GHG sustainability of biomass and bionenergy

Implications of system boundaries, dynamics and uncertainties

Kim Pingoud[1], Leif Gustavsson[2], Sampo Soimakallio[1], and Ilkka Savolainen[1]

[1] VTT Technical Research Centre of Finland, [2] Mid Sweden University

Mittuniversitetet
MID SWEDEN UNIVERSITY

Expert Consultation Sustainable Biomass,
25 – 26 October 2007, Dubrovnik, Croatia

VTT

Outline

- Definition and criteria of GHG sustainability
- Major issues when evaluating sustainability
  - System boundaries
  - Dynamics
  - Parameters
  - Uncertainties
- Indicators of GHG sustainability

Definition of GHG sustainability of biomass and bioenergy? (1)

1. Biomass must be renewable
   - Regrowth of new biomass - time horizon important
   - CDM Executive Board definition of renewable biomass is too strict Example:

Biomass is "*renewable*" if one of the following five conditions applies:

…

4. The biomass is a **biomass residue**[2] and the use of that biomass residue in the project activity **does not involve a decrease of carbon pools, in particular dead wood, litter or soil organic carbon**, on the land areas where the biomass residues are originating from.

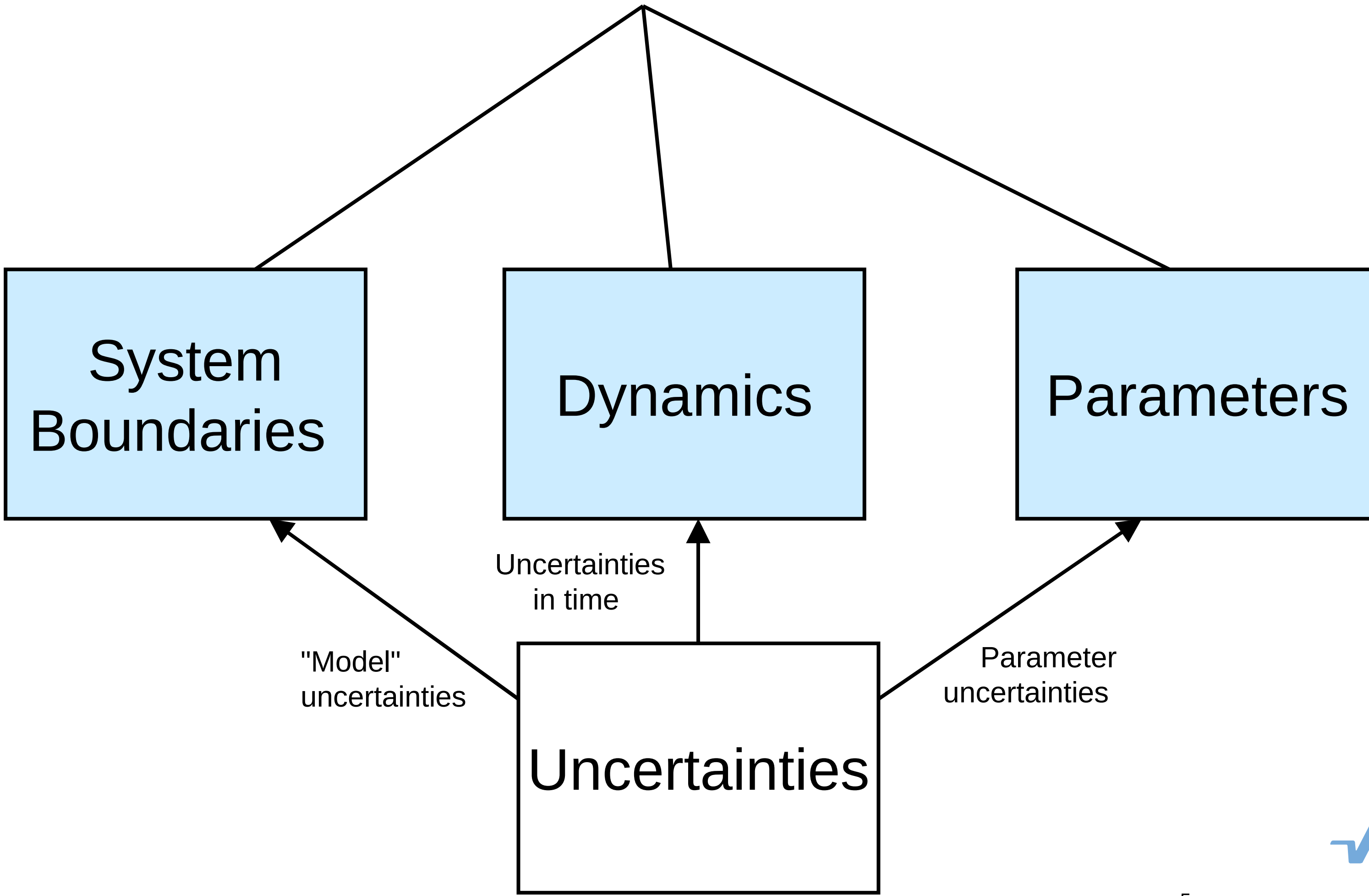
…

[2] Biomass residue is defined as biomass by-products, residues and waste streams from agriculture, forestry, and related industries. (Please refer to Annex 8 of the report of the twentieth meeting of the Executive Board, see http://cdm.unfccc.int/EB/Meetings/020/eb20rep.pdf).

Definition of GHG sustainability of biomass and bioenergy?(2)

2. Biomaterial/bioenergy used must contribute to GHG mitigation
   - Biomass (and available land) is a limited resource
   - Atm. GHG stabilisation within next few decades is a huge target ⇒ Biomass resources should be used *as efficiently as possible* (e.g. high conversion efficiency and, if possible, cascading of material and energy-use)
   - GHG sustainable use of biomass a *quantitative* rather than *qualititative* concept, measured by the GHG benefits of the whole lifecycle

Evaluation of GHG sustainability: key factors to be considered



System boundaries (1)

Two basic, distinct viewpoints:

1) "Absolute" emissions: Atmospheric GHG balance of biomass stocks + GHG emissions from biomass use chain
2) "Relative" emissions: Emissions 1) relative to a functionally equivalent reference system (e.g. fossil-fuel based, business as usual)

The second viewpoint is basically more relevant in climate change mitigation: How to reduce emissions compared with the existing practice?

System boundaries (2)

Difficulties and uncertainties in definition:

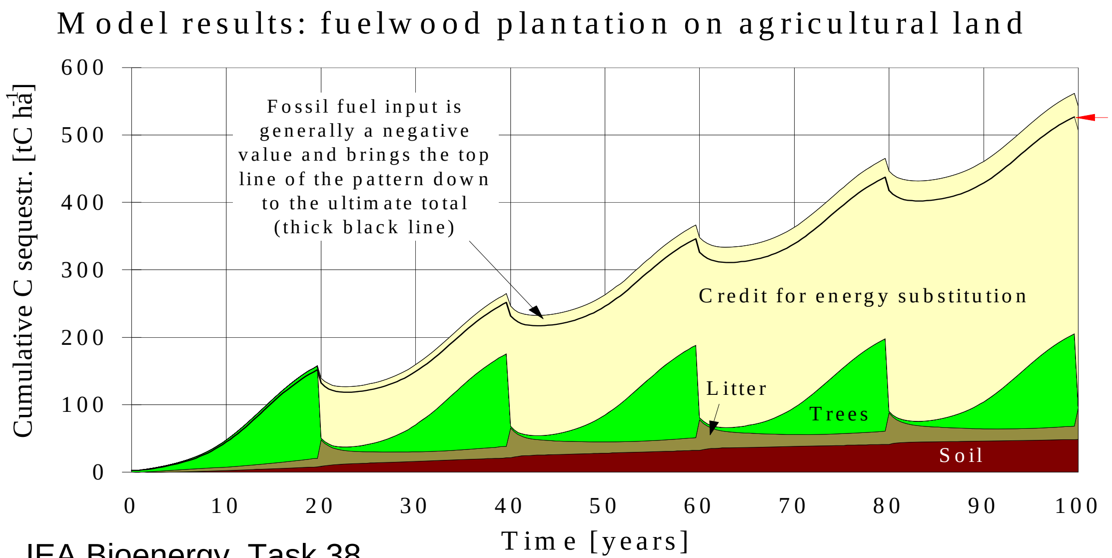
- What is the functional unit
- Description of the full process chain
- Definition of the reference system
- Main products and by-products
- How to valuate macro-economic impacts?

System boundaries (3)

- Examples of imaginable macro impacts from increasing demand for biofuels :
  - Palm oil production may have an influence on fires of tropical peatswamp forests
  - Corn ethanol production in US may lead to increasing demand for Brasilian soy driving Amazon deforestation
- Broader system boundaries to be considered; worst case analysis needed

Dynamics (1)

- Dynamics of biomass stocks
  - In the long run: GHG benefits from fossil energy and material substitution



IEA Bioenergy, Task 38

  - The dynamics is often neglected or integrated over some long time horizon (e.g. 100 yrs)

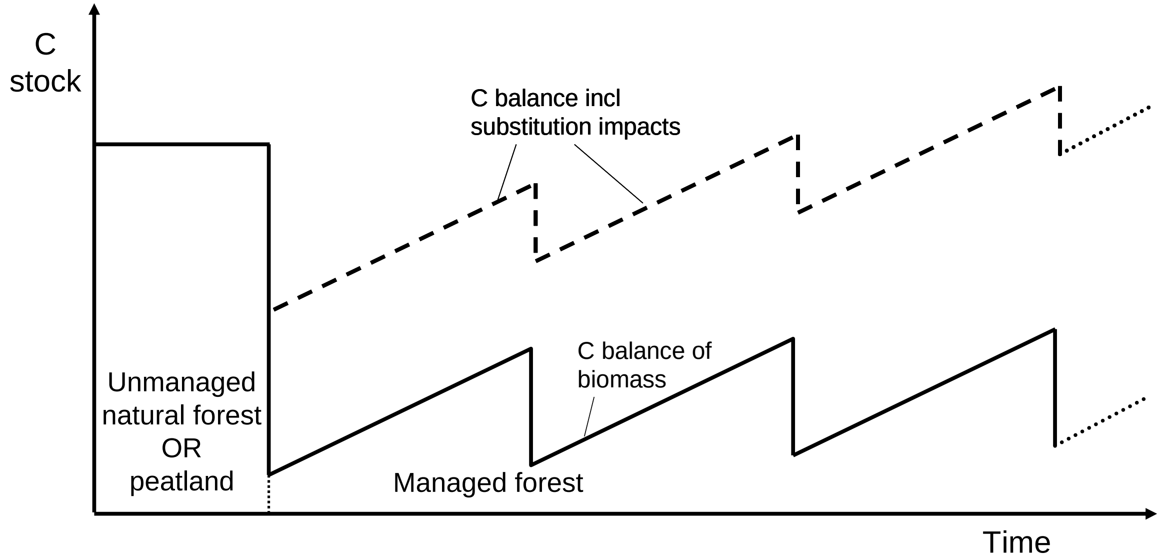
Dynamics (2)

- The GHG benefits in a short time horizon are also relevant:
- Time horizon of climate change mitigation:
  - Currently CO_2 380 ppm, other GHG 50 ppm $CO_{2\,eq}$ = 430 $CO_{2\,eq}$
  - Increase rate 2 ppm/yr
  - 450 ppm corresponds equilibrium warming of 2°C
  - After 10 years we are over the 450 ppm and the critical 2°C boundary
  - Hence, the effective measures should be assessed using short time horizon
- The measures, however, should be balanced with another essential time horizon:
  - Time required for development/commercialisation of new renewable energy and material technologies
  - Securing their resources in the future, e.g. biomass supply

Dynamics (3)

Examples:

- Big initial biomass C stock, e.g. old-grown forest, peatland:



- Uncertainties, risks depending on the measures:
  - Harvest and change into managed forestry ⇒ regrowth of biomass can take very long, GHG benefits can be realised after several rotations – even when the substitution impacts are included; uncertainties in assessing GHG impacts: future land and biomass use, changing energy technologies and changing climate

Dynamics (4)

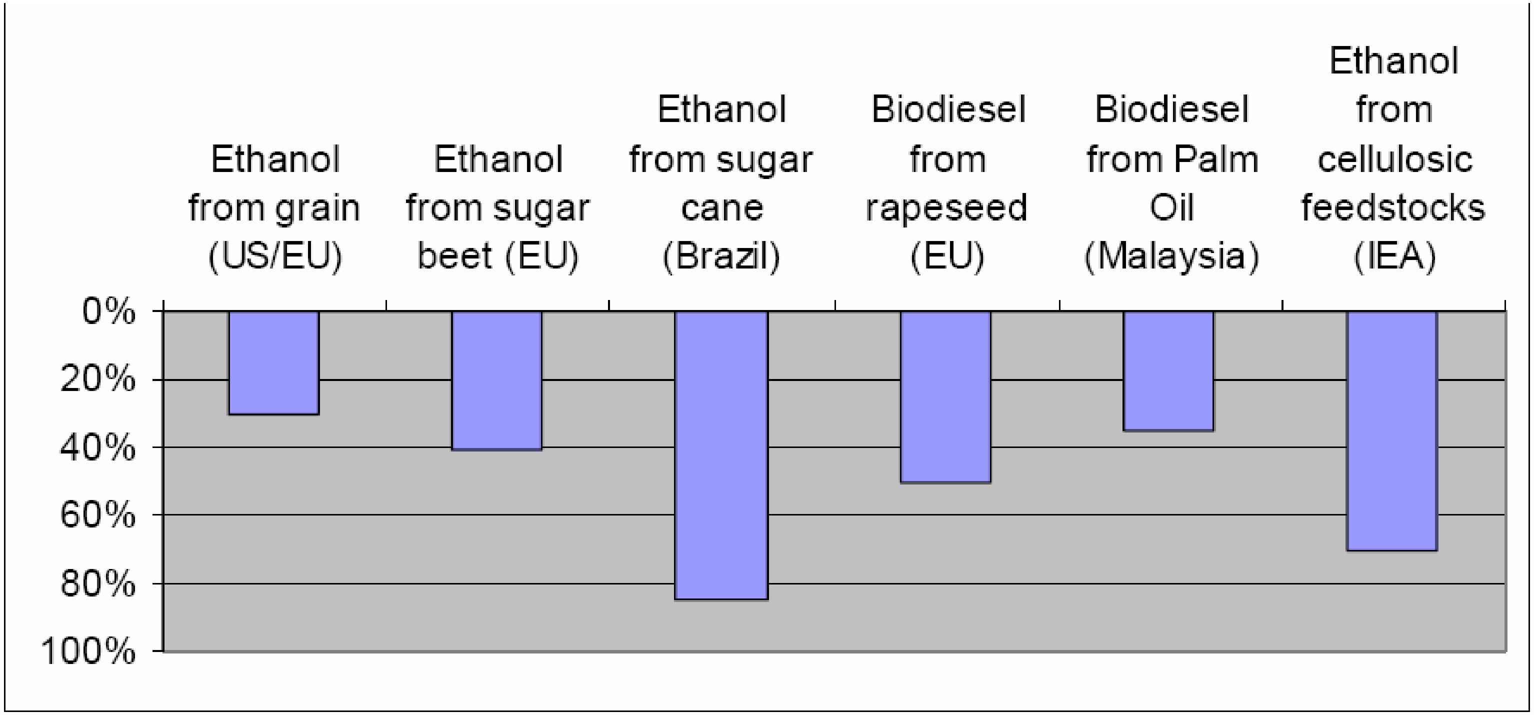
- Example:
  - Uncertainties, risks depending on the measures:
    - Conservation of big biomass C stocks $\Rightarrow$ in some cases risk of natural disturbances, forest fires, insects, etc. together with changing climate; instant C emissions, no substitution benefits
    - Tropical deforestation and larg-scale transformation into cropland and biofuel plantations $\Rightarrow$ risk of irreversible changes in climate of large areas (e.g. Amazon), drought, fires; loss of big carbon stocks from the previous biomass and soil, N_2O emissions from fertilizers needed for the monocultures; low relative GHG benefits from substitution by liquid biofuels
    - Drainage of tropical peatlands and peatswamp forests (e.g. in Indonesea) $\Rightarrow$ loss of carbon through oxidation, high risks of forest fires, irreversible loss of a huge biomass stock (about 50 billion tonnes or 50 Pg C in South-east Asia's peat); the main driving force being the biofuel plantations

Parameters (1)

- Existing practice: typical average values
- Uncertainties:
  - How to valuate purchased energy, electricity marginal average emission factors
  - Soil carbon, N_2O default values
  - Yield rate, natural yearly variations
  - High uncertainties of transport biofuel cycle, especially in N_2O

Parameters (2)

GHG benefits often presented by single numbers:

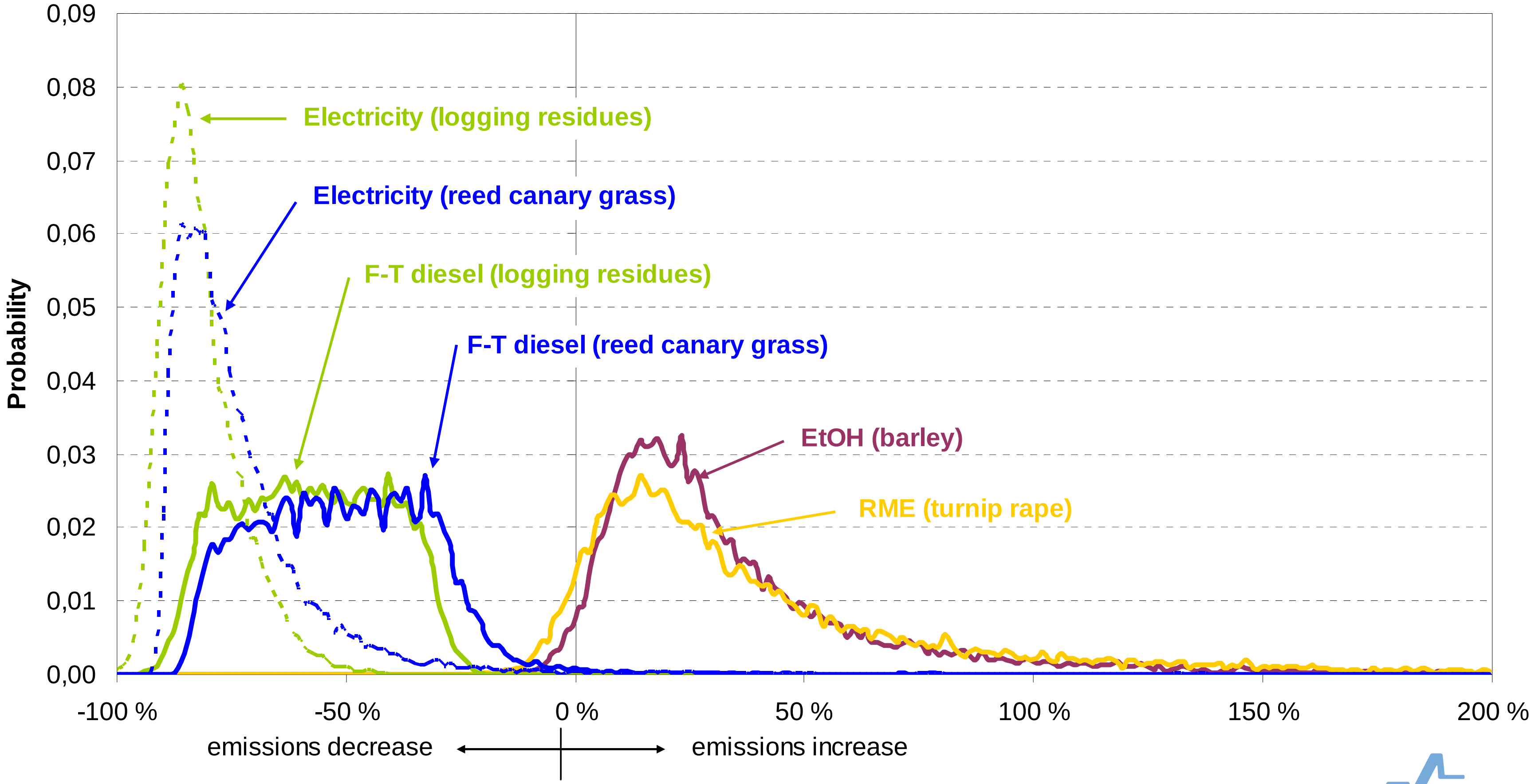


Source: IEA, 2005 and EMPA (biodiesel from Palm oil). Note: Reduction in well-to-wheels CO_2-equivalent GHG emissions per kilometre.

Parameters (3)

But the parameter uncertainty is a major factor:

Probability distributions for relative greenhouse gas emission impact when replacing fossil fuels

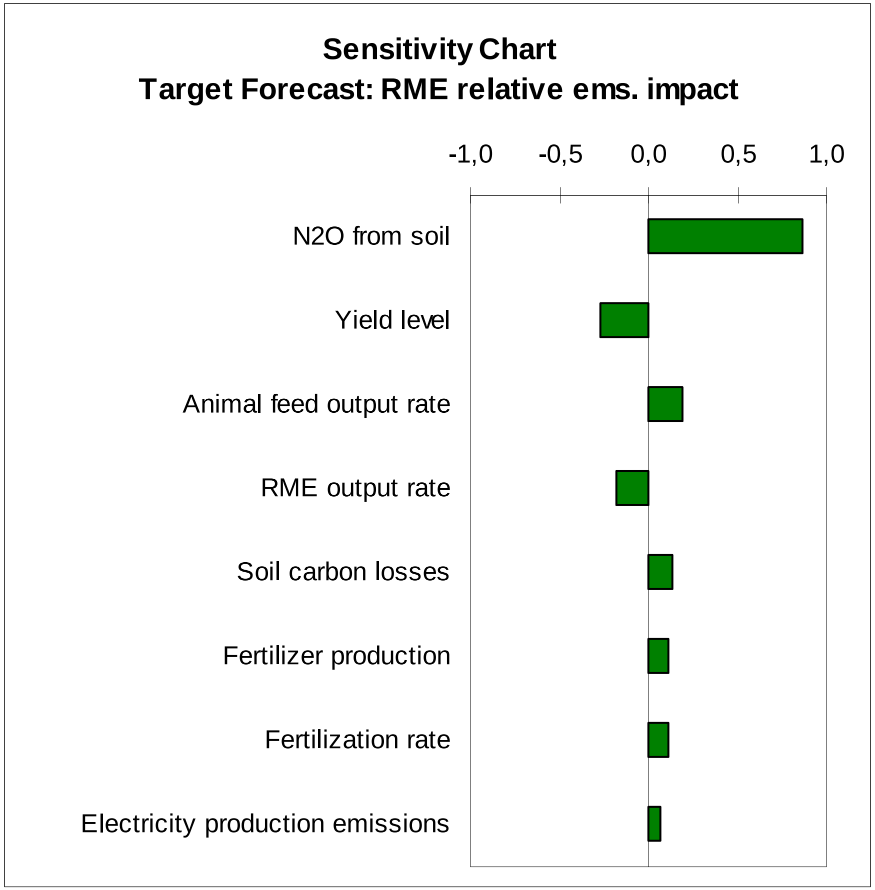


Soimakallio et al. (2007)

Parameters (4)

Sensitivities for relative GHG emission impact

- **RME (turnip rape)**
  - N2O from soil (0,9)
  - Yield level (-0,3)
  - Animal feed output (0,2)
- **EtOH (barley)**
  - N2O from soils (0,8)
  - electricity production (0,3)
  - Yield level (-0,3)
- **F-T diesel (logging residues)**
  - electricity production (1,0)
  - soil carbon losses (0,2)
- **F-T diesel (reed canary grass)**
  - electricity production (0,9)
  - N2O from soils (0,2)
  - Yield level (-0,2)
- **Electricity (logging residues)**
  - replaced electricity (-0,7)
  - soil carbon losses (0,7)
- **Electricity (reed canary grass)**
  - replaced electricity (-0,7)
  - N2O from soils (0,5)
  - Yield level (-0,4)



Soimakallio et al. (2007)

Possible sustainability indicators

- Complementary indicators (where emission reduction is implicitly integrated over some time period):
    - *Emission reduction/functional unit is often used;*
    - *But more relevant from GHG sustainability point of view are:*
        - *Emission reduction/amount of biomass* when comparing various end-uses of biomass, or
        - *Emission reduction/amount of land area used, being* fundamental, as land available is a limited resource
- Time horizon should be considered more explicitely:
    - Thus dynamic indicators needed such as *cumulative radiative forcing*
- Uncertainty analysis a real issue:
    - Uncertainty bounds should be estimated
    - Worst case analysis required