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Life cycle analysis of first and second generation bio-energy systems: a comparison

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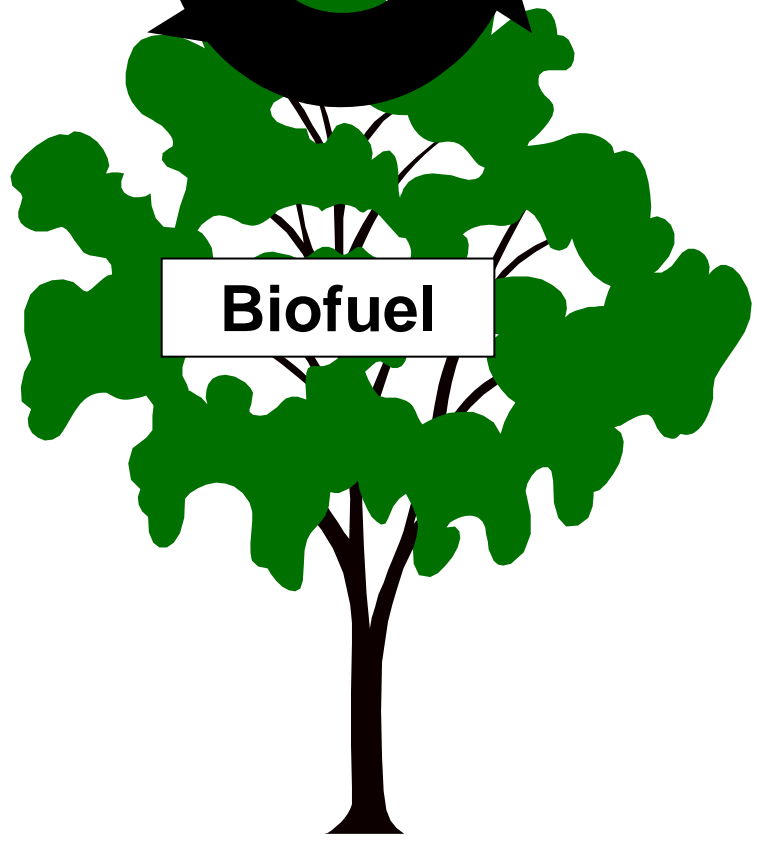
CO₂

CO₂

Growth

Biofuel burning

Fossil fuel burning



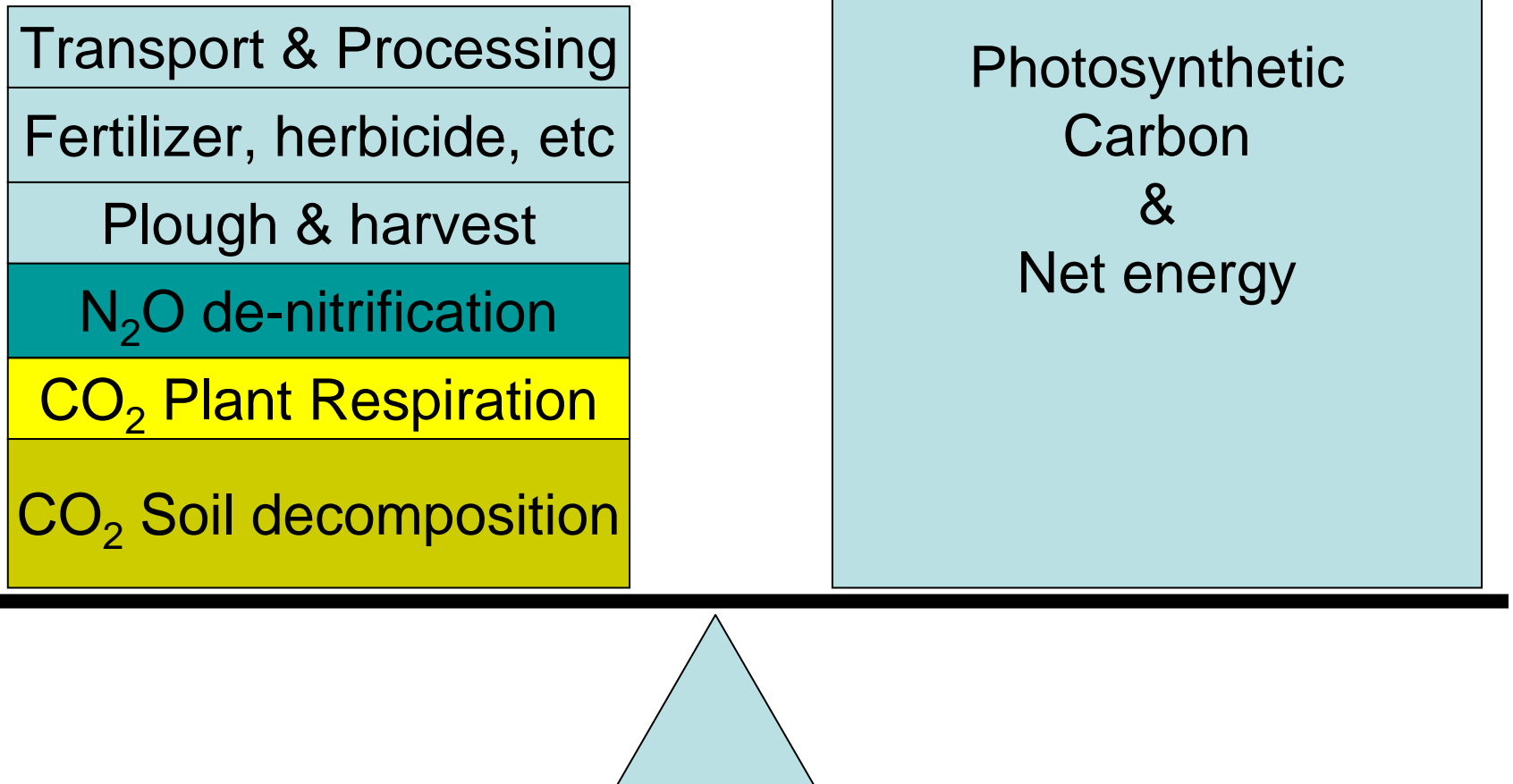
Energy



LCA comparison criteria

- Net energy produced per hectare land - GJ ha^{-1}
- Net energy / energy input (EUE)
- Carbon Intensity (CI) - $\text{g CO}_2 \text{ C Equiv MJ}^{-1}$
- Transport Carbon (TC) - $\text{g CO}_2 \text{ km}^{-1}$

Life Cycle Analysis = carbon & energy balance

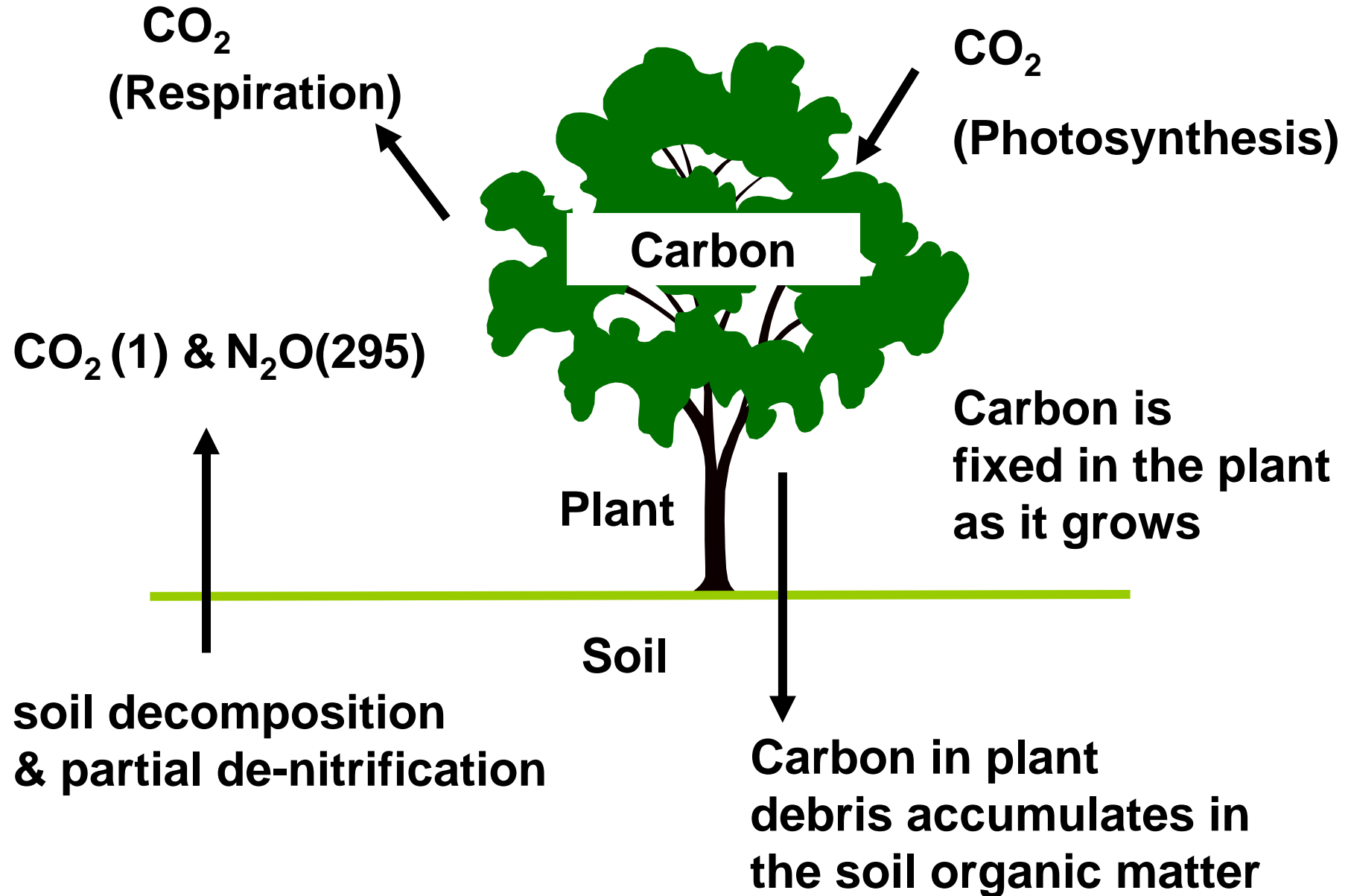


Net energy yields net GJ ha⁻¹

• Ethanol from wheat	7
• Ethanol from sugar beet	15
• Ethanol from Maize	15
• Cellulosic Ethanol (<i>Miscanthus</i>)	20
• Bio-diesel from oil seed rape	17
• Bio-refined <i>Miscanthus</i> bio-diesel	61
• SRC Willow co-fired current	42
• <i>Miscanthus</i> co-fired current	191
• <i>Miscanthus</i> local CHP future	223



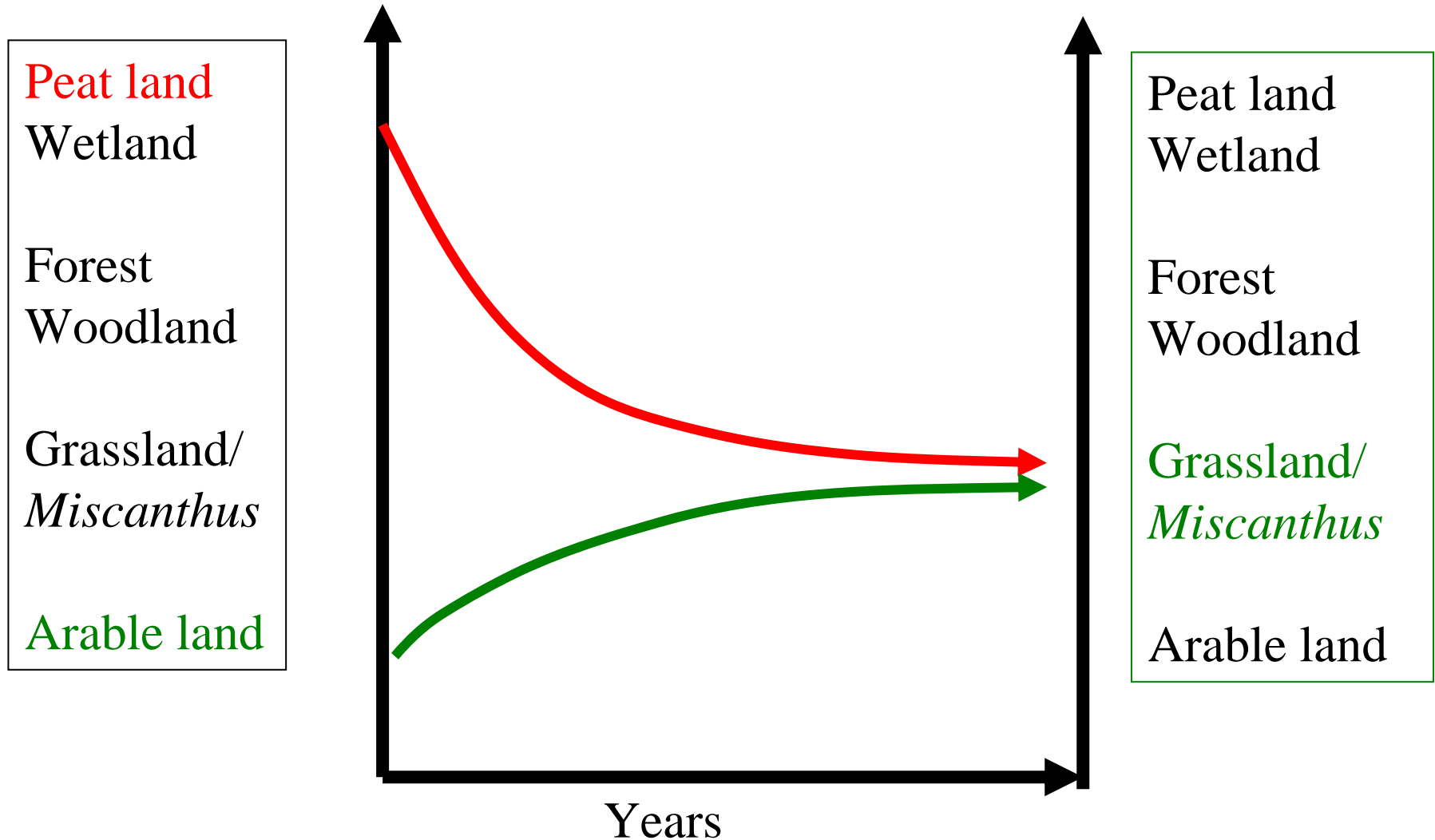
Soil emission of greenhouse gasses



Each ecosystem has a carbon equilibrium

Initial Soil Carbon Level

Final soil carbon level



Bio-energy systems LCA comparison

		EUE	CI
Otto cycle	Gasoline	4.0	19.7
	Wheat ethanol	1.0	89.0
	Maize ethanol	1.2	77.0
	Sugar-beet ethanol	1.1	67.0
	Wood cellulosic ethanol	1.2	46.0
	<i>Miscanthus</i> cellulosic ethanol	1.2	40.0
Diesel cycle	Diesel	4.0	21.3
	OSR biodiesel	1.7	67.0
	Wood bio-refined diesel	3.9	11.0
	<i>Miscanthus</i> bio-refined diesel	3.6	9.0

Electricity CI g C MJ⁻¹

Fuel Carbon

+

Capex Carbon

+

Opex Carbon

+

Thermal efficiency 30-90%

+

Generation efficiency 95%

+

Distribution / utilization efficiency

•UK grid 2006 55

•Coal 98

•Gas combined cycle 52

•Offshore Wind 36

•Land wind 20

•Advanced nuclear 16

•Hydro 17

•Wood CHP 26

•*Miscanthus* co-fire 16

•*Miscanthus* CHP 14

Typical car



- 90% transmission efficiency
- Front wheel drive
- Needs 34 MJ to travel 1km at 60 kph

Assume all types of fuel require the same amount of construction carbon

E.g. Ignore battery carbon cost

Carbon emission & fuel system - g CO₂ km⁻¹

Otto cycle	Gasoline	129
	Maize ethanol	423
	Sugar-beet ethanol	369
	Wood cellulosic ethanol	281
	<i>Miscanthus</i> cellulosic ethanol	221
Diesel cycle	Diesel	106
	OSR biodiesel	334
	Wood bio-refined diesel	64
	<i>Miscanthus</i> bio-refined diesel	45
Electrical	UK national grid	134
	Coal	240
	Gas combined cycle	129
	Nuclear	40
	Land wind	41
	Offshore wind	88
	Co-fire <i>Miscanthus</i>	41
	CHP <i>Miscanthus</i>	36

Conclusions & questions

- Bio-fuel sustainability
 - Energy security or C emissions reduction
 - Is EUE or CI the issue
- Availability of suitable land
 - *Miscanthus* is best use
 - 10% UK arable land = 39,000 boe d⁻¹
- Incentives for perennial crops
- Infrastructure for bio-energy
 - local CHP or bio-refineries
- Landscape?

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