TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

IEWT 2013

# Biomass Utilization & Sustainability of Biofuels

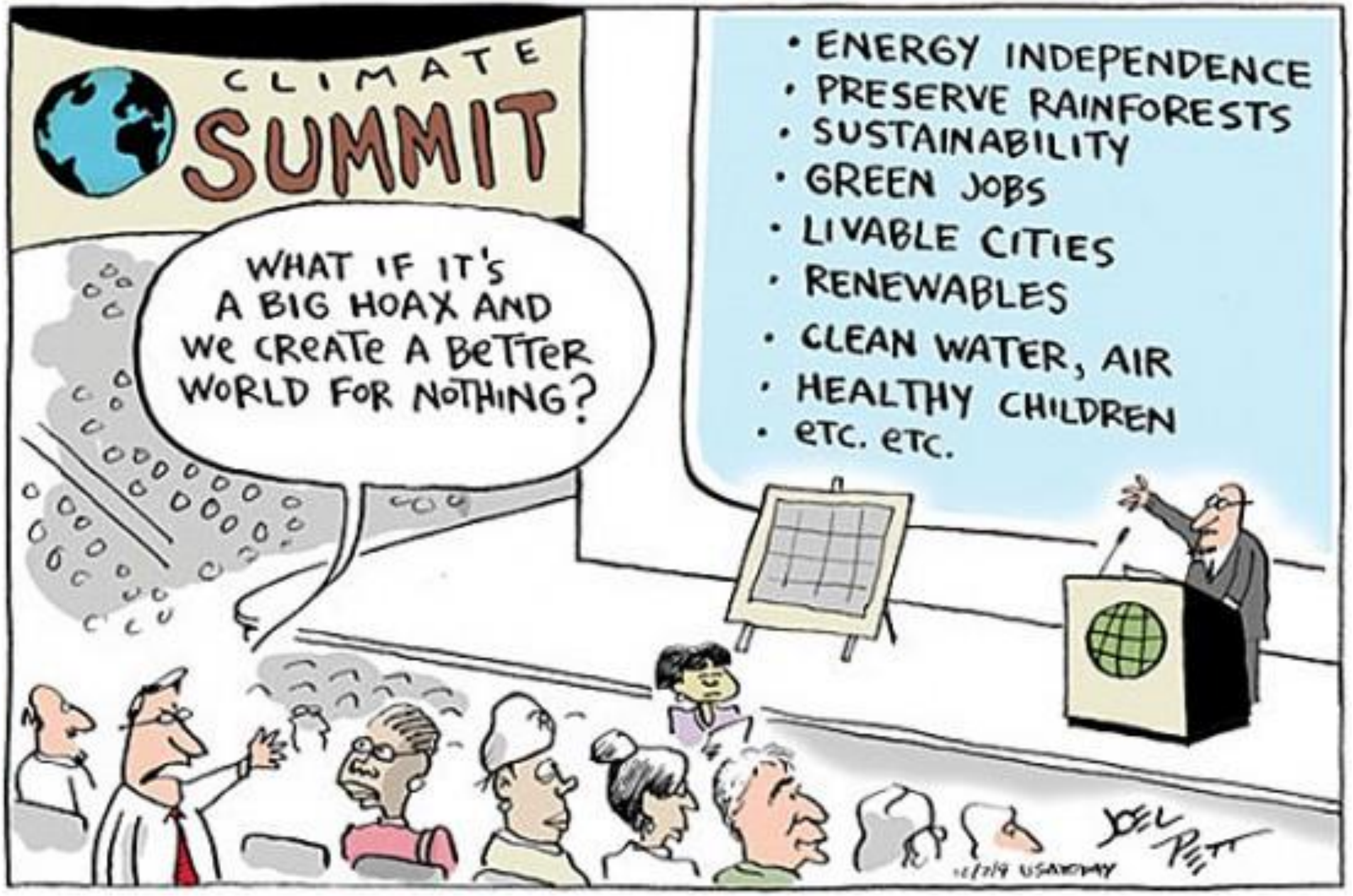

**Michael Harasek**

Technische Universität Wien
Institut für Verfahrenstechnik, Umwelttechnik und Technische Biowissenschaften
michael.harasek@tuwien.ac.at

# Outline

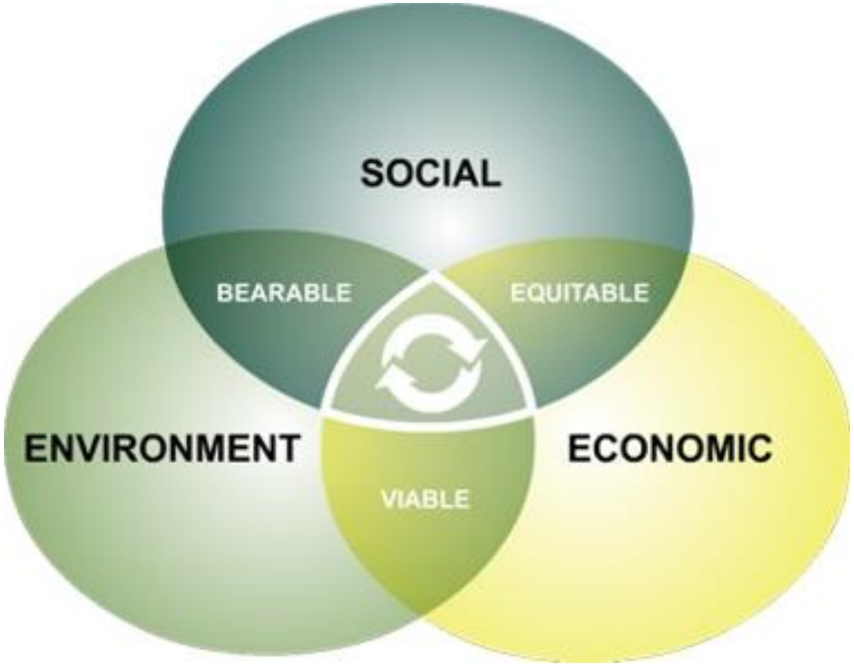
- Introduction
- Sustainability criteria – the European perspective
- Primary energy composition
- Global biomass related issues
- Biomass gasification
- Biogas digestion
- Biomethane for grid injection and as vehicle fuel
- Conclusions

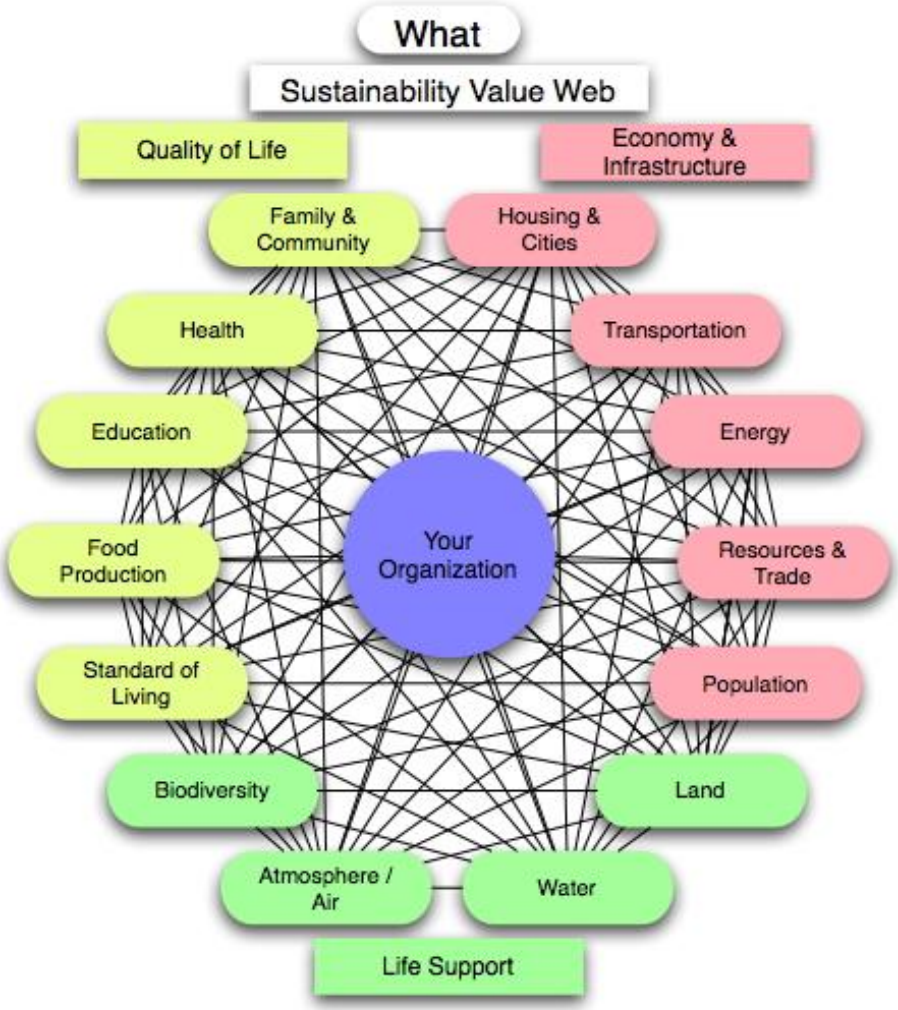
# Why should we care about sustainability?



# Sustainability Criteria of Biofuels

- The **Directive 2009/28/EC** sets out sustainability criteria for biofuels in its articles 17, 18 and 19. These criteria are related to greenhouse gas savings, land with high biodiversity value, land with high carbon stock and agro-environmental practices.
- The **criteria apply since December 2010**. The European Commission (EC) has adopted a number of Decisions and Communications to assist the implementation of the EU's sustainability criteria.




- ✓ Sustainability involves all aspects of life

# Are new Biofuels the Solution?


Source: IHT 11-04-2008

# European Union's Definition of Sustainable Biofuels

- EU Directive 2009/28/EC (Renewable energy directive: RED) requires:
- Proof of sustainability of biomass:
  - no production from no-go areas (high biodiversity or high carbon stocks),
  - sustainability of production and operations
  - monitor social sustainability and food security
- Raw material should not be obtained from :
  - wetlands
  - continuously forested areas
  - from areas with 10-30% canopy cover
  - from peatlands
  - if the status of the land has changed compared to its status in January 2008
- GHG savings:
  - biofuels and bio-liquids must yield a GHG emission savings of at least 35%
  - (50% from 2017, 60% from production started after 2017)
- Traceability and mass balance must be assured

European Commission

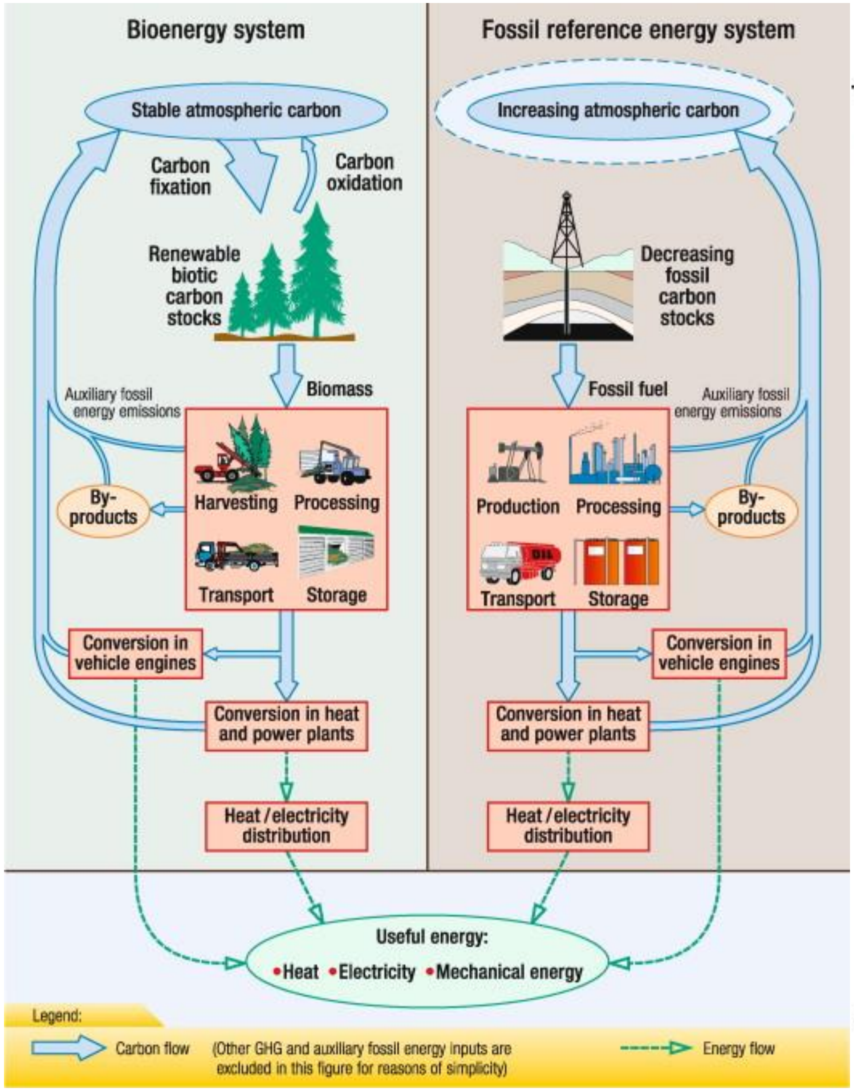
# Rules for calculation of GHG savings – Methodology

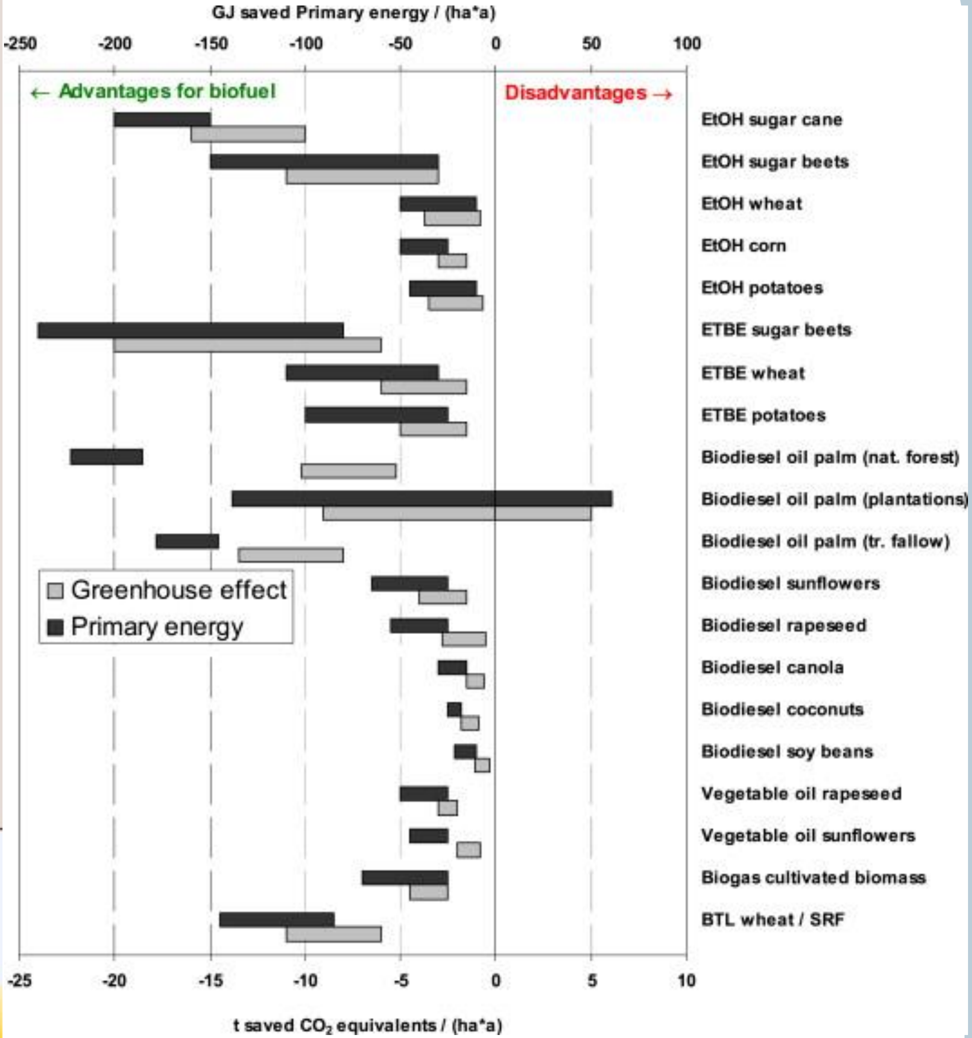
- Includes all process steps (life-cycle) (Annex VII.C)
- End-use efficiency may be taken into account
- Land use change has to be taken into account
- Carbon capture and storage/ replacement

- Co-products by energy allocation, except:
  - agricultural crop residues (not counted)
  - surplus electricity from CHP (special rule)

- Special rule for biofuels from wastes/ residues
- Comparison with EU average for petrol & diesel

# Baselines: GHG Emissions of Fuels

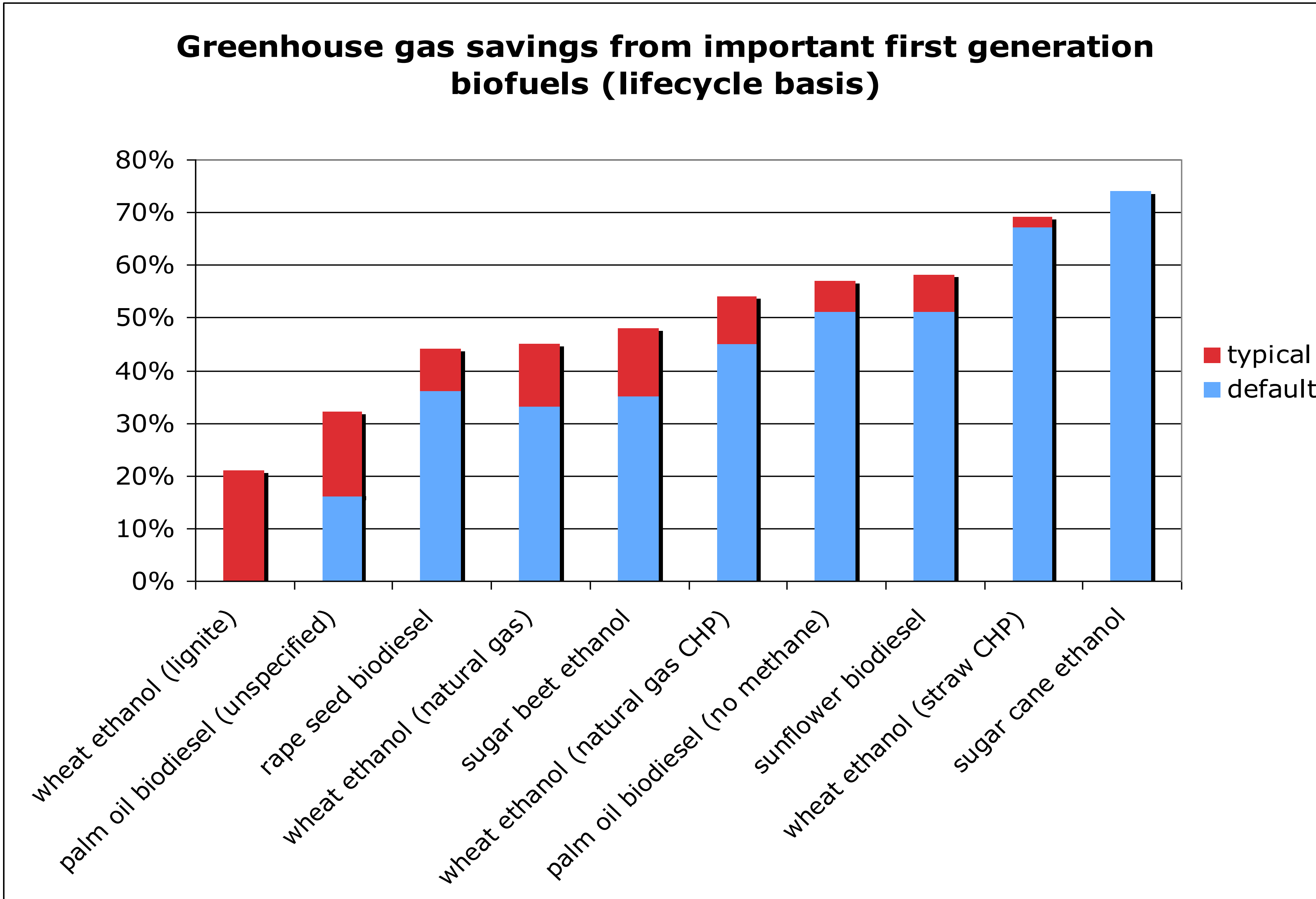



http://www.sciencedirect.com/science/article/pii/S0921344909000500

http://www.sciencedirect.com/science/article/pii/S0961953410004071

# Greenhouse Gas Savings from Biofuels



# Trade… or will the fuel be used locally?

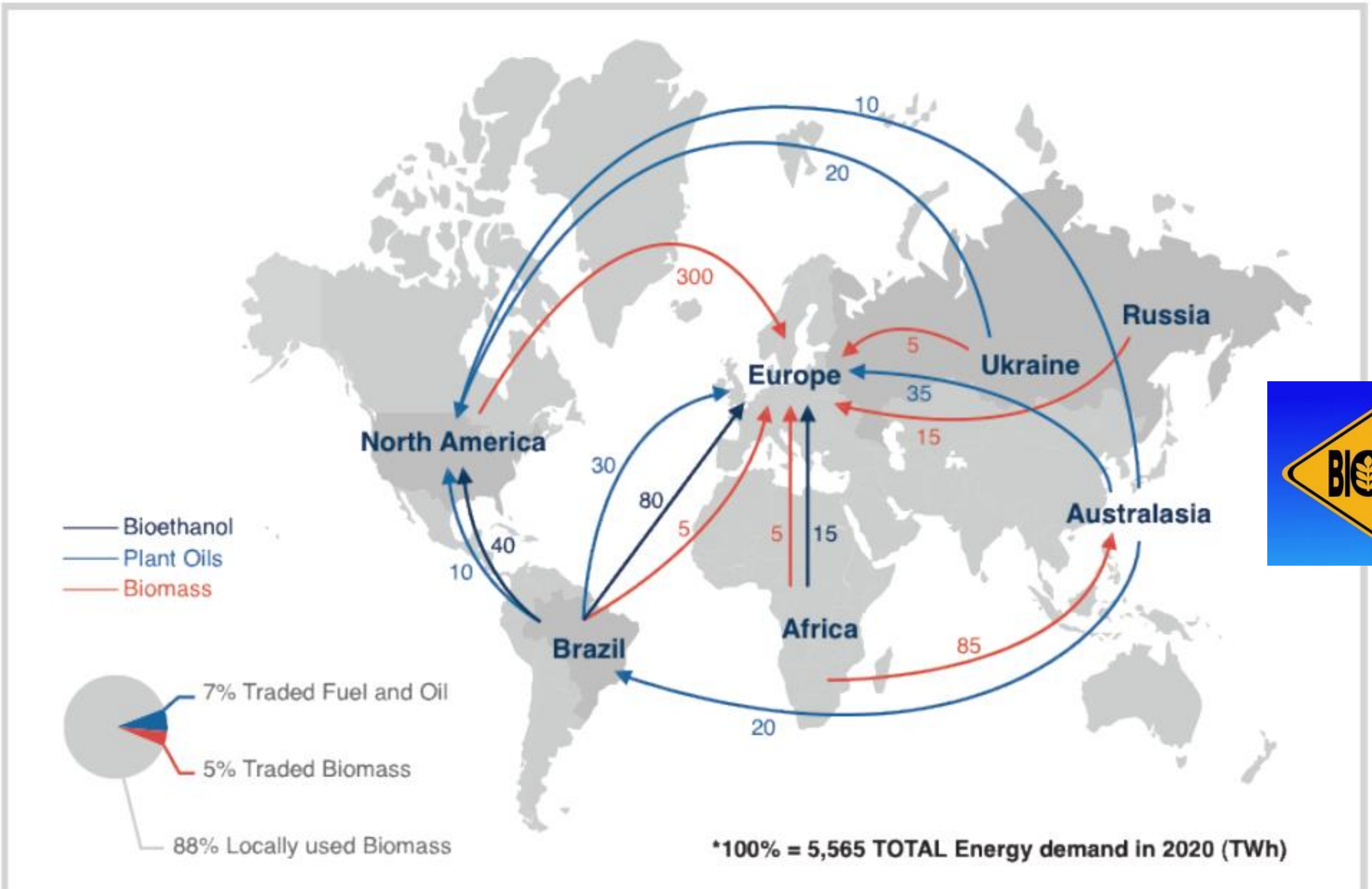



Figure 5: *Expected Biomass Trade Routes.* Values represent final energy demand in 2020.

# Biomass Feedstocks

**Biomass feedstocks**

**Wastes**
- Organic waste (MSW)
- Sewage sludge
- Manure/dung

**Processing residues**
- Timber residues
- Black liquor
- Bagasse
- Rice husks
- Food processing wastes

**Locally collected feedstocks**
- Agricultural residues (*e.g.* straw)
- Forestry residues
- Roundwood and thinnings
- Energy crops

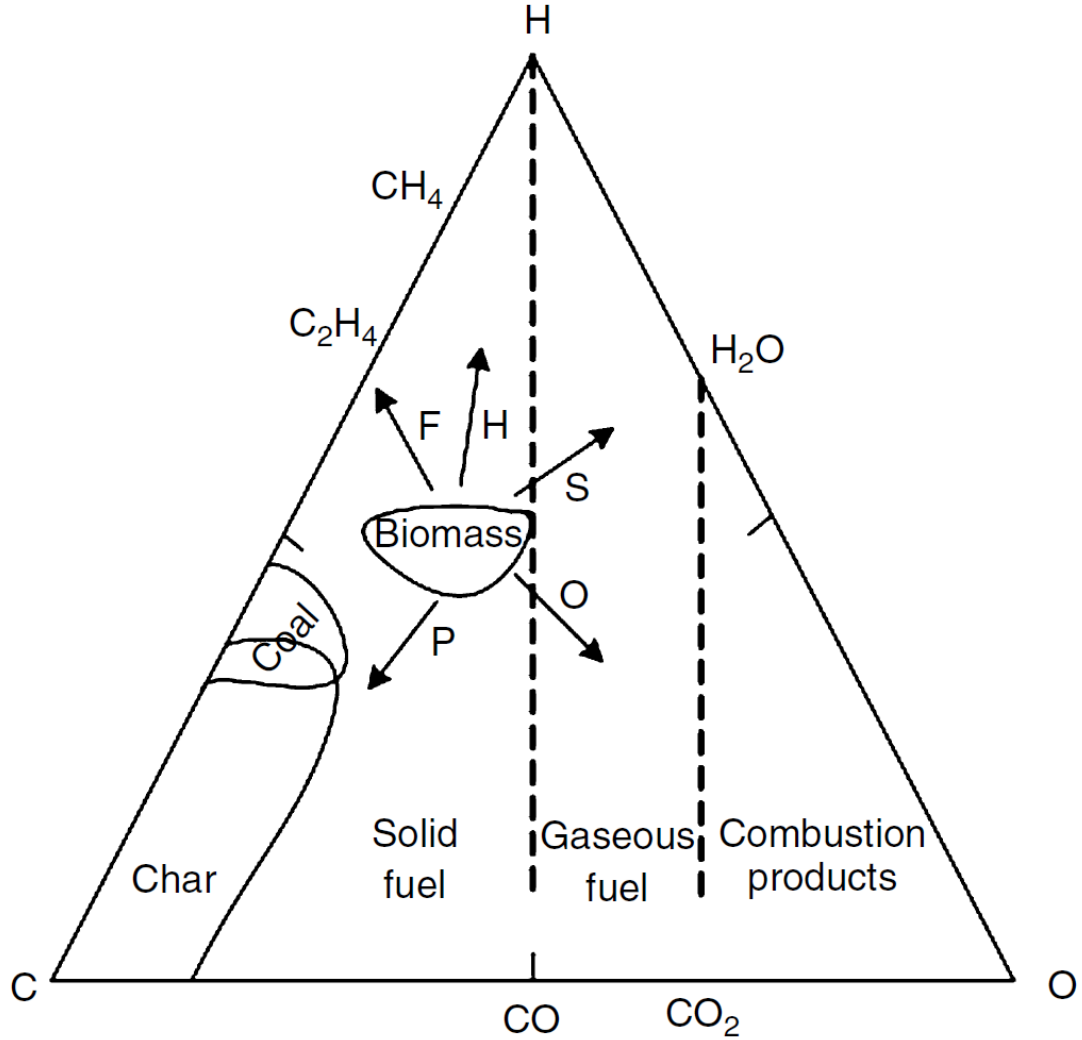
**Internationally traded feedstocks**
- Roundwood
- Wood chips
- Biomass pellets (wood, torrefied)
- Biomethane
- Pyrolysis oil

| | Wastes | Processing residues | Locally collected feedstocks | Internationally traded feedstocks |
|---|---|---|---|---|
| Typical feedstock costs (USD/GJ) | negative to 0 | 0 – 4 | 4 – 8 | 8 – 12 |
| Typical plant capacity (MW electric) | 0.5 – 50 | 0.5 – 50 | 10 – 50 | > 50 |

Examples of different biomass feedstocks, typical feedstock costs, and plant capacities

Source: IEA (2012)

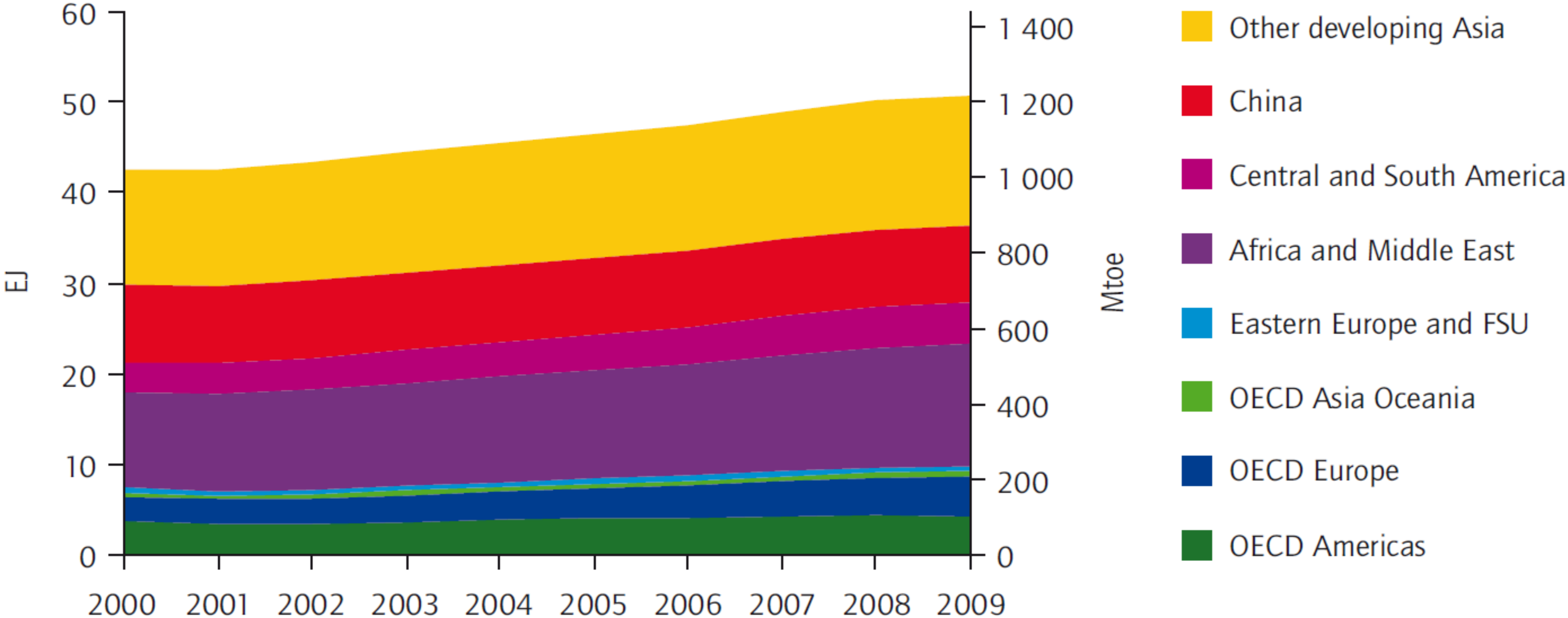
# Biomass Composition and Utilization




H hydrogen S steam O oxygen P slow pyrolysis
F fast pyrolysis L lignin C cellulose/hemicellulose

Composition triangle C/H/O (mol/mol)

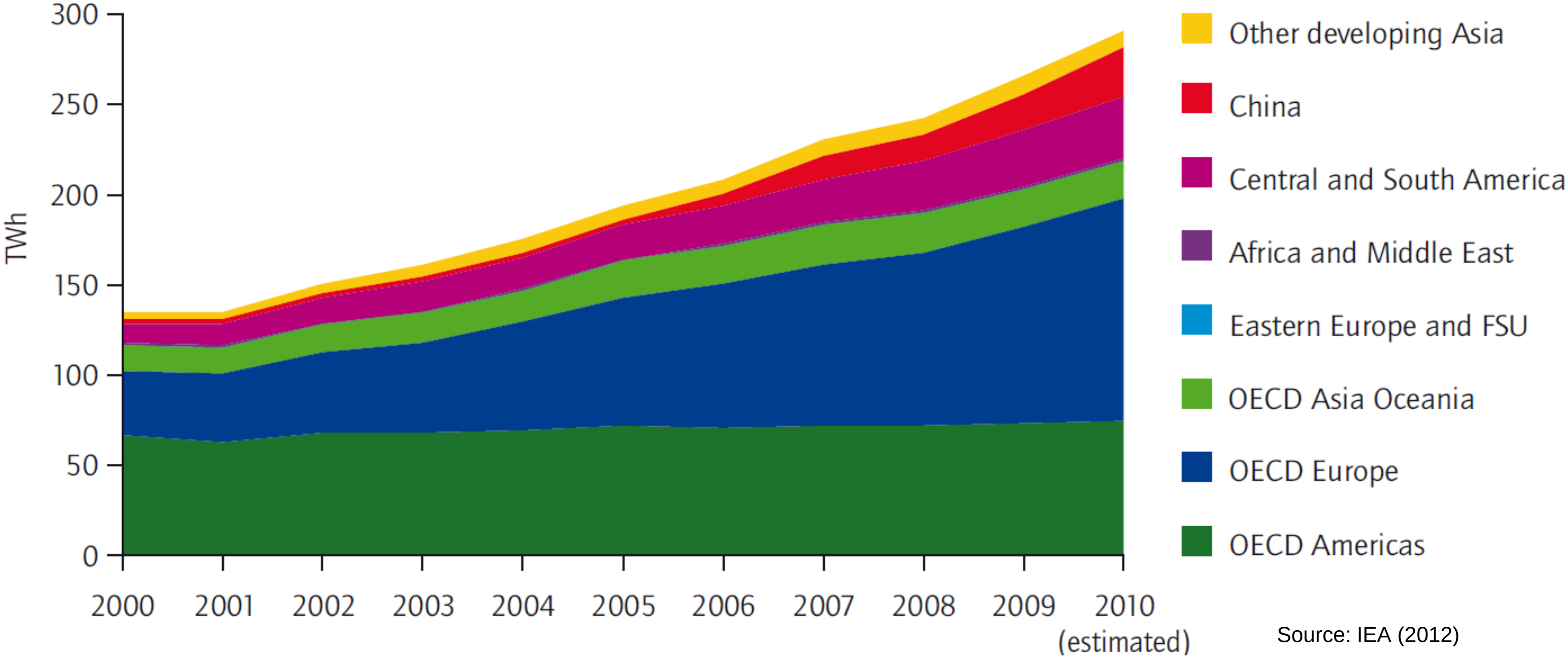
# Global Primary Bioenergy Supply




Source: IEA (2012)

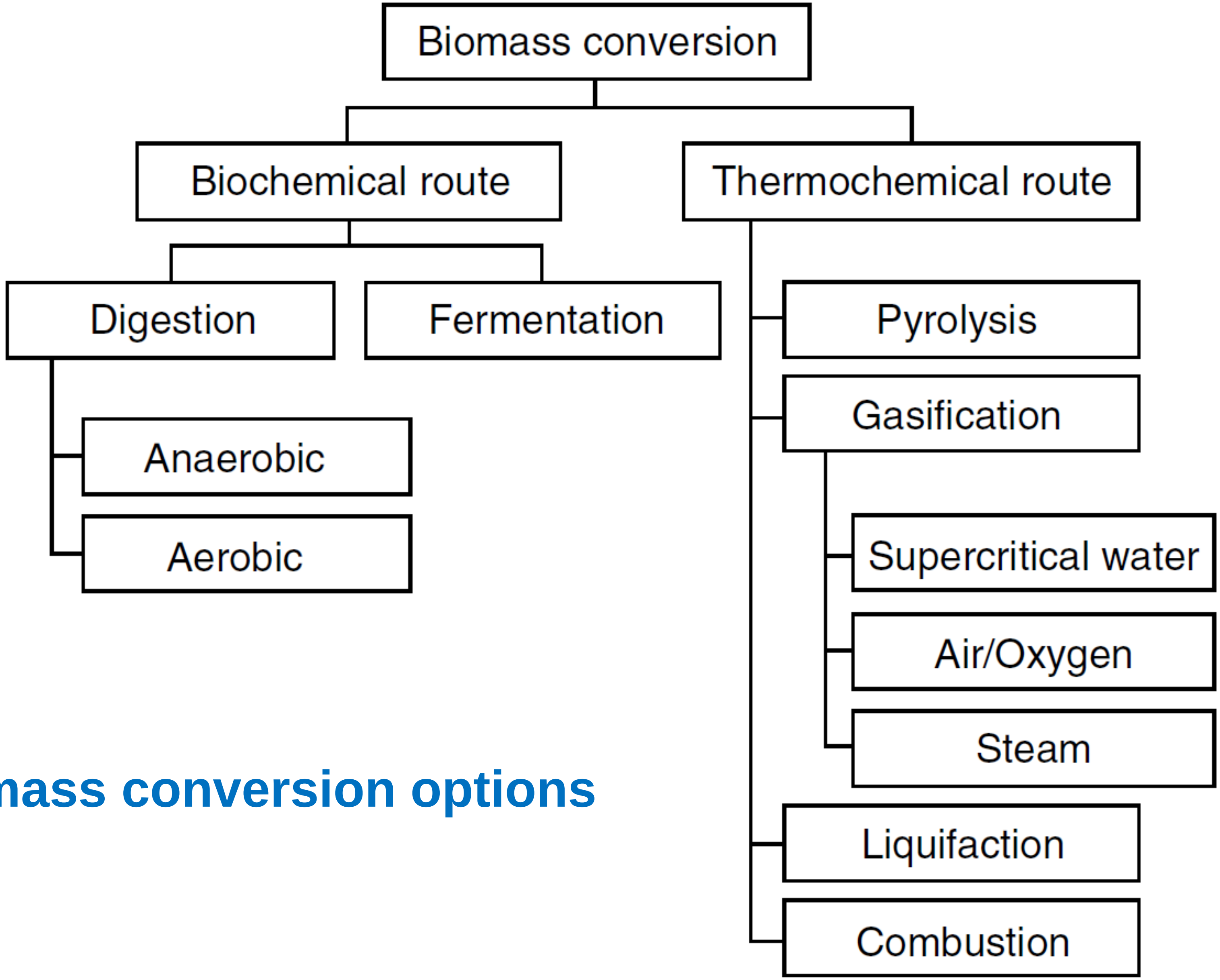
Global primary bioenergy supply 2000-2009

# Electricity from Biomass – Global Perspective



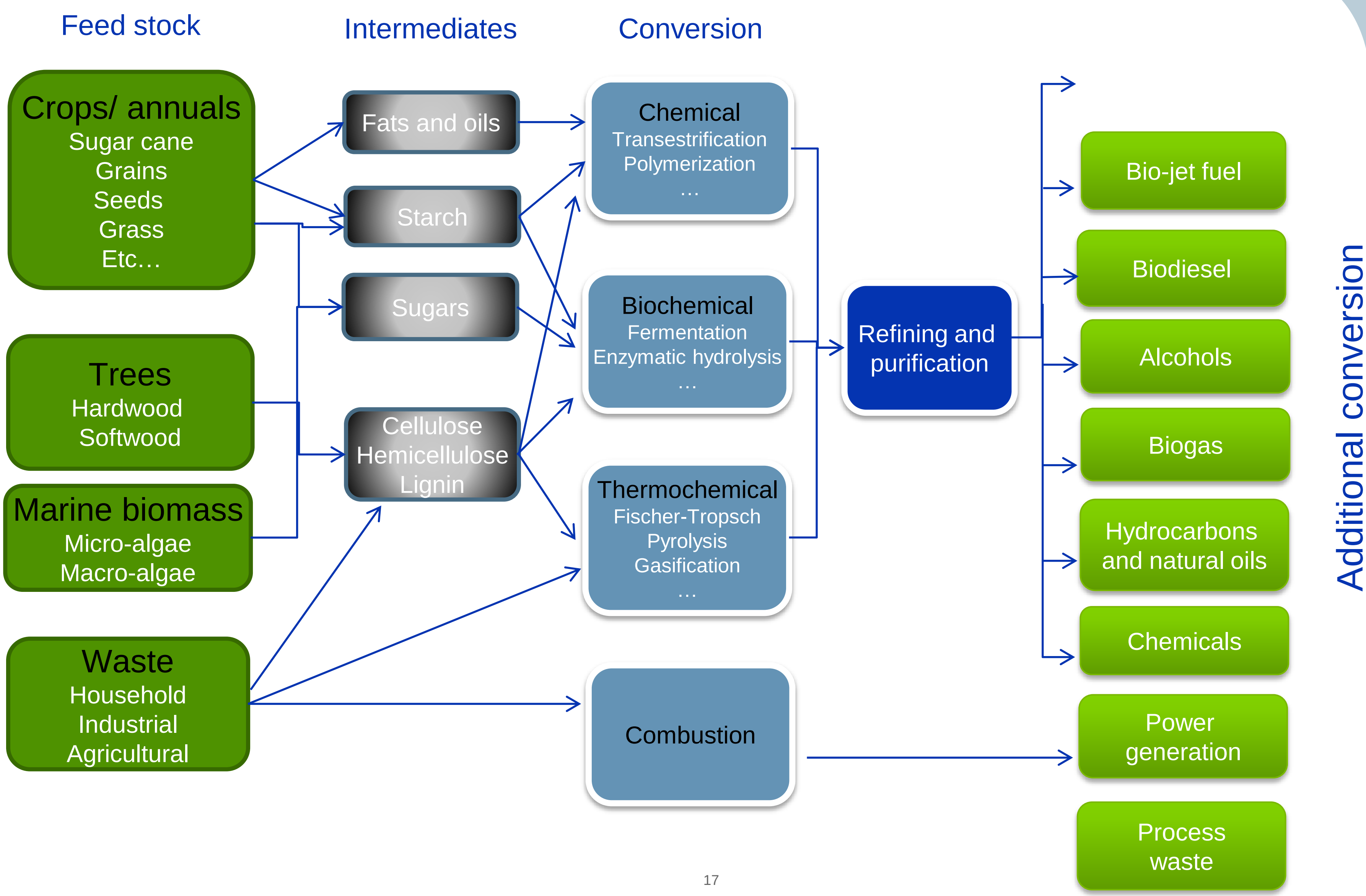

Source: IEA (2012)

Global bioenergy electricity generation 2000-2010



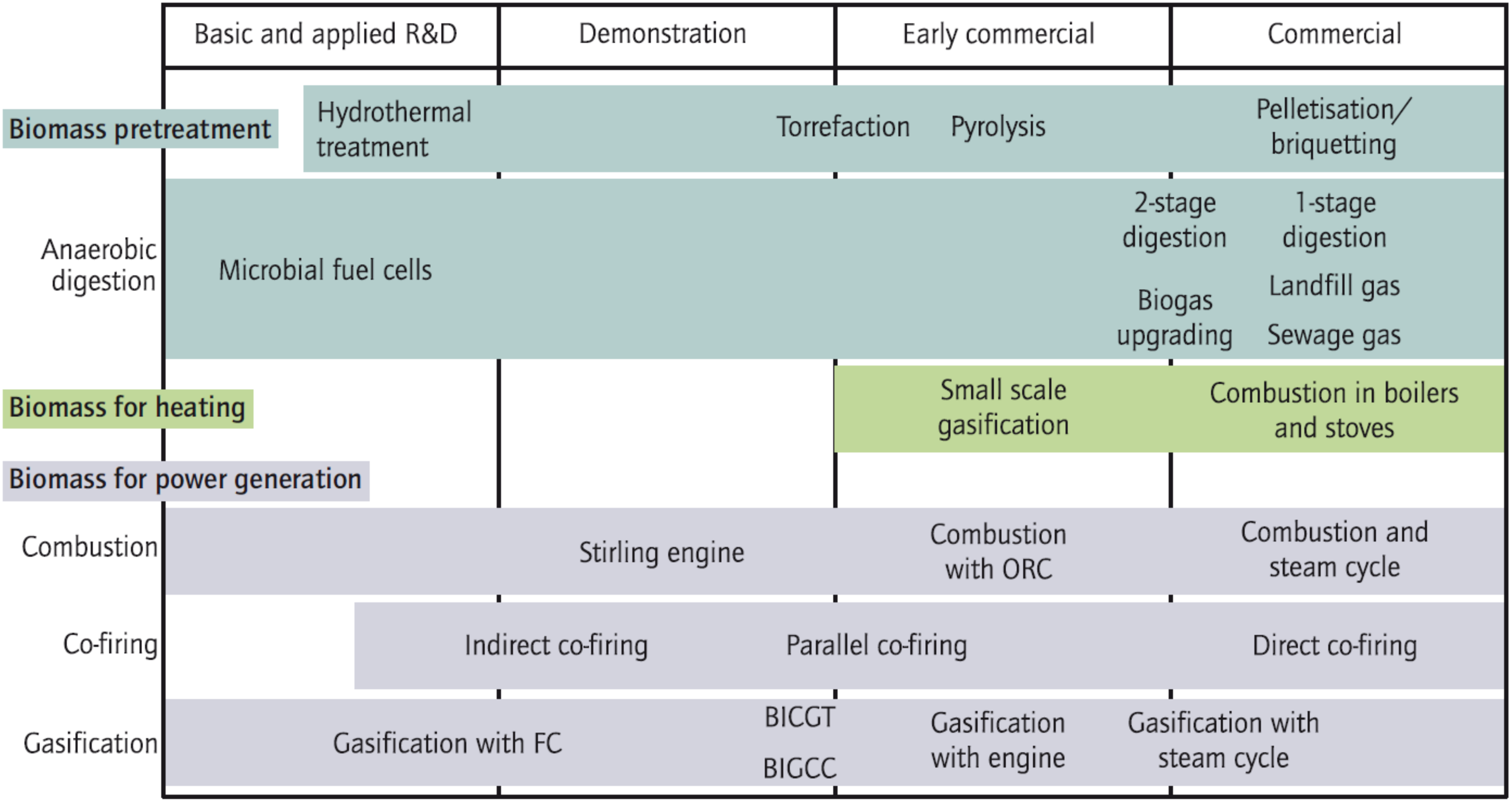

## Biomass conversion options

# Biofuels…


Feed stock
Intermediates
Conversion
Crops/ annuals
Sugar cane
Grains
Seeds
Grass
Etc…
Trees
Hardwood
Softwood
Marine biomass
Micro-algae
Macro-algae
Waste
Household
Industrial
Agricultural
Fats and oils
Starch
Sugars
Cellulose
Hemicellulose
Lignin
Chemical
Transestrification
Polymerization
…
Biochemical
Fermentation
Enzymatic hydrolysis
…
Thermochemical
Fischer-Tropsch
Pyrolysis
Gasification
…
Combustion
Refining and purification
Bio-jet fuel
Biodiesel
Alcohols
Biogas
Hydrocarbons and natural oils
Chemicals
Power generation
Process waste
Additional conversion

17

# Biomass Utilization Options




Note: ORC = Organic Rankine Cycle; FC = fuel cell; BICGT = biomass internal combustion gas turbine; BIGCC = biomass internal gasification combined cycle

Technology status of biomass utilization options

Source: Bauen et al. (2009), IEA (2012)

# Biomass / Bioenergy Facts

## Bioenergy

- Bioenergy represents over 10% of global primary energy supply
- Primary bioenergy demand > 50 EJ (end of 2011)

## Biomass use:

- 86% for cooking, heating & cooling (only 25% modern bioenergy)
- **10,5% for power generation**
- 3,5% for transport fuels

## Biomass electricity

- 70 GW of biomass power generation capacity end of 2011, over 65 GW in 2010
- Production in power-only and CHP plants by direct firing or co-firing
- (EU in 2010: 36 % power only , 64 % CHP)
- 88 % derived from solid biomass (US, EU, Brazil, China)

Source: Renewable Energy Policy Network for the 21st Century (2012)

# Bioenergy Trends

## Consequences of policies to reduce GHG and to diversify energy source

- Increasing demand for biomass fuels
- Local feedstock not sufficient to cover demand
- increasing international trade of biomass fuels
- creation of large feedstock plantations in tropical & sub-tropical regions (often corporate investments)

Increasing size of bioenergy power facilities over the last decade:

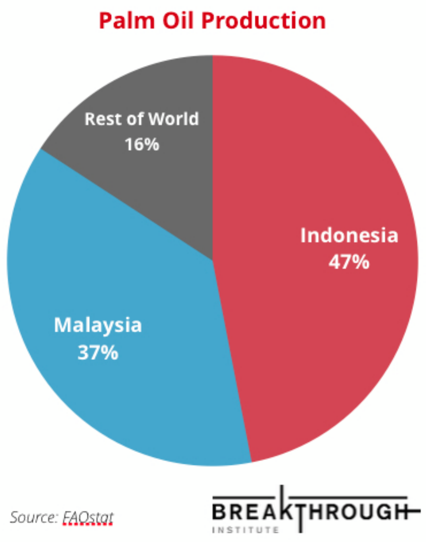
- 20 MW →750 MW in the UK (conversion of coal-fired power plant)
- Trend is enhanced because of co-firing developments

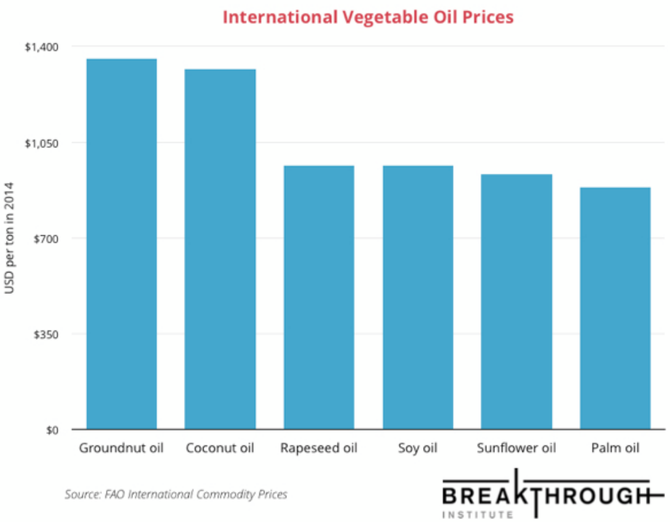
## Locally used biomass versus internationally traded biomass

## New challenges

- Ensure sustainability of modern bioenergy
- Develop and report on local bioenergy

# Palm Oil Production & Sustainability




# Scale Influence on some Bioenergy Technologies

| | Scale | Power range | Thermal efficiency | Electric efficiency |
|---|---|---|---|---|
| **Heating** (boiler) | Small | 25 – 100 $kW_{th}$ | 80 – 85 % | |
| | Medium | 100-500 $kW_{th}$ | 85 – 87 % | |
| | Large | 500-5000 $kW_{th}$ | 87 – 93 % | |
| **CHP** (boiler + steam turbine) | Small | 1-10 $MW_e$ | 63 – 70 % | 13-21 % |
| | Medium | 10-25 $MW_e$ | 59 – 63 % | 21-26 % |
| | Large | 25-50 $MW_e$ | 52 – 59 % | 26-35 % |
| **CHP** (gas engine) | Small | 0.1- 0.25 $MW_e$ | | 31 – 33 % |
| | Medium | 0.25 -1 $MW_e$ | | 33 – 38 % |
| | Large | 1 -2 $MW_e$ | | 38 – 40 % |
| **CHP** (diesel engine) | Small | 0.1 – 0.75 $MW_e$ | 46 – 50 % | 37-42 % |
| | Medium | 0.75 -1.5 $MW_e$ | 45 – 50 % | 42-44 % |
| | Large | 1.5 - 5 $MW_e$ | 44 – 45 % | 44-45 % |
| **Co-firing** Coal power plants (boiler + steam turbine) | Only Large | 500 - 750 $MW_e$ | 50 – 52 % | 35-43 % |

Source: Ecofys, EU-Project TREN/A2/143-2007 (2010)

# Biomass Combustion

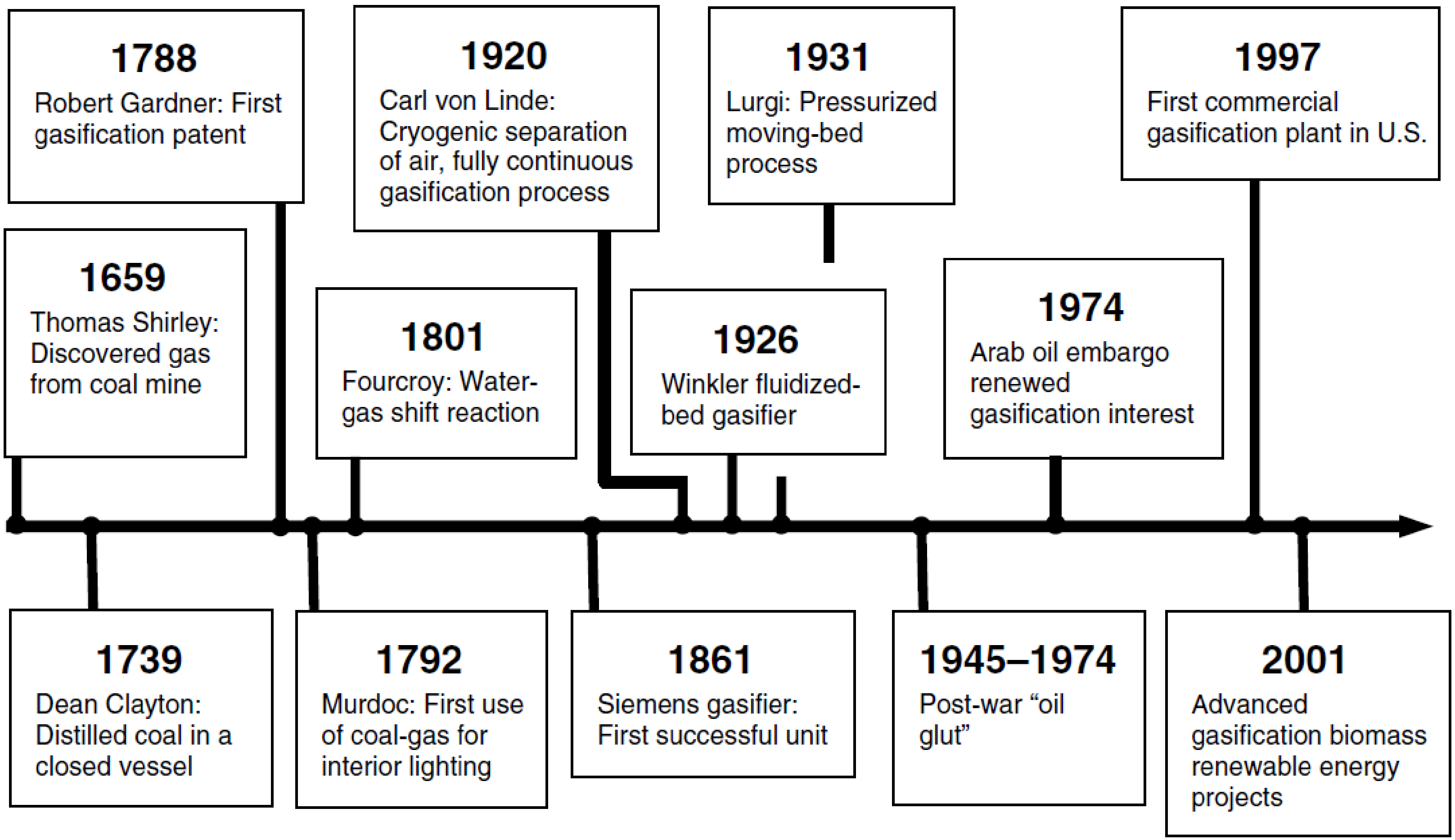
- Grate furnace and fluidized bed technology
- Steam turbines
- Combined heat and power
- Large scale facilities > 100 $MW_{el}$


# Woody Biomass: Pulp + Electricity


Fray Bentos Pulp Mill produces 200 MW el. (10% of Uruguay’s domestic consumption) + 1 Mt/a eucalyptus pulp

# Biomass Gasification

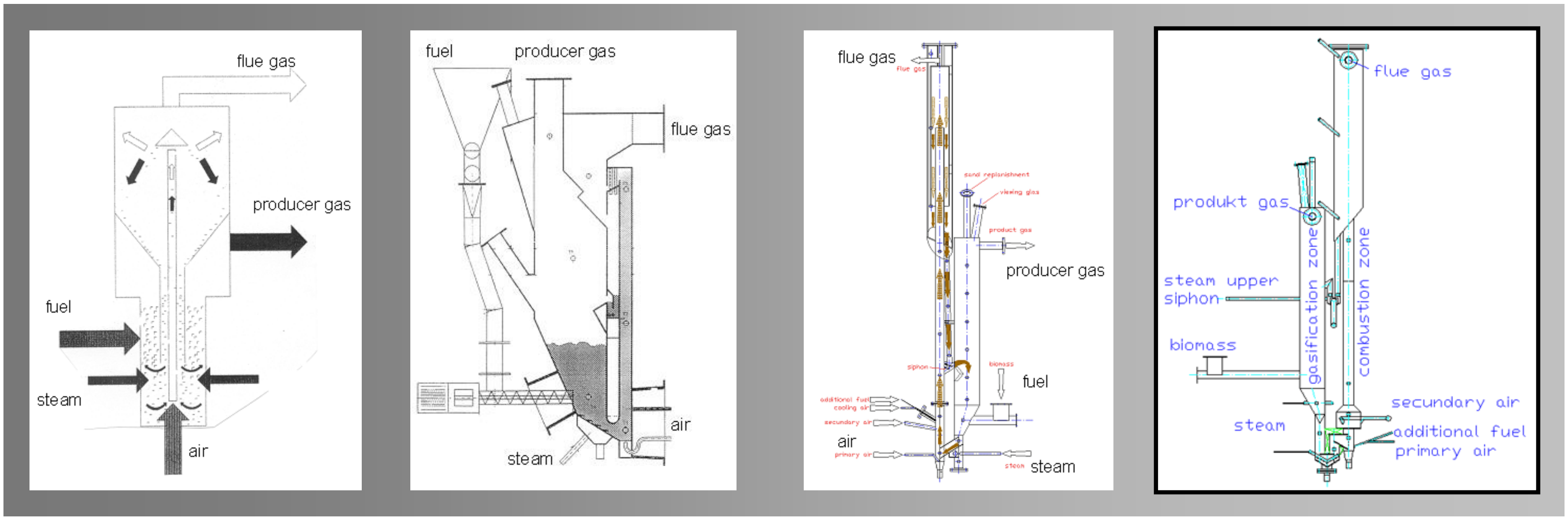
# History of Gasification Technology




Source: P.Basu, Academic Press (2010)

## Development of fluidized bed steam biomass gasification

### Research @ TU Wien – Institute of Chemical Engineering



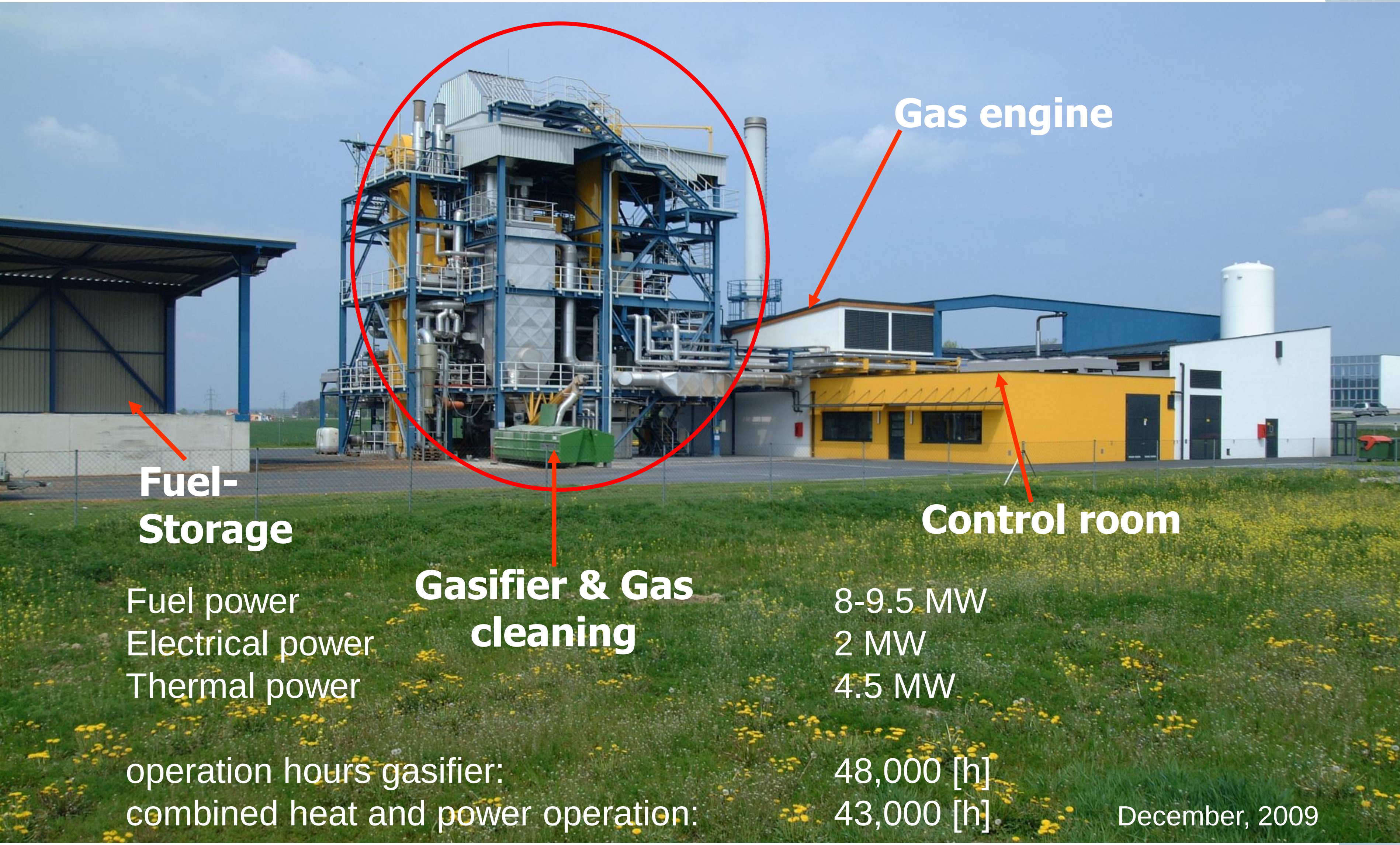

**1993 - 1996**
FICFB gasifier

**1995 - 1999**

**1999 - 2003**

**2004 - now**
DFB gasifier

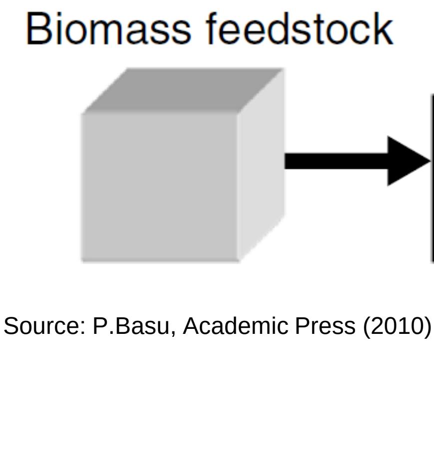
# Biomass CHP Güssing

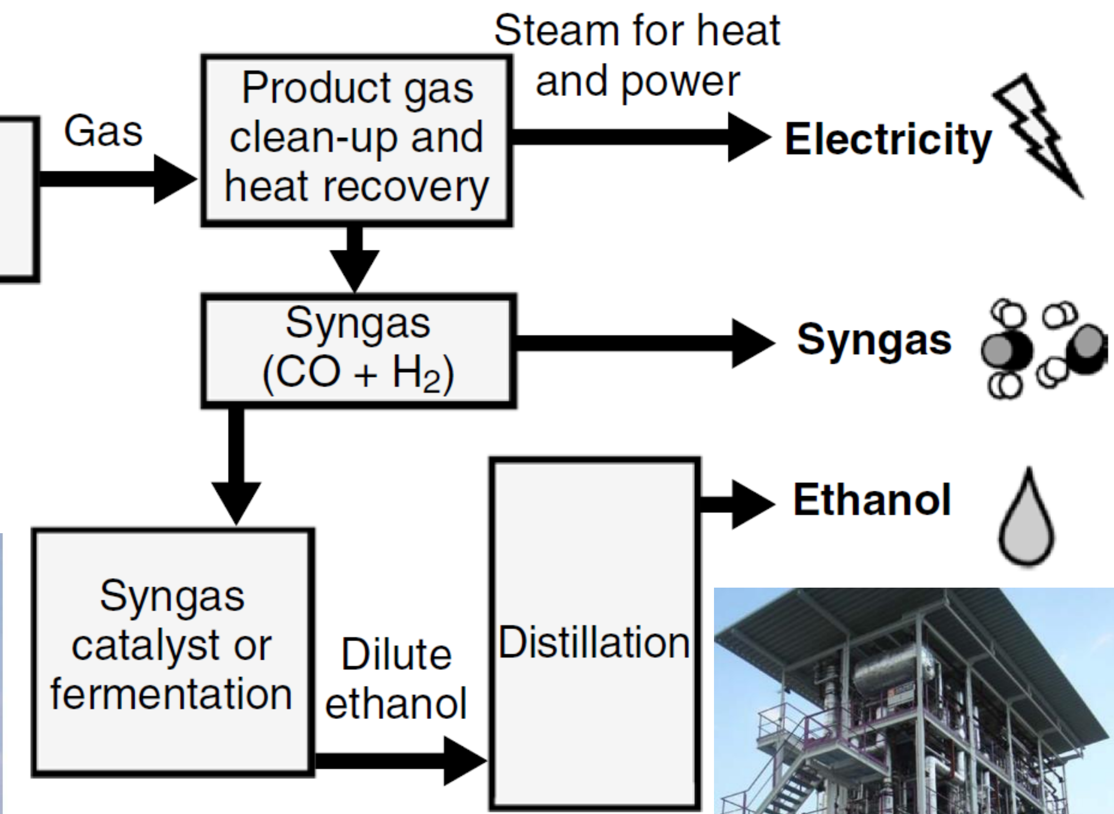



| | |
|---|---|
| Fuel power | 8-9.5 MW |
| Electrical power | 2 MW |
| Thermal power | 4.5 MW |
| operation hours gasifier: | 48,000 [h] |
| combined heat and power operation: | 43,000 [h] |

December, 2009

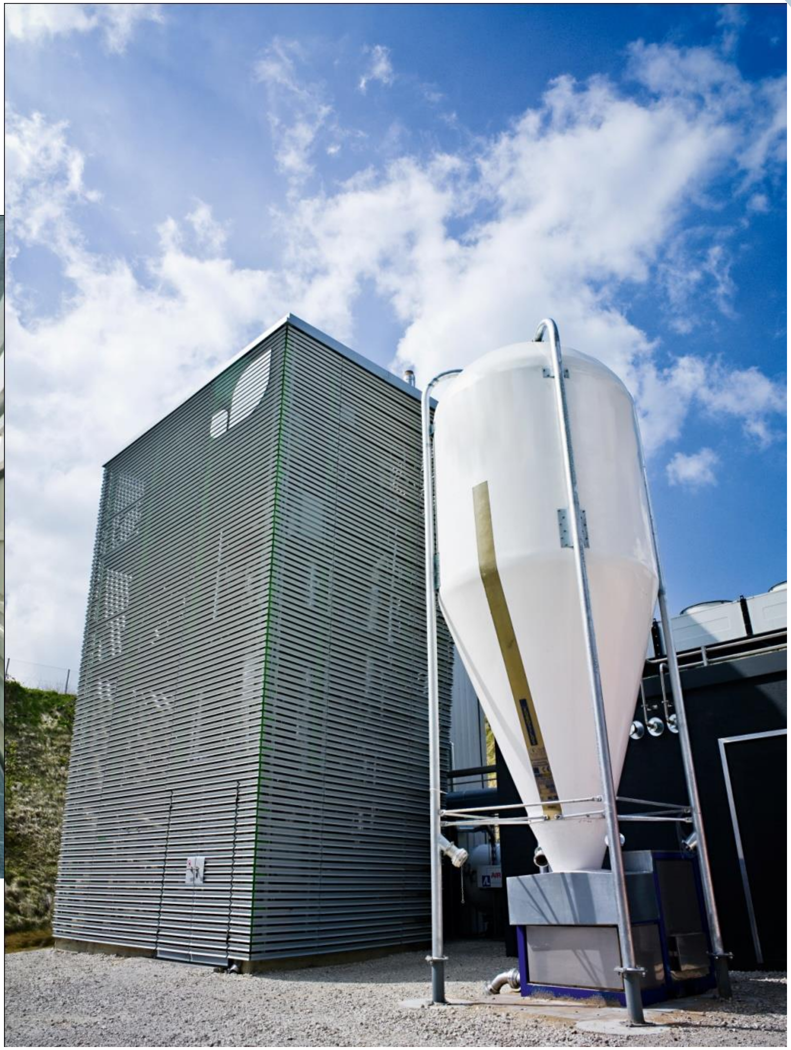
# Biomass Gasification






Source: P.Basu, Academic Press (2010)

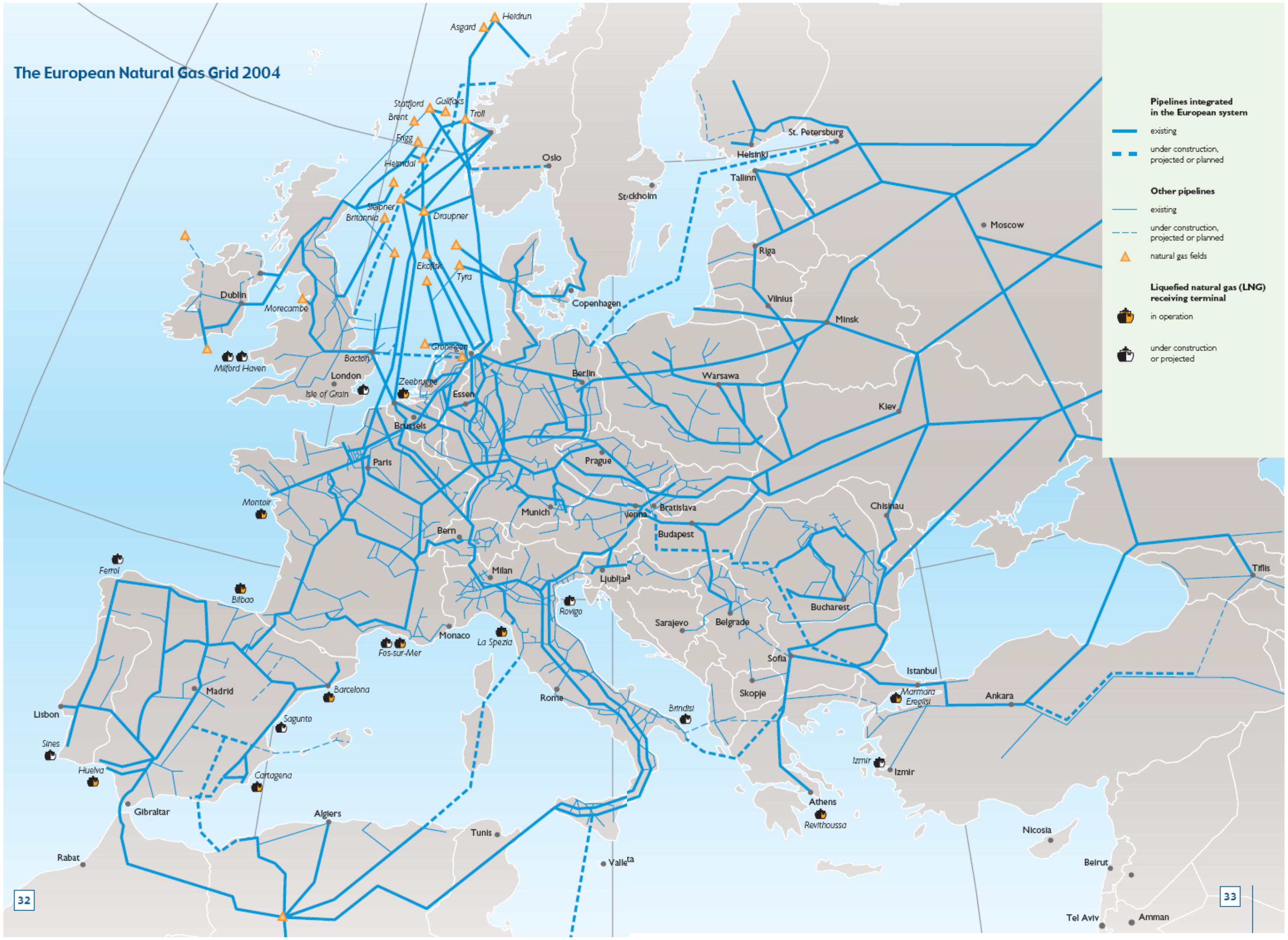

**Additional options via gasification**



Agnion Heatpipe Reformer Technology for small scale application (e.g. 0,5 - 1 $MW_{el}$)

# Biogas Digestion and Grid Injection and Bio-CNG Use

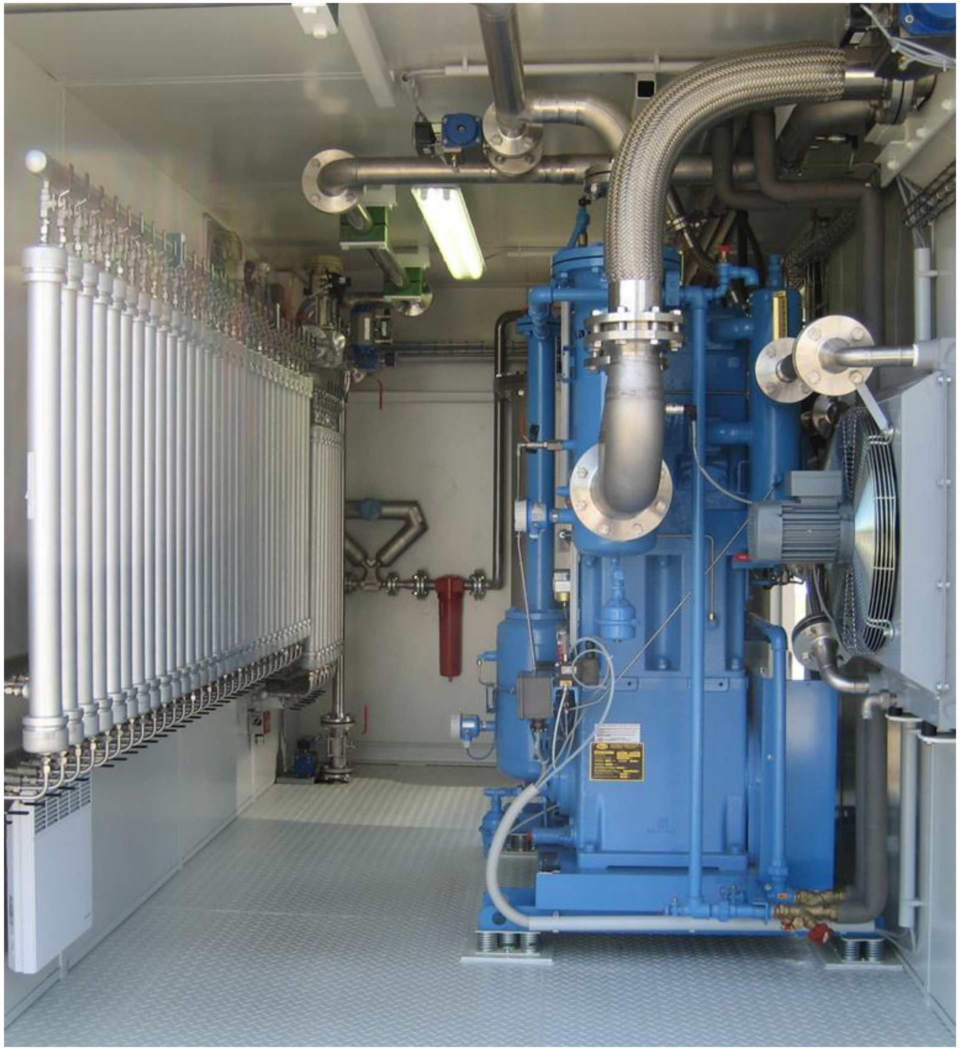
# Natural Gas Grid




## The European Natural Gas Grid

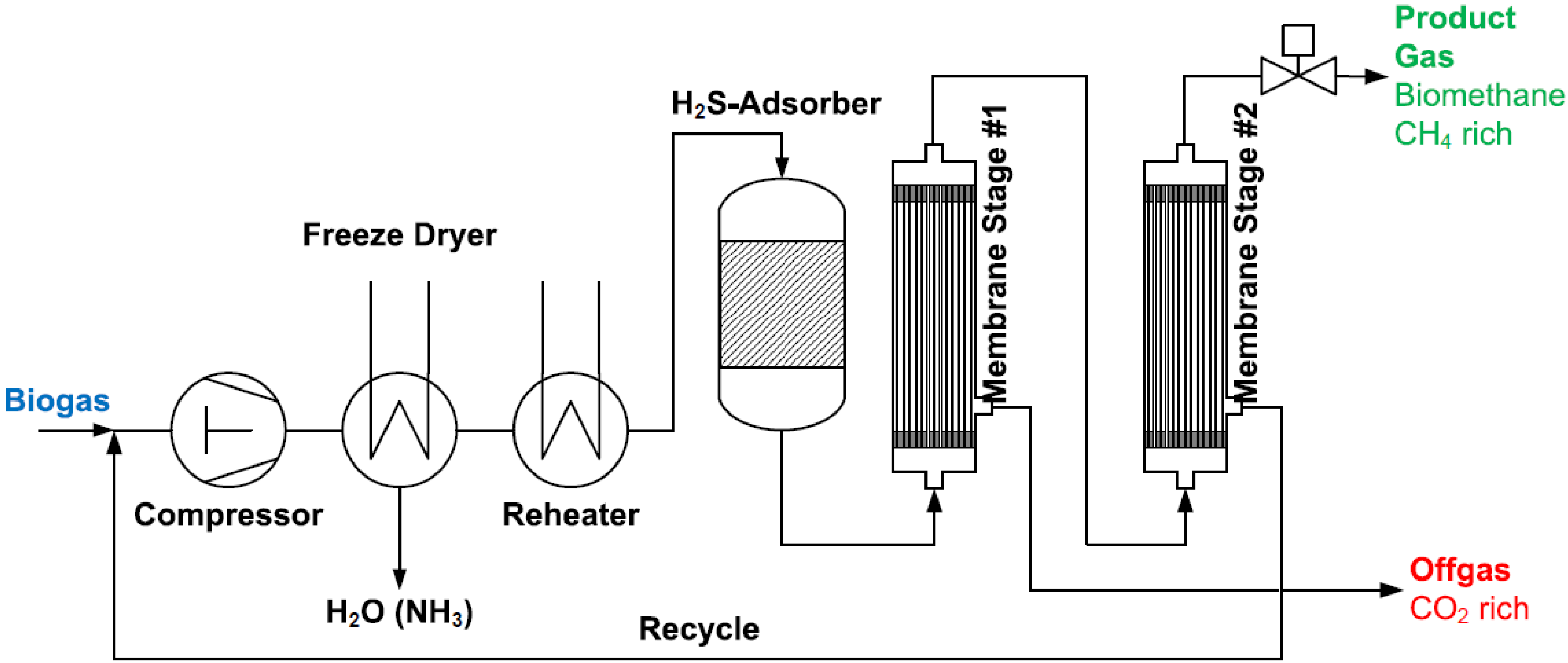
Source: Eurogas (2005)

# Biogas Upgrading in Bruck/Leitha

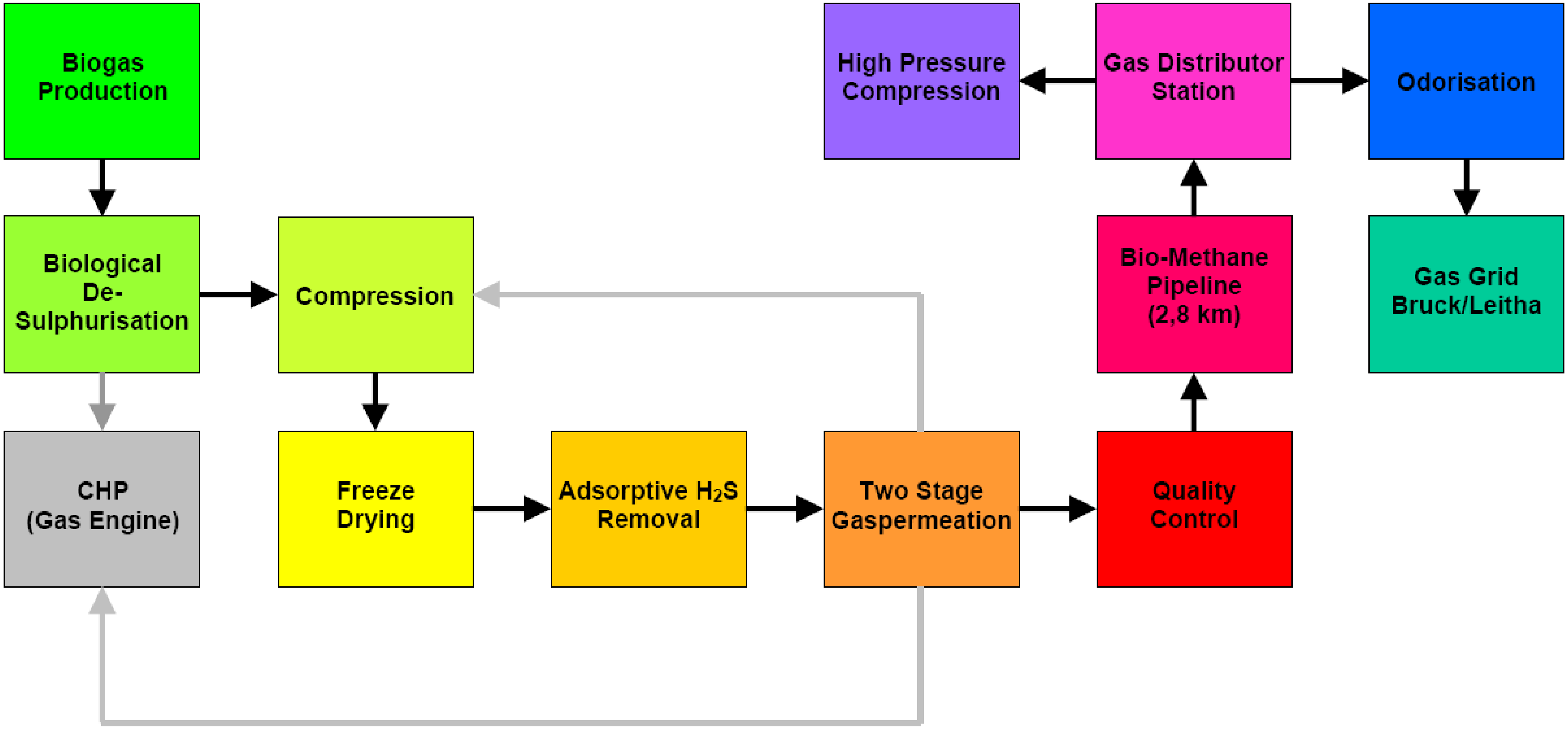



- Axiom – Membrane separation (180 m³/h biogas)

# Process Scheme of a Two-stage Membrane System

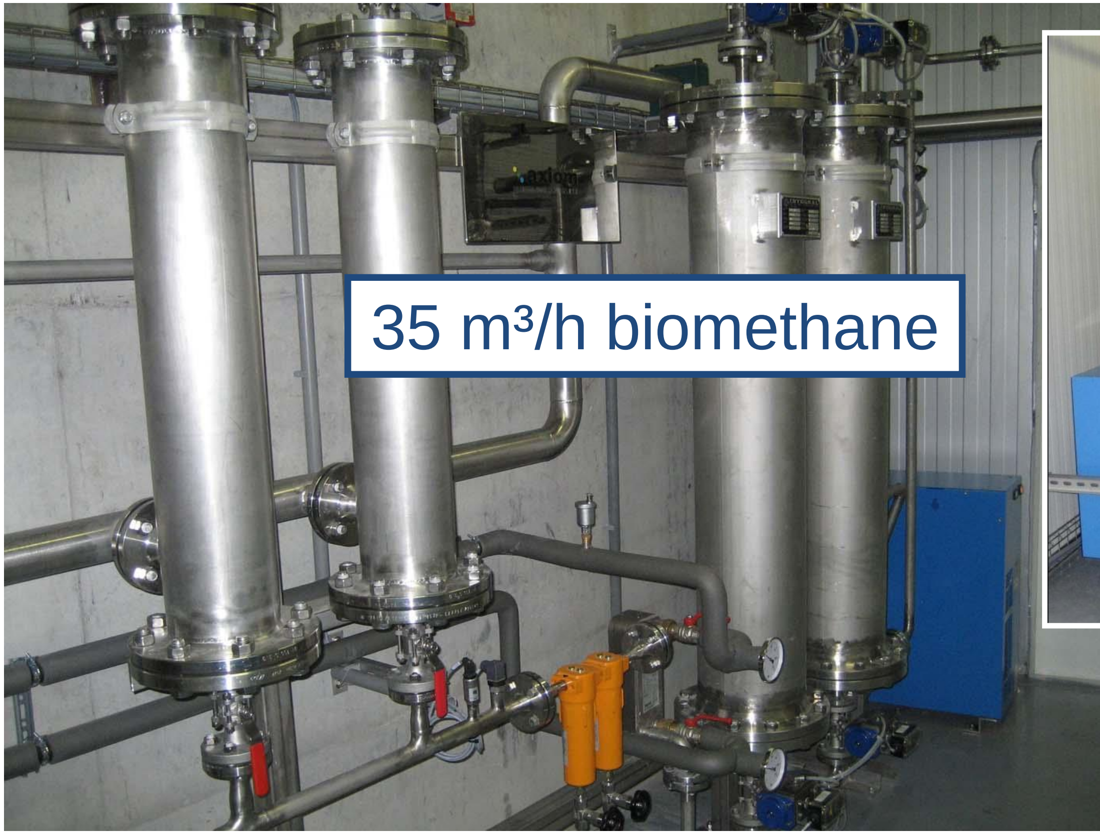


# Process Integration (Two-stage design)




- **Biological desulphurisation prior to membrane treatment**
- **Permeate is recycled to CHP plant – „zero methane“ emission of upgrading system**

# Biomethane Fuel Station using Membrane Technology



35 m³/h biomethane

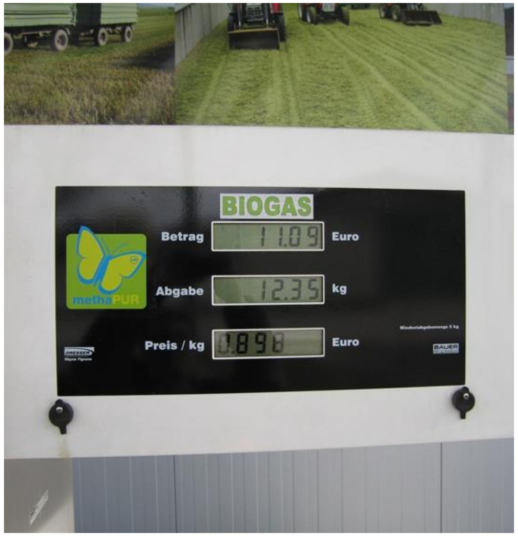
Permeate recycle to CHP plant

Further information: **www.methapur.com**

Biomethane fuel station Margarethen/Moos

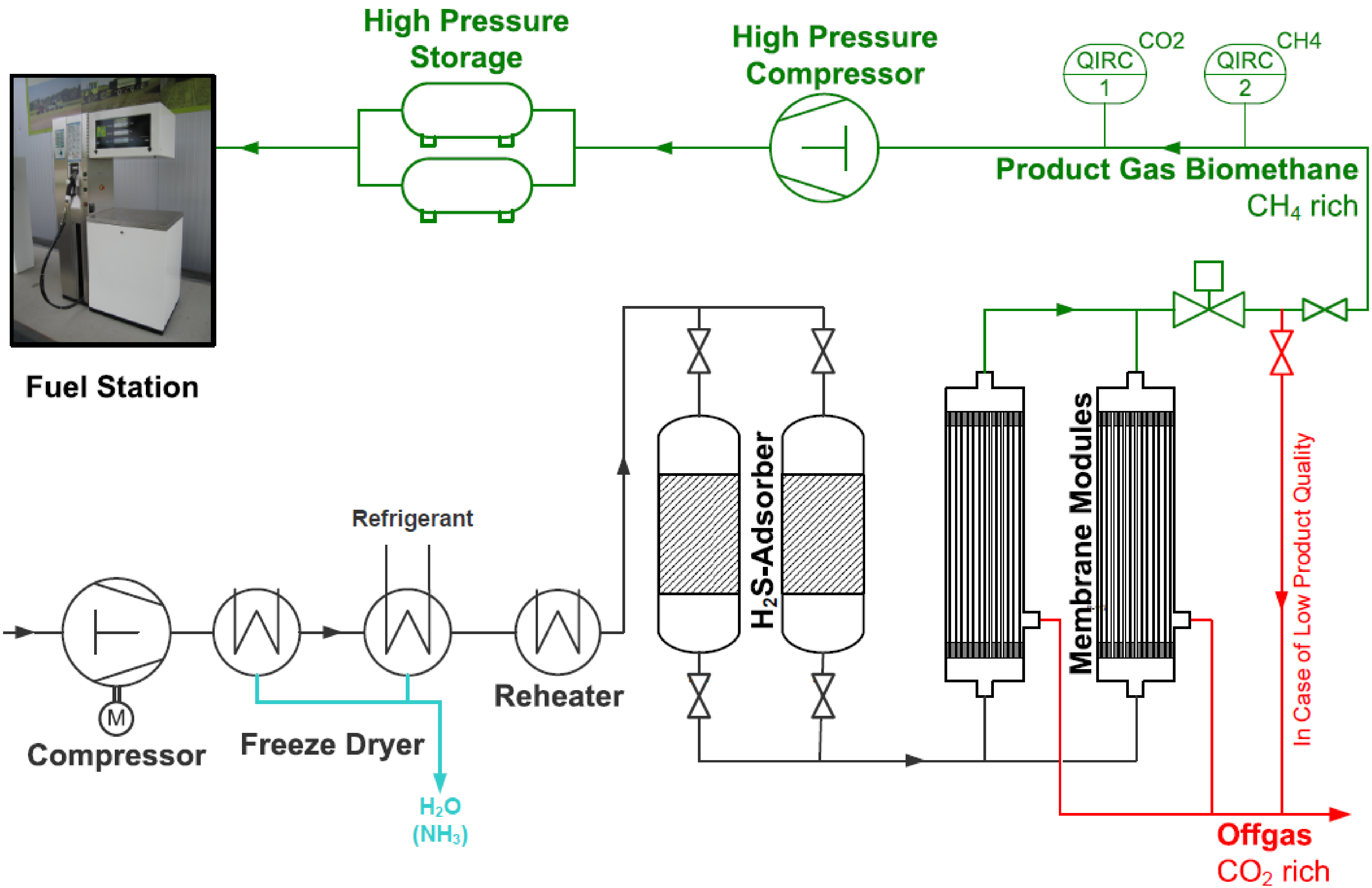
# Bio-CNG with on-site fuel station



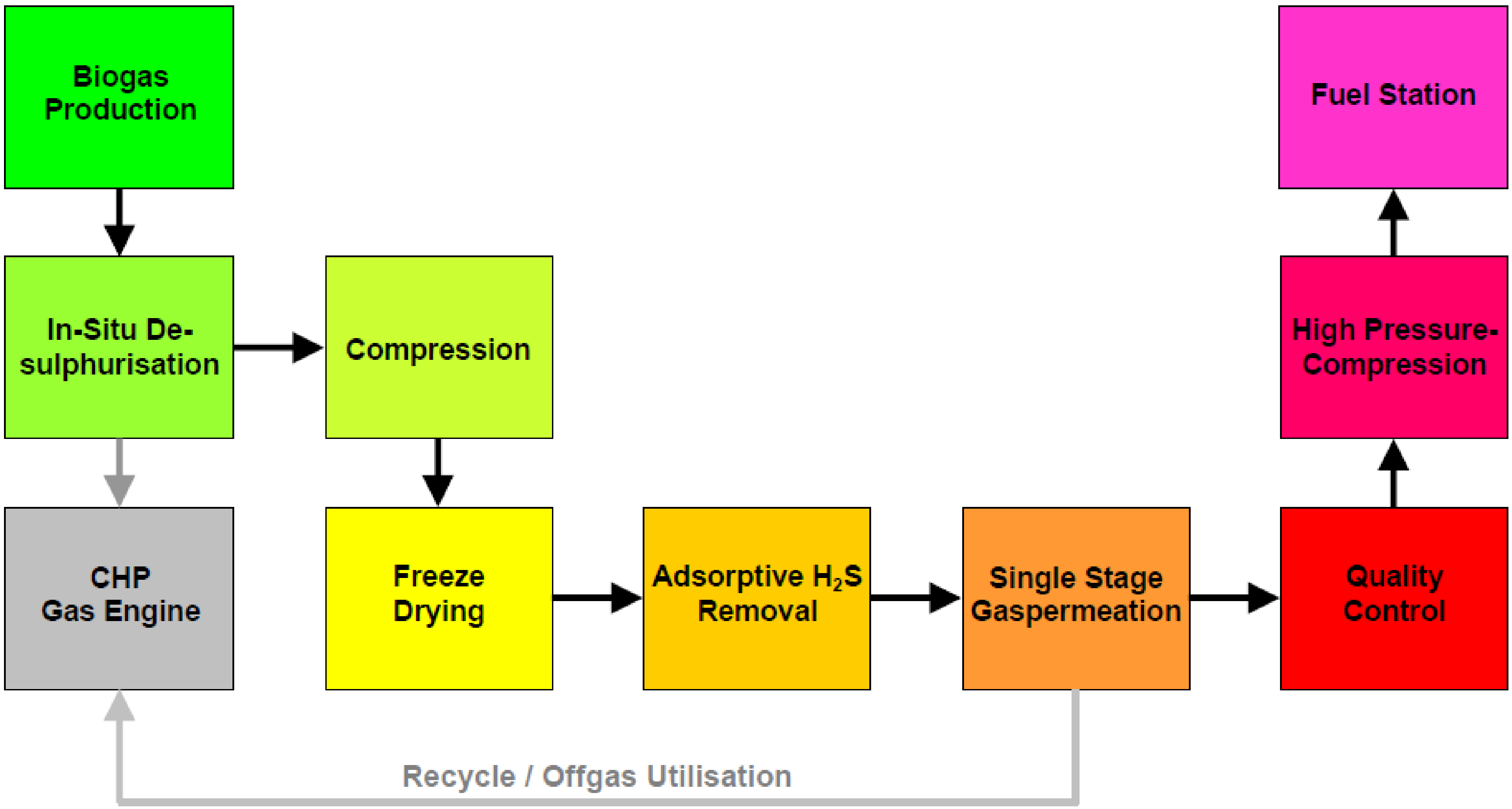



- Capacity: 500 kg/d bio-methane
- Bio-methane as fuel alternative (tractors, harvesting)

# Biomethane Fuel Station: Single Stage Upgrading



# Process Integration (Margarethen am Moos)




- **In-situ desulphurisation (addition of iron salts into the fermentation broth to catch suphides)**
- **Permeate is recycled to CHP plant – „zero methane“ emission of upgrading system**

# Biogas Engerwitzdorf – Grid injection


- Capacity 1,000.000 m³ Bio-methane / a
- BCM (MT-Energie) amine scrubber

# Bio-methane Wiener Neustadt


- Capacity: 220 (300) m³/h biogas
- Axiom – Membrane separation

# Recent Start-up of First AXIOM Plant in Germany

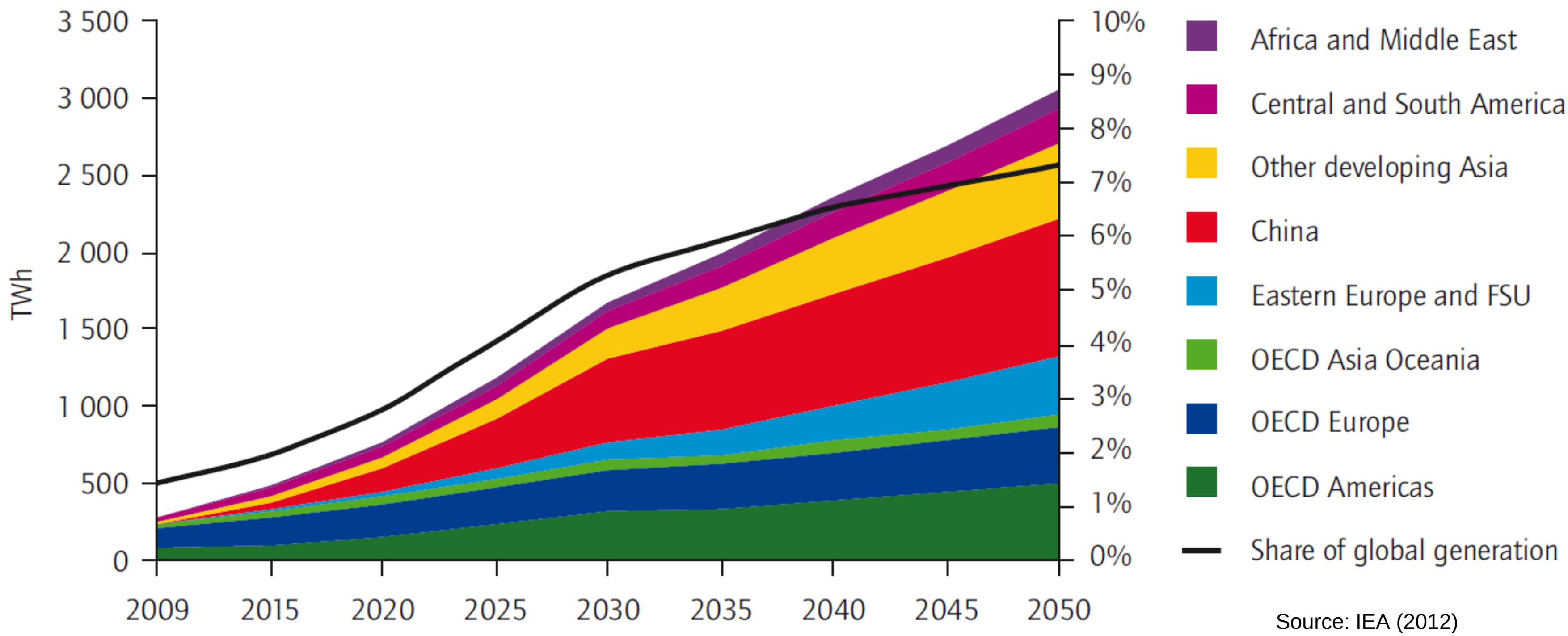

- Capacity 500 m³/h biogas, 300 m³/h biomethane, approx. 8 km pipeline for grid injection and high pressure compression to 60 bar

# What about Scale-up?

## Rightsizing …

# Bigger and BIGGER…

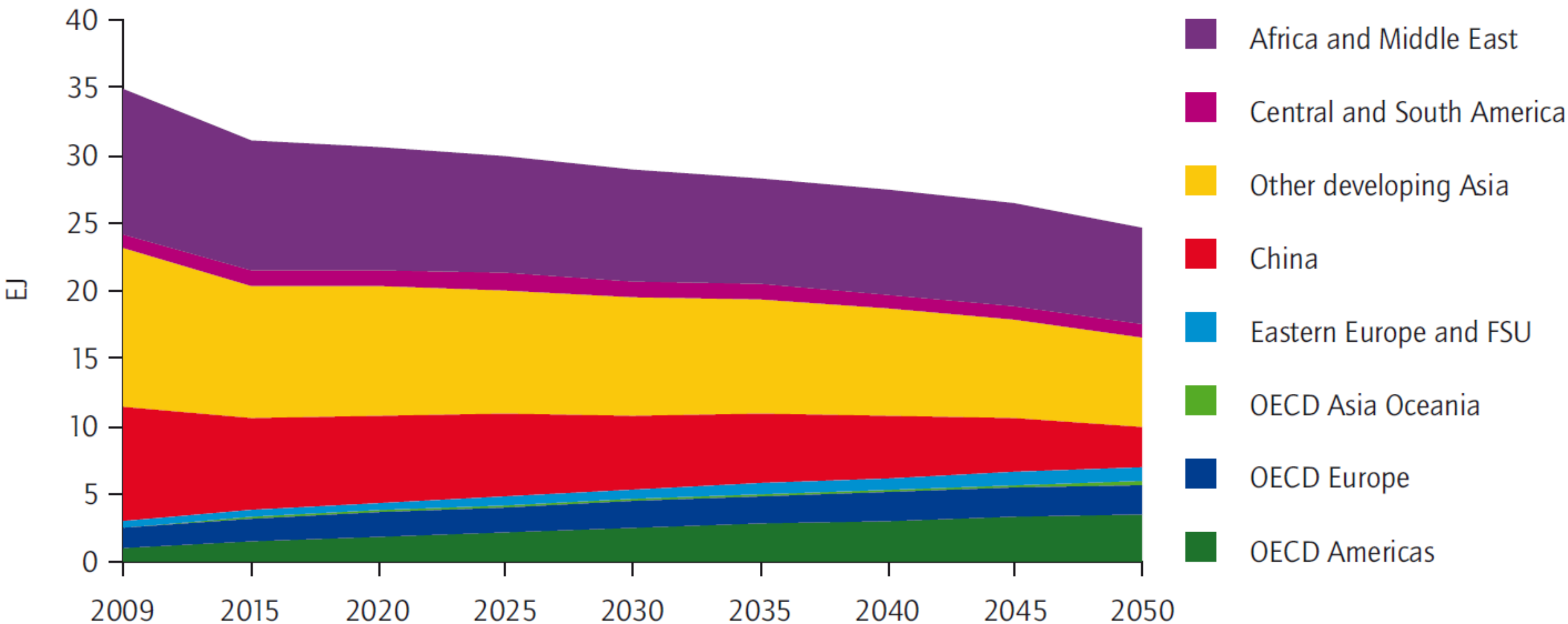
# Electricity from Biomass – IEA Future Scenario




Source: IEA (2012)

In 2050, IEA estimates 2 460 TWh of electricity will be produced from biomass and waste, a fivefold increase on 2010

# Bioenergy for Heating – IEA Future Scenario

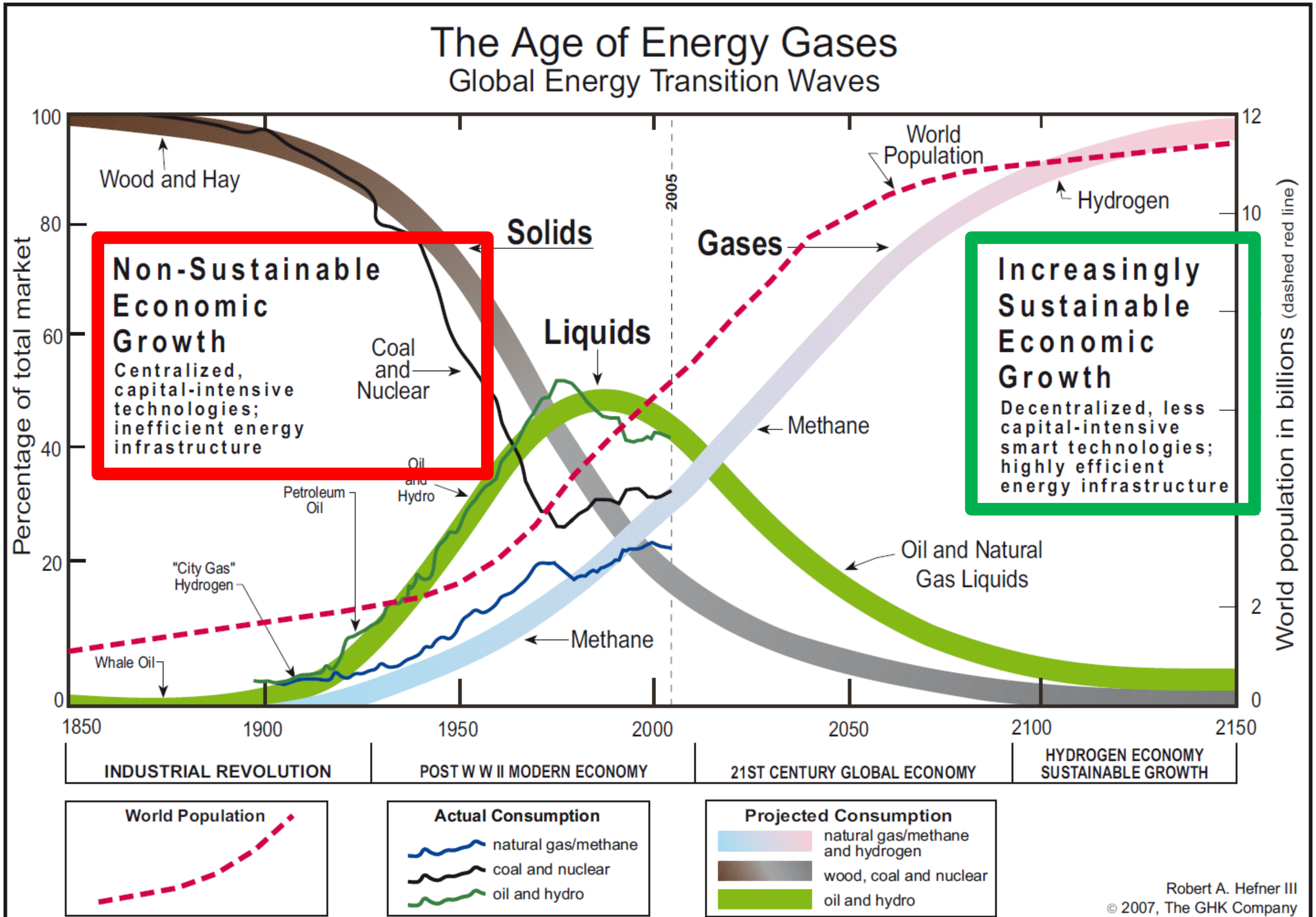



Source: IEA (2012)

Final bioenergy consumption in the buildings sector in different world regions

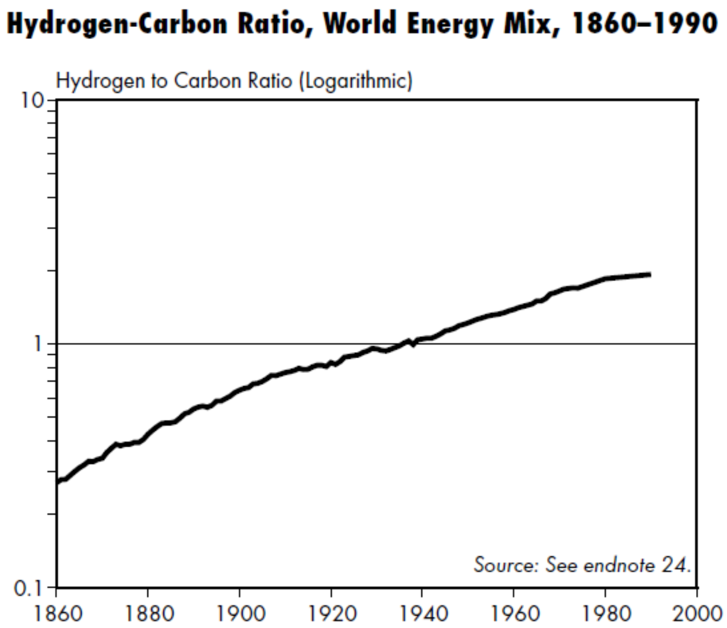
# And the Future?

# The Age of Energy Gases?



# Lessons Learned

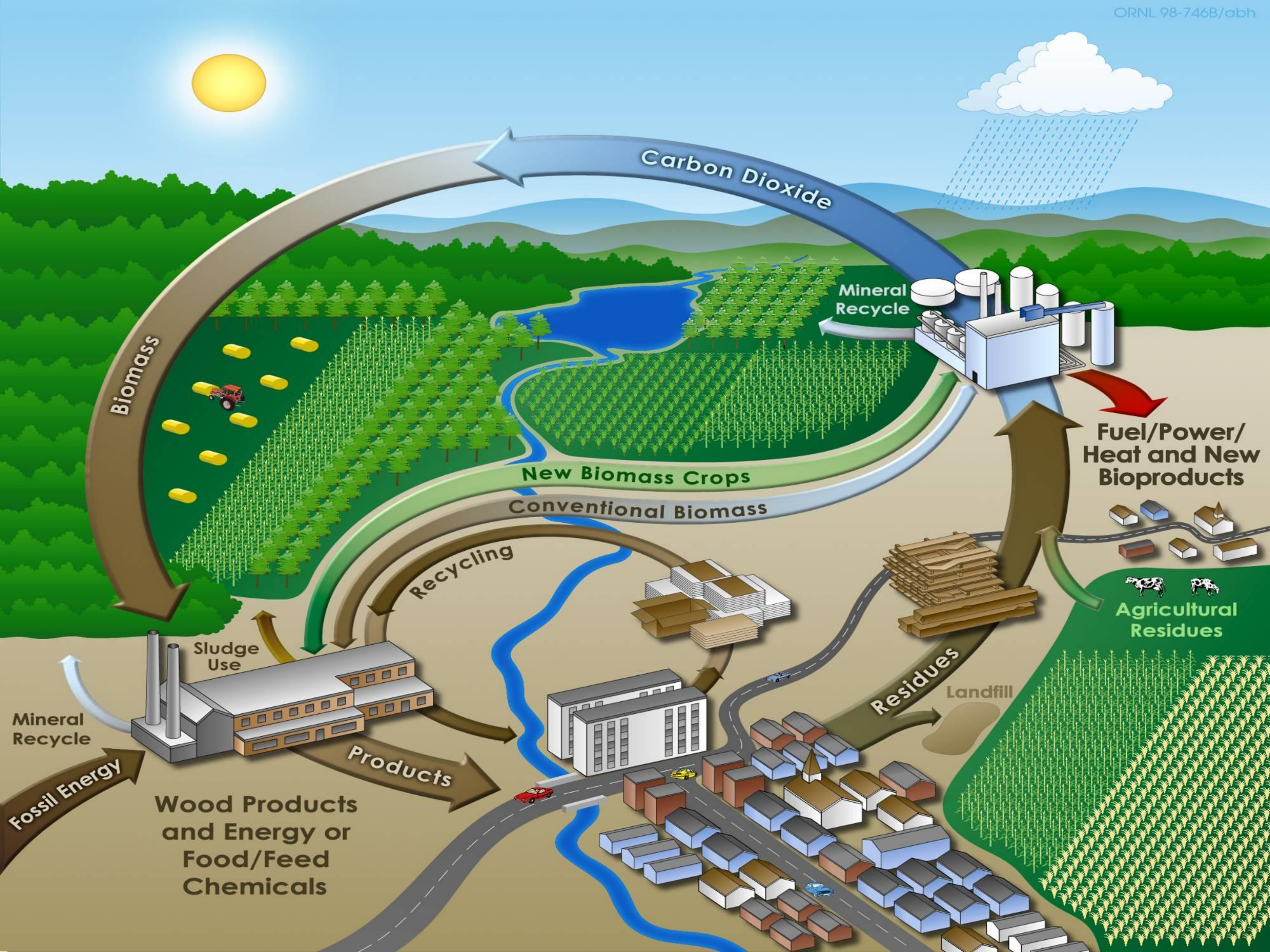
- Biomass to grid is more than power!
- Polygeneration technology options available
- Thermochemical and biochemical routes dependent on biomass composition
- These routes will also contribute to the production of sustainable biofuels
- Electricity from biomass share on global energy production to rise in the next decades



TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

# Thank you for your attention!

Visit us @ www.bio-methaneregions.at



ORNL 98-746B/abh
Carbon Dioxide
Biomass
Mineral Recycle
Fuel/Power/ Heat and New Bioproducts
New Biomass Crops
Conventional Biomass
Recycling
Agricultural Residues
Sludge Use
Landfill
Residues
Mineral Recycle
Products
Fossil Energy
Wood Products and Energy or Food/Feed Chemicals