# Integration of energy systems in Denmark – Sustainability and feasibility

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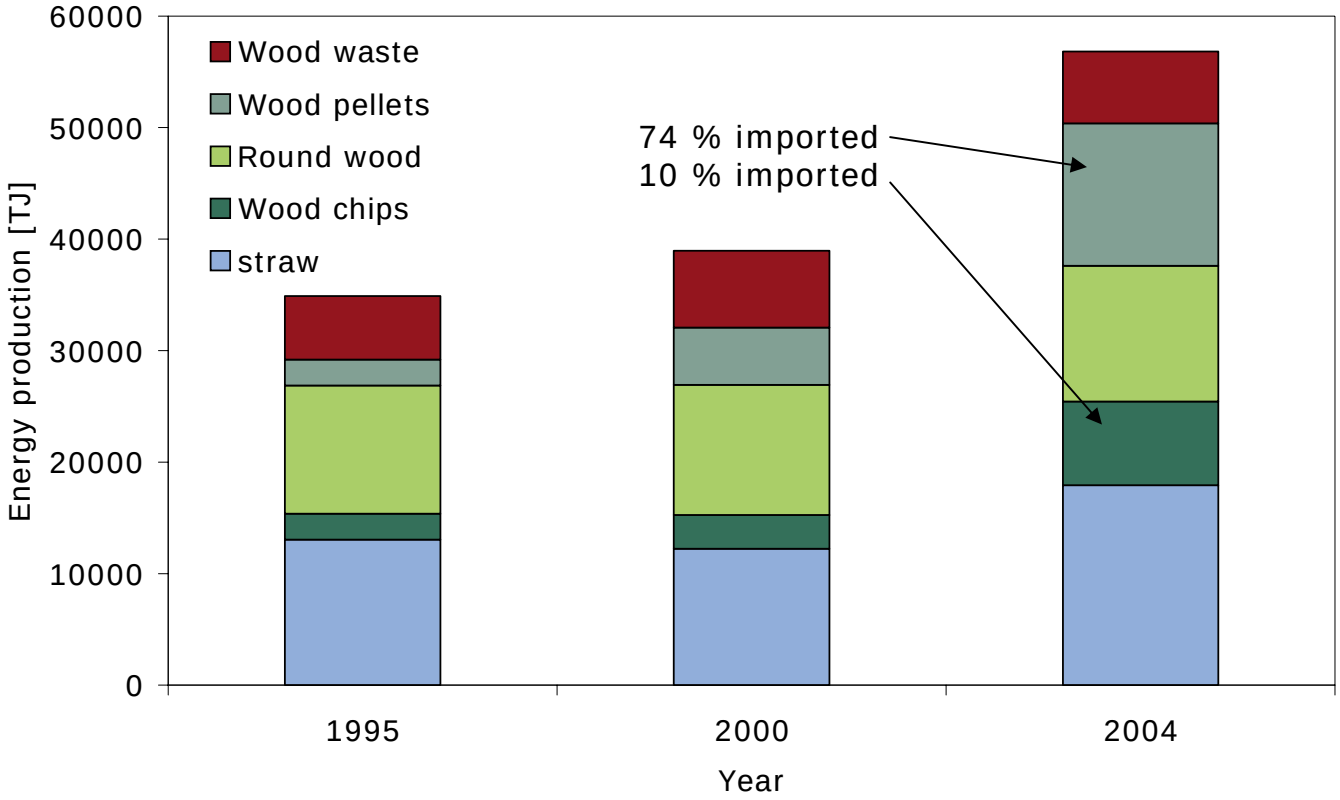
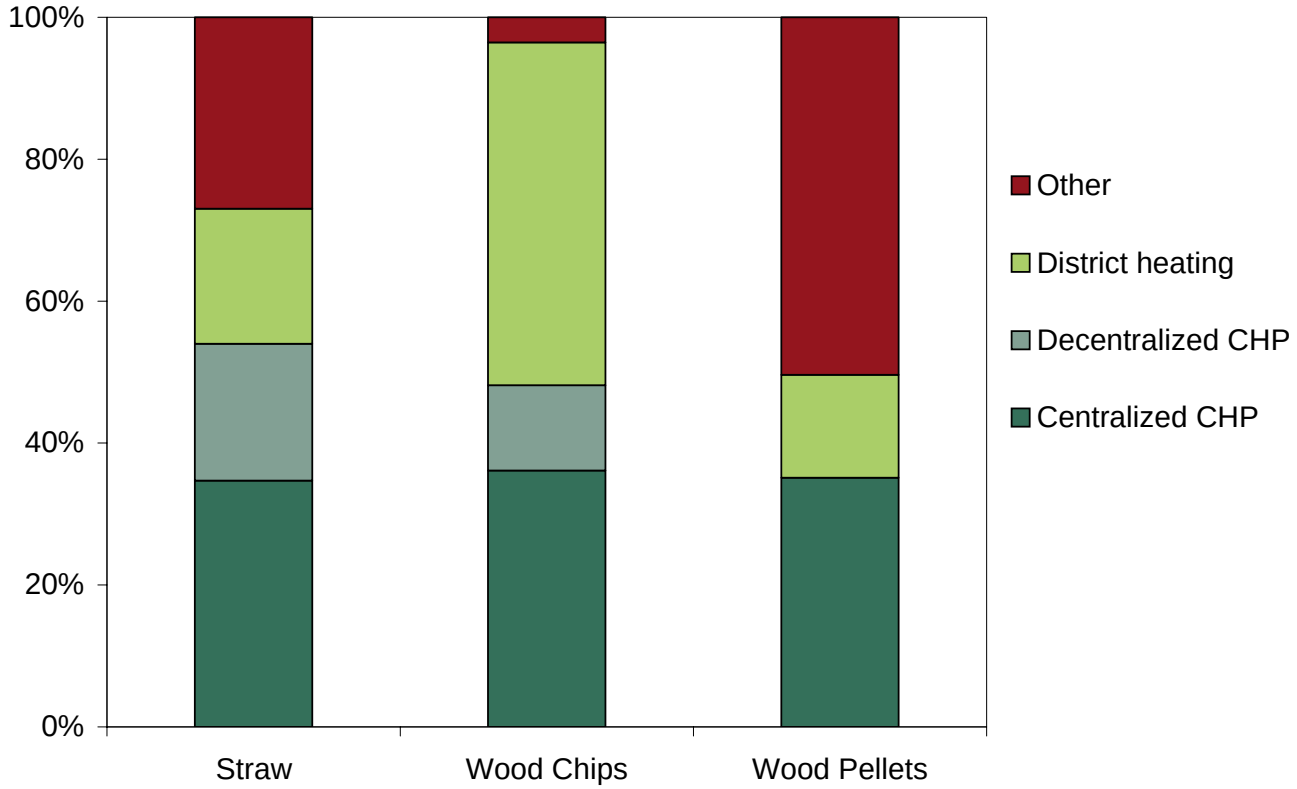
# Energy from biomass in Denmark




Energy from domestically produced and imported biomass

In 2004 56800 TJ = 6.6 % of total energy consumption in Denmark

# Use of biomass for heat and power




96 % of wood chips, 75 % of straw and 50 % of wood pellets used for heat and power production in large facilities

# Danish Biomass Action Plan

- Political decision has forced Danish power plants to use biomass for production of power and heat (Danish Biomass Action Plan 1993)
- Present use
  - 1.4 mio. tonnes of straw (potentially 2.0 mio tonnes)
  - 2.3 mio. tonnes of wood

⇒ Infrastructure for trade, handling and supplying large quantities of biomass to power plants well established

# Logistics for handling biomass

- Delivery of straw to power plants are based on contracts (typically 3-5 years) directly with the farmers
- Straw is supplied to the power plants by the farmers directly – only limited storage at power plant
- Farmers are responsible for storage (and delivery of dry straw)
- Farmers are responsible for delivery of negotiated amounts at scheduled time

The straw trade and handling system has been operated successfully for more than 10 years

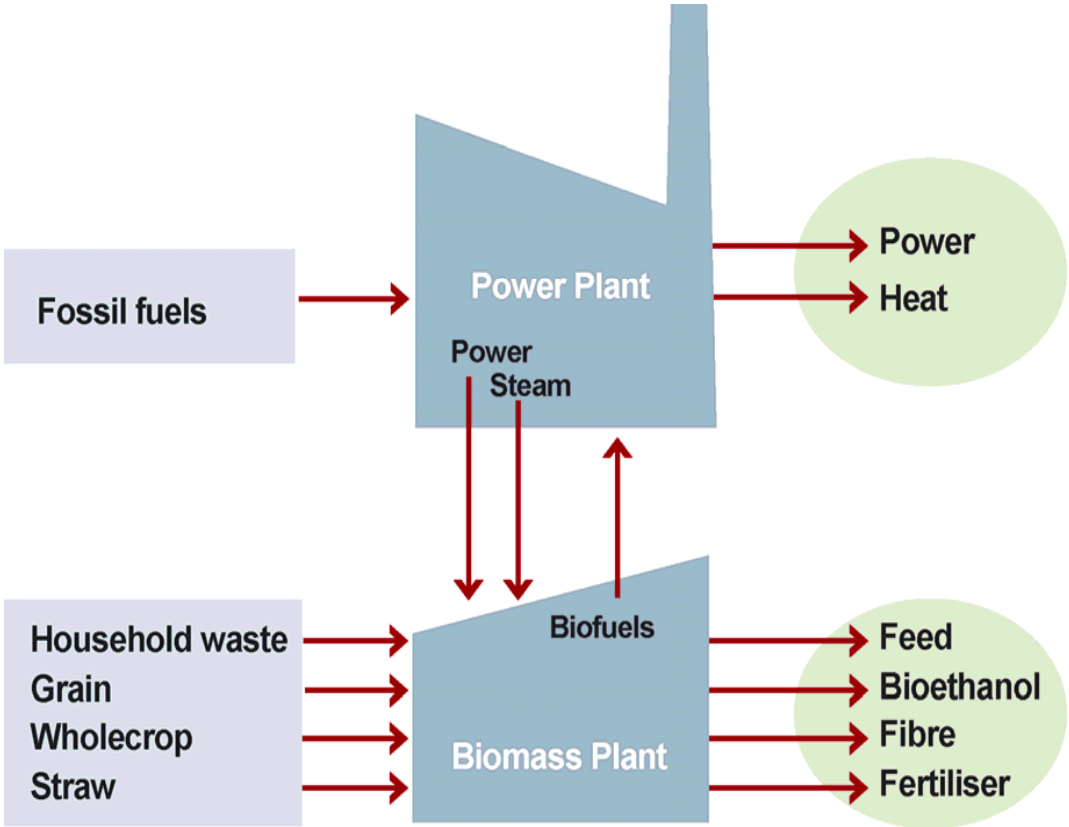
# Biomass for CHP

Avedøre 2 CHP plant
Copenhagen

Production:
570 MW electricity
570 MW district heating

- Worlds largest straw fired boiler – 25 tonnes per hour
- Yearly consumption
  - 300,000 tonnes wood pellets
  - 150,000 tonnes straw pellets
- Pellets produced on own pellets factory

# Integration of energy systems - IBUS




EU FP5 funded project from 2002 to 2006.

Participants Elsam (DK), Sicco (DK), Risø (DK), TMO Renewables (UK) & KVL (DK)

# Project scope and goals

## Scope

- Development of new and energy efficient technologies for conversion of lignocellulose into bioethanol, solid biofuel and feed

## Goals

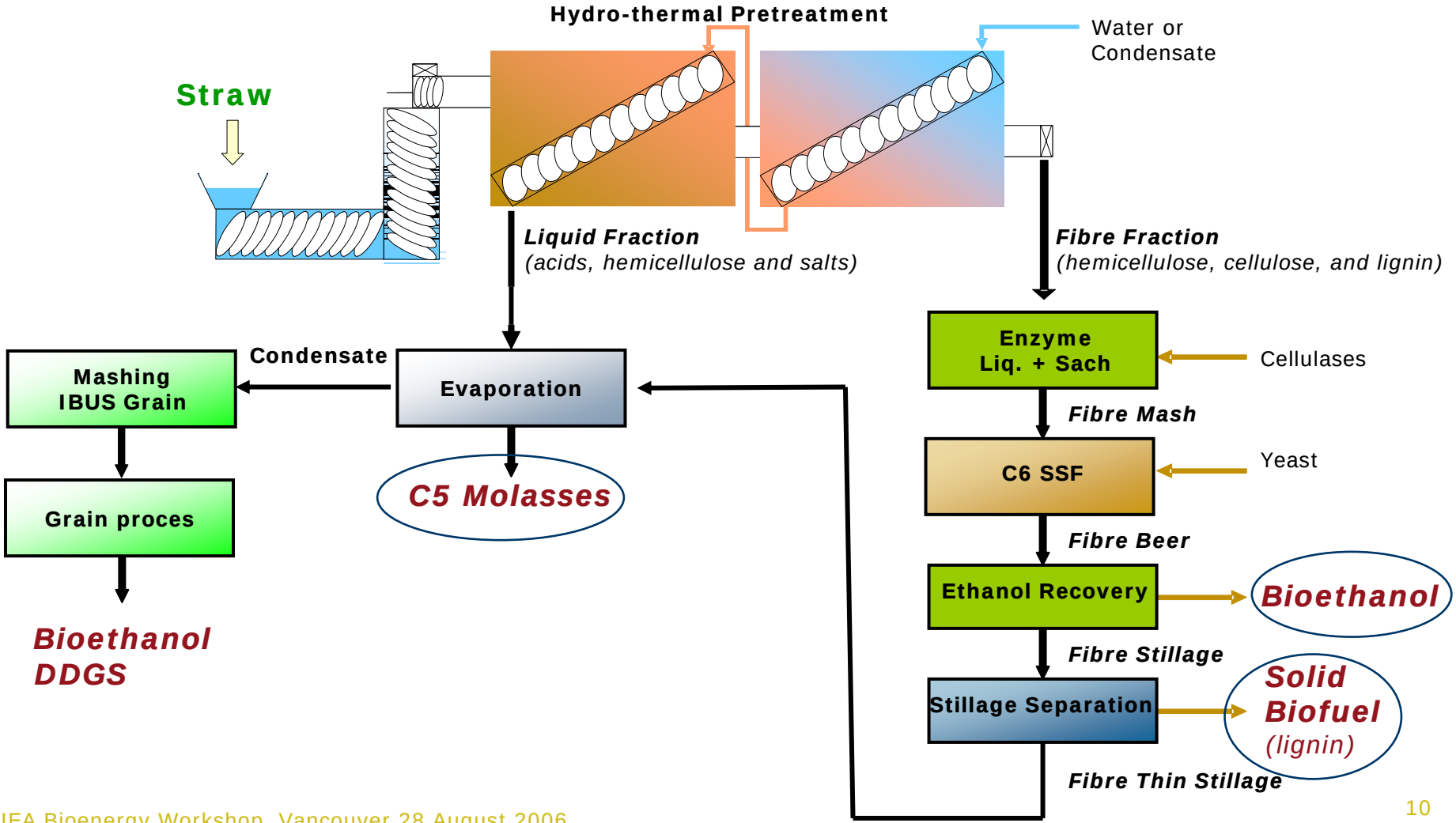
- Simplicity - reliable technology
- Sustainable and environmentally friendly production (zero discharge)
- Recirculation of minerals, N and P to the soil
- Maximum integration of bioethanol production with power plant
- Multi-feedstock process; Integration of lignocellulosic biomass and grain/sugar

# The IBUS pilot plant

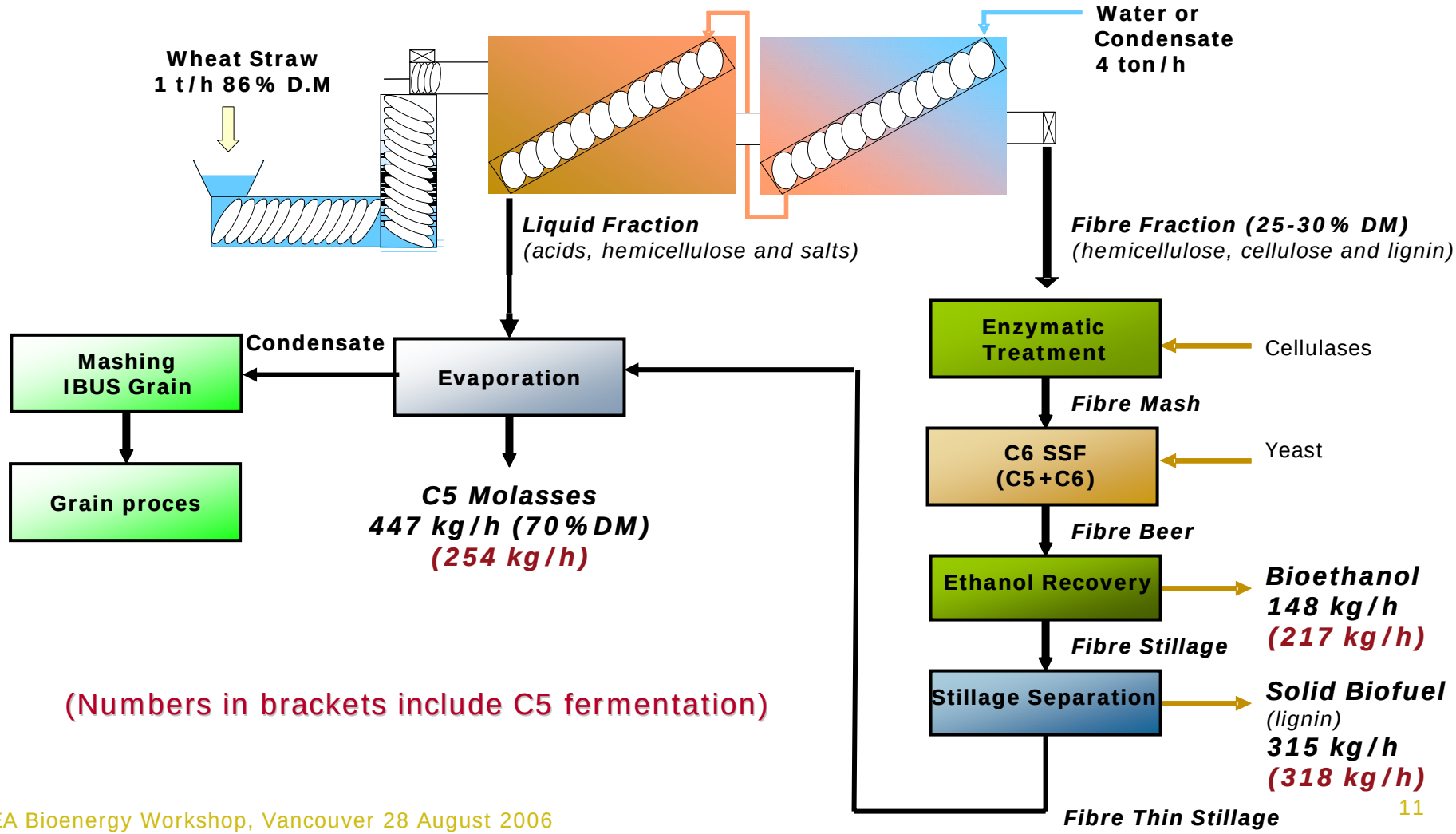
The IBUS pilot plant in autumn 2005

Pilot plant is now being rebuild at power plant next to the head quarter of Elsam

# The IBUS process scheme



# IBUS conversion of straw

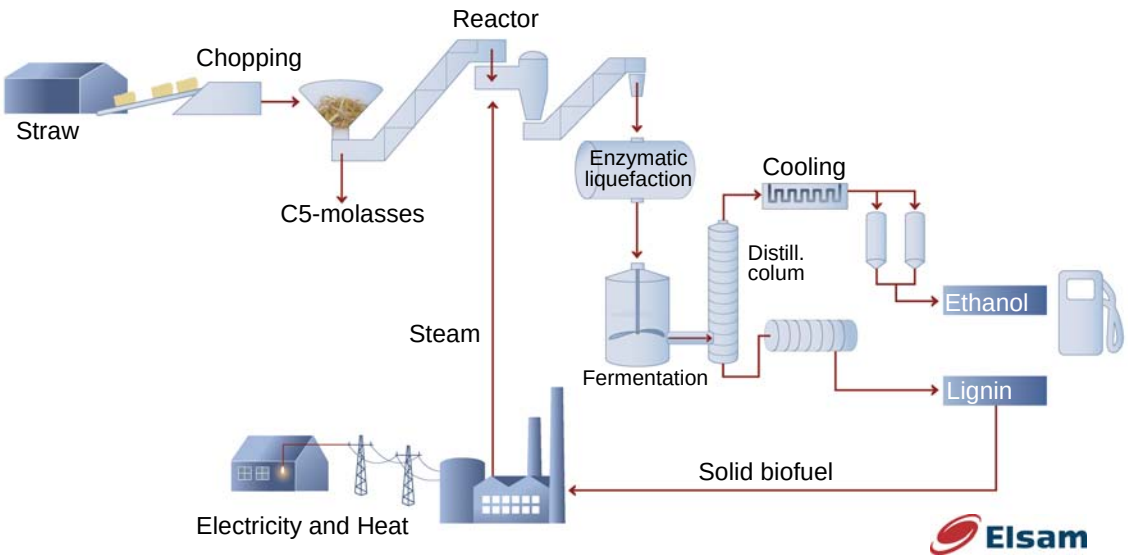



(Numbers in brackets include C5 fermentation)

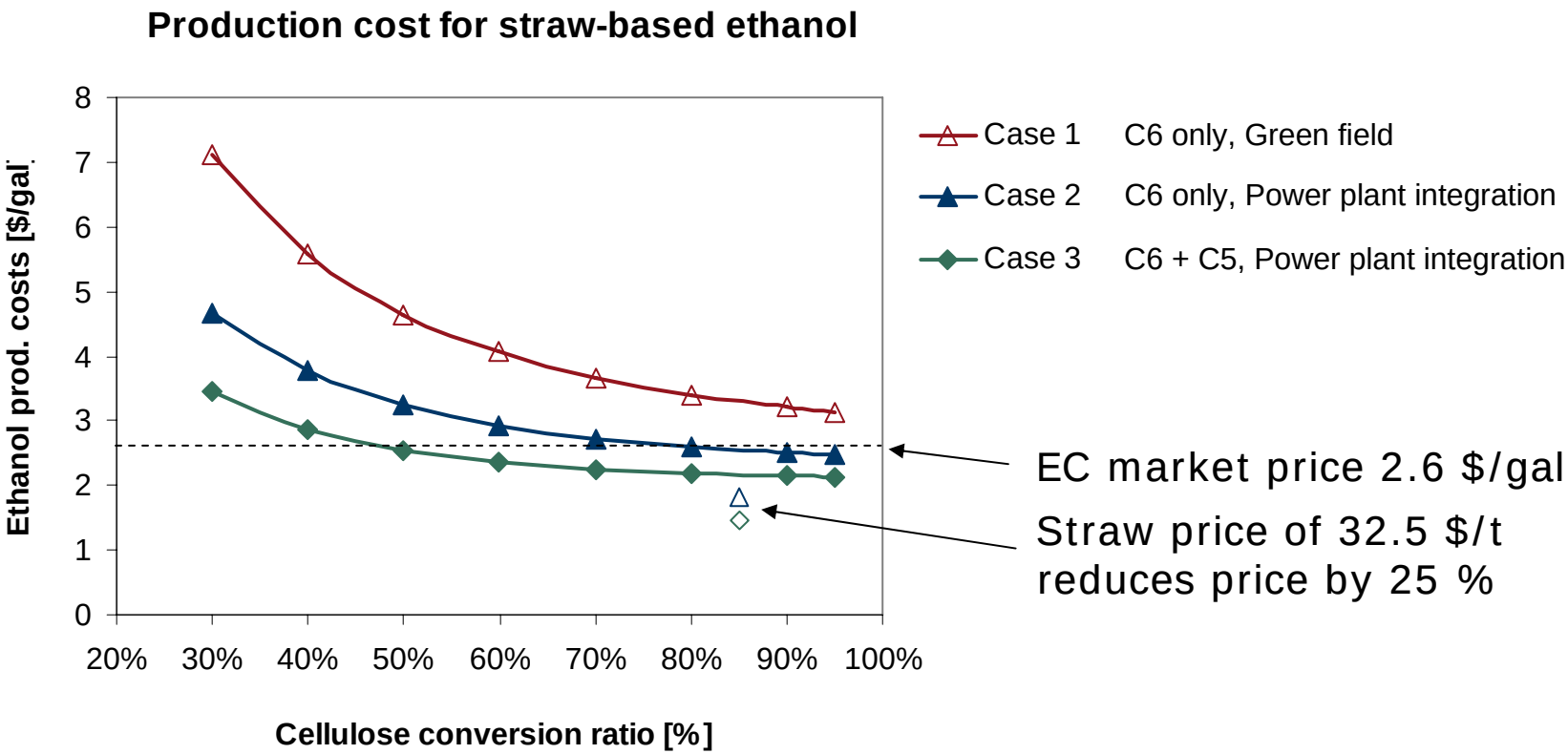
# The IBUS feasibility study

| Case | C6 Fermentation | Integration with power plant | C5 Fermentation |
|---|---|---|---|
| 1 | + | - | - |
| 2 | + | + | - |
| 3 | + | + | + |

- 20 ton/h wheat straw per hour
- Investment app.: 80 M USD
- Cellulase X (250 FPU/ml; 2,400 USD/tonne),
- 85 % cellulose conversion, 7 FPU/g DM, 140 h
- Straw price 65 USD/tonne
- No tax exceptions or any production subsidies incalculated



# The IBUS feasibility study



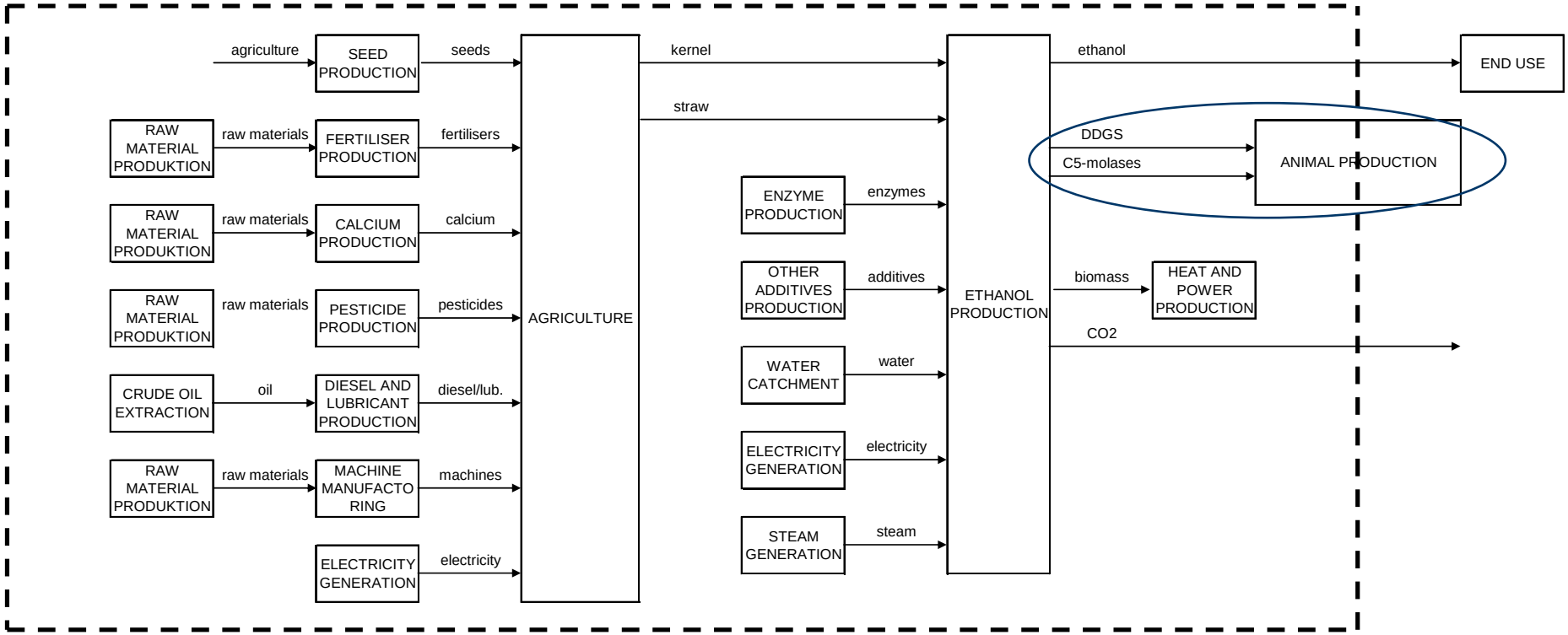
# Energy balance

## LCA study of IBUS system operated under Danish (North European) conditions

- Wheat production under Danish conditions using good agricultural practices (conventional farming)
- Ethanol production based on wheat straw and grain (whole crop) with fermentation of both C5 and C6 sugars
- Integration with CHP or green field plant using natural gas for heat generation

- Recycling of minerals and nutrients have not been included

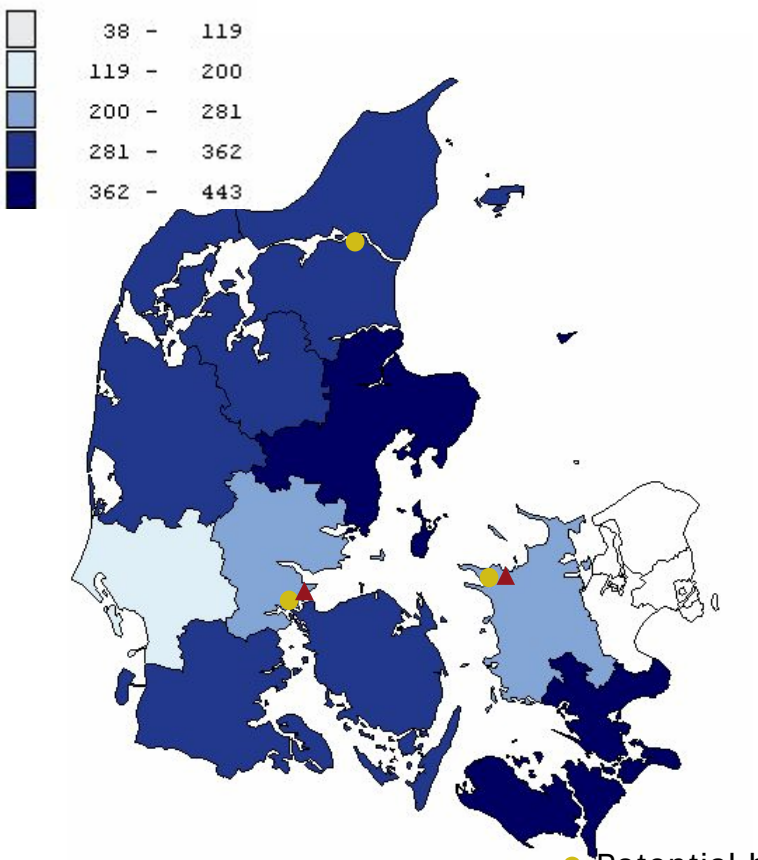
# Methodology



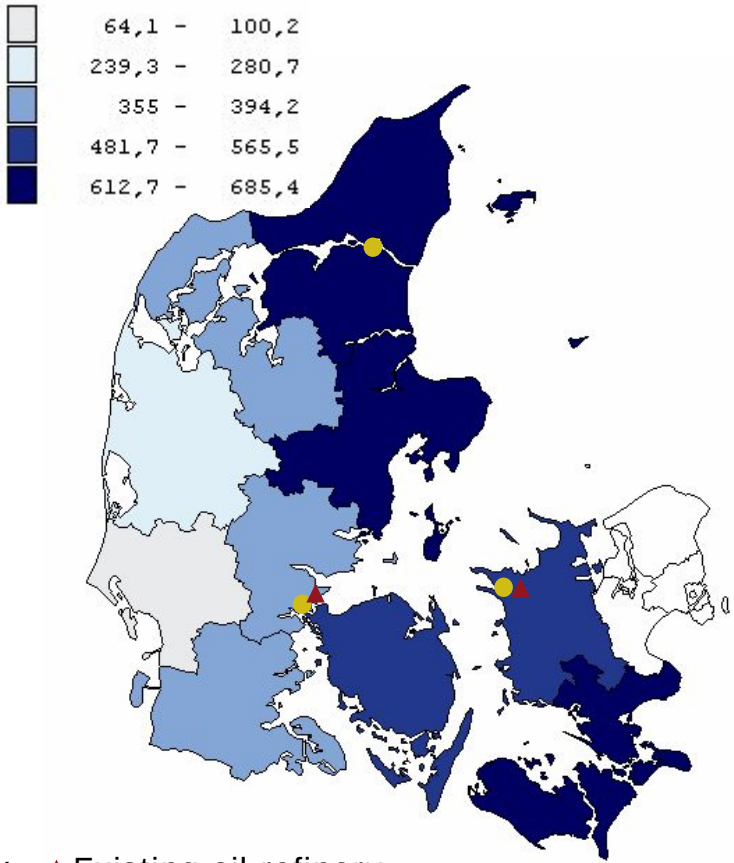

Minerals and nutrients goes into DDGS and C5-molasses and are thereby returned to the soil – 50-60 % of nitrogen used for wheat production is from animal manure

# Wheat production in Denmark

Straw production (mio kg)



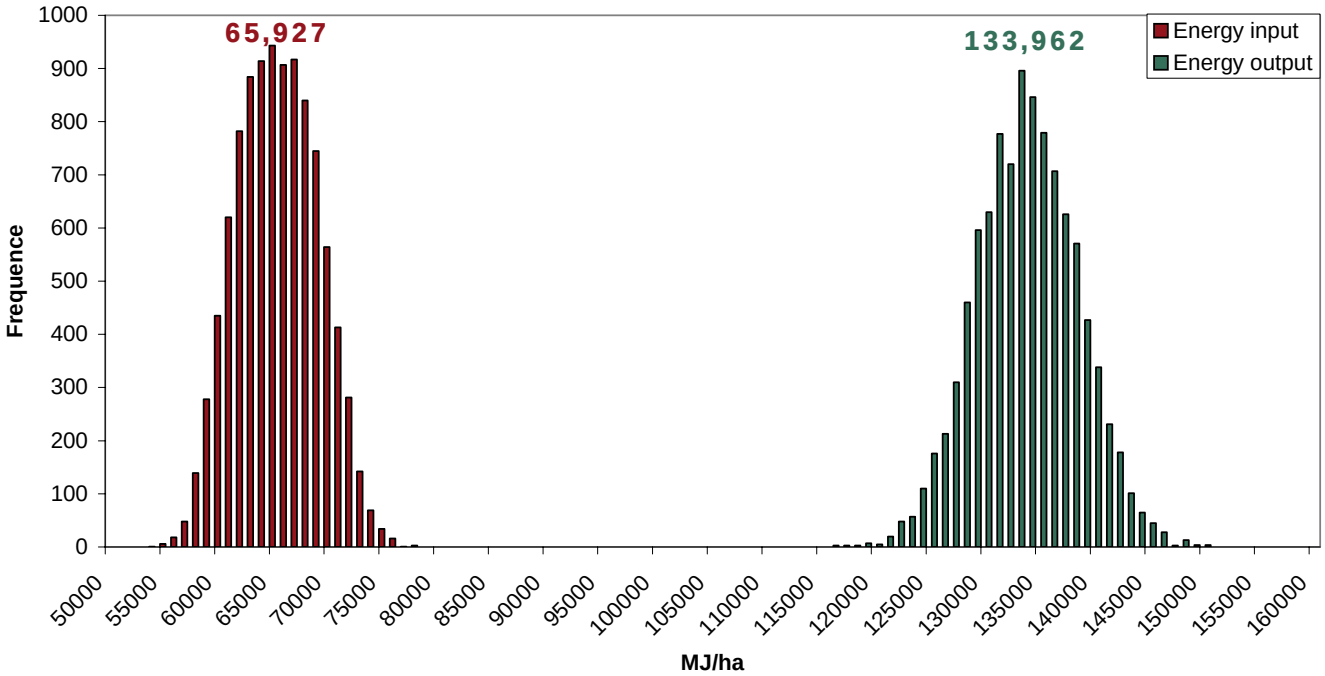

Grain production (mio kg)




● Potential biorefinery ▲ Existing oil refinery

# Input and output

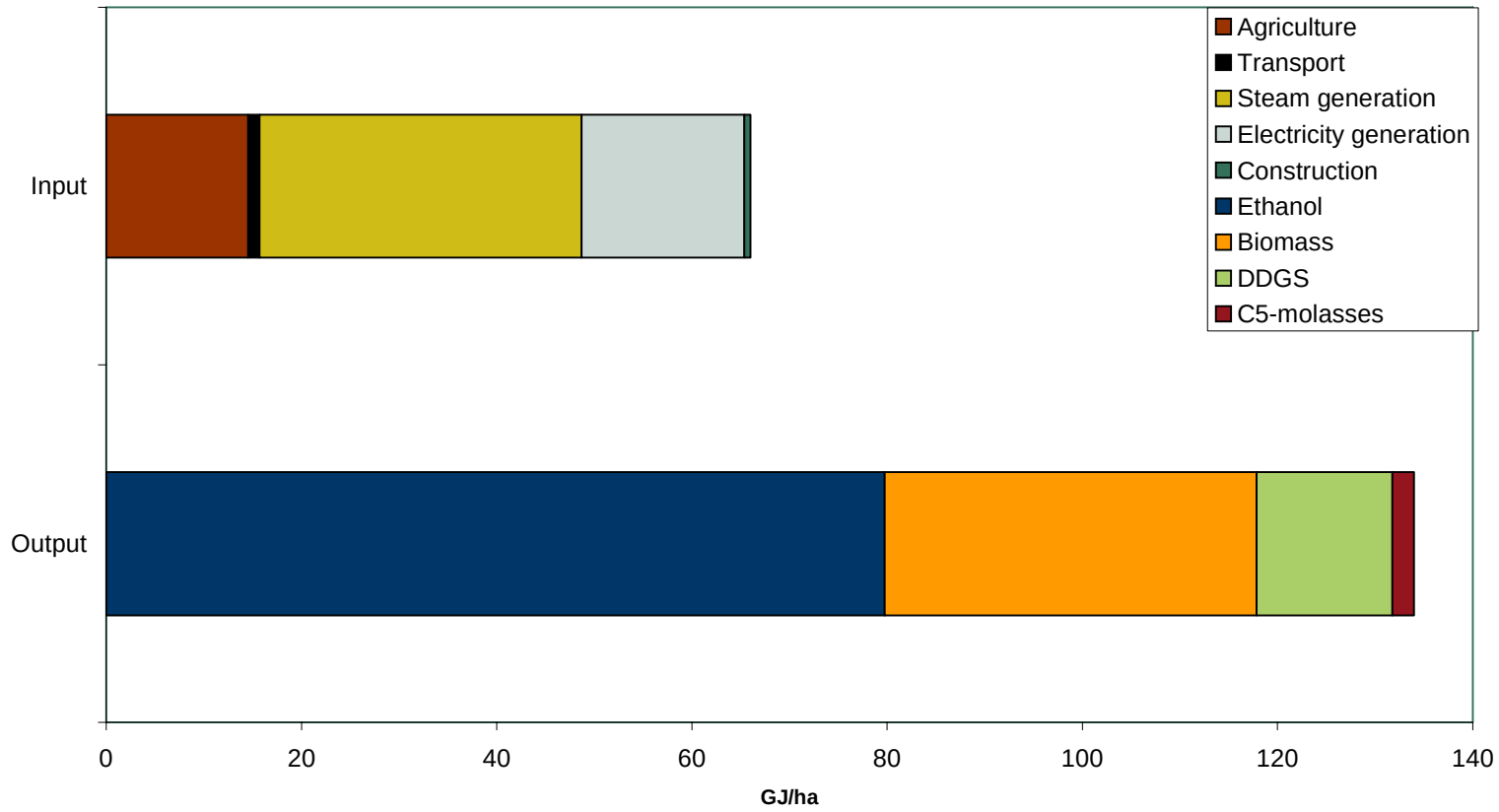
Simulated energy input and output from the wheat to ethanol production with an integrated system (IBUS)




Output-input ratio : IBUS system 2.03

Green field 1.51

# Distribution of energy input and output



# Integrating energy systems

- Logistics and handling of biomass at CHP is in place
- 30 % reduction in capital costs
- Production costs reduced by 17 % (85 % cellulose conversion)
- High efficiency conversion of solid residues into heat and power
- Low energy costs due to use of low or no value steam from power plant
- High flexibility between production of ethanol, heat and power
- Total energy surplus for a sustainable process

For more information
www.bioethanol.info

# Acknowledgement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# Questions?