Climate impacts of bioenergy – role of CC(U)S

IEA bio-CC(U)S special project
Sustainability and GHG impact of bio-CC(U)S workshop
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- Climate impact assessment of bioenergy
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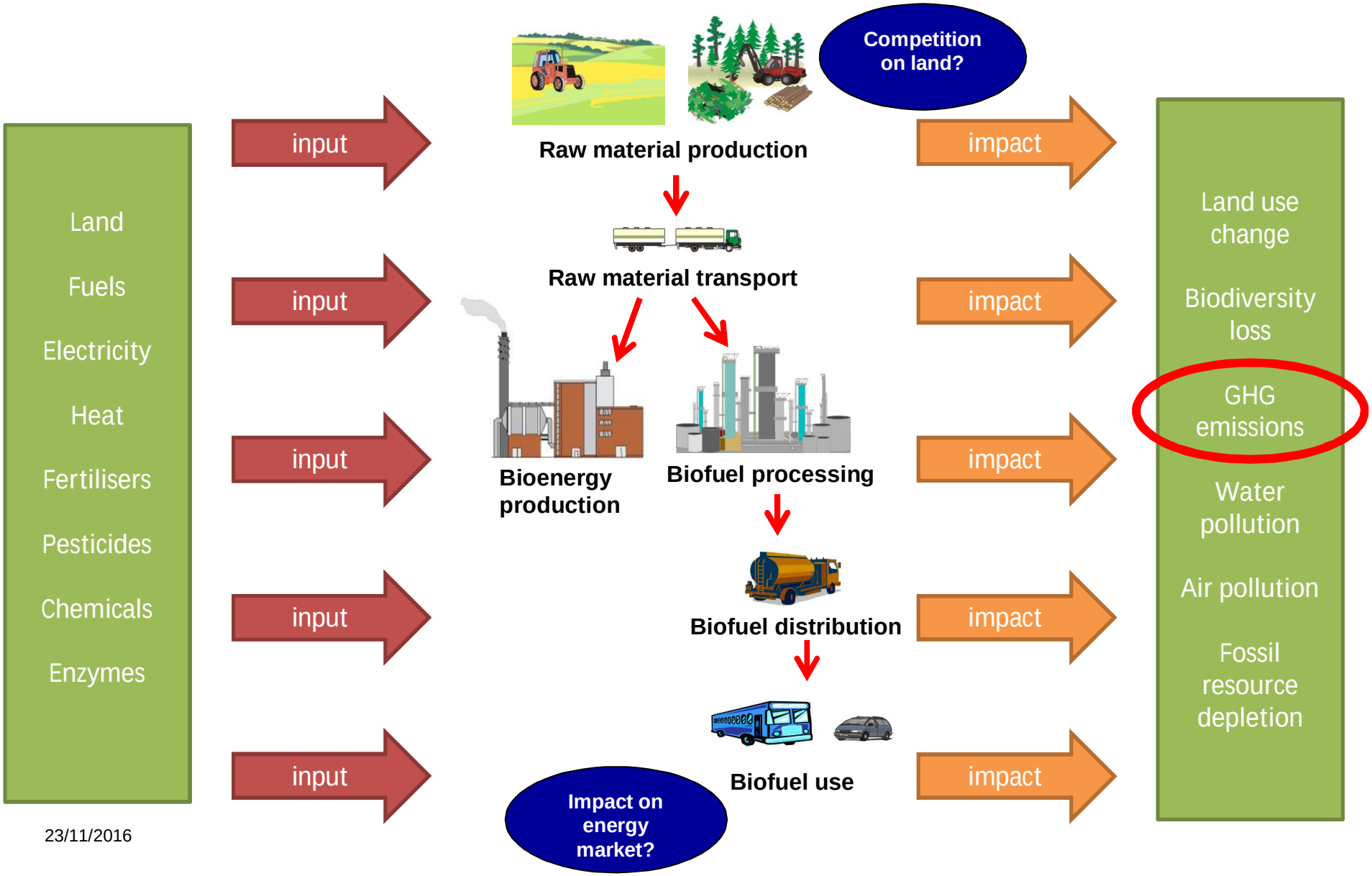
(Extra slides)

Life cycle assessment (LCA) of bioenergy

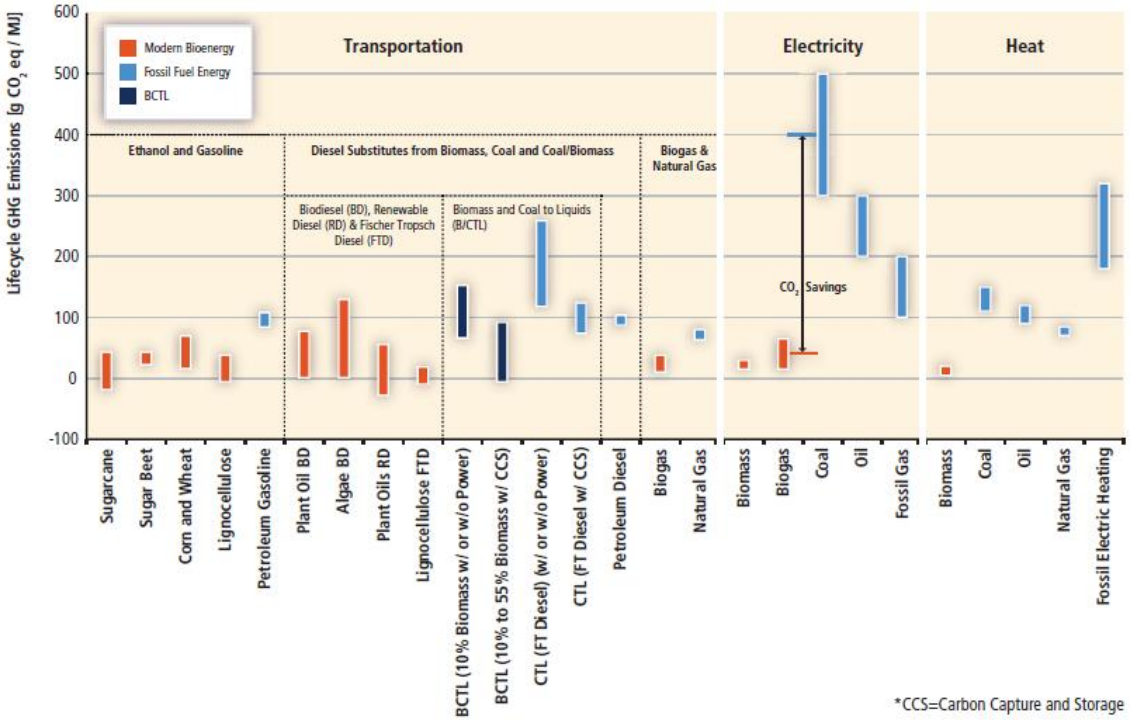


European Union sustainability criteria for biofuels

- GHG emissions are in focus also in the European Union sustainability criteria for liquid and gaseous biofuels in the Renewable Energy Directive (2009/28/EC)
  - 60% emission saving required compared to fossil fuels
  - LCA based approach for the first time in legislation

- New EU sustainability criteria also for solid biomass to be published?

Typical GHG emissions

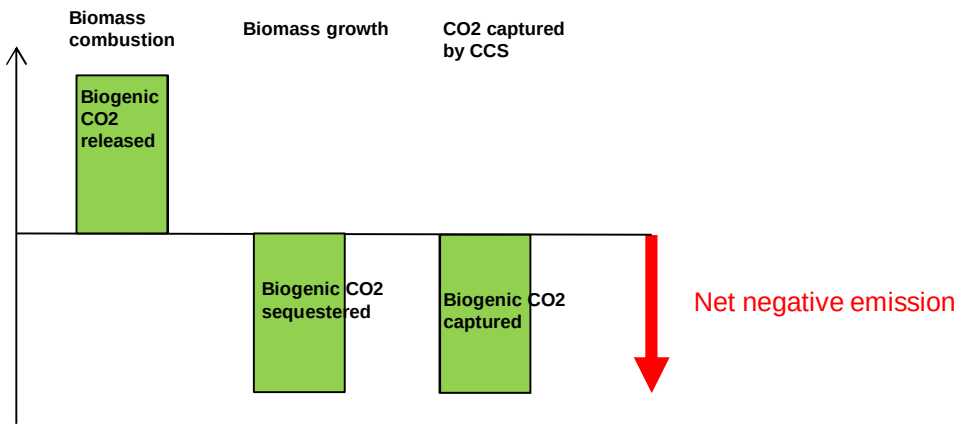


Source: Chum et al. 2014. Bioenergy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation

- Variation in LCA results can occur due to:
  - Case specific features
  - Local conditions
  - Varying LCA methods
    - System boundary
    - Allocation
    - Reference system
  - Data uncertainty

→ Important to understand the assumptions made behind the results

Basic assumption on GHG balances of bio-CCS & negative emissions

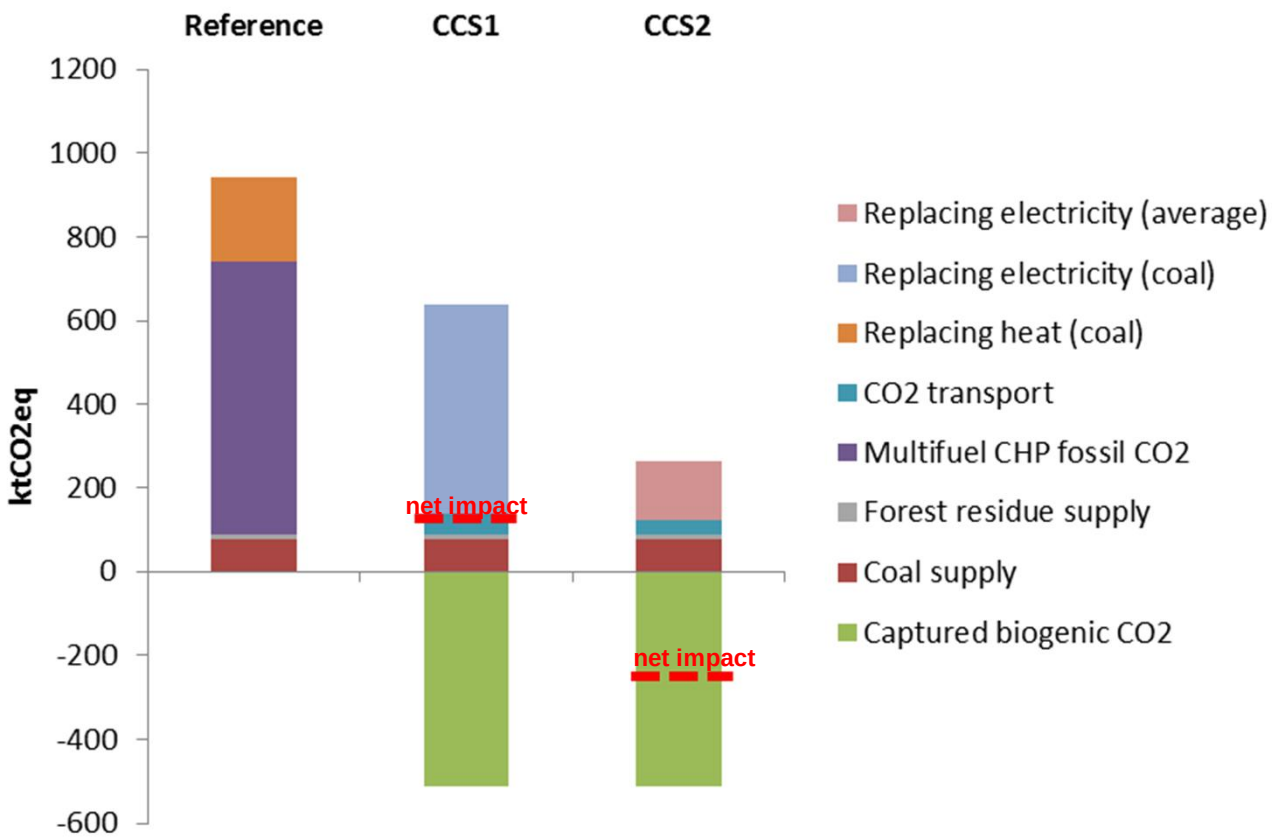


”Sustainable bioenergy” assumption

- Further things to consider:
  - Other life cycle emissions related to the system?
  - The land use change and carbon stock issues related to the biomass?

Example of GHG impacts in bio-CCS

Greenfield oxy-CFB combustion (CHP) utilising 43% forest residues and 57% coal



Functional unit:

- 1.1 TWh/year electricity
- 2.4 TWh/year heat

Scenarios

Reference:

- Replacing heat (277 GWh) produced with coal

CCS1:

- Replacing electricity (514 GWh) produced with coal
- Transport of CO_2 with 10 000 m^3 ship.

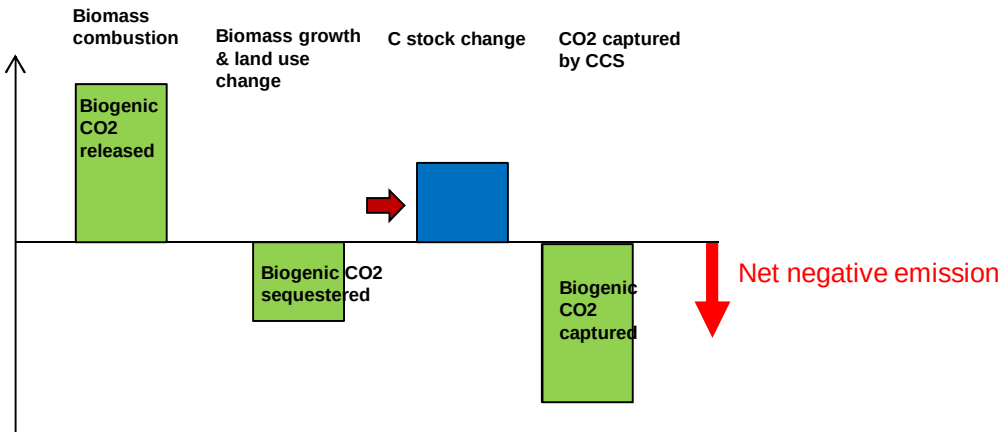
CCS2:

- Replacing electricity (514GWh) considered as Finnish average electricity
- Transport of CO_2 with 20 000m^3 ship

In CCS scenarios 99% of CO2 captured

Source: Modified from VTT 2016. CCSP programme final seminar

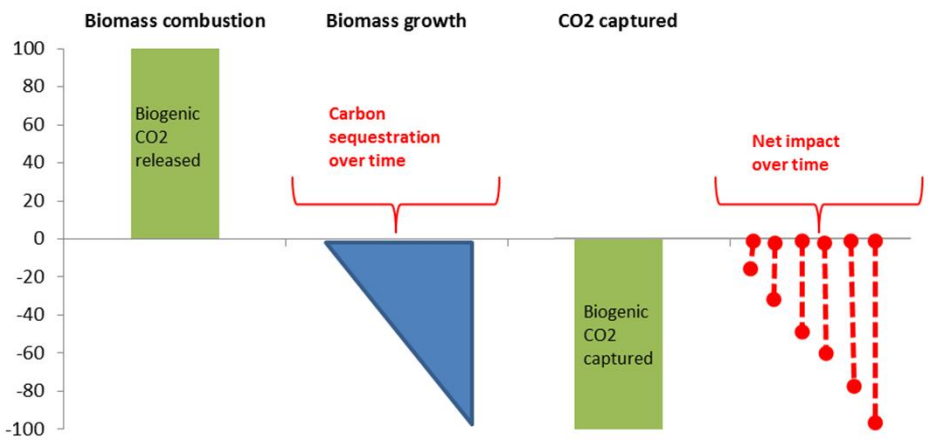
Land use change and carbon stock changes?



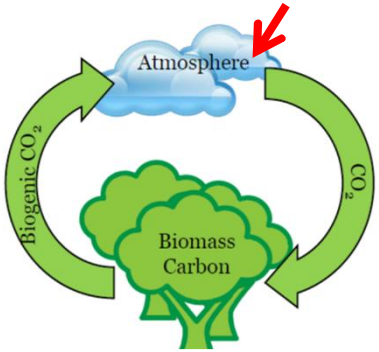
”Non-sustainable” bioenergy due to land use change

- Direct land use change
- Indirect land use change (ILUC)

Impact of temporal scale?

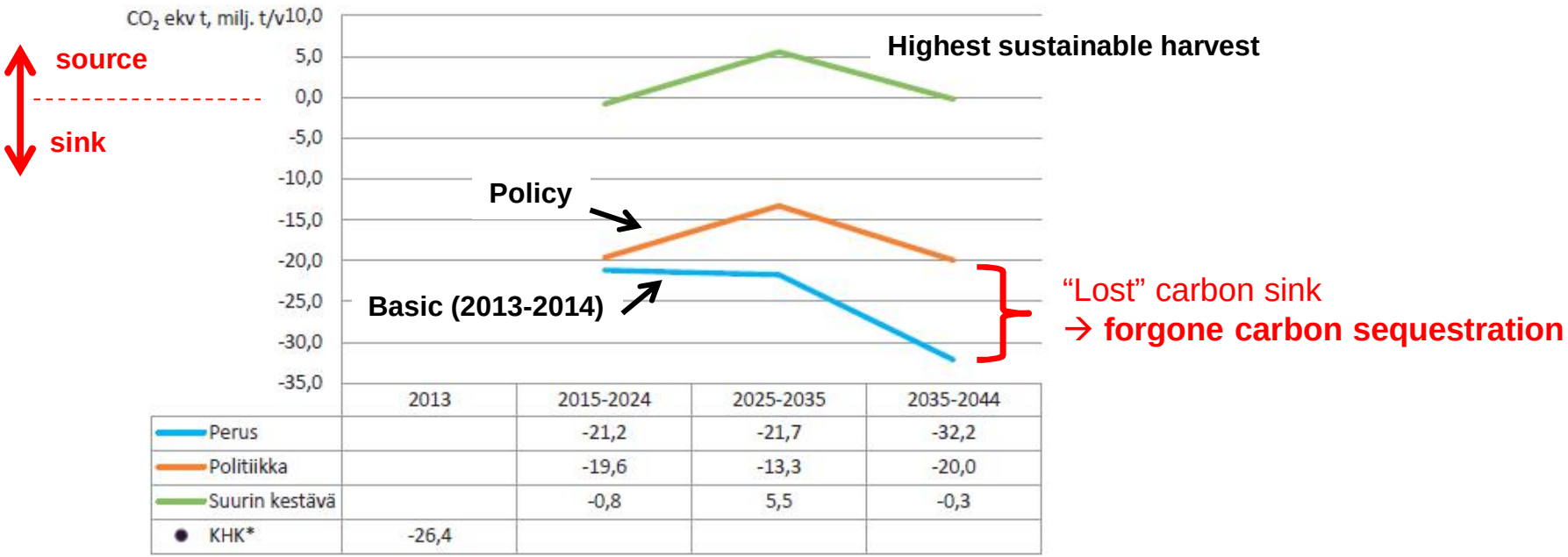


How long time CO_2 stays in the atmosphere?



The effect of additional wood harvesting on the carbon balance on landscape level:

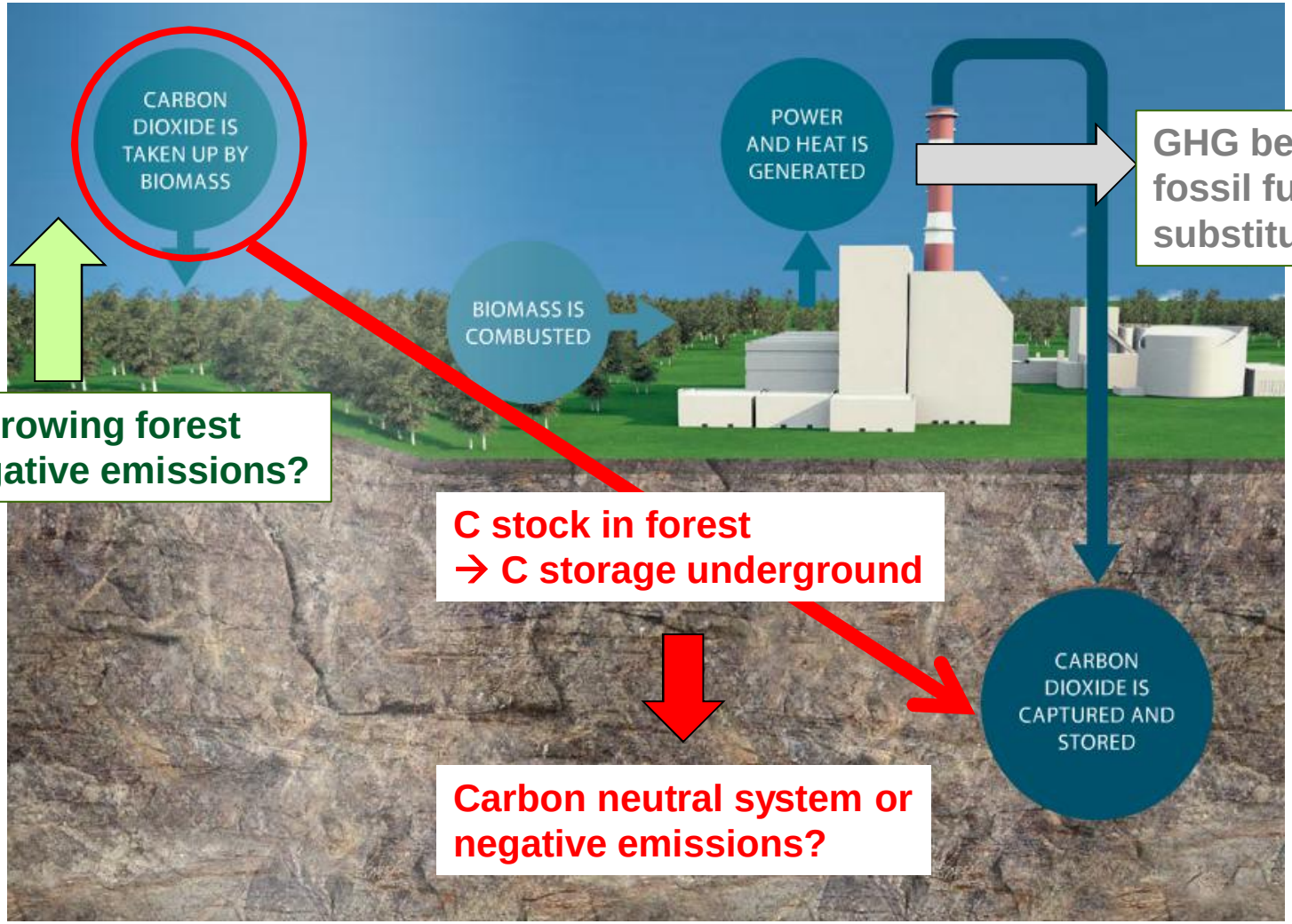
Scenarios on the development of carbon stock in Finnish forests by 2044:



	2013	2015-2024	2025-2035	2035-2044
Perus		-21,2	-21,7	-32,2
Politiikka		-19,6	-13,3	-20,0
Suurin kestävä		-0,8	5,5	-0,3
KHK*	-26,4			

Source: Kallio et al. 2016. Skenaariolaskelmiin perustuva puuston ja metsien kasvihuonekaasutaseen kehitys vuoteen 2045. (Scenarios for Finnish Energy and Climate strategy)

Climate impacts of bio-CCS?



New growing forest → negative emissions?

GHG benefits from fossil fuel substitution

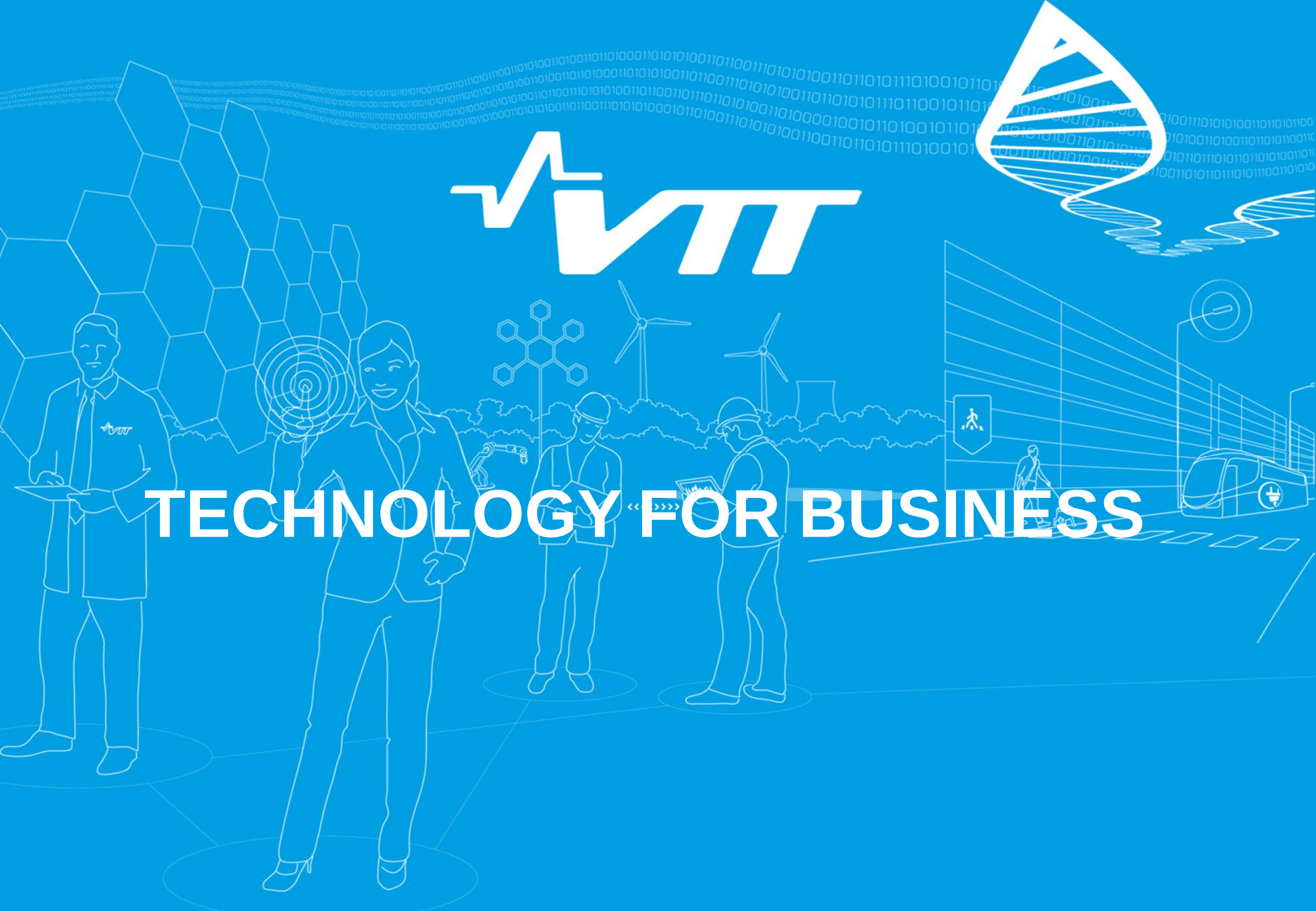
C stock in forest → C storage underground

Carbon neutral system or negative emissions?

Figure adapted from: Teir et al. 2016. CCSP programme final report

Conclusions

- The GHG impacts due to carbon stock changes in biomass reservoirs are an important factor
  - No agreement on how these should be included in LCA
  - Currently not included in the EU sustainability criteria for biofuels
- The climate impact assessment of bioenergy systems can include uncertainties and different assessment methods provide different conclusions
  - Very important to understand the assumptions made in order to interpret the results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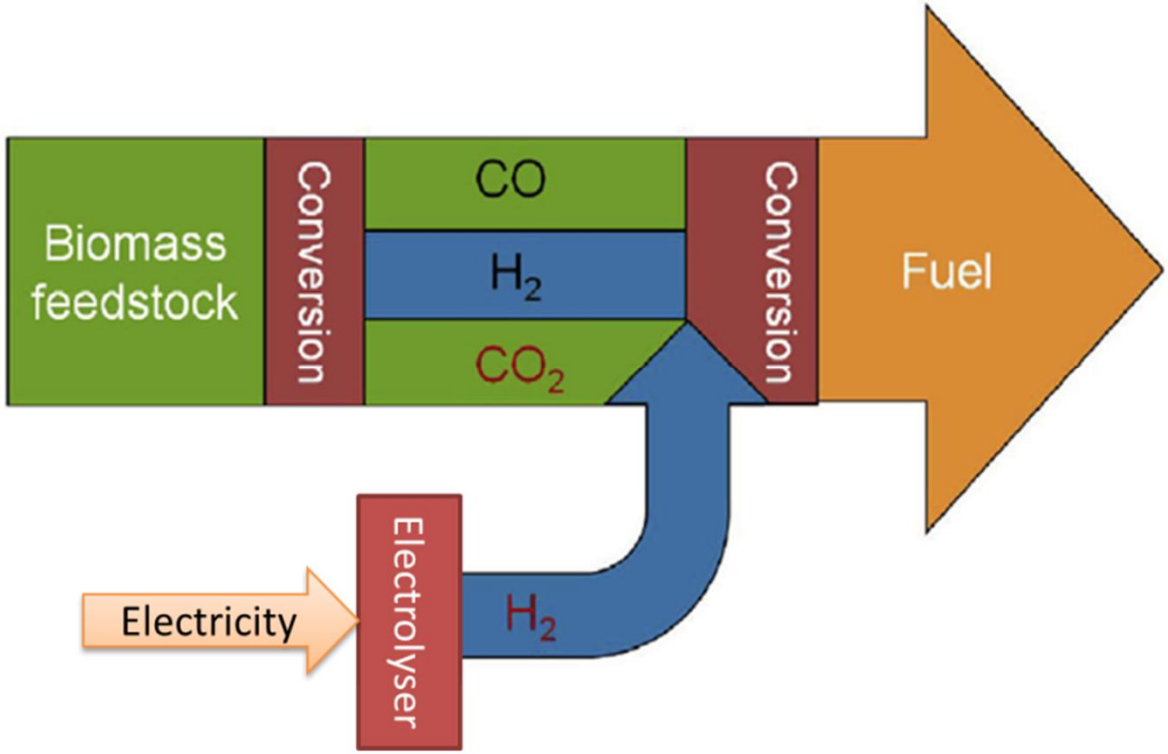
EXTRA SLIDES:

Example of bio-CCU

Example of bio-CCU

- Hydrogen enhanced synthetic biofuel



SUMMARY: Fuel output from 100 MW_{bio} input

When the maximally enhanced by an external H2 source, following increases in fuel output can be observed:

- **2.2-fold** (methane) or **1.9-fold** (gasoline) for steam gasification;
- **3.1-fold** (methane) or **2.6-fold** (gasoline) for oxygen gasification.

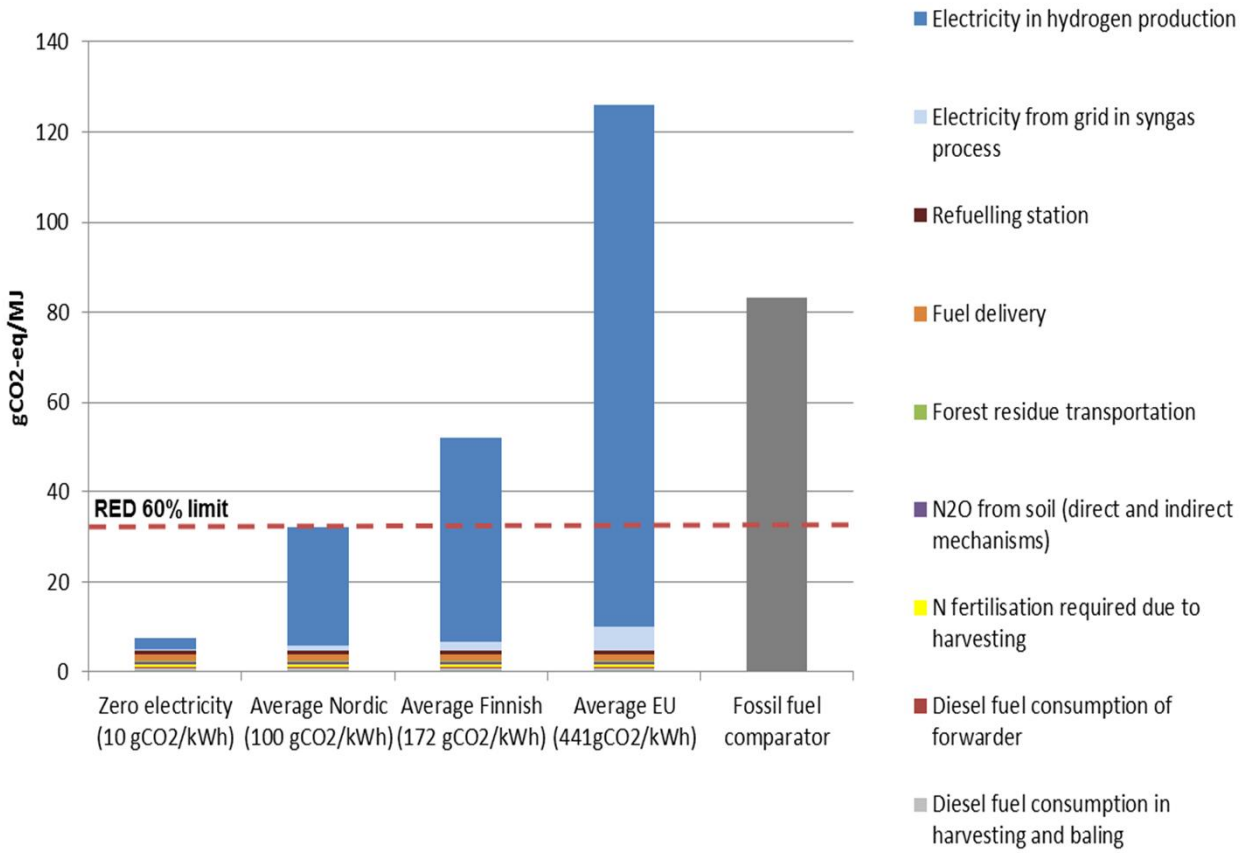
Overall carbon conversions for enhanced configurations:

- **67.0%** (methane) and **58.4%** (gasoline) for steam gasification;
- **98.0%** (methane) and **79.4%** (gasoline) for oxygen gasification.

Econ. feasible over base case when low-GHG H2 cost lower than

- 2.2 €/kg (methane) and 2.7 €/kg (gasoline) for steam gasification;
- 2.4 €/kg (methane) and 2.8 €/kg (gasoline) for oxygen gasification.

GHG balances calculated according to the EU sustainability criteria



Source: Koponen & Hannula 2016 (submitted paper)