Quantifying the climate effects of forest-based bioenergy: dealing with time

Annette Cowie, Göran Berndes
Miguel Brandão and Task 38
Costs of climate change

In 2010, climate change cost:

- 700 billion USD
  - 0.9% global GDP
- 400,000 deaths per year – 90% children

Climate change + Carbon economy

- costs 1.2 trillion USD
- kills 4.975 million

DARA, 2012
Too late to avoid 2° C?

- 2° C: target of the Copenhagen Accord to avoid catastrophic outcomes
- Already increased by 1 degree
- At least 0.5 degree unavoidable
- Without immediate and drastic action we cannot meet the 2° C target
IPCC AR5: Bioenergy a key technology to meet 2° C target
Technical potential for forest bioenergy in 2050: 50-100 EJ
Bioenergy – “carbon neutral”?
Task 38 Climate change effects of biomass and bioenergy systems

IEA Bioenergy Task 38

“Climate change effects of biomass and bioenergy systems”

- Leader: Annette Cowie
- Manager: Miguel Brandão
- Operating agent: Stephen Schuck
- Participants: Australia, Brazil, France, Finland, Germany, Norway, Sweden, USA

Bioenergy Australia September 2014
National Team Leaders:

- Australia  Annette Cowie
- Brazil      Manoel Regis Lima Verde Leal
- Finland     Sampo Soimakallio, Kim Pingoud (Kati Koponen)
- France      Alice Gueudet
- Germany     Sebastian Rüter
- Norway      Anders Strømman (Francesco Cherubini, Ryan Bright)
- Sweden      Leif Gustavsson, Matti Parikka
- USA         Alison Goss Eng, Kristen Johnson
Objectives of Task 38

- Develop, demonstrate and promote standard methodology for GHG balances
- Increase understanding of GHG outcomes of bioenergy and carbon sequestration
- Emphasise net atmospheric impact
- Aid decision makers in selecting most effective mitigation options
- Promote international exchange of ideas, methods and scientific results
Task 38 focus: Life cycle climate change effects of bioenergy
Not carbon neutral because:

- Production chain emissions
- Non-CO$_2$ GHGs
- C stock change in biomass, soil (direct effect)
- C stock change in biomass or soil thru ILUC
- Albedo and other biophysical effects on climate
Indirect land use change from corn-based ethanol

<table>
<thead>
<tr>
<th>Author/Study and Year</th>
<th>iLUC Emissions (gCO₂-e/MJ)</th>
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<tbody>
<tr>
<td>Searchinger et al., 2008</td>
<td>104</td>
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<td>CARB, 2009</td>
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<td>Elliott et al., 2014</td>
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</table>
Impact of albedo

Coniferous forest and snow
High latitudes (Austria)

Pine plantations and savanna
Low latitudes (South Africa)

Neil Bird, 2009
Greenhouse gases emitted in the manufacture of building materials used in a range of construction components for a single story house in Sydney, Australia

<table>
<thead>
<tr>
<th>Component</th>
<th>CO2-e (t)</th>
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<tr>
<td>Floor structure</td>
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<tr>
<td>Floor covering</td>
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<tr>
<td>Wall frame</td>
<td>5.6</td>
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<tr>
<td>Roof frame</td>
<td>4.8</td>
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<tr>
<td>Windows</td>
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- Steel sub-frame
- Concrete slab
- Timber sub-frame
- Ceramic tiles
- Brick
- Steel
- Timber
- Hardwood T&G
- Softwood
- Steel
- Timber
- Aluminium
- Timber
Task 38

IEA Bioenergy

Bioenergy system
- Stable atmospheric carbon
- Carbon fixation
- Renewable biotic carbon stocks
- Carbon oxidation
- Biomass
  - Harvesting
  - Processing
  - Transport
  - Storage
  - Conversion in vehicles engines
  - Conversion in heat and power plants
  - Heat/electricity distribution

Fossil reference energy system
- Increasing atmospheric carbon
- Decreasing fossil carbon stocks
- Fossil fuel
- Auxiliary fossil energy emissions
  - Production
  - Processing
  - By-products
  - Conversion in vehicles engines
  - Conversion in heat and power plants
  - Heat/electricity distribution

Useful energy:
- Heat
- Electricity
- Mechanical energy
Reference energy system

- Fossil energy source
- Conversion efficiency

Displacement factor

\[= \frac{\text{efficiency}_{\text{bio}}}{\text{efficiency}_{\text{ref}}} \times \frac{\text{CO2}_{\text{ref}}}{\text{CO2}_{\text{bio}}}\]

- Nearly always <1
Reference land use

• Timber without biomass harvest?
• Conservation forests? With natural disturbance?
• If there is decline of pulpwood market??
• Purpose-grown crop?
• If there is marginal or degraded land?
• When to start the clock?
Choosing the land use reference system

Koponen et al, in prep
Reference biomass use

(For biomass residues)

• Slash, thinnings: Leave in forest?
• Sawmill, C&D, C&I: Landfill??
• When regulation requires avoidance of landfill / use for energy?
Units?

- Emissions CO$_2$-e per MJ?
- Biomass and land are limited resources

- Emission reduction per unit biomass
- Emissions reduction per unit land area
Task 38 Standard Methodology

- Compare project with reference
- Consider whole system life cycle
  - Production chain, end of life
- System boundary
  - Deliver equivalent service
- Scope:
  - All greenhouse gases CO2 and non-CO2
  - C stock change in biomass, soil, ILUC, albedo
- Emissions reduction per unit biomass/land
- Result is specific to each situation
Data from Cherubini et al 2009

Excludes indirect land use change
Reforestation for timber + bioenergy

Graph showing carbon stock [tC/ha] over time [years].

- Fossil fuel spent
- Fossil fuel displaced
- Net carbon stock
- Products in landfill
- Products in use
- Trees
- Litter
- Soil
Case Study – South Coast NSW

The graph illustrates the carbon storage and substitution over a period of 200 years, measured in tC ha⁻¹. The lines represent:
- **Yellow**: Net product substitution
- **Orange**: Bioenergy (30% of available forest residues)
- **Light Green**: Carbon storage in products
- **Green**: Forest carbon (remaining in harvested forest)
- **Dark Green**: "Conservation" forest

The x-axis represents the years, ranging from 0 to 200, and the y-axis represents the carbon storage in tC ha⁻¹, ranging from 0 to 250.
Considering full life cycle, what is the best use of biomass resources?

How can land be used to provide energy and meet other needs?

How can policies and accounting methods distinguish systems with highest mitigation value?
Credibility of bioenergy is suffering

- Indirect land use change
- The “carbon debt” issue
  - Long pay-back time for forest-based bioenergy
- Policy support diminishing
- What advice can we give?
Biomass better than coal? War over carbon accounting erupts

In Washington, the Environment Working Group has released a study that claims the impacts of the American Clean Energy and Security Act (ACESA)—which has already passed the House of Representatives—would require the equivalent of cutting between 18 and 30 million acres by 2025, and up to 50 million acres by 2030.

"From Maine to Washington state, from Ohio to Florida," the EWG report says, "electric utilities have been embracing "biomass power" as a way to reduce dependence on coal and other fossil fuels and to meet ambitious goals for limiting greenhouse gas emissions."

Fixing a Critical Climate Accounting Error

Timothy D. Searchinger,1* Steven P. Hamburg,2* Jerry Melillo,2 William C. Chamecki,3 Petr Havlík,4 Daniel M. Kammen,6 Gene E. Likens,7 Ruben N. Lubowski,2 Michael Oppenheimer,1 G. Philip Robertson,8 William H. Schlesinger,7 G. David Horiuchi4 and G. David Horiuchi4

Rules for applying the Kyoto Protocol and national cap-and-trade laws contain a but fixable, carbon accounting flaw in assessing bioenergy.

The accounting now used for assessing compliance with carbon limits in the U.S. and other countries does not count changes in emissions when biomass for energy is harvested from land with high carbon density, such as wetlands and forests.
Why Dedicating Land to Bioenergy Won't Curb Climate Change

by Tim Searchinger - January 28, 2015

New Report Calls for Significant Roll-Back on Global Bioenergy Policies

WRI's Searchinger says land and crops should not be used for bioenergy production, biofuels not curbing climate change
“Carbon debt” papers

Kyoto context

- Bioenergy treated as CO₂ neutral in energy sector
- Assumes C stock changes included in LULUCF
- Assumes fossil energy inputs in energy sector
- Assumes non-CO₂ included in agriculture
- Correct where these assumptions are valid

But

- Only Annex I countries covered
- Previously didn’t count forest C stock change (but do now)

Could:

- limit C neutral status to sources that meet assumptions
- Use other policy measures

Calls to revoke carbon neutrality, and count as for fossil emissions
Bioenergy

- Carbon neutral?
  - Maybe nearly

- Climate neutral?
  - Not if you start with existing forest

F Cherubini NTNU
Time in LCA

- Environmental flows summed across life cycle
- Timing of flows ignored ISO 14040, 14044
- ISO TS14067 allows for timing in supplementary value

- Does time matter?
  - Credit for temporary storage?
  - Is there a value in delaying emissions?
  - Buys time for technology development
  - Avoids tipping points?
  - Includes value judgment
    - Assumes next generation better able to cope
Atmospheric [CO2] - pulse emission
Lashof approach

Atmospheric [CO2] - pulse emission
$y(t) = A_0 + \sum_{i=1}^{i=3} A_i e^{\left(\frac{-t}{\tau_i}\right)}$

$f_{IRF}(t, r = 100)$

$f_{CBC}(t, r = 100)$

F Cherubini NTNU
Atmospheric decay

FGF to MF

Fossil CO2/Deforestation

GWP_{100} = 0.73

\[
GWP_{bio} = \frac{AGWP_{bioCO_2}}{AGWP_{CO_2}} = \frac{C_0 \int_0^{TH} \alpha_{CO_2} \cdot f(t) \, dt}{C_0 \int_0^{TH} \alpha_{CO_2} \cdot y(t) \, dt}
\]

GWP_{100} = 0.73

F Cherubini NTNU
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<th></th>
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Spatial scale?
Forest stands in the landscape

Berndes et al 2011
Forest estate, all stands mature, stable C stocks

Year 1: One stand harvested

Year 2: Second stand harvested, first beginning to regrow.

And so on each year for remaining stands

Year 10 – 10th stand harvested. 1st stand regrown, will be harvested in 11th year
Above-ground C stock (t)

Δ C stock

Year

0 5 10 15 20 25
On the Timing of Greenhouse Gas Mitigation Benefits of Forest-Based Bioenergy

Annette Cowie, Göran Berndes, Tat Smith and others from Tasks 38, 40 and 43
Single stand

Blue: Reference, harvested for timber only

Average C stock blue stand

C stock

T0  T1  T2  T3

Time
Single stand

C stock

Average C stock blue stand

Landscape scale: Carbon stocks stable

C stock

T0  T1  T2  T3

Time
**Single stand**

- C stock

  - Blue: Reference, harvested for timber only
  - Average C stock blue stand

**Landscape scale: Carbon stocks stable**

- C stock

**Landscape scale: Carbon stocks increasing**

- C stock
Figure 1a  Single stand

C stock

ΔC: Additional biomass (residues) harvested for bioenergy.
Decays on site in reference case.

Average C stock blue stand

GHG cost

Average C stock red stand

Red: harvested for timber + bioenergy.
C stock reduced throughout the rotation compared with blue stand.

Time
T0 T1 T2 T3
**Figure 1a Single stand**

- Blue: Reference, harvested for timber only.
- GHG cost:
- Average C stock red stand
- Average C stock blue stand
- Red: harvested for timber + bioenergy. C stock reduced throughout the rotation compared with blue stand.

**Landscape scale: Carbon stocks stable**

- GHG cost (red cf blue)
Figure 1a  Single stand

C stock

ΔC: Additional biomass (residues) harvested for bioenergy.
Decays on site in reference case.

ΔC: Reference, harvested for timber only

Average C stock blue stand

GHG cost

Average C stock red stand

Red: harvested for timber + bioenergy.
C stock reduced throughout the rotation compared with blue stand

T0  T1  T2  T3

Time

Landscape scale: Carbon stocks stable

C stock

T0  T1  T2  T3

Time

Landscape scale: Carbon stocks increasing

C stock

T0  T1  T2  T3

Time
Experience from Sweden is that increased biomass output need not take place at the cost of reduced forest stocks if the increased biomass extraction is accompanied by activities that promote regeneration and enhance growth.

Picture shows annual increment 1926 – 2003 and gross felling 1853 – 2003. Felling is shown in two series reflecting different methods of estimation. Cubic metres standing volume including stem volume over bark from stump to tip is denoted m3 sk. A positive trend for forest C follows from the strategic planning paradigm in the forest sector.
Carbon stock and harvest in Swedish forests have both grown over last century
Planning in the Swedish forest sector – adapting to a future situation where sawnwood, pulpwood and bioenergy are equally important products – results in larger average forest stocks compared to planning to produce only sawnwood and pulpwood.

BASB = “more bioenergy”, SB = “less bioenergy”. Forest fuel output is about 160% higher in BASB. Average rotations 9% longer in BASB. Pulpwood output increases in BASB due to increased thinning frequency.

(Provided by Holmström et al (2012) using the Heureka decision support system for the Swedish forest sector.)

Göran Berndes
Forest C stock

Time

GHG savings

Time

GHG savings

Time

GHG costs

GHG avoided

net GHG savings

GHG costs

GHG avoided

net GHG savings

bioenergy

reference

GHG savings

net GHG savings
Bioenergy

- Carbon neutral?
  - maybe
- Climate neutral?
  - Not if you start with existing forest
  - Consider single stand
  - Omit forest management impacts

F Cherubini NTNU
IEA Bioenergy Statement:

- Policymakers need to consider the big picture - the whole life cycle, the long term, human influences
- Biomass for energy is usually one of several products from a managed forest
- Forest C stocks fluctuate (at the stand level) over time and space - a forest is a mosaic of age classes
- Forest C stock should be considered across the estate
  - A function of management and natural factors
  - May be increasing or decreasing or stable
IEA Bioenergy Statement:

- If C stock decreases (relative to “without bioenergy” scenario), this is an emission that must be compensated through avoiding fossil fuels, before bioenergy gives net mitigation benefit.
- Loss in C stock can be minimised by investment in intensive forest management.
IEA Bioenergy Statement:

- Bioenergy benefits increase in long term
- GHG cost of forest bioenergy is an investment in establishing renewable energy system
• To meet global temperature targets, scientists have estimated a concentration of atmospheric GHGs that should not be exceeded.

• The difference between current concentrations and this threshold represents the atmospheric capacity for GHG emissions – the “emissions space”

• Critical strategic question: how should society use the remaining emissions space?
Development of new energy and transport systems will take time, and will create GHG emissions
Some of the emission space could be used to develop a bioenergy industry to provide renewable and climate friendly energy services for the world.
Since it is urgent to reduce GHG gases it is important to quickly implement forest bioenergy projects that provide long term GHG savings.
IEA Bioenergy Task 38

Climate Change Effects of Biomass and Bioenergy Systems

www.ieabioenergy-task38.org

annette.cowie@dpi.nsw.gov.au
Climate Change Effects of Biomass and Bioenergy Systems

Task 38 investigates the climate effects of bioenergy and land-based carbon sequestration systems to support development of climate change mitigation strategies.