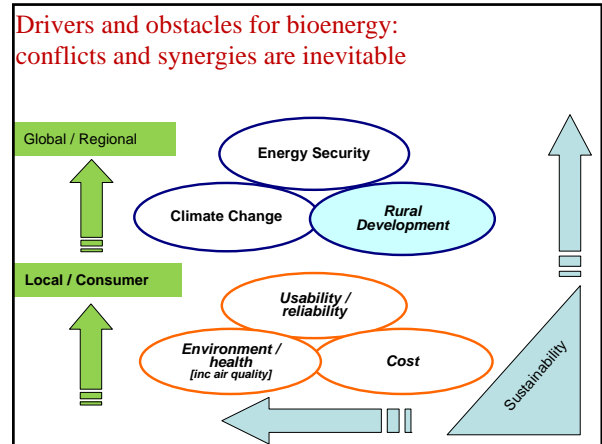


**THE ROYAL SOCIETY**  
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**Sustainable Biofuels: Prospects and Challenges**  
(EPSCO Meeting, 28<sup>th</sup> May 2008)

Dr Jeremy Woods  
A member of the UK Royal Society Working Group on Biofuels  
& Porter Institute, Imperial College London

500 years of excellence in science



### Are Economics or Policy driving biofuel demand?

**UK Petrol Price (2007)**

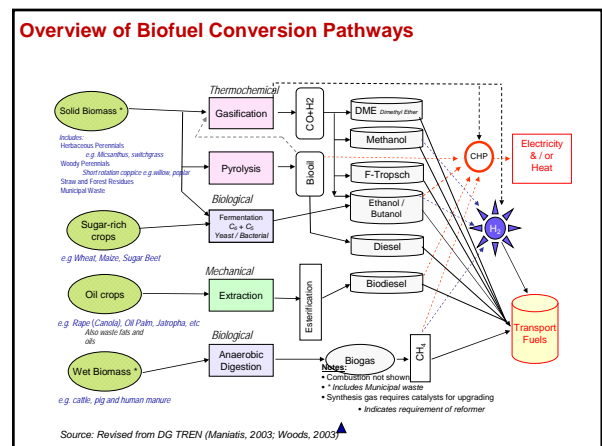
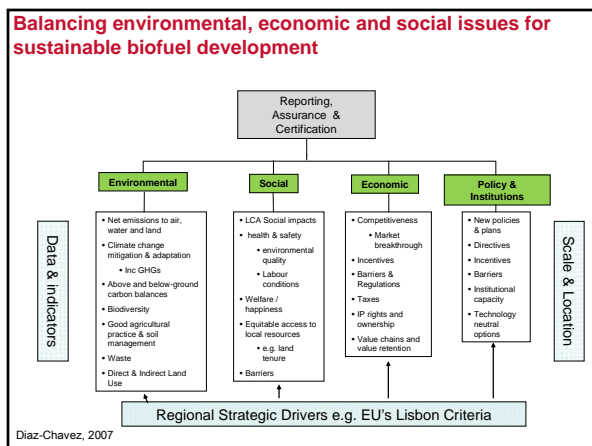
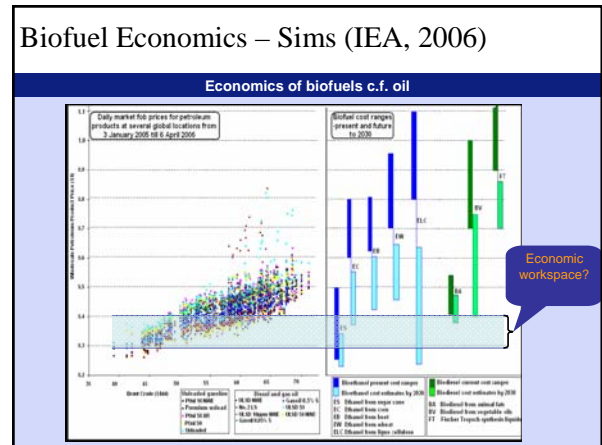
- Wholesale petrol = \$15/GJ
- Pump purchase = \$55/GJ

**Zambia Petrol Price (March 2006)**

- Wholesale petrol = \$18/GJ
- Pump purchase = \$44/GJ

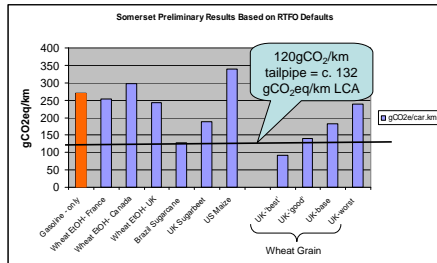
**Zambia projected ethanol production costs**

- \$16 to \$38/GJ (no taxes)
- C-molasses to straight juice used
- Assumes no value for co-products e.g. electricity



## UK- RTFO implications for E85 use in Somerset

Woods & Brown (2007; EU-BEST project data)



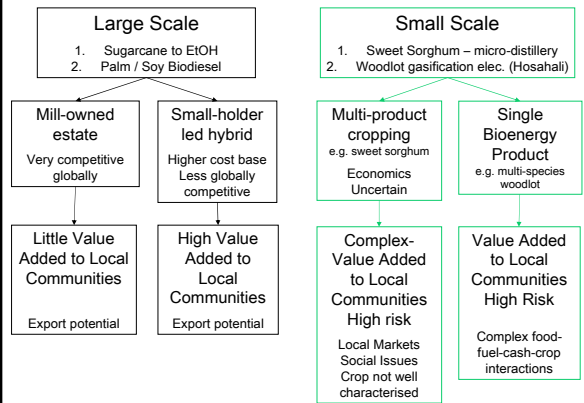
- 'Worst case' GHG savings between 53% to -25%
- Using 'country level (conservative) default factors' as defined by the UK-Renewable Transport Fuel's Obligation Reporting Requirements (RFA, 2007)

## Assurance Pyramid – walking the 'tight-rope'

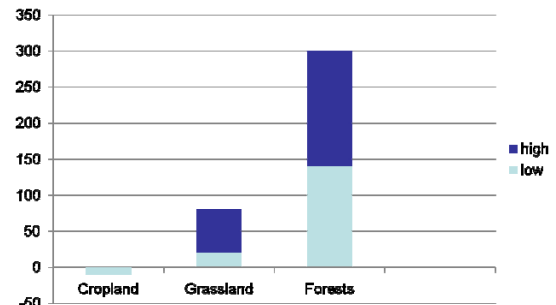


Adapted from: Jim Smith, BSI Professional Standards Services (his presentation to LCVF on 18Feb05)

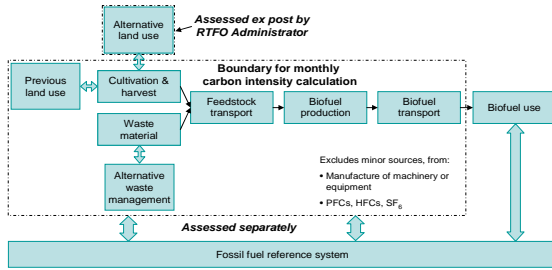
## Bioenergy Development Options - scale matters



## Land Use – Land Use Change – Impacts (tC/ha gross)



## Understanding supply chains and boundary issues (E4TECH / RTFO)



- Changes at one point in the supply and use chain have implications for other segments of the chain

## Is there enough land? (GAEZ)

Country	Population (people)	Total Land (1000 ha)	Arable land (1000 ha)	Land Considered Suitable for Crop Growth (1000 ha)		% Suitable (%)	% of suitable used (%)
				2001-2005			
				no constraints	with constraints		
Brazil	186,831	853,363	58969	239,573	614,064	28%	25%
China	1,312,979	934,949	142265	178,228	756,722	19%	80%
India	1,134,403	306,140	159712	139,357	166,783	46%	115%
Southern Africa							
Tanzania	38,478	93,819	9118	35,964	57,855	38%	25%
South Africa	47,939	122,300	14753	31,154	91,075	25%	47%
Mozambique	20,533	79,854	4270	48,043	31,811	60%	9%
Zambia	11,478	74,837	5260	22,304	52,533	30%	24%
Angola	16,095	123,776	3200	40,383	83,313	33%	8%
UK	60,245	24,418	5728	9,888	14,530	40%	58%
South East Asia							
Indonesia	226,063	189,220	22600	79,444	109,776	42%	28%
Malaysia	25,653	33,300	1800	16,495	16,805	50%	11%
Total	3,080,697	2,835,976	427,675	840,833	1,995,267	30%	51%
World	6,515,000	12,976,000		3,500,000			
	47%	22%		24%		27%	

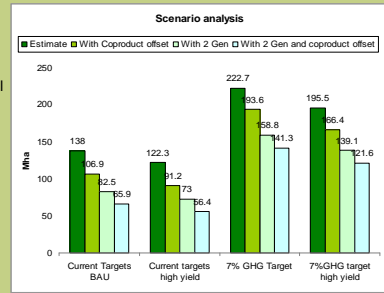
## Understanding potentials

Jayant Sathaye (Lawrence Berkley and IPCC) outlines the following progression from theoretical to practical / realisable potentials:

1. Biological/theoretical potential
2. Technological potential
3. Economic potential
4. Ecological potential
5. Realistic potential/implementation

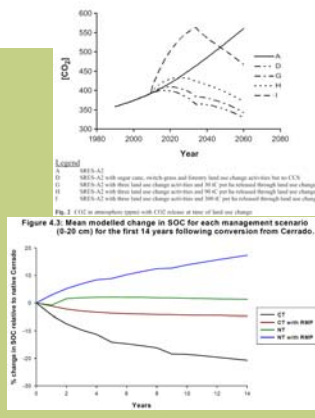
## New land for biofuels by 2020?

- E4TECH scenario analysis for RFA review (2008)
- 'Current targets (BAU)' - equates to 10% of global transport fuels by volume in 2020 from biofuels
- '7% GHG target' - 7% reduction in global transport GHG emissions by 2020
- Additional land for 'food and crops' by 2020 = 200 to 500Mha
  - Global cropland = 1.68ha
- C.f. New land for biofuels = 55 to 230 Mha

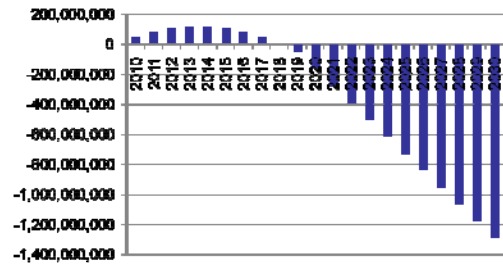


## GHG balances

- 'The Greenhouse Gas Calculator'
- Economics
  - Capital costs
  - Operation & Maintenance costs
  - Land 'rental' costs / social costs
- Understanding 'Direct' & 'Indirect Effects'
  - Read (2007)
  - Searchinger et al + Fargione et al (2008)
  - Galbraith (2005)



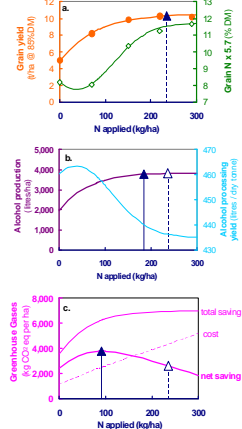
## Biofuels as a climate change mitigation tool - Including Indirect LUC Impacts



Avoided CO<sub>2</sub>eq emissions from EU bioethanol production inc indirect LUC:  
 • assumes 50% GHG reduction factor for Bioethanol using RTFO methodology  
 • 20 Mha directly required; planted at 2Mha/yr for 10 years from 2010  
 • 50% wheat and 50% sugarbeet

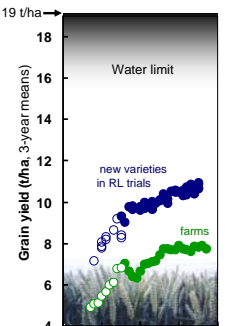
## Nitrogen dynamics and ethanol production (Sylvester-Bradley, 2008)

- For wheat and rape-derived biofuels (ethanol and biodiesel) N plays a critical role in the GHG balance and yield
- Optimums of 236 kgN/ha for feed grain, 184 kgN/ha for alcohol production, and 91 kgN/ha for maximum GHG savings per GJ fuel
- 'Carbon pricing' will play a major role in deciding what levels of N are financially optimal



## Developing yields (ADAS, 2008)

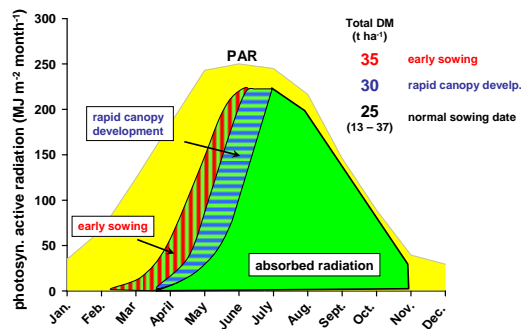
- On-farm
  - No increase for >10 years
- Recommended varieties
  - Increasing: 0.7 tonne ha<sup>-1</sup> decade<sup>-1</sup>
- Possible causes
  - Economics: low prices, cost cutting
  - Climate change ?
  - Technology gap ?
- Can yields respond fast enough to cancel extra land requirements ?
- 18t/ha (above and below ground = c. 1% RUE)



Roger Sylvester-Bradley (ADAS, 2008)

### Light interception of sugar beet (Hoffmann, 2008)

PAR: 400-700 nm, Göttingen 1952-2004; absorption according to Röver (1995)

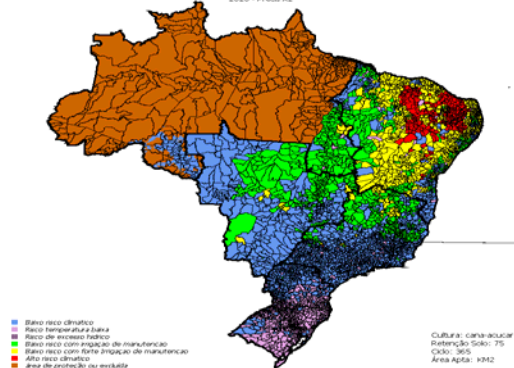


Christa Hoffmann, Institut für Zuckerrübenforschung, IIRB congress, Brussels, 13/14.feb.2008

### What grows where – matters! Agro-ecological zoning in Brazil (Hilton, 2008)

Municípios com plantio favorável em: 3, 4, 5, 6, 9, 10

2020 - Projeção



Cultura: cana-de-açúcar  
Rendimento Solo: 75  
Ciclo: 30/5  
Área Apéa: 1042

#### Climate Change

- Biofuels can contribute to a meaningful reduction in greenhouse gas emissions but requires the development of highly efficient and integrated supply chains.
- Existing examples of biofuels programmes around the world starkly illustrate the range of greenhouse gas savings that can be realised.
  - Average Brazilian ethanol results in reductions of c 80% in greenhouse gas emissions, on a life cycle analysis, compared to petrol (Worldwatch Institute 2006).
  - US maize-based ethanol struggles to deliver reductions in greenhouse gas emissions of 10%.
  - UK- projected reductions in greenhouse gas emissions of anywhere between 10% and 80% could be delivered from wheat to ethanol (Woods & Bauen 2003).
- Current policy frameworks and subsidies for biofuels are not directed towards reducing greenhouse gas emissions, but rather provide incentives for national supply targets. As a result, there is currently no incentive to invest in the systems that would deliver low greenhouse gas biofuels.

#### Energy Security

- Global primary oil demand projected to grow 1.3% per year up to 2030
  - reaching 116mb/d (from 84mb/d in 2005).
  - transport sector accounting for most of this increased demand (IEA 2006).
- Much of the current demand for oil is met by OPEC; this has energy security implications especially if supply routes are disrupted.
- The surge of demand for oil from developing regions (China, India and Latin America in particular) + continued high demand from Europe & USA is continuing to drive oil prices higher.
- The current era of high oil prices has started to make biofuels, and other close to market alternative technologies, a realistic alternative.
- Virtually any degree of energy security can be achieved if countries are willing / able to pay for it. E.g. exploiting tar sands and oil shales to produce synthetic fuels.
  - Note: costs of producing synthetic fuels are high and are much more carbon intensive than for conventional oil fuels.
- Using unconventional energy resources could seriously compromise objectives to mitigate climate change.
- Whether this trade-off between energy security and climate change mitigation is avoided by the production of biofuels will depend on how biofuels are produced and on developments right across the supply chain.**

#### Rural development

- Will biofuel production compromise food production and decrease the quality of life for the rural poor of the world?
- Biofuels could provide a part of the answer to this problem by diverting 'surplus' production to a new market whilst maintaining productive capacity.
- In many developing countries, rising food-based commodity prices will assist investment in agriculture and forestry which, in turn, will improve yields and production efficiencies.
- With careful implementation, the rural poor of these countries could be major beneficiaries of a new biofuel-inspired development dynamic.
- However, without specific intervention, the urban poor in developing countries will suffer as a result of increased food prices unless (i) economic prosperity rises as a whole, and; (ii) a reasonable amount of the value generated by biofuels is retained locally.
  - This is a critical component of understanding how to harness FDI beneficially
- We do not assess these issues in detail, but highlight the dangers of an overly simplistic food versus fuel debate when synergistic opportunities for food and fuel exist and should be maximised.

#### RS Biofuels Working Group Conclusions

A coherent approach will:

- avoid the unintended consequence of solving one problem at the expense of exacerbating another;
- see biofuels as part of a portfolio of approaches that also includes, for example, greater energy efficiency, electric vehicles, hydrogen and fuel cells, and fiscal incentives such as carbon pricing based on avoided greenhouse gas emissions;
- balance growth of feedstock against other uses of land;
- deploy an assessment of sustainability that encompasses the complete cycle from growth of the raw material to end-use irrespective of where each stage in the cycle takes place;
- commit to invest properly in the required R&D;
- provide aptly targeted fiscal incentives;
- develop a process for effective public engagement on biofuel issues.

# THANK YOU!

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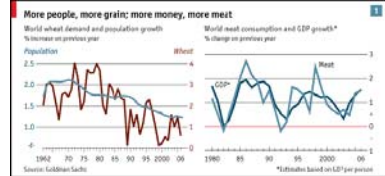
Quantifying and  
 Understanding  
 the Earth System

IEA Task 40



## What's driving food prices & land use change? (Economist, Dec07)

Total Cereals 2007: 1.66 Bt  
 Record and 89 Mt larger than  
 last year  
 Cereal prices up 50 to 100%  
 c. last year



'Farmers now feed about 200m-250Mt more grain to animals than 20 years ago accounting for a significant share of the world's total cereals crop. 3 kg cereals produces 1 kg pork, 8 for beef. Because this change in diet has been slow and incremental, it cannot explain the dramatic price movements of the past year. The rampant demand for ethanol as fuel for American cars. In 2000, c. 15Mt US's maize crop was turned into ethanol, this year likely to be c.85 Mt. US is world's largest maize exporter—now uses more of its maize crop for ethanol than it exports. Ethanol is the dominant reason for this year's increase in grain prices. It accounts for the rise in the price of maize because the federal government has in practice waded into the market to mop up about one-third of America's corn harvest. A big expansion of the ethanol programme in 2005 explains why maize prices started rising in the first place.'