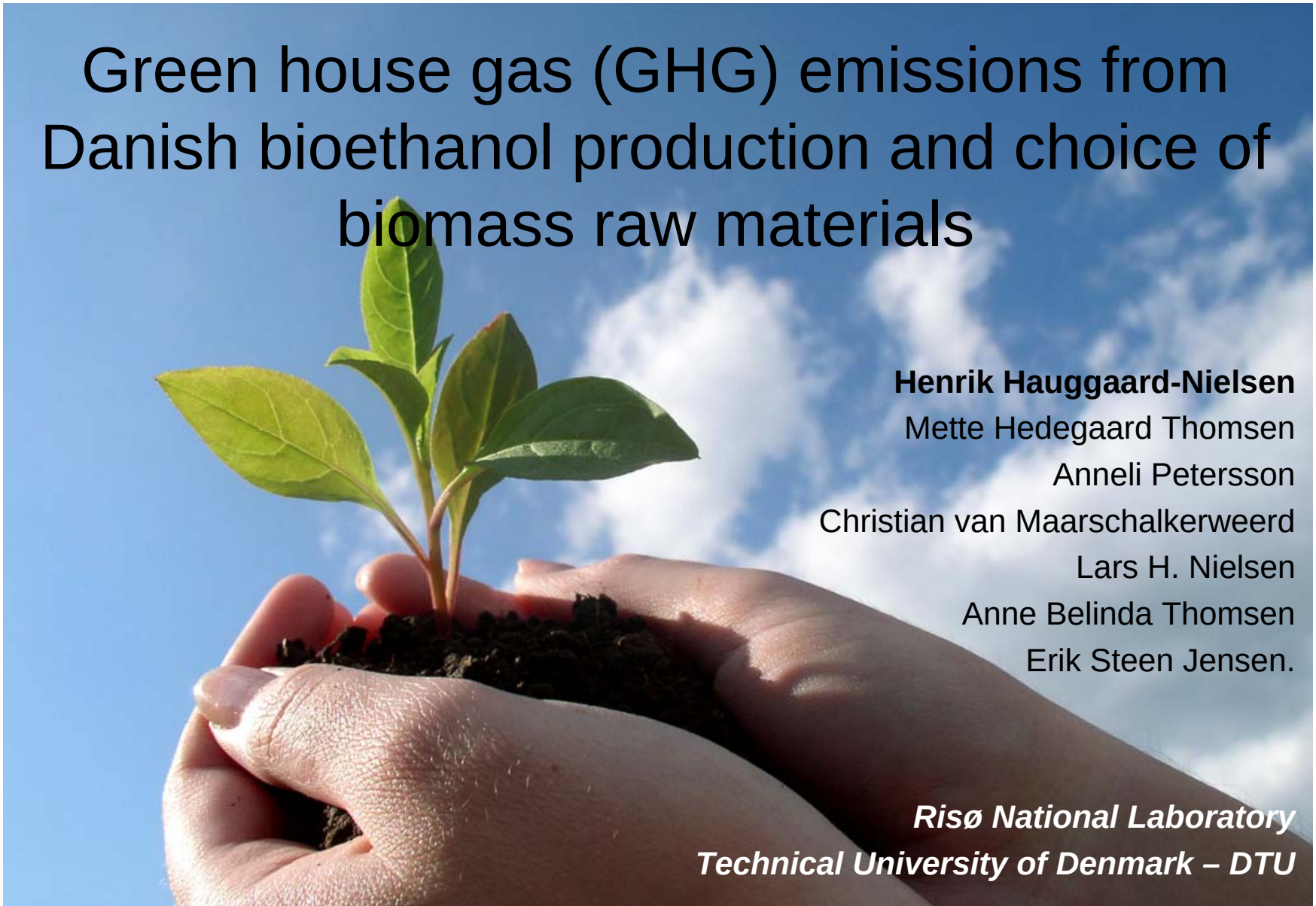
NJF 23rd Congress in Copenhagen, 26 - 29 June 2007

Green house gas (GHG) emissions from Danish bioethanol production and choice of biomass raw materials



Henrik Hauggaard-Nielsen
Mette Hedegaard Thomsen
Anneli Petersson
Christian van Maarschalkerweerd
Lars H. Nielsen
Anne Belinda Thomsen
Erik Steen Jensen.

Risø National Laboratory
Technical University of Denmark – DTU

Why bioethanol?

- Between 1985 and 2004, road transportation (i.e., cars and trucks) fuel consumption in Western Europe (primarily the EU) grew by nearly 50%
  - The transport sector in EU is responsible for around 21 % of all GHG emissions
- Under the Kyoto Protocol the EU has committed to an 8% reduction of carbon dioxide (CO_2) emissions by the end of 2012.
- Bioethanol and biodiesel bioethanol produce substantially less CO_2 emissions (depending on the particular feedstock) than their fossil fuel counterparts.

- In 2005 the EC set a goal of replacing 20% of conventional motor fuels with alternate fuels (e.g., biofuels, natural gas, and hydrogen fuels) by 2020.

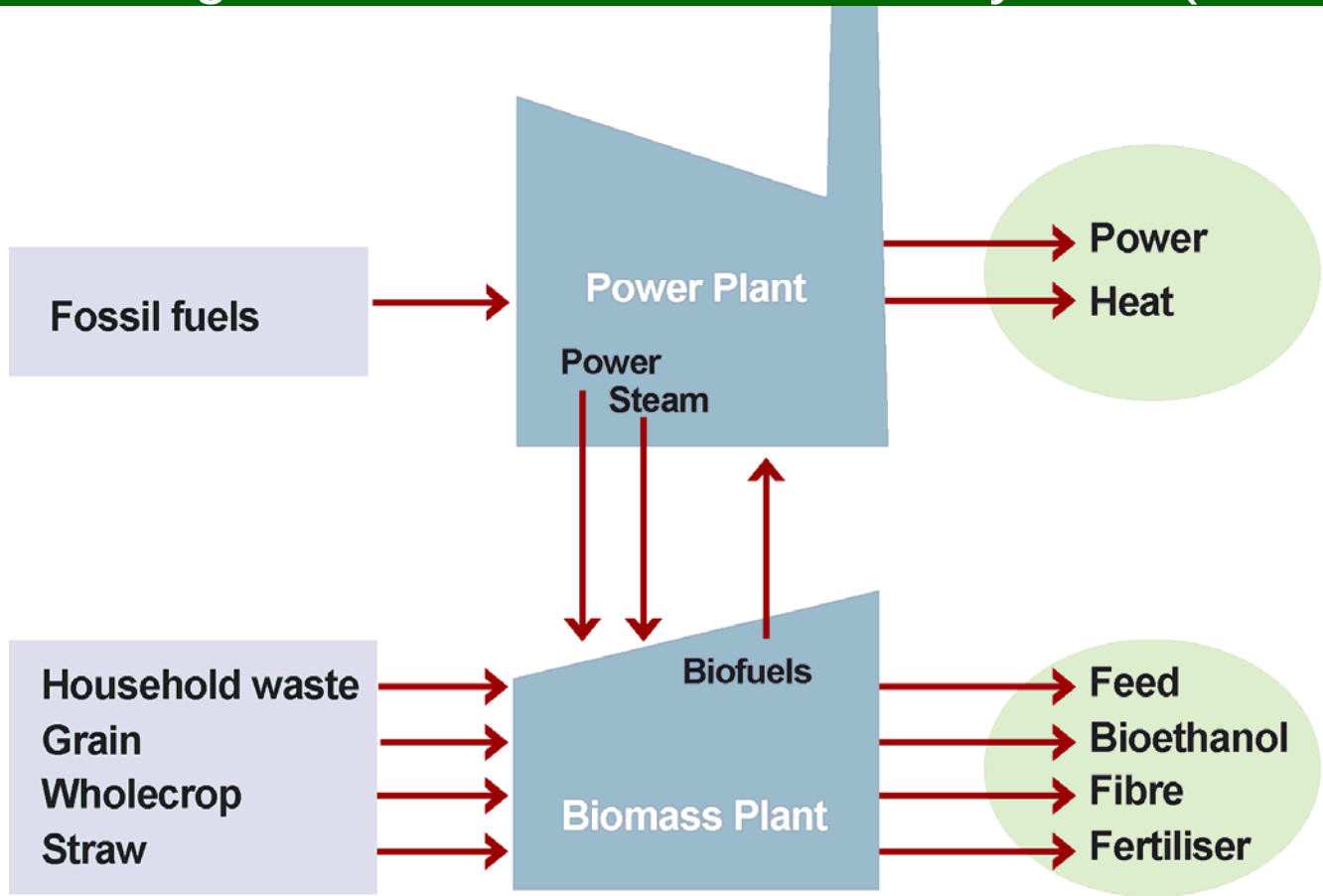
Source: An EU Strategy for Biofuels, COM (2006)

Up-scaling pilot studies to commercial factory

100 kg straw h^{-1} (2004)

1000 kg straw h^{-1} (2006)

The Danish Integrated Biomass Utilization System (IBUS)



Partners:

Copenhagen University Life

Sicco K/S (DK – engineering company)

TMO biotec (UK – termophilic microorganisms)

Risø National Laboratory, Technical University Denmark

GHG balances using the IBUS concept

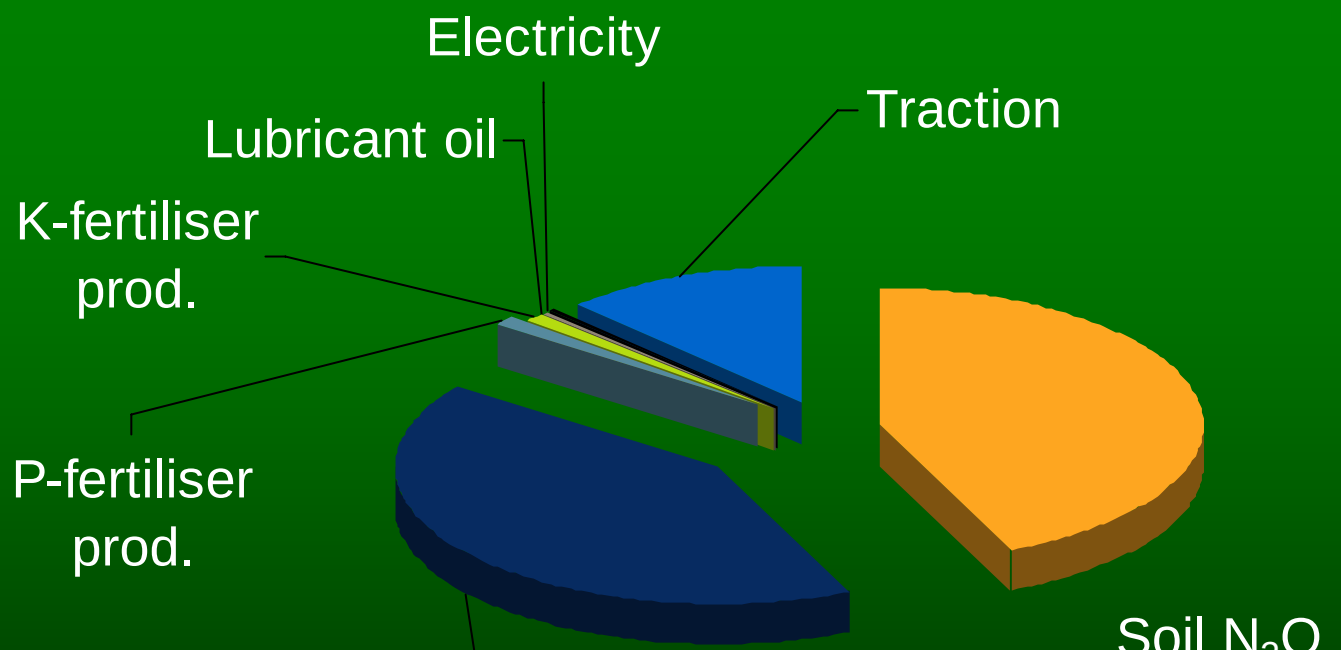
Conclusions based upon LCA perspectives incl. entire production chain

- Grain (wheat) based ethanol results in modest or even negative GHG emissions compared to neat petrol reference case
- Straw (wheat) based ethanol show a great potential for GHG savings

- Biomass production and management is a very prominent source of GHG emissions in these calculations
  - Looking at the entire ethanol production cycle it can be concluded
    1. generation ethanol - 60-70% of total emissions
    2. generation ethanol - 30-45% of total emissions

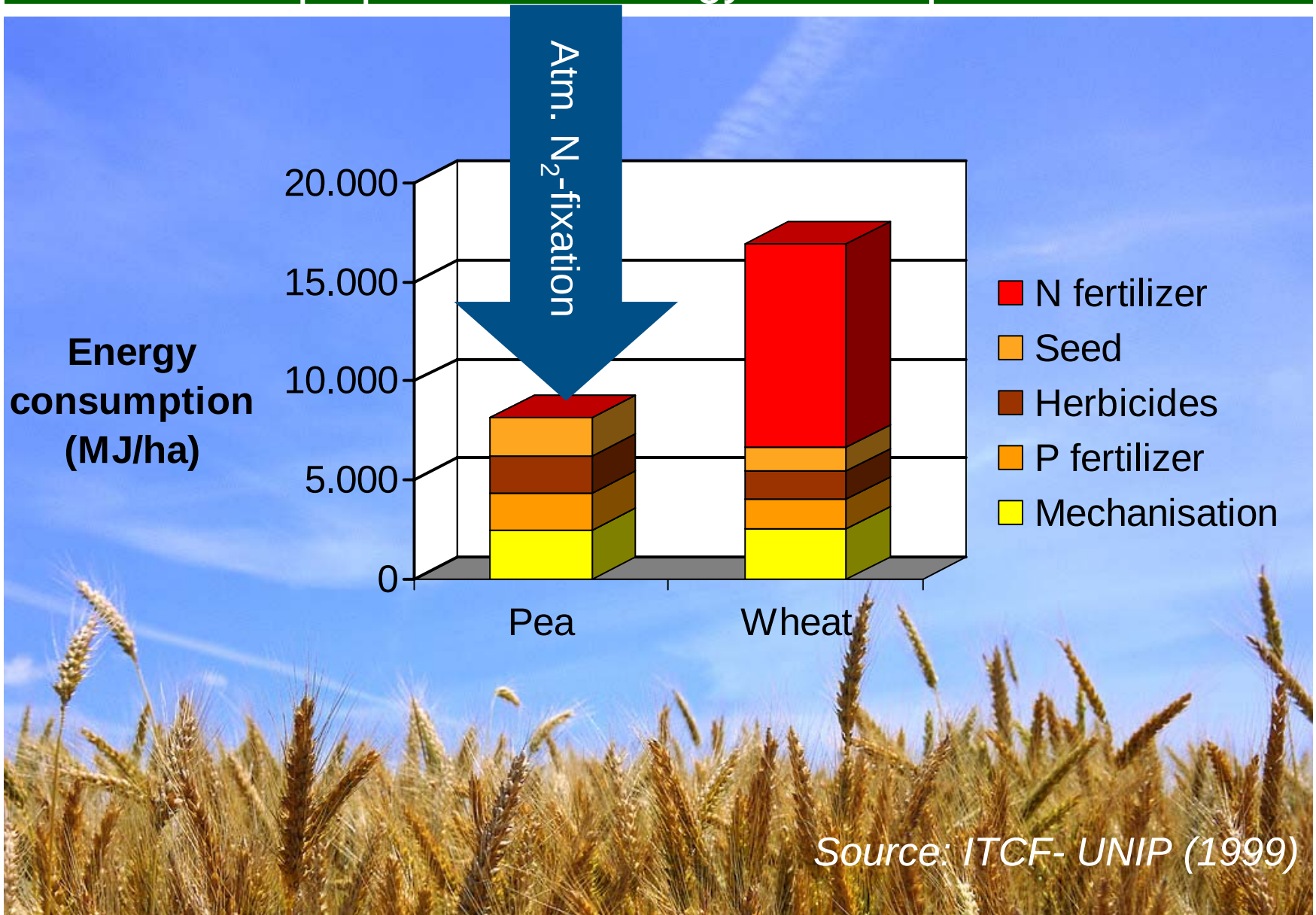
Source: van Maarschalkerweerd, 2006

GHG emission sources from Danish wheat grain production



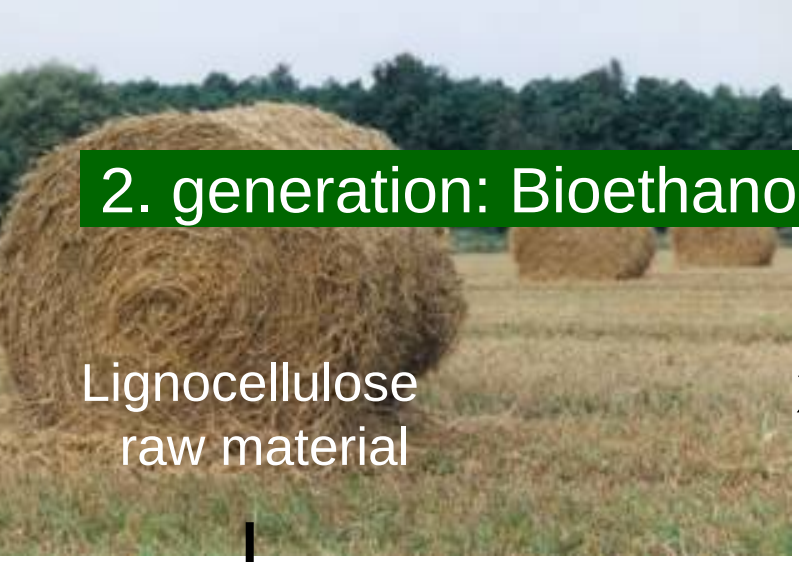
Source: LCA Food, 2006

Choice of crop species and energy consumption



Source: ITCF- UNIP (1999)

2. generation: Bioethanol from straw



Lignocellulose
raw material

Xylanase

Microorganism?

C5

250 kg EtOH
per tons straw

Pretreatment

Hemicellulose

Cellulose

Lignin

Cellulases

Yeast

C6

Hydrolyses

Fermentation

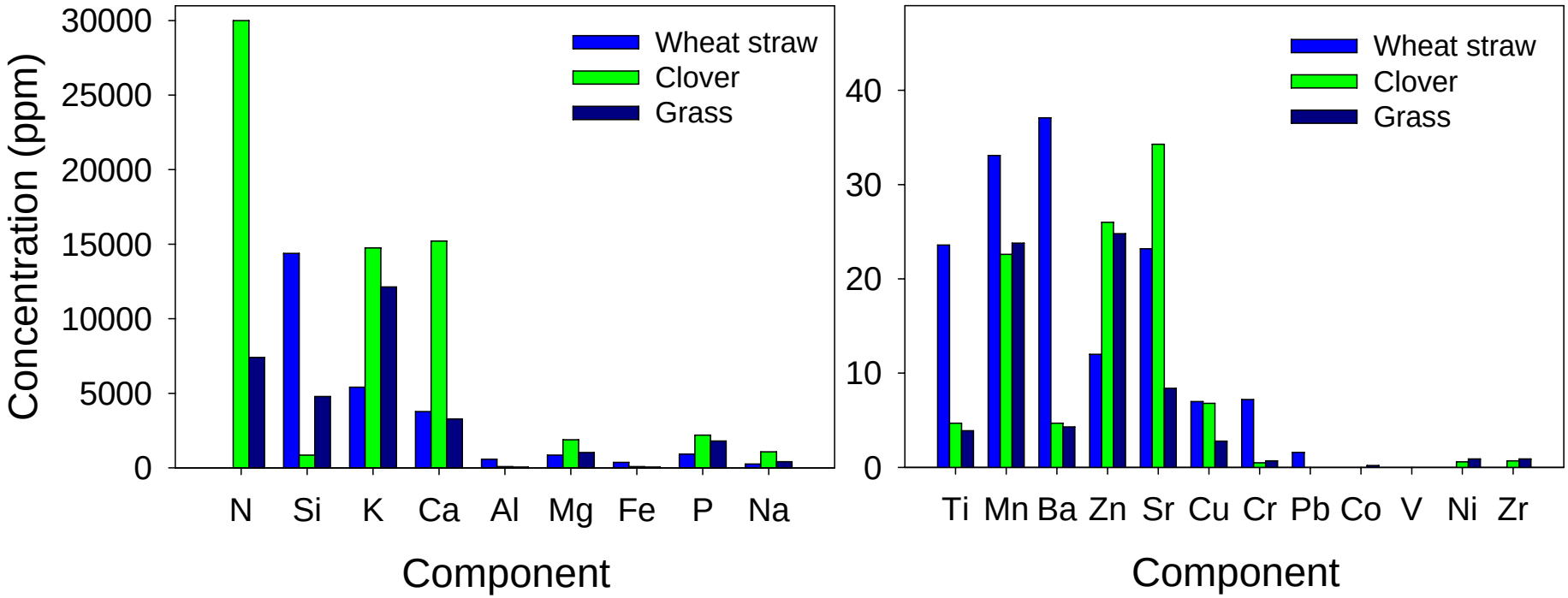
Distillation

Testing alternative 2. generation raw materials

1. Annual crops
   - Petersson et al., 2007; Biomass and Bioenergy (in press)
     - Testing: i) winter rye straw (*Secale cereale* L.), ii) oilseed rape straw (*Brassica napus* L.) and iii) faba bean straw (*Vicia faba* L.).
       - CONCLUDE: Possible raw materials for either biogas or ethanol production, however, optimization needed before an economical process can be achieved.

2. Perennials
   - Clover (*Trifolium repens* L.) - grass (*Lolium perenne* L.) mixtures
     - cropping system engine in many low-input systems
     - rich in carbohydrates, complete mineral fermentation medium
     - several harvests, ethanol can be processed throughout the year.

Mineral composition and fermentation medium

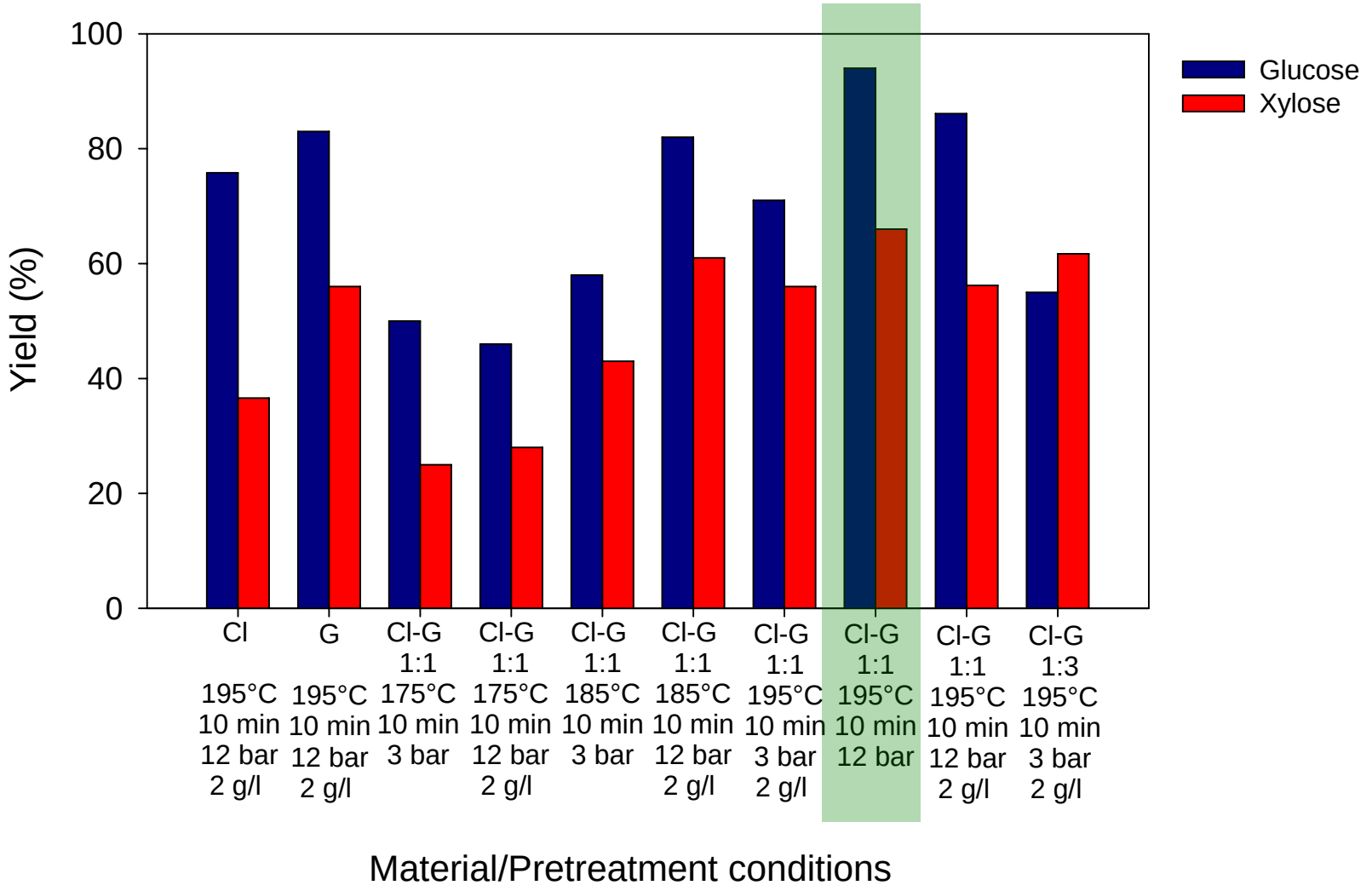


High mineral content ⇒

sufficient nutrients for microbial fermentation ⇒

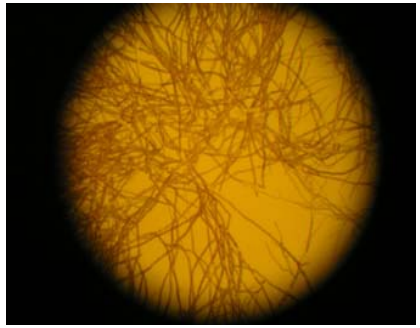
less fossil energy input in ethanol process

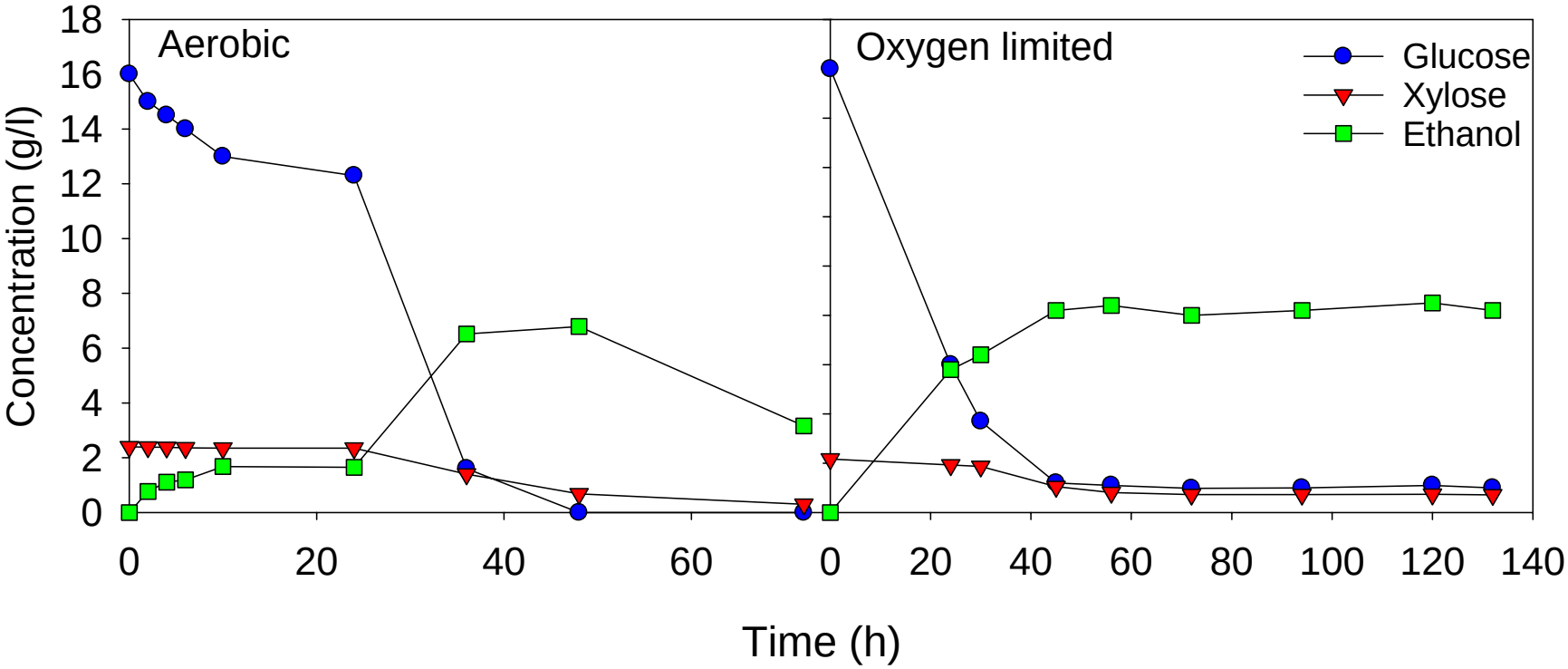
Pretreatment yields



Fermentation of pre-treated clover-grass with *Mucor indicus*





Theoretical ethanol production

The highest sugar yields were obtained with clover grass pretreated at 195ºC for 10 min. using 12 bar O_2 and no Na_2CO_3.

$Y_{cellulose}$ = 94 %

$Y_{hemicellulose}$ = 66 %

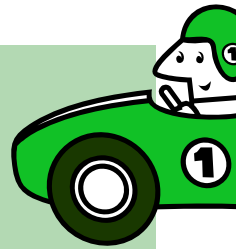
203 kg cellulose/ton DM clover grass ⇒ 107 kg ethanol/ton DM

140 kg hemicellulose/ton DM clover grass ⇒ 63.5 kg ethanol/ton DM

138 kg fructan/ton DM clover grass ⇒ ~ 70.6 kg ethanol/ton DM

Total: 241 kg ethanol/ton DM **~ 2.4 ton EtOH/ha**

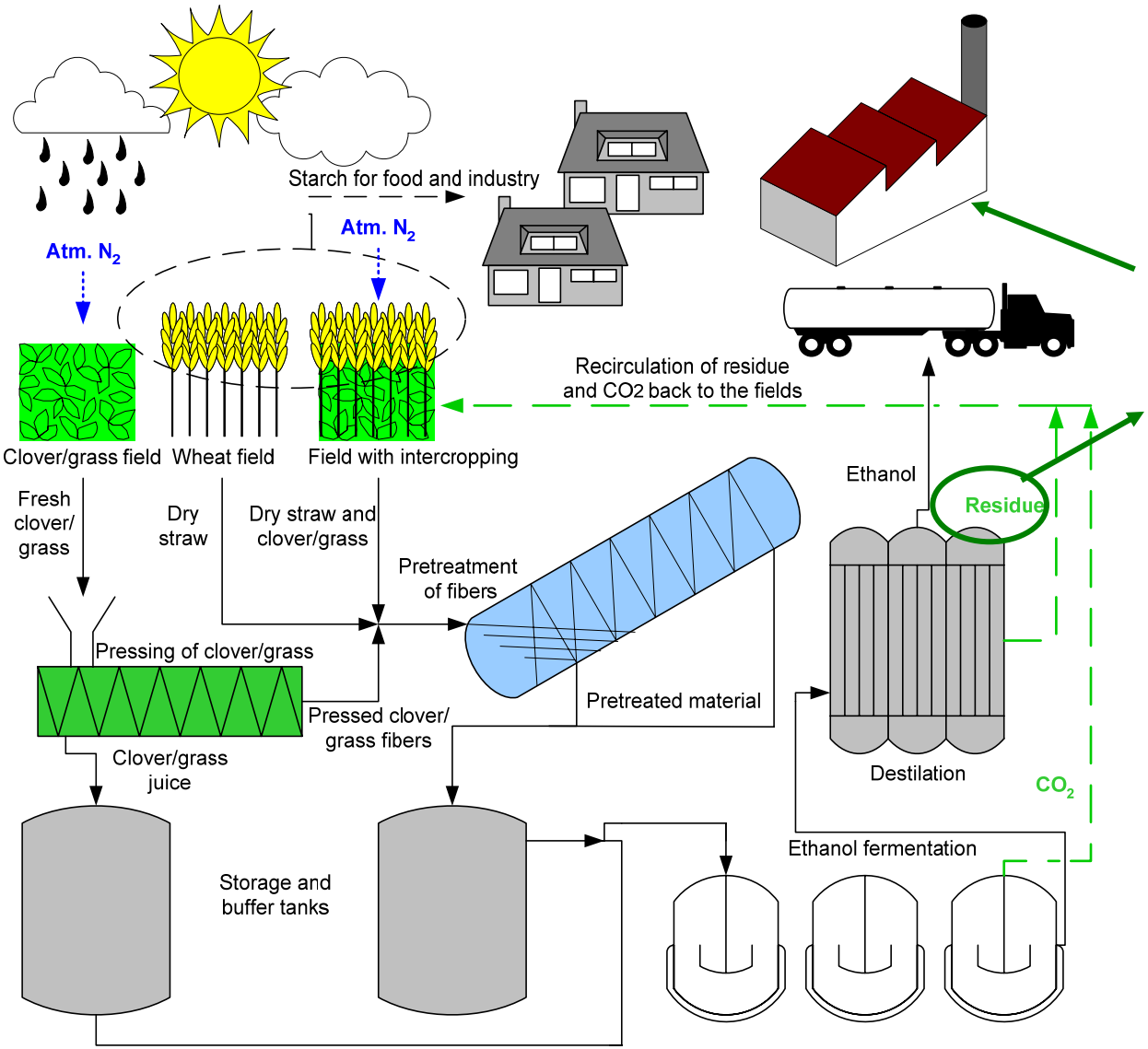
Wheat straw: ~ 250 kg ethanol/ton DM ~ 1.25 ton/ha (IBUS treatment)



Annual + perennial alternative:

Clover-grass undersown in wheat ~ 964 + 1.25 ton/ha = 2.2 ton/ha
+ grain for food/feed

Centralized and/or decentralized biorefinery concept



High value protein rich feed product

Fertiliser rich in micro and macro nutrients

Conclusions

- Biomass is a key diversification strategy to improve energy supply security and mitigate GHG emissions
- Starch is an important food source, lignocellulose should be the primary raw material for bio-fuel production
- Biomass for bioethanol production should be cultivated using the lowest possible input of fossil energy
- All sugars in the chosen biomass raw materials can be utilized by using the right biorefinery concept
- Ecosystem services should be validated together with their ethanol production potential

- Bioenergy systems are relatively complex, intersect
  sitespecific.
  - Solving prob
    tribution from agriculture,
    and environmental sectors

Are we able to create such interdisciplinary collaborations?

Thanks for your attention

Criteria to include when producing biomass

- no effect on food production;
- no increase in pressure on biodiversity;
- no increase in environmental pressure;
- no ploughing of previously unploughed permanent grassland;
- a shift towards more environmentally friendly farming
  - agroforestry – local integration and adoption of wood resources
  - perennial energy crops
  - environmental sensitive areas – e.g. groundwater protection

Source: http://ec.europa.eu/energy/res/biomass_action_plan

- It is required to design new cropping methods and multifunctional cropping systems when addressing a ”new” issue - **energy**.
  - low-input systems (energy and pesticides)
  - harvest, storage and transportation
  - Win-win solutions energy, environment, and recreation