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Energy research Centre of the Netherlands

Biomass with CCS: achieving negative emissions

Michiel C. Carbo

IEA-CERT CCS workshop, Sydney, 20 February 2012

ECN
Energy research Centre of the Netherlands

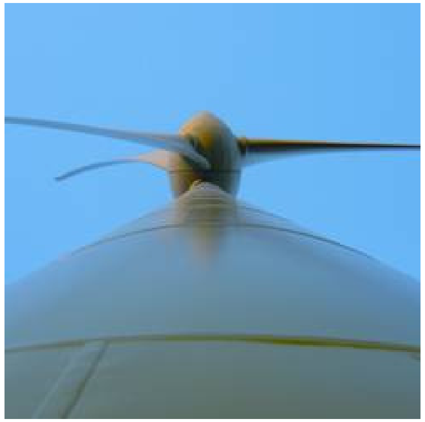
ECN mission:
With and for the market,
we develop knowledge and
technology that enable a transition
to a sustainable energy system

- 500 FTE
- 600 publications & reports/y
- 140 M€ turnover/y (2010)
- Locations: Petten, Amsterdam, Eindhoven, Brussels, Beijing
- Integrated Bio-CCS R&D programme

ECN R&D units

Biomass &
Energy Efficiency

Solar Energy



Wind Energy

Policy Studies

Biomass co-firing R&D: Torrefaction

Woody biomass

Agricultural residues

Mixed waste

Tenacious and fibrous
10 - 17 MJ/kg (LHV, ar)
Hydrophilic
Vulnerable to biodegradation
Heterogeneous

Torrefaction and pulverisation

Friable and less fibrous
19 - 22 MJ/kg (LHV, ar)
Hydrophobic
Preserved
Homogeneous

Fuel powder

Pelletisation

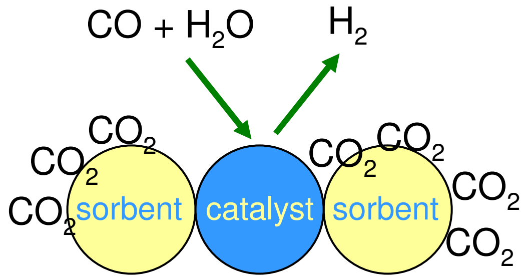
Fuel pellets

Bulk density 650-750 kg/m^3
Bulk energy density 13-17 GJ/m^3

Improved fuel properties:

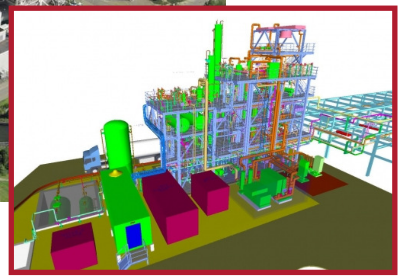
- Transport, handling, storage
- Milling, feeding
- Gasification, combustion
- Broad feedstock range
- Commodity fuel

Pre-combustion CCS R&D



Sorption-enhanced water-gas shift

SEWGS



Buggenum IGCC CO_2 capture pilot

Policy Studies Biofuels & CCS R&D

What happened in Barendrecht?

Case study on the planned onshore carbon dioxide storage in Barendrecht, the Netherlands

C.F.J. Feenstra, T. Mikunda, S. Brunsting

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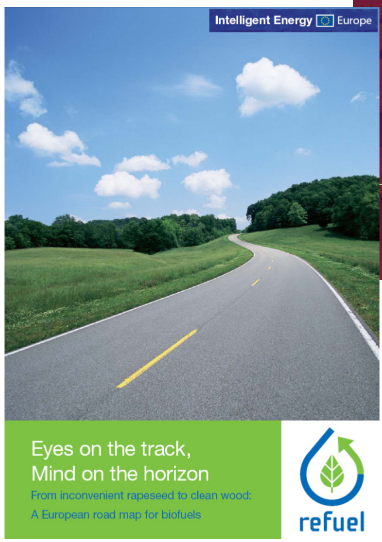
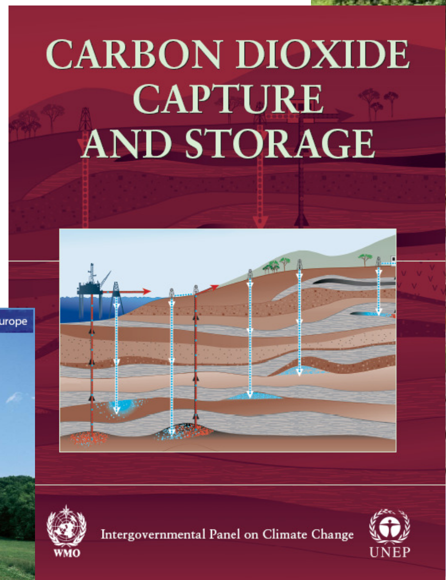
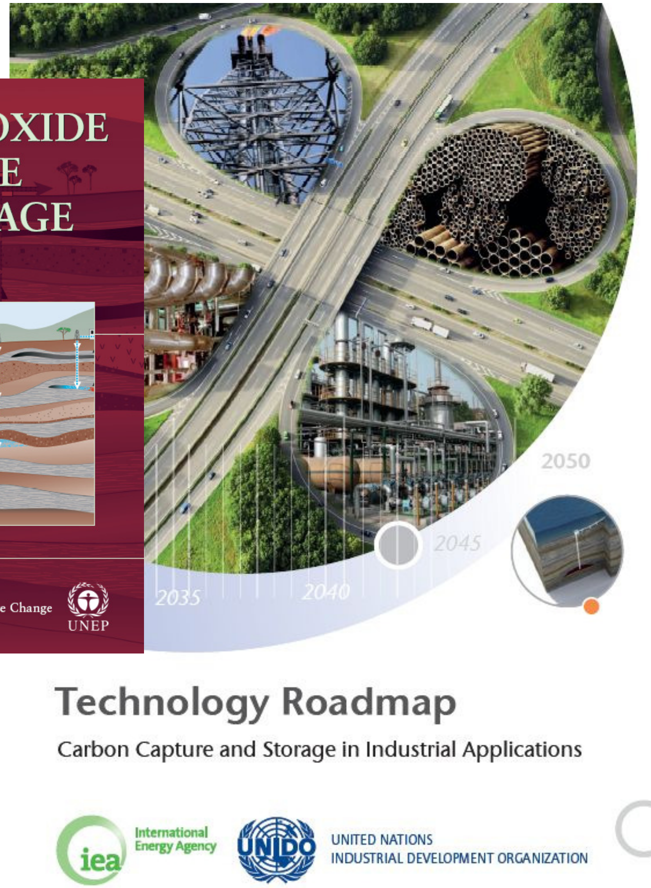


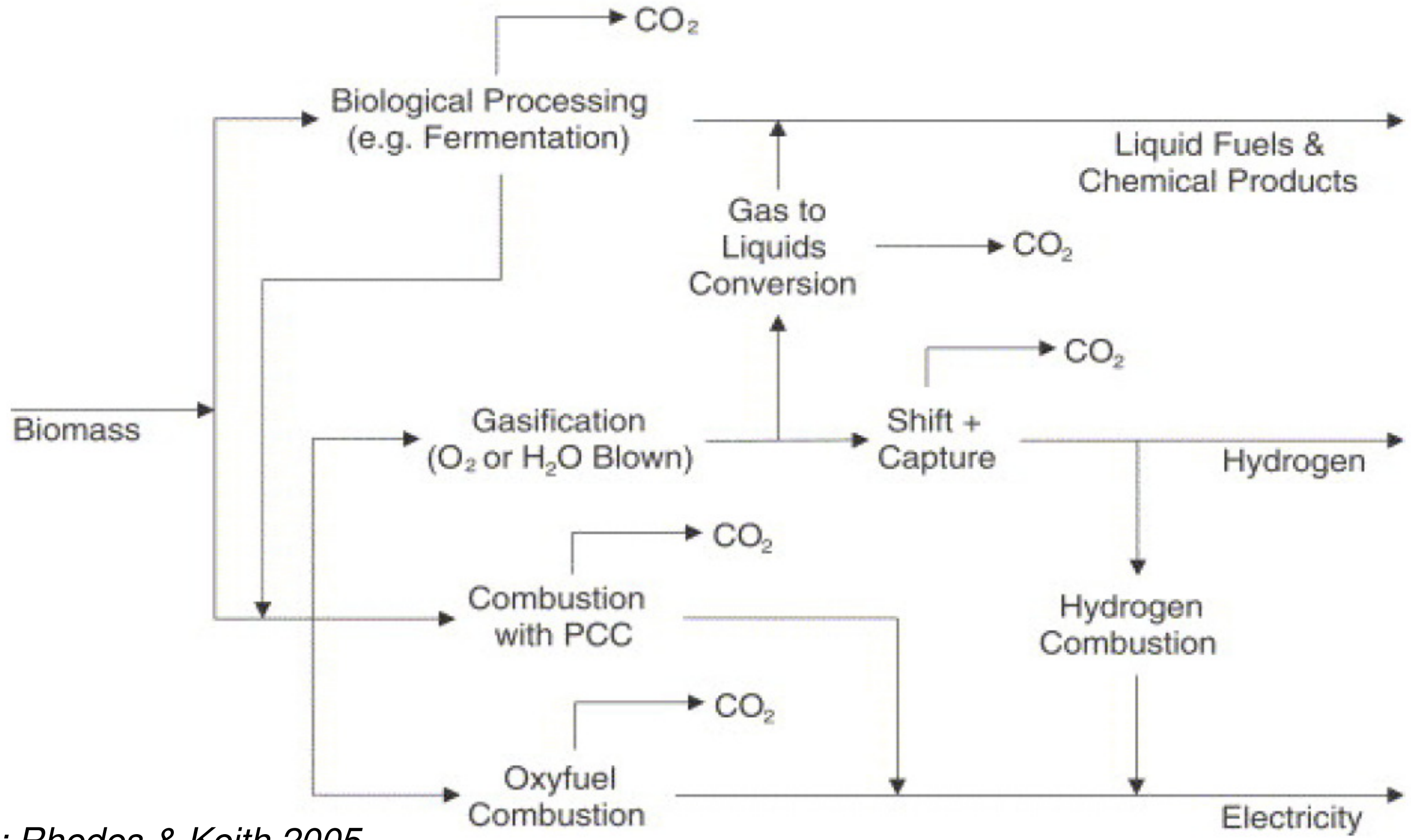




What is Bio-CCS?

- Conversion of biomass to electricity/heat/fuels/ products combined with CO_2 capture and storage
- Bio-CCS potentially leads to negative CO_2 emissions, i.e. CO_2 uptake from the atmosphere through natural sequestration of CO_2 in biomass
- Allows for offset of both historical and distributed CO_2 emissions
- Bio-CCS is indispensable to cost-effectively achieve most stringent global warming stabilisation scenarios

Bio-CCS pathways (1)

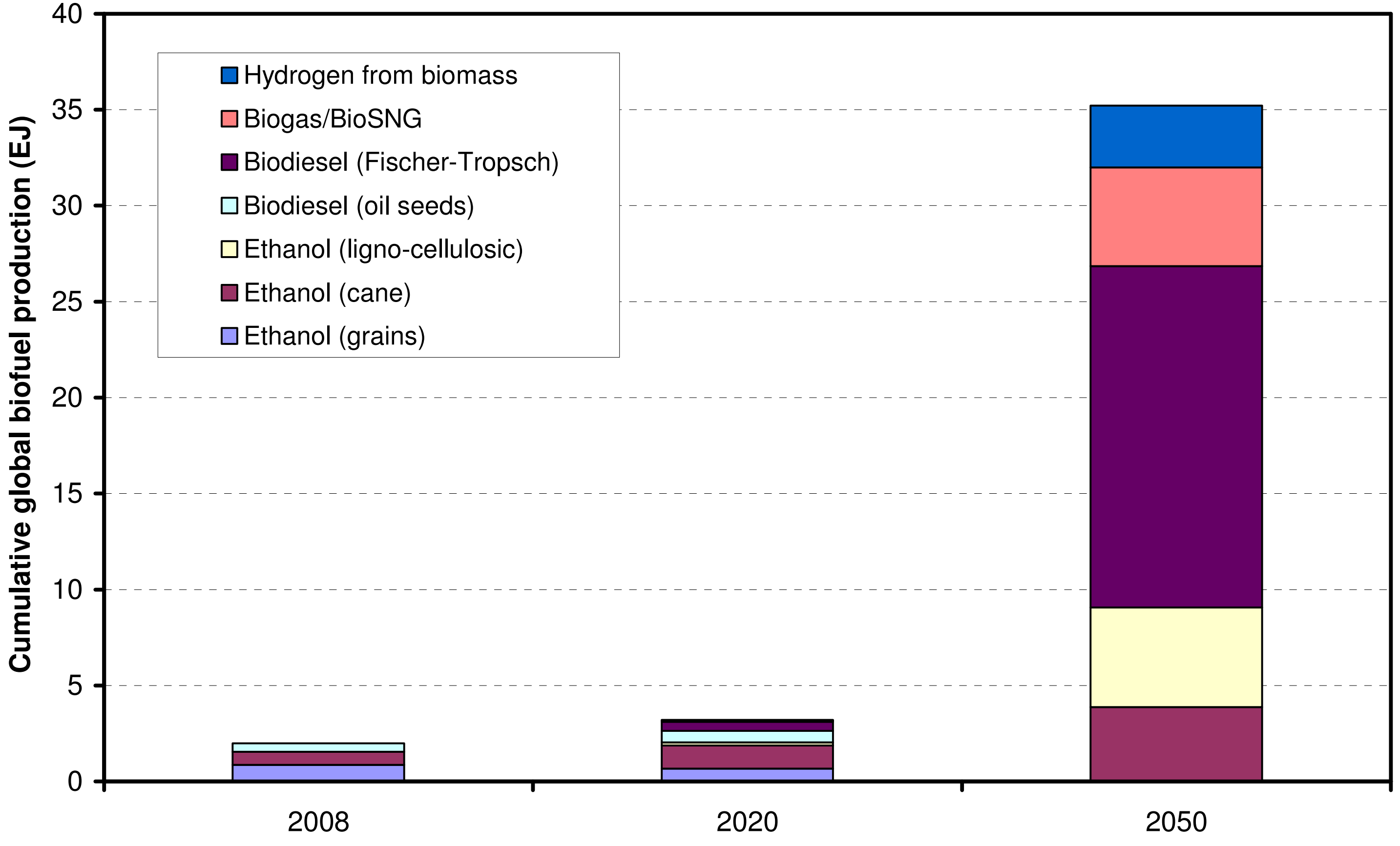


Source: Rhodes & Keith 2005

Bio-CCS pathways (2)

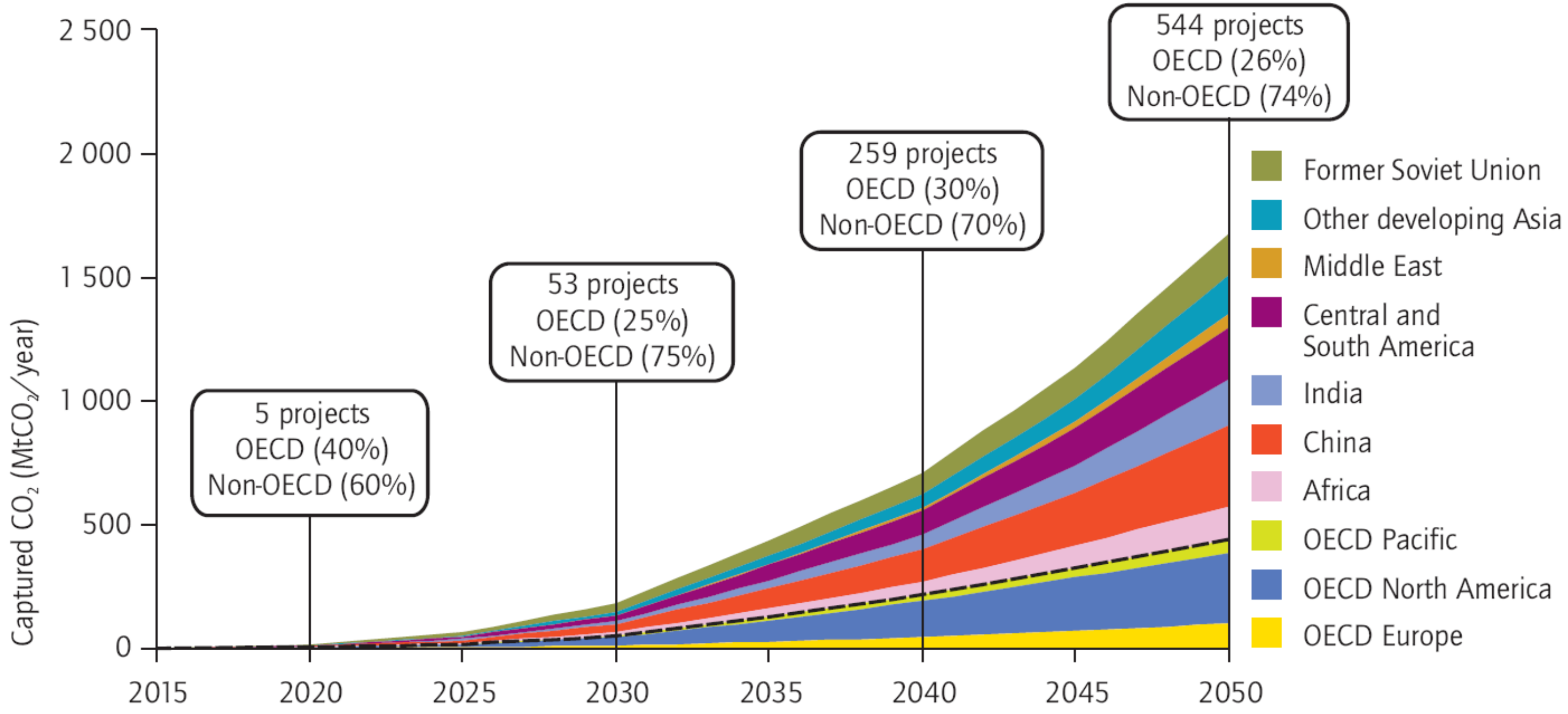
- Biomass co-firing in CCS equipped power plants:
  - High biomass co-firing ratios required to obtain negative CO_2 emissions → increased complexity
  - Capture penalty: CO_2 separation and compression
- Biomass-based hydrogen/fuels/chemicals synthesis with CCS:
  - Adjustment of H/C-ratio by CO_2 separation usually required during conversion, but does not affect primary product yield
  - Capture penalty: CO_2 drying and compression

Biofuel Projections



Sources: REN21 (2009) and IEA ETP (2010, BLUE Map scenario)

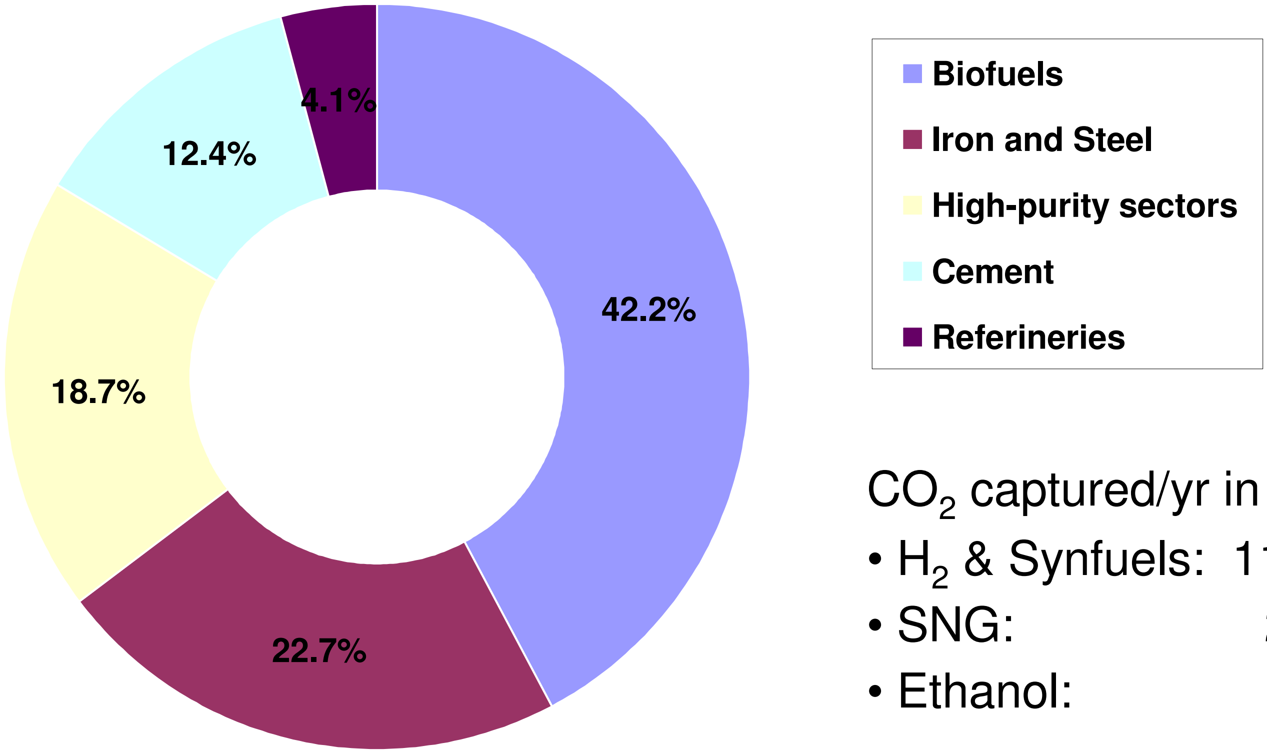
Bio-CCS Projections



Source: IEA/UNIDO (2011, Technology Roadmap CCS in Industrial Applications)

Industrial CCS Projections (1)

CO_2 captured in 2050 (4,032 Mton CO_2/yr)

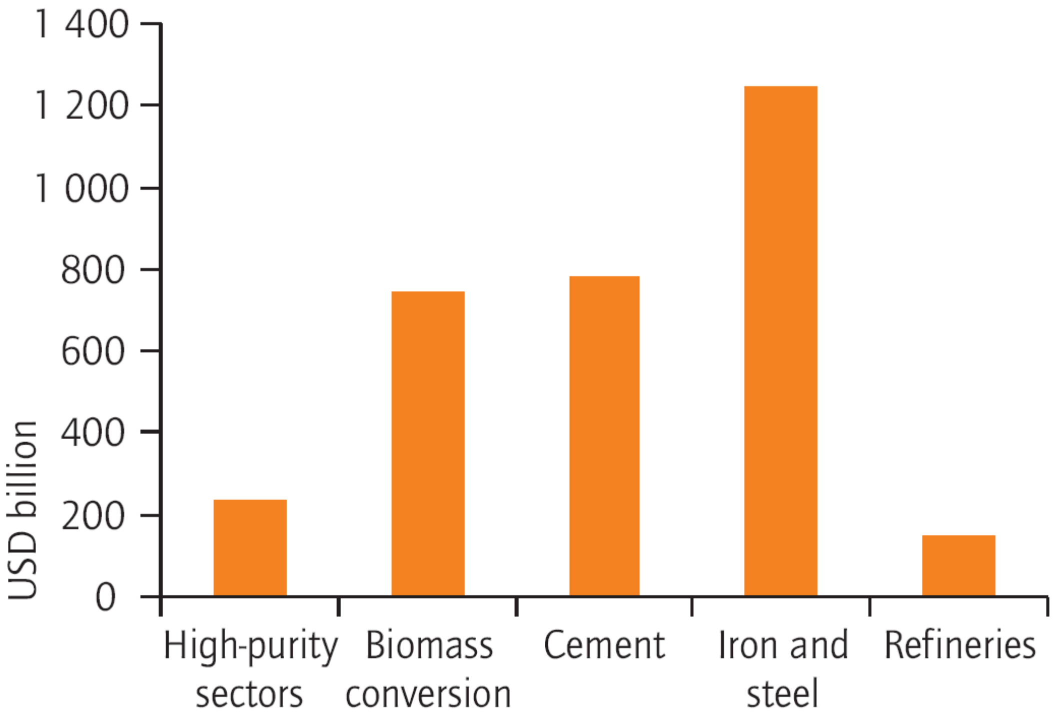


CO_2 captured/yr in Biofuels production:

- H_2 & Synfuels: 1190 Mton
- SNG: 289 Mton
- Ethanol: 187 Mton

Source: based on IEA/UNIDO (2011, Technology Roadmap CCS in Industrial Applications)

Industrial CCS Projections (2)



Accumulated investment 2010-2050: 3 trillion USD

	High-purity sectors	Biomass conversion	Cement	Iron and steel	Refineries	
CO_2 captured/yr [Mton]	753	1,700	500	914	165	4,032

Source: IEA/UNIDO (2011, Technology Roadmap CCS in Industrial Applications)

Policy Instruments (1)

- IPCC Guidelines for GHG inventory reporting recognise Bio-CCS
- EU-ETS: free allocation for biomass up to 97%, no negative accounting, no sustainability criteria for biomass
- Project-based mechanisms:
  - Biomass plays important role in both CDM and JI
  - Recent inclusion of CCS in Clean Development Mechanism (CDM) allows accounting of Certified Emission Reductions (CERs) for negative emissions

Policy Instruments (2)

- Low-carbon fuel standards (such as EU RED or US RFS) could be of interest for biofuels with CCS:
  - Aim at lowering lifecycle emissions transport fuels
  - Sustainability criteria for biofuels define minimum GHG emission reductions
  - EU RED calculation methodology allows subtraction of biomass-based CCS during biofuel production
  - EU RED minimum GHG emission reduction of 60% by 2018 could be obtained with 2nd generation biofuels without need for combination with CCS

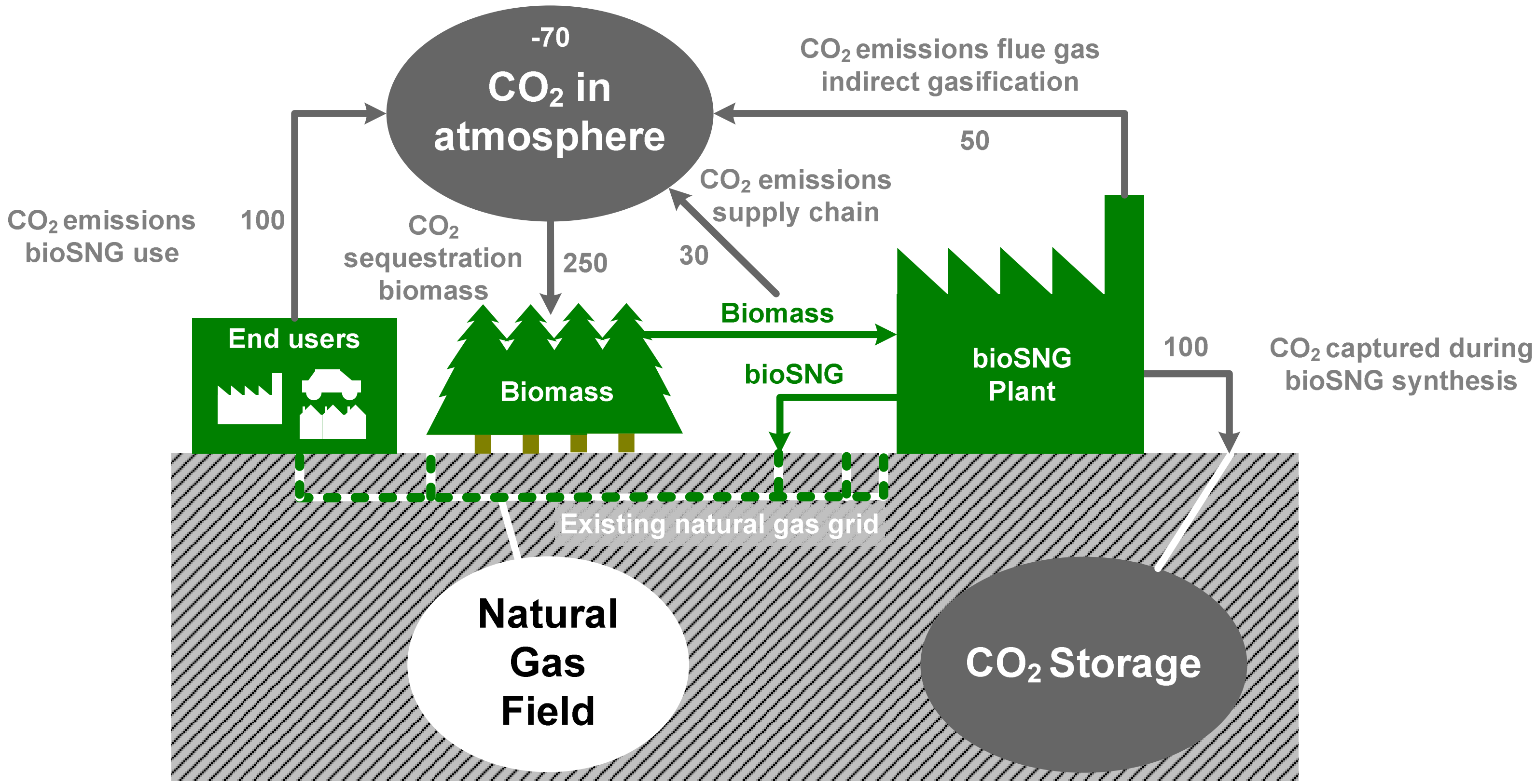
Roadmap: Actions

- Create Bio-CCS stakeholder network
- Investigate impact of negative emissions accounting
- Implement policies that recognise Bio-CCS
- Scale-up and commercial-scale demonstration of biomass gasification, gas cleaning & treating and biofuel synthesis
- Expand number of bioethanol CCS demonstration plants

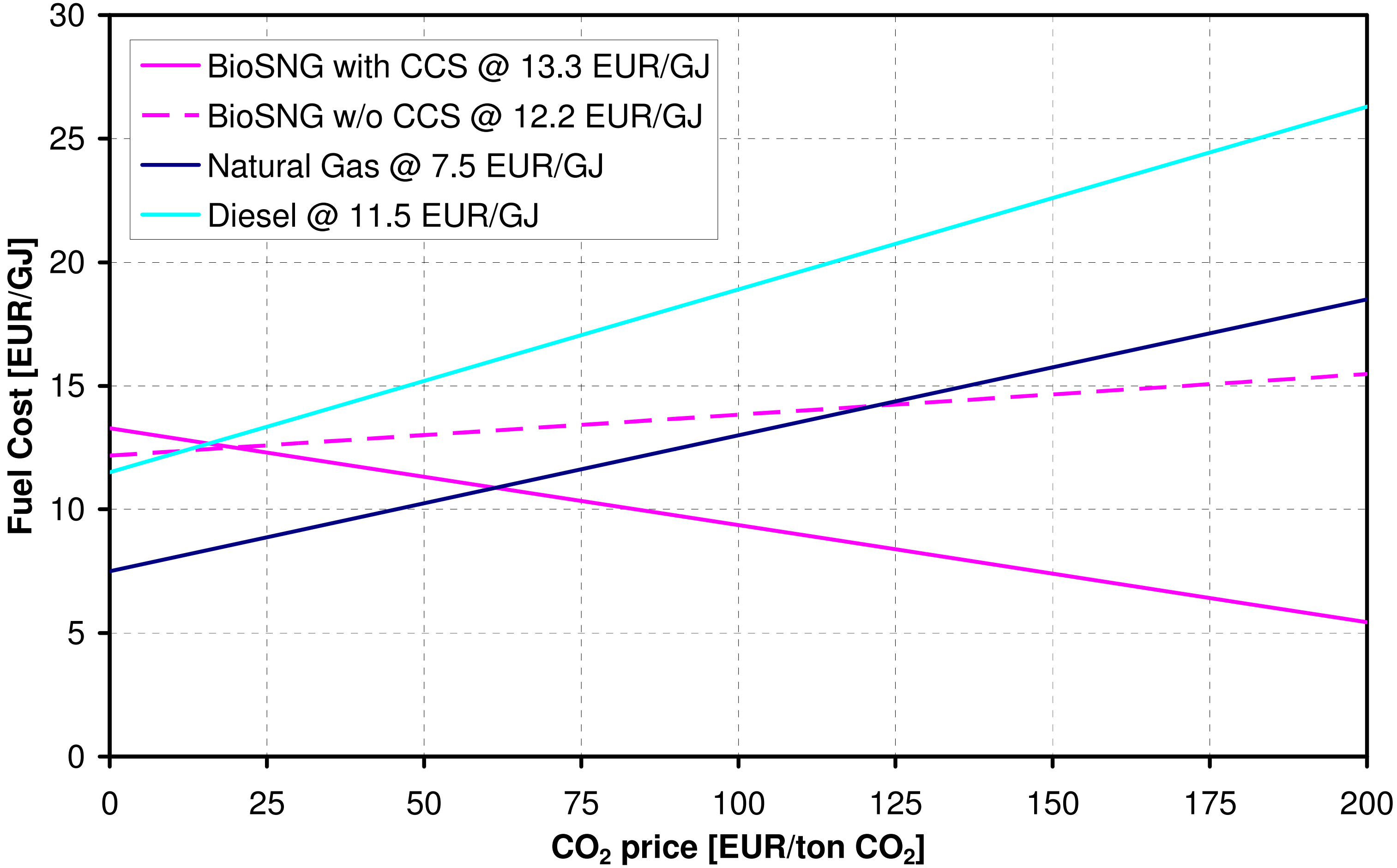
Existing Bio-CCS Projects

- 2009: 170-180 kton CO_2/yr captured at Arkalon ethanol plant (Liberal KS); used for EOR (Booker TX)
- 2011: Decatur Carbon Sequestration Project
  - CO_2 captured at ADM ethanol plant and storage in saline Mount Simon Sandstone formation
  - Total cost: 164 M$; Total CCS: 2.5 Mtons
  - 66 $/ton or 49 €/ton CO_2 captured
- 2012: Global Environment Facility (GEF) of UNDP funded CCS pilot at ethanol plant in São Paolo state, Brazil; 20 kton CO_2/yr in local saline formation

BioSNG production and CCS (1)



BioSNG production and CCS (2)



Conclusions

- Incremental cost for CCS are low for biofuels:
  - Small effect on primary product yield
  - CO_2 separation equipment already in place
- CCS retrofitting in biofuels production is straightforward
- Accounting for net CO_2 uptake from atmosphere lowers avoidance costs and accelerates biofuels deployment
- Need to change/clarify mechanisms to allow negative emission accounting
- Scale-up and broad deployment of biomass conversion technologies required

Questions

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Milena indirect gasifier: www.milenatechnology.com
OLGA tar removal: www.olgatechnology.com
SNG: www.bioSNG.com and www.bioCNG.com

Assumptions BioSNG with CCS (1)

- Plant size ~500 MW_{th} input
- Plant simulated using AspenPlus V7.1
- Costing:
  - Early 2010
  - Greenfields, overnight
  - N^{th} plant, North-western Europe

Assumptions BioSNG with CCS (2)

- Gasification pressure: 7 bara
- TCI: 1,100 €/kW_{SNG}
- O&M: 5% of TCI
- Other fixed cost: 2% of TCI
- Return on Investment: 12%
- Interest: 5%
- Biomass price (dry): 4 €/GJ
- Electricity price: 0.05 €/kWh (14 €/GJ)
- CO_2 emission natural gas combustion: 55 kg/GJ

Economic analysis BioSNG with CCS

	Annual Cost (M€/yr)	Cost (€/GJ)
TCI	55.2	3.50
Biomass	89.7	5.69
Electricity	10.9	0.69
O&M	28.6	1.82
Other fixed cost	11.4	0.73
Total cost	195.8	12.42
Result	13.5	0.86
Revenues	209.4	13.28