A full Supply chain optimization model to locate the forest biomass-based bioenergy production plants in Finland

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Contents

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Background

• 2020 Renewable energy targets of Finland:
  – 38% renewable energy share (from 25% 2009)
  – 25.2 PJ / 20% minimum biofuel distribution requirement (double counting)

• National Renewable Energy Action Plan:
  – 13.5 Mm³ forest chips use (from 6 Mm³ 2009)

Measures

• Incentives e.g, wood incentive per MWh electricity and linked with CO2 price.
• Subsidies for small wood procurement eg. Thinning
• Mandatory blending % with fossil transport fuels
BeWhere Finland

Bioenergy supply chain costs

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Biomass transport</th>
<th>Production</th>
<th>Biodiesel transport</th>
<th>Distribution</th>
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</thead>
<tbody>
<tr>
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<td>.investment</td>
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<td>.fuel station</td>
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<tr>
<td>.forwarding</td>
<td>.train</td>
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<td>.interest rate</td>
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<tr>
<td>.storage</td>
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</tbody>
</table>

Candidate sites
- close to biomass supply
- close to energy demand
- pulp & paper industry
- ports

Transport network
- Road
- Rail

Energy demand
- transport fuel
- district heating

Biomass supply

Bioenergy production

Biofuel demand

Heat Demand

Parameters
- biofuel yield
- heat yield
- electricity yield
- emission factor

Constraints
- biomass supply
- production plant
- energy demand
- heat transport

Other costs
- fossil fuel
- heat price
- electricity price

Model results
1. plant no
2. optimal location
3. Size
4. biomass area
5. biomass share
6. biofuel sold
7. heat sold
8. electricity sold
9. minimized costs
   a. biomass
   b. transport
   c. production
   d. fuel station
10. biofuel cost
11. CO₂ emissions
12. parameter sensitivity
13. biofuelblend
14. import & export
Flow of Feedstock and energy

- **Resources**
  - Sawmill
    - woodchips
    - residuals
  - Forest
    - sawnwood
    - pulpwood
    - energywood
  - Import
    - roundwood
    - woodchips

- **Feedstock**
  - Pulp & paper
  - Pellet industries
  - CHPs/DHs
  - FT biodiesel

- **Processing**
  - heat
  - electricity
  - transport

- **Energy Products**
  - Fossil fuel
  - Biofuel import

- **Fuel**
Spatial distribution of feedstock resources
Energy demand

Fuel station Demand (GJ)

- 76,090 - 1,247,102
- 1,247,103 - 3,400,185
- 3,400,186 - 13,084,916

Heat Demand (GJ)

- 29,073 - 289,002
- 289,003 - 720,066
- 720,067 - 1,530,182
Scenarios for 2020 biofuel target

• Base Scenario

• Feedstock availability

• Industrial competition

• Parameter costs and energy price
Cost-optimal locations

• Five FTplants: Rovaniemi, Lapinjärvi, Rauma, Salo, Kauhava >90 times

• Minimised transportation costs means abundant feedstock supply and high energy demand

• Max heat transport distance
Cost breakdown of biodiesel production supply chain

- P3 produces the cheapest biodiesel.
- Unit cost varied between 22.15€/GJ and 22.49€/GJ without any by-product sales.
Biomass supply and feedstock resource allocation
Costs and feedstock resource allocation

- 30% decrease would completely substitute sawmill residuals
- 30% increase = 40% energy wood + 51% pulpwood + 9% sawmill residuals
- 40% increase = pulpwood replace energywood completely

<table>
<thead>
<tr>
<th>Cost (€/GJ)</th>
<th>-30%</th>
<th>-20%</th>
<th>-10%</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
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<tbody>
<tr>
<td>Feedstock cost</td>
<td>21.20</td>
<td>24.23</td>
<td>26.55</td>
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<td>Feedstock transport</td>
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<td>FTbiodiesel cost</td>
<td>75.20</td>
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<td>82.73</td>
<td>85.05</td>
<td>87.02</td>
<td>87.18</td>
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</table>
Costs and feedstock resource allocation

Maximum pulpwood utilization potential at -30%

SMR price no influence as maximum utilization potential is reached
Costs and feedstock resource allocation

- 31 PJ of wood imports used when 40% decrease in cost
- Cost changes in energywood, pulpwood and sawmill residuals did not influence
- Because:
  - Expensive
  - Longer transport distance
Influence of biofuel import price, fossil diesel price and carbon tax on the 2020 biofuel target
Parameter sensitivity analysis

Variation of FT-biodiesel cost (%)

Parameter change (%)

- Feedstock share
- Industrial demand
- Energywood cost
- Transport cost
- Investment cost
- Heat price
- Electricity price
- Plant size
- Conversion efficiency
Eastern Finland - Model Scheme

Sawmill Residuals (GJ/ha):
- 3,304 - 65,079
- 66,080 - 165,199
- 165,199 - 395,403

Forest Biomass (m³/yr):
- 6,985 - 85,971
- 85,971 - 190,542
- 190,542 - 203,272

Biomass source: Sawmill, Forest
Biomass demand: Pulp and paper, CHP/DH plant, Pellet plant, Methanol plant, IGCC plant
Energy demand: Heat, Electricity, Transport fuel
Fossil fuel supply: Fossil fuel
Optimal plant locations

Influence of CO$_2$ cost on technology diffusion and emission savings
Future work

Social

Employment

Environment

Sustainability

Economy

LCA
THANK YOU!