Issues relating to the timing of emissions from bioenergy systems

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IEA Bioenergy Conference 2012

Nov. 13 – 15 2012, Vienna

Outline

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- Points of contention
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  - When does the juggler start?
- Sensitivity
- Emerging issues
  - Disturbances
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- Policy indicators
- Conclusions

Introduction

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1. Analysis of the impacts of bioenergy generally uses conventional LCA
   - Ignores the timing of emissions and removals (life-cycle)
   - Emissions from biomass use = 0
     - Over the lifetime biomass used will regrow
2. Misconception - bioenergy has zero emissions …
   - *bioenergy has zero emissions in the energy sector because loss of carbon stocks will be computed in the land use sector*

- Temporal dimension to emissions from bioenergy use
  - Specifically from woody biomass
  - A large emission from combustion followed by many small removals over many years during regrowth (or avoided decay)
  - A “carbon-debt” or a “carbon-investment” ?

Timing, the problem….

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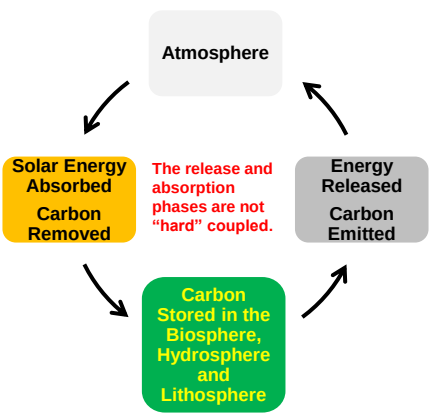
Even though bioenergy is in the long term a low carbon energy source, in the short term it may cause more emissions than fossil energy



Causes

1. Use existing carbon capital for bioenergy
2. Bioenergy is more carbon intense and less efficient than fossil energy
3. Accelerating the energy release phase causes a temporary increase of carbon in the atmosphere
4. Accelerating the absorption phase can compensate but it is difficult to accelerate at the same magnitude
5. Continuous or increasing use causes a persistent increase of carbon in the atmosphere

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The Effect of Constant or Increasing Demand

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- There is a persistent emission that is larger for bioenergy systems with a longer time to first benefit (*pay-back time*)
- Analogy to a juggler
  - A single ball when thrown in the air returns to Earth
  - A juggler continuously throws balls in the air
    - After a transition phase there is constant number of balls in the air
    - To influence the number of balls in the air
      - Throw the balls higher with the same frequency
        "Use biomass with longer decay times or that regrows quickly"
      - Throw the balls more frequently with the same height
        "Increase the biomass use"

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An Example

Forest residues to biorefinery for bioethanol

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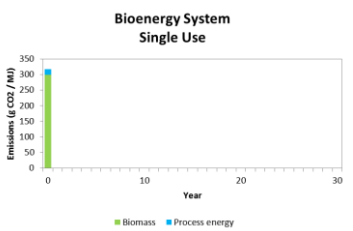

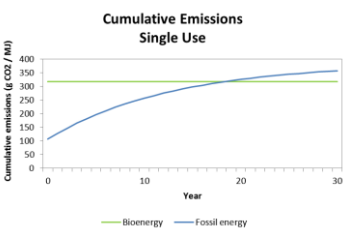

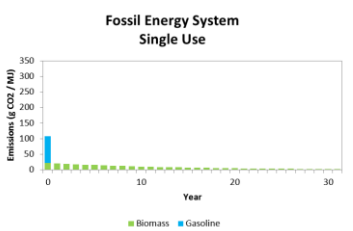

- Bioenergy System
  - Biorefinery producing bioethanol and phenols
  - Approx. 30% conversion efficiency
  - Supply-chain emissions = 18 gCO2/MJ
- Reference System
  - Residues decay, average lifetime = 12.9 years
  - Gasoline, process emissions = 85 gCO2/MJ

From Cherubini et al – Task 38 Case Study
In press.

The Juggler Effect

If this example provides all EU biofuel demand

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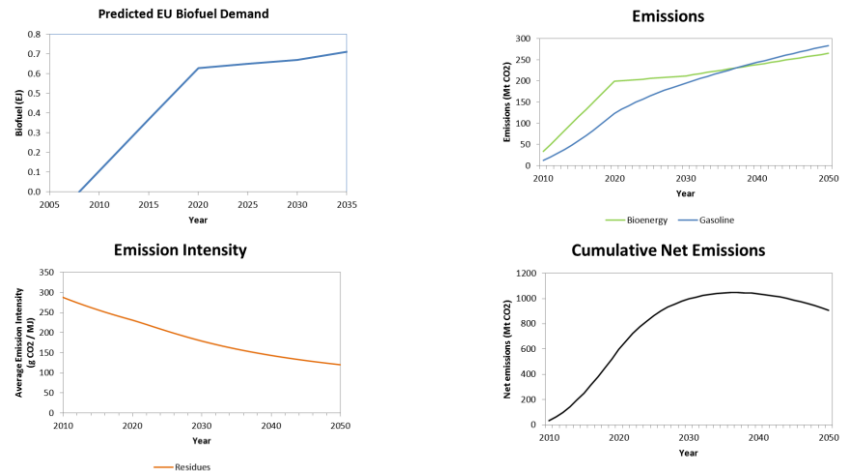

Point of Contention

The forest or the trees?

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- Foresters' view
  - The forest stock is increasing. How can bioenergy be causing an emission?
  - Landscape approach versus a stand approach
  - Forest management can increase carbon stocks
    - increasing forest area
    - Short rotation forestry

- The consequences of bioenergy
  - Comparing *with* bioenergy to *without* bioenergy
  1. The forest stock will continue to increase, but <u>less</u> than without bioenergy
     - See reference list
  2. If the forest is harvested in individual blocks then most of the forest is the same in both the *with* and *without* scenarios. Only the harvested blocks are important.
  3. Forest management <u>needs to change</u> because of bioenergy

Point of Contention
When does the juggler start?

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- Why start counting from existing carbon capital forward?
- The consequences of bioenergy
  - Comparing *with* bioenergy to *without* bioenergy
  1. Past growth of stocks appears in both the *with* and *without* scenarios
  2. Analogy to financial analysis. We have capital, how do we invest it?
  3. To be consistent if we count from the past, why not count the sequestration of biomass to create fossil fuel deposits? (*Reductio ad absurdum)*
- Problem compounded by increasing bioenergy demand
- Solutions
  1. Plant first then there is no problem (Schulze et al, Sedjo)
  2. Cascading systems

Sensitivity
Technology

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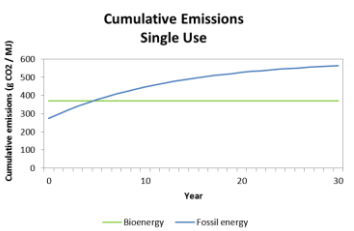
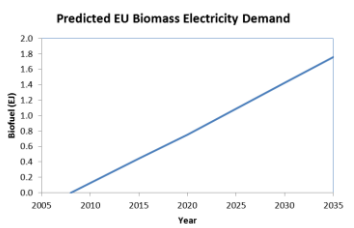
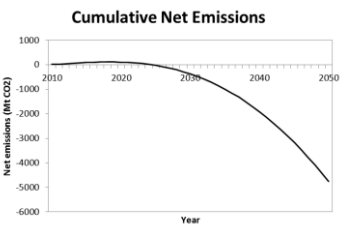


- Bioenergy System
  - **Residues to wood chips to CHP**
  - Approx. 27% conversion efficiency
  - Supply-chain emissions = 22 gCO2/MJ
- Reference System
  - Residues decay, average lifetime = 12.9 years
  - Coal burning CHP
  - Conversion efficiency 43.5%
  - Emissions = 248 gCO2/MJ

From GEMIS





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Sensitivity
Fossil energy replaced

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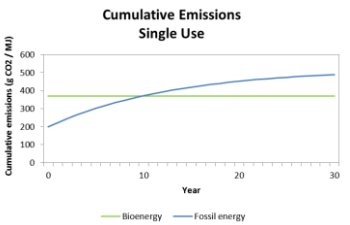
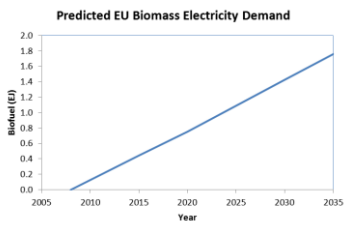
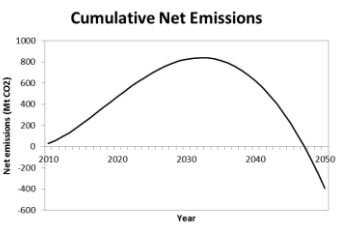


- Bioenergy System
  - Residues to wood chips to CHP
  - Approx. 27% conversion efficiency
  - Supply-chain emissions = 22 gCO2/MJ
- Reference System
  - Residues decay, average lifetime = 12.9 years
  - **Natural gas CHP**
  - Conversion efficiency 42.3%
  - Emissions = 173 gCO2/MJ

From GEMIS





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Sensitivity
Efficiency

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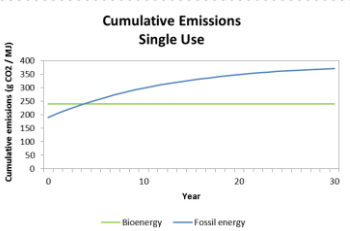
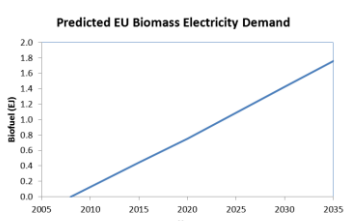
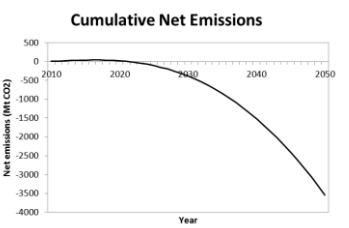


- Bioenergy System
  - Residues to wood chips to CHP
  - **Approx. 42% conversion efficiency**
  - Supply-chain emissions = 22 gCO2/MJ
- Reference System
  - Residues decay, average lifetime = 12.9 years
  - Natural gas CHP
  - Conversion efficiency 42.3%
  - Emissions = 173 gCO2/MJ

From GEMIS





Sensitivity
Biomass

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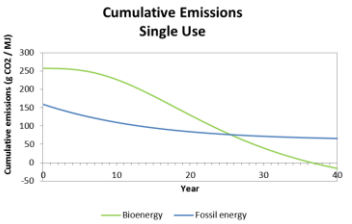
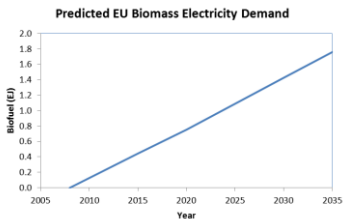
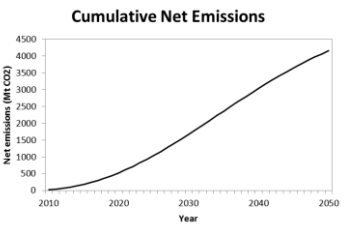




- Bioenergy System
  - **Whole trees to wood chips to CHP**
  - Optimal rotation length = 30 years
  - Approx. 42.3% conversion efficiency
  - Supply-chain emissions = 40 gCO2/MJ
- Reference System
  - Continued forest growth
  - Natural gas CHP
  - Conversion efficiency 42.3%
  - Emissions = 173 gCO2/MJ

From GEMIS



Work in Progress !!

This diagram is work in progress. It involves a very simplistic disturbance model and assumption. This diagram should be taken to illustrative the importance and potential impacts of disturbances only.

Emerging Issues
Disturbance

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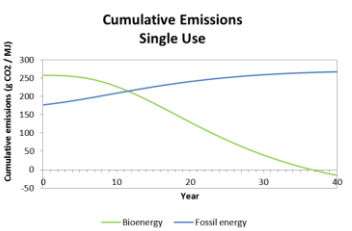
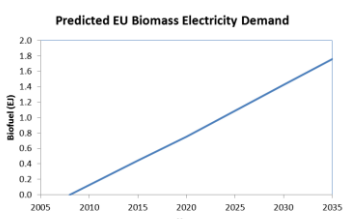
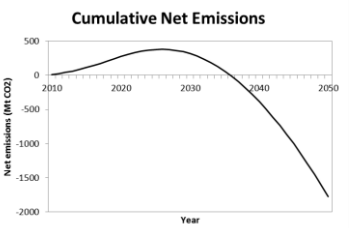




- Bioenergy System
  - Whole trees to wood chips to CHP
  - Optimal rotation length = 30 years
  - Approx. 42.3% conversion efficiency
  - Supply-chain emissions = 40 gCO2/MJ
- Reference System
  - Continued forest growth, **with 2% chance of total loss**
  - Natural gas CHP
  - Conversion efficiency 42.3%
  - Emissions = 173 gCO2/MJ

From GEMIS



Emerging Issues
Albedo

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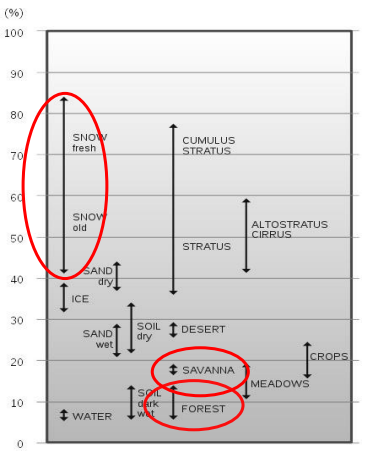

Coniferous forest and snow
High latitudes (Austria)

Pine plantations and savanna
Low latitudes (South Africa)

Neil Bird, 2009

Policy Indicators

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- Current policy provides incentives for bioenergy systems that reach a specific emission intensity
  - Emission intensities are time dependent
- Policy should provide incentives for bioenergy that meets a specific time to payback

$$T_{payback} = f(I_B, I_S, I_F, T_{return})$$

I_B	Conversion emission intensity
I_S	Supply-chain emission intensity
I_F	Displaced fossil fuel intensity
T_{return}	Recovery time (e.g. decay rate, rotation length)

Conclusions

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- Even though bioenergy is in the long term a low carbon energy source, in the short term it may cause more emissions than fossil energy
  - Is this a carbon investment or a carbon debt?
- This occurs because:
  - Bioenergy often starts with existing carbon capital.
  - Bioenergy tends to be more carbon intense and less efficient than fossil energy
  - Accelerating the energy release phase causes a temporary increase of carbon in the atmosphere
- Increasing bioenergy demand increases the length of time before the bioenergy has less emissions that fossil energy
- This period of time can be minimised by using bioenergy
  - From purpose grown biomass (e.g. new short rotation forests)
  - To replace appropriate technology
  - To replace carbon intense fossil energy
  - With high efficiency
  - With quick recovery or natural return
- Disturbances and albedo should be considered in the analysis

Suggested Reading

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- Timing

  - Biomass Energy Resource Center. 2012. Biomass Supply and Carbon Accounting for Southeastern Forests.
  - Holtsmark, B. 2010. Use of wood fuels from boreal forests will create a biofuel carbon debt with a long payback time. Statistics Norway, Research Department.
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Suggested Reading

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- Forest level impacts of bioenergy
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  - Schwarzbauer, P and Stern T. 2010. Energy vs. material: Economic impacts of a "wood-for-energy scenario" on the forest-based sector in Austria — A simulation approach. Forest Policy and Economics, 12, 31–38.

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Thank-you for your attention

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