# Investments into forest biorefineries under different price and policy structures

*Kangas, H.-L., Lintunen, J., Pohjola, J., Hetemäki, L. & Uusivuori, J.*

*Finnish Forest Research Institute*

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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 and
  - analyze biofuel supporting policy impacts in this setting

# Motivation (2)

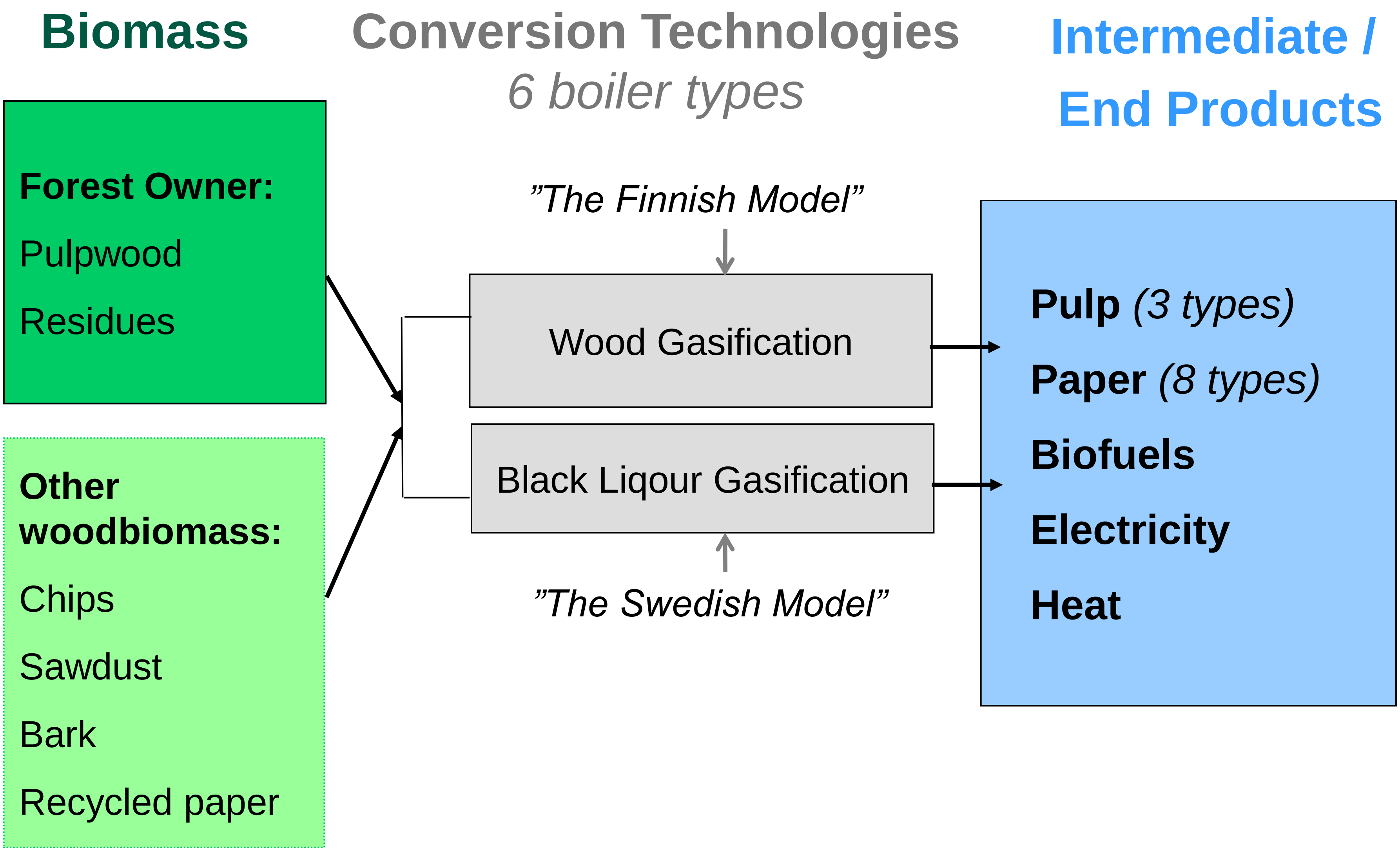
- Companies in e.g. North America and Europe are considering investments in pulp and paper mill integrated biorefineries
- There are a number of different possibilities as regards to the choice of raw-materials, outputs and technology
- Viability of each depends on end markets, substitute markets (e.g. 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



# The Model*

- Leontief production functions for paper, pulp, biofuel and CHP production
- Biorefinery investments. Two different technologies: 1) wood or 2) black liqour gasification
- Producers maximaize profits (at plant level)
- Endogenously from the model (i) Supply of pulp, paper, biofuel and heat; (ii) Demand for wood; (iii) Demand for pulp
- Demand/supply curves (constant elasticity):Demand for paper and heat; Supply of wood

*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 a 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 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)

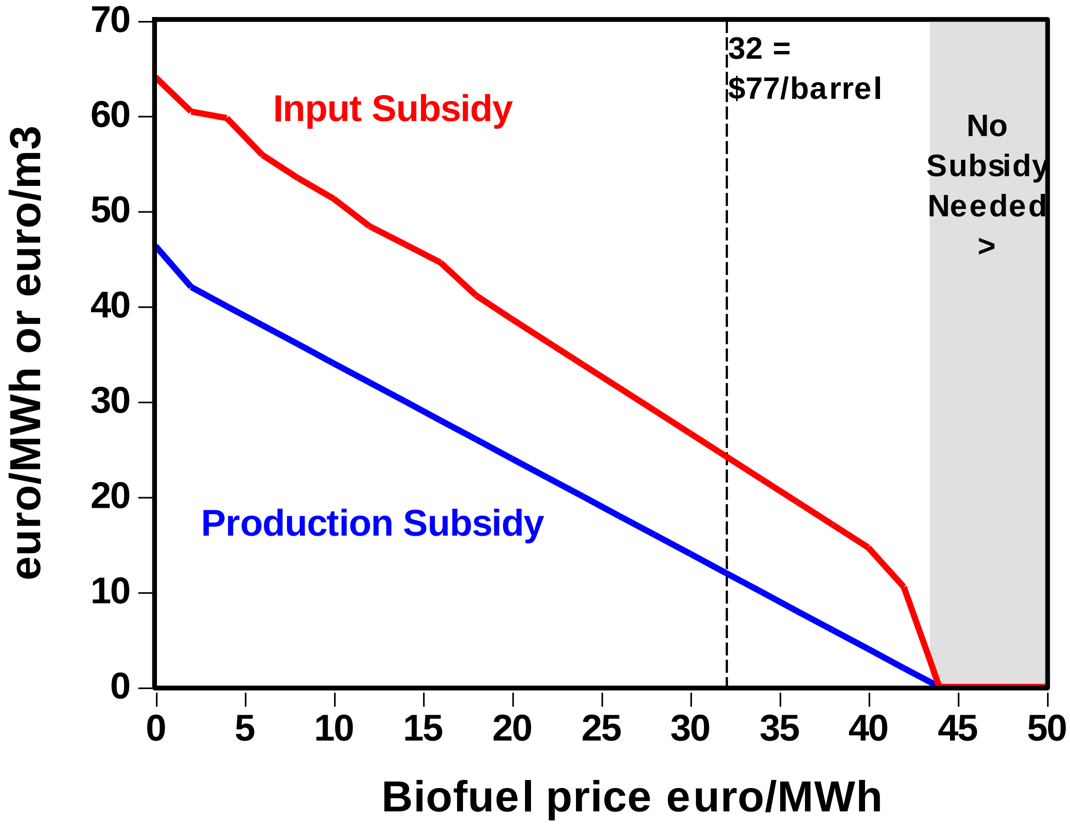
**3. Investment subsidy**

- a share of the total investment costs

# RESULTS

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

# Input or Production Subsidies Needed to achieve 6 TWh (≈10 %) requirement level

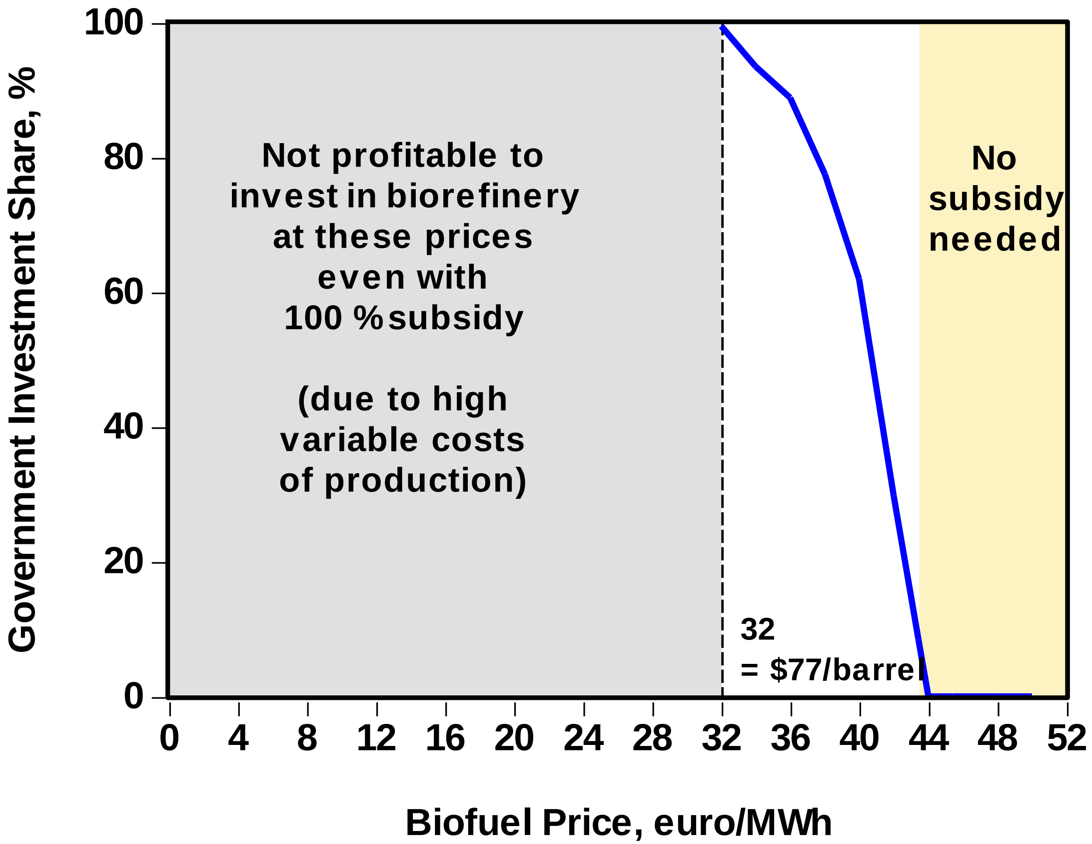



➢ At biofuel price level 32 €/MWh (≈ $77/barrel, i.e. current level):

→ production subsidy would need to be 12 €/MWh

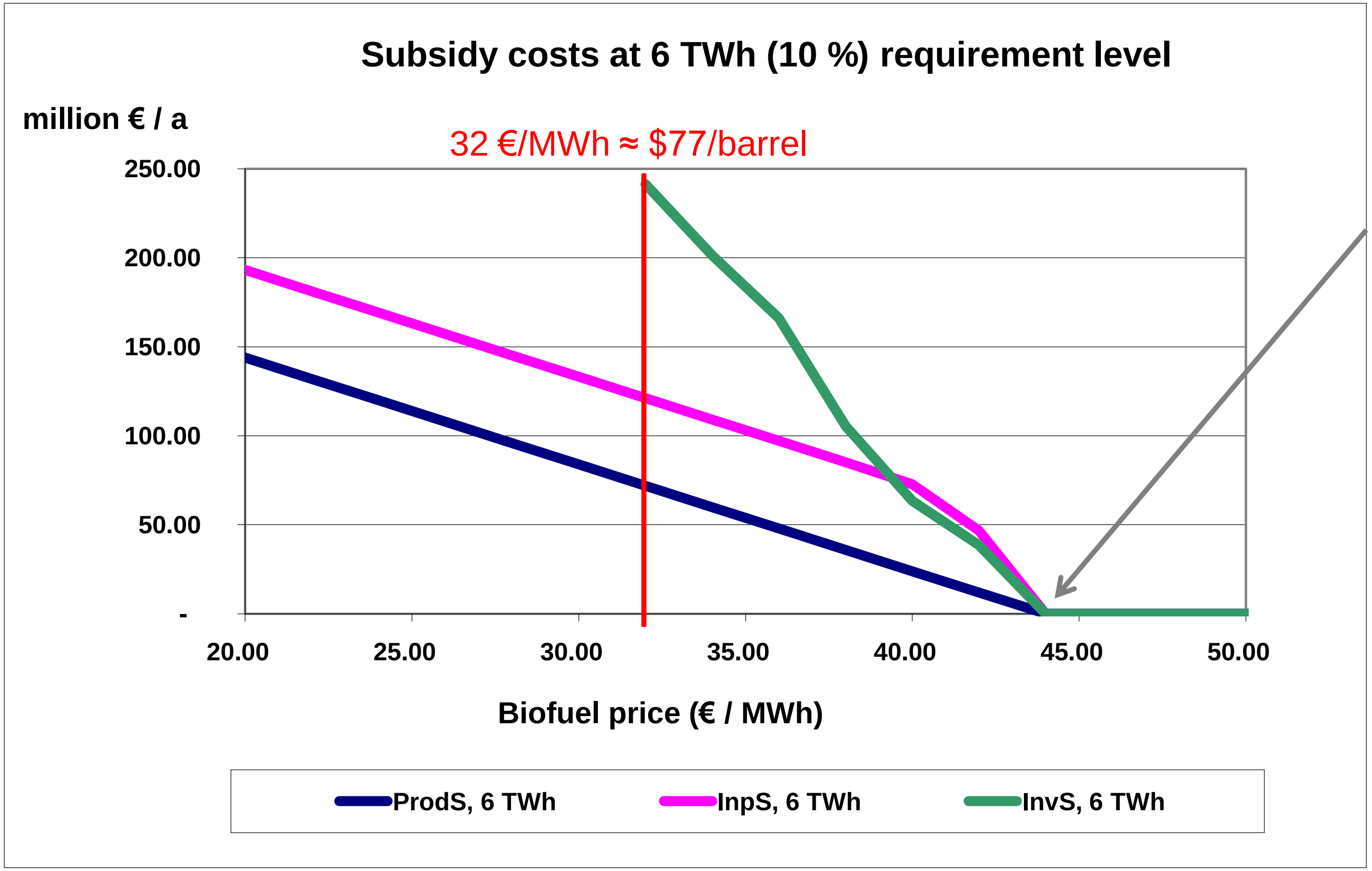
→ input subsidy would need to be 24 €/$m^3$ (19.2 MWh; since 0.8 residue $m^3$ ≈ 0.8 MWh energy)

# Investment Subsidy Needed to achieve 6 TWh (≈10 %) requirement level




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

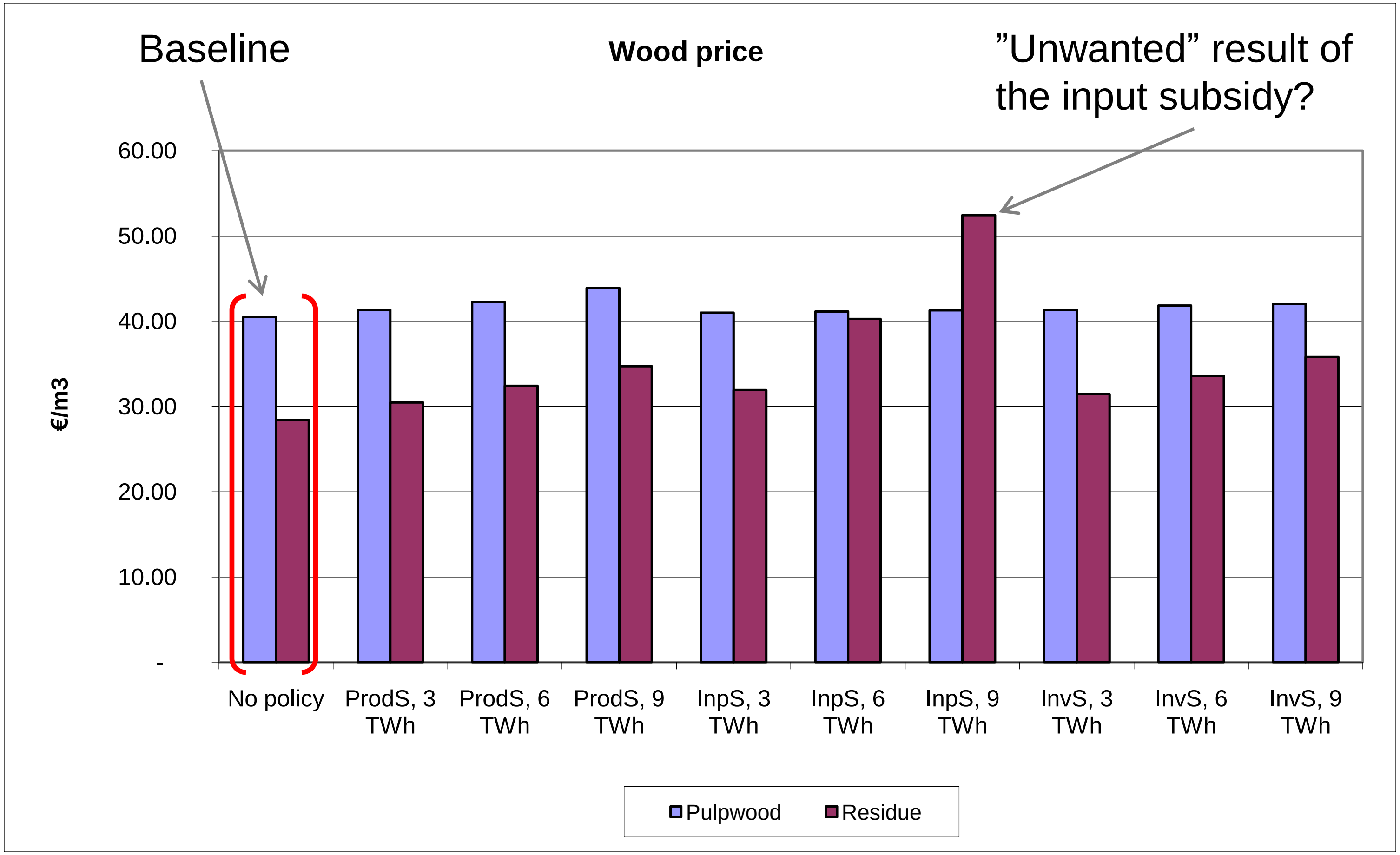
# What Would Policy Cost be at 6 TWh (10 %) level?




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

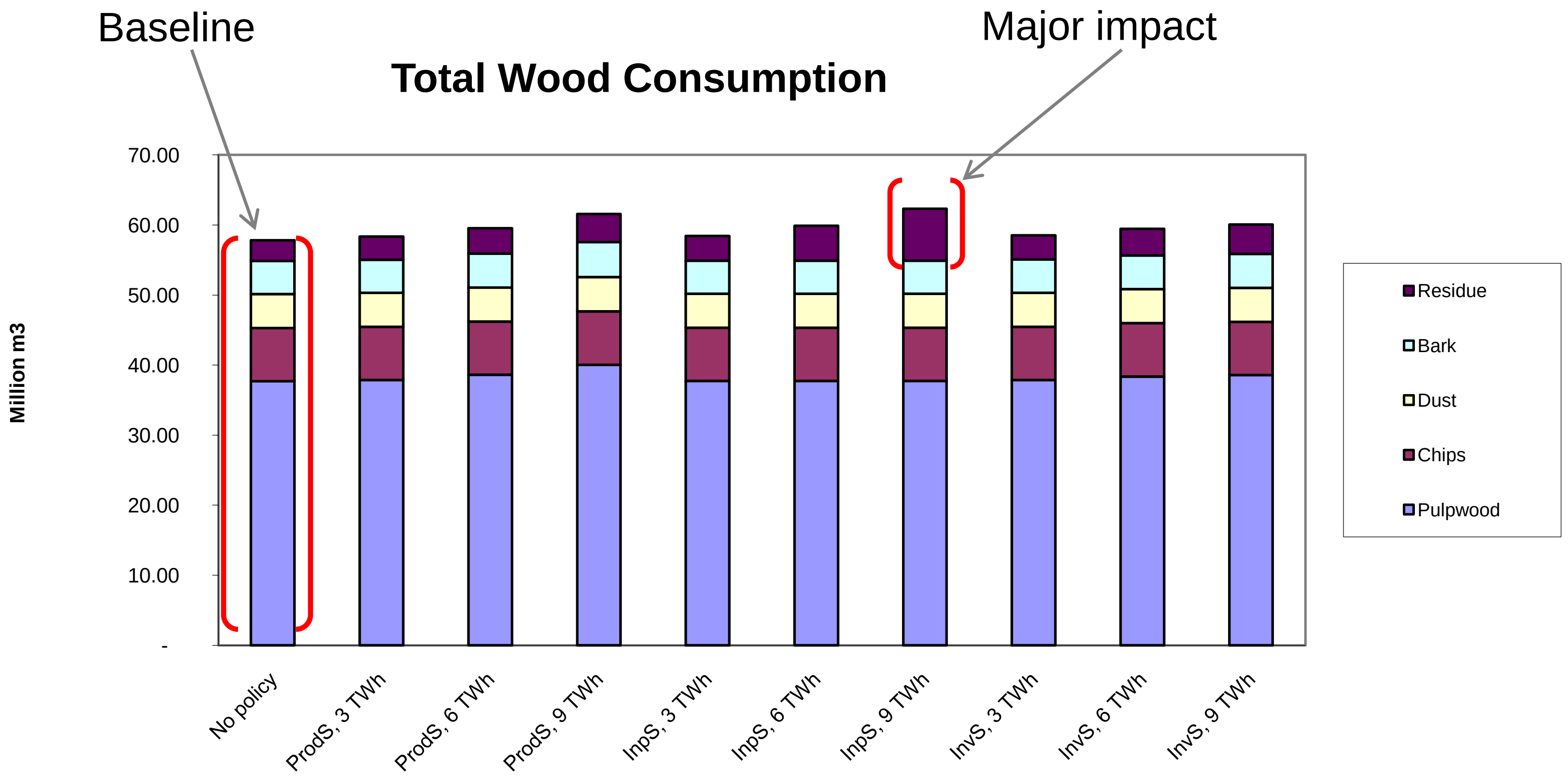
- Production subsidy is most cost-efficient policy
- Investment subsisdy is the least cost-efficient policy

# 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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# 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
- Interesting extensions: incorpoporate the model to a larger model framework, which, e.g., includes transportation sector and fully developed forest owner supply equation

# 감사합니다 !

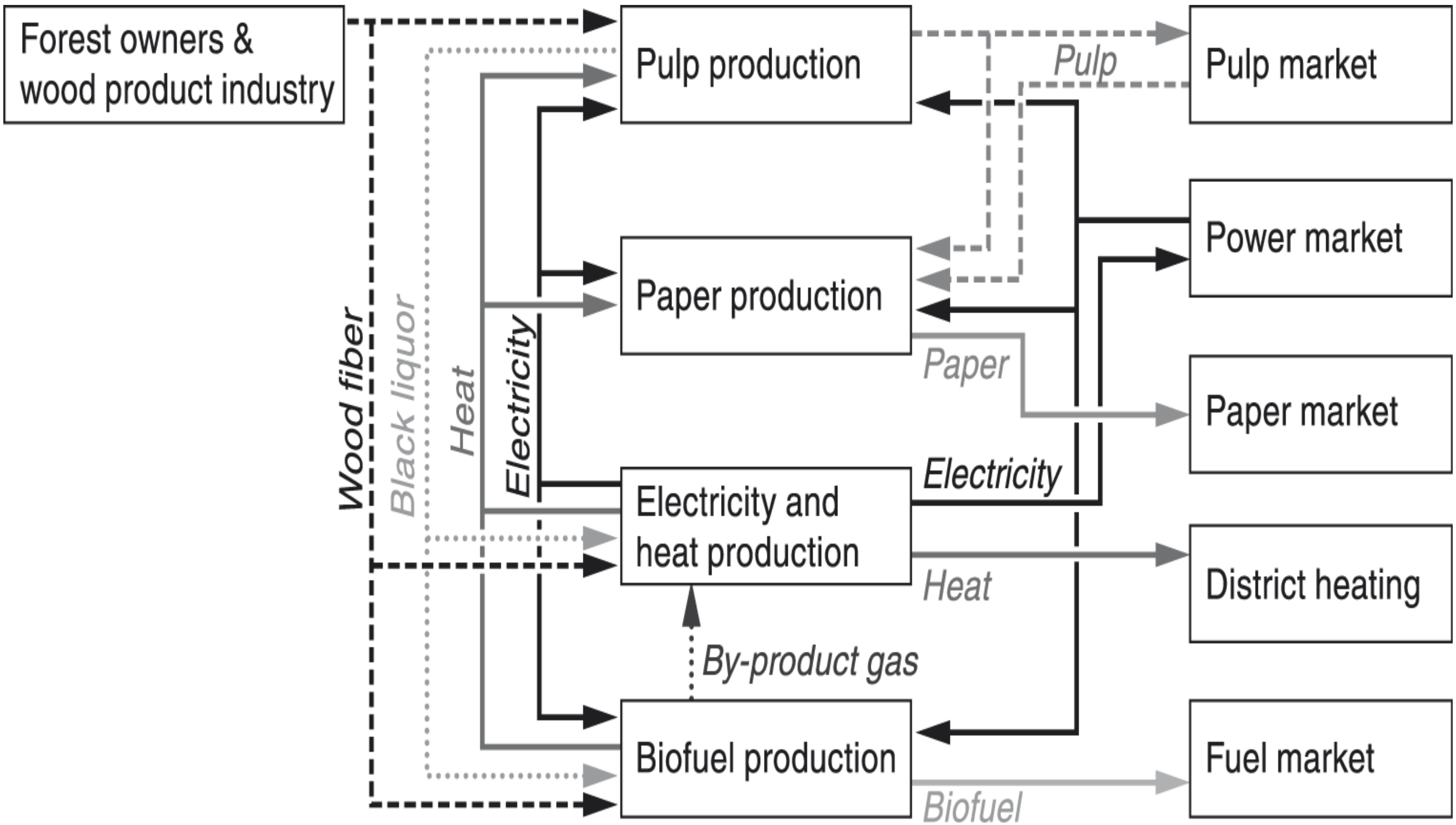
## THANK YOU!

More about the modelling project, see the reserch 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<br>Uncoated finepaper<br>Coated finepaper<br>Uncoated magazinepaper<br>Coated magazinepaper<br>Tissue<br>Container board<br>Carton board |
| ***Pulp grades*** | Mechanical<br>Chemical<br>Recycled |
| ***Wood fiber types*** | Pulpwood<br>Chips<br>Sawdust<br>Bark<br>Forest residues<br>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 |

# 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 |

# Pulp and Paper Plant's Profit Maximization Function

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

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

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

- ❑ 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