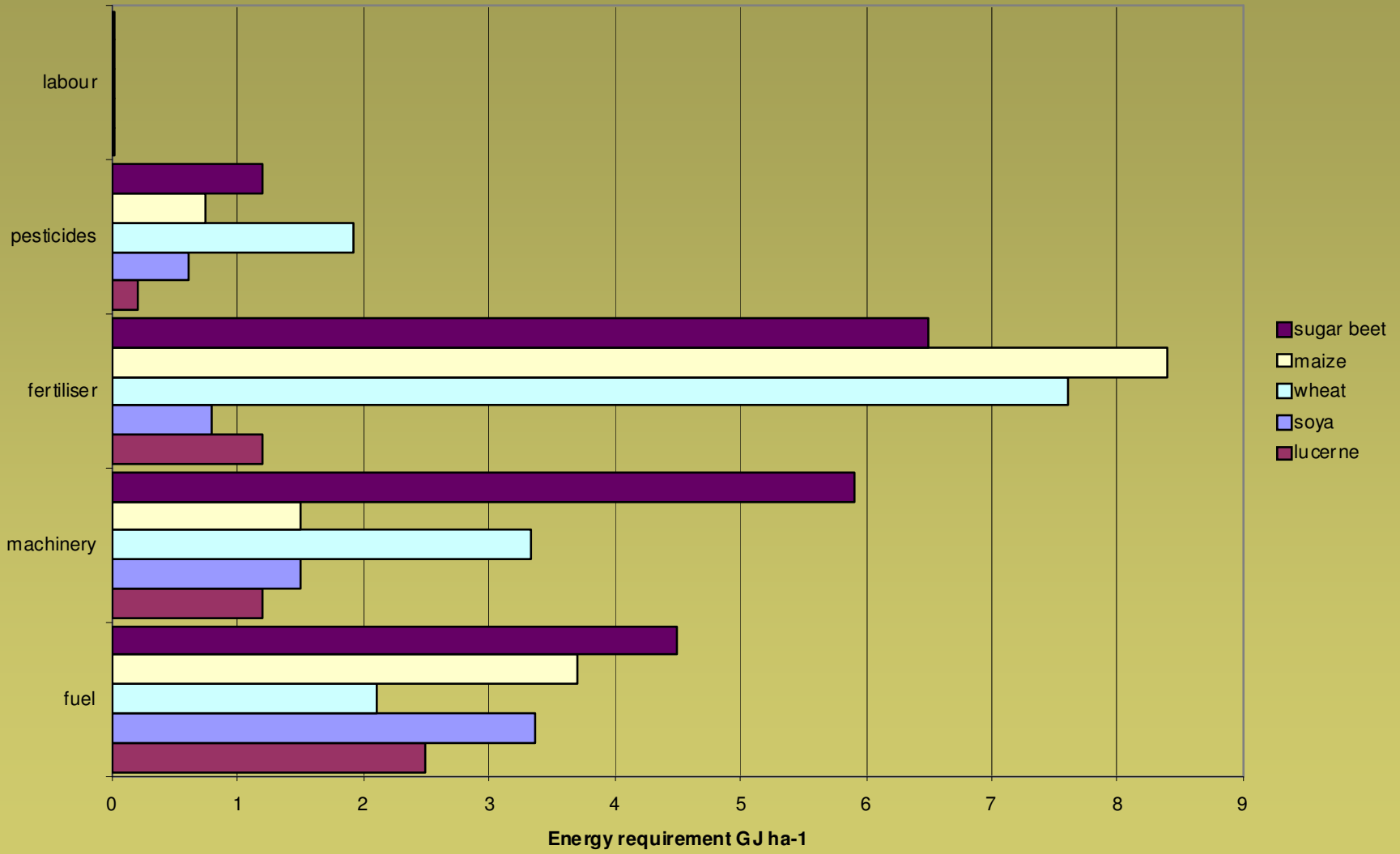
Crop production inputs



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Digestate

- the digestate is what remains after the biogas has been removed
- it contains most of the nutrients of the original feedstock
- the nutrients are in a form which are more available for crop uptake
- it has a consistency similar to slurry (approx 10% solids)
- it can be separated into solid and liquid fractions

Other agricultural inputs

- crop residues / wastes
  - sugar beet leaves
  - rejected potatoes
- catch crops
  - grow, collect, return the residue to the land

Fuel usage

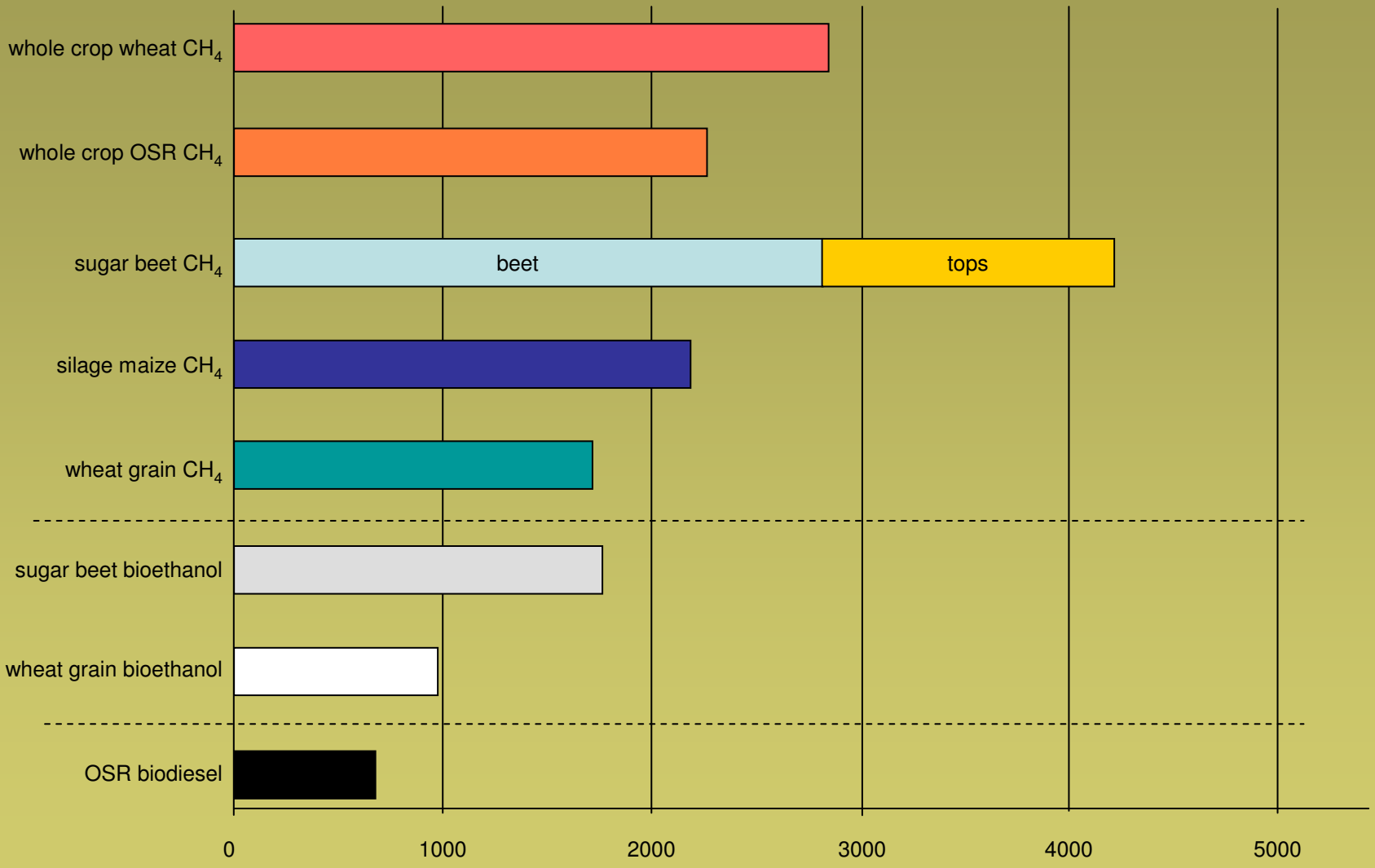
- bioethanol - liquid, mostly used as vehicle fuel
- biodiesel - liquid, mostly used as vehicle fuel

- biogas - gas
  - burn for heat
  - burn in CHP units
  - add to gas grid
  - scrub and use as vehicle fuel (compress for extended range)

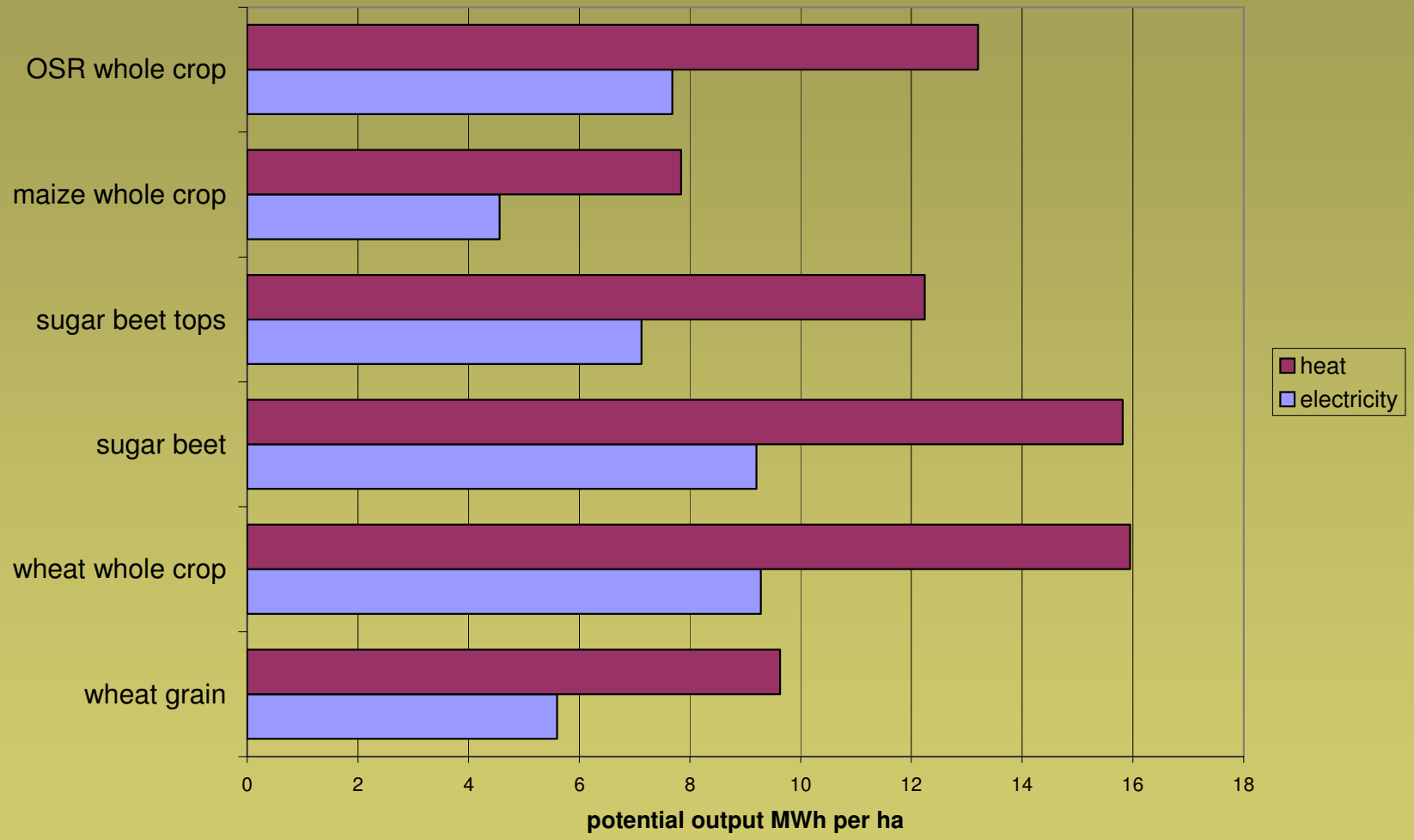
Biogas use

- CHP already well established - land fill gas, electricity production in Austria and Germany
- addition to the gas grid - occurs in Denmark
- use as vehicle fuel - also well established
  - Sweden - 3000 gas powered vehicles, 19 fuel stations in Western Sweden
- biogas trains - Sweden, India, Peru
- the Hardstaff Group (UK) - HGV fleet

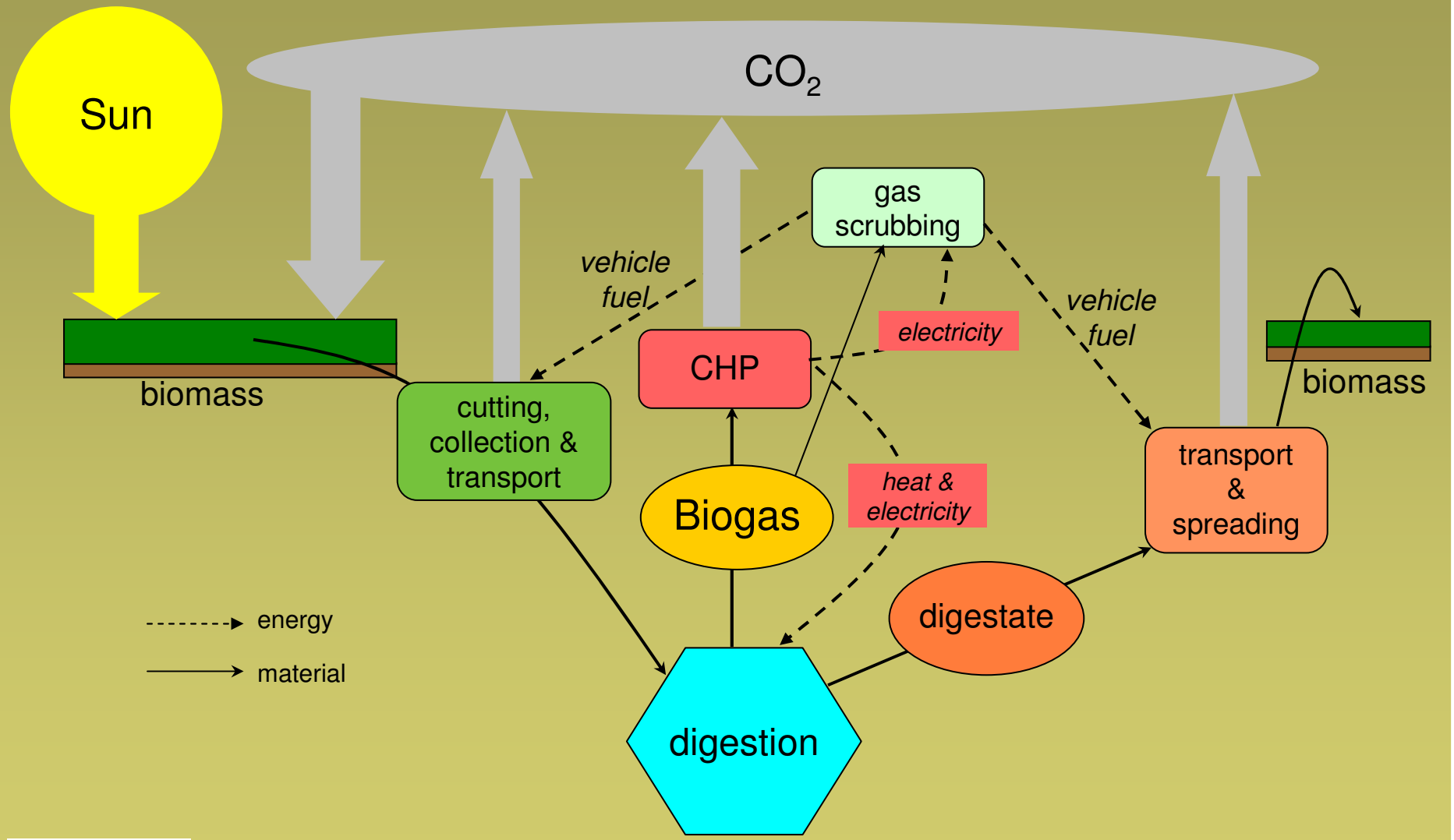
Potential vehicle fuel produced per ha



Potential CHP per hectare



CO_2 and energy cycles



Some benefits of anaerobic digestion

- AD fits well with organic farming
- Allows diversification into ‘other’ crops but not necessarily new ones - allows avoidance of mono-crops
- Provides an alternative use for grassland – does not need to be ploughed up so helps to maintain soil CO_2
- Dairy farms - reduction in pathogens, improved uptake of nutrients, CHP to light and heat farm sheds and buildings.
- Not changing the landscape may be better for environmental reasons, biodiversity, tourism

Conclusions

- We need all possible sources of renewable energy
- Biodiesel – can be done on farm, relatively simple technology, low yield/ha
- Bioethanol – more efficient but requires larger, centralised plants, more transport of grain
- Both of these use a limited range of crops which have high fertiliser requirements requiring energy

Conclusions (2)

- Biogas - scaleable, can be farm based
- Uses a wide range of crops, which can be included in crop rotations, and other organic materials
- Produces digestate which can be used as fertiliser
- Can close the CO_2 and energy cycles

- To get the most out of the available plant material we need a combination of all the processes for producing renewable fuels

Thank you

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