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Crops as energy feedstock and the concept of energy farming

Dr Andrew Salter

TULES Public seminar on sustainable local energy
American centre, Prague, 31st March 2009

BRITISH COUNCIL

RURAL ECONOMY AND LAND USE

Outline

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- Renewable vs. sustainable
- Food vs. fuel
  - available land area
- Biomass - energy conversion processes
- Energy balances
- Maximising land use
- An integrated approach

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Renewable energy

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- Renewable
  - Non-fossil fuel based
  - Biomass based fuels
- Sustainable
  - Can produce the same or more energy each year
  - Without harm to the environment

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Available land area

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- Total land 13 * 10^9 ha
- Agricultural 5 * 10^9 ha (38%)
  - Arable 1.5 * 10^9 ha
  - Grassland 3.4 * 10^9 ha
- Forest cover 3.9 * 10^9 ha (30%)
- Semi-natural vegetation 4.1 * 10^9 ha (32%)

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What are crops?

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- 250,000 species of higher plants in the world
- 1000 species comprise the world's crops
  - These are the species cultivated to provide
    - Food (human & animal)
    - Industrial uses
    - Construction materials
- 80% of edible plant material comes from 11 species (of which two-thirds are cereals)

Major food crops

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Crop	World production (t * 10^6)	Contribution to total world food production (%)
Wheat	508	16.3
Rice	485	15.6
Maize	405	13.0
Potatoes	266	8.5
Barley	170	5.5
Cassava	137	4.4
Sweet potatoes	111	3.6
Soya beans	92	3.0
Tomatoes	63	2.0
Sorghum	61	2.0
Leguminous grains	55	1.8
Oats	39	1.3
Millet	31	1.0
Rye	29	0.9
Total food crops	3116	100

(FAO production yearbook)

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Biomass to energy conversion

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Biomass - energy conversion processes

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- Direct use (size reduction, compaction)
  - Combustion and co-firing
- Thermochemical conversion
  - Pyrolysis
  - Gasification
- Physical-chemical conversion
  - Vegetable oils
    - Biodiesel (transesterification)
- Fermentation (biochemical conversion)
  - Anaerobic digestion
  - Bioethanol

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Combustion

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- Is the oldest use of energy crops
- Dry matter >50%
  - Storage stability
  - Removal of moisture requires energy (2.441 kJ/kg water)
- Lignocellulosic materials
  - Wood and wood wastes, Miscanthus, switchgrass, etc.
  - Short rotation forestry (poplar, willow)
  - Agricultural residues (straw, chaff, stover, …)

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Other thermal processes

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- Pyrolysis
  - T = 400-500˚C in the absence of Oxygen
  - Produces pyrolysis oil, tar, charcoal, water and gas

- Gasification
  - T = 800-900˚C
  - Partial oxidation at high temperature with steam and catalyst
  - Produces 'syngas' (mainly H_2, CO & CO_2)

Physical conversion (bio-diesel)

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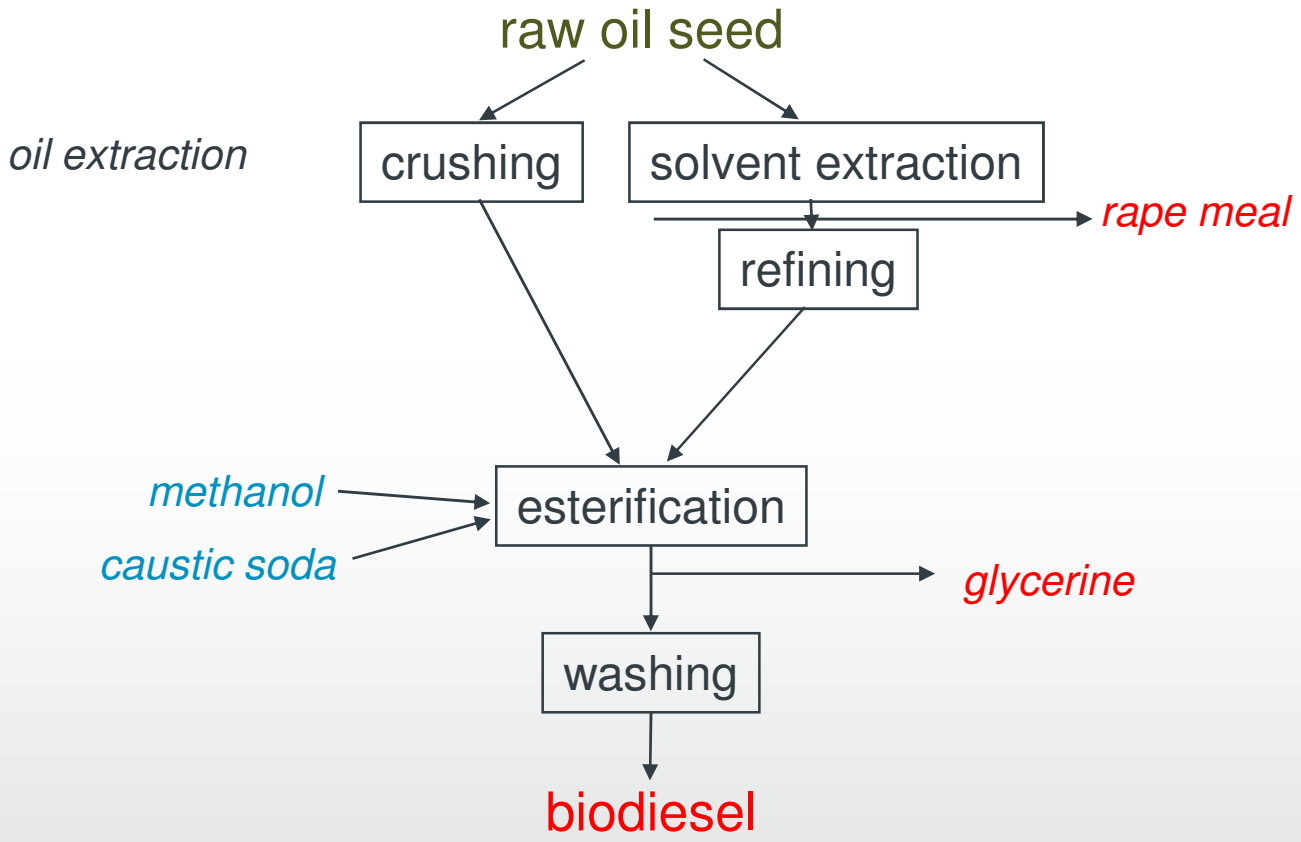

Fermentation (bio-ethanol)

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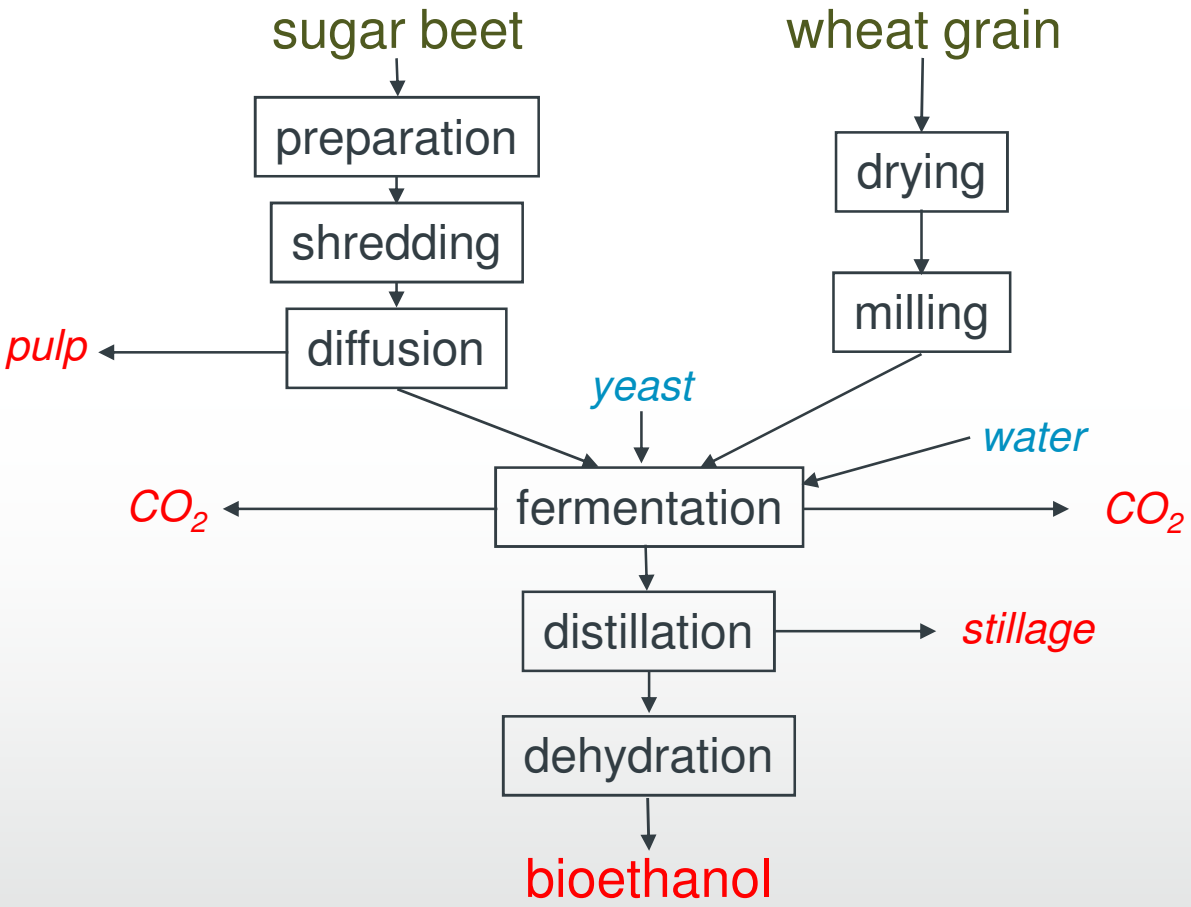

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Fermentation (biogas)

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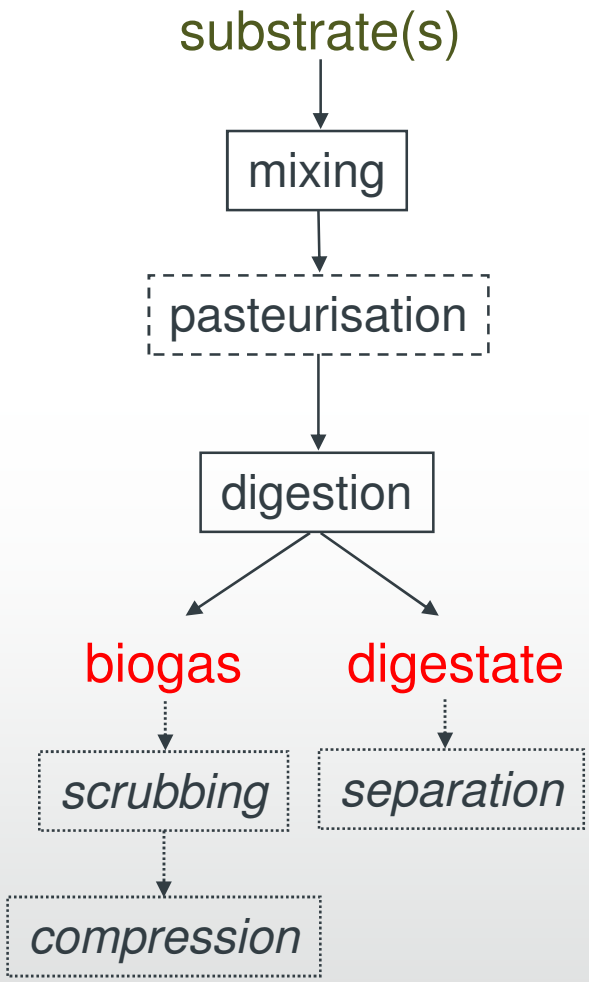

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Crops for bio-fuel production

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- for bio-diesel
  - oilseed rape
  - sunflower
  - linseed
  - soya
  - Peanut
  - Jatropha
- for bio-ethanol
  - wheat
  - sugar beet
  - maize
  - sugar cane
  - *lignocellulosic material*
- for biogas
  - crops
  - agricultural wastes
  - green waste

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Potential crops for biogas -

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- 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
- Oilseed rape
- Reed canary grass
- Rhubarb
- Ryegrass
- Sorghum
- Sugar beet
- Triticale
- Turnip
- Verge cuttings
- Vetch
- Wheat

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Scales of production

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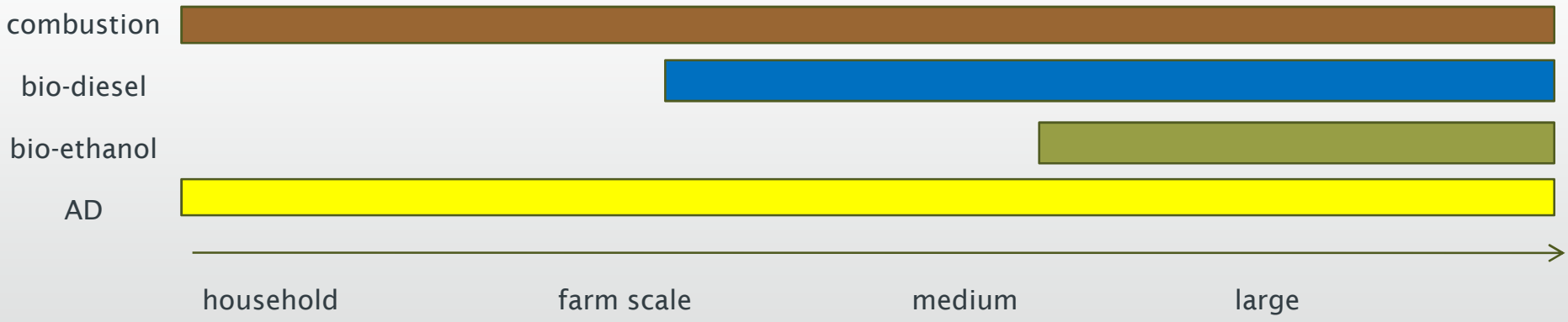
- Farm based - (farmer can produce most of the feedstock to produce fuel for own use plus a little extra)
- Medium sized - (input material sourced from a number of farms, can supply farmers and excess which can be sold)
- Large scale - (1000s of tonnes of input material – commercial enterprises).



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Energy Balances

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Energy balance

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- What is meant by an energy balance?

  = *Energy out - Energy in*

  Energy out / Energy in

- Parasitic inputs
  - Direct energy
  - Indirect energy
- Beneficial outputs
- System boundaries

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System boundaries

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- Need to identify what energy goes in
- What energy comes out

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Three phases of fuel production

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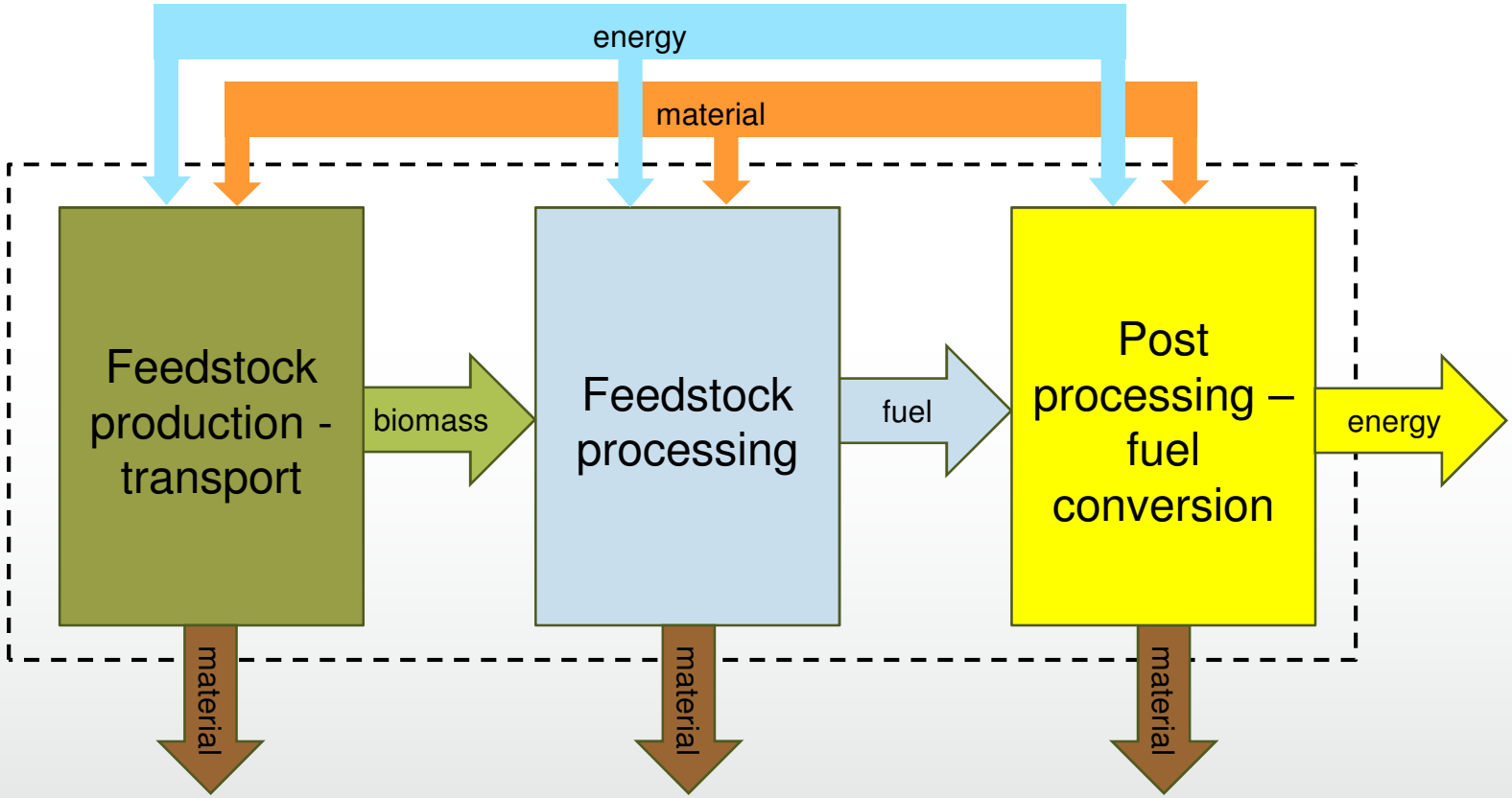

An example system (AD)

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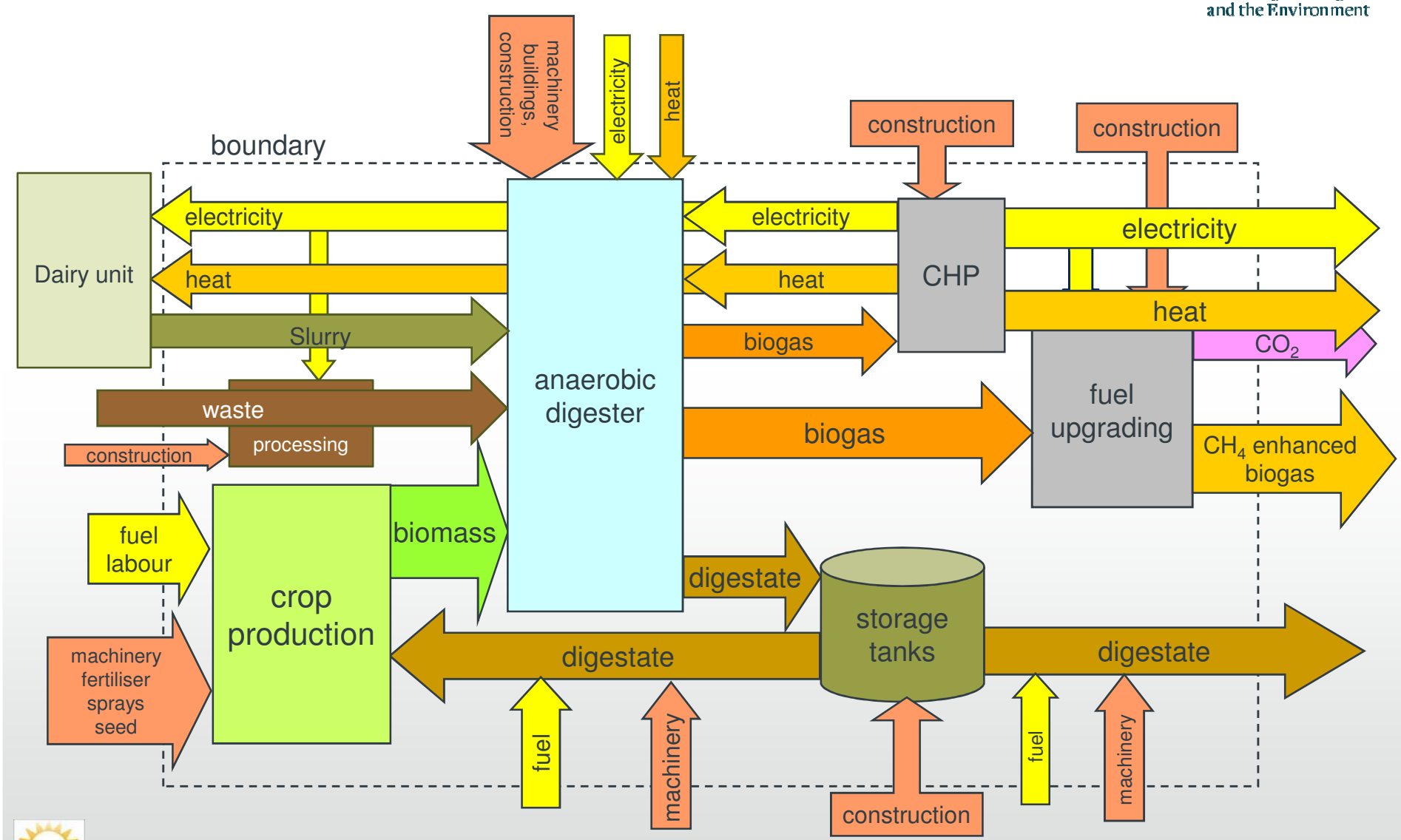

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AD – energy balance

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		CHP	vehicle fuel
crop production (direct & indirect)	GJ/year	1859	
parasitic electricity	GJ/year	393	3261
parasitic heat	GJ/year	3655	3655
digester embodied	GJ/year	109	109
total	**GJ/year**	**6174**	**9043**
energy in methane produced	GJ/year	38702	38702
generated electricty	GJ/year	13546	3261
generated heat	GJ/year	19351	4658
exported electicty	GJ/year	13153	
	MWh/year	3654	
exported heat	GJ/year	15696	
	MWh/year	4360	
energy in upgraded CH_4	GJ/year		29386
	l diesel/year		820831
energy balance (E_{out} - E_{in})	**GJ/year**	**22675**	**20343**
ratio (E_{out}/E_{in})		**4.7**	**3.2**

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Production of vehicle fuel

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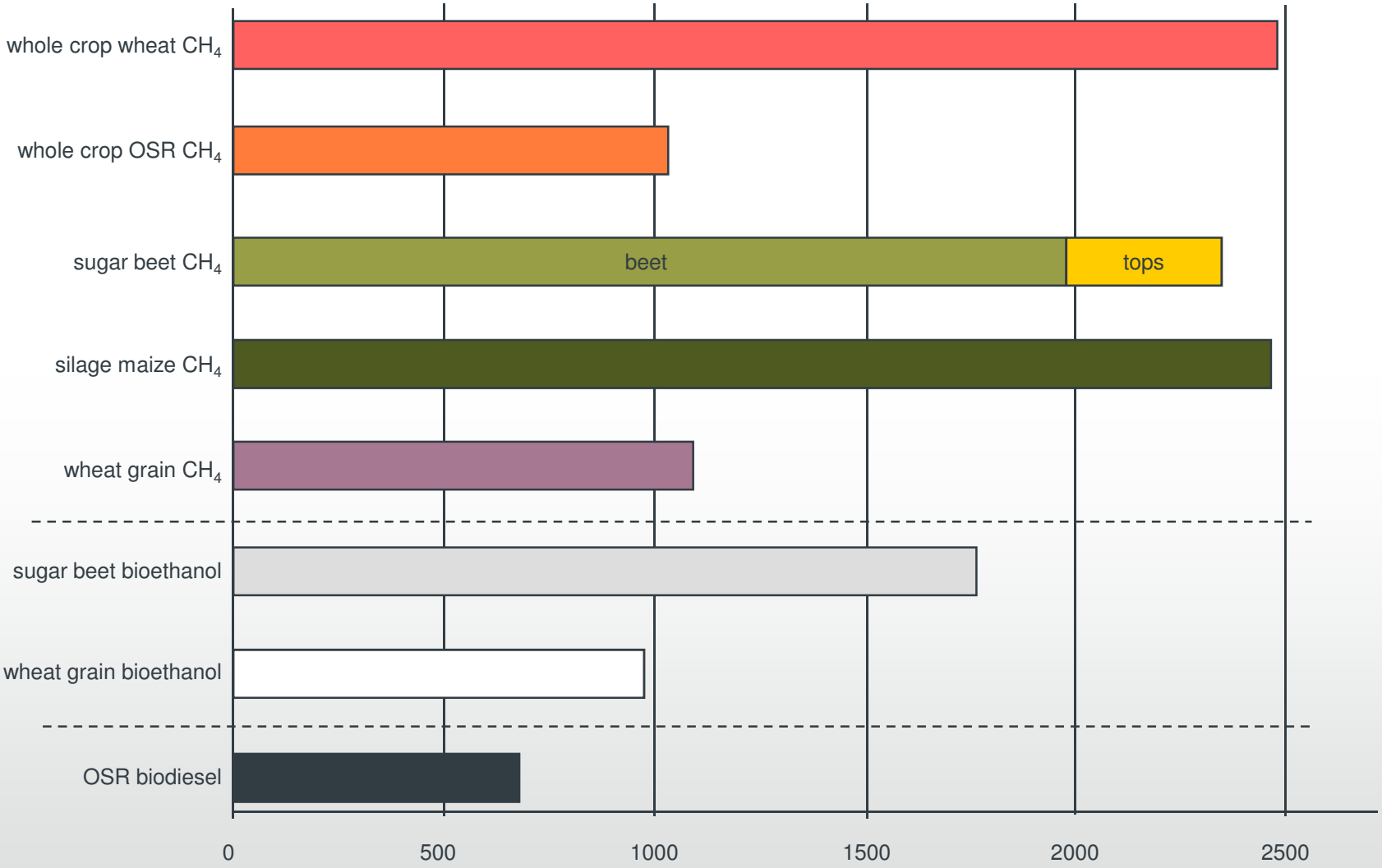

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Crop production – maximising land yield

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Mono crops

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- Mono-crops
  - The same crop grown in the same field each year
- e.g. wheat in high productivity areas
  - requires high inputs of fertilisers
  - risk of disease increases
  - soil fertility decreases
  - weed problems
  - pest problems

Crop rotations

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- Crop rotations
  - several different crops grown over a succession of years
  - reduces requirement for fertilisers
  - reduces risk of disease
  - helps to maintain soil structure
  - can increase soil fertility
  - different rooting depths

Crop rotations - examples

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mono-crop

wheat	wheat	wheat	wheat	wheat

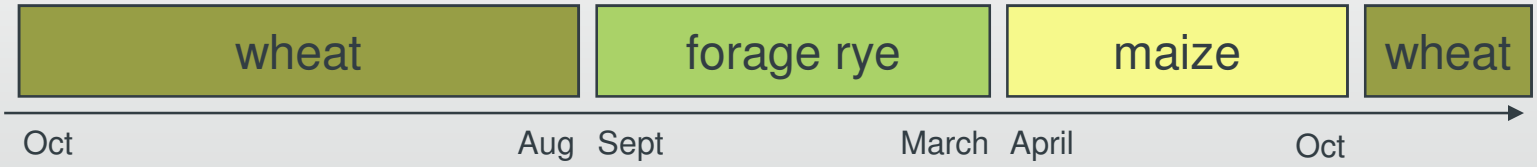
2 year rotation

maize	soybean	maize	soybean	maize

4 year rotation

	year 1	year 2	year 3	year 4	year 5
field 1	wheat	barley	oilseed	clover	wheat
field 2	clover	wheat	barley	oilseed	clover

crop rotation for energy / food / food + energy



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Double cropping

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growing two or more crops in the same space during a single growing season

- reduced ploughing
- green crop harvesting (silage) reduces the growing period of one crop leaving time for production of an extra (biomass) crop
- reduced herbicide application (weeds can also grow on the field)
- diversity on the field
- negative impact due to double harvesting
- the system is restricted to regions with sufficient water ability and long enough growing season

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Multiple-cropping

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growing of two or three crops simultaneously on the same land

- crop diversity and structural diversity
- crops has higher stress tolerance – more yield security
- lower need for pesticides and herbicides (lower pest pressure – no monoculture)
- better soil cover and lower crop quality levels need to be reached

- increases landscape diversity (biodiversity in farmlands)
- help to prevent erosion and lower nutrient losses

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(www.intercrop.dk)

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Other agricultural feedstock materials

An integrated approach

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Alternative feedstock

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- Agricultural
  - Animal slurries and manures (EU27 = 1500 million tonnes)
  - Crop residues
- Food waste (EU > 200 million tonnes)
- Others
  - Verge cuttings
  - Communal grass areas
  - Glycerol & oilseed rape cake
  - Brewers grains

Integrated energy farming

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- Can combine different types of energy production.
- Crop grown for bio-diesel – waste products can be used in AD plant.
- Bio-diesel crops act as break crops for food crops
  - wheat for food
  - OSR break crop for fuel, cake as feedstock
  - legume (clover) before wheat to capture nitrogen, can be digested and used as feedstock

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Farm integration

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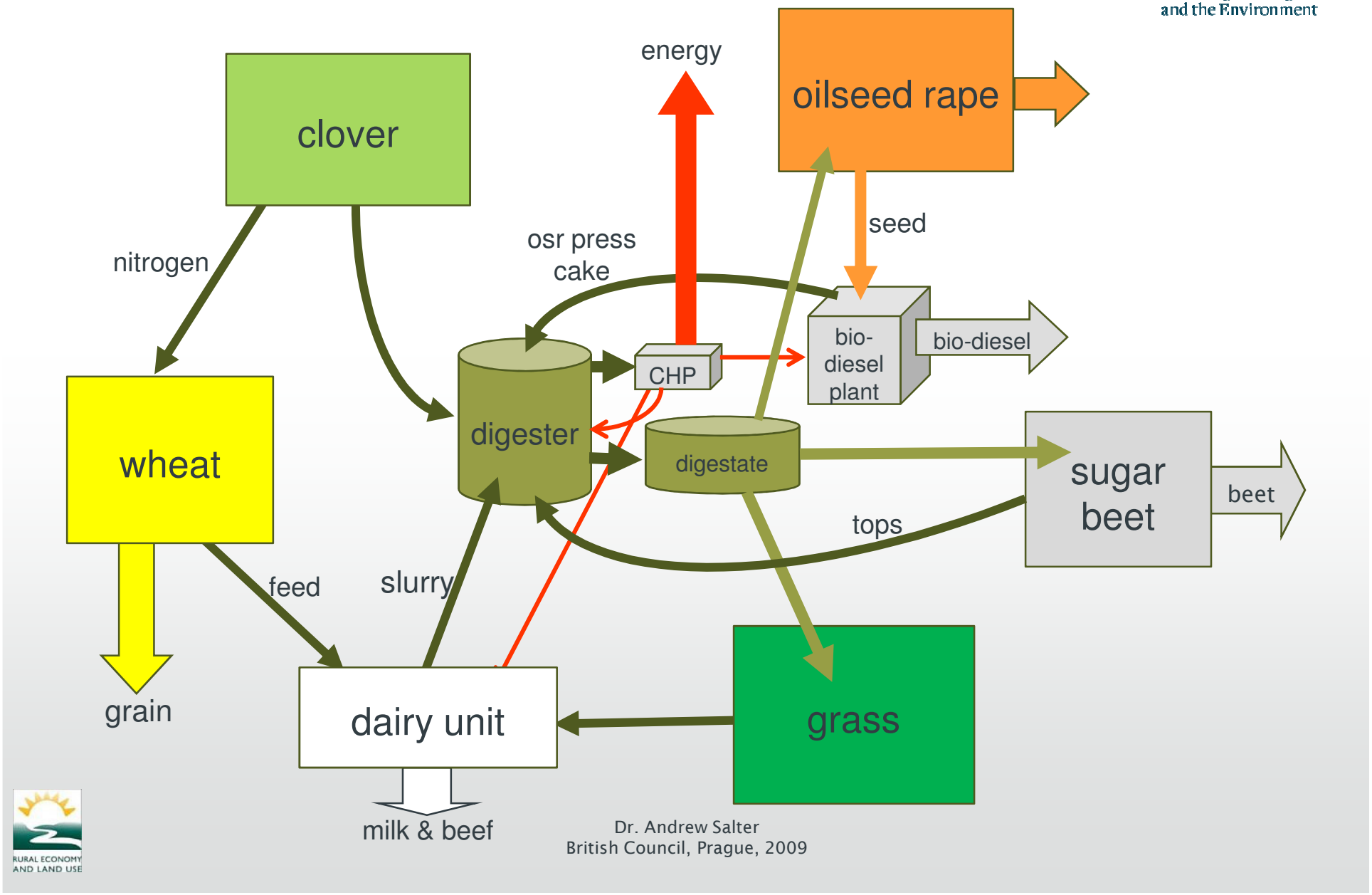

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Conclusion

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- Land availability is limited
- All of the biomass produced needs to be used in some form
- Alternative cropping systems help to maximise yield and minimise use of artificial fertiliser
- Process all of the manures and residues
- Food and fuel crops can be integrated
- Different energy systems can be integrated
- Decentralised energy generation

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Thank you

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More information can be found at:

http://www.AD4RD.soton.ac.uk

http://www.cropgen.soton.ac.uk

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