TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Biomass Utilization & Sustainability of Biofuels

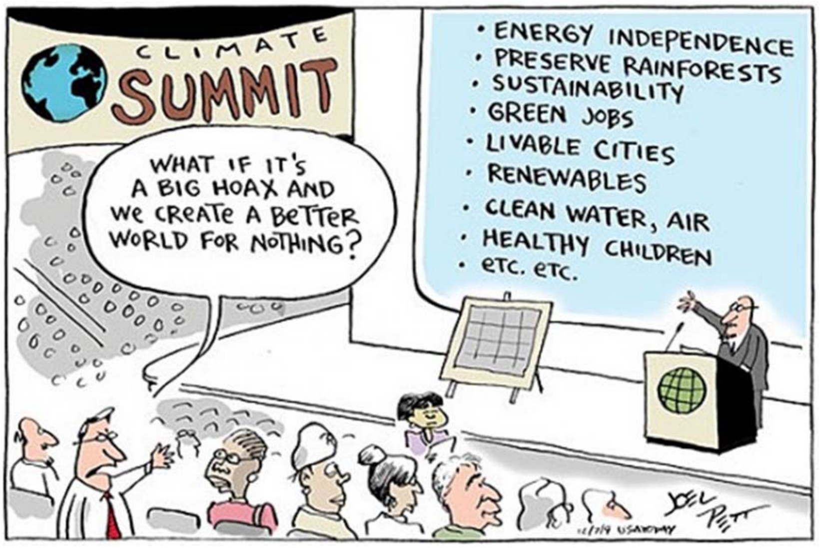
Michael Harasek

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

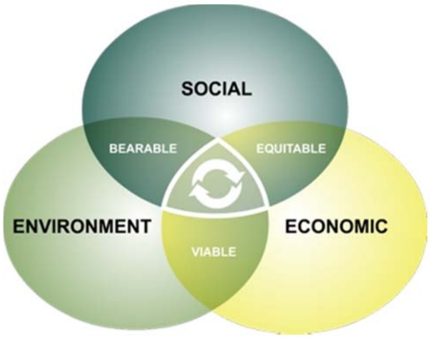
Why should we care about sustainability?

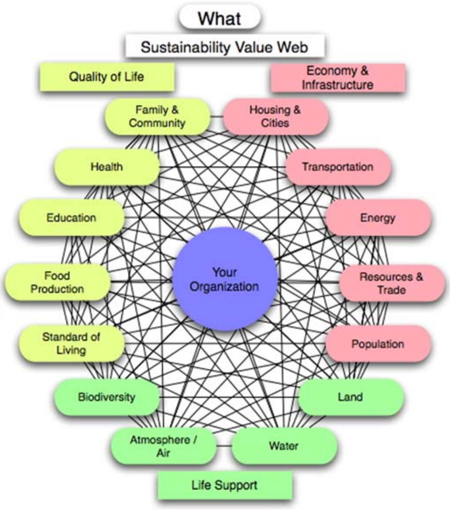


Sustainability Criteria of Biofuels

- 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…





- ✓ 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

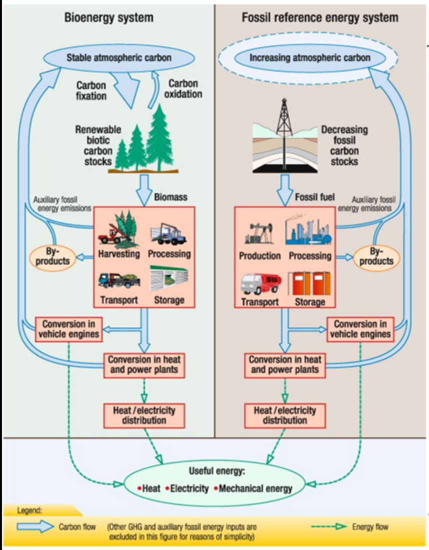
Rules for calculation of GHG savings – Methodology

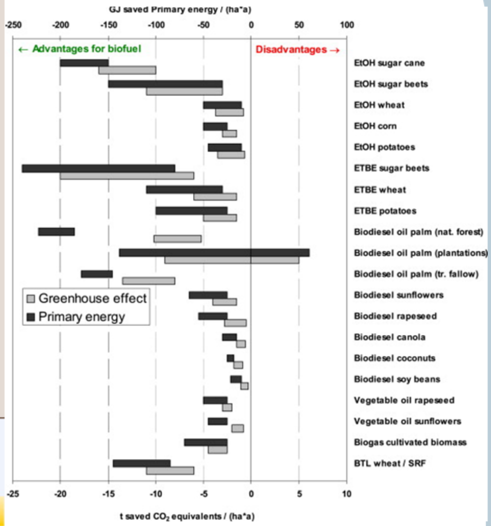
- Includes all process steps (life-cycle) (Annex VII.C)
- End-use efficiency may be taken into account
- Land use change has to be taken into account
- Carbon capture and storage/ replacement

- 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

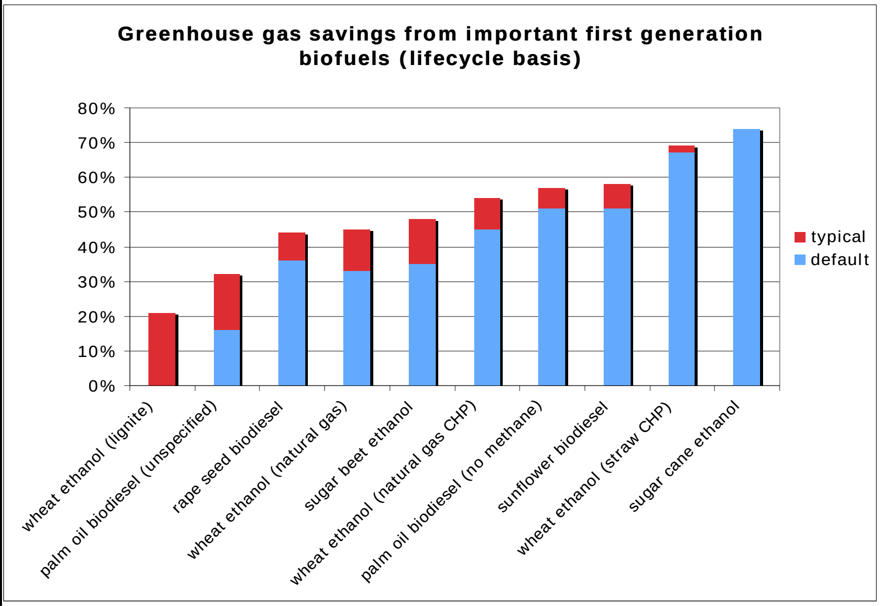




http://www.sciencedirect.com/science/article/pii/S0921344909000500

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

Greenhouse Gas Savings from Biofuels



Trade… or will the fuel be used locally?

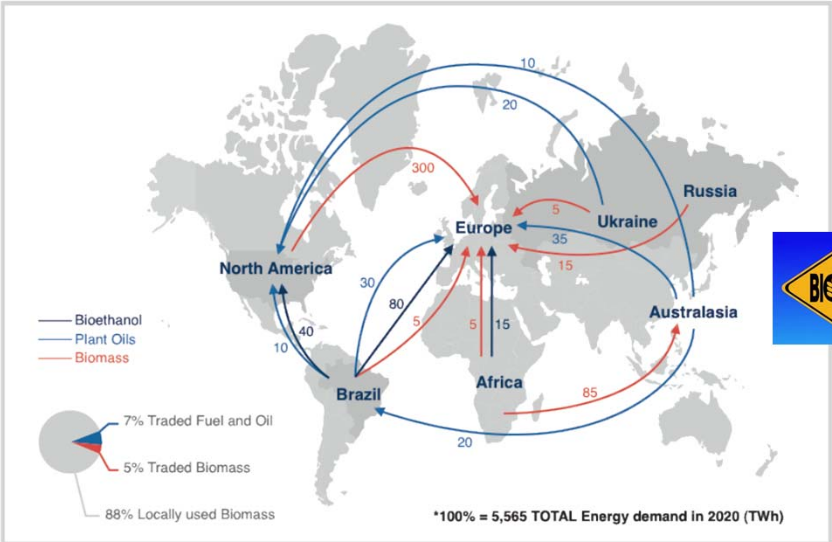


Figure 5: *Expected Biomass Trade Routes.* Values represent final energy demand in 2020.

Biomass Feedstocks

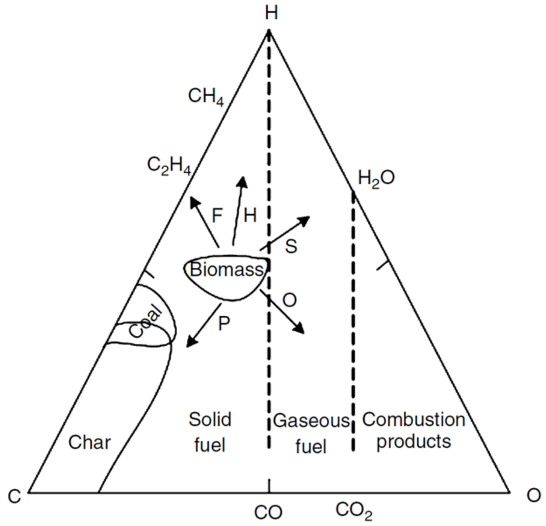
Biomass feedstocks

	Wastes	Processing residues	Locally collected feedstocks	Internationally traded feedstocks
	■ Organic waste (MSW) ■ Sewage sludge ■ Manure/dung	■ Timber residues ■ Black liquor ■ Bagasse ■ Rice husks ■ Food processing wastes	■ Agricultural residues (*e.g.* straw) ■ Forestry residues ■ Roundwood and thinnings ■ Energy crops	■ Roundwood ■ Wood chips ■ Biomass pellets (wood, torrefied) ■ Biomethane ■ Pyrolysis oil
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)

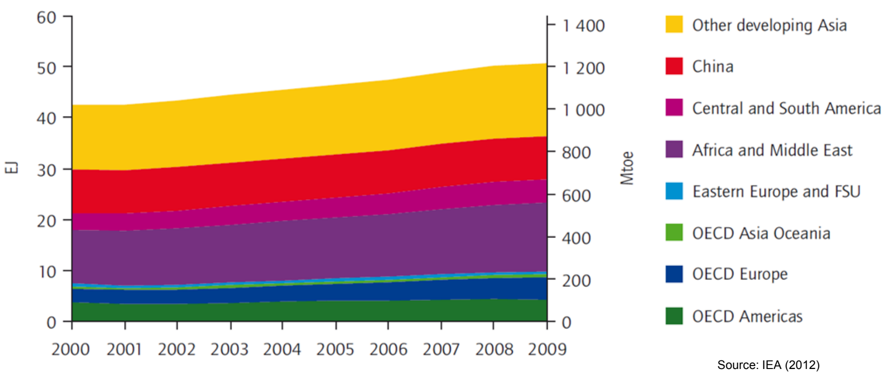
Biomass Composition and Utilization



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

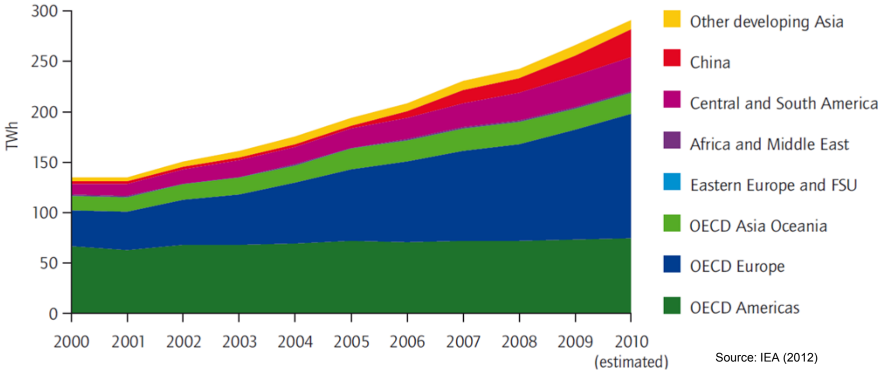
Composition triangle C/H/O (mol/mol)

Global Primary Bioenergy Supply



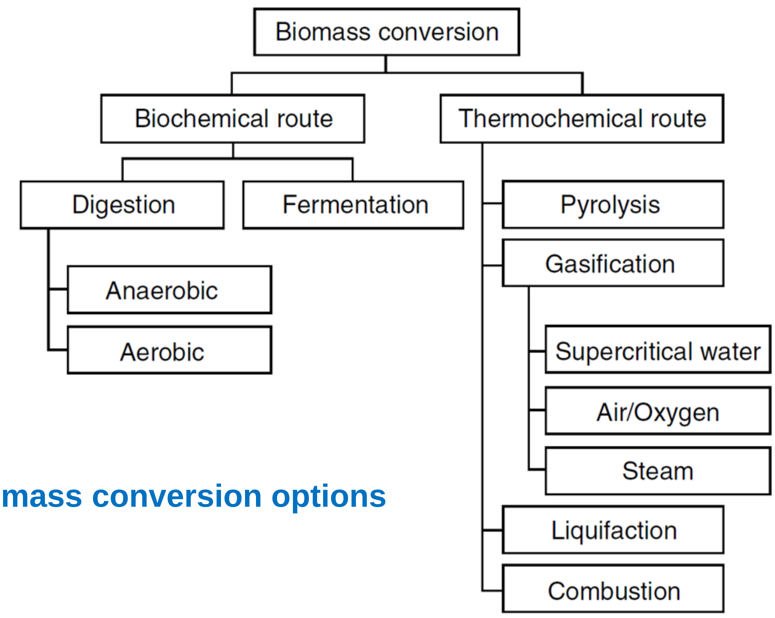
Global primary bioenergy supply 2000-2009

Electricity from Biomass – Global Perspective



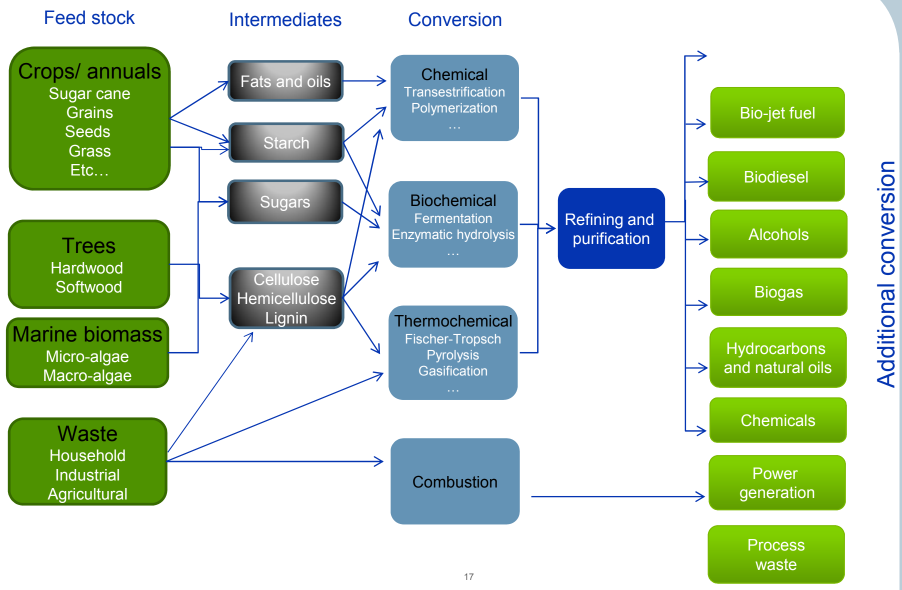
Global bioenergy electricity generation 2000-2010

Biomass Conversion



Biomass conversion options

Biofuels…



Biomass Utilization Options

	Basic and applied R&D	Demonstration	Early commercial	Commercial
Biomass pretreatment	Hydrothermal treatment	Torrefaction	Pyrolysis	Pelletisation/ briquetting
Anaerobic digestion	Microbial fuel cells		2-stage digestion Biogas upgrading	1-stage digestion Landfill gas Sewage gas
Biomass for heating			Small scale gasification	Combustion in boilers and stoves
Biomass for power generation				
Combustion		Stirling engine	Combustion with ORC	Combustion and steam cycle
Co-firing		Indirect co-firing	Parallel co-firing	Direct co-firing
Gasification	Gasification with FC	BICGT BIGCC	Gasification with engine	Gasification with steam cycle

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

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}

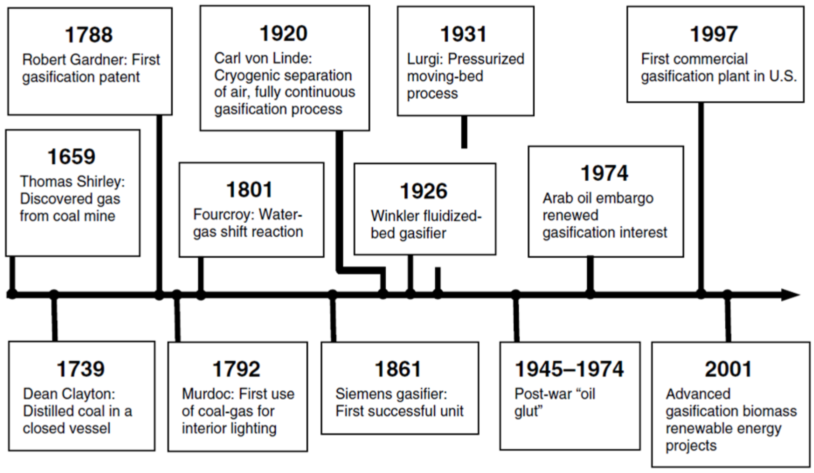

Woody Biomass: Pulp + Electricity

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

Biomass Gasification

Biomass Gasification

History of Gasification Technology

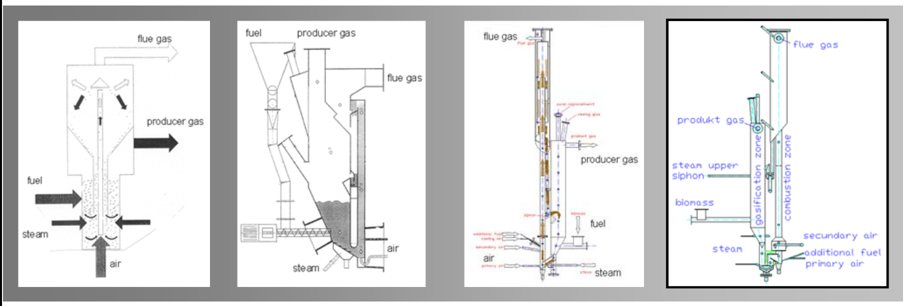


Source: P.Basu, Academic Press (2010)

Fluidized Bed Steam Gasification - Historical Review

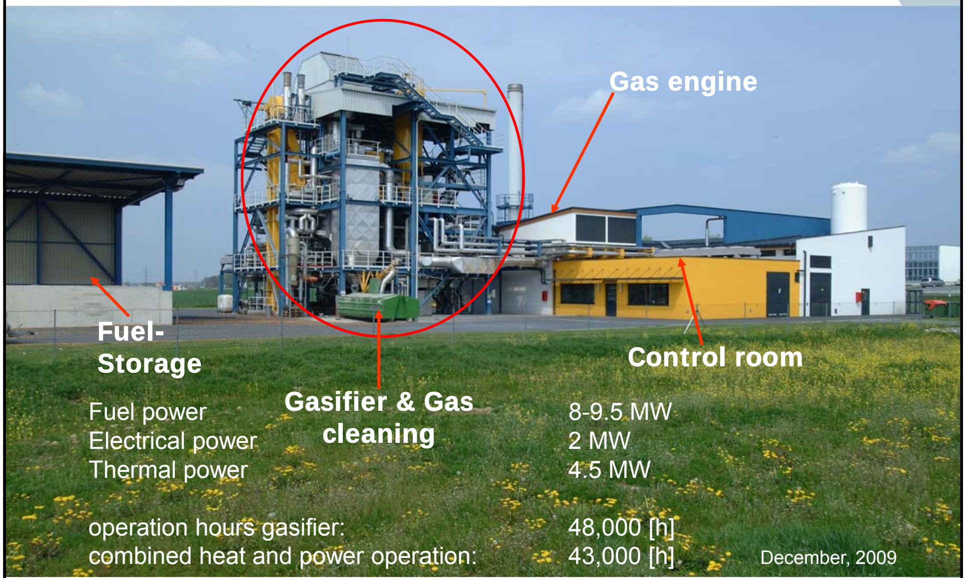
Development of fluidized bed steam biomass gasification

Research @ TU Wien – Institute of Chemical Engineering

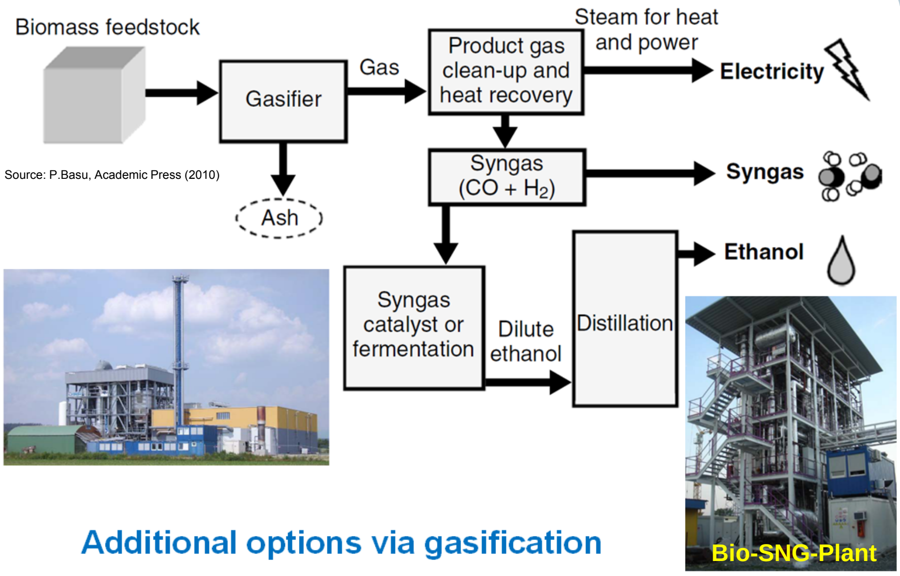


1993 - 1996 FICFB gasifier	1995 - 1999	1999 - 2003	2004 - now DFB gasifier

Biomass CHP Güssing



Biomass Gasification



Source: P.Basu, Academic Press (2010)

Additional options via gasification

Biomass Gasification

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

Biogas Digestion

Biogas Digestion and Grid Injection and Bio-CNG Use

Natural Gas Grid

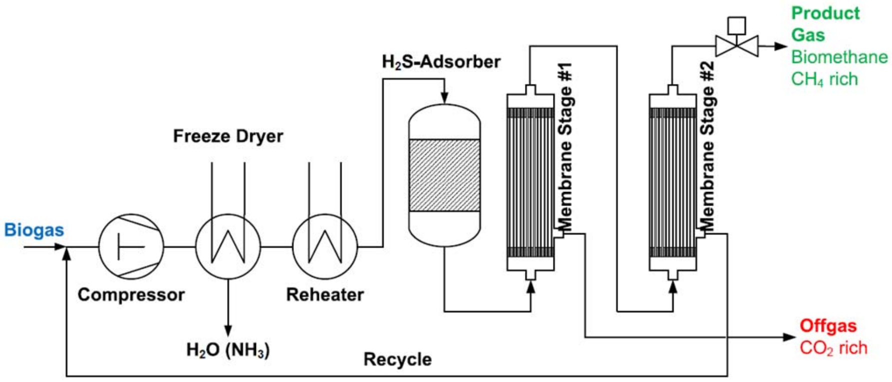
The European Natural Gas Grid

Source: Eurogas (2005)

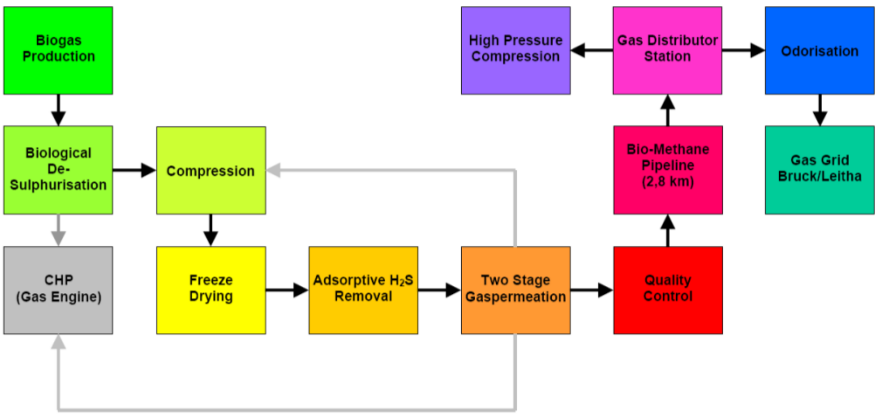
Biogas Upgrading in Bruck/Leitha

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

Process Scheme of a Two-stage Membrane System

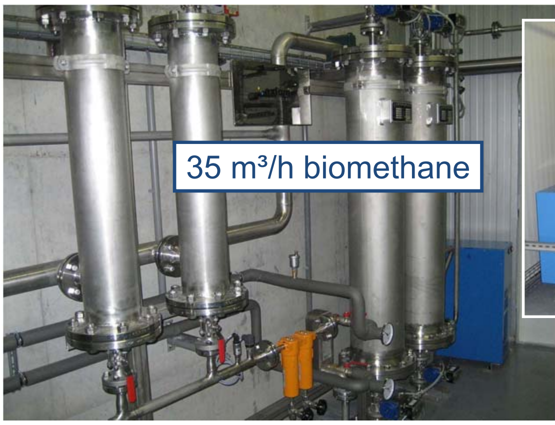


Process Integration (Two-stage design)



- **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

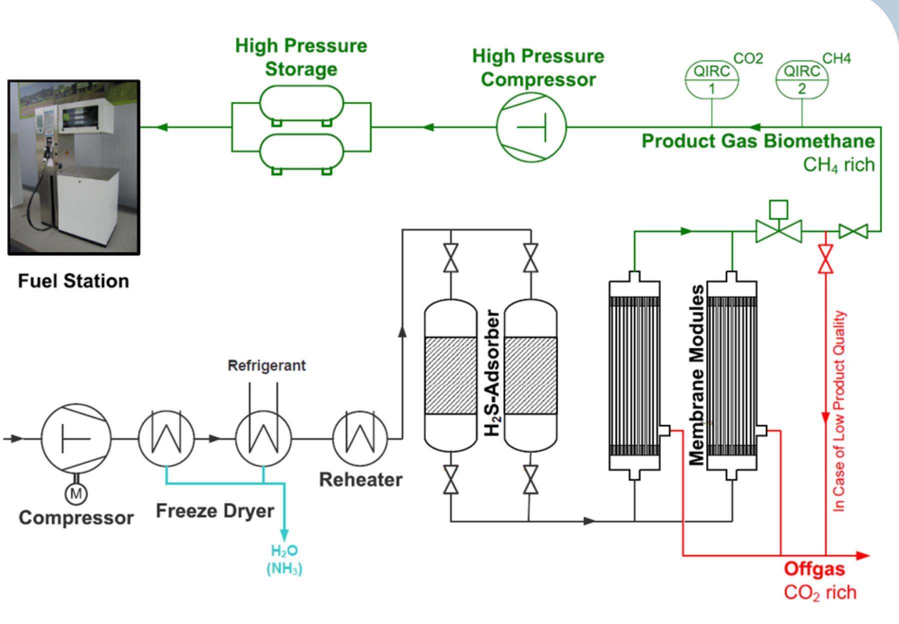
Further information: **www.methapur.com**

Biomethane fuel station Margarethen/Moos

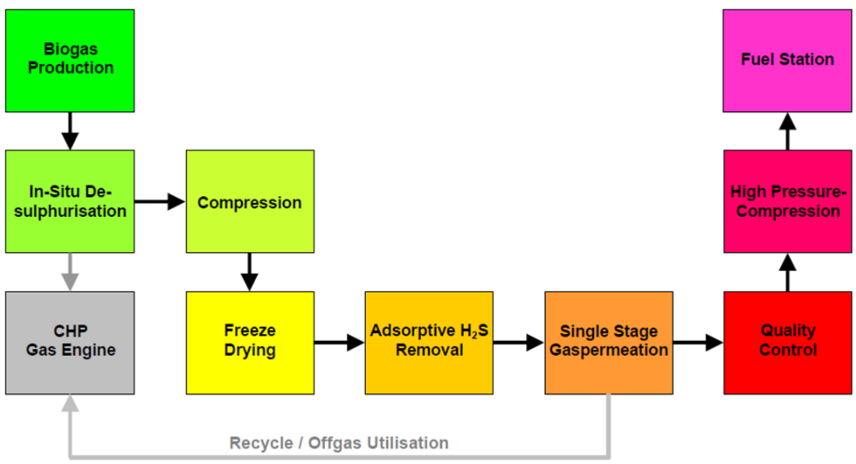
Bio-CNG with on-site fuel station

- 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

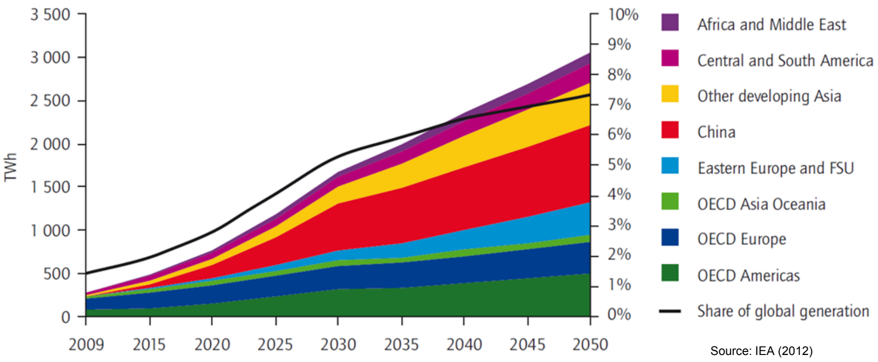
- Capacity 500 m³/h biogas, 300 m³/h biomethane, approx. 8 km pipeline for grid injection and high pressure compression to 60 bar

What about Scale-up?

Rightsizing …

Bigger and BIGGER…

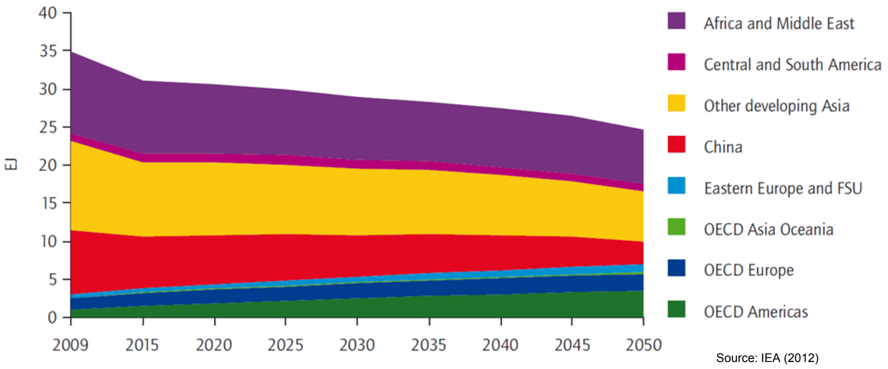
Electricity from Biomass – IEA Future Scenario



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



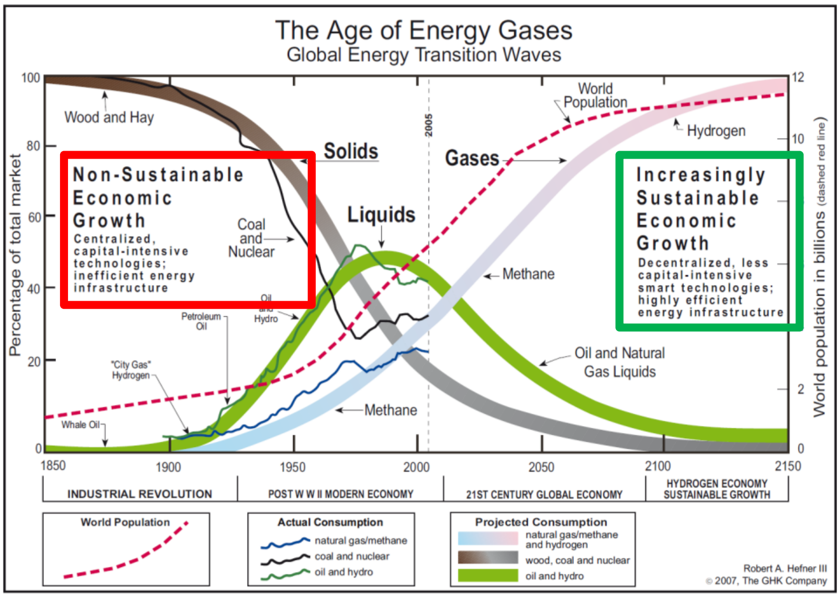
Source: IEA (2012)

Final bioenergy consumption in the buildings sector in different world regions

And the Future?

And the Future?

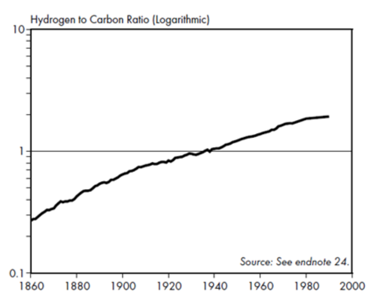
The Age of Energy Gases?



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

Hydrogen-Carbon Ratio, World Energy Mix, 1860–1990



TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Thank you for your attention!

Visit us @ www.bio-methaneregions.at