System analysis

An economists perspective

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System analysis

in the Bio4Energy platform

- Integration methods to optimise plant energy and material flows
  - Techno-economic assessments
  - Environmental assissments by applying LCA
  - Policy design and implementation
  - Market dynamics and innovation dynamics
  - Spatial modeling of cost efficient production, taking the entire system into account
- One (my) interpretation
  - An analysis of how a system is affected by the individual parts. The ”system” can for example be a
    - Specific market
    - A national economy, a region, or the whole world
    - An environmental system

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LCA or CBA?
Or both?

- Life Cycle Assessment (LCA) and Cost Benefit Analysis (CBA) are both considered as system analysis tools
- Both try to describe and analyse ”processes” and its consequenses for a system
- Both claim to be decision support tools...
  - ...that is, as a tool to choose between options

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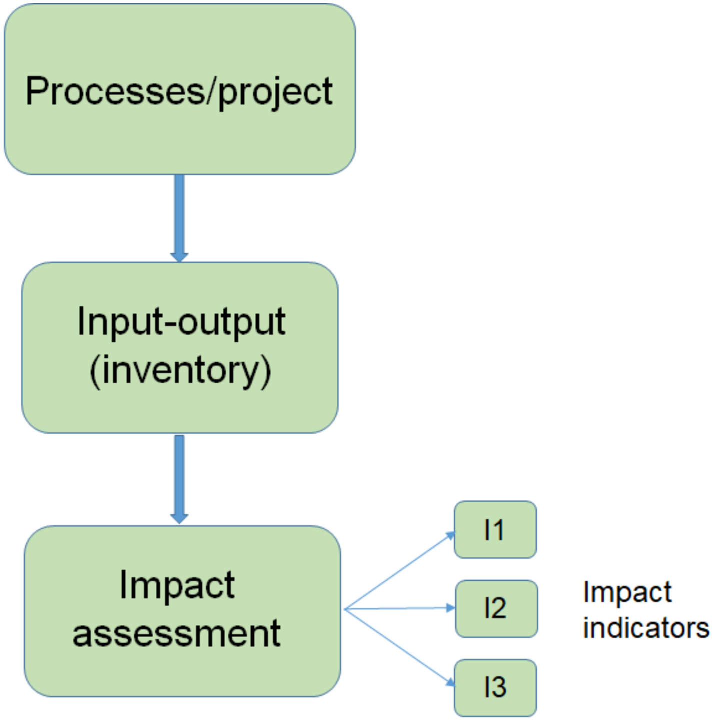
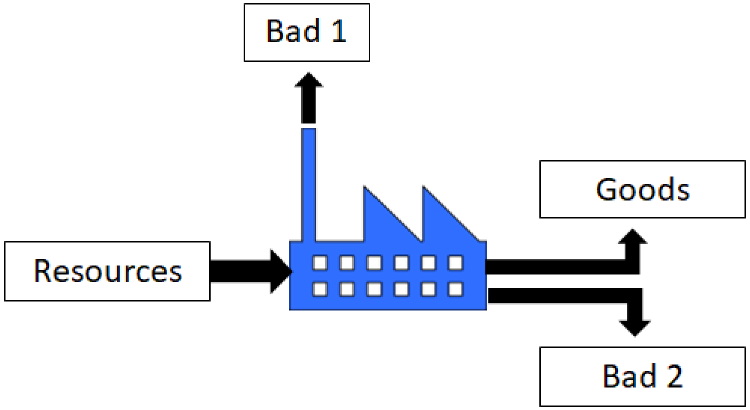
LCA

- Evaluates all known environmental impacts of a ”process” through its lifetime
- Attempts to cover all physical exchanges in the life cycle
- Knowledge about physical and ecological effects are sufficient for the analysis
- Value of ”trade-offs” can’t be made
  - No common measurement unit
  - Cannot say if process A is better than process B



The (environmental) economics perspective

- Knowledge about physical and ecological impacts are not sufficient
- Some kind of objective with the process is needed
- Economics aims to infer “values” on the results of a process



- It costs 100 kr to decrease ”bad 1” with 1 ton, and 200 kr for ”bad 2” (In terms of lost ”Goods” by changing the process.
- What is the optimal process? That is, how much in total should we reduce ”Bad1” and ”Bad 2”, and should we reduce both ”bads” equally much?

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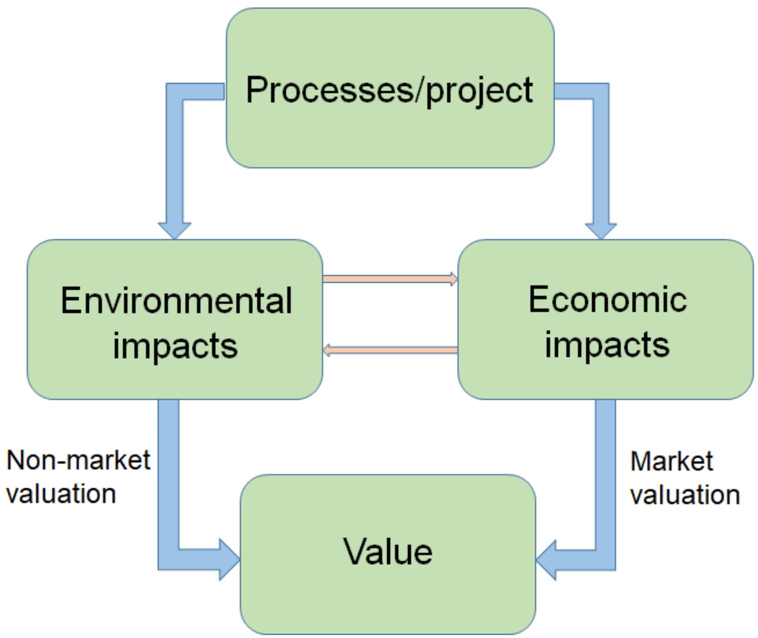
Economics - CBA

- A CBA analysis of a process goes beyond LCA
  - Attempts to measure the net utility (value) of a specific process, product or project
  - By that different physical impacts are translated to a common measure (usually money)
  - Attempts to take ”market effects” into account
- LCA is used as an input in the economic analysis
- Processes or projects can be compared in a CBA since there is a common metric



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Two examples of CBA

- What are the benefits and costs of intensified forest management (to get more bioenergy, for example)?
  - Market benefits and costs?
  - Climate benefits?
  - Non-market benefits and costs?
  - Overall societal benefits and costs?
- What are the consequenses of increasing the share of forest based bioenergy in the energy system?
  - Climate effects?
  - Consequenses for forest owners and users of timber?

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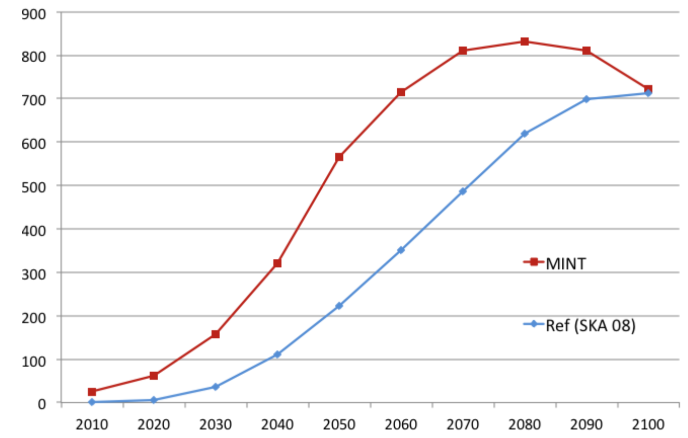
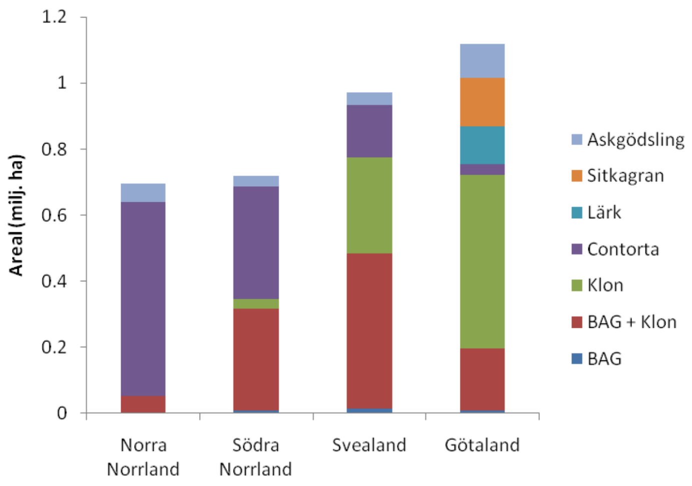
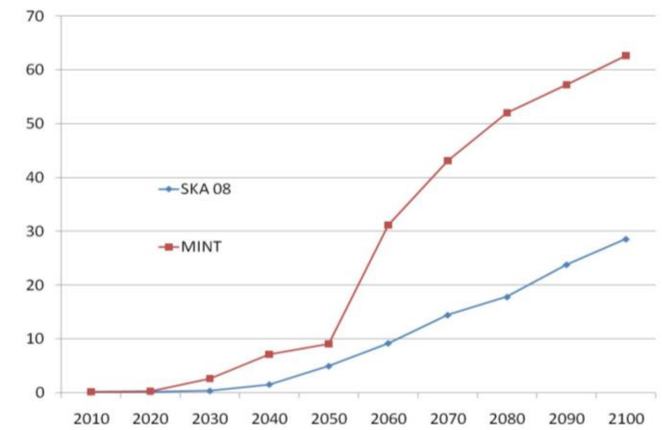
Intensive forest management
A CBA

The ”project”:

Intensive forest management on 3.5 million hectares forest land







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The CBA

The effects from the project can be divided into:

- **Market effects**: changes in production and consumption
- **Environmental/amenity effects**: changes in acidification, biodiversity, landscape, recreation, etc.
- **Climate effects**: changes in emissions/sequestration.

Market effects

- Scenario A – Low net value of timber production
- Scenario B – Net value corresponding to 2008 year prices
- Scenario C – High net value of timber production

Scenario A is assumed to illustrate the effect of lower timber prices due to the increase in timber supply, an excess supply resulting from intensive cultivation.

Scenario B is the ”business as usual” in which the timber unit value is unchanged

Scenario C is assumed to illustrate the effect of higher timber prices due to an increased demand for biofuel motivated by climate and energy policy.

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Climate impact/effect

N = forest growth
H = harvest
P = carbon price
T = 100 years

SR = emissions included
LR = emissions not included

$$CE = \sum_{t=1}^{T} \left\{ P \left[0.9N_t - \left(0.9 \times 0.5 \left((H_t + 0.1H_t) + \sum_{t-i=2}^{T-1} 0.1H_{t-i} \right) \right) + 0.5H_t\ 2.744/11.5 \right] \Big/ 1.34^t \right\}$$

Sequestration = biomass growth

Emissions

Substitution = bioenergy instead of fossil fuels

0.9 = CO_2 content 1 m^3 wood
2.744 = CO_2 content 1 m^3 oil
11.5 = energy content 1 m^3 oil in relation to 1 m^3 wood

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Other environmental effects

- ***Acidification***. WTP/ha to protect ecosystems from acidification in Europe estimated to 100 Euro/year. 5-20% of the IFM is affected. **The cost/ha is then 48 - 192 SEK/year.**
- ***Recreation***. Mattsson and Li (1993) estimate the recreational and aestetic value of forests per individual to be 7748 SEK/year. We assume 5-20% of IFM area is affected. This translates to a per hectare value loss of **113 - 451 SEK/year**.
- ***Hunting***. Mattsson et al. (2008, 2009) estimate a value of 11872 SEK for the typical hunter in Sweden 2006. 280 000 hunting licenses in 2006, giving a total hunting value of 3.32 billion SEK. The per hectare value is approximately 144 SEK/year, which corresponds to **a loss of 7 - 29 SEK/year** when at least 5-20% of the hunting is made impossible under IFM.

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CBA, intensive forest managment

Emissions from biofuels included

	Sc A low timber value	Sc B same timber value	Sc C high timber value
Timber value	– 1.07	15.6	23.6
Carbon value	2.0	2.0	2.0
Other environmental value	-51.4 to -23.1	-51.4 to -23.1	-51.4 to -23.1
Sum	**- 50.5 to -22.2**	**-33.8 to -22.1**	**-25.8 to 2.5**

Emissions from biofuels excluded (carbon neutral)

	Sc A low timber value	Sc B same timber value	Sc C high timber value
Timber value	– 1.07	15.6	23.6
Carbon value	13.8	13.8	13.8
Other environmental value	-51.4 to -23.1	-51.4 to -23.1	-51.4 to -23.1
Sum	**- 38.7 to -10.4**	**-22.1 to 6.2**	**-14.0 to 14.3**

CO2 price = SEK 1 per kg

Source: Brännlund et.al (2012)

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CBA, intensive forest managment

- How climate effects are considered and valued are crucial
- Impacts on landscape and how recreation and amenities are valued are very crucial
- The methodology make comparisons of different impacts possible

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Increased use of bioenergy

Impacts and consequenses

- What are the impacts and consequenses?
  - Market impacts: Harvest level, timber markets
  - Market impacts: who wins, who loses?
  - Non-market impacts: Climate impacts, Impact on amenity values

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A forest sector model

Guo, Gong and Brännlund (2018)

- Consist of four “modules”
  - Economic module (market effects):
    - supply of timber, pulpwood and bioenergy
    - Demand for sawtimber, pulpwood and bioenergy
  - Bioenergy module:
    - Converts wood that is used for energy to energy units. Energy demand exogenous (no market effects on the energy sector).
  - Forest dynamic module:
    - Updates the forest inventory from one period (year) to another using a growth function, the forest area
  - Carbon module (non-market effects):
    - Keeps track of the carbon balance. Account for changes in: standing volume of forests + carbon in final wood products + energy substitution + combustion of biomass

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Scenarios

- **Base**: bioenergy production maintains the current level of 95 TWh with residues extraction rate of 40%
- **Bio40:** bioenergy production is projected to increase to 120 TWh in 2050 with residues extraction rate of 40%
- **Bio60:** bioenergy production is projected to increase to 120 TWh in 2050 with residues extraction rate of 60%
- **Bio80:** bioenergy production is projected to increase to 120 TWh in 2050 with residues extraction rate of 80%

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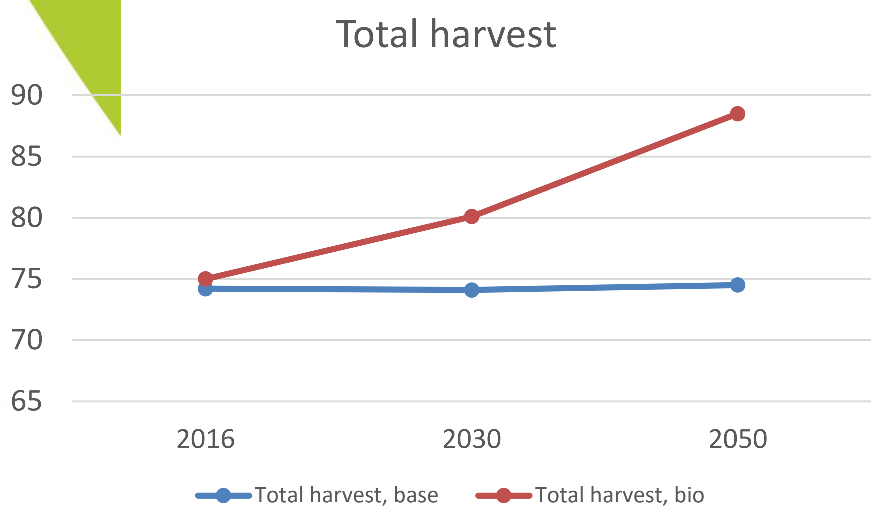
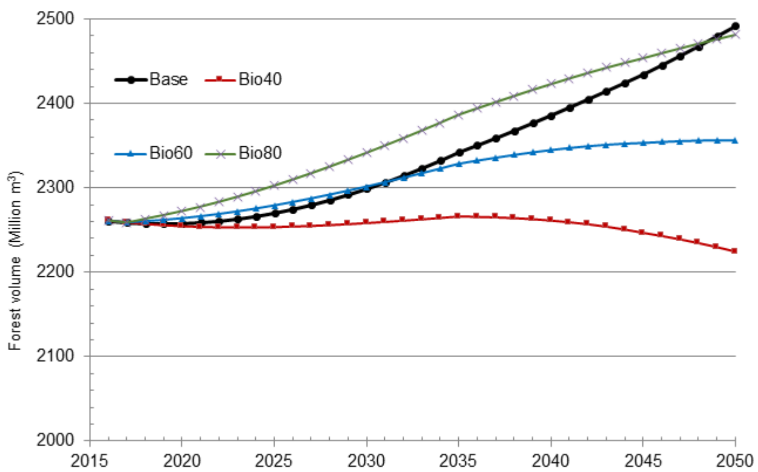
Some results

increased harvest and younger forests





Source: Guo et.al (2018)

- An increase of bioenergy demand will increase harvest in all scenarios
- The standing volume will decrease unless a sharp increase in the use of forest residues occur
- The increase in bioenergy implies a shift in wood supply from pulpwood to wood for energy
- This will push up the price on pulpwood
- The “competition” for raw material gets more intensified

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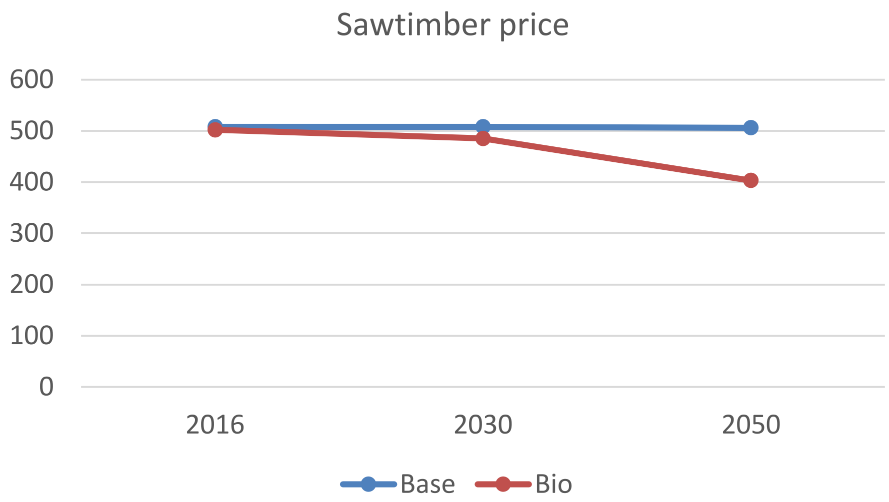
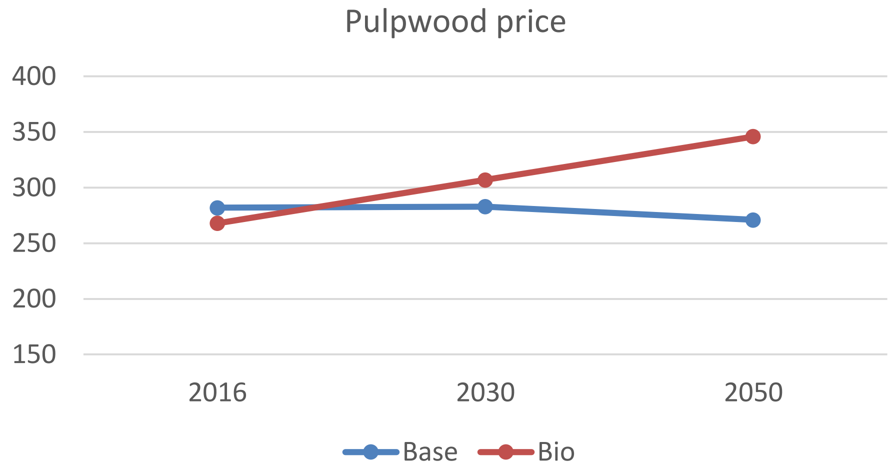
Some results

shift in supply and change in relative prices





Source: Guo et.al (2018)

- The increase in bioenergy implies a shift in wood supply from pulpwood to wood for energy (and sawtimber)
- This will push up the price on pulpwood
- Overall “competition” for raw material gets more intensified

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Carbon balance

average annual 2016-2050

	Base	Bio40	Bio60	Bio80
Changes in HWP storage	0.02	0.02	0.03	0.01
Material substitution	8.87	9.73	9.35	8.99
Fossil fuel substitution	24.85	28.14	28.14	28.14
Forest sequestration	8.33	-1.45	3.27	7.74
Emissions from timber harvest	-1.93	-2.12	-2.04	-1.96
Carbon balance	**40.14**	**34.33**	**38.75**	**42.92**

	Base	Bio40	Bio60	Bio80
Changes in HWP storage	0.02	0.02	0.03	0.01
Material substitution	8.87	9.73	9.35	8.99
Fossil fuel substitution	24.85	28.14	28.14	28.14
Emissions from bioenergy	-37.23	-42.15	-42.15	-42.15
Forest sequestration	8.33	-1.45	3.27	7.74
Emissions from timber harvest	-1.93	-2.12	-2.04	-1.96
Carbon balance	**2.91**	**-7.83**	**-3.40**	**0.77**

Source: Guo et.al (2018)

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Who wins and who loses?

- Sawlog users will be winners. Harvest will increase, pushing down the price on sawlogs.
- Pulpwood users (pulp mills) are losers. Less pulpwood supply will push up the price.
- Forest owners are winners (higher overall demand for their products)
- Non-timber benefits (carbon excluded) will decrease as a result of a forest with less old trees

Concluding remarks

- A system analysis from an economic perspective
  - All impacts are considered, economic and environmental
  - Market impact in terms of general equilibrium effects are accounted for
  - We have a common ”value scale”
  - Without a common value scale, comparisons cannot be made
- A proper CBA is an example of a system analysis

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People (primary) involved

- Runar Brännlund, CERE/UmU
- Tommy Lundgren, CERE/UmU
- Peichen Gong, CERE/SLU
- Jinggang Guo, CERE/SLU
- Wenchau Zhou, CERE/UmU

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