Limits of Bioenergy for Carbon Mitigation

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Harvard’s Energy Policy Seminar, March 20, 2017

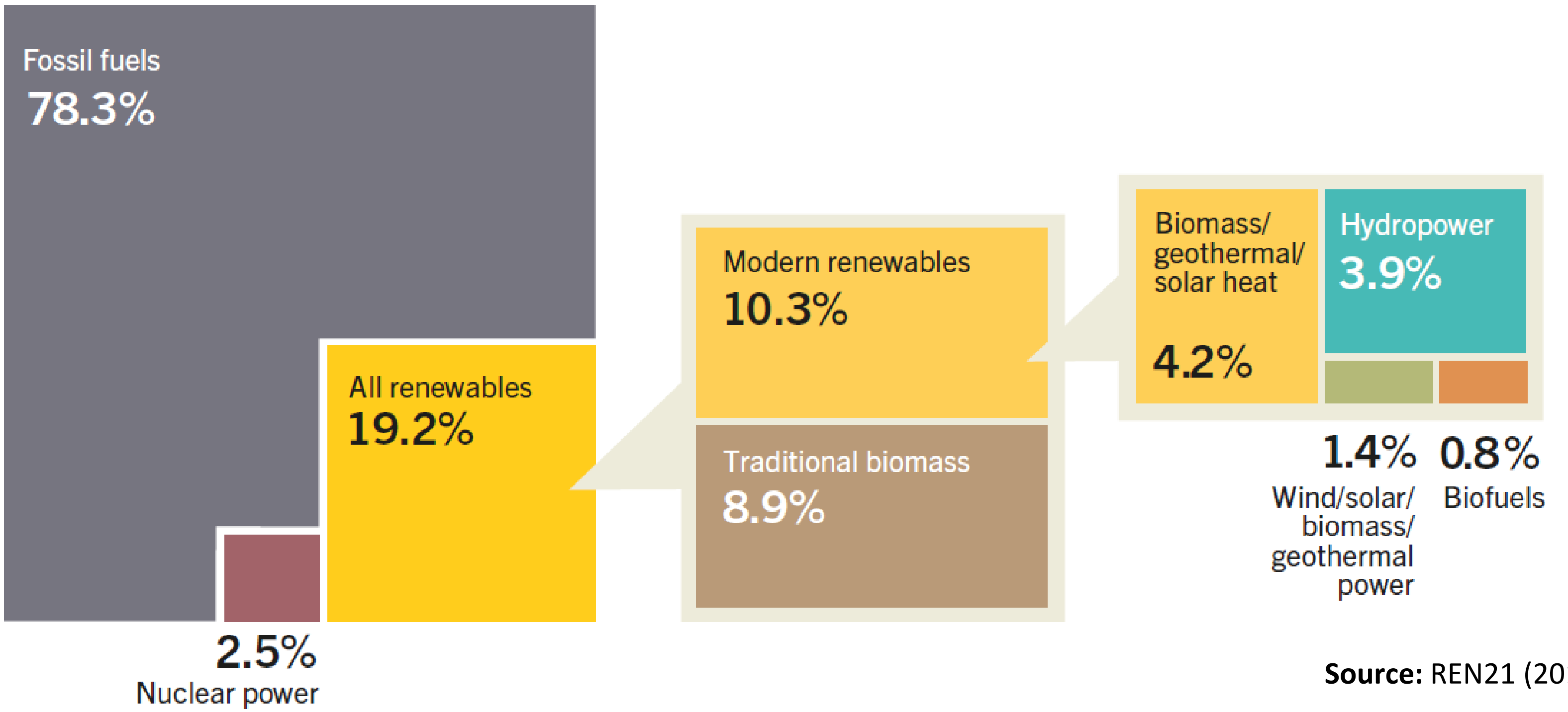
What is bioenergy?

Liquid biofuels
e.g. ethanol and biodiesel

Solid biomass

Biogas

World final energy consumption



Source: REN21 (2016, ref 2014)

World biofuel ranking (2015):

1. USA: 62 billion litres
2. Brazil: 32 billion litres
3. EU28: 16 billion litres
4. China: 3 billion litres

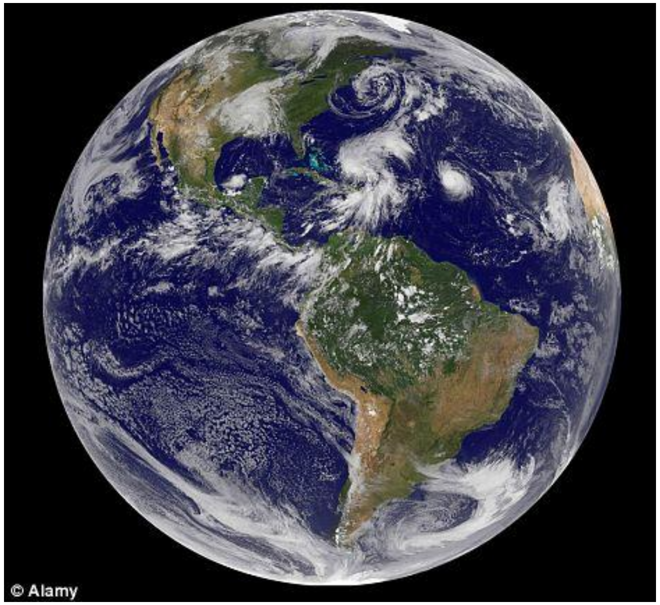
World total: 131 billion litres

Total primary bioenergy production (2015): 60 EJ y^{-1}
(approx. 40 EJ of traditional biomass)

Are there limits to bioenergy?

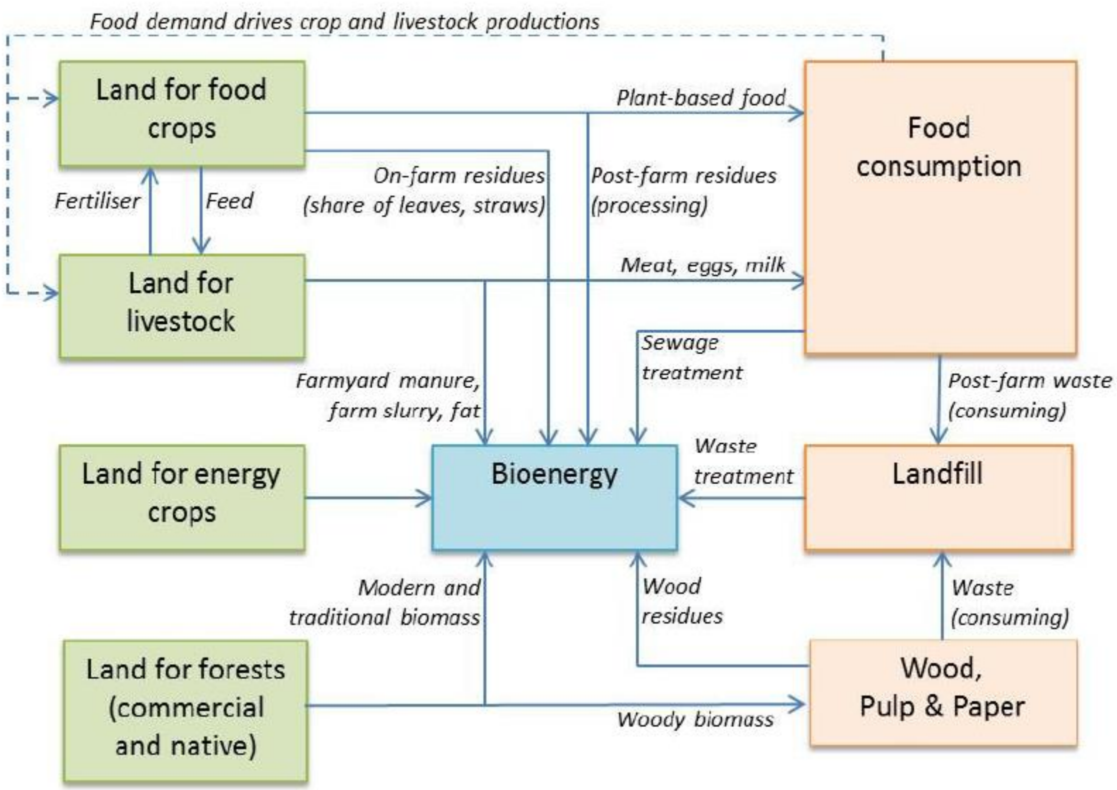
Main physical constraints:

- Land availability
- Photosynthesis efficiency
- Water and plant nutrients



Key issues associated with bioenergy

- Total food consumed per person
- Meat consumed per person
- Crop yields
- Livestock yields
- Bioenergy yields and forms
- How to use freed-up lands
- Use of wastes and residues
- Land multiuse
- Land degradation



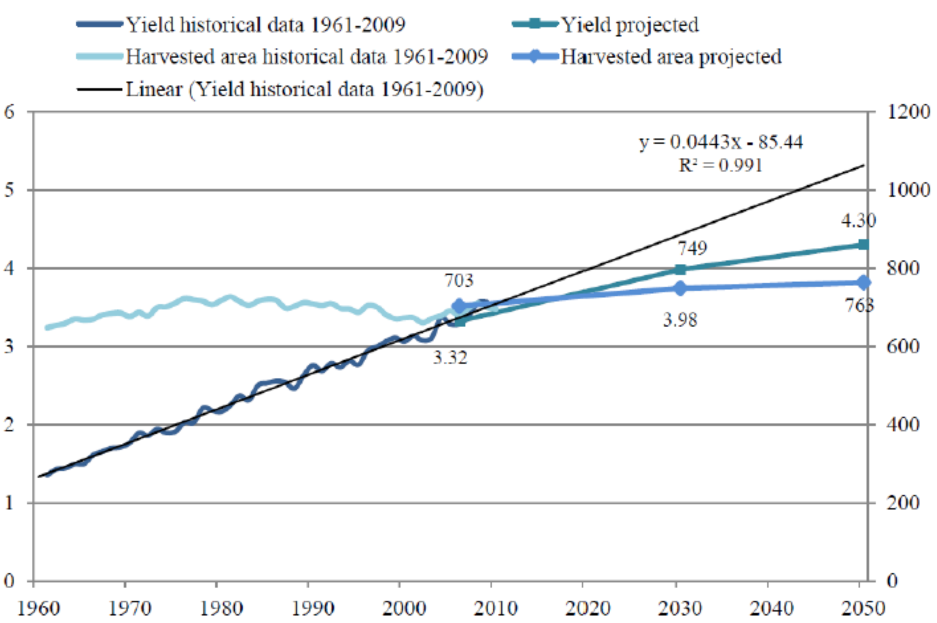
Source: Strapasson *et al.* (2014)

Meat and total food consumption worldwide

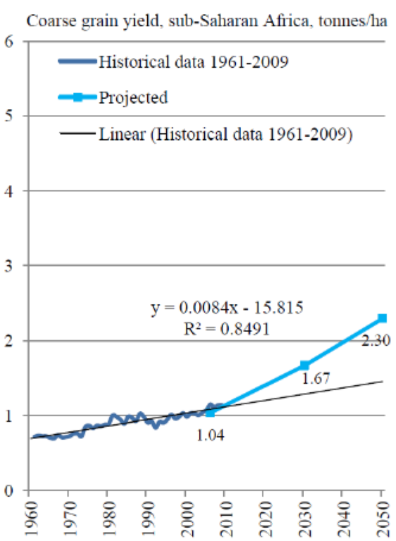
Source: Strapasson (2014)

Agricultural yields

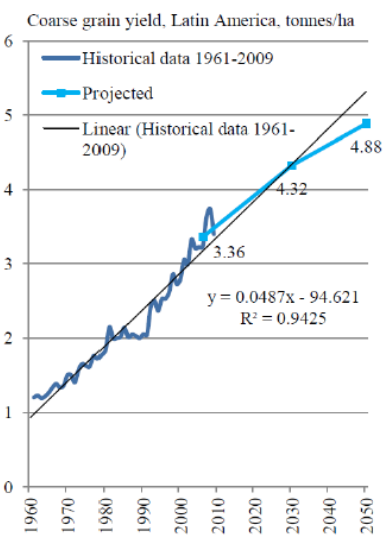
World



Africa

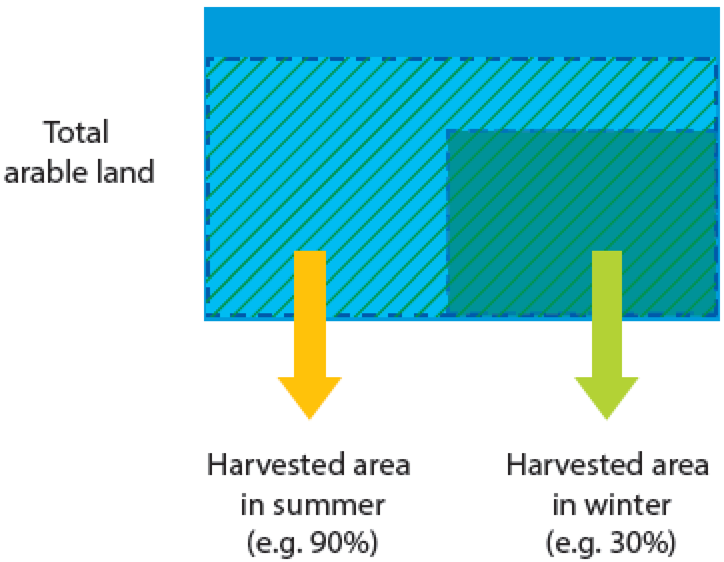


Latin America

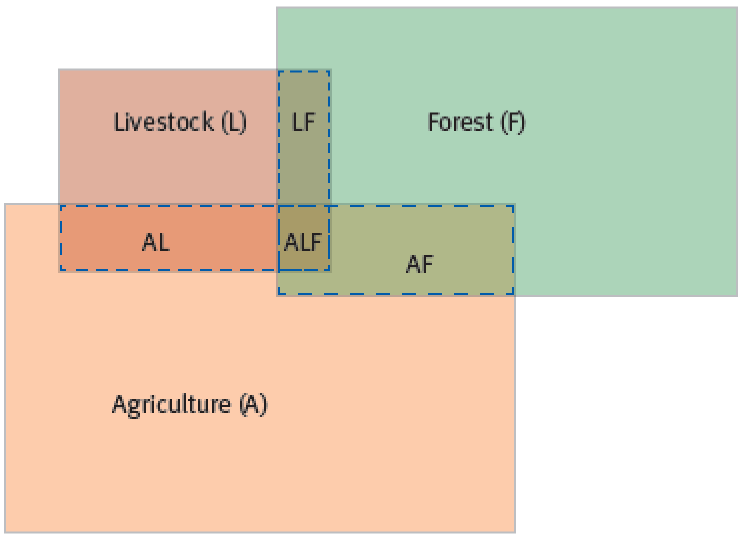


Source: FAO (2012)

Land multiuse



Multiple cropping systems



Land use integration systems

Source: Strapasson et al. (2016)

Livestock yields

- **Feed Conversion Ratio (FCR)**

  Conversion of feed intake into edible meat

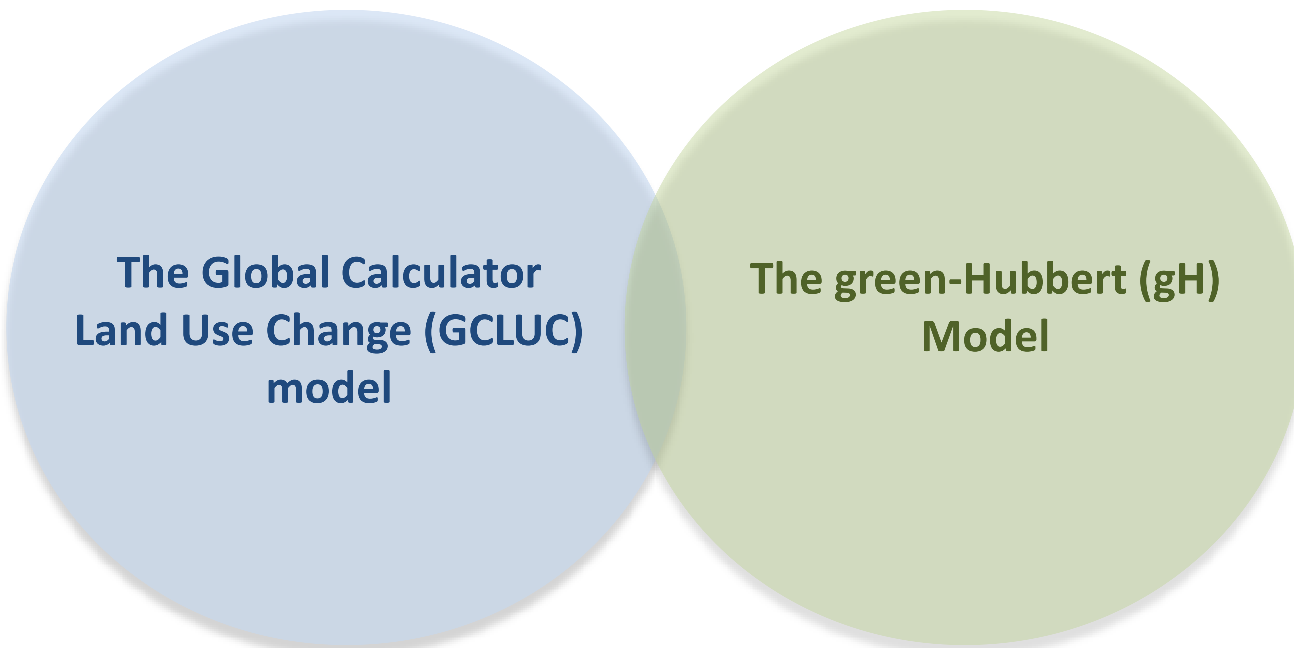
- **Feedlot systems**

  Intensive animal farming

- **Animal density**

  Number of animals per hectare on pasturelands

Assessing the fundamental limits of bioenergy



Global Calculator

- ✓ It is an open access global model for energy, food and land use, aiming to inform the climate debate
- ✓ It includes the three main greenhouse gases: CO_2, CH_4 and N_2O
- ✓ Presents a large variation of potential mitigation efforts by 2050 for all sectors of the economy
- ✓ More than 100 international experts involved in building this tool
- ✓ Several stakeholder consultations and two calls for evidence before its official launch at the UK Royal Society in Jan 2015

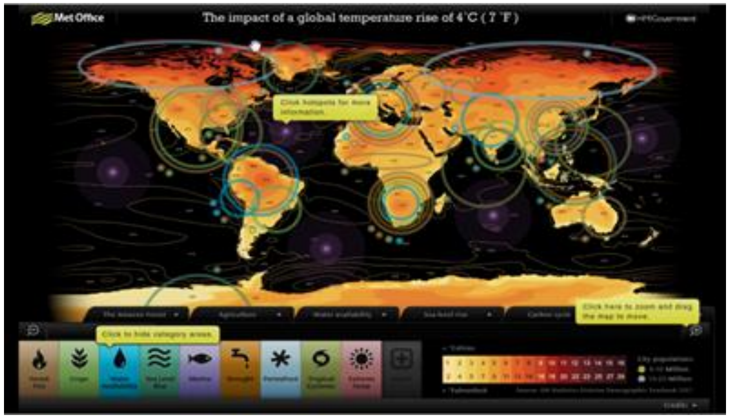
National Calculators vs. Global Calculator

Countries with completed calculators to date:

1. Australia
2. Austria
3. Belgium
4. Bangladesh
5. Brazil
6. China
7. Colombia
8. India
9. Indonesia
10. Japan
11. Mauritius
12. Mexico
13. New Zealand
14. Nigeria
15. South Africa
16. South East Europe
17. South Korea
18. Switzerland
19. Taiwan
20. Thailand
21. **United Kingdom** (1st)
22. Vietnam

See all national calculators at www.2050.org.uk/calculators

The Global Calculator allows us to model the impacts on the climate system

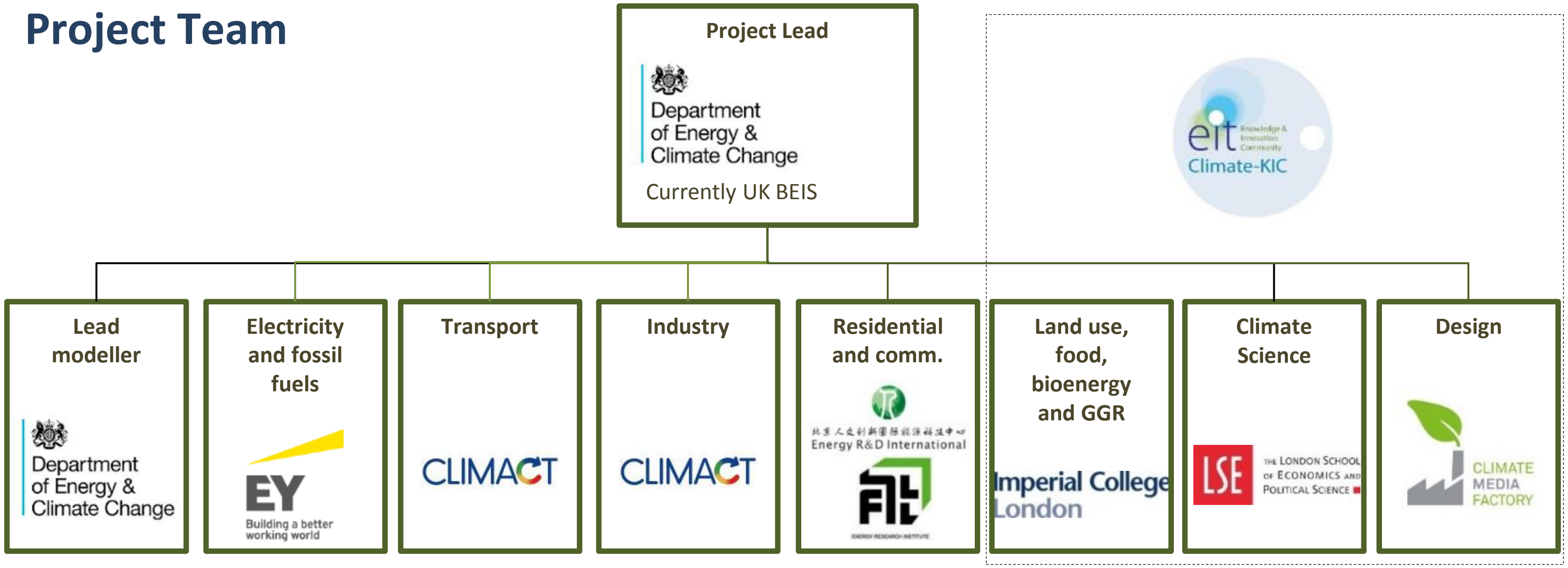


Target audience:

- Policy makers
- Business leaders and NGOs

Global Calculator

Project Team



Sponsors:

- UK DECC (ICF funds)
- Climate-KIC (EU)

Partner institutions:

- World Resources Institute (WRI)
- PIK Potsdam
- London School of Economics
- University of Reading
- UK Met Office
- Rothamsted Research
- University of Versailles
- Tyndall Centre
- University of Oxford
- Utrecht / Groeningen Universities

How does it work?

The global calculator's user has 40 parameters (levers) for reducing GHG emissions.
For each of them, there are 4 levels of ambition to mitigate emissions.

Higher carbon mitigation effort

Level 1:
No mitigation
(pessimist scenario)

Level 2:
Low to moderate
mitigation

Level 3:
Very ambitious
mitigation

Level 4:
Extremely ambitious
(technically possible)

Most of the experts tend to agree with these levels

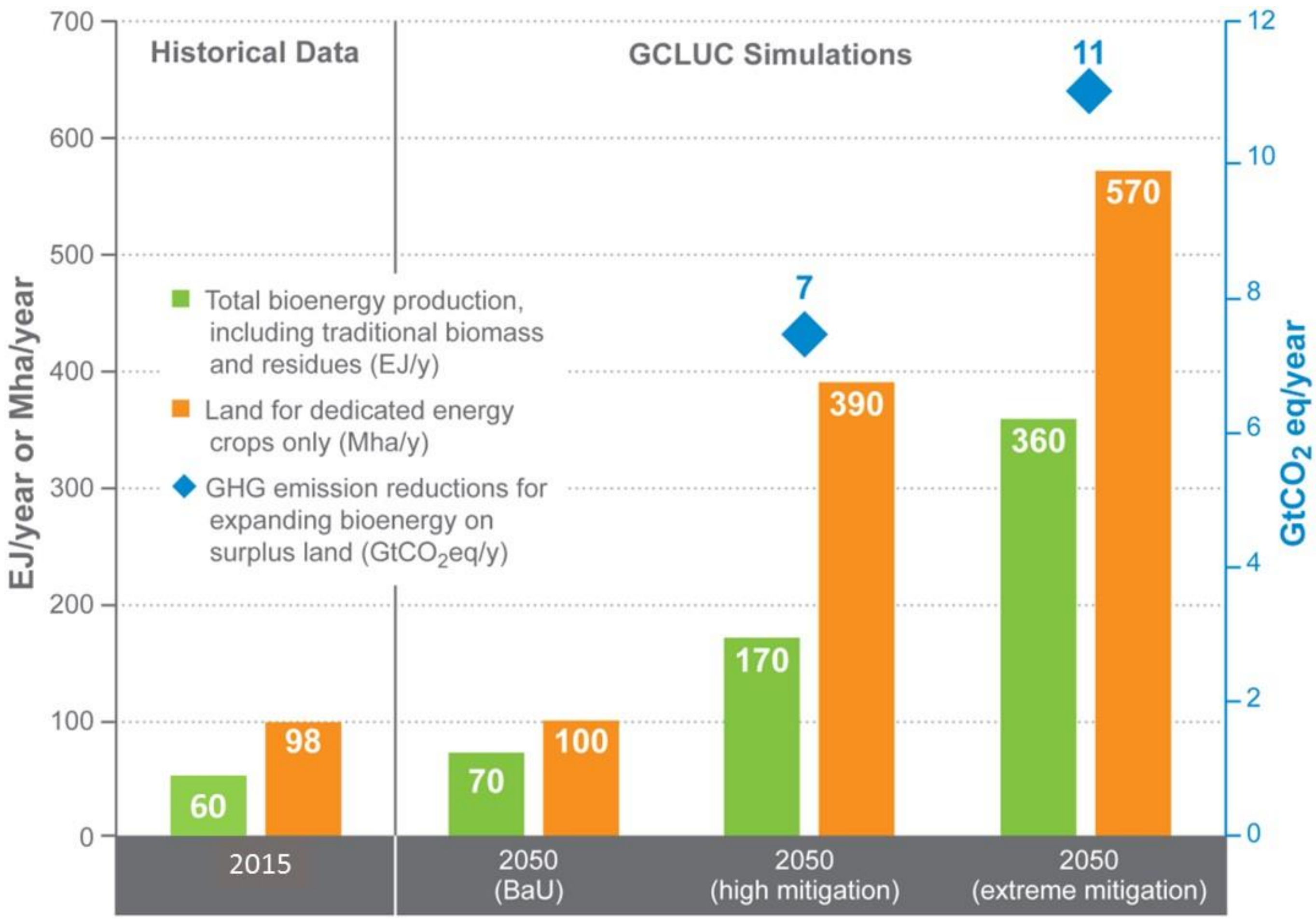
Only few experts agree that this level would be possible to achieve

Playing the Global Calculator

www.globalcalculator.org

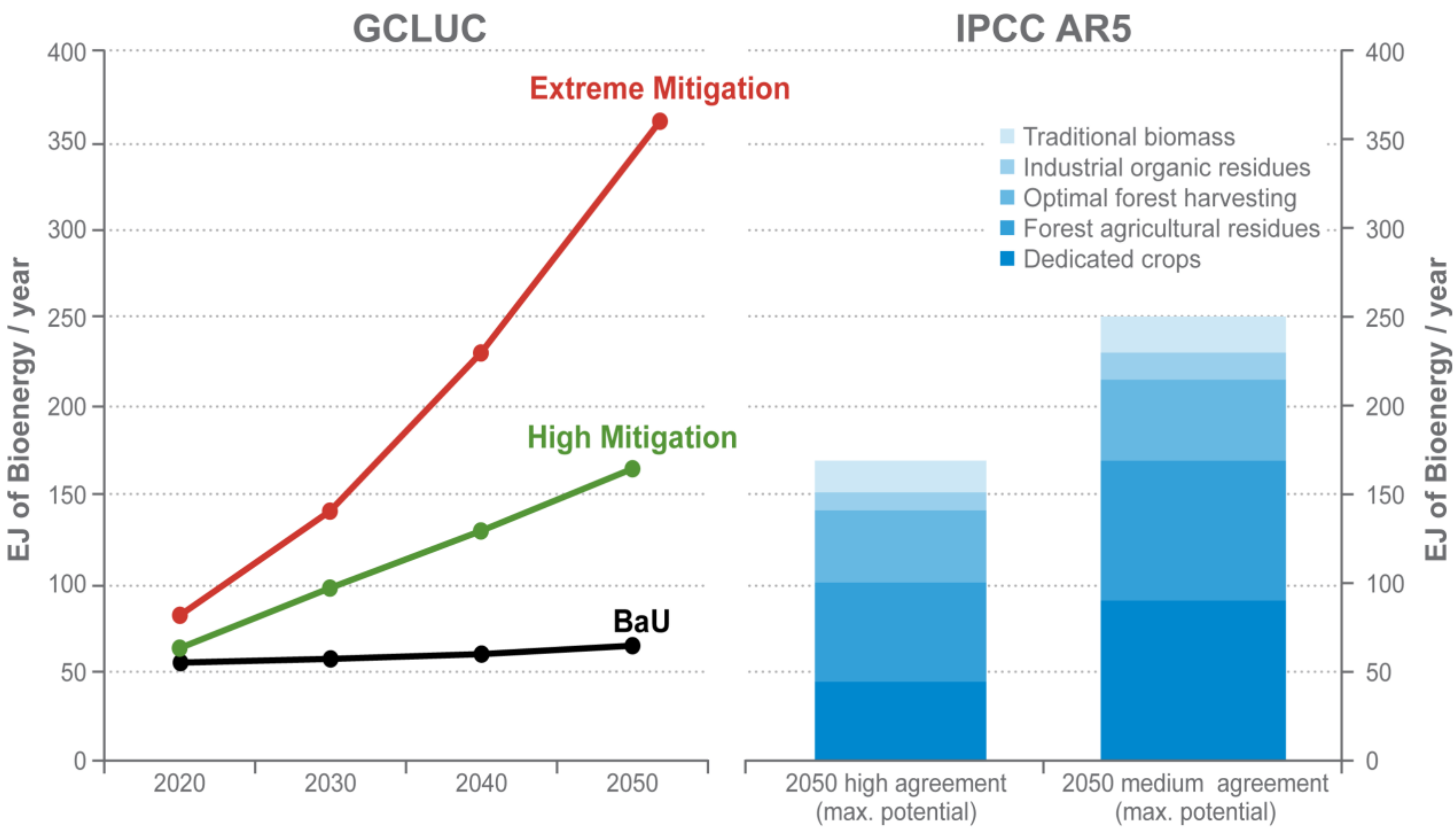
Twitter: @GlobalCalc #GlobalCalculator

Global simulations for bioenergy expansion by 2050



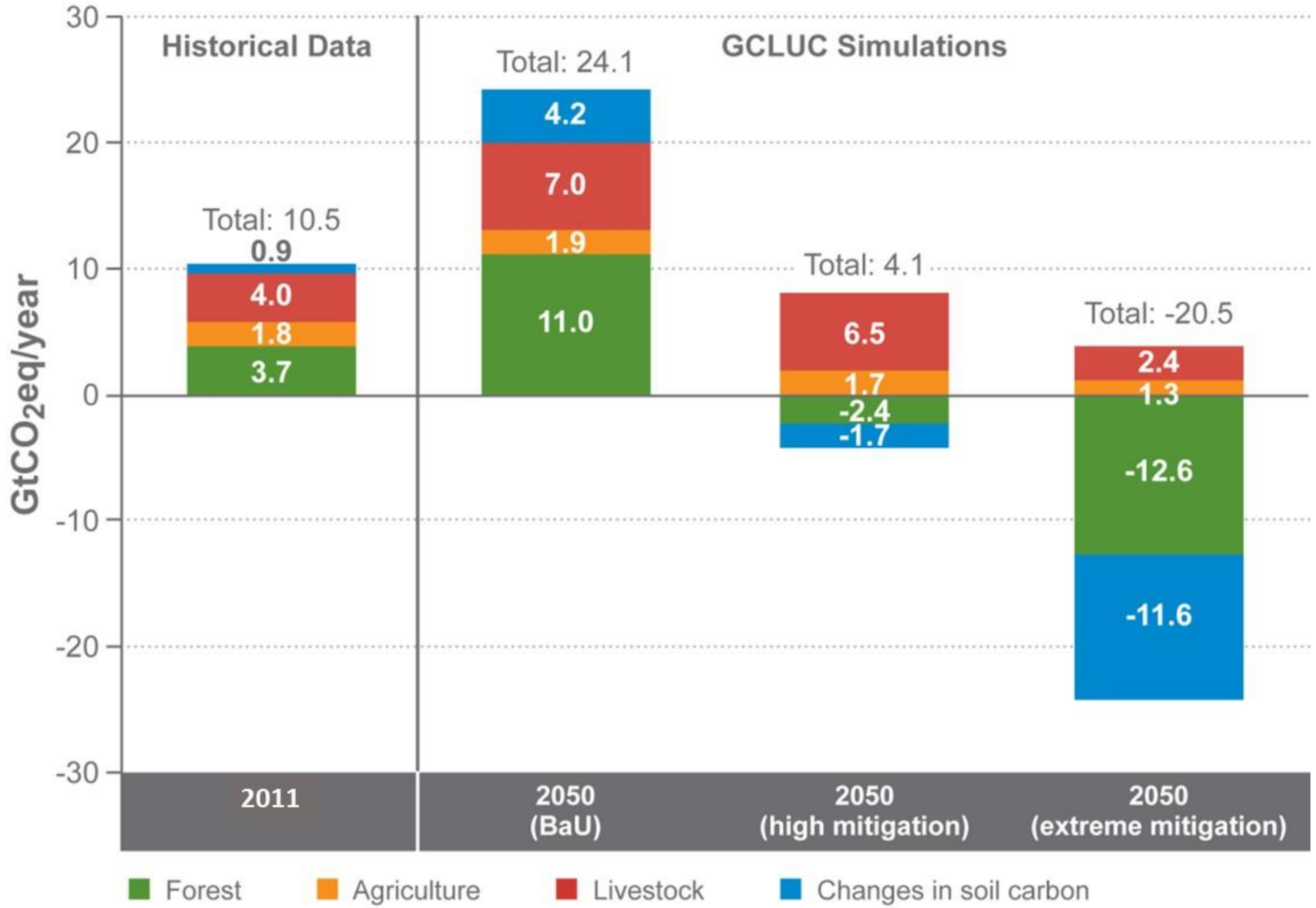
Source: Strapasson et al. (2017, in press)

Global simulations for bioenergy expansion by 2050



Source: Strapasson et al. (2017, in press)

Global simulations for GHG mitigation in the agriculture, forestry and other land uses (incl. bioenergy) by 2050

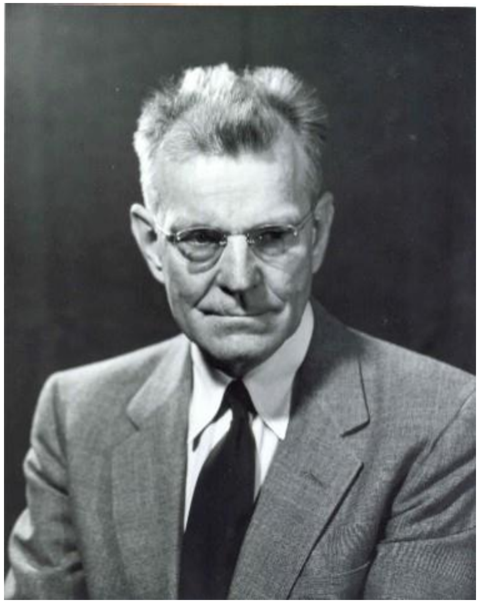


Source: Strapasson et al. (2017, in press)

How should bioenergy expand in well delimited areas?

For oil reserves, M.K. Hubbert proposed in the 1950s
a logistic curve to describe a potential "peak oil" over time.

The Hubbert's model is controversial, but it shows reasonable accuracy
when the oil reserves and their exploitation rate are well known



Would it make sense to think about land as a finite resource and therefore a "green" Hubbert curve for its exploration over time for bioenergy purposes under zoning schemes?

The green-Hubbert Model

Land use allocation for bioenergy production (S curve):

$$gH_s = \frac{Z\,.\,EXP\,(b(t - tm))}{1 + EXP\,(b(t - tm))}$$

gH_s = green-Hubbert S-curve
Z = land suitable for sustainable bioenergy production
t = reference date (year)
tm = date at midpoint (year)
b = factor describing the slope of the curve

Land Use Change (LUC) for bioenergy production (bell curve):

$$gH_{LUC} = \frac{Z}{(1 + COSH(b(t - tm))}$$

gH_{LUC} = green-Hubbert Land Use Change curve

Source: Strapasson (2014)

gH Model and Agro-Ecological Zonings for Bioenergy

Brazil is the only country that already has an AEZ for biofuels in place which provides the technical potential for the sustainable expansion of sugarcane nationwide.

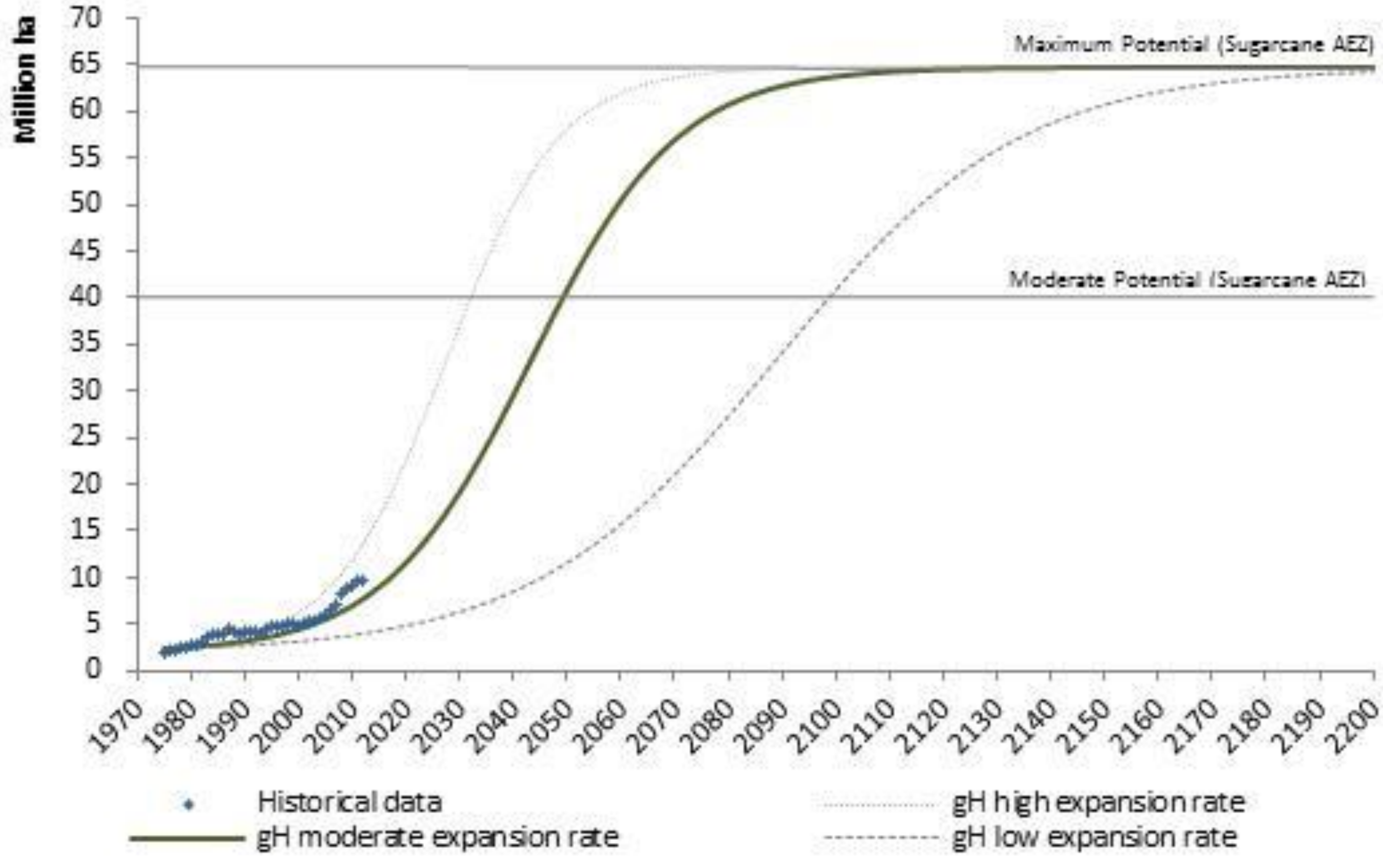
This potential represents the sugarcane EUR (Expected Ultimate Recovery), i.e., the Z value.

<u>Restricted areas</u> for the sugarcane expansion in Brazil:

- Amazon and Pantanal (swampland) biomes
- Lands with any kind of native vegetation
- Lands without soil and climate favourable conditions
- Lands that would require full irrigation systems
- Land slope > 12%, in order to stimulate mechanical harvest
- Protected areas and indigenous reserves
- Lands with high conservation value for biodiversity

Source: MAPA

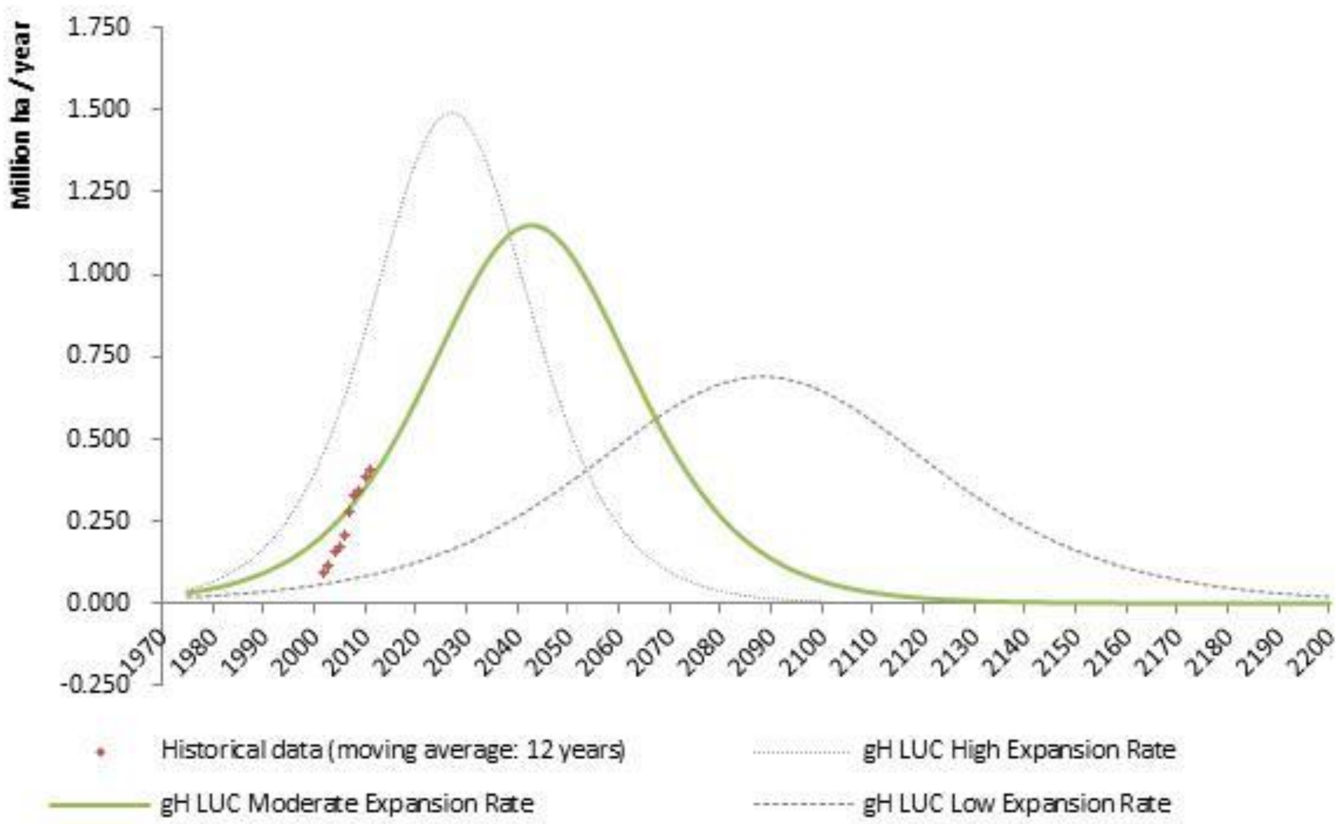
green-Hubbert model simulation for sugarcane expansion in Brazil



Land use curves for the expansion of sugarcane in Brazil, using the green-Hubbert Model

Source: Strapasson (2014)

green-Hubbert model simulation for sugarcane LUC in Brazil



Land use change curves for the expansion of sugarcane in Brazil, with historical moving average data (12 years), using the green-Hubbert Model

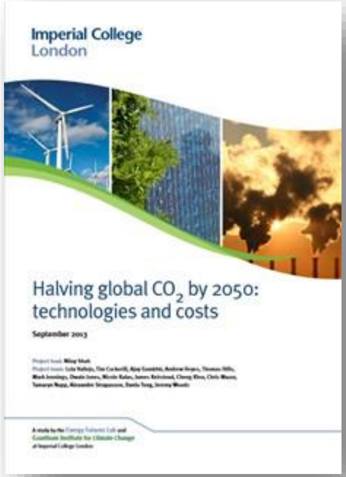
Source: Strapasson (2014)

Other alternative approaches

- **Financial Times' calculator for INDCs of major economies**

  http://ig.ft.com/sites/climate-change-calculator/

- **Imperial College's global econometric simulation for climate mitigation**



www.imperial.ac.uk/grantham/publications

Adapted land use model for the EU28

Imperial College London

Grantham Institute
Briefing paper No 17
March 2016

Land use futures in Europe

How changes in diet, agricultural practices and forestlands could help reduce greenhouse gas emissions

ALEXANDRE STRAPASSON, JEREMY WOODS AND KOFI MBUK

In partnership with the UK Department of Energy and Climate Change (DECC) and the UK Foreign and Commonwealth Office (FCO)

Foreign & Commonwealth Office

Department of Energy & Climate Change

Headlines:

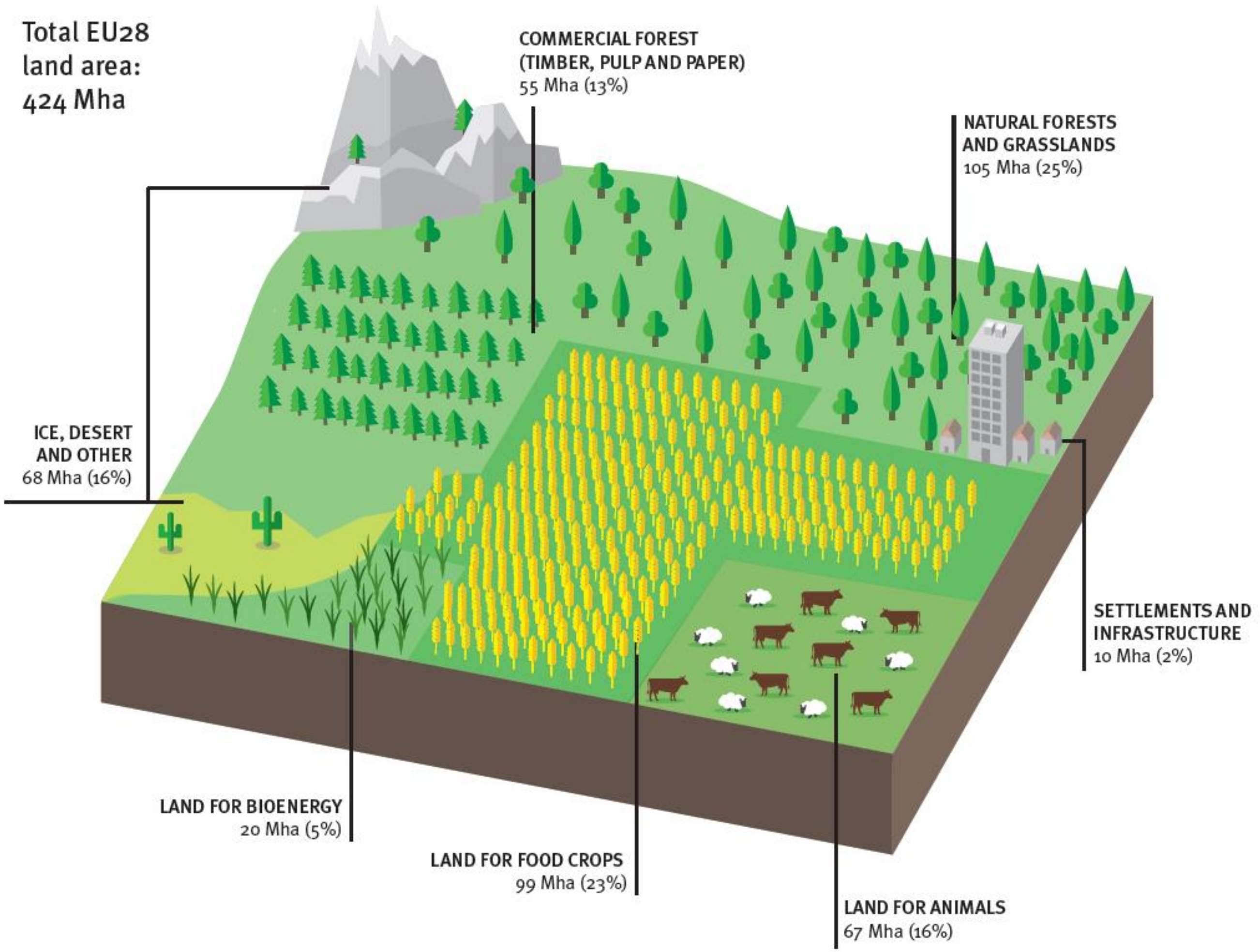
- Land use change, such as afforestation, reforestation and multiuse of land resources, has the potential to contribute substantially to reducing Europe's greenhouse gas emissions.
- Changes in the types and quantities of food consumed per person and reduced food wastes would help the EU meet its climate change targets by 2050.
- EU greenhouse gas emissions are highly sensitive to the food trade balance, both within and outside the EU. Choices made about the EU's level of self-sufficiency in food and food security are key determinants of net EU and global greenhouse gas emissions.
- To assess complex land use dynamics, including multiple uses of varying intensities, combinations of empirical data, mapping tools and integrated systems models are needed.
- To achieve greenhouse gas emissions reduction through land use and dietary change, the right mix of short and long-term policies is needed. In the case of dietary changes and reduced food waste, success may depend on systemic behavioural changes which would require a range of policy levers ranging from market regulations through to education and links with the health agenda.

Contents

Grantham Briefing Papers analyse climate change and environmental research linked to work at Imperial, setting it in the context of national and international policy and the future research agenda. This paper and other Grantham publications are available from www.imperial.ac.uk/grantham/publications

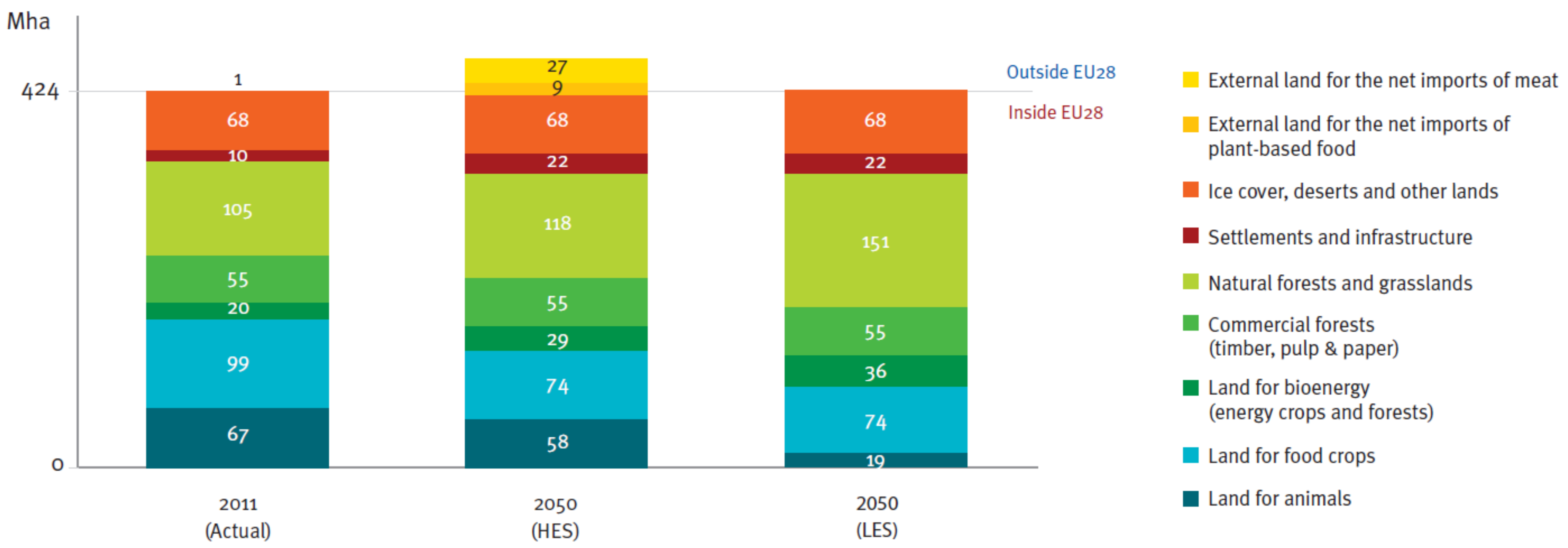
www.imperial.ac.uk/grantham/publications/briefing-papers/

Current land use in the EU28



Source: Strapasson et al. (2016)

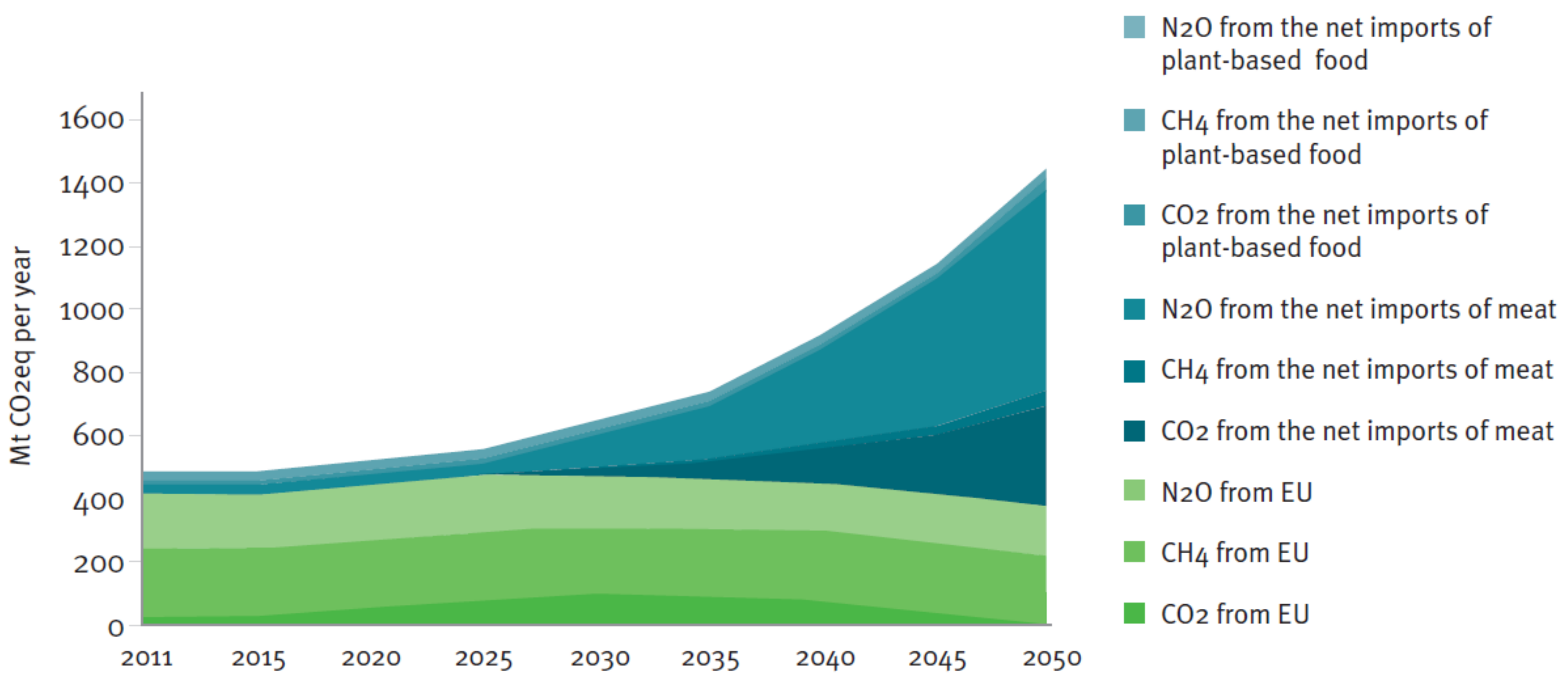
Simulation for High and Low Emission Scenarios



Land use change for the EU28

Source: Strapasson et al. (2016)

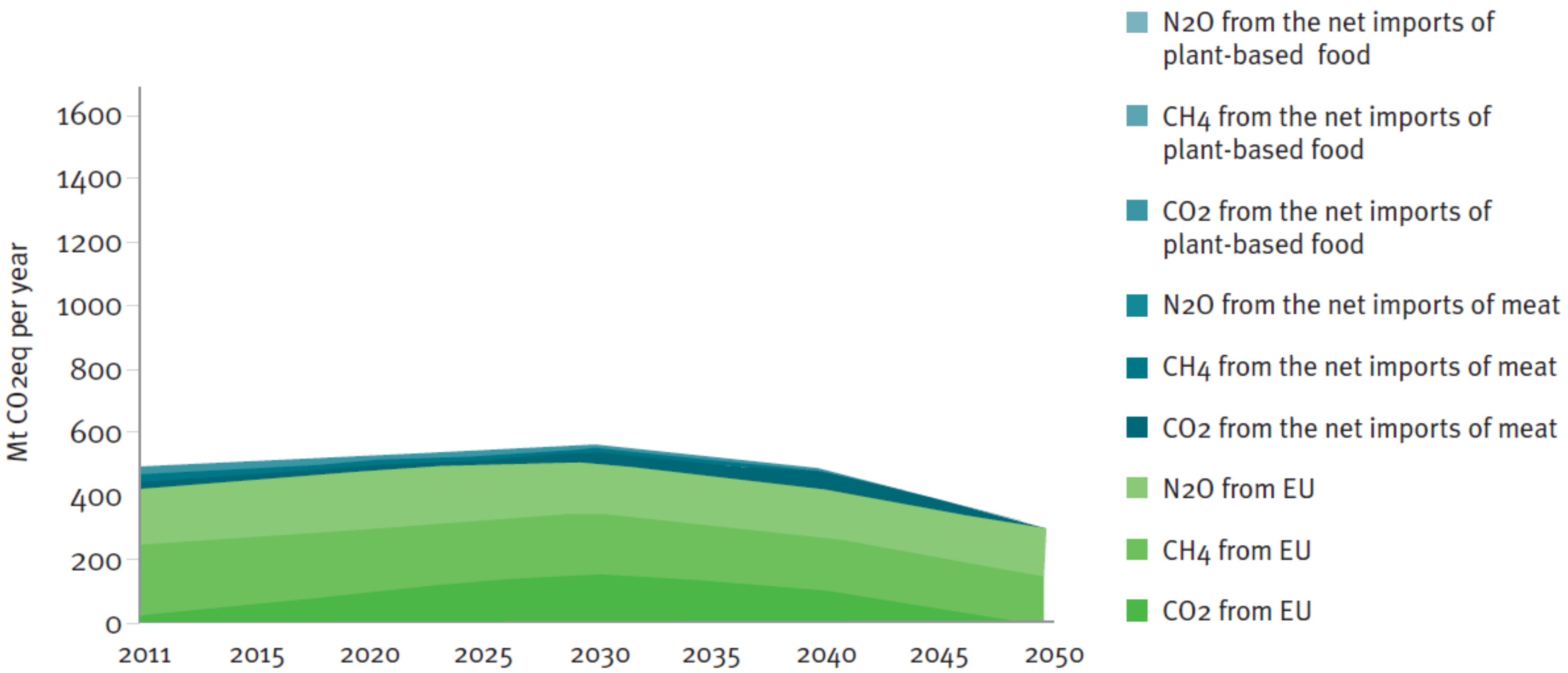
Simulation for a High Emission Scenario (HES)



Greenhouse gas emissions for the EU28

Source: Strapasson et al. (2016)

Simulation for a Low Emission Scenario (LES)



Greenhouse gas emissions for the EU28

Source: Strapasson et al. (2016)

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