The consequences of increasing bioenergy production

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Outline

1 Introduction

- Bioenergy in Sweden
- Literature review

2 Research method

- Model overview
- Scenarios setting

3 Key results

4 Conclusions

Bioenergy in Sweden

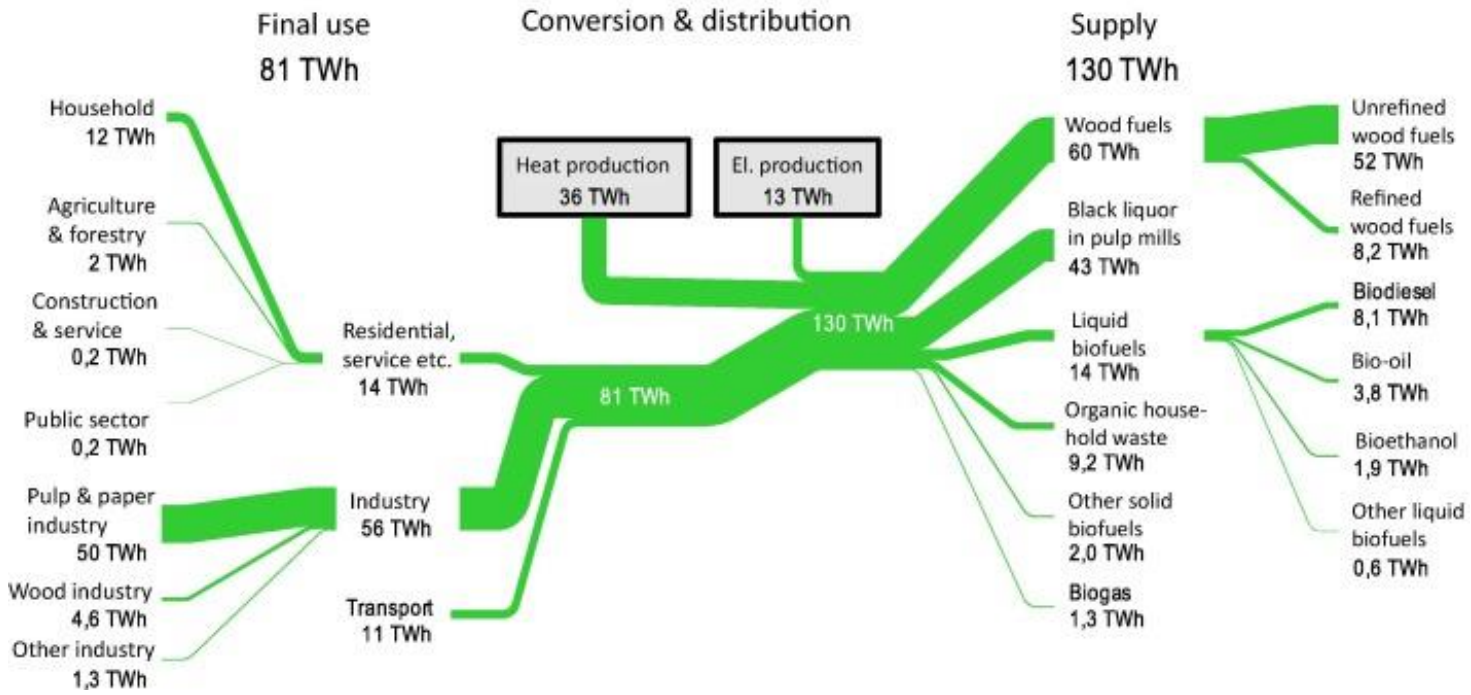


Fig. 1. Biomass-based energy in the Swedish energy system 2014 (Swedish Energy Agency, 2015a). From Börjesson et al. (2017)

Current climate and energy framework

- A binding EU target: at least 40% domestic reduction in GHGs by 2030 compared to 1990
- A binding EU target: at least 27% of EU energy consumption from renewable sources by 2030
- Sweden has committed to 100% renewable energy by 2040

Key questions

How will increased bioenergy production impact:

- Annual timber harvest
- Net carbon emissions
- Traditional wood-processing industries

Literature review

Regional level

- Ince et al. (2011): Fuelwood will compete for fiber with traditional products
- Schwarzbauer & Stern (2010): Panel and paper industries will be worse-off
- Kong et al. (2012): Competition between wood energy users and pulp manufacturers grows

Global level

- Moiseyev et al. (2013): No scarcity of round wood in Europe in the next 10 to 15 years
- Buongiorno et al. (2011): Fuelwood demand increases; Price of all other products rises unevenly

Research method

A partial equilibrium model on the Swedish forest sector; track the market prices and quantities of raw wood products, growing forest resources, welfare changes and use of round wood for energy. It consists of four modules:

- **Economic module**: include an aggregate supply equation and two demand equations for sawlog and pulpwood; calculate the prices and production of primary timber products by maximizing total welfare
- **Bioenergy module**: calculate the amount of energy produced from forest residues, fuelwood, sawdust, black liquor and bark following the Input-Output coefficients; link bioenergy target and forest harvest (95 TWh); e.g.,

  I-O table for producing one unit of sawn products

Sawlog	Chip	Dust	Bark	Sawn products
-2.159 m³	0.7 m³	0.3 m³	0.2 m³	1 m³

  Input coefficients of each component for producing one unit of energy (1 MWh)

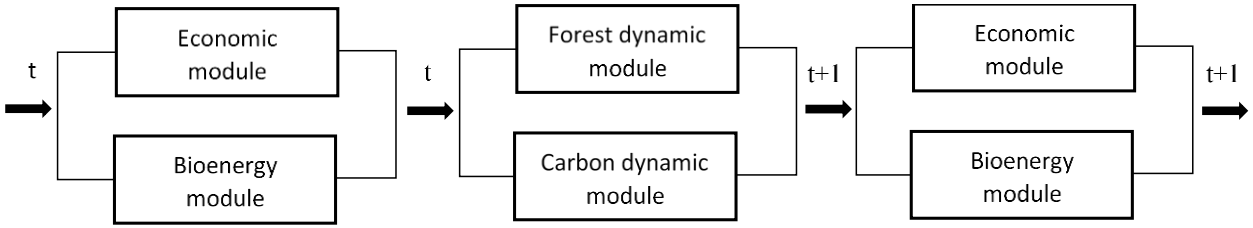
Fuelwood	Chip	Dust	Bark	Black liquor
-0.556 m³	-0.521 m³	-0.521 m³	-0.622 m³	-1 MWh

- **Forest dynamic module**: cut the oldest trees towards the younger until the supply is meet; link the total felling, harvest area and forest growth; yield the available forest state for the next year

Research method

- **Carbon dynamic module**: yield the carbon balance. If it is positive, additional carbon is captured from the atmosphere in the forests pools and wood products pools, and vice versa.

C balance = Changes of CO_2 in the standing volume of forests
+ Changes of CO_2 in the harvested wood products pools
+ CO_2 reduction by energy substitution and materials substitution
− CO_2 emission from harvesting, transporting and processing
− CO_2 emission from the combustion of biomass

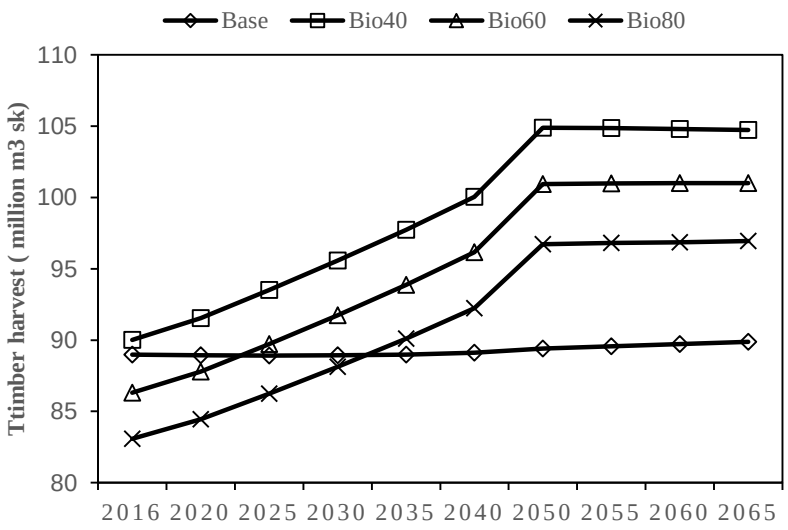


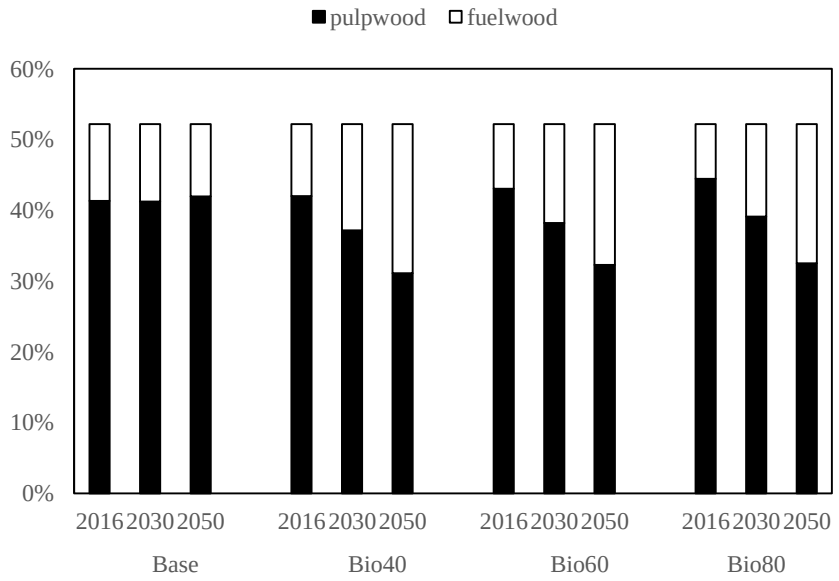
Four scenarios considered:

- **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%

Key results

- In the baseline scenario around 90 million m³ of standing volume are felled in Sweden each year. To ensure an additional 25 TWh of forest-based bioenergy, more trees are expected to be cut since the beginning (40 %).
- In Bio40, 105 million m³ of standing volume will be harvested in 2050, 18 % higher than the baseline level.
- Increasing the utilization of forest residues will postpone the final harvest, a higher extraction rate is associated with a lower timber harvest level in 2050.
- Competition between the use for pulpwood and for fuelwood gets intensified as the production continues to grow.

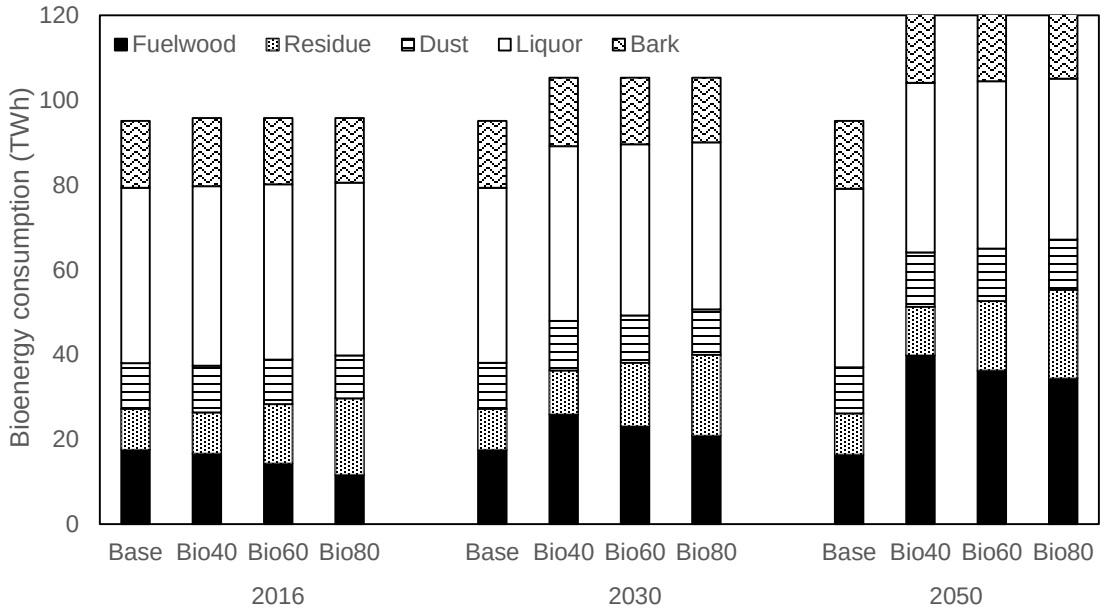




Key results

Shifting balance between fuelwood and pulpwood changes the the composition of bioenergy

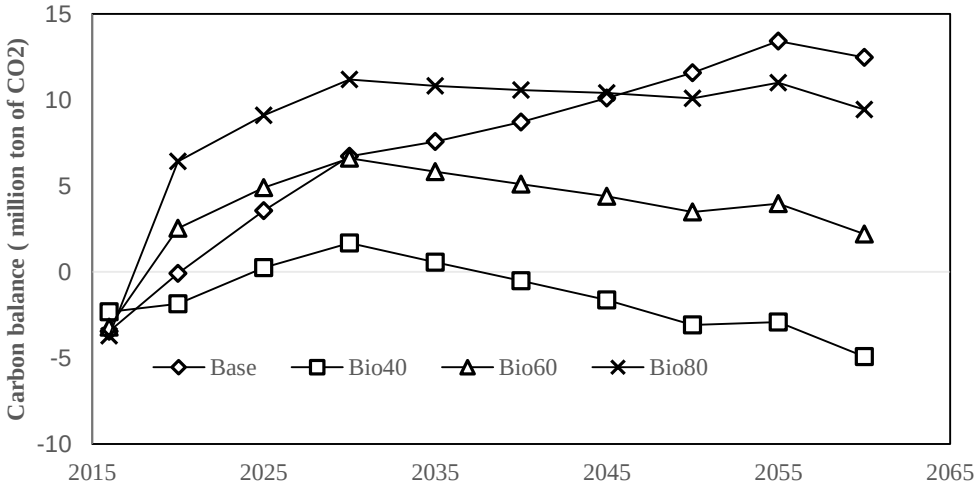
- Compared to the baseline level of 17 %, bioenergy produced from the fuelwood experienced a marked increase, accounting for 33 %, 30 % and 28 % of the total bioenergy supply, respectively
- Bioenergy produced from black liquor decreases as the extraction rate increases, which indicates that less pulp will be produced.



Key results

In general, the lower the harvest level is, the more carbon would be stored in forest standing volume over time.

- In Bio40 forest-based bioenergy is achieved at the expense of forest carbon sequestration and leads to a negative carbon balance.
- Increasing the use of forest residues delays the final harvest, which in turn could improve the carbon balance. In Bio60, 3.5 million ton of CO2 / year is removed from the atmosphere in 2050.
- Doubled extraction rate yields a lowest harvest level in all Bio scenarios and a positive carbon balance of 10 million ton of CO2 / year in 2050 will be achieved.



Key results

Increasing bioenergy production will affect the welfare across sectors

- Sawlog consumers will benefit since the consumer surplus is always above the baseline level.
- Pulpwood consumers are worse off because shortage of pulpwood supply pushes up the price.
- Forest owners' welfare decreases in Bio40 compared to Base, but increases in Bio60 and Bio80.
- Bio40 is the only scenario that the total welfare is lower than the Base.

(Unit: Million SEK)	Base	Bio40	Bio60	Bio80
Sawlog consumers:	0 (705068)	48962	26212	2912
Pulpwood consumers:	0 (336812)	-15448	-18008	-23733
Forest owners:	0 (440138)	-10423	6771	27905
Non-timber benefits:	0 (589032)	-23687	-9670	3212
Total surplus:	0 (2071049)	-595	5306	10297

Conclusions

- **Changes in total harvest level:** to meet the additional 25 TWh of bioenergy production, 105 million m³ of timber harvest may be required. The additional bioenergy production can be achieved without scarifying the total standing volume.

- **Changes in the Carbon Balance:** currently Swedish forest consists of stands with an uneven distribution of age-classes. Promoting the use of forest residues will buy some time to convert the forest into middle-aged forests, enhance the ability to sequester carbon and lead to a positive carbon balance.

- **Changes between alternative uses of wood:** increasing bioenergy production alters the current balance between material use and energy use; Competition between the use of wood for pulp and for bioenergy grows; Pulp and paper industries will face a difficult market situation due to the reduced pulpwood supply.

Thank you