



Integration of Land Use Change into Life-cycle Analysis

Transportation Biofuels: For greenhouse gas mitigation, energy security or other reasons ?

IEA Bioenergy Task 38: Greenhouse Gas Balances of Biomass and Bioenergy Systems
Salzburg, Austria

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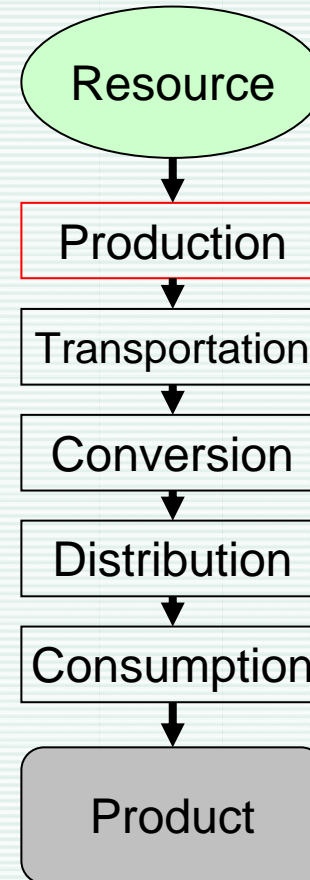
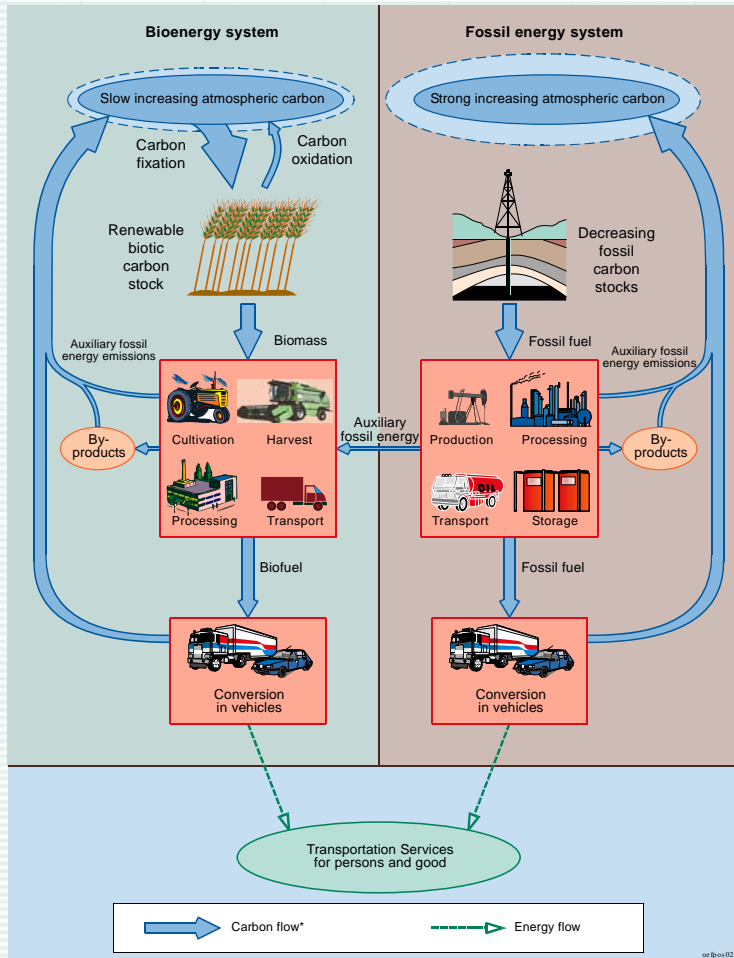
.....
a TRADITION of INNOVATION



Overview

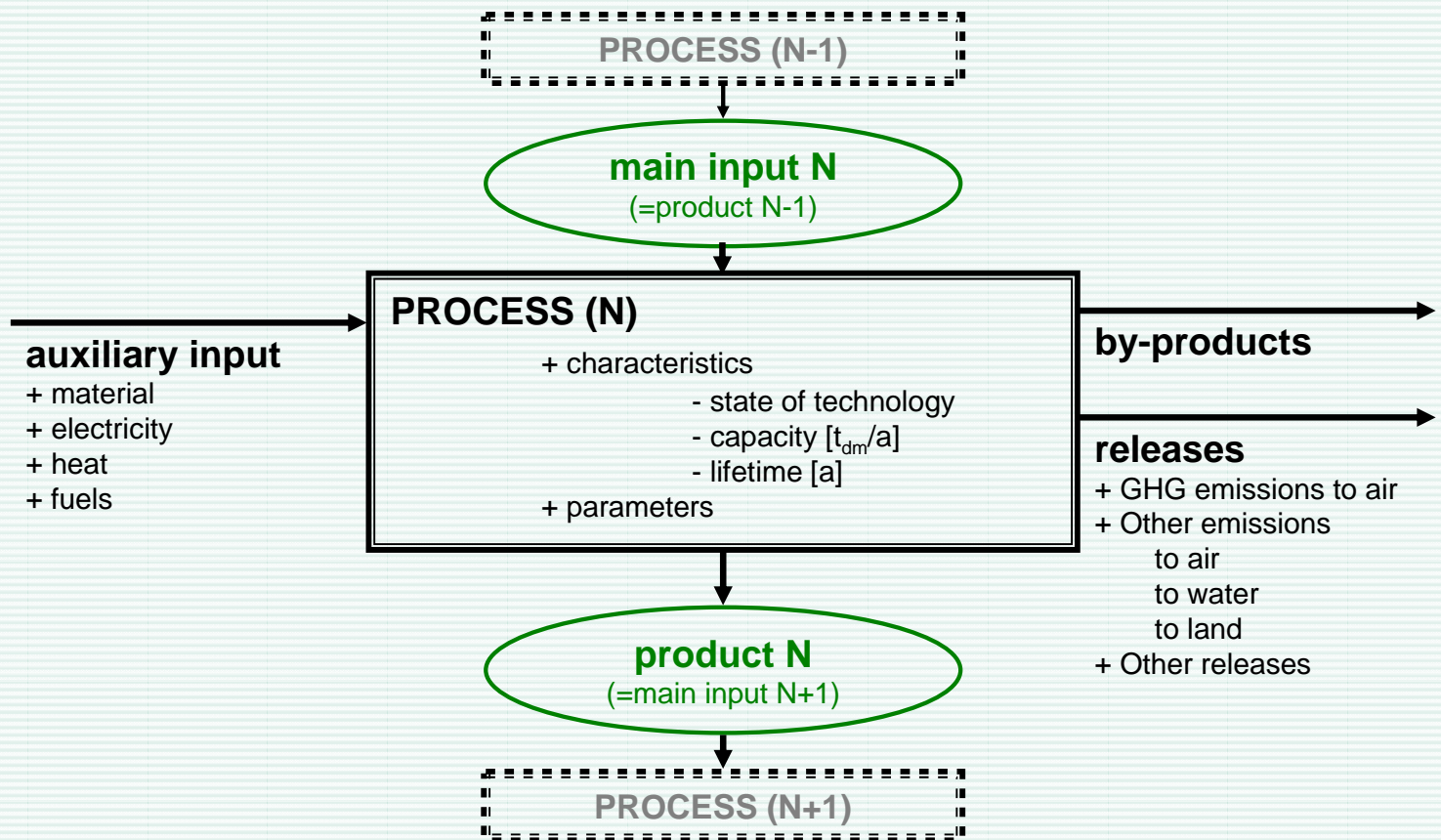
- **Task 38 – Standard Methodology**
- **Land use as a process**
- **Equivalency**
 - ➔ Albedo and GHG emissions
- **Comparing systems**
- **Damage functions**
- **Timing and time-value of damages**
- **Conclusions**

Task 38 – Standard Methodology





Generic Process

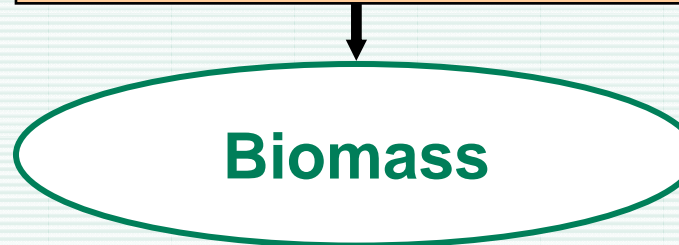
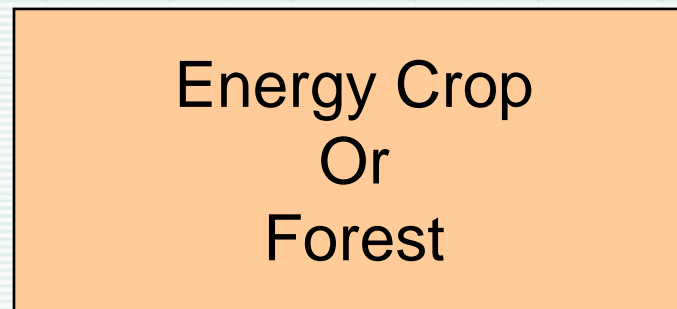




Land use as a Process Bioenergy System

Oxygen
CO₂
Other GHGs
Water
Sunlight
Soil
Contaminants

Fertilizer
Pesticides
Other Soil Additives
Fossil fuels



Oxygen
CO₂
Other GHGs
Water
Water vapour
Reflected light
Soil
Contaminants

Biodiversity
Recreation

Wood products
Other forest products

Fodder
Food
Other food products

Lodging



Land use as a Process Fossil Fuel System

Oxygen
CO2
Other GHGs
Water
Sunlight
Soil
Contaminants

Fertilizer
Pesticides
Other Soil Additives
Fossil fuels



Oxygen
CO2
Other GHGs
Water
Water vapour
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Wood products
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Lodging



Equivalences

■ GHGs \Rightarrow CO₂e

→ Global Warming Potential

■ CO₂e \Rightarrow Climate forcing

■ Albedo change \Rightarrow CO₂e

→ Light land surfaces reflect more energy

→ Change in land use to a darker surface \Rightarrow CO₂e

→ Betts (2000) - A/R in areas with snow

→ Schaeffer et al (2006) – Bioenergy crops in snowy climates

→ Field et al (2007) – Any land-use change

→ Sensitivity:

■ Latitude, snow depth, cloud cover, atmospheric absorption, drought

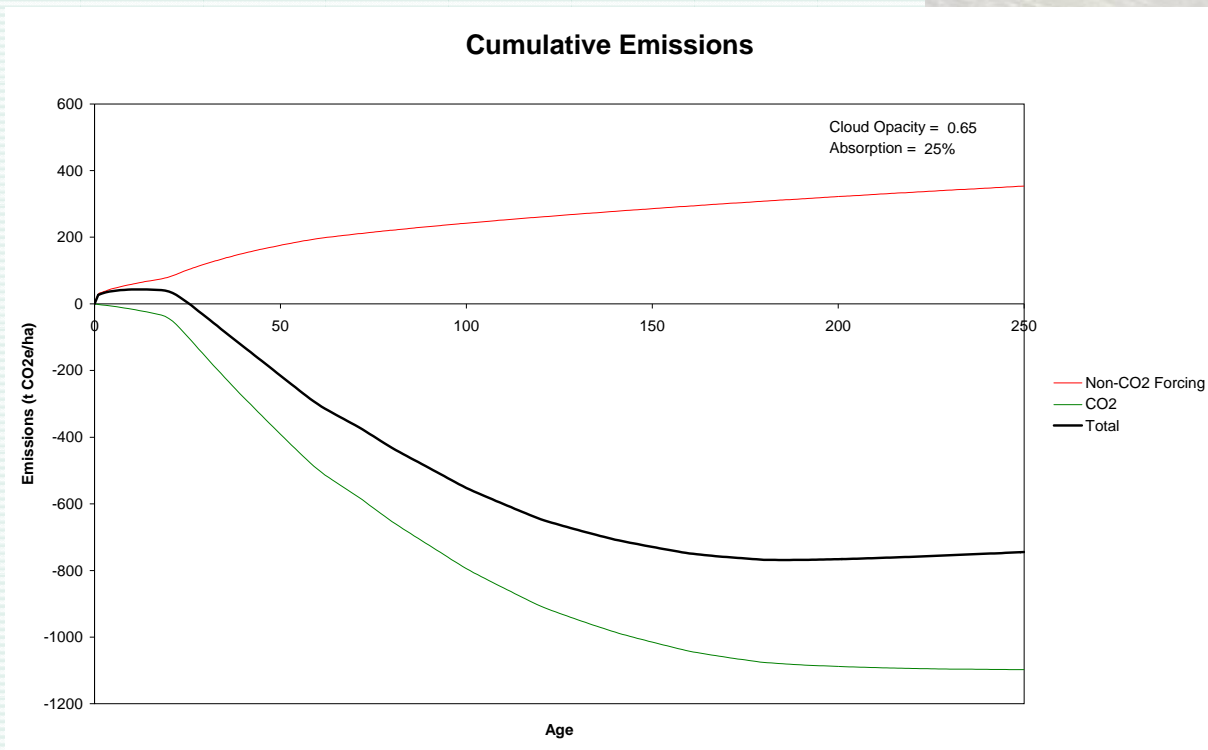
■ Tree type, growth rate, canopy closure



Reforestation Areas with Snow



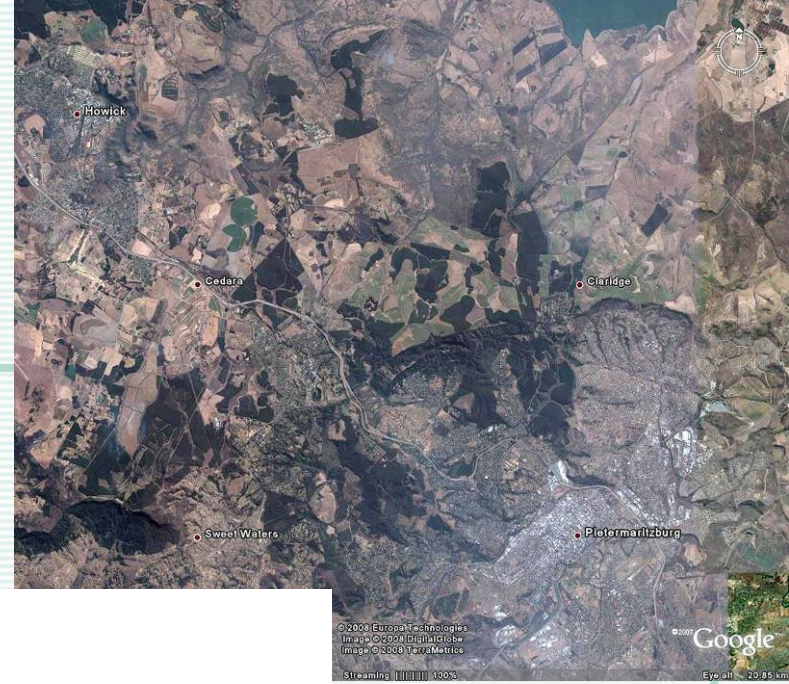
Spruce plantation
Prince George, Canada



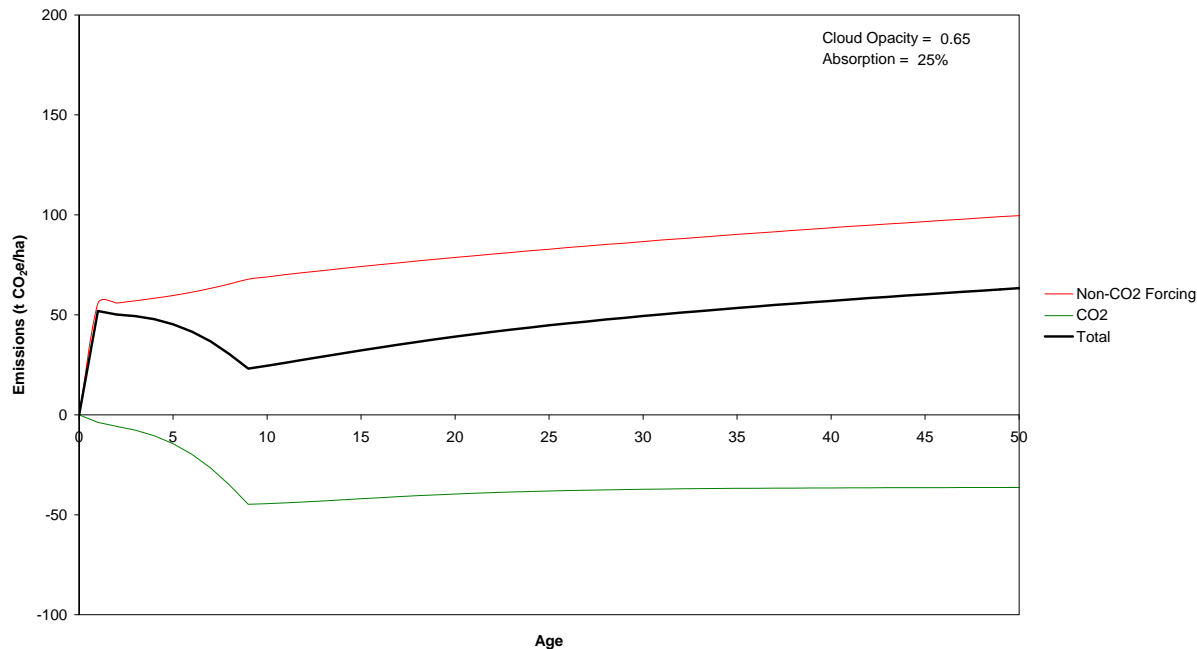


Crop Changes Savannas

Jatropha plantation
Johannesburg, South Africa



Cumulative Emissions



* very preliminary model – do not quote



Comparing Systems

Bioenergy system

Energy Crop

Food Crop

Corn

Food Crop 2

Wheat

Grassland

Fossil fuel system

Food Crop

Corn

Food Crop 2

Wheat

Grassland

Other
Values



Options for Comparing Systems

- **Ignore**
- **Standardization**
 - ➔ First land use change
- **Optimal system**
 - ➔ Linear combination of land uses that minimizes the difference in services and by-products provided
- **Combine into a weighted value**
 - ➔ UBP 60 or Eco-indicator 99
- **Accept and report the differences**
 - *“The energy system reduces CO₂ by X AND service is decreased by Y”*
 - Damage functions



Damage Functions

■ **Relative measure of damage**

■ **Decrease in ecological value**

→ Biodiversity, soil structure, water

■ **Increase in pollutants**

→ GHGs, PMs, POCs, heavy metals

■ **Decrease in consumer products**

→ Energy, wood, pulp, food

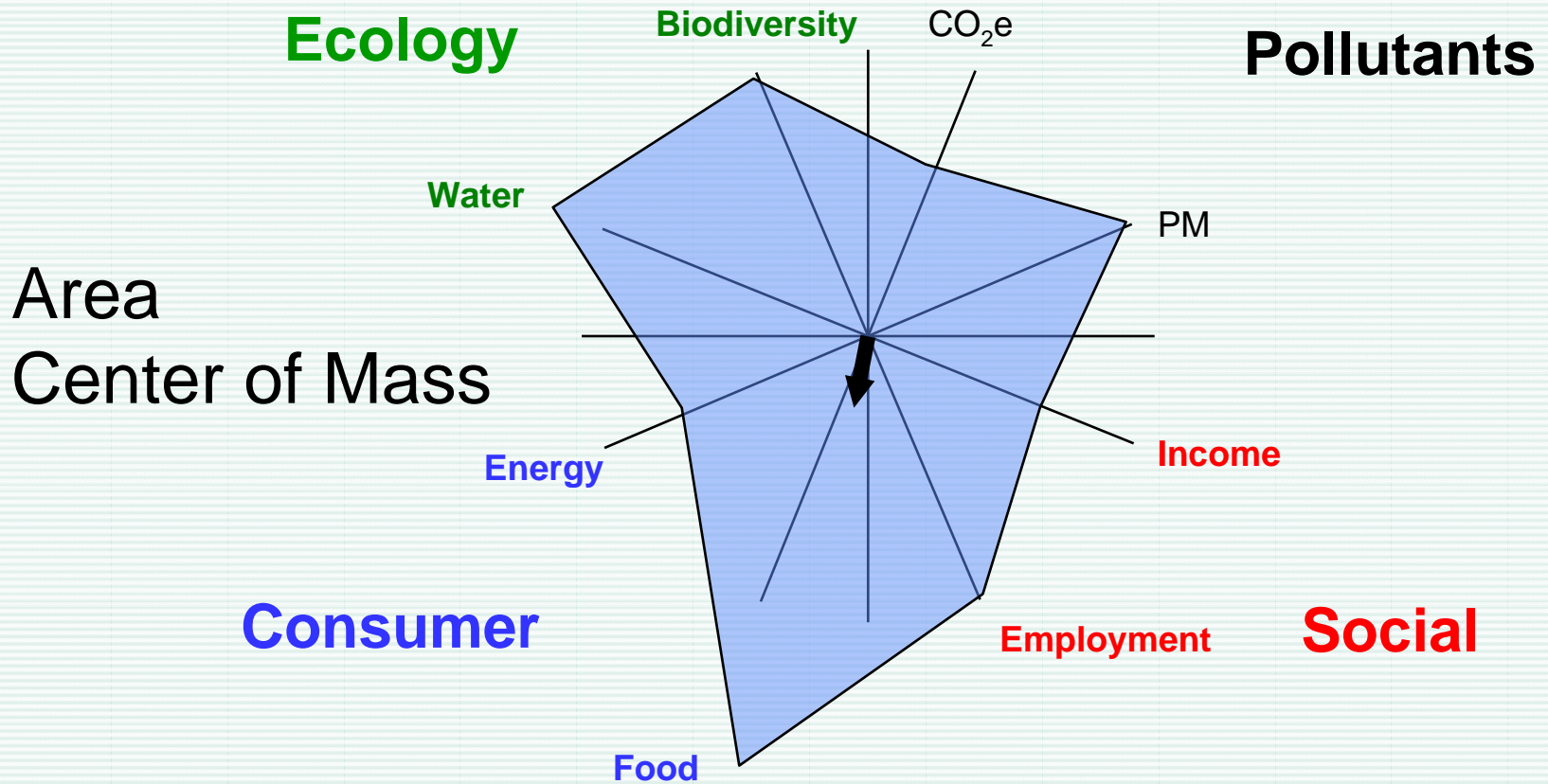
■ **Decrease in social values**

→ Income, employment, recreation, land tenure

$$D_{GHG} = \frac{GHG_{Study}}{GHG_{Reference}}$$



Damage Spiders



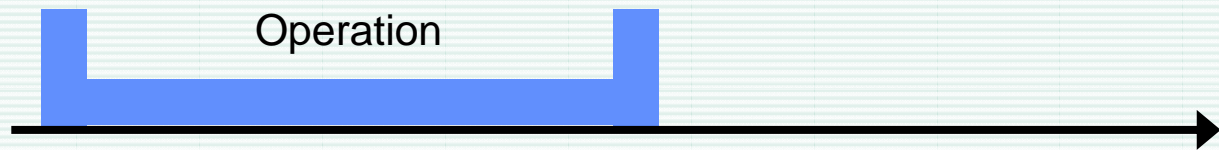


Timing Issues

Factory

Construction

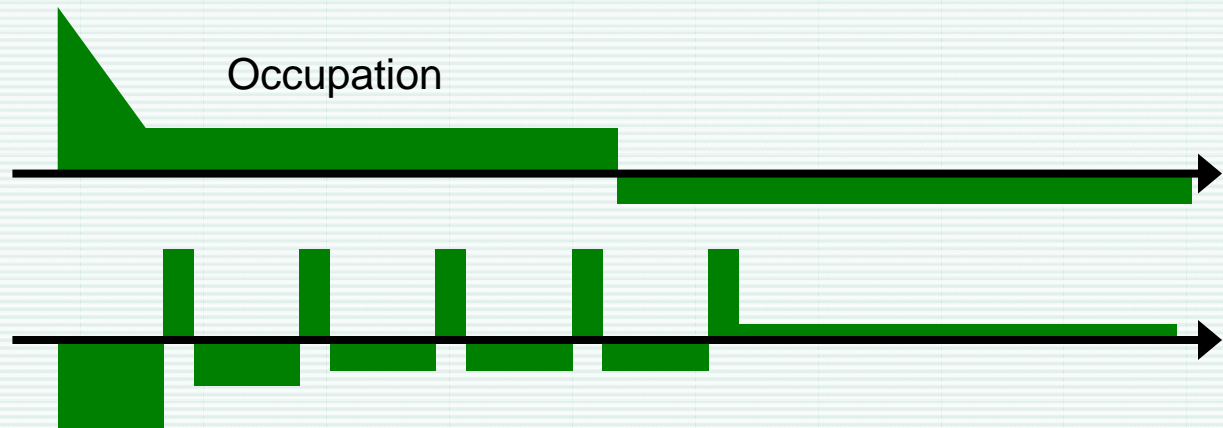
Restoration



Land-Use Change

Transformation

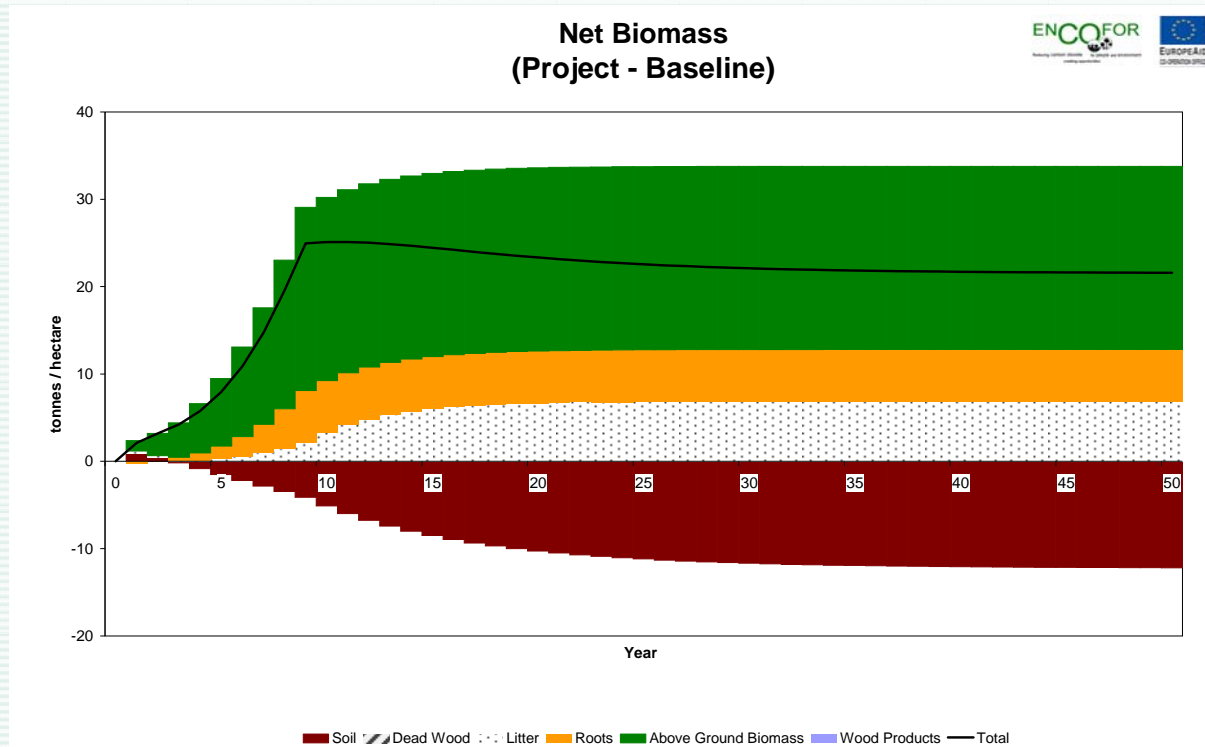
Restoration





Transformation and Timing

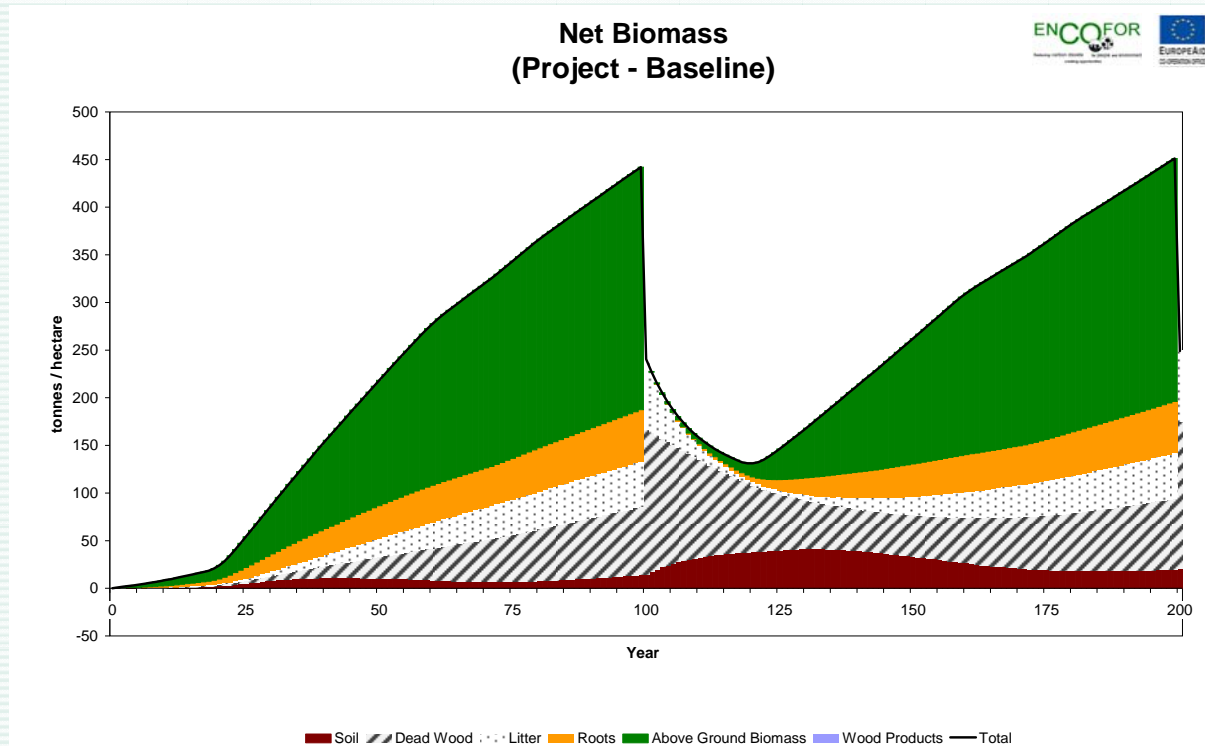
Jatropha plantation
Johannesburg, South Africa





Transformation and Timing

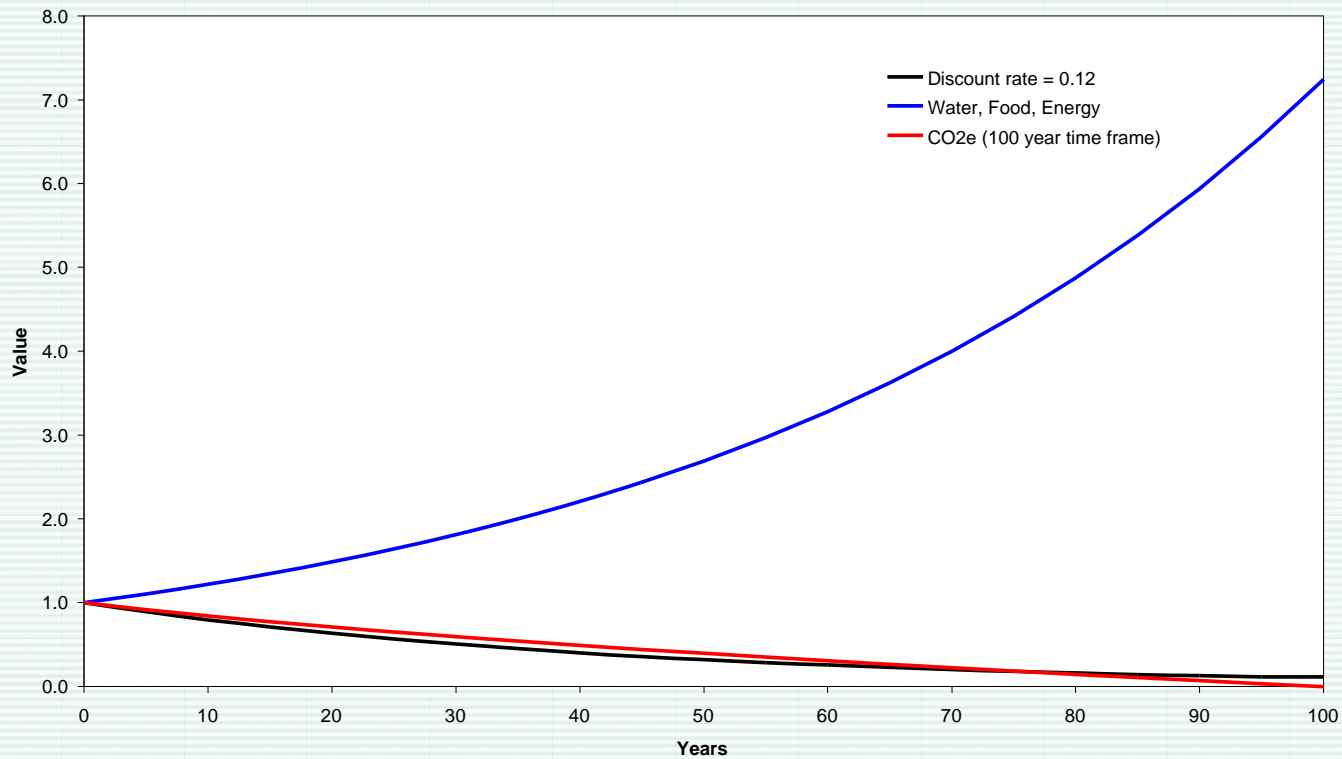
Spruce plantation
Prince George, Canada





Time Value of Damages

Time Value of Damages





Conclusions

■ Task 38 – Standard Methodology

→ Build on existing methodology

■ Improved methodology for comparison when land-use change is involved

→ Adopt a methodology for comparison
or

→ Adopt a methodology for demonstrating full impacts

■ Address the timing issue

→ Adopt a methodology for construction and restoration

→ Adopt a standard for timing

→ Rabl et al (2007): *Int. J. LCA* 12