Investments into forest biorefineries under different price and policy structures

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Motivation (1)

- **Need for alternative, renewable transportation fuels**
  - Oil scarcity and CO_2 emissions
  - EU requirement: 10 % of overall petrol and diesel consumption should be covered by sustainable biofuels by 2020

→ Biorefineries offer one important solution for biofuel production

- **The research on biorefineries has been technology driven** None of the previous studies link:
  - pulp and paper markets with
  - investment possibilities for different biorefinery technologies

Motivation (2)

- Companies in e.g. North America and Europe are considering investments in pulp and paper mill integrated biorefineries
- There are a number of different possibilities as regards to the choice of raw-materials, outputs and technology
- Viability of each depends on end markets, substitute markets (e.g. oil), biomass markets, and policies:
  - → At what energy price and subsidy levels are forest biorefineries profitable?
  - → What type of raw-material basis, technology or end product-mix is most profitable?
  - → How do different policy measures change the prices and choices?
- **There is a lack of studies analyzing these questions!**

Purpose of the Study

1. Set up a pulp and paper market model with biorefinery investment possibility
2. Analyze at what *fuel (oil) price* and *subsidy* levels forest biorefineries are profitable?
3. How do different policy measures change *prices*, *policy costs* and *input choices*?

⟶ Application and data relate to Finnish pulp and paper sector. However, the framwork can be generalized to other settings (countries with large forest resources and integrated pulp an paper mills)

The Pulp and Paper Plant Biorefinery

Biomass

Forest Owner:

Pulpwood

Residues

Other woodbiomass:

Chips

Sawdust

Bark

Recycled paper

Conversion Technologies

6 boiler types

”The Finnish Model”

Wood Gasification

Black Liqour Gasification

”The Swedish Model”

Intermediate / End Products

Pulp *(3 types)*

Paper *(8 types)*

Biofuels

Electricity

Heat

The Model*

- Model is similar to those often used in energy economic literature. It incorporates economic theory (markets) with detailed technical description of the production processes
- Different production functions for pulp, paper, biofuel and CHP production
- Biorefinery investments. Two different technologies: 1) wood or 2) black liqour gasification
- Producers maximaize profits (at plant level)
- Model computes equilbrium levels of: (i) pulp, paper, biofuel and heat *supply*; and (ii) wood and pulp *demand*

*Detailed description of the model, data and results in paper:

Kangas, Lintunen, Pohjola, Hetemäki & Uusivuori (2010). Investments into forest biorefineries under different price and policy structures, *paper submitted to Energy Economics -journal*

Numerical Simulation Application

- Use GAMS to solve the model and compute simulations
- Targets for biofuel production: 3, 6 or 9 TWh per year
  - amounts to 5, 10 or 15 % of the total transport fuel consumption in Finland, respectively (EU target 2020 10%, Finnish target 2020 7 TWh)
  - analyze levels of fuel price and policy instruments that are needed to reach these targets
- Application is based on real plant level data (35 plants) from pulp and paper industry and the energy market in Finland in 2008 (technology description and investment costs from engineering literature)

Three Different Policies Analyzed

1. Production subsidy

- price premium on top of biofuel price for all the biofuel units produced (by wood or black liquor)

2. Input subsidy (for forest residues)

- received for each unit of a wood fiber type used in biofuel production (in our analysis only for forest residue)

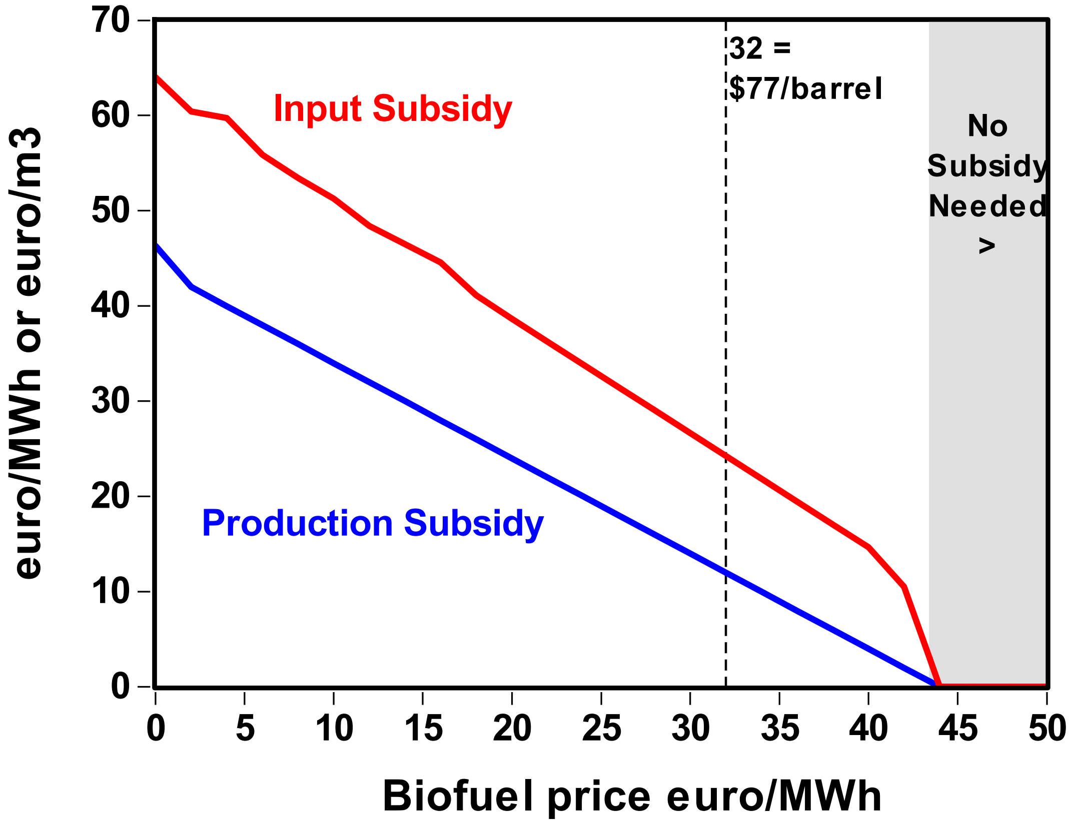
3. Investment subsidy

- a share of the total investment costs

RESULTS

(only some case examples, for full results, see the paper)

How Big Subsidies are Needed to Achieve 6 TWh (≈10 %) Requirement at Different Biofuel Price Levels?



- At biofuel price level 32 €/MWh (≈ $77/barrel, i.e. about current level):

→ production subsidy would need to be 12 €/MWh

→ input subsidy would need to be 24 €/m^3

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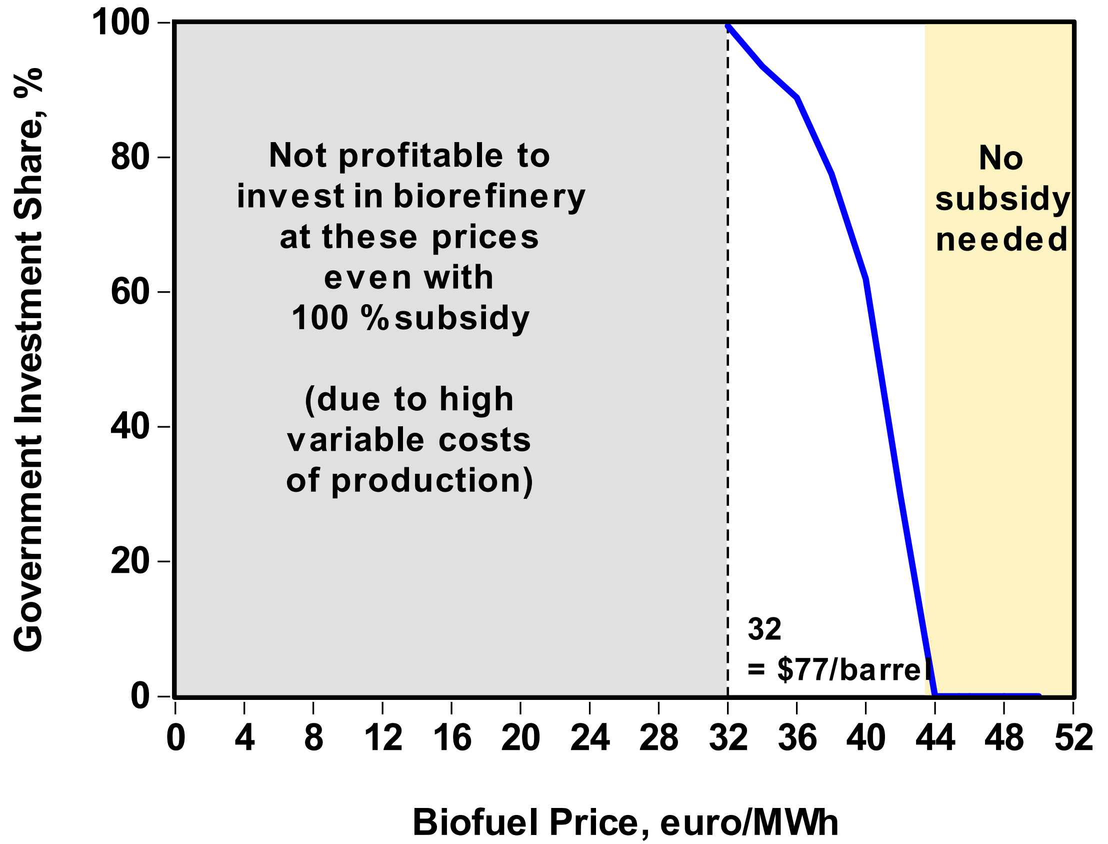
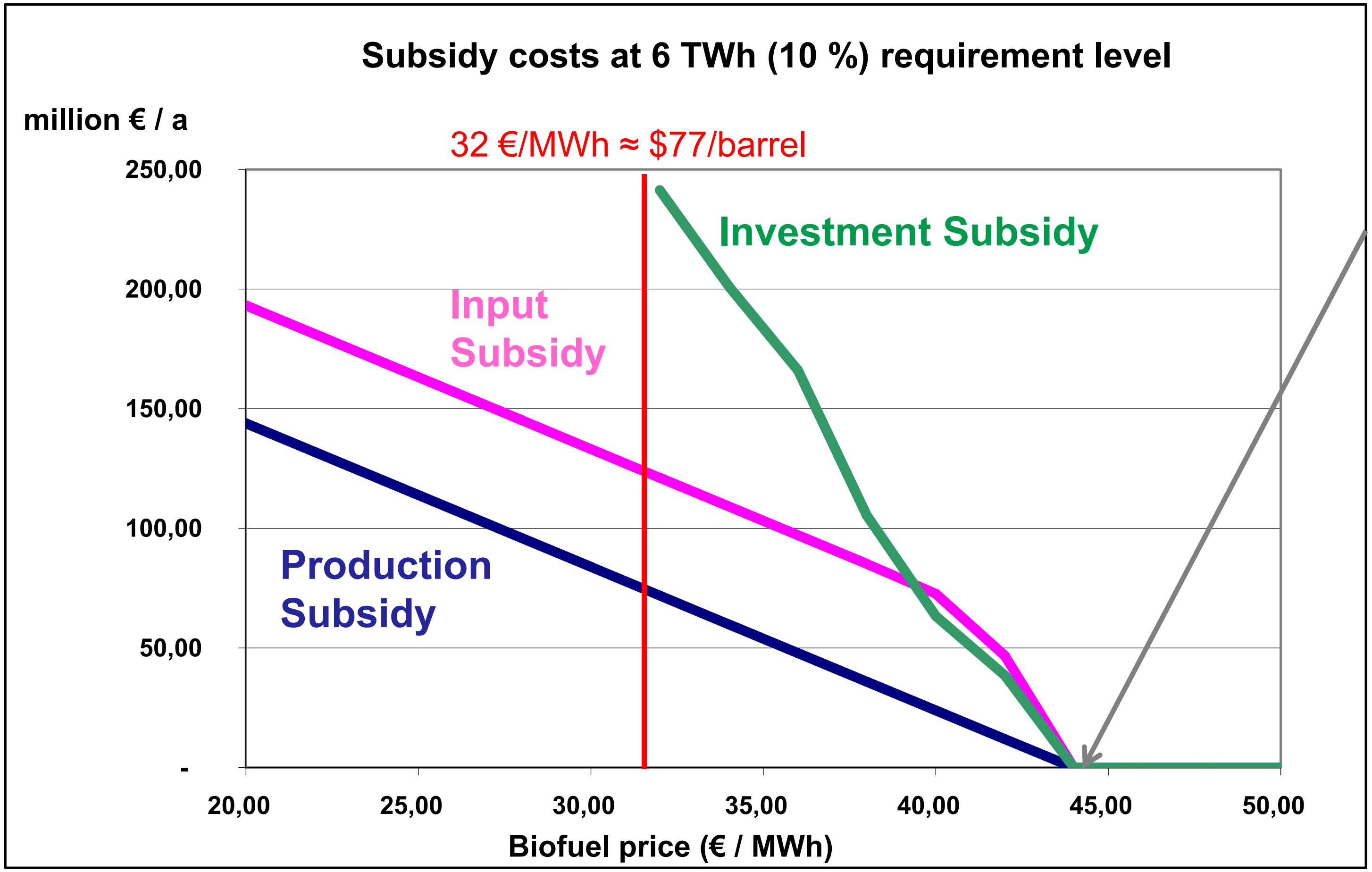
Investment Subsidy Needed to Achieve 6 TWh (≈10 %) at different biofuel price levels



- Investment subsidy effective only at a very tight biofuel price range 32-44 €/MWh ($77-$105/barrel)

What Would Policy Costs Be to Achieve 6 TWh (10 %)?



At price level over 44 € / MWh (≈ $105/ barrel) no subsidy needed

- Production subsidy is most cost-efficient policy
- Investment subsisdy is the least cost-efficient policy

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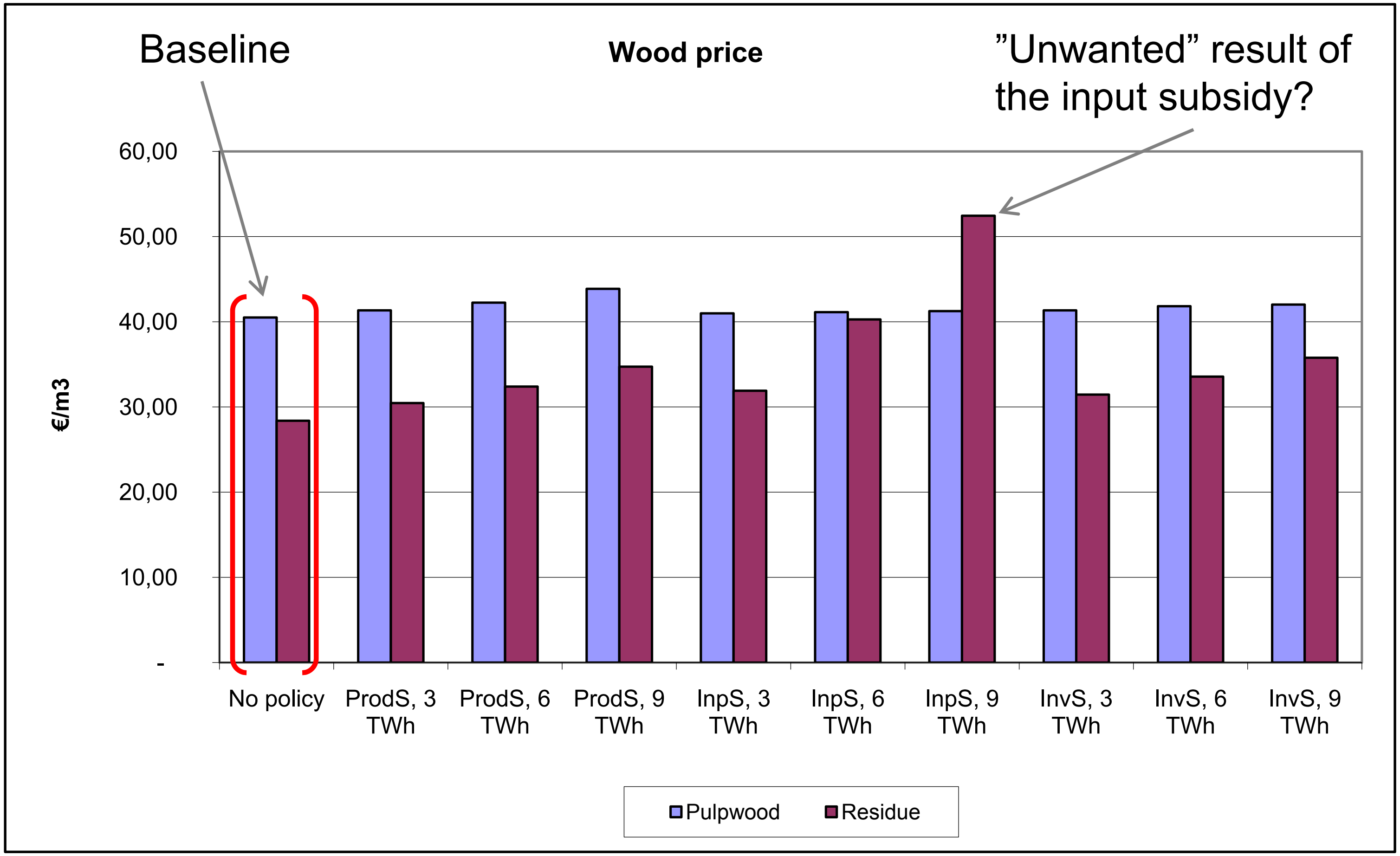
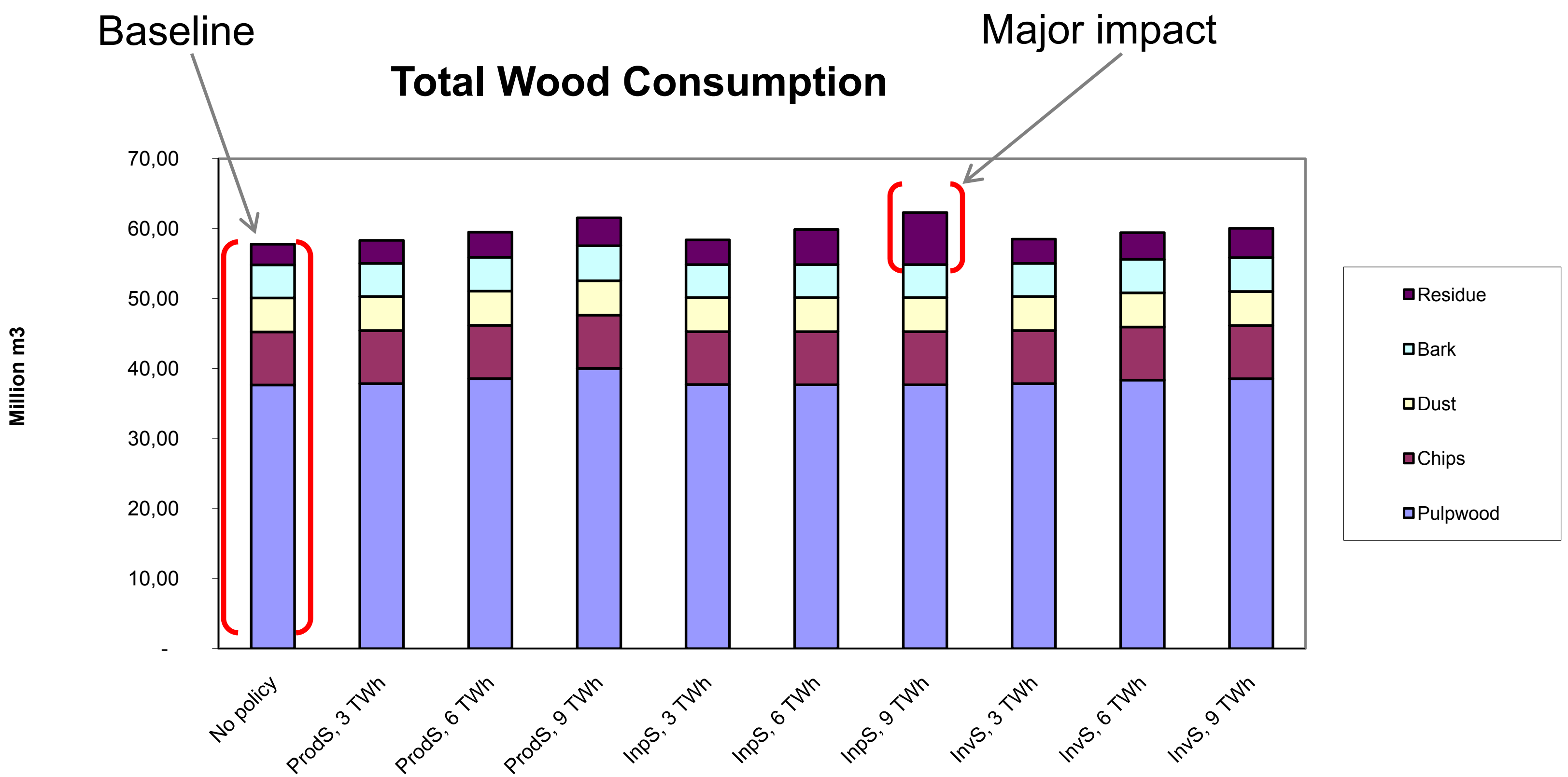
Policy Impacts to Pulpwood & Residue Prices



- policies have only marginal impacts to pulpwood prices
- input subsidies have significant impacts to residue prices

Policy Impacts to Pulpwood & Residue Consumption



- Policies hardly impact pulpwood consumption
- Input subsidy clealry impacts wood residue consumption
- Policies do not have notable impact on total wood consumption

Number of biorefinery investments

(at biofuel price 38 €/MWh)

		Number of biorefineries
Production subsidy	3 TWh target	2
	6 TWh target	**4**
	9 TWh target	6
Input subsidy	3 TWh target	2
	6 TWh target	**5**
	9 TWh target	7
Investment subsidy	3 TWh target	3
	6 TWh target	**10**
	9 TWh target	18

So What Is the Best Policy?

→ Dependes on the Policy Objective

Minimize Policy Costs	Increase Residue Use + Secure Pulpwood Price
1. Production Subsidy	1. Input Subsidy
2. Input Subsidy	2. Investment Subsidy
3. Investment Subsidy	3. Production Subsidy

Concluding Comments

- Study contributes to the literature:
  - by formulataing a model that allows investments in pulp and paper mill integrated biorefineries
  - analysing policy impacts to output and input choices, and the cost of policies
- Obviously, the results are as good as the model and data
- Have to be careful when using the results for policy advice. Still, it is helpful analytical tool.
- Interesting extensions: incorpoporate the model to a larger model framework, which, e.g., includes transportation sector and more detailed forest owner supply function

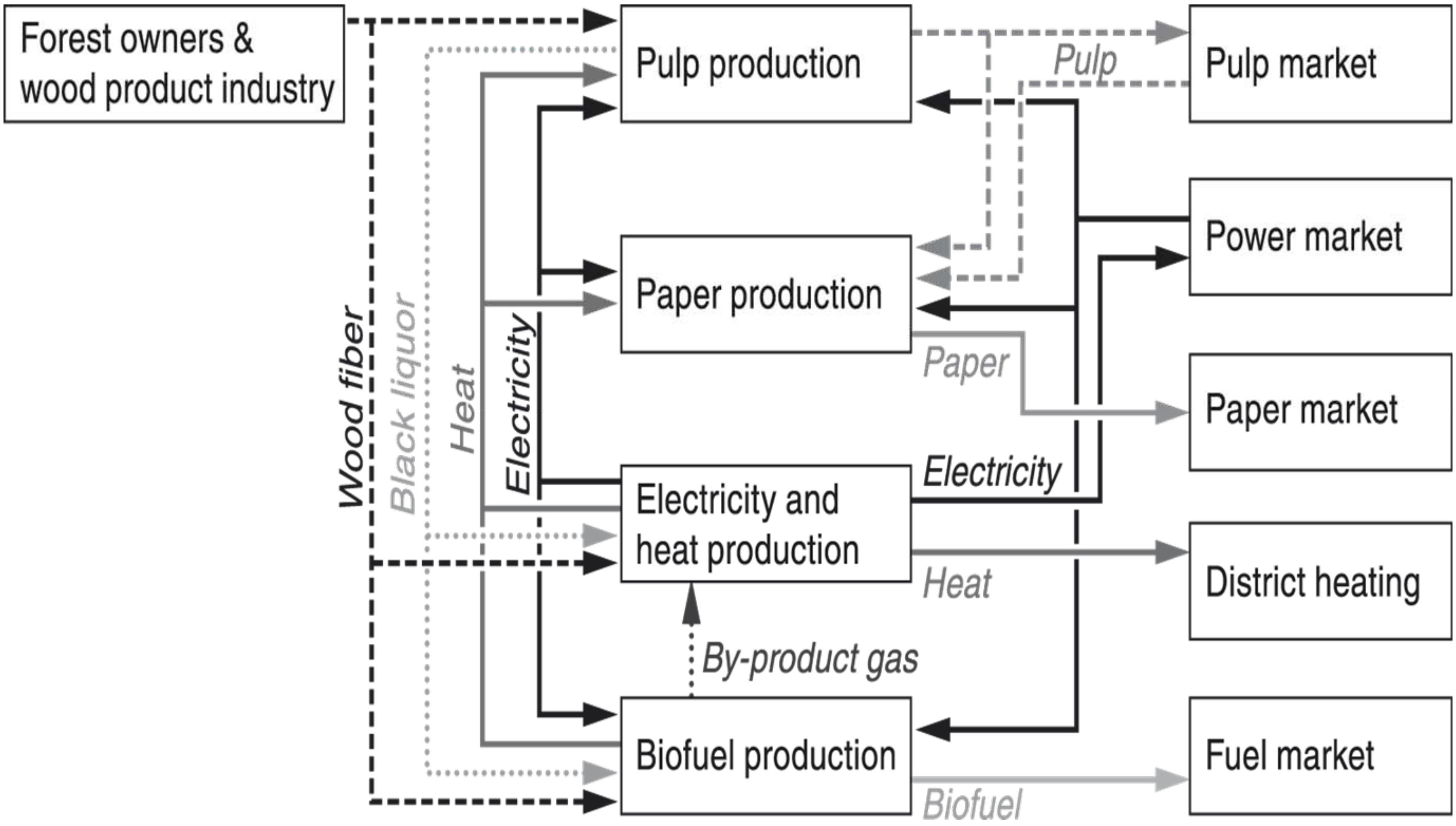
THANK YOU!

More about the modelling project, see the research group's home page:

http://www.metla.fi/hanke/50168/index-en.htm

Additional technical slides

BIOREFINERY WOOD AND ENERGY FLOWS



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The paper and pulp grades and wood fiber types

GRADES/TYPES	
Paper grades	Newsprint Uncoated finepaper Coated finepaper Uncoated magazinepaper Coated magazinepaper Tissue Container board Carton board
Pulp grades	Mechanical Chemical Recycled
Wood fiber types	Pulpwood Chips Sawdust Bark Forest residues Recycled paper

The allowed fuels for different boiler types

BOILERS AND FUELS	Allowed fuel 1	Allowed fuel 2	Products
Recovery boiler	Black liquor	-	Electricity and heat (CHP)
Fluidized bed boiler	Wood fiber*	Peat	Electricity and heat (CHP)
Gas turbine	Natural gas	By-production gas	Electricity and heat (CHP)
Oil boiler	Oil	-	Electricity and heat (CHP)
Heat boiler	Wood fiber*	-	Heat

Pulp and Paper Plant's Profit Maximization Function

$$\max_{\{y,z,x,I\}} \pi(\boldsymbol{y},\boldsymbol{z},\boldsymbol{x},\boldsymbol{I}) = \sum_{m\in PA}\left(p_m - \sum_{i\in I_m} p_i a_i^m\right) y^m + \sum_{g\in PU}\left(p_g - c_g^S\right) x_g^S - \sum_{g\in PU}\sum_{w\in WT_g} \alpha_w^g z_w^g \sum_{i\in I_g} p_i a_{iw}^g$$

$$+ p^{bf}\sum_{b\in GT}\alpha_b^{bf} z_b^{bf} - \sum_{b\in GT}\alpha_b^{bf} z_b^{bf}\sum_{i\in I_{bf}} p_i a_{ib}^{bf} + \sum_{s\in BT}\left(\sum_{j\in J} p_j \eta_{js}\sum_{f\in F_s} x_{fs} - c_{fs}\left(\sum_{f\in F_s} x_{fs}\right) - \sum_{f\in F_s} p^{ec}\varepsilon_f x_{fs}\right)$$

$$-\sum_{w\in WT}\left(p_w z_w^B + \frac{2}{3} t_w \left(z_w^B\right)^{\frac{3}{2}}\right) - \sum_{g\in PU} p_g x_g^B - \sum_{b\in GT} c_{inv,b}^{bf} I_b^{bf}\left(\frac{I_b^{bf}}{\chi_{calib,b}^{bf}}\right)^{(\omega_{I,b}^{bf}-1)} - \sum_{s\in BT} c_{inv,s}^{chp} I_s^{chp}\left(\frac{I_s^{chp}}{\chi_{calib,s}^{chp}}\right)^{(\omega_{I,s}^{chp}-1)}$$

- ❑ Leontief function (fixed input proportions per output unit)
- ❑ There are several constraints in the pulp and paper plant's profit maximization problem
- ❑ A competitive market partial equilibrium model is formulated as a mixed complementarity problem, which is solved using PATH solver in GAMS modeling system