Negative emissions to meet the global carbon budget: necessity and opportunities for bio-CCS concepts

IEA Bioenergy Task 33 & IEA Industrial Energy-related Technologies & Systems
Workshop: ***System and Integration Aspects of Biomass-based gasification***
Chalmers University, Göteborg - Sweden, November 20th , 2013

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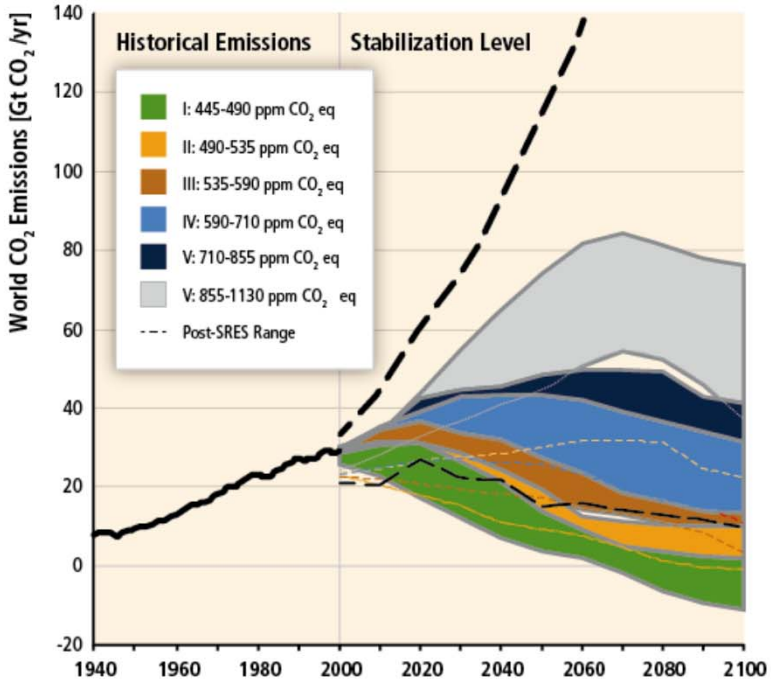
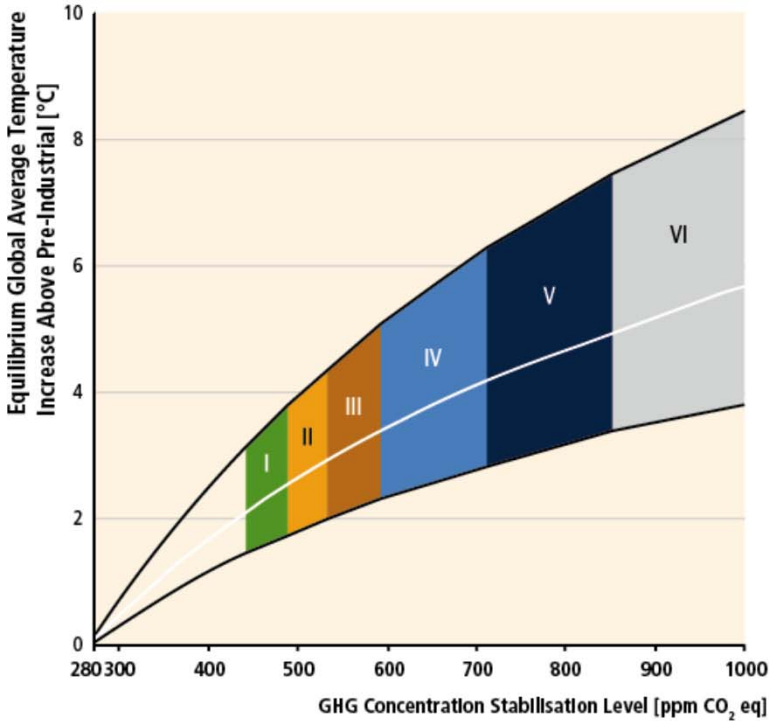
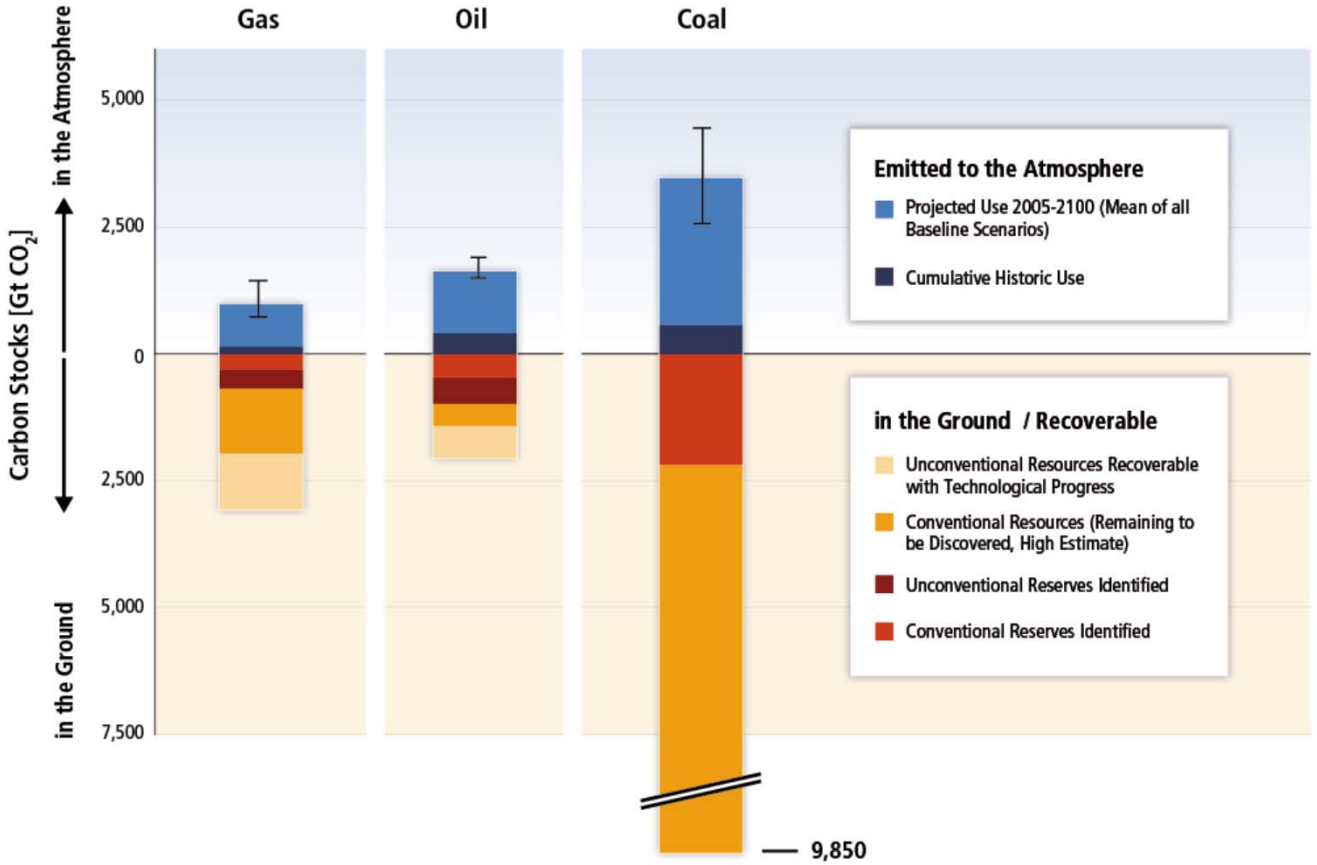
Copernicus Institute
Sustainable Development and Innovation Management

Energy demand, GHG emissions and climate change…

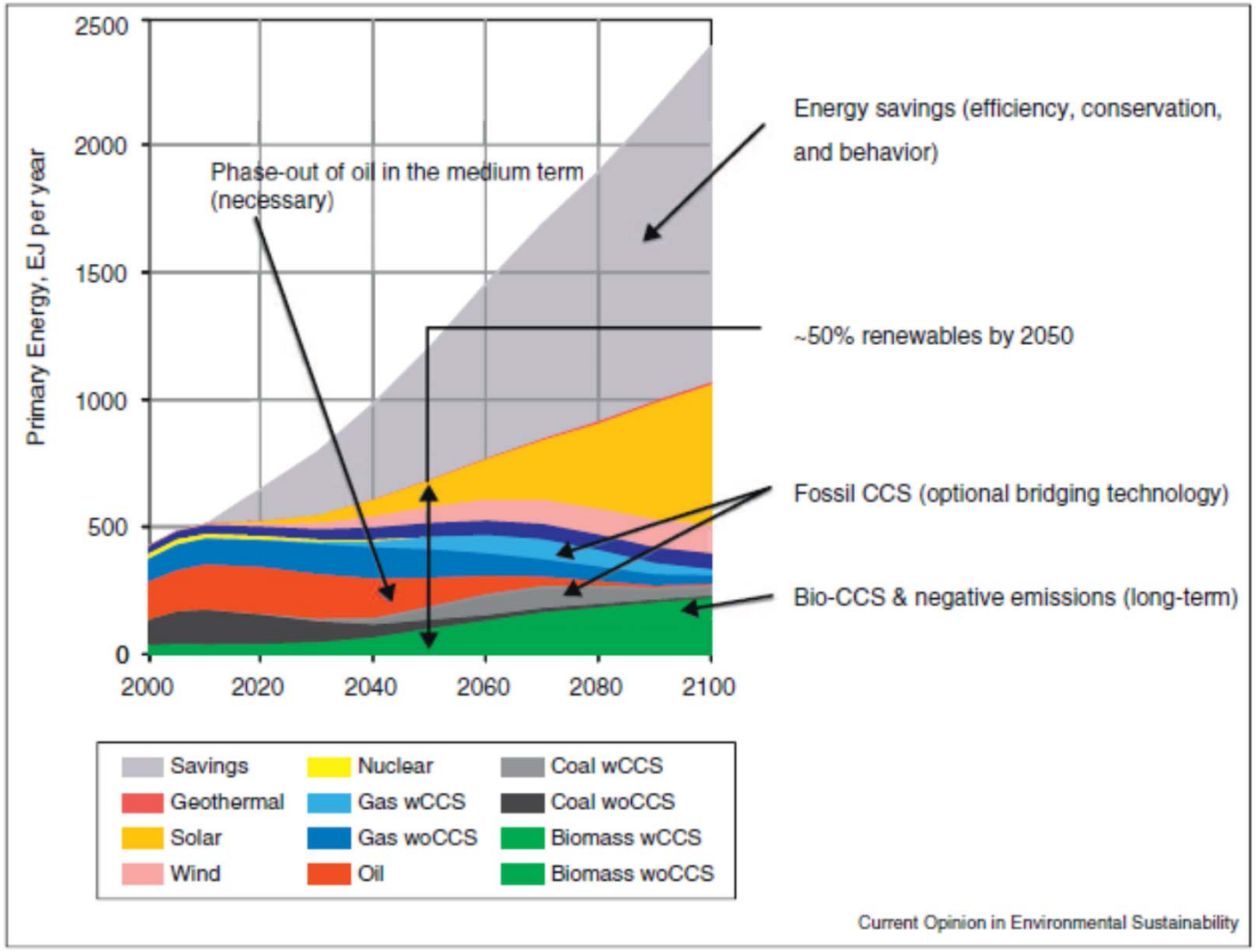




Potential emissions from remaining fossil resources could result in GHG concentration levels far above 600ppm.



Energy system transformation…



[GEA/van Vuuren et al CoSust, 2012]

CO_2 budget approach

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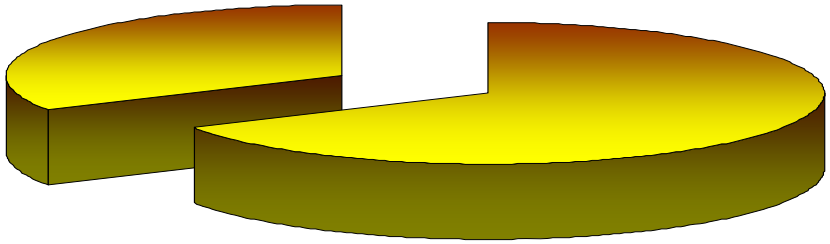
If we want 2/3-3/4 probability to stay below +2°C, global CO_2 emissions should stay below 1000 Gton (from the year 2000).

2000-2009: 33%



2010-2050: 67%

→ At current consumption the budget will be exhausted in 2030.

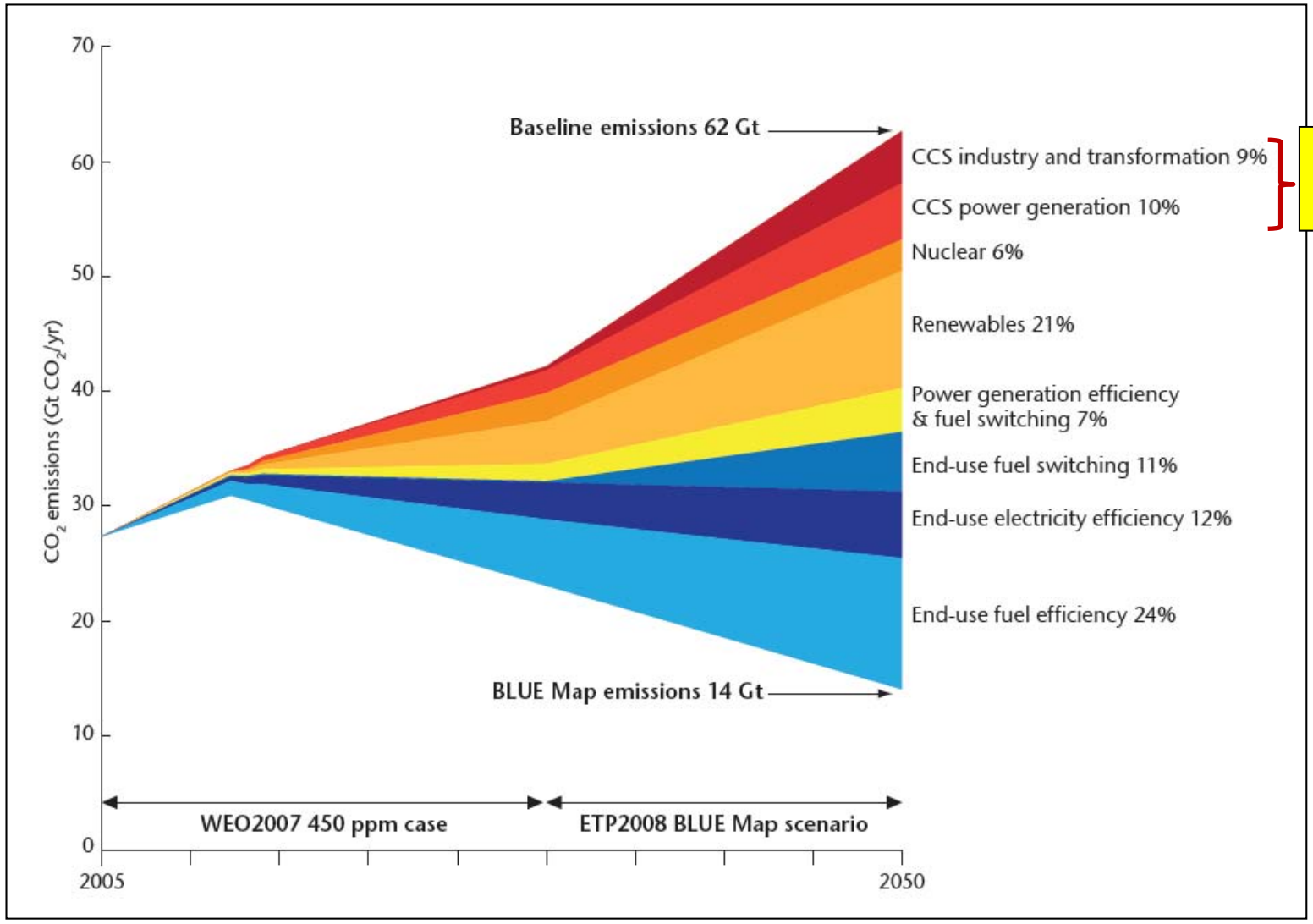
Sources: M. Meinshausen et al., Nature, 30 April 2009;
A. Levermann, GHGT-10, 19-23 Sept. 2010

→ Without CCS less than 1/3 of fossil fuel reserves (and only a fraction of fossil fuel resources) can be utilized .

→ Minister Maria van der Hoeven (NL, 2010): "Without CCS no fossil fuels; without fossil fuels no energy security".

***→ Also attention needed for* NG & CCS *and for* Biomass & CCS.**

CCS Potential



1/5 of the portfolio

Source: IEA, Energy Technology Perspectives, 2008

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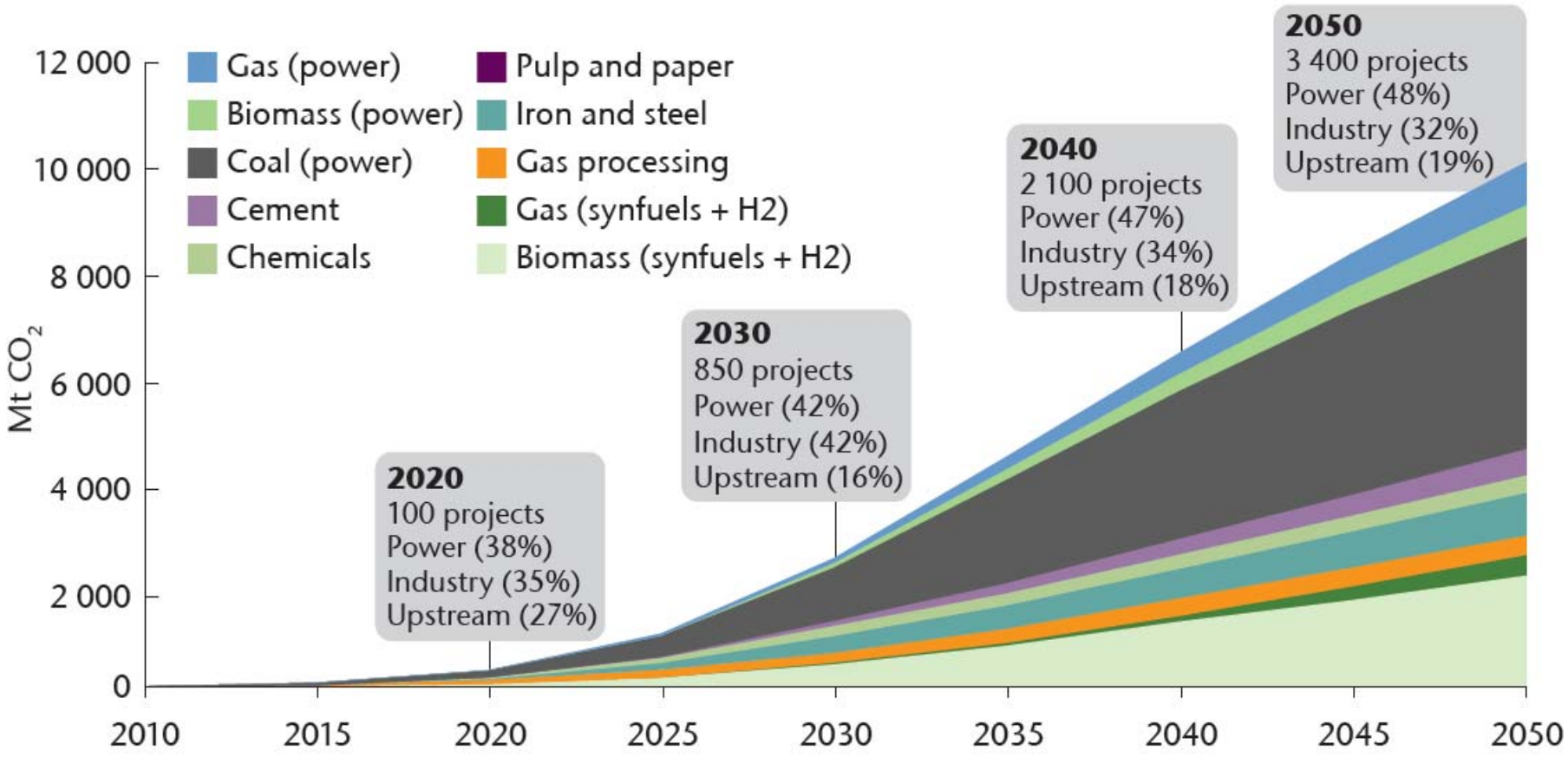
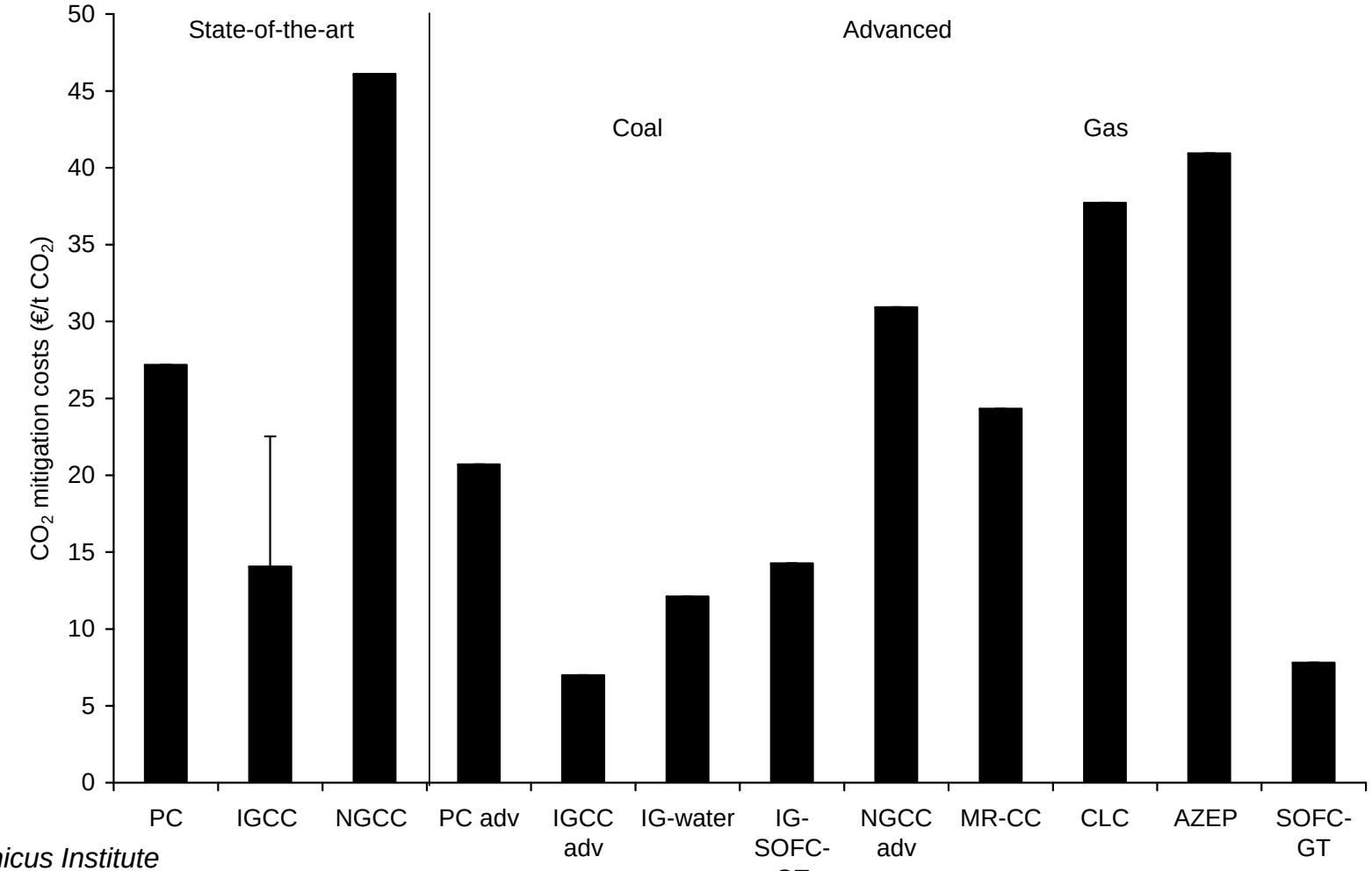
CCS is not only about coal or power



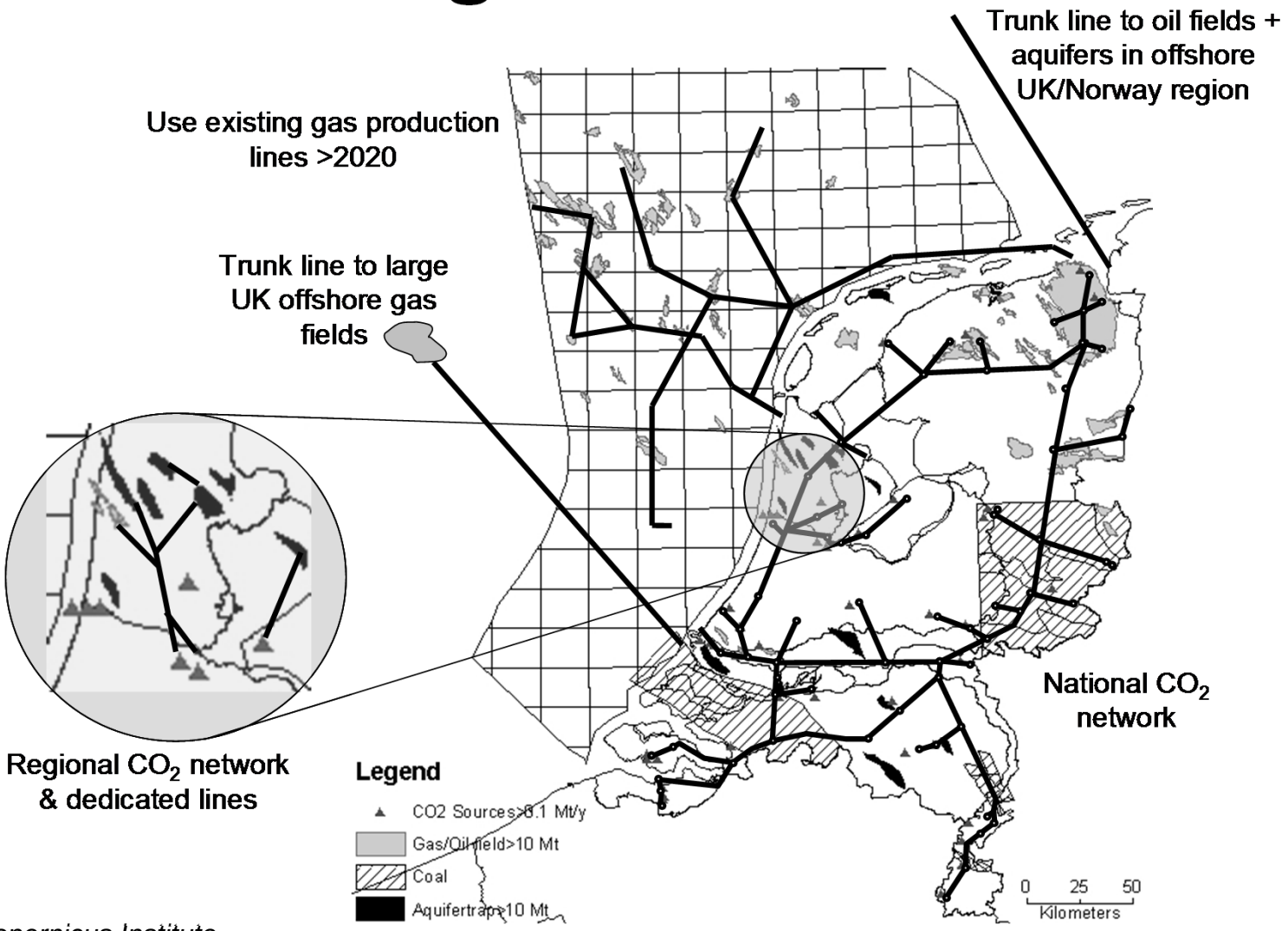
Source: IEA, Technological Roadmap CCS, 2009

CO2 avoidance costs for electricity production (ref: identical technology without CCS).



[Damen et al., Progr. in En. & Comb. Sc., 2007]

Conceptual CO2 transport configurations



Damen et al., 2008

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Key options for Bio-CCS

- Flexfuel power and synfuel production.
  - (B)IGCC/FT/MeOH/DME
  - Co-firing: coal AND natural gas (CC's)
- CO2 capture at biorefineries (ethanol in particular)…
- Steel industry…

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Key conditions for bio-CCS

- CO2 storage options.
- Suited energy infrastructure
- Access to biomass
- Larger scale (complex) systems.

- Potential regions: Great Plains US, SE Brazil, East Australia, Central China, Sea harbors NW Europe (imported biomass).

Bioethanol from lignocellulosic biomass

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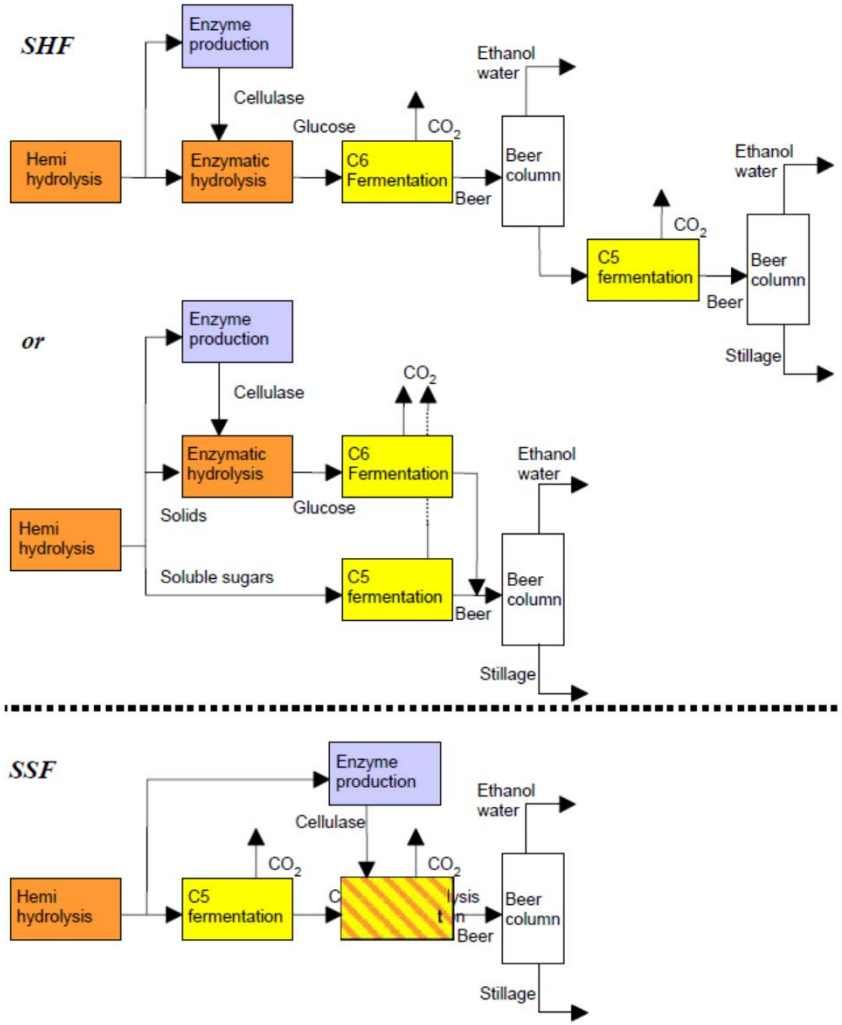
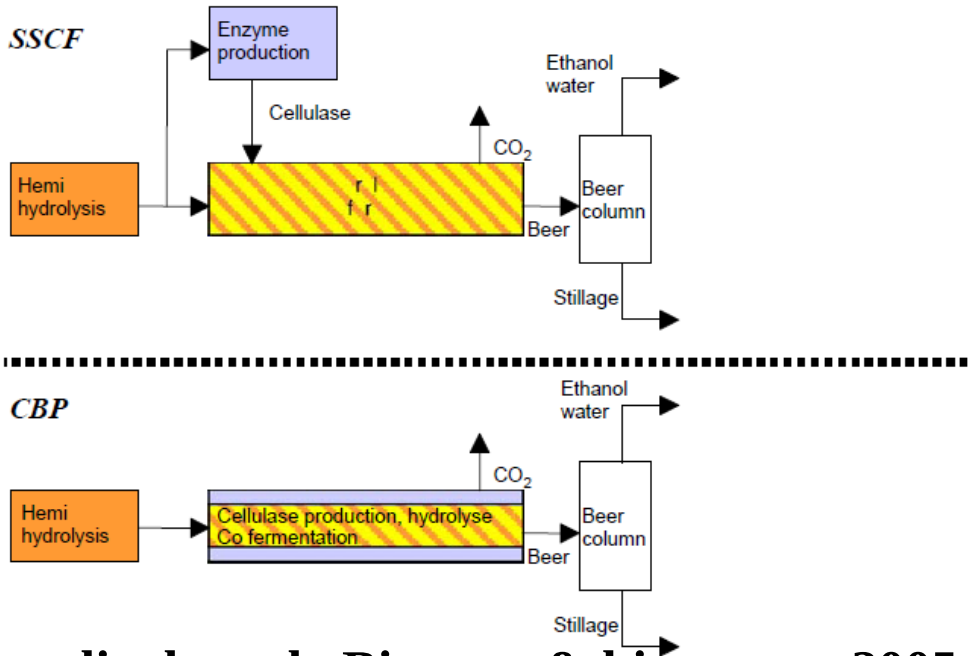


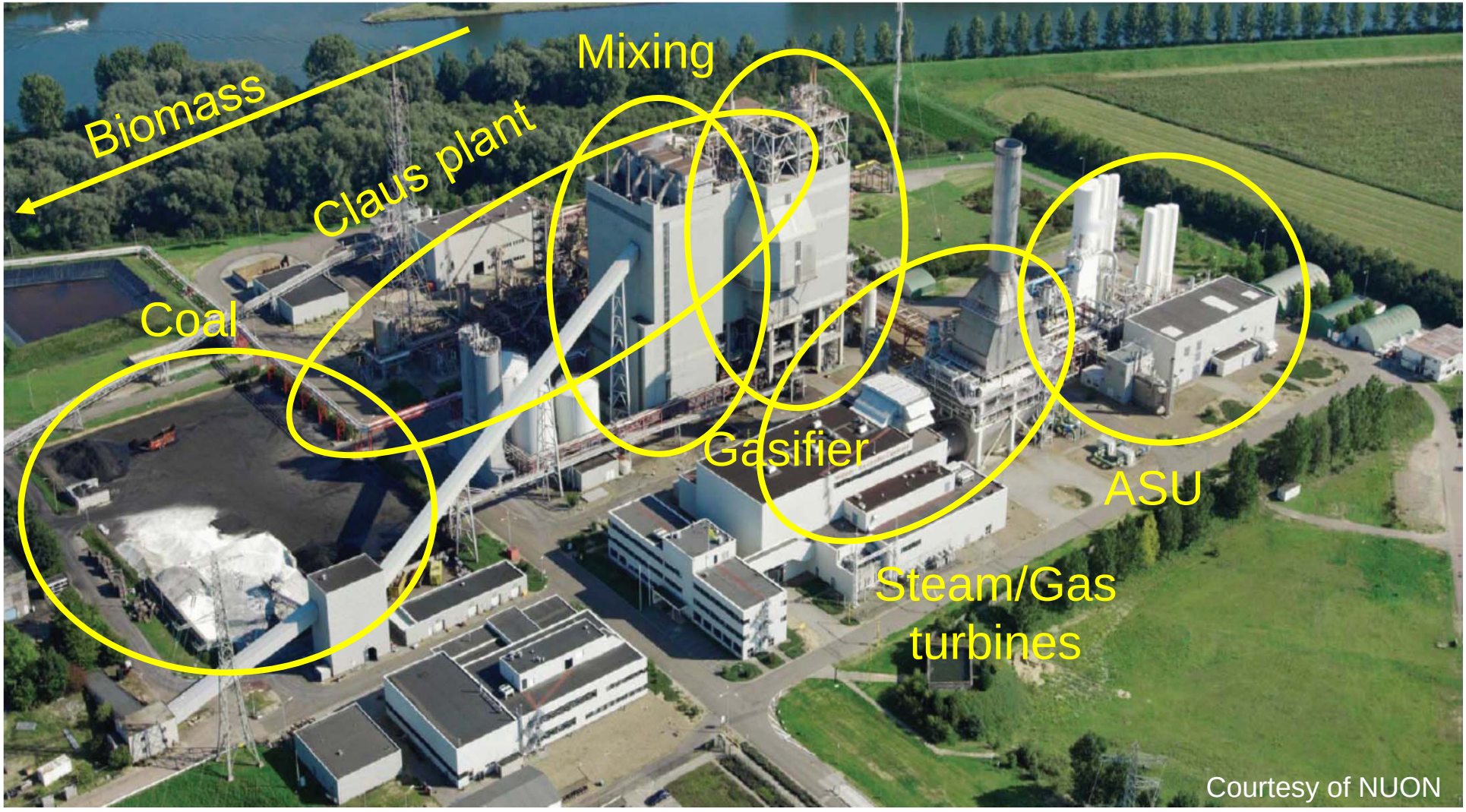
$3C_5H_{10}O_5 \rightarrow 5C_2H_5OH + 5\mathbf{CO_2}$ (1)

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + \mathbf{2CO_2}$ (2)

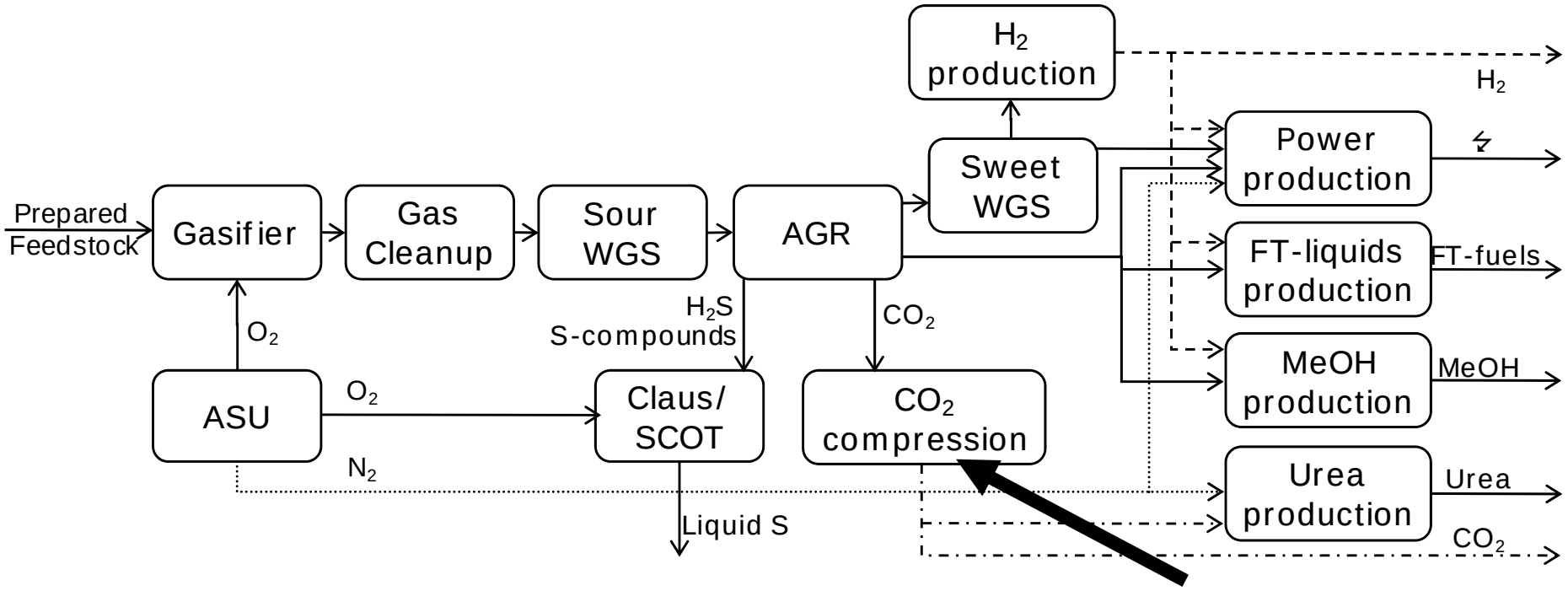


Hamelinck et al., Biomass & bioenergy, 2005

Willem-Alexander Power Plant



An ultimate energ transition machine: flex-fuel IG/synfuel/power +CCS



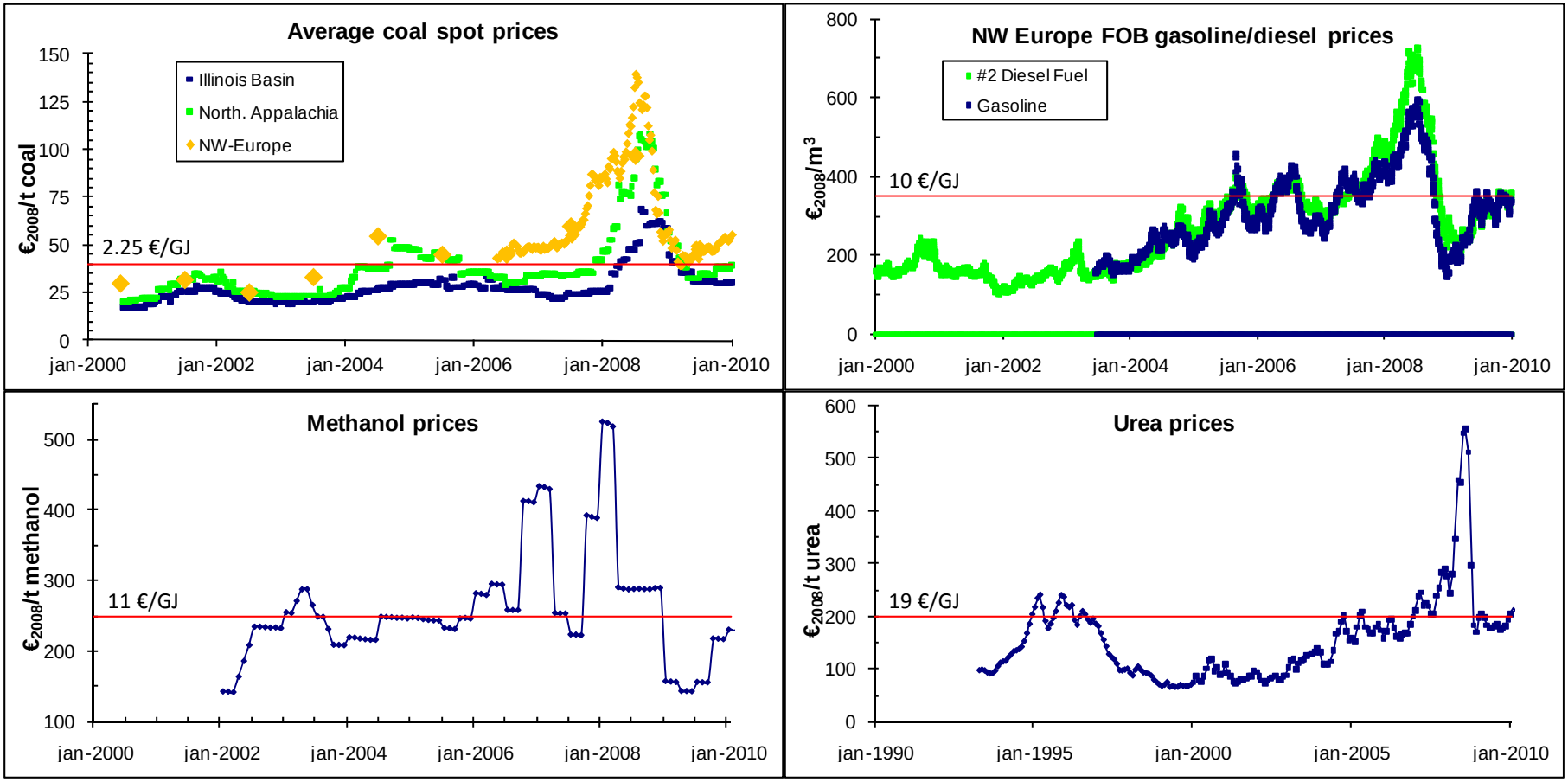
Major investments in China.

- No oil for transport!
- 50 % biomass + CCS = net 0 CO2 emission.

About 50% of carbon!

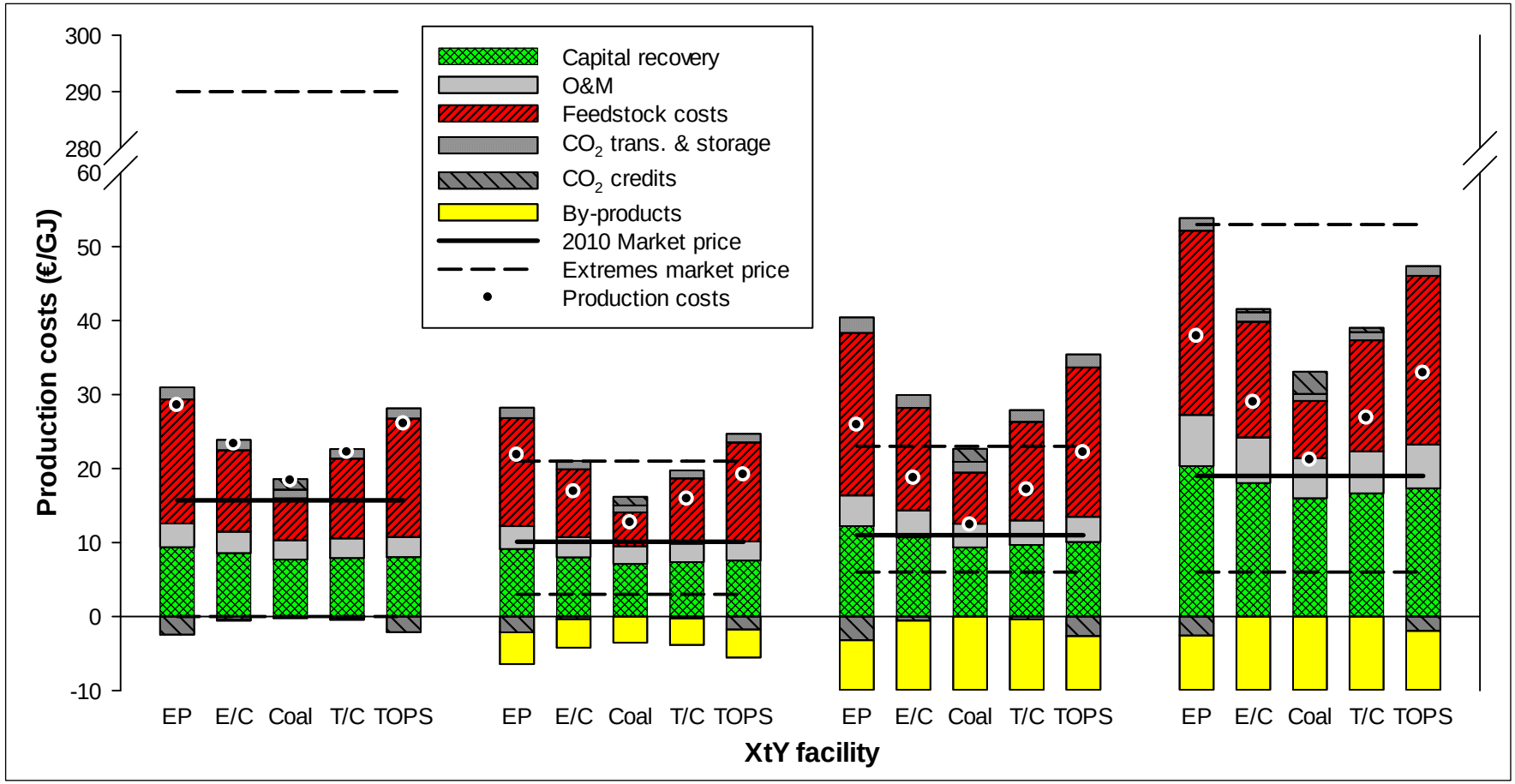
[Meerman et al., RSER, 2012]

Commodity prices



[Meerman et al., RSER, 2013]

Production costs



Electricity **FT-liquids** **Methanol** **Urea**

[Meerman et al., RSER, 2013]

Coal-TOPS-CO_2 credit

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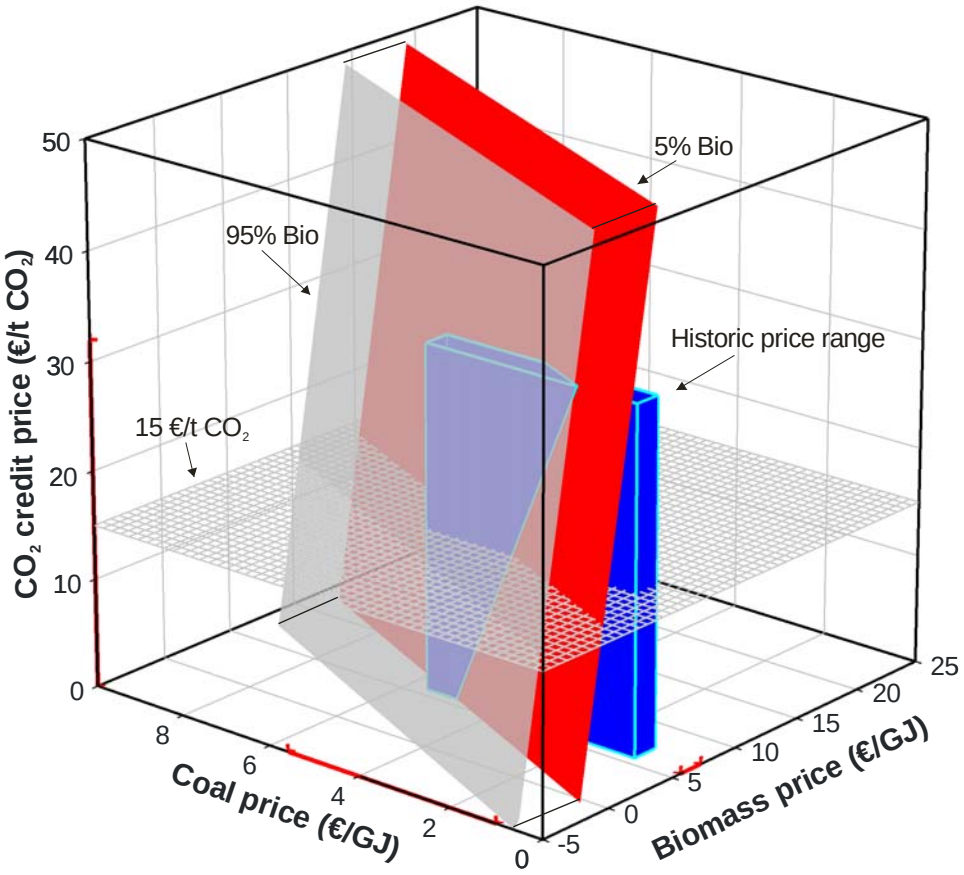
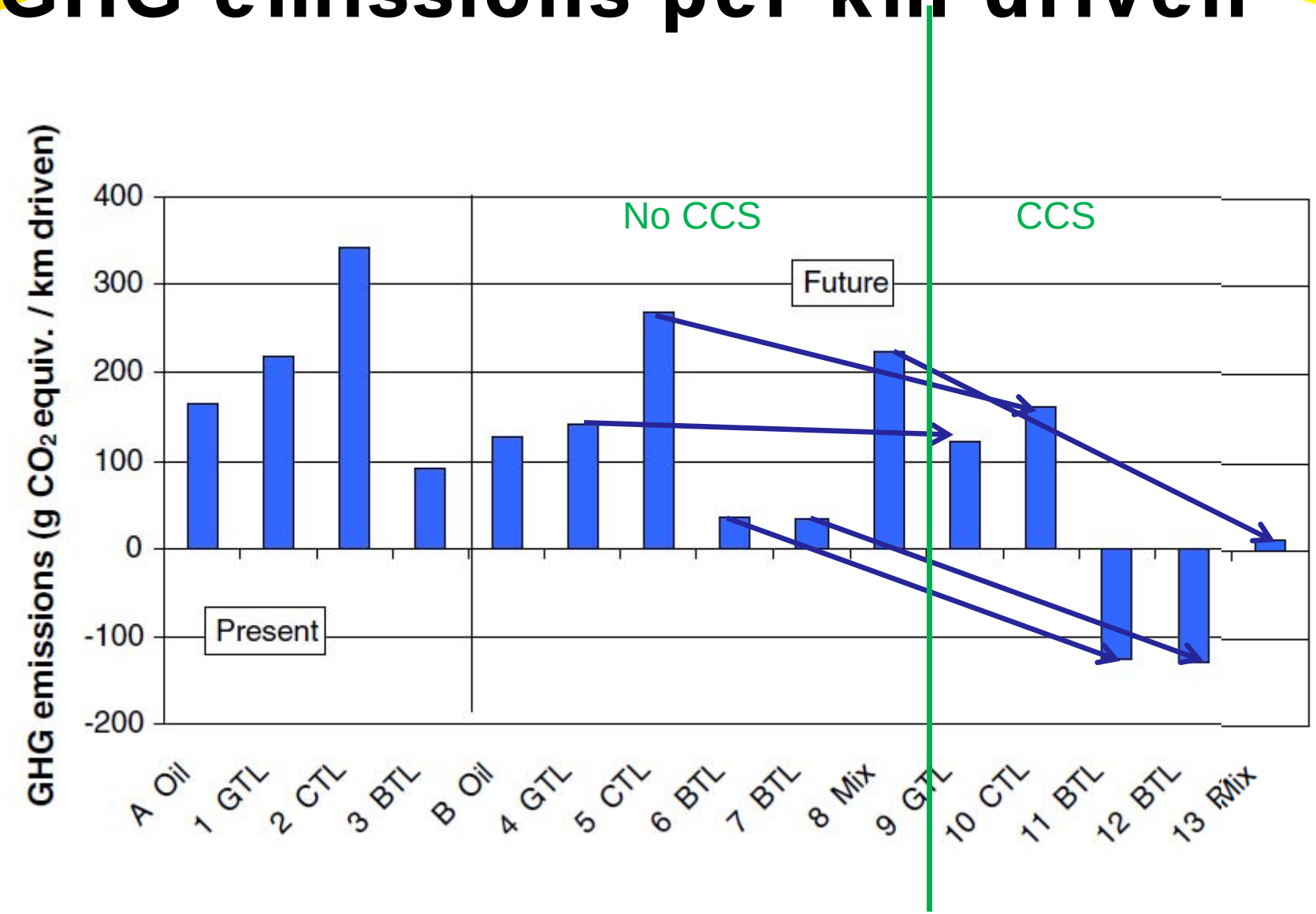
- Price combination where flexibility is desired
- Historic prices reached this area



Source Meerman et al., Performance of simulated flexible integrated gasification polygeneration facilities.
Renewable and Sustainable Energy Reviews 2010:15;2563-87

[Meerman et al., RSER, 2013]

GHG emissions per km driven



[Van Vliet et al., 2009]

Netherlands vs. China…

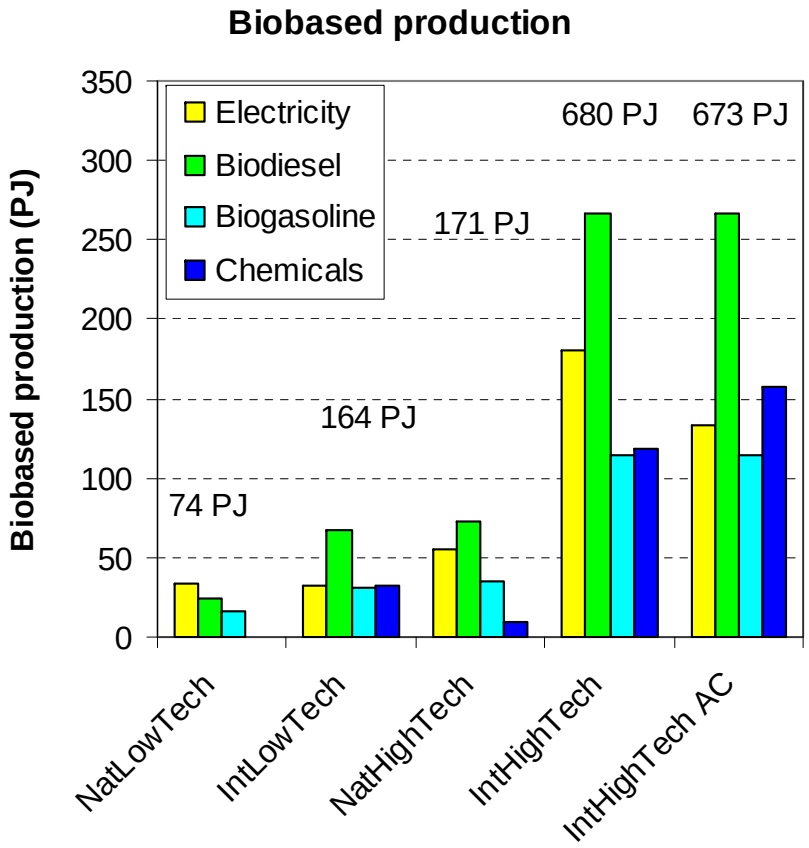
Yueyang Sinopec-Shell Coal gasification project; (China)

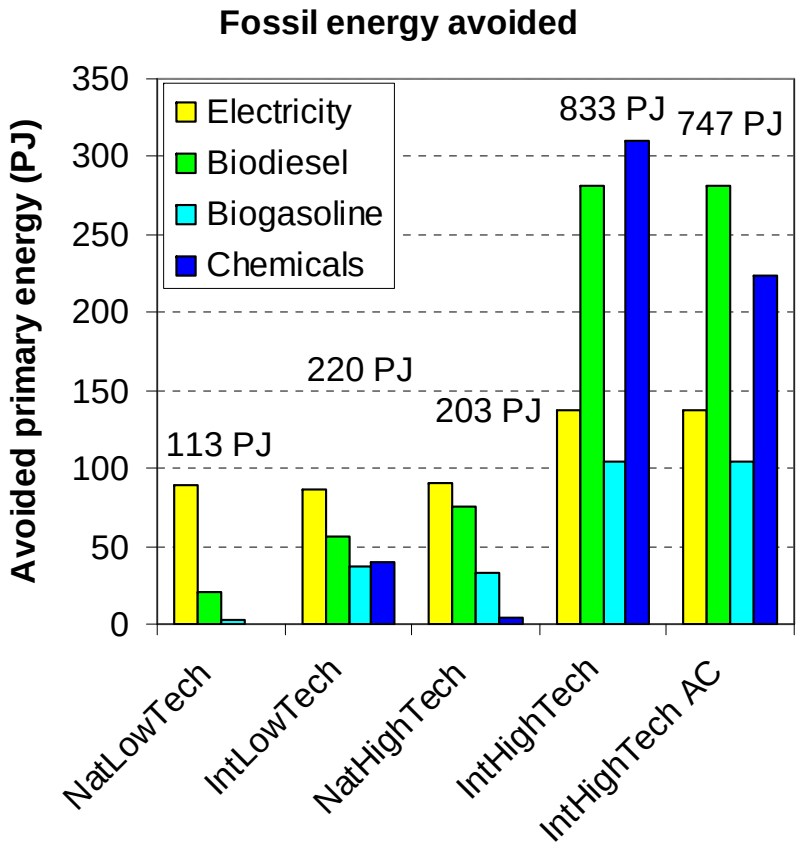
Shell gasifier arriving at site September 2006.

15 licences in China at present…

Courtesy of Shell

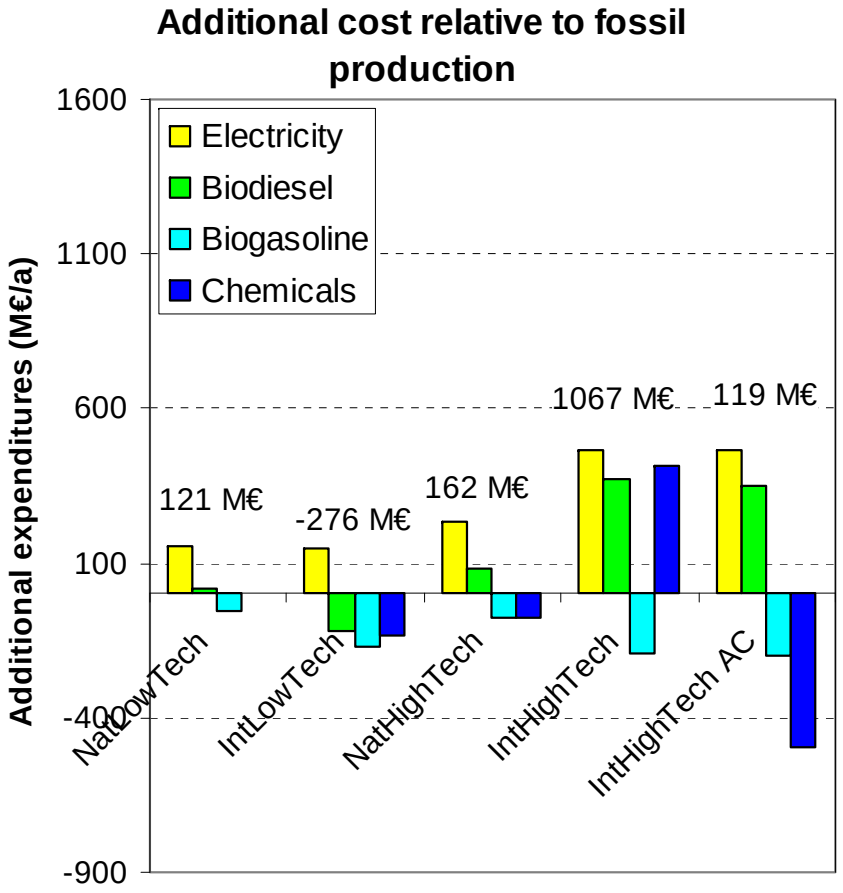
Bioenergy in the scenarios in 2030 (+) (NL)



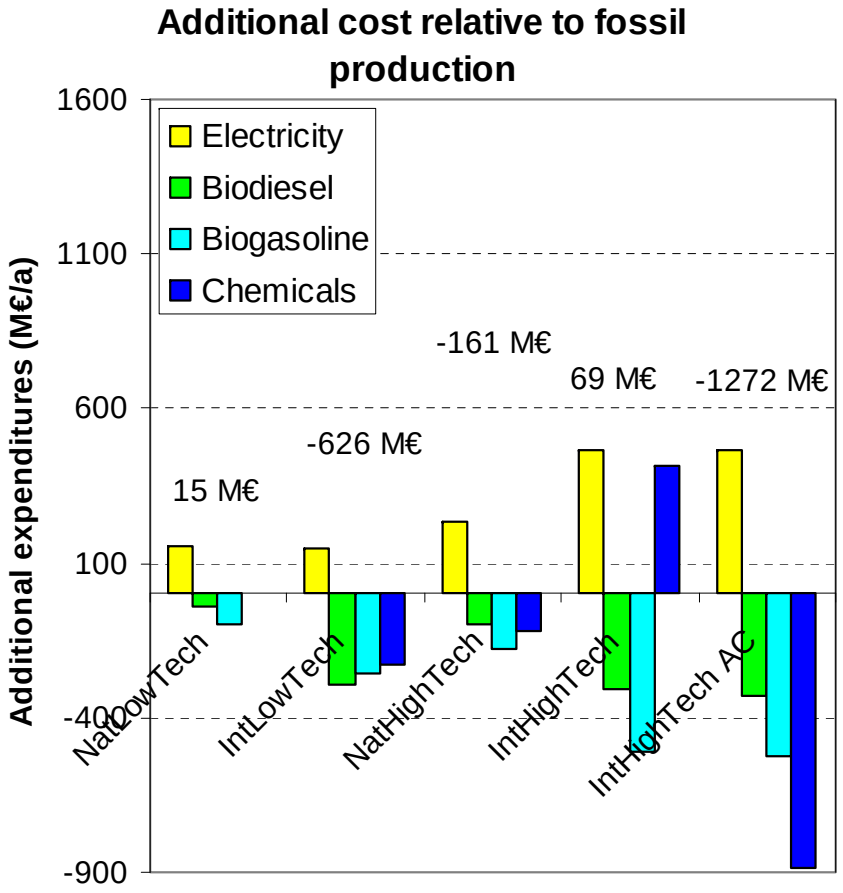


[Hoefnagels et al., Energy Policy 2013]

Sensitivity to fossil fuel prices



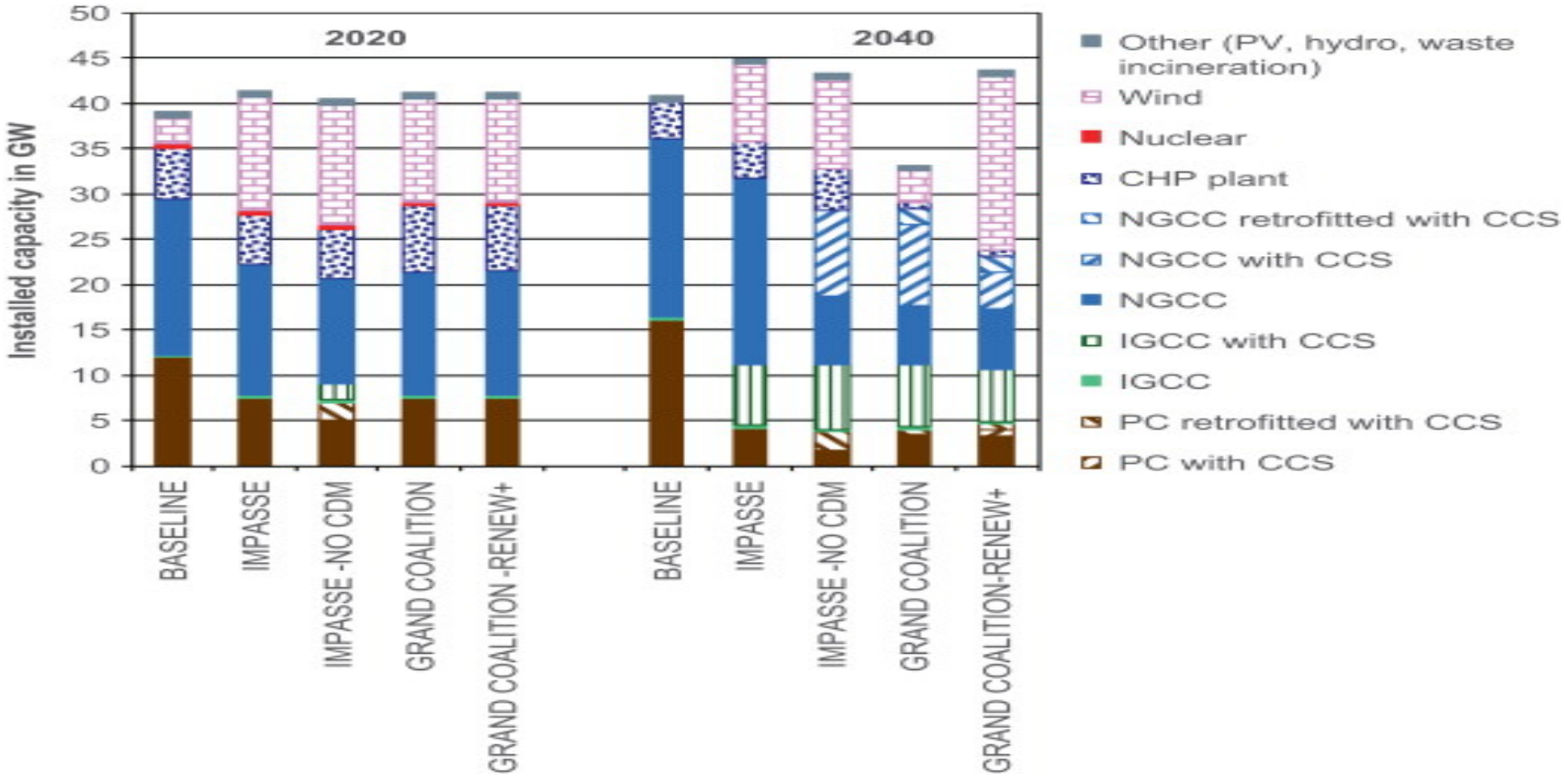
Oil price: 75 US$/bbl



Oil price: 90 US$/bbl

[Hoefnagels et al., Energy Policy 2013]

Total installed electricity generating capacity in the Netherlands in 2020 and 2040 for five scenarios as calculated with MARKAL-NL-UU.



[van den Broek et al., Energy Policy 2011]

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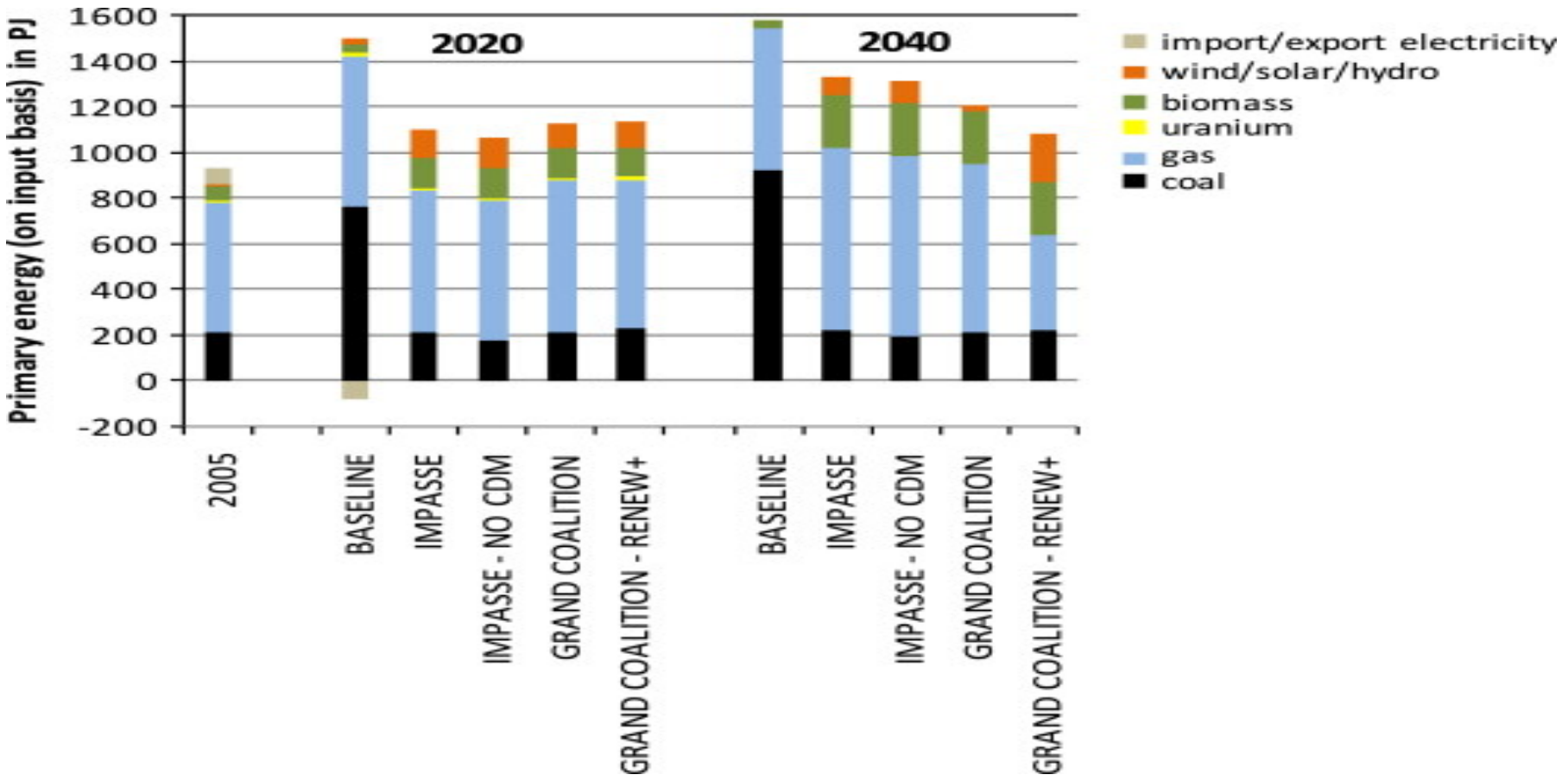
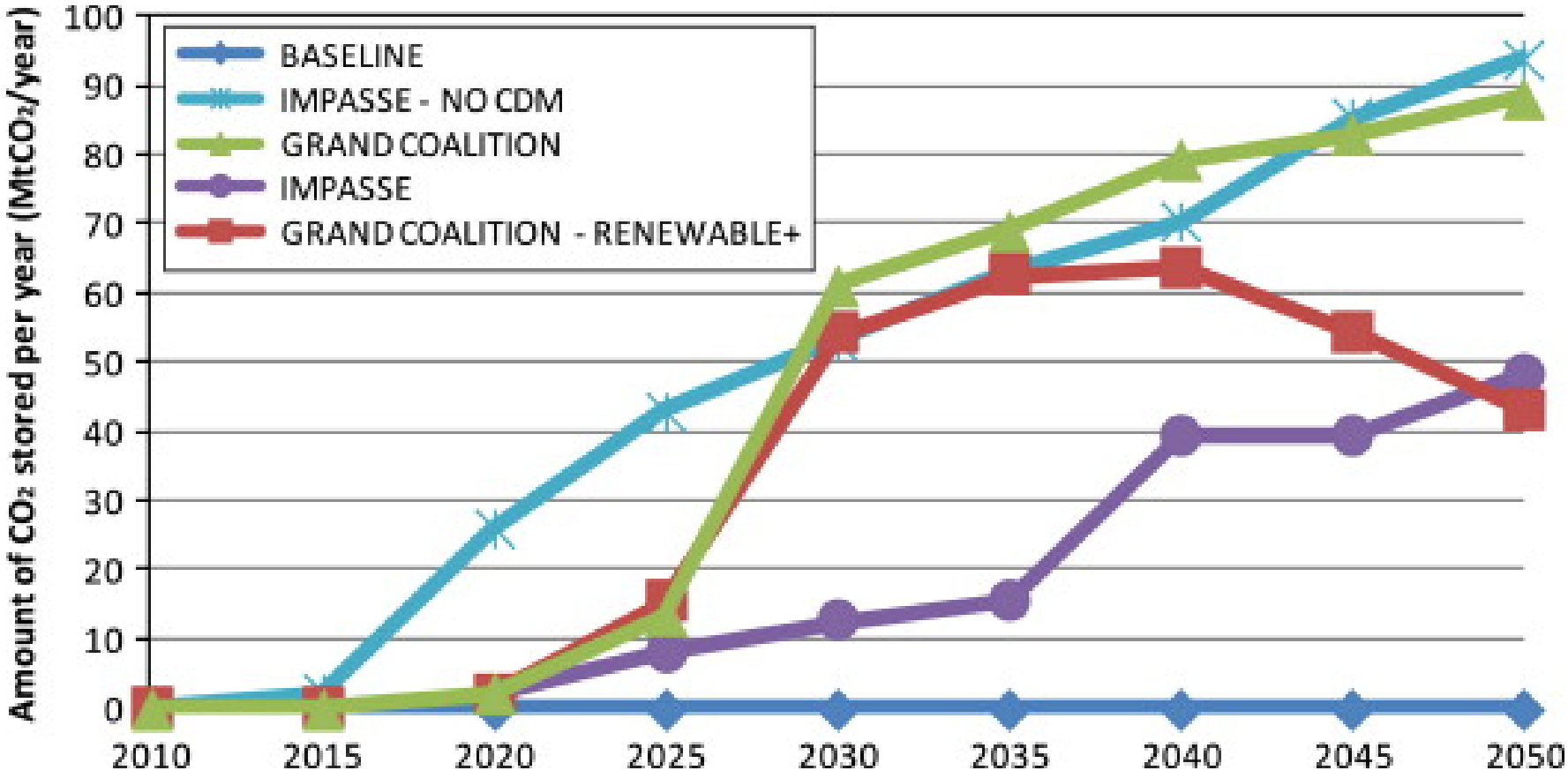
Fig. 8 Primary energy use in the power sector of the Netherlands in 2020 and 2040 per scenario as calculated with MARKAL-NL-UU.



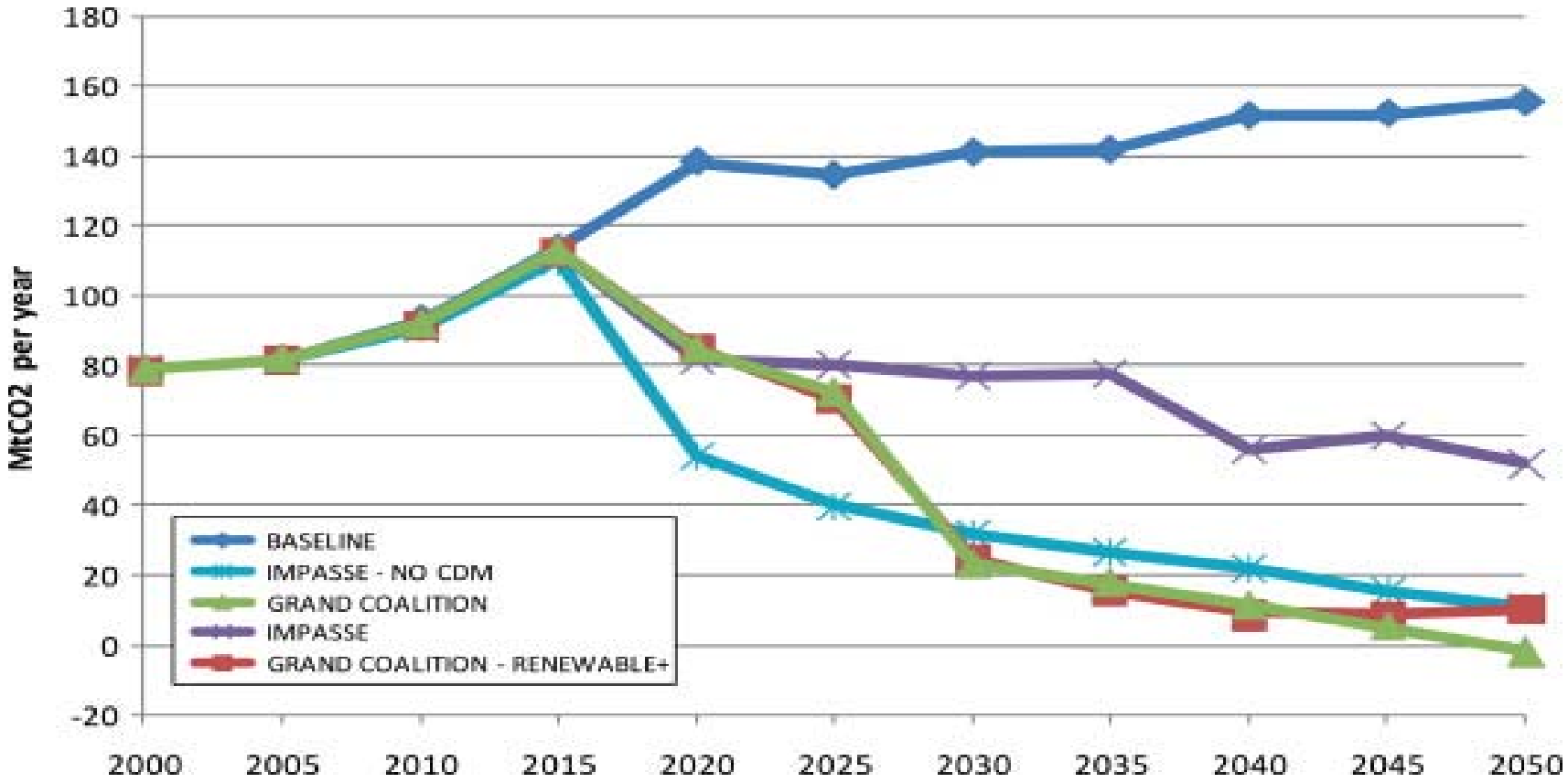
[van den Broek et al., Energy Policy 2011]

CO2 capture and storage deployment for the different scenario's



[van den Broek et al., Energy Policy 2011]

CO_2 emissions from the power sector and CO_2 intensive industry in the Netherlands per scenario as calculated with MARKAL-NL-UU.



[van den Broek et al., Energy Policy 2011]

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Final remarks

- CCS and bio-CCS are an essential part of desired global GHG mitigation strategies.
- Within such strategies the role of coal will diminish, but (co-fired) PC and (P/I)GCC +CCS can provide key platforms for large scale bio-CCS on medium term.
- Short term co-firing and building capacity for large scale sustainable biomass supplies is a vital stepping stone.
- Can provide remarkable low mitigation costs and much needed flexibility on short to medium term.

Thanks for your attention

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For more information, see:

- **Sciencedirect/Scopus (scientific)**
- **Google scholar citations (personal)**

J.C. Meerman, C.A. Ramírez, W.C. Turkenburg and A.P.C. Faaij, *Performance of simulated flexible integrated gasification polygenerationfacilities. Part B: economic evaluation*. Renewable and Sustainable Energy Reviews, Vol. 16, Issue 8, Oct 2012, Pp. 6083-6102

J.C. Meerman, A. Ramirez, W. Turkenburg, A. Faaij, *Performance of simulated flexible integrated gasification polygeneration facilities. Part A: A technical-energetic assessment, Renewable and Sustainable Energy Reviews*, Vol. 15, No. 6, Aug 2011, Pp. 2563-2587

Machteld van den Broek, Paul Veenendaal, Paul Koutstaal, Wim Turkenburg, and André Faaij, *Impact of international climate policies on CO_2 capture and storage deployment Illustrated in the Dutch energy system*, Energy Policy, Vol. 39, Issue 4, April 2011, PP. 2000-2019.

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Carlo N. Hamelinck, Geertje van Hooijdonk, André P.C. Faaij, *Future prospects for the production of ethanol from ligno-cellulosic biomass.* Biomass & Bioenergy, Vol. 28, Issue 4, April 2005, Pages 384-410

R. Hoefnagels, M. Banse, V. Dornburg, A. Faaij, *Macro-economic impact of large-scale deployment of biomass resources for energy and materials on a national level—A combined approach for the Netherlands*\, Energy Policy, Vol. 59, Aug. 2013, Pp. 727-744

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