WCBE-2012

Task 4: Feedstock's and Biomass

Congress of Bioenergy

Renewable Energy for Sustainability, April 2012, Xian, China

Large Scale Utilization of New Feedstocks for Biofuels

- Land Use Planning and Paradigm Shifts in Agricultural Growing Systems

by

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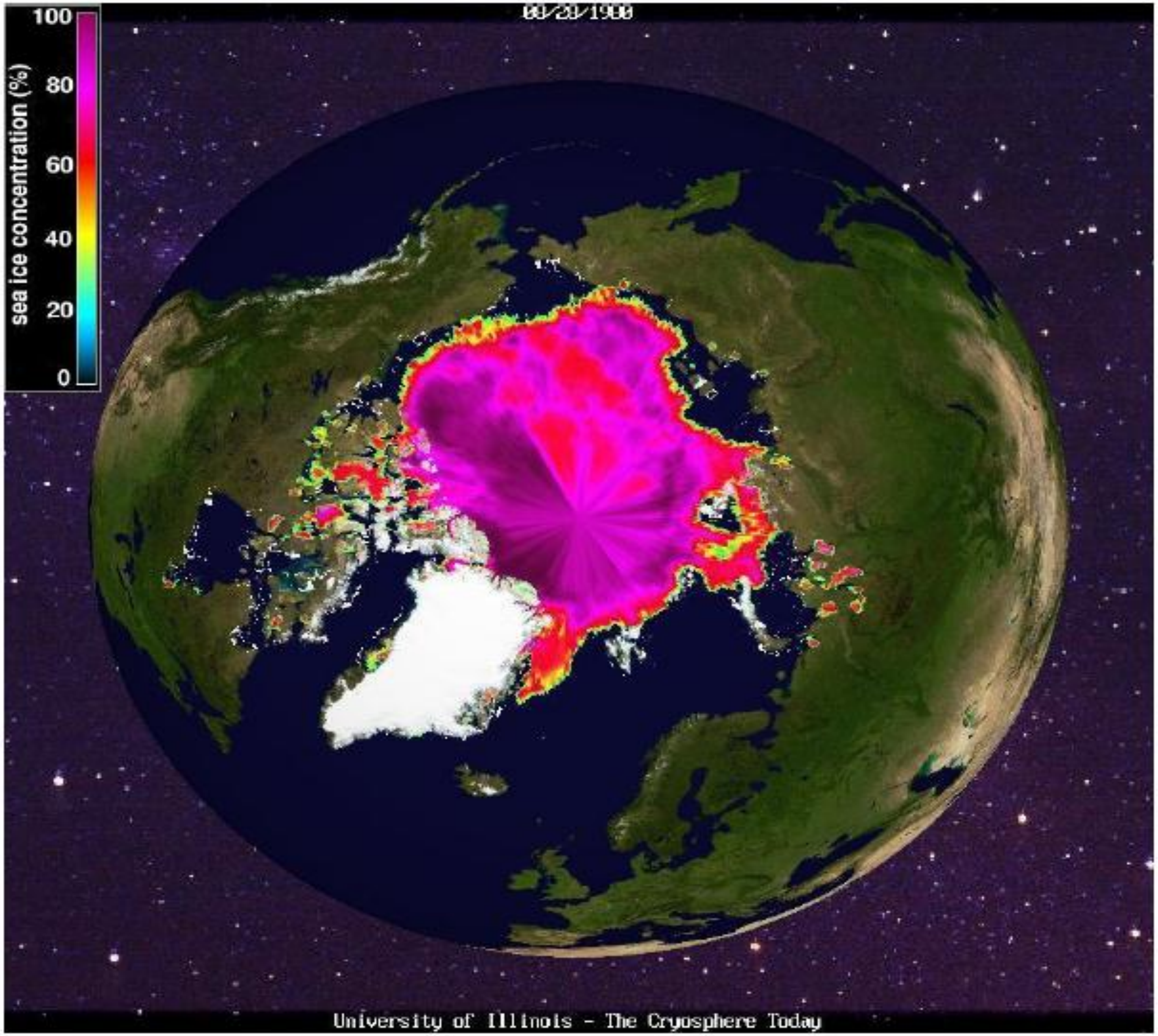
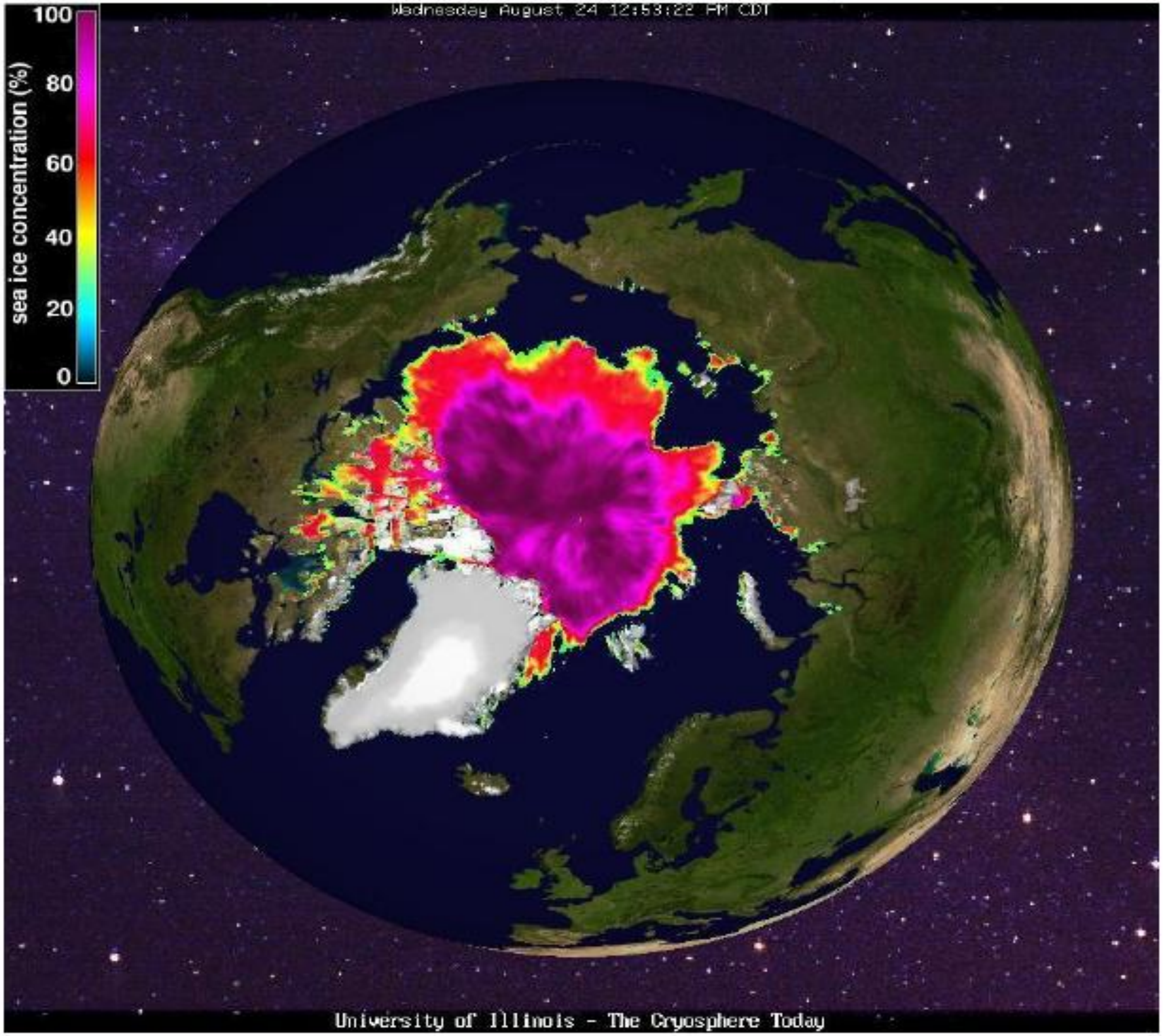
Sea Ice Concentration 29 Aug 1980

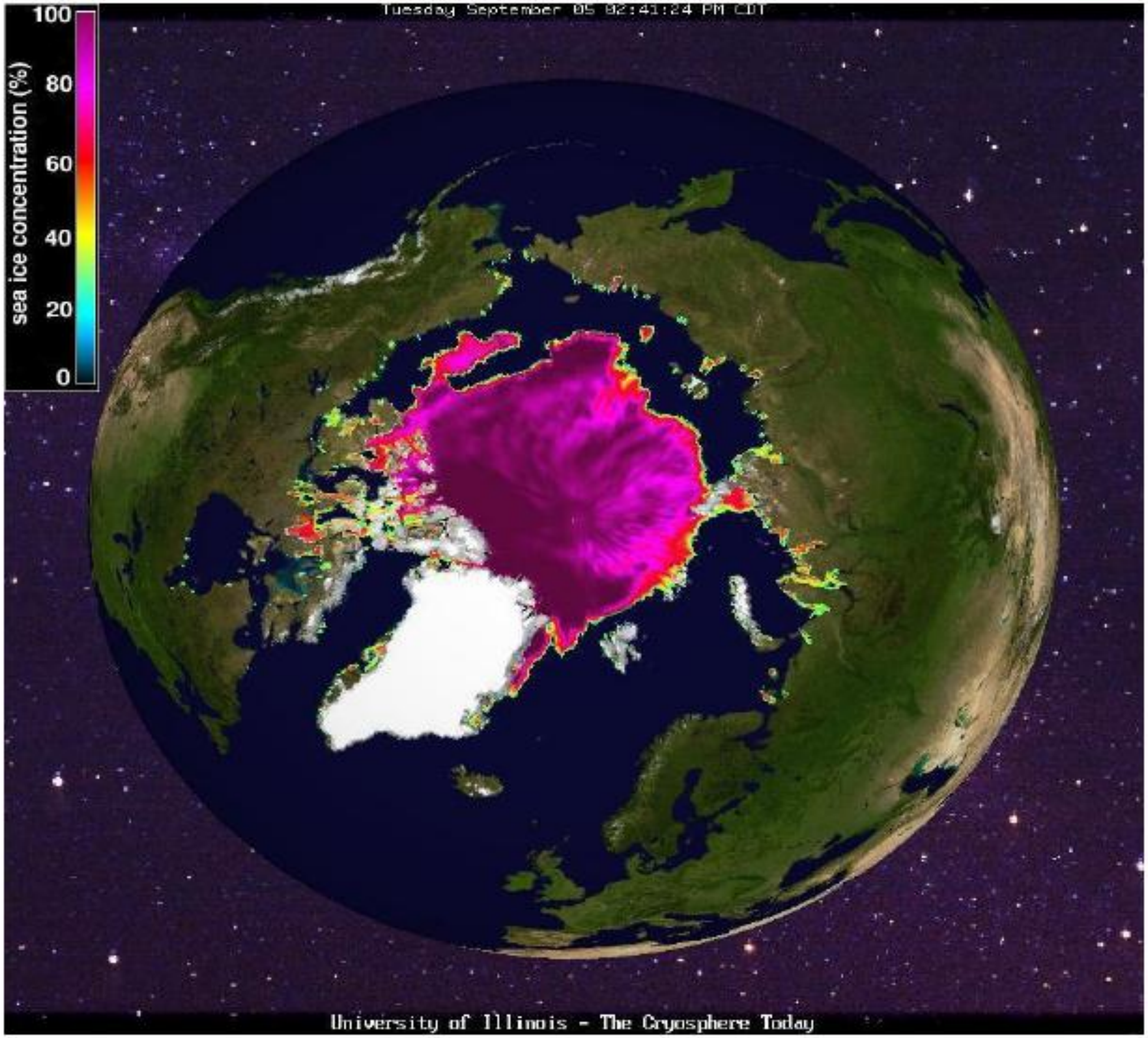


University of Illinois - The Cryosphere Today

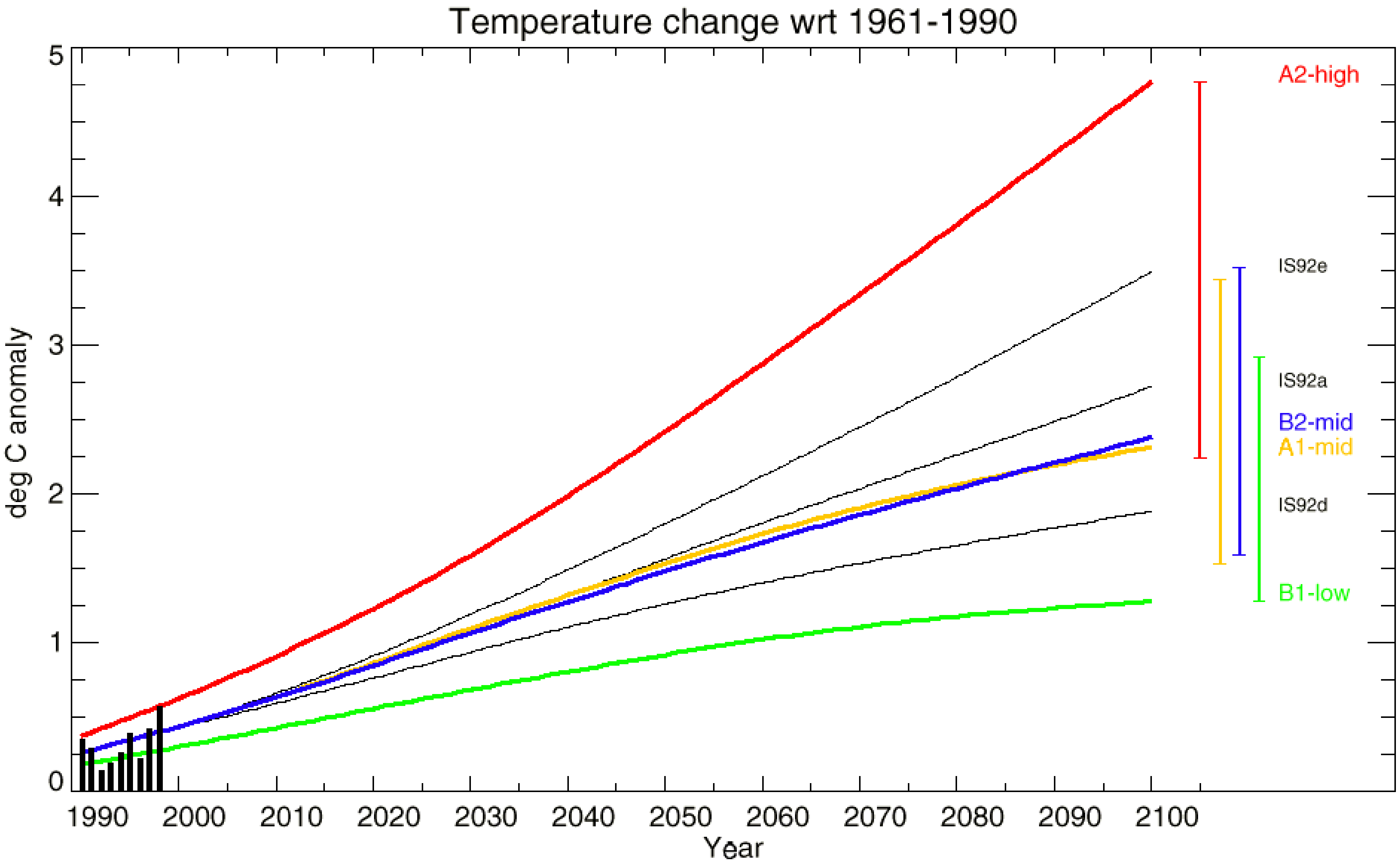
Sea Ice Concentration 25 Aug 2005



Sea Ice Concentration 6 Sep 2006

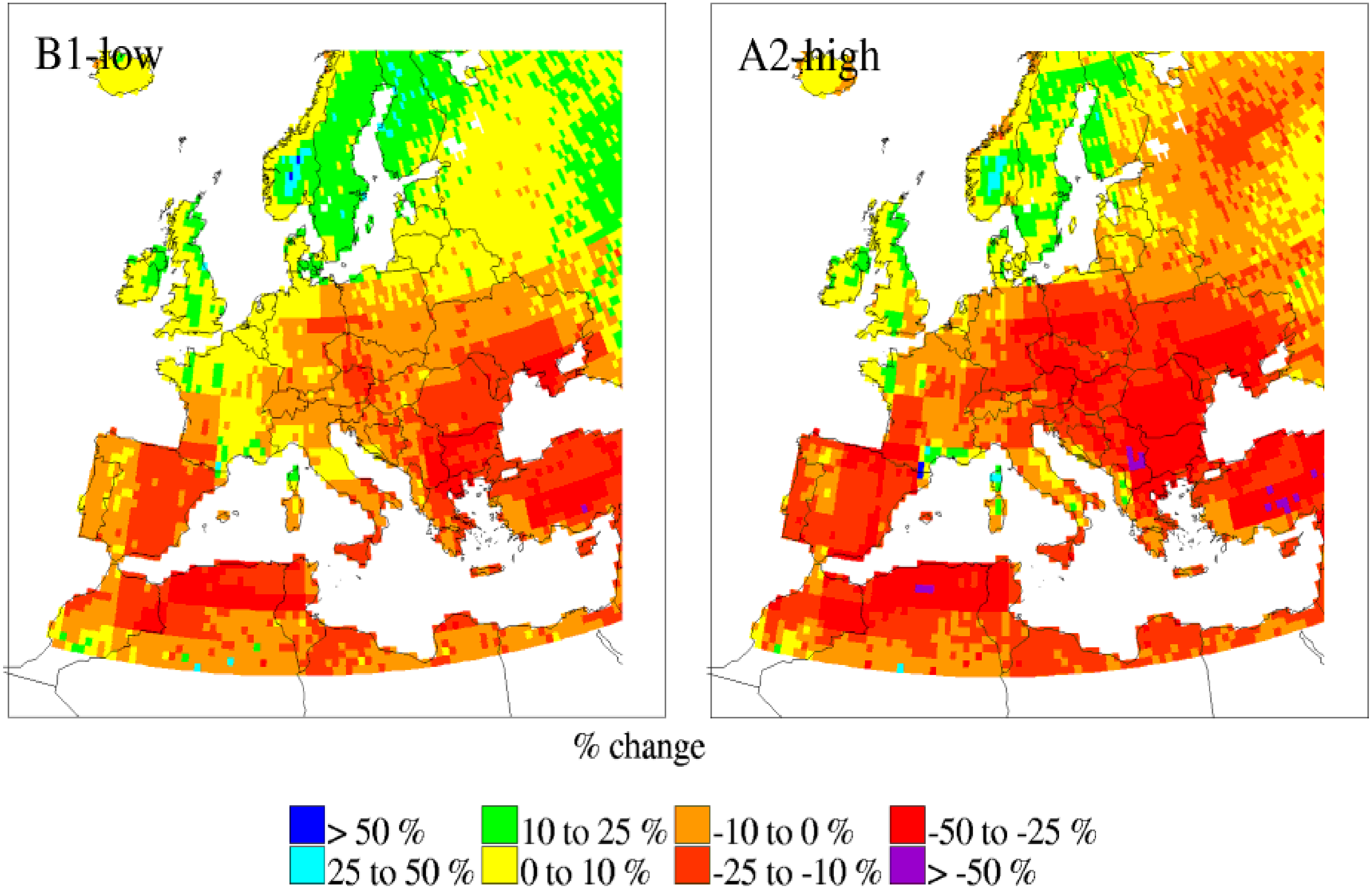


Scenarios for the global mean temperature



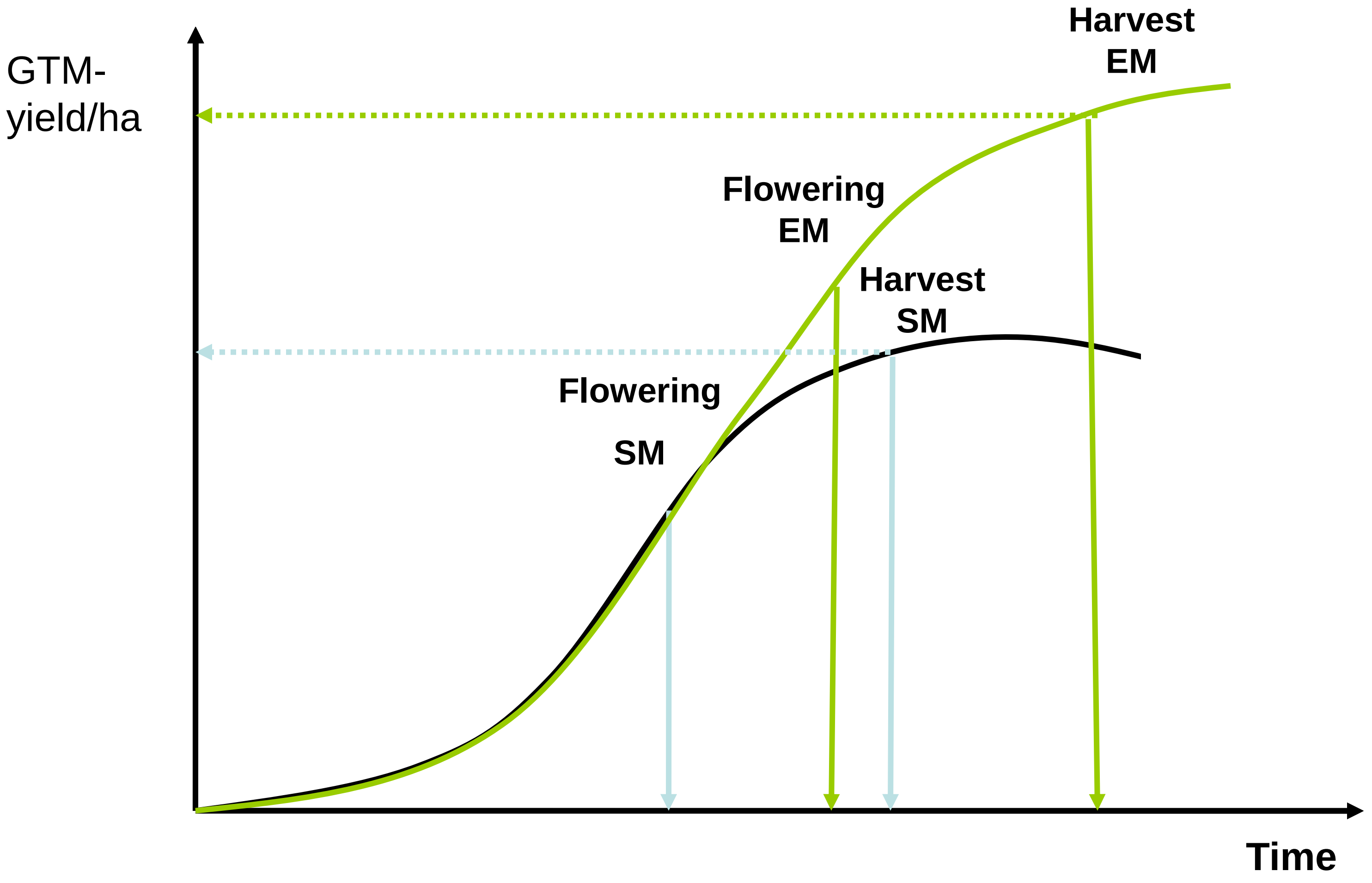
Source: IPCC

Changes in the water balance in the 2050'ties



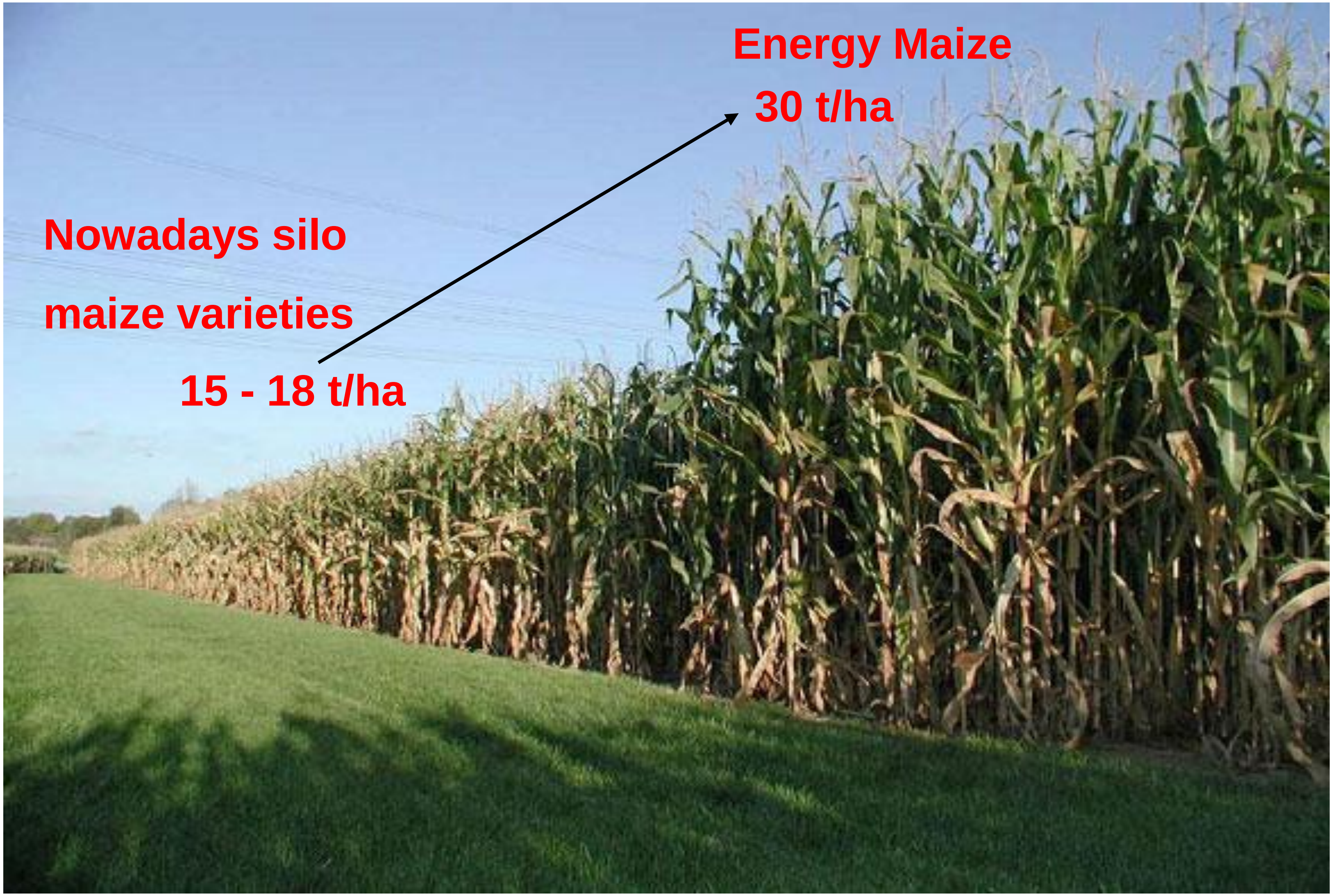
Growth Progress of a Conventional Silo Maize (SM) and an Energy Maize (EM)

Clearly later harvest of the Energy Maize



Source: KWS

Cultivation target:
Stepwise increase of the energy yield to approximately 100 % in 10 years



Energy Maize

30 t/ha

Nowadays silo

maize varieties

15 - 18 t/ha

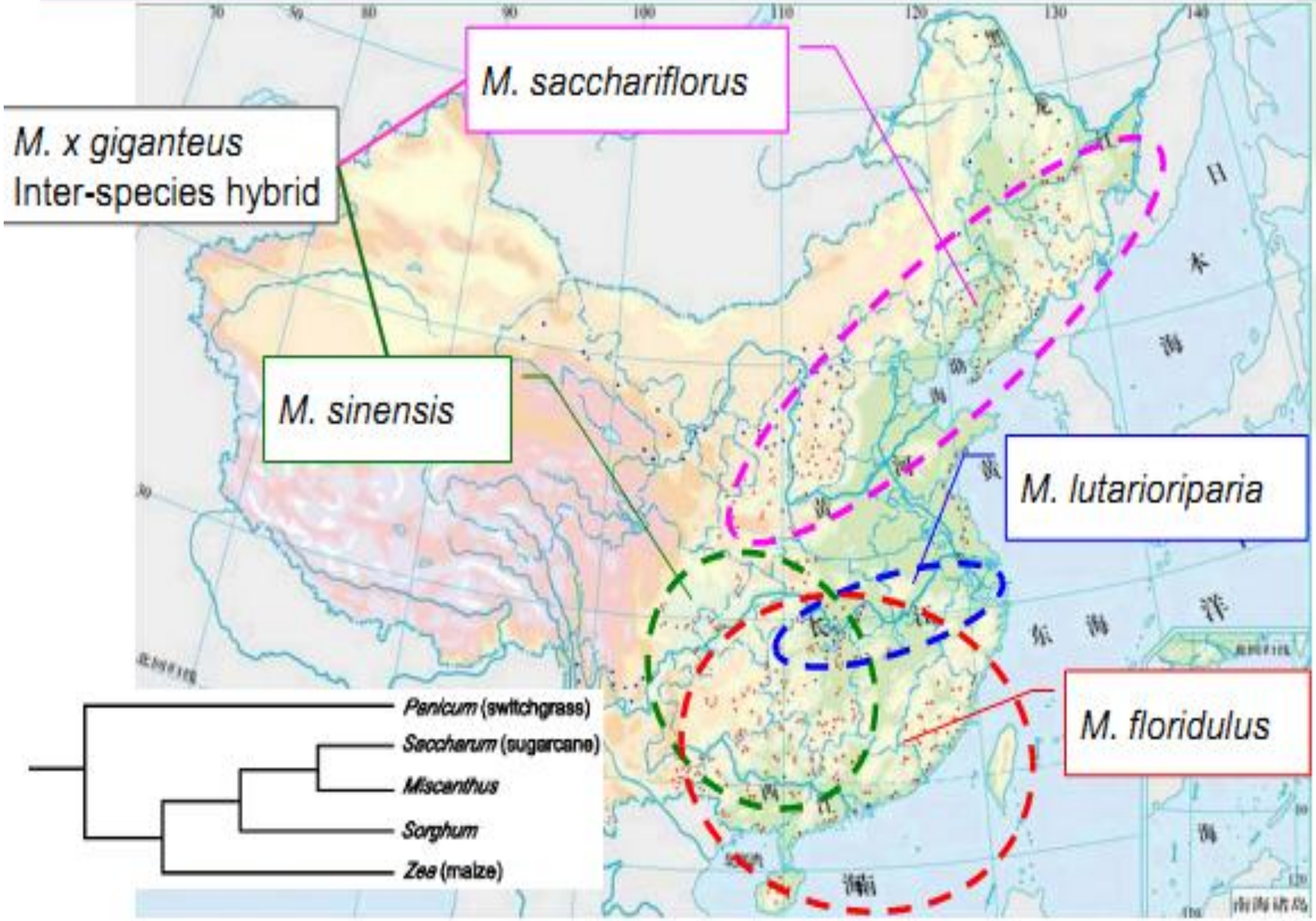
Source:
KWS

Where does Mendel's miscanthus come from?

Mendel BIOENERGY SEEDS

- 15 year old German commercial breeding program
- New collections from the wild in China

What is miscanthus?



M. x giganteus
Inter-species hybrid

M. sacchariflorus

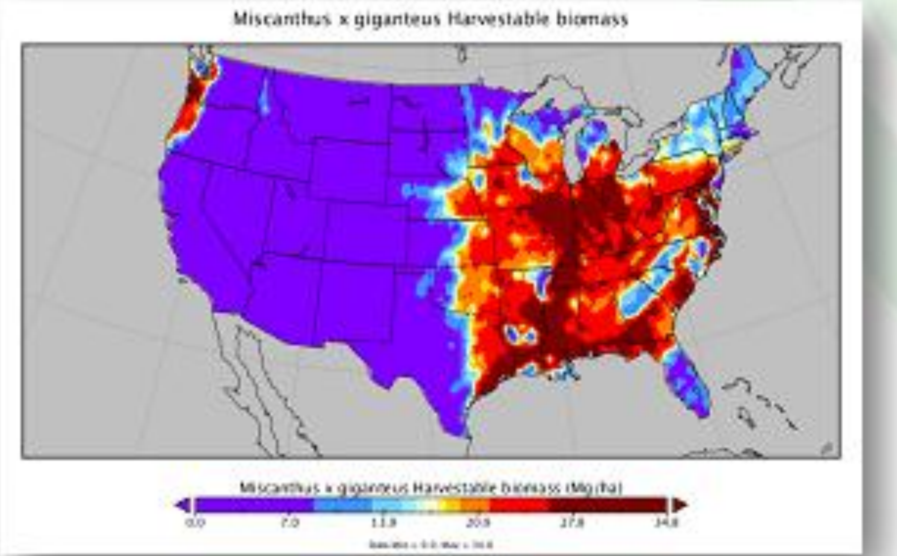
M. sinensis

M. lutarioriparia

M. floridulus

Projected yields are excellent in target markets

- Miscanthus produces more biomass than switchgrass in a majority of important geographic regions studied*



10 → 16 Tons / A

Work of F. Miguez, Iowa State. Published in review: C Somerville, H Youngs, C Taylor, SC Davis, SP Long - Science, 2010

** Meta-analysis of 21 published studies showed average yield (dry tons/acre) of miscanthus and switchgrass as 10 and 4.6, respectively. Heaton E.A., Voigt T., and Long S.P. 2004. Biomass and Bioenergy 27, 21-30.*

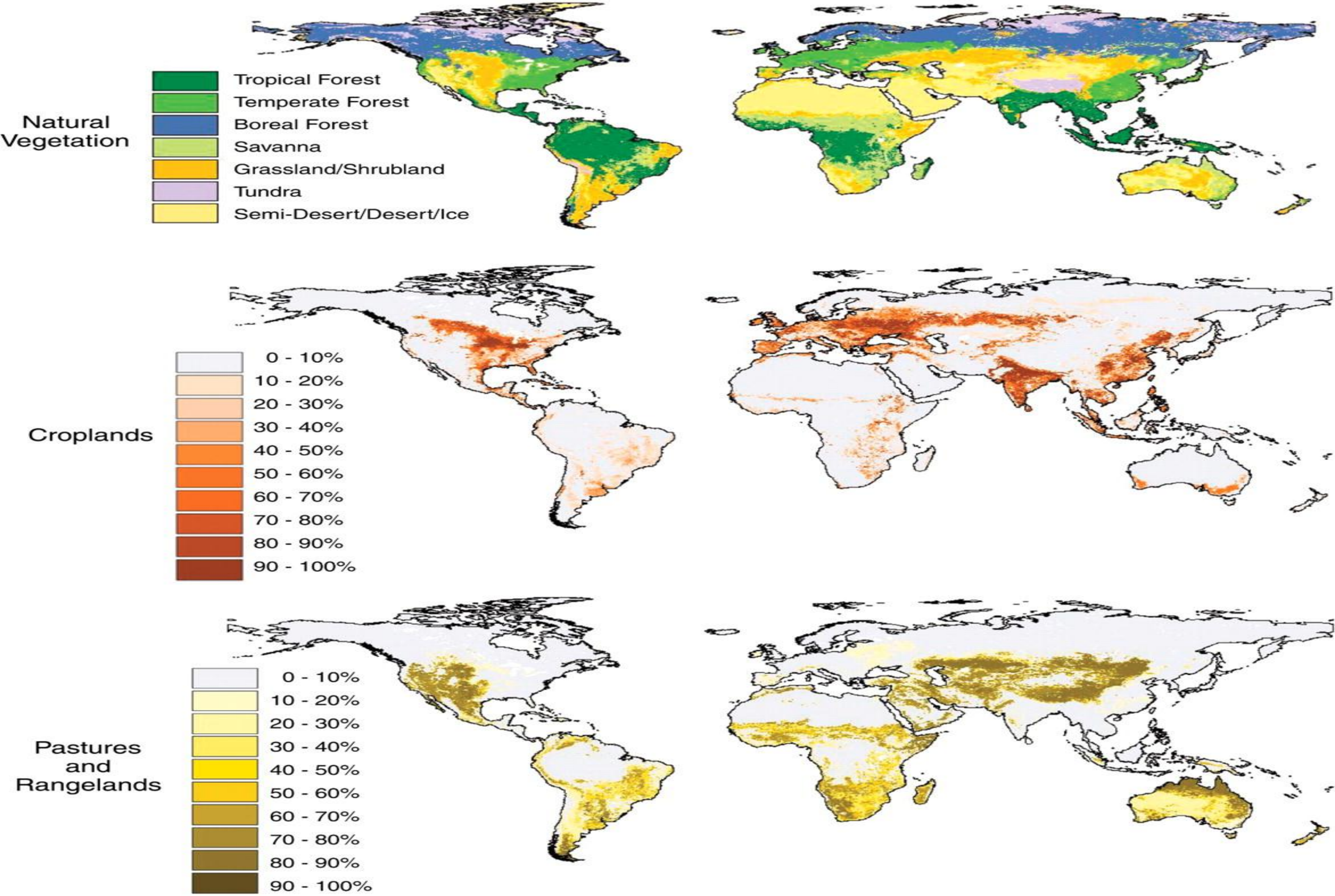


Fig. Worldwide extent of human land-use and land-cover change

Published by AAAS: **J. A. Foley et al., Science 309, 570 -574 (2005)**

“ We are what we are eating! ”

Food – Feed – Fuel considerations

Global food requirement for three diets: **vegetarian**: 2388 kcal cap^{-1} day^{-1} of which 166 kcal cap^{-1} day^{-1} from animal products; **moderate**: 2388 kcal cap^{-1} day^{-1} of which 554 kcal cap^{-1} day^{-1} from animal products; and an **affluent**: 2746 kcal cap^{-1} day^{-1} of which 1160 kcal cap^{-1} day^{-1} from animal products. The actual population size in 1998 ($5.9 \cdot 10^9$ people) and the estimated population size in year 2050 ($9.37 \cdot 10^9$ people), as expressed in grain equivalents 10^9 tons dry weight per year. *Adapted from Wolf et al.*

Diet type	**Vegetarian diet**		**Quality diet (Moderate)**		**Affluent diet**	
Year	1998	2050	1998	2050	1998	2050
Food requirement [10^9tTS $\cdot$year^{-1}]	2.80	**4.45**	5.17	**8.21**	9.05	**14.36**

Wolf J., Bindraban P.S., Luijten J.C., Vleeshouwers L.M.: Exploratory study on the land area required for global food supply and the potential global production of bioenergy. (2003) “Agricultural Systems”, Vol. 76, 841-861.

Percentage of present agriculture and arable land required for food production under moderate diet with crop yielding equal to 6 t TS grain·year^{-1} (1998), and 9 t TS grain·year^{-1} (2050)

	EU-27	**World (1998)**	**World (2050)**
Population [people]	$4.9 \cdot 10^{8}$	$5.9 \cdot 10^{9}$	$9.37 \cdot 10^{9}$
Agricultural area [1000 ha]	$19.7 \cdot 10^{7}$	$50.1 \cdot 10^{8}$	$50.1 \cdot 10^{8}$
Arable land [1000 ha]	$11.3 \cdot 10^{7}$	$14.0 \cdot 10^{8}$	$14.0 \cdot 10^{8}$
Land requirement [ha·year^{-1}]	$7.1 \cdot 10^{7}$	$8.6 \cdot 10^{8}$	$9.1 \cdot 10^{8}$
Percentage of total agricultural area [%]	36.0	17.2	18.2
Percentage of arable land [%]	62.4	61.4	65.0

Vast Areas of the Globe Are Not Suitable for High Levels of Terrestrial Agriculture

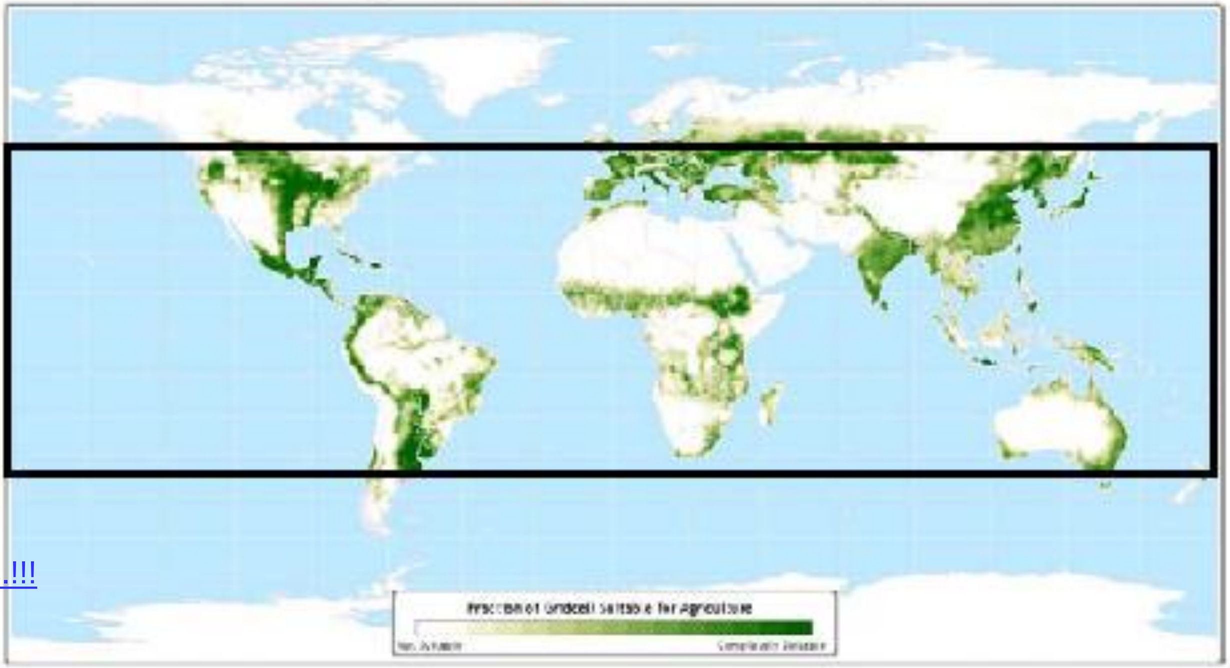
a. Crop lands
-green area

b. Pasturelands
- partly green areas

c. Rain forests and forests
- no go!!!

d. Deserts areas
algal productions
Solar-biofuels refineries.!!!

e. More actions now -
What are we waiting fore?



Atlas of the Biosphere
Center for Sustainability and the Global Environment
University of Wisconsin - Madison

But could be used for algal culture.

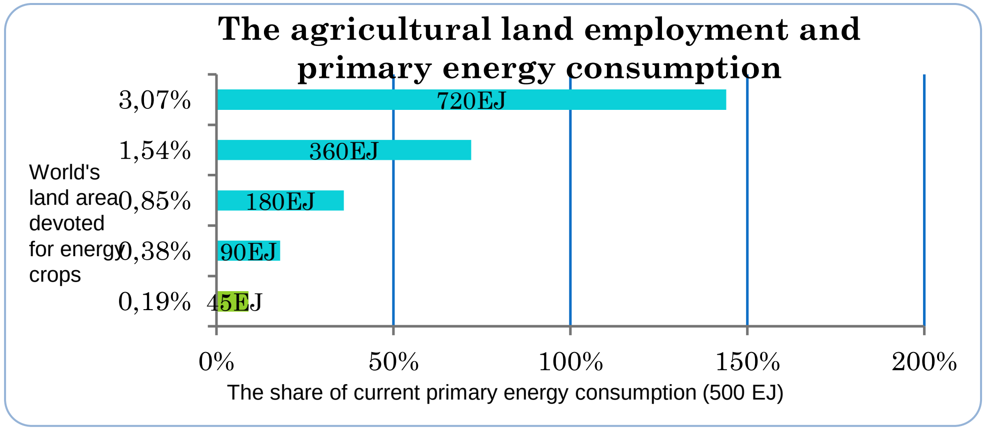
World energy scenarios – Future goals

No.	**Bioenergy potentials - terrestrial**	Predicted value	Source
1.	Non collected straw (50%)	75 000 PJ/year	Sanders J.: *Biorefinery, the bridge between Agriculture and Chemistry*. Wageningen University and Researchcenter. Workshop: Energy crops & Bioenergy.
2.	Collected waste processing (50%)	45 000 PJ/year	
3.	Forest/pastures (50%)	150 000 PJ/year	
4.	10% of arable land – World Wide (20tTS/ha)	51 000 PJ/y	Holm-Nielsen J.B., Madsen M., Popiel P.O.: *Predicted energy crop potentials for biogas/bioenergy. Worldwide – regions – EU25*. AAUE/SDU. Workshop: Energy crops & Bioenergy.
5.	20% of arable land – World Wide (20tTS/ha)	101 000 PJ/y	
6.	30% of arable land – World Wide (20tTS/ha)	152 000 PJ/y	
Sum: 1+2+3+5		371 000 PJ/year	

Total energy consumption forcast	Predicted value	Source
Total energy required year 2050	1 000 000 PJ/year	Sanders J.: *Biorefinery, the bridge between Agriculture and Chemistry*. Workshop: Energy crops & Bioenergy.
Total energy demand year 2050	1 300 000 PJ/year	Shell’s World Energy Scenario

Agriculture potentials:

- Energy crops today and land devoted for cropping



- Energy crops in 2050 - **120 – 330 EJ**, IEA Bioenergy, 2009

- Residues in 2005, Greg J.S. 2010

Unit: EJ yr^{-1}	Wheat	Corn	Rice	Other grain	Oil crops	Sugar crops	Misc crops	*TOTAL*
Global Residu	5,58	4,16	6,51	2,01	7,41	6,17	3,89	***35,72***

- Residues in 2050 - **55-72 EJ**, Smeets et al. 2004

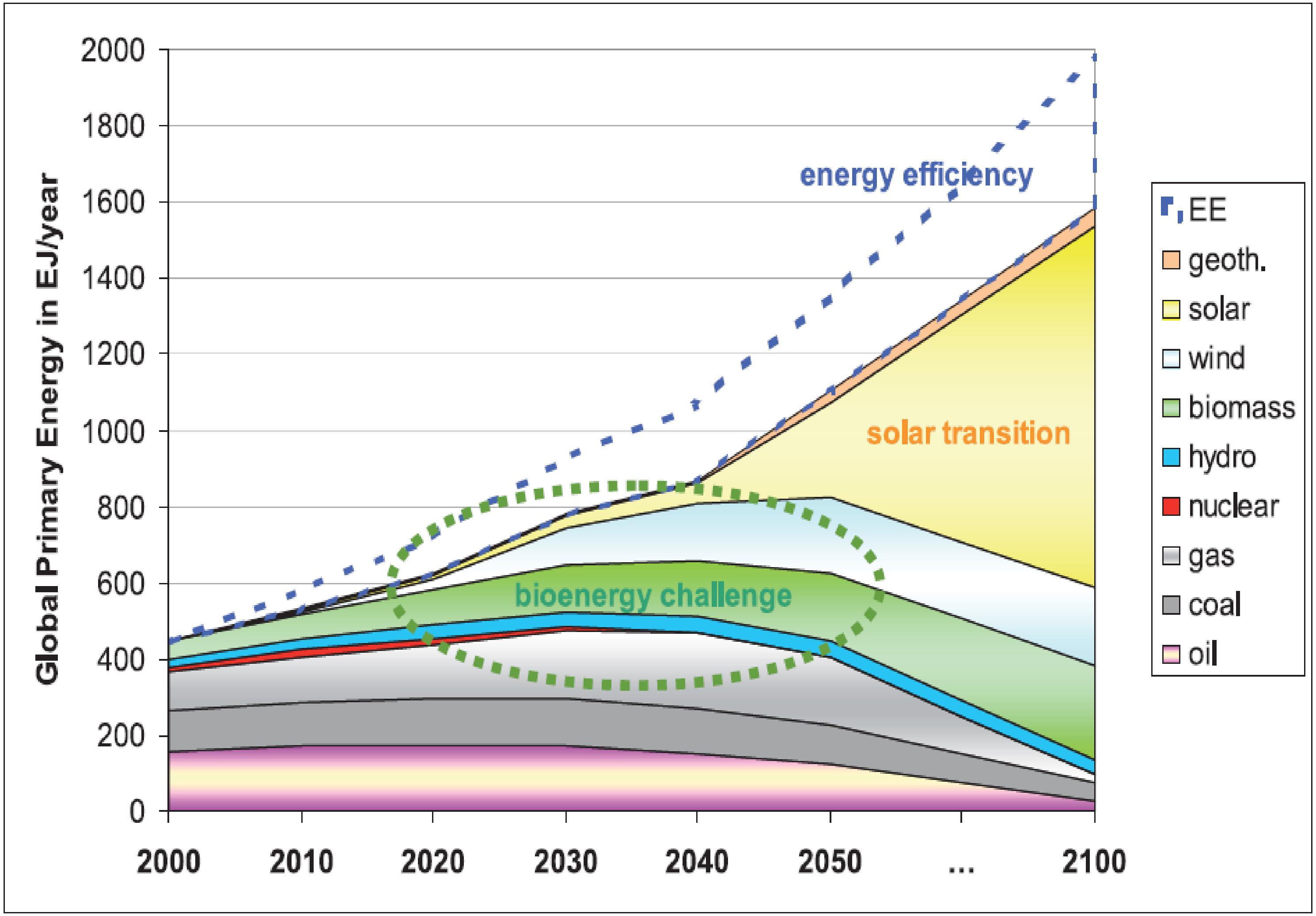
Forestry potentials:

- Wood including wood from forests, forest plantations and trees outside forests **0 - 93 EJ/yr.**
- Wood residues including wood harvest residues (22 %), process residues (39 %) and wood wastes (39 %) to **21 - 35 EJ/yr.**

Final summary of projections and potentials of biomass resources analysis.

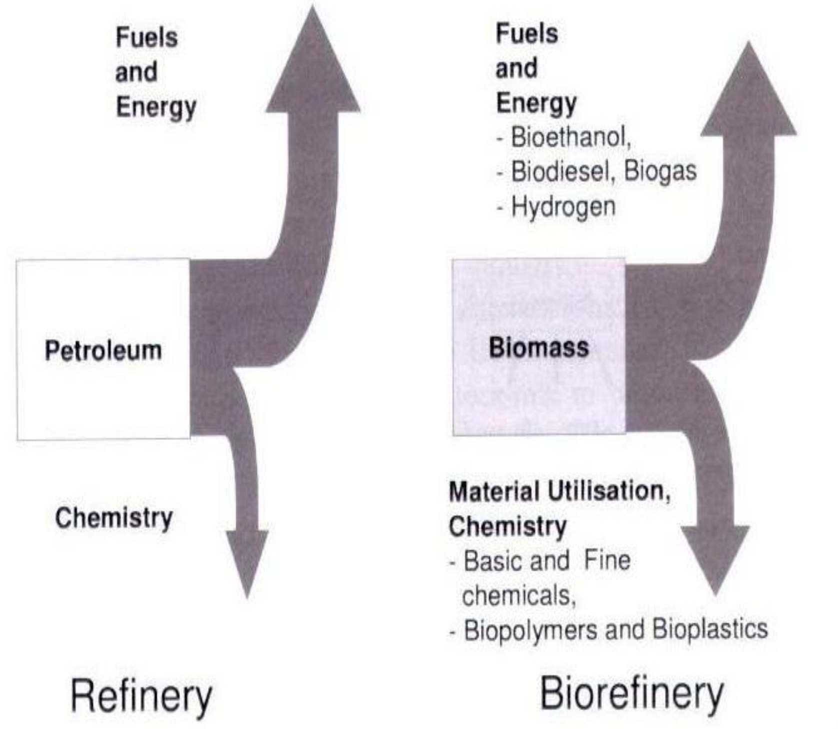
Concluding biomass table	
Biomass from Agriculture	*175 – 402 EJ*
Biomass from Forestry	*21 – 128 EJ*
Assumed primary bioenergy potential in 2050	**196 – 530 EJ**

Sustainable Global Energy

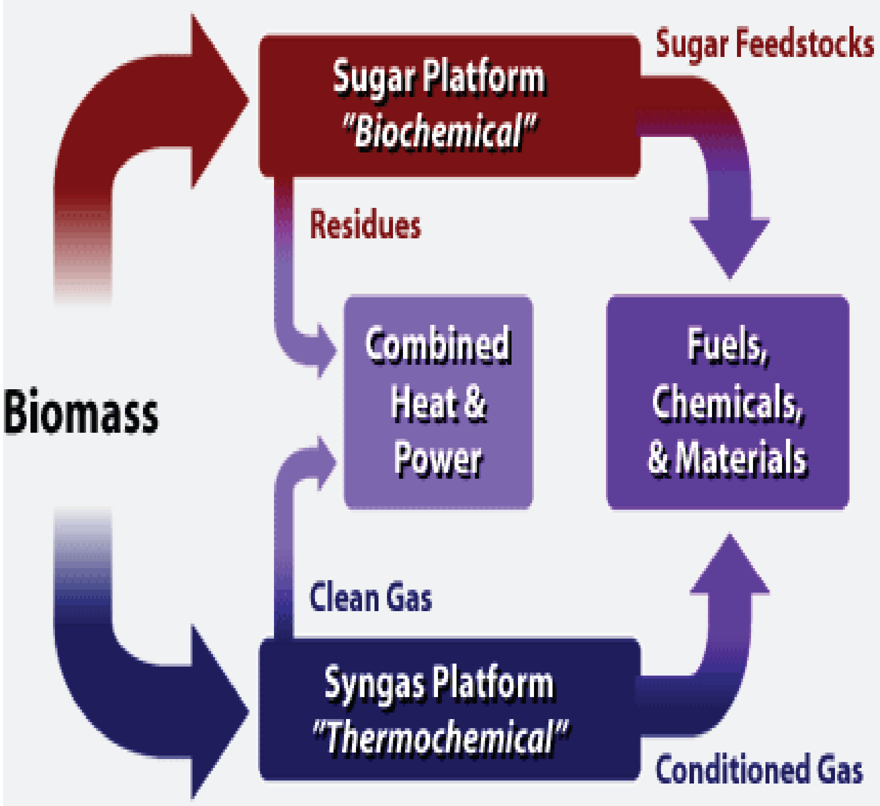


Source: IEA (2007), IPCC (2007), UNPD (2004) and WBGU (2003)

→ Bioenergy will be here to stay, and grow!



Comparison of the basic principles of the petroleum refinery and the biorefinery, Source: Kamm et al. 2006



Two-platform biorefinery concept
Source: NREL 2006, Biomass Programm, DOE/US]

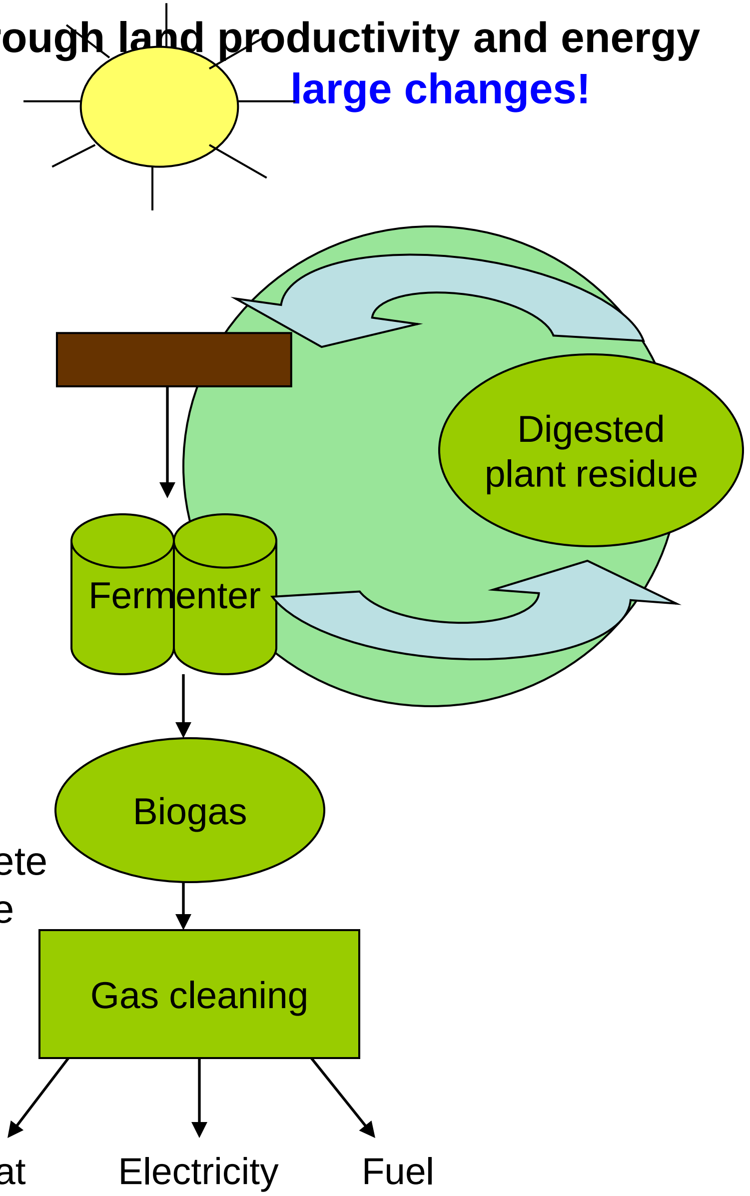
→

Energy crops - Paradigm shift through land productivity and energy balance; Crop productions needs large changes!

- The Sun as energy source
- Special energy crops that use the entire vegetation period
- Total digestion of the whole plant

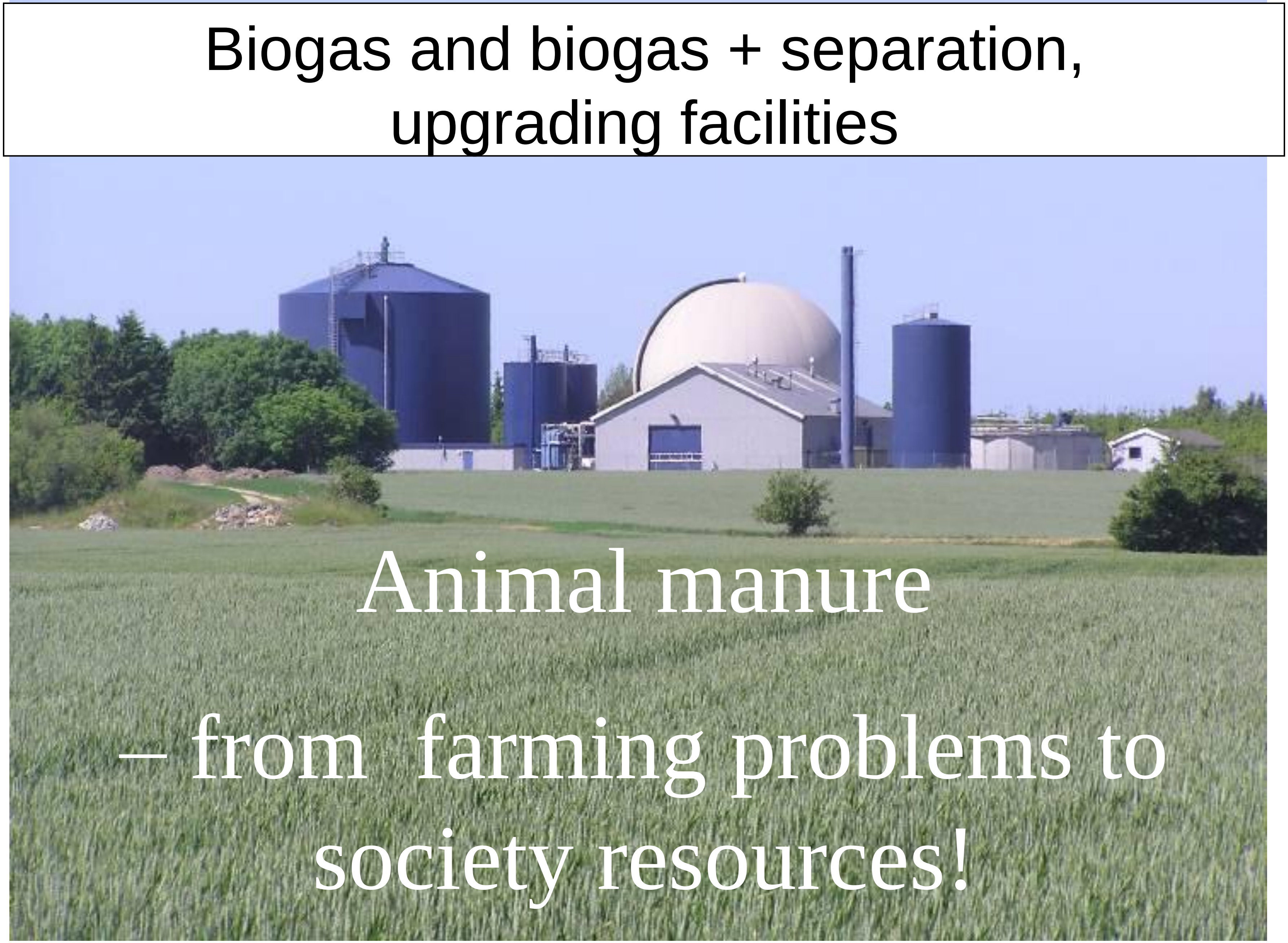
→

- Nutrient cycle possible
  Low Input - High Output
- Large installations work efficiently and are friendly towards the environment
- Upgrading of biogas enables complete utilisation of the crop (the gas can be stored)
- **Biorefineries;**biothanol/biogas/ biodiesel and higher value products



Source: KWS, D

Biogas and biogas + separation, upgrading facilities



Animal manure

– from farming problems to society resources!

Maize silos, digester and gas storage of the Energy Crop Digestion Plant Reidling

AD Co-digestion - heterogeneous feedstock's

- Manure
- Food waste
- Organic by-products
- Crops

Energy potential of pig and cattle manure in EU-27

Total manure	Biogas	Methane	Potential	Potential
[10^6 tons]	[10^6 m^3]	[10^6 m^3]	[PJ]	[Mtoe]
1,578	31,568	20,519	827	**18.5**

Methane heat of combustion: 40.3 MJ/m^3; 1 Mtoe = 44.8 PJ
Assumed methane content in biogas: 65%

Biogas Production & Forecast:

Actual 2008 production of biogas in EU 27:	7 Mtoe
2012-2015 EU forecast	15 Mtoe
Manure potentials	18.5-20 Mtoe
Organic waste and byproducts	15-20 Mtoe
Crops and crop residuals	20-30 Mtoe
Total long term forcast Biogas	**60 Mtoe**

Biogas can cover 1/3 of EU's total RES 20% demands year 2020

Source: T. Al Seadi, Department of Bioenergy, SDU, Denmark

Source: T. Al Seadi, Department of Bioenergy, SDU, Denmark

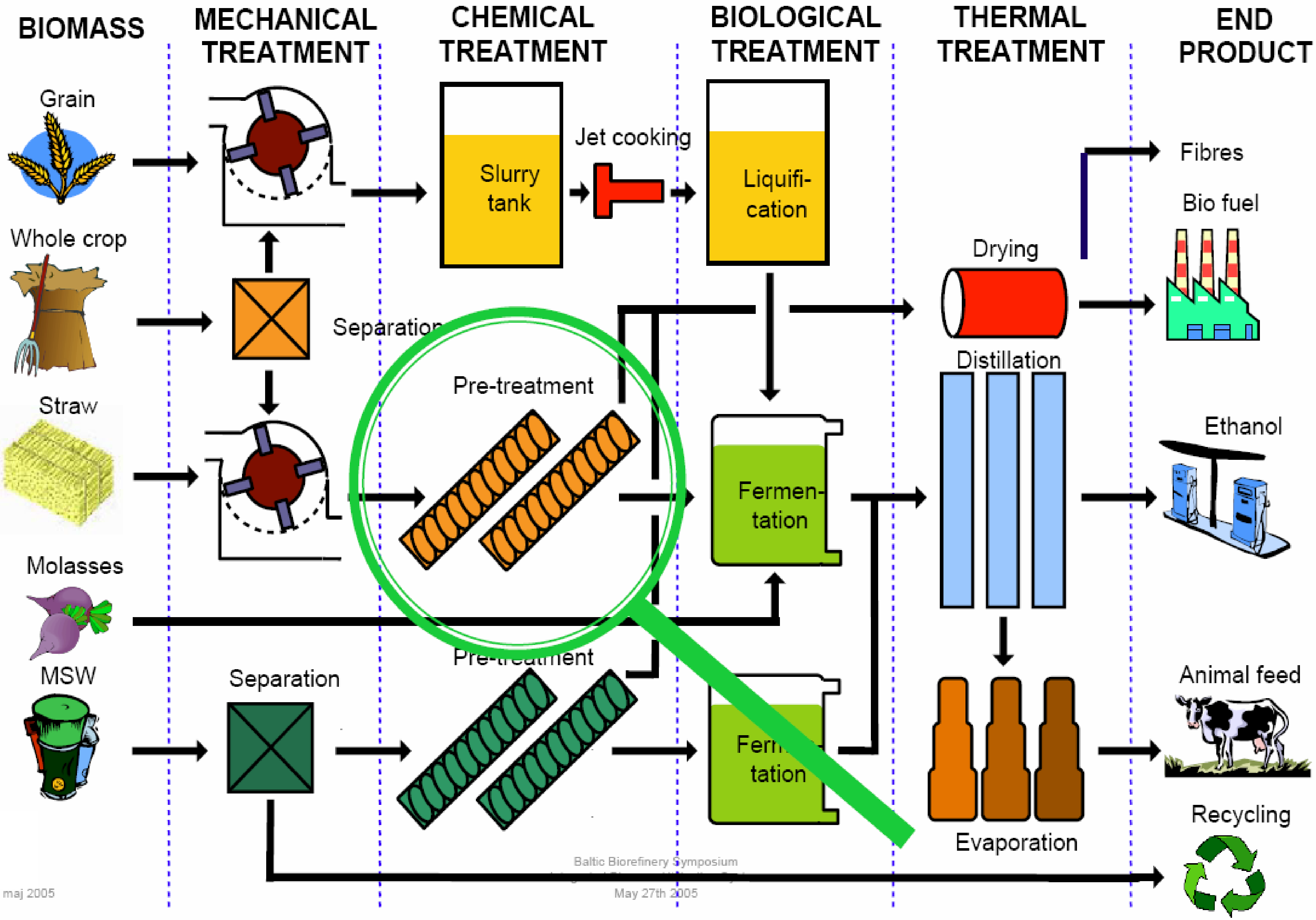
Ribe Biogas; 15 years of production, 18.000 m3 biogas/day.

.Source J. B. Holm-Nielsen, Bioenergy Dept., SDU, Denmark.

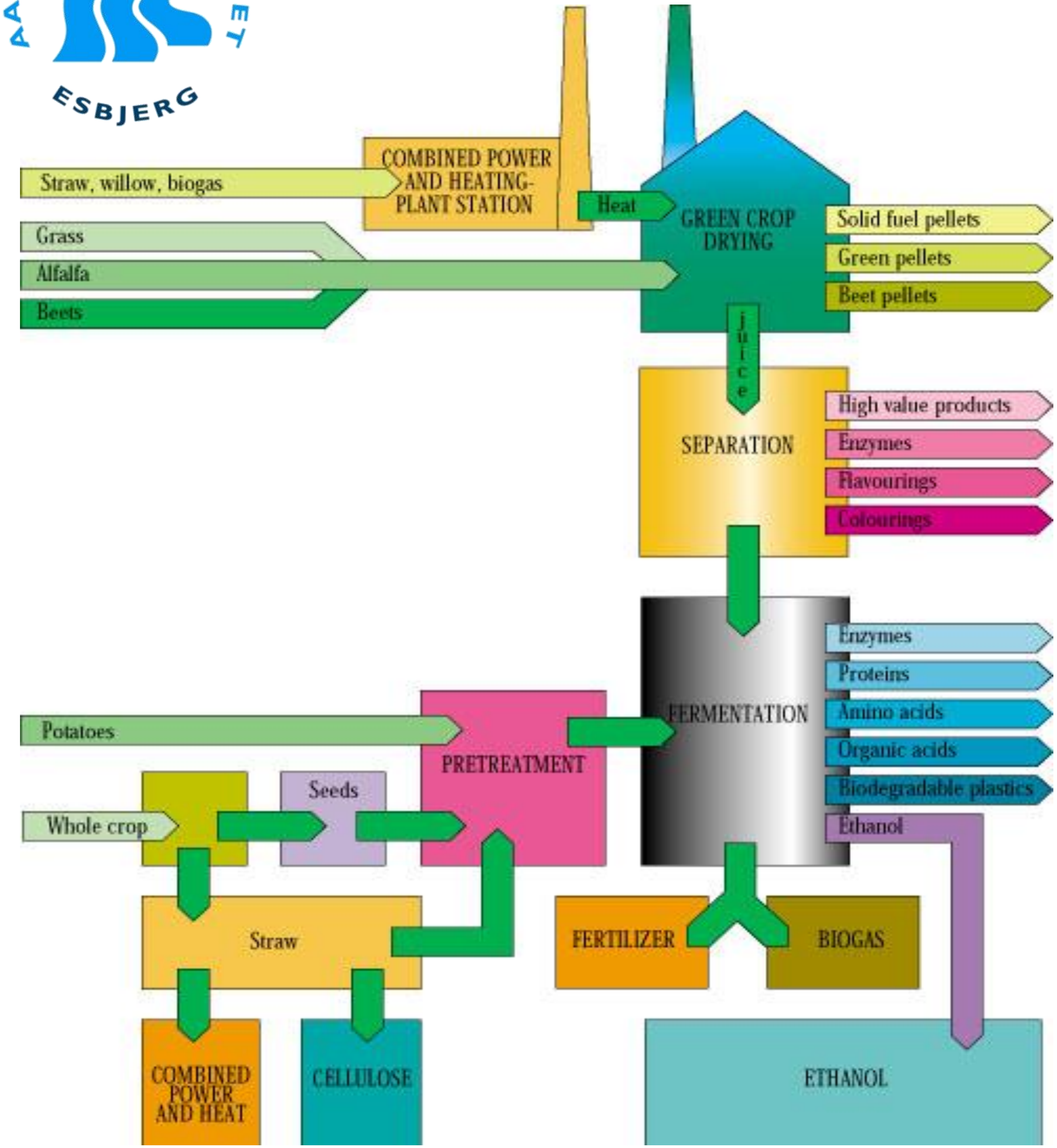
Biogas and separation
Big perspectives liquid and gaseous separation

AALBORG UNIVERSITET ESBJERG

ACABS
Research Group


BIOMASS
MECHANICAL TREATMENT
CHEMICAL TREATMENT
BIOLOGICAL TREATMENT
THERMAL TREATMENT
END PRODUCT
Grain
Whole crop
Straw
Molasses
MSW
Slurry tank
Jet cooking
Liquifi-cation
Separation
Pre-treatment
Pre-treatment
Separation
Fermen-tation
Fermen-tation
Drying
Distillation
Evaporation
Fibres
Bio fuel
Ethanol
Animal feed
Recycling

The Green Biorefinery



From ideas, brainstorms, lab scale, scale up tests to full scale reality takes more than 10 years!

Source:
P. Kiel & J.B. Holm-Nielsen
University of Southern Denmark
1994. Project for the Danish Board of
Technology,

ESBJERG INSTITUTE OF TECHNOLOGY
AALBORG UNIVERSITET

CAMBI
- recycling energy

Modelling and optimisation of the CAMBI TH process for biomass pretreatment

Sebastian Buch Antonsen
Henrik Tækker Madsen
Anna Frederike Goßmann

8. semester 2010

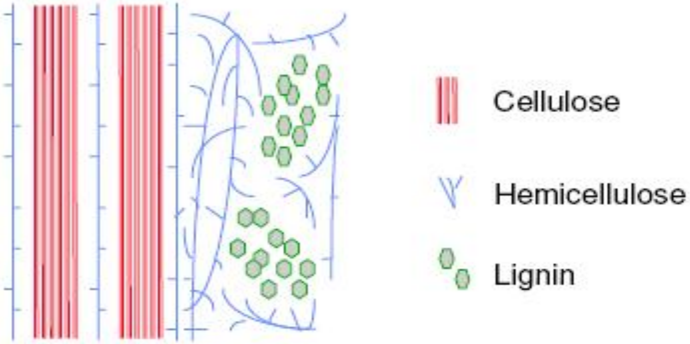
Danish biomass action plan for the Power Plants from the 90.tie's continue at full speed!

Example: Strawbarn Unit 2, Avedøre, DongEnergy –150.000 tons of straw per year


MULLERUP

Straw (constituents and uses)

Hemicellulose	Cellulose	Lignin
C5 – sugars	C6 – sugars	
20-25%	30-40%	15-20%
Feed Bioethanol Green chemicals	Bioethanol	Biofuel

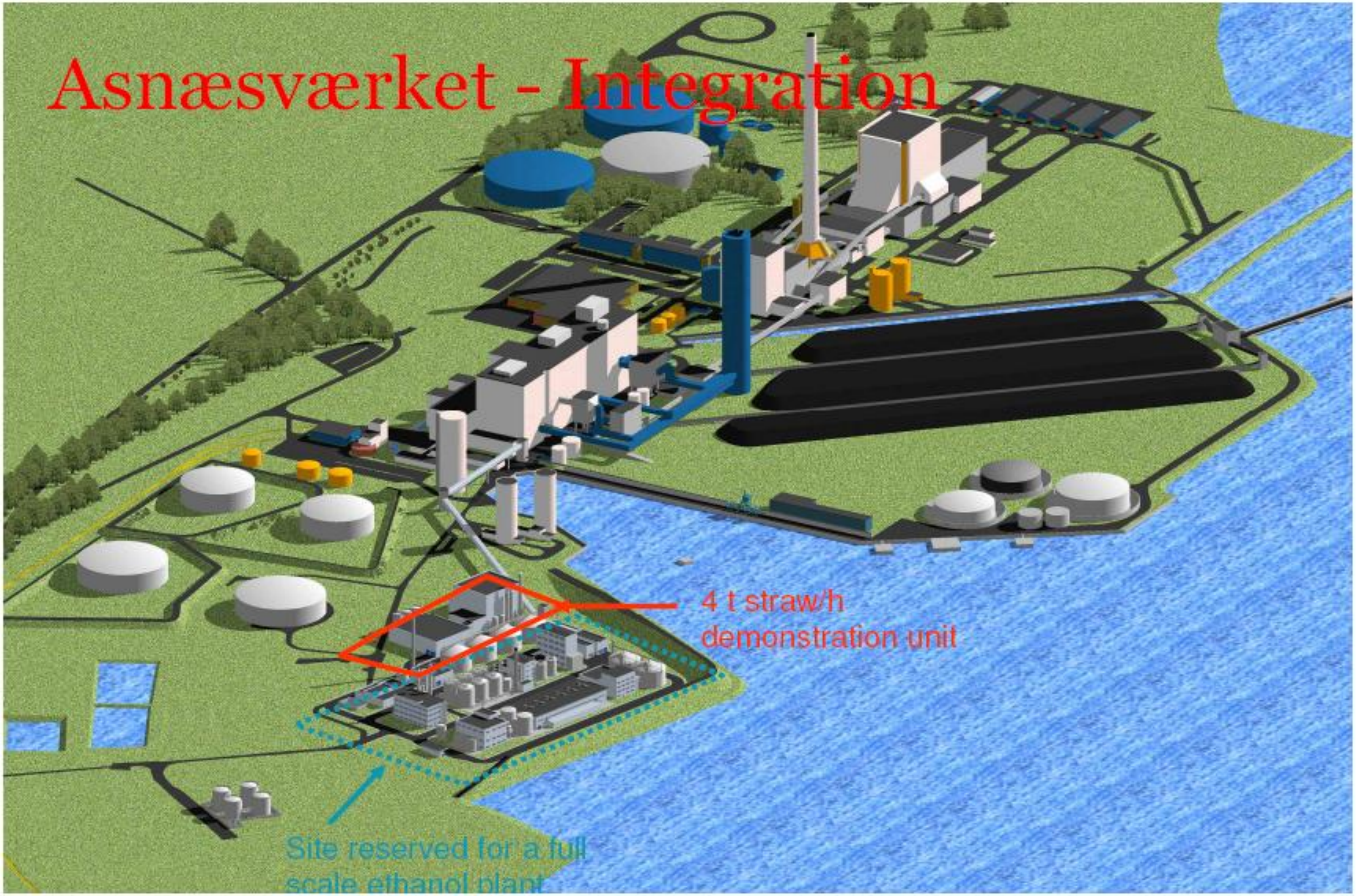


Hydro-thermal Pre-treatment

Enzymatic liquefaction with high dry matter (25 – 40%)

5 Chamber Reactor

Asnæsværket - Integration

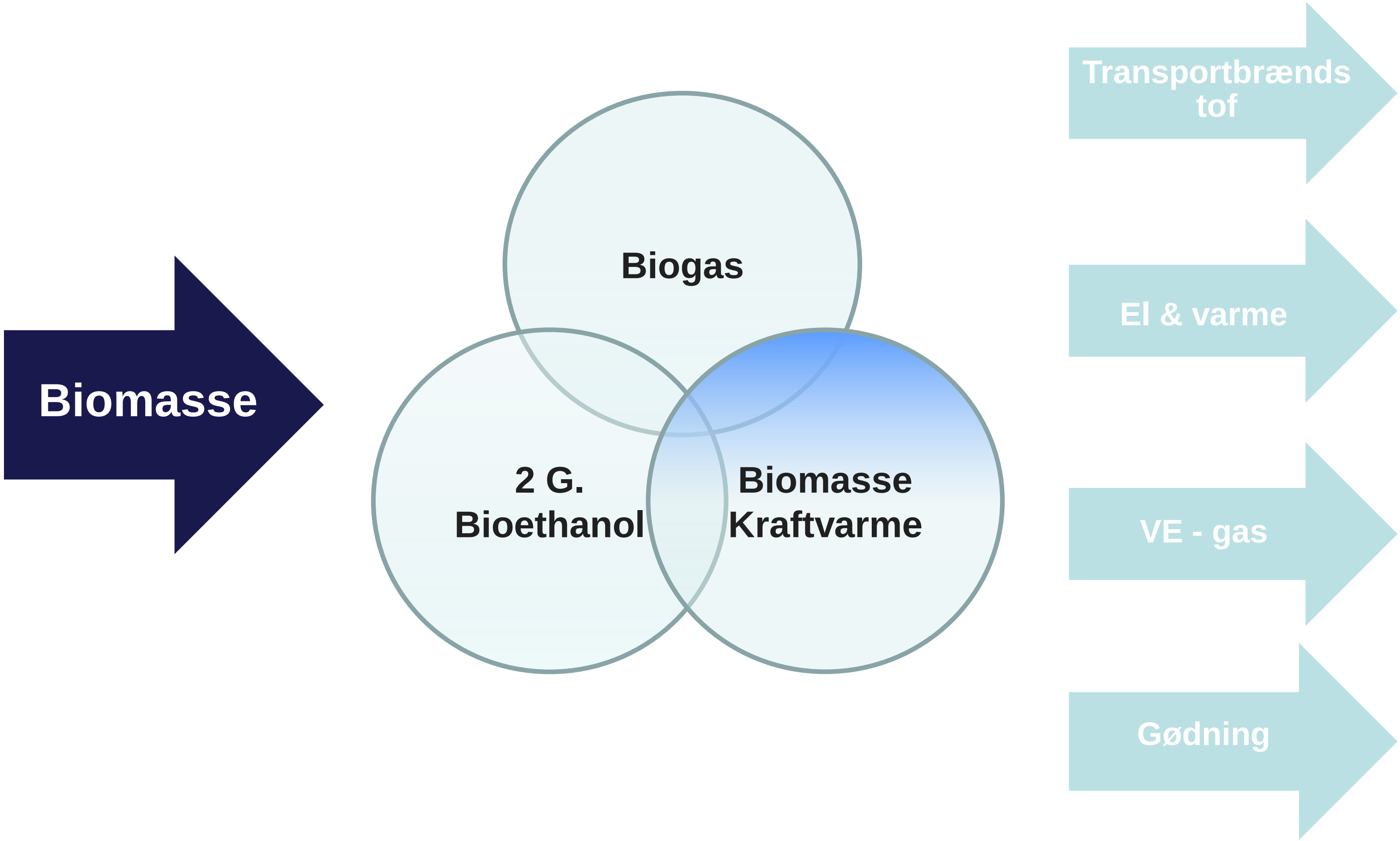


4 t straw/h demonstration unit

Site reserved for a full scale ethanol plant

MEC konceptet

Udnyttelse af synergi i råvareomsætning og procesanlæg



Biomasse

Biogas

2 G. Bioethanol

Biomasse Kraftvarme

Transportbrændstof

El & varme

VE - gas

Gødning

MAABJERG
ENERGY CONCEPT

HOLSTEBRO STRUER

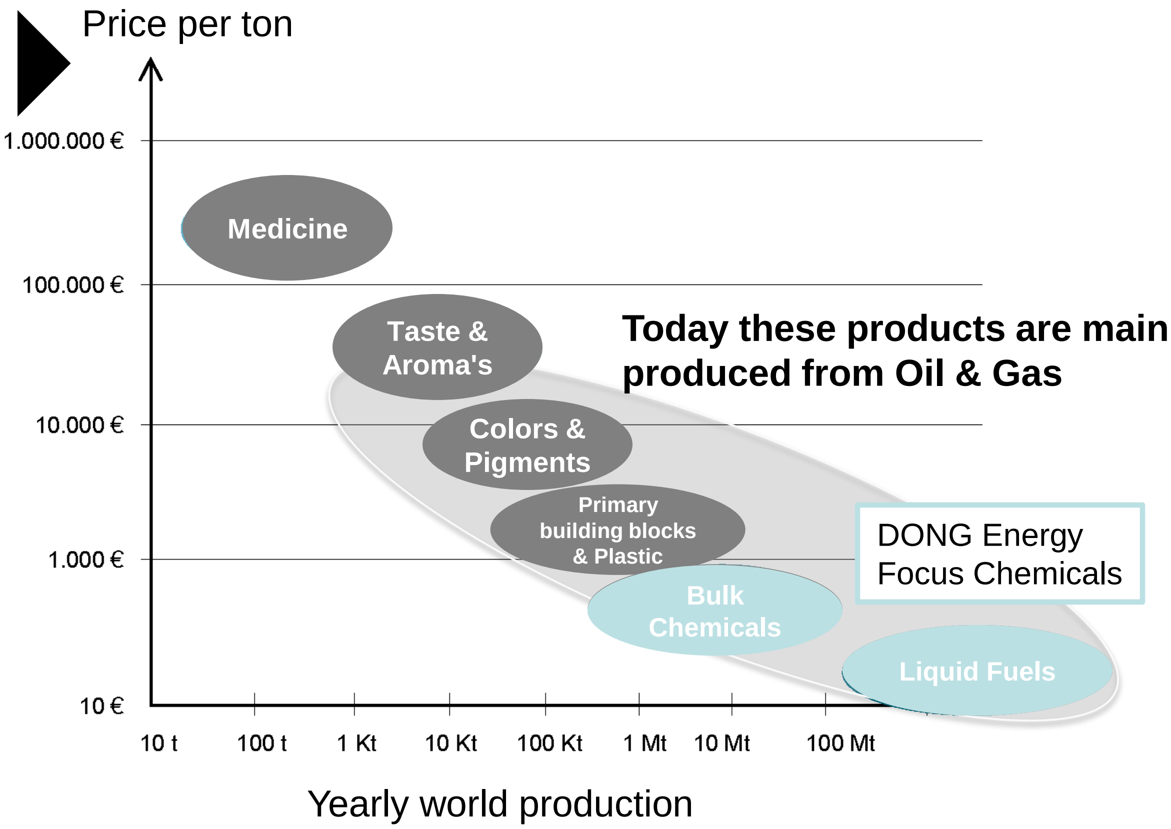
High Value Chemicals

-In the future also from Biomass

The amount of biomass is limited, and ultimately the biomass will end up where it can be most profitable.

How to maximize the Value of biomass:

Burn it or Convert it ??



Today these products are mainly produced from Oil & Gas

DONG Energy Focus Chemicals

A new research focus is the sugar platform

Straw

Residues

Sugar

'Starch

Advanced pre-treatment

None or minor pre-treatment

Production of sugar based on sustainable biomass

Inbicon

Today

Statoil

DONG energy

Tomorrow

Valuable renewable chemicals and biomaterials

New Danish advanced and specialised technology industries

LANDBRUG FØDEVARER

DANISCO

novozymes®
Rethink Tomorrow

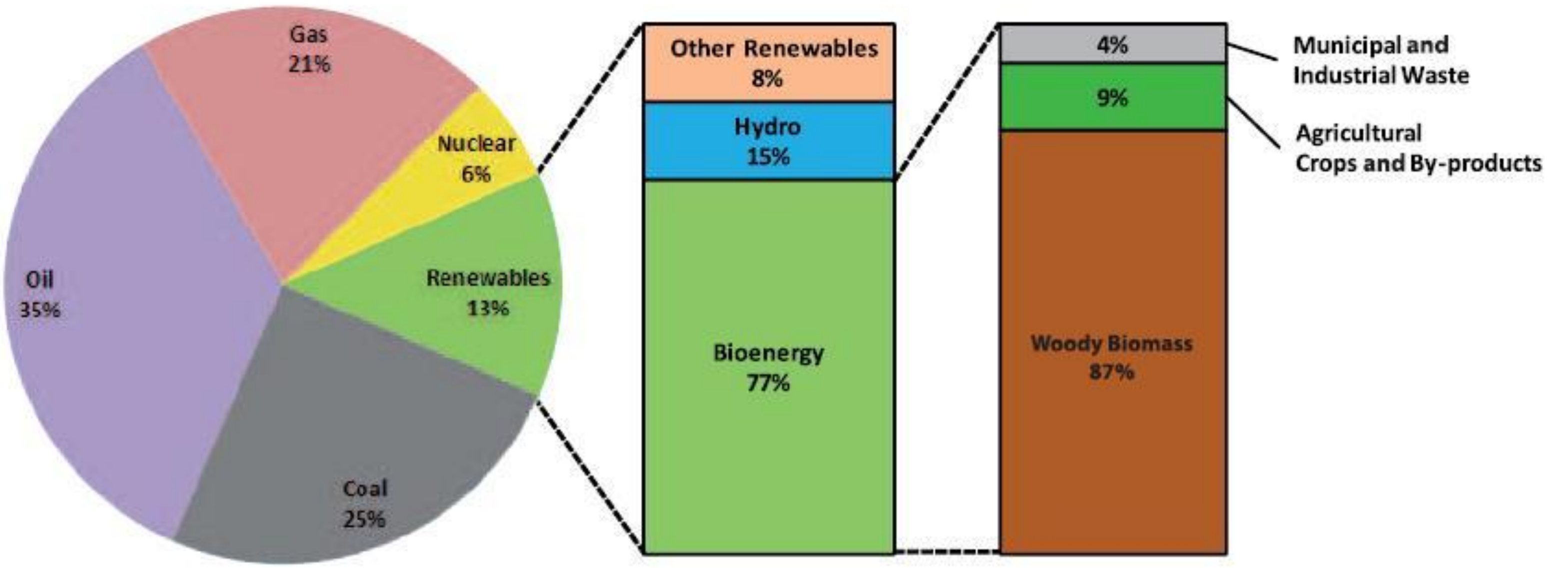
HALDOR TOPSØE

Effects and quantification of land use change from bioenergy production: review of impacts, measures, sustainability criteria and application of iluc factor example

UNIVERSITY OF SOUTHERN DENMARK
AALBORG UNIVERSITY

Introduction to Land Use Change (LUC)

- Biomass is a renewable source of energy that has expanded last decades
- It presently supposes around 10% of the global primary energy supply (around 50 EJ/year) and is expected to increase sustainable in the next years
- Increased markets for biomass for energy purposes → leads to creation of international market (mostly wood pellets – future biopellets from energy crops)

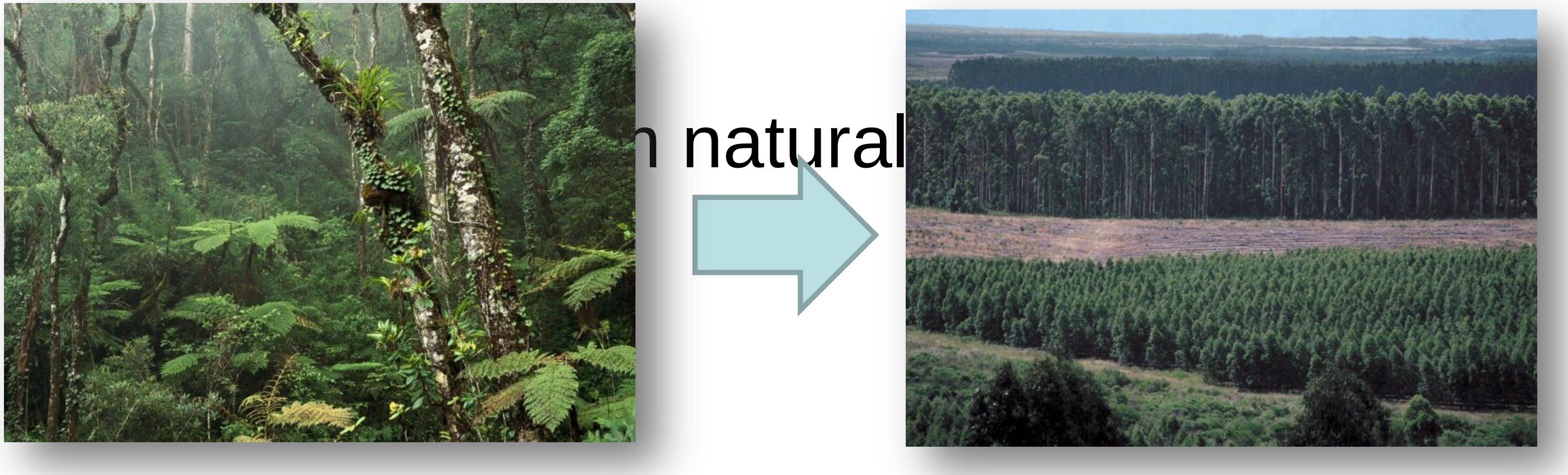


Share of bioenergy in the global energy supply (IEA Bioenergy, 2010)

1. Introduction to Land Use Change (LUC)

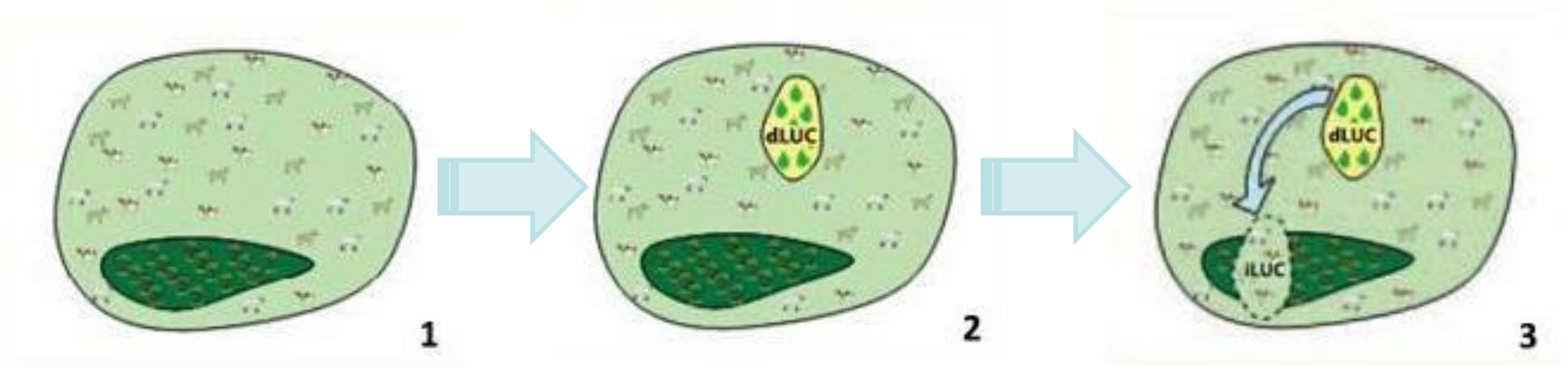
- Direct Land Use Change examples:
  - From food production to biomass feedstocks

natural



1. Introduction to Land Use Change (LUC)

- Example of direct and indirect land use change process:



➢ ***Stage 1***: Before bioenergy production, land is composed by a combination of forest and grazing use.

➢ ***Stage 2***: Introduction of bioenergy production in grazing land causes direct land use changes (dLUC). Expected effects are loss of carbon stocks , leading to emissions. dLUC may vary depending on type of land and biomass.

➢***Stage 3***: Macroeconomic causes and other incentives lead to indirect land use changes (iLUC). Land use substituted by bioenergy production (grazing) is established in other portion of land, converting it. iLUC can potentially produce emissions for the loss of carbon stocks.

Introduction to Land Use Change (LUC)

Land use change can be divided in:

- ***Direct LUC (dLUC)***

  Those changes in land use taking place **within** the site used for bioenergy production (**system boundary**) after displacing a prior land use. Some examples are:

  - ✓ Change from food or fiber production to biomass feedstocks
  - ✓ Conversion of natural ecosystems to forest plantation

- ***Indirect LUC (iLUC)***

  Those changes in land use taking place **out** of the bioenergy system boundary. Mainly occurs when the demand of the previous land use remains. Some examples are:

  - ✓ Displaced food production is re-allocated in new places by the conversion of natural systems
  - ✓ Displacement of agricultural production causes the expansion of agriculture area to other lands subjected to have a significant value (rainforest , high conservation value areas)

Introduction to Land Use Change (LUC)

- **Impacts** by Land Use Change:

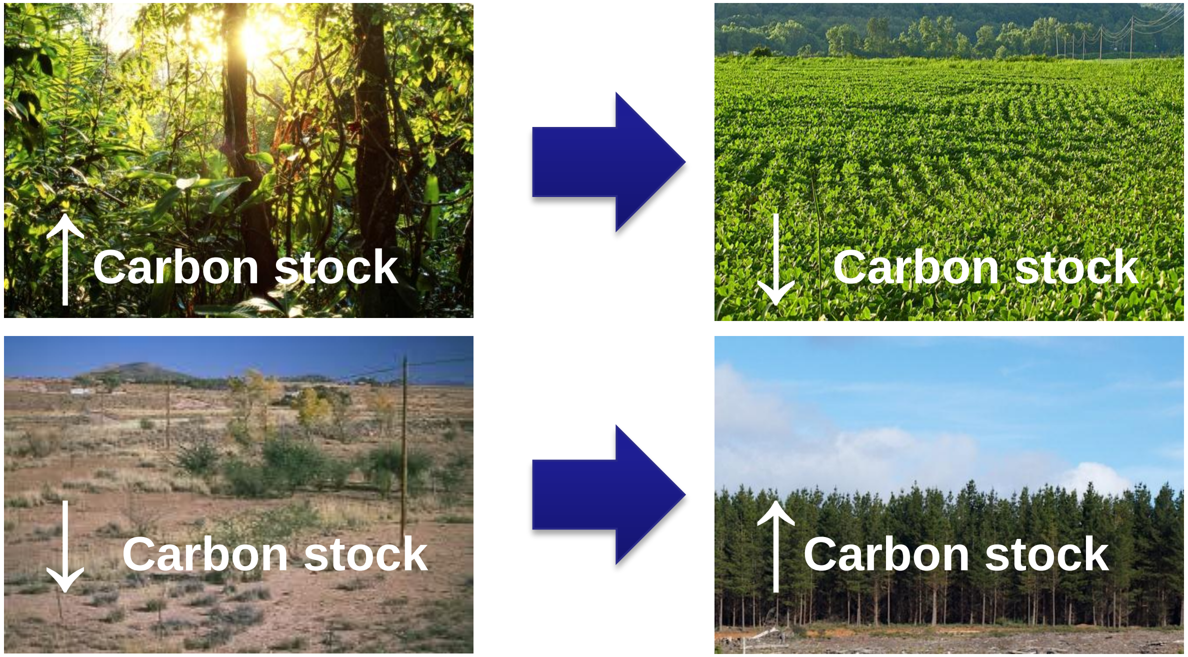
✓ Release of carbon emissions (CO_2)

✓ Expressed as changes in carbon pool stocks

Impacts in carbon equilibrium → Changes in carbon content in atmosphere

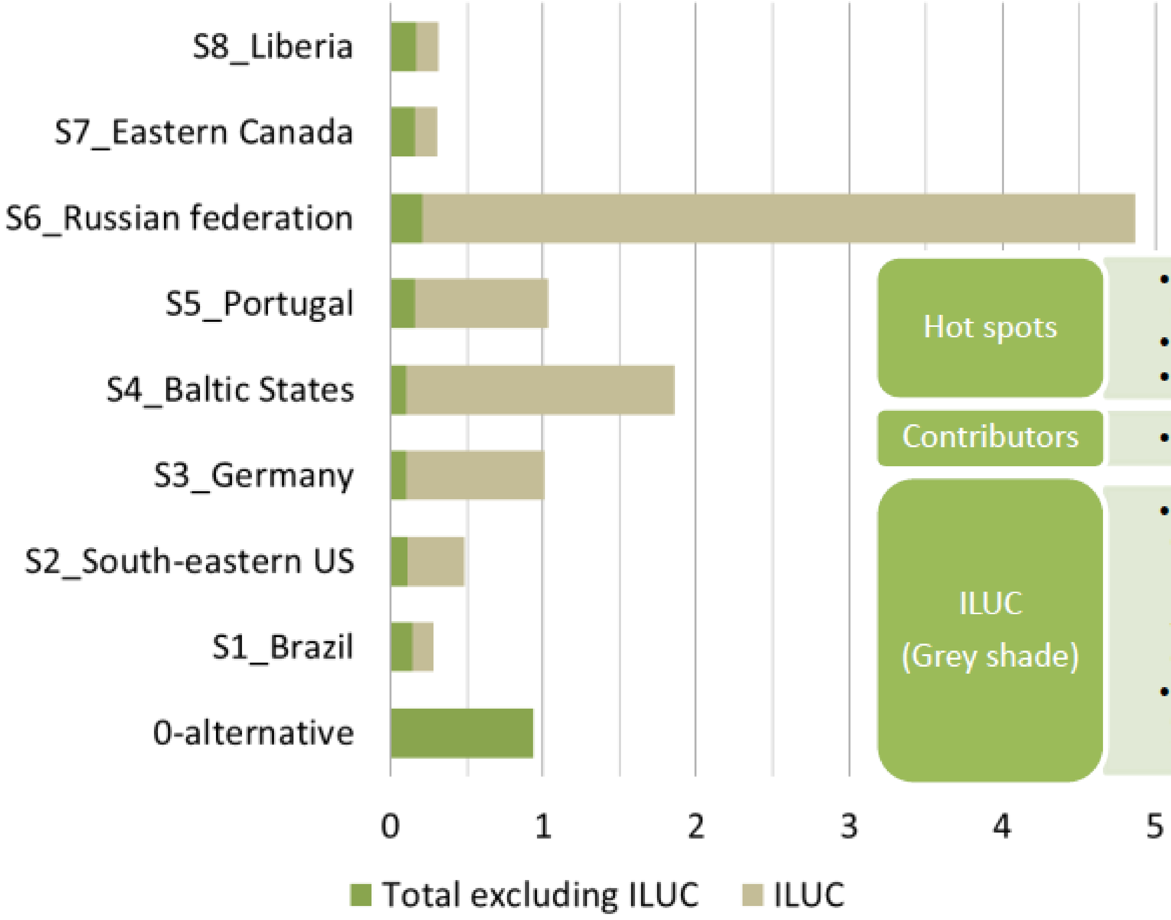
Negative impact

Positive impact



Global warming

- With ILUC



Hot spots	•Forest management (ILUC) •Wood pellet production •Combustion of fossil fuels
Contributors	•CO_2
ILUC (Grey shade)	•Wood pellets from all countires with extensive harvest from semi-natural forests are out-weitghed the CO_2 eq. emissions of 0-alternative •Most ILUC contribution is derived from land intensification

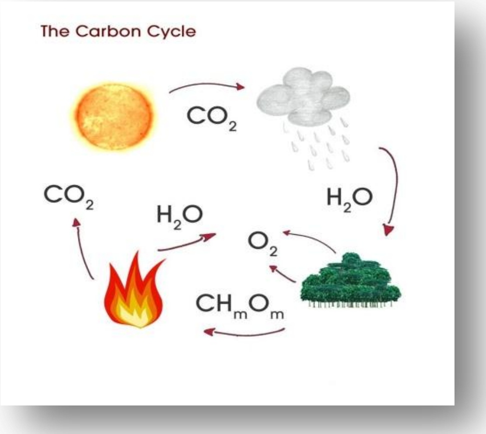
Functional Unit : Production of 1 kWh of electricity

Recommendation

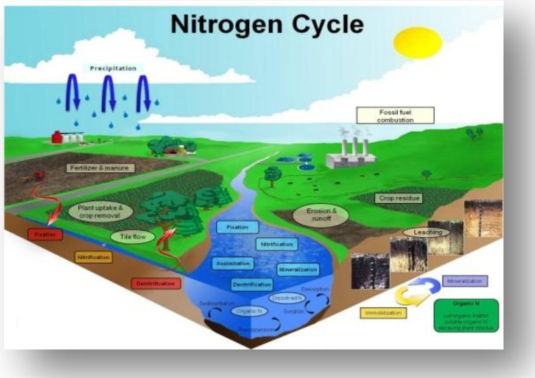
- To consider higher than 60% of GHG emission reduction targets;
- Consider Energy balance;
- Evaluate resources originating from certified forests according to forest management activities in the means of GHG and Energy balances;
- Residues shall be evaluated properly according to forest and/or agricultural management, fertilization management, soil protection from erosion, soil properties and climate;
- For biodiversity enhancement, factors such as location of plantations, landscape mosaics, adjacency of plantations to native forests and age mosaics shall be considered prior the establishment of biomass plantations for energy;
- Account for meso- and macro- level effects and not only for micro-level;
- Include iLUC to the bioenergy assessments for support of decision making;
- Carefully evaluate the biomass suppliers from developing countries.

1. Introduction to Land Use Change (LUC)

- Climate impacts related with LUC:



Alteration of carbon flow between atmosphere, soil and plants



Affection to the Nitrogen cycle and other pollutants (CH_4)

Change in components of hydrological cycle

Modification of physical properties of land surface (albedo)

Review of LUC biomass sustainable criteria

Global trade in biomass **increased**

Need of sustainable production

Standards and certification schemes

Main strategies

Stakeholders importance

Sustainability criteria categories	✓ **Environmental criteria** ✓ **Socio-economic criteria** ✓ **Other issues**: Direct and indirect Land Use Change
Sustainability regulations relating LUC	➢ European Union: **Renewable Energy Directive (RED)** ➢ The Netherlands: **NTA 8080** ➢United Kingdom: **Renewable Transport Fuel Obligation (RTFO)** ➢Germany: **Biofuels Sustainability Ordinance (BioNach V)** ➢Other: **-** Switzerland: **Biofuels LCA Ordinance (BLCAO)** **-** United States: **Renewable Fuel Standard (RFS)** **-** United States: **Low Carbon Fuel Standard (LFCS)**

Conclusion

- **Biomass as a key renewable energy for the future**
  - Considered as a **real alternative** to substitute fossil fuels
  - Lead to positive and negative externalities: **Land Use Change and its implications**
- **Land Use Change and its assessment**
  - Divided in dLUC and iLUC → **Might counteract emission savings**
  - **Sustainable production of biomass needed:**
    - Existence of mitigation and monitoring measures
    - Establishment of standards and certification schemes
  - **Present criteria must consider Land Use Changes and impacts**
- **iLUC factor approach for international power and supply chain**
  - **Attempt of quantification the impact of LUC** in the power supply chain, Substituting the fossil fuels
  - Need of introduction of **sustainability criteria** for all kinds of biomass
  - **Results obtained contribute to the discussion of how to consider Land Use Changes in upcoming criteria.**

International standards needed now !!! – not 2015 or beyond!

Thank you for your attention

Thank you for your attention!

Q & A 's

<u>R, D & D cooperation partners;</u>

- **AAU – Energy Technology, Denmark**: Bioenergy Research Group; - *Ane Katharina Paarup Meyer, Ehiaze Augustine Ehimen, Michael Madsen, Kim H. Esbensen, Felicia Nkem Ihunegbo (HIT), Saqib Sohail Toor, Lasse A. Rosendahl, Simas Kirchovas, Mario Caseres Gonzalez.*
- **UMB, Norway**: Biogas and Bioenergy Center; - *Kristian Fjørtoft, Maria Magdalena Estevez, Magdalena Bruch, Zehra Sapci, John Morken.*
- **FHF, Germany**; Biogas R&D group - *Lars Jürgensen, Thorsten Philips, Jens Born*
- **Poldanor Ltd., Poland**; Biorefinery test-platform – *Benny Laursen, Pawel Krawat, Bjarne Møller, Grzegorz Brodziak.*

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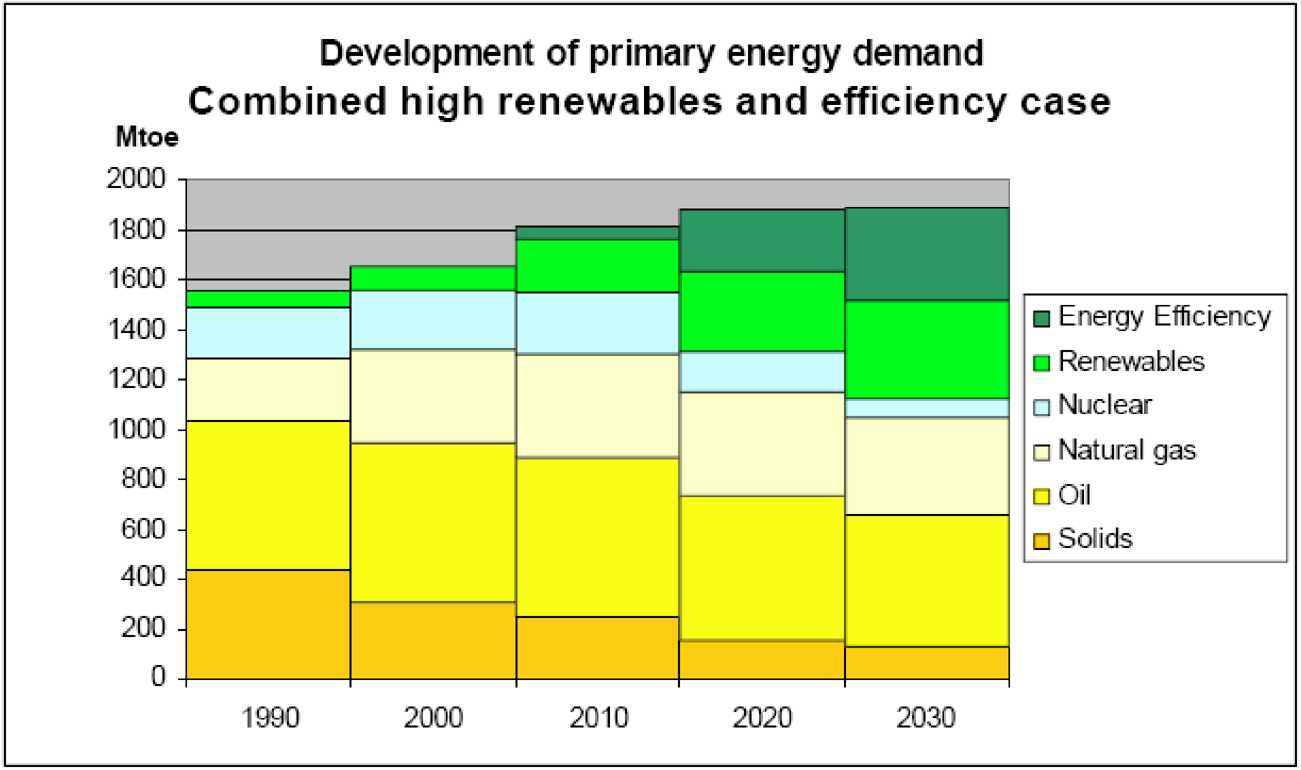

Figure 9: Impact of the strong renewable energy and energy efficiency penetration on the EU's primary energy demand (PRIMES modelling results)

Source: European Commission

182 Mtoe can be achieved from biomass cultivated on 20% of arable land in EU-27.

This corresponds to more than 10% of primary energy demand in 2020, equals 50-60% of the RES share.

Energy unit: PJ	**2007**	**2009**	**2010**	**2025**
Biomass	101	112	127	200
Windpower	30	30	35	90
Solarpower	~0			75-100
-photovoltaic	~0			
-passive	~0			
Hydropower	~0			
-Wave	~0			
Geothermal	~0			
Fossil fuels	650	666	678	200
Total consumption	800-850	809	836	600
VE pct.	15,2%	17,6%	19,4%	66%

Source; JBHN – Centre for Bioenergy, AAU, Esbjerg 2011 ,
& Energistyrelsen, Energistatistik foreloebige tal 2010

Branding – Esbjerg
Energy Metropolis of Denmark