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Wood Use Increase in Construction Sector: Market, Forest Management and Climatic Impacts-Towards an Integrated Modeling Framework

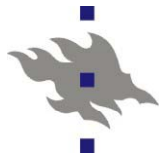
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Forest Sector Modeling - State-of-Art and Future Challenges in an Expanding Global Market Place. November 17-20, 2008 Seattle, Washington, USA



Research Team

Climate change mitigation benefits of wood use in construction sector

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Forest sector market model

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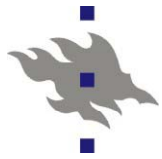
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Regional level forest model

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Stand level forest model

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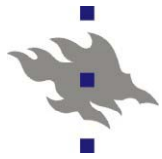


Motivation for the Study

Climate change mitigation: forestry and wood products' lifecycle as a whole

- Carbon stocks in the forest
 - Forest management practices ↑↓
- Carbon sequestered in wood products during their life span
- Wood energy and wood products can replace fossil fuels and energy intensive materials
 - Substitution management is affected by several factors
- Trade-offs between different mitigation measures
 - All aspects can not be maximised simultaneously

WHERE SHOULD THE CARBON BE AND WHAT SHOULD IT DO?

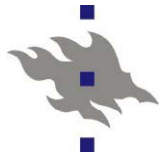


Research Questions and Approach

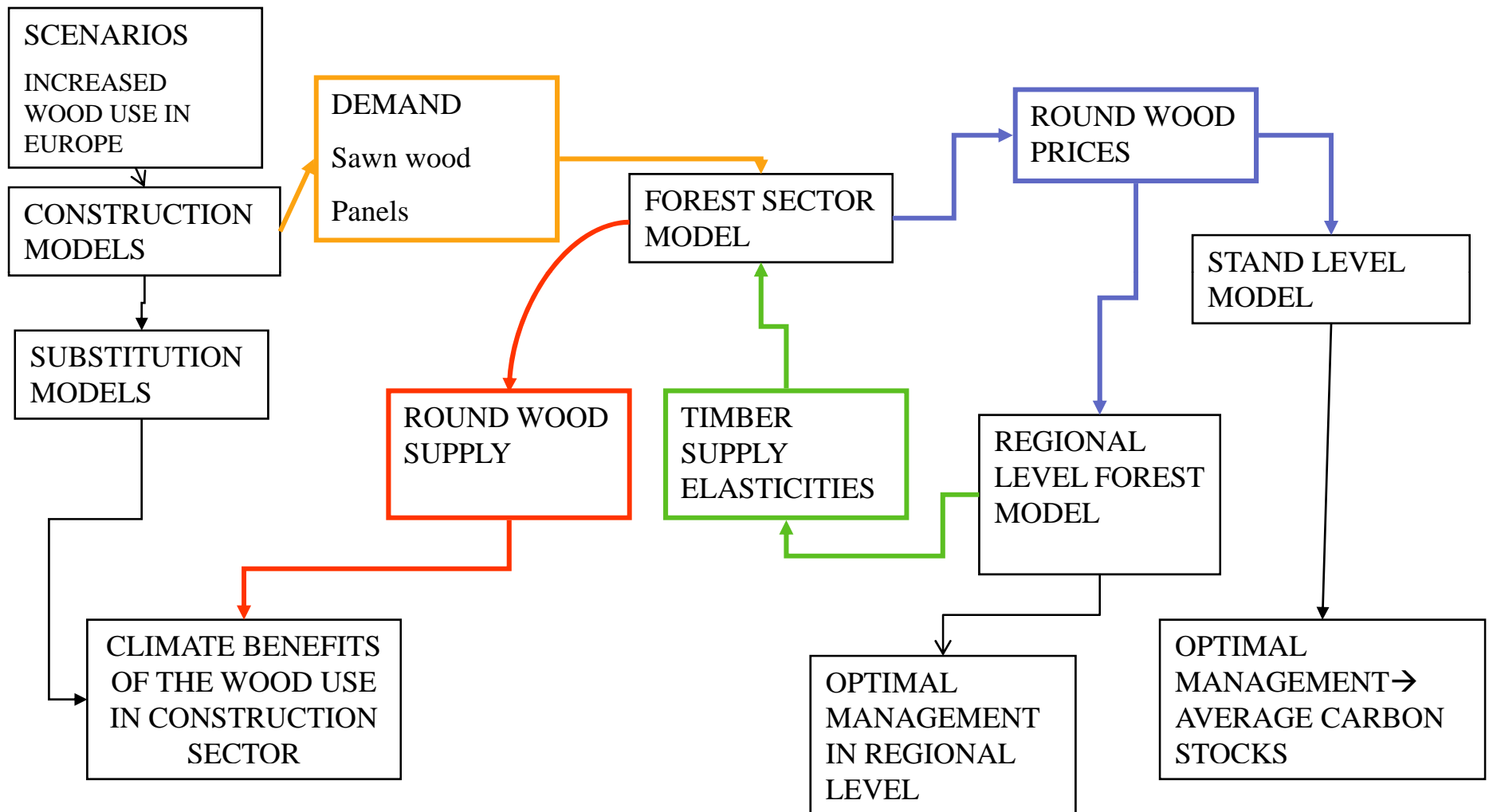
- What would happen if the use of wood in housing construction increased from the current practices?
 - Round wood supply and demand
 - Growing stocks of forests, forest management and the overall carbon balance **in Sweden**

- Existing models are combined
 - Forest management on **stand and forest level**
 - **Forest product markets**
 - **Models of wood substitution in construction sector**

- The consistency of the linkages between models investigated and missing models and linkages are identified



Framework- Models, Linkages, Outputs and Information Flows

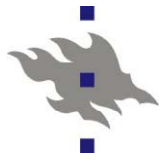




■ Increased Wood Use in Construction sector: ■ Scenarios and Emission Reduction Calculation ■ Methods

- 4 scenarios for wood consumption → year 2030
 - Two different approaches + Baseline

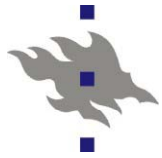
- Baseline (Base)
 - “Business-as-usual”
 - Predicted demands for the final forest industry products
 - Product price and consumer income in each European country
 - Certain price and income elasticities
 - No price changes
 - Based on the past per capita consumption, GDP growth and population forecasts
 - The growth rate of total European softwood sawn wood consumption quantity was estimated **to be 1.48 % annually up to 2030**



Scenario 1: 1m³/capita

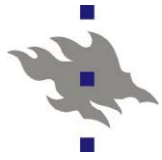
- Consumption of sawn wood in all European countries → 1.0 m³ per capita in 2030
 - Annual consumption growth in Europe about 7% up to 2030

- The substitution impact on emissions estimated using a rough emission displacement factor calculated for sawn wood, based on a study by Pingoud and Perälä (2000)
 - 1 kg of wood-based building materials substitutes for 3.6 kg of masonry products
 - concrete
 - bricks
 - tiles
 - and 0.12 kg of metals



Scenario 2 "Swedish House" and Scenario 3 "Finnish House"

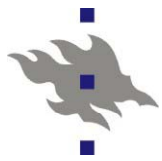
- Annual number of **new flats** in **wooden houses** will gradually increase to 1 million by 2030 **replacing** conventional **concrete apartment** blocks in new construction
- Scenario "Swedish House": data from a case study of the building constructed in Växjö, Sweden
- Scenario "Finnish House": data from a case study in Helsinki, Finland
- The difference between the two scenarios is the type of wood construction, and the type of reference concrete construction replaced
- In the scenarios, the results of micro-level case studies of single multi-story houses are scaled up to macro-level
- Comparisons were made on a building level
- All materials composing are included in the calculations



Emission Reductions Calculations

- The relative emission reductions with respect to Base:
 - Fossil fuel combustion for material processing and logistics
 - Avoided emissions in cement process reactions
 - Carbon stock change in wood materials
 - Biomass flows associated with the building construction
 - Biomass residues from the harvest, processing and demolition that are available for use outside of the production process → biofuel to replace fossil fuel

- Marginal energy is supposed to be coal



Round wood Demand and Emission Reduction Compared to the Baseline, by 2030

Scenario 1m³/cap

- Additional round wood demand of ~ 600 Mm³ /yr
 - Emissions reduction: 200 Mt C /yr ≈ 700 Mt CO₂ /yr
- Sawn wood demand fulfilled from Swedish harvest 14 Mm³
 - Emission reductions: 5 Mt C/yr ≈ 20 Mt CO₂/yr

6 % of global yearly carbon increase to the atmosphere

1/3 of CO₂ emissions of Sweden

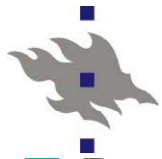
Million wood-framed flats instead of concrete-framed flats

"Swedish House"

- Additional round wood demand of ~ 9.7 Mm³ /yr
- Over the complete lifecycle of the buildings produced each year, the carbon emission reduction ≈ 4.2 million tC

"Finnish House"

- Additional round wood demand of ~ 23.8 Mm³ /yr
- Over the complete lifecycle of the buildings produced each year, the carbon emission reduction ≈ 9.7 million tC



Forest Sector Model EFI-GTM

- Partial equilibrium model for forest sector = Forestry, wood using industries, markets for round wood and forest industry products
 - Consumers' and producers' surplus maximization
 - Myopic decision making
 - Forest management NOT endogenous

- Additional demand due to increased consumption of sawn wood in construction sector was added to the base case demand
 - Scenarios 'Swedish House' and 'Finnish House', also panels

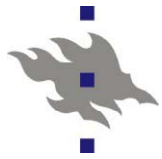
- Timber supply: Stumpage prices and volume of growing timber stock
 - The elasticities for Sweden were examined with the simulations by Matrix model, 0.5 for both saw logs and pulpwood



Results from EFI-GTM

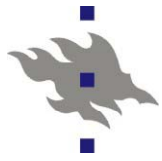
Changes in Swedish Round Wood Harvests and Prices with Respect to the Base Case, in 2030

	HARVESTS						PRICES		
	mill. m ³ sub bark			%			%		
	Finnish House	Swedish House	1m ³ cap	Finnish House	Swedish House	1m ³ cap	Finnish House	Swedish House	1m ³ cap
Softwood saw logs	0.9	0.5	14.2	2	1	35	5.2	2.7	110
Hardwood saw logs	0	0	0	0	0	1	0.2	0.1	0.6
Softwood pulpwood	-0.1	0	-4.8	0	0	-16	0.3	0.3	-19
Hardwood pulpwood	0	0.1	-0.2	0	0	-4	0.2	0.2	-9



Regional Forest Model, SMAC Swedish Matrix Model

- An area matrix model built on NFI data, forest area distributed ~10,000 states
- Which forest management activities will be pursued by the forest owners?
 - The optimal management under given conditions is derived by solving an infinite horizon problem with value iteration
- 5-year periods → prices from EFI-GTM aggregated to 5-year periods
- Purposes for the simulations: (1) yield price elasticities to the global forest sector model (2) evaluate the price scenarios produced by EFI-GTM in terms of forest management
- SMAC model was run with price levels 0.5 - 2 * original prices at the current state of the forest → EFI-GTM
- Only scenario 1m³/capita was studied, modest price reaction in others



Results from SMAC

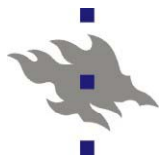
First 10-year period

- Harvested saw log volumes in SMAC slightly smaller than the EFI-GTM volumes
- The SMAC pulpwood volumes are higher compared with EFI-GTM

Following 10-periods

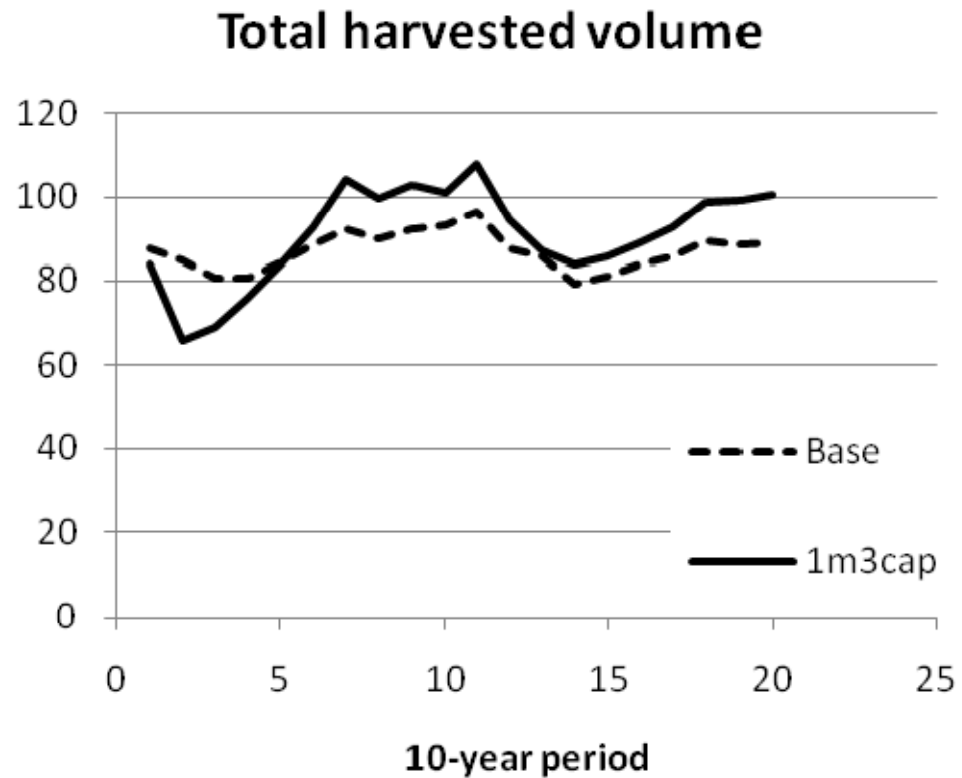
- Saw log volumes in SMAC are reduced, increase in EFI-GTM
- Trend of the SMAC pulpwood volumes closely follows the timber volumes
- Timber volumes in SMAC smaller in the 1m³/capita scenario than in the Base scenario

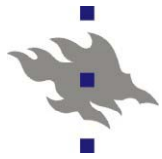
WHY? It is profitable, with relatively better profitability in final felling compared with thinning, to postpone final harvests



In the Long Run, Increase in the Harvests...

Prolonged rotation period
and less thinning →
relatively more timber
the long run





Stand Level Model

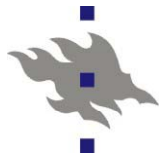
SMA, Stand Management Assistant

Simulation-optimization system

- The objective function: Discounted net returns over an infinite time horizon, 3 % real discount rate in this study

- Non-linear, non-differentiable optimization
 - Hooke and Jeeves + random search
 - Control variables: 1) time to the first thinning 2) times between thinnings 3) intensities & types of thinnings 4) time to the final harvest after the last thinning, and planting density
 - Number of thinnings exogenous

- Individual-tree, distance-independent growth and mortality models
 - BEF for Norway spruce 0.8139 Mg m^{-3} and Scots pine 0.7051 Mg m^{-3}

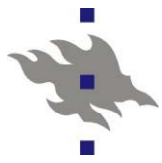


- Stand-level results: long-term steady state solutions giving an overall picture about the impacts of price changes to the optimum stand management

- Pine and spruce stands, different site indexes and number of thinnings

- Differences between "Base" and "1m³/capita"- scenarios studied
 - Softwood logs price ↑ 110%
 - Softwood pulp price ↓19%

- Optimal management strategies
 - Average saw logs/ pulpwood supply
 - Average carbon stock



Changes in Optimal Management in Stands Compared to Base Scenario

Spruce, fertile stand

Rotation \uparrow 8 yrs

Thinnings 1 \rightarrow 2

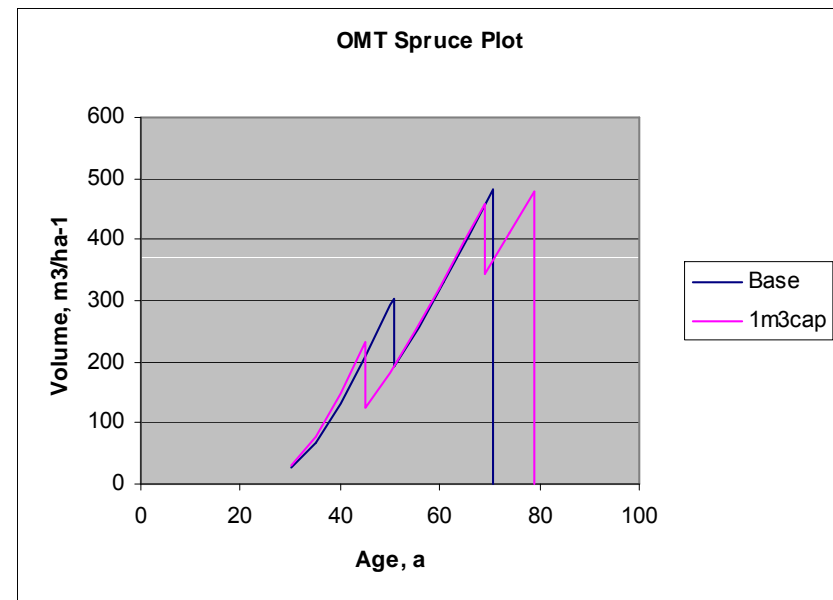
Planting density \uparrow

Average volume \uparrow

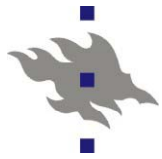
Production of saw logs /ha \uparrow

Production of pulp wood \downarrow

Average carbon stock \uparrow 9.4 t CO₂/ha



Smaller changes in medium fertile site, same directions



Changes in Optimal Management in Stands Compared to Base Scenario

Pine, Medium fertile stand

Rotation \uparrow 4 yrs

Thinnings 4 \rightarrow 5

Planting density \uparrow

Average volume \uparrow

Production of sawlogs / ha \uparrow

Production of pulp wood \downarrow

Average carbon stock \uparrow 3.9 t CO₂/ha

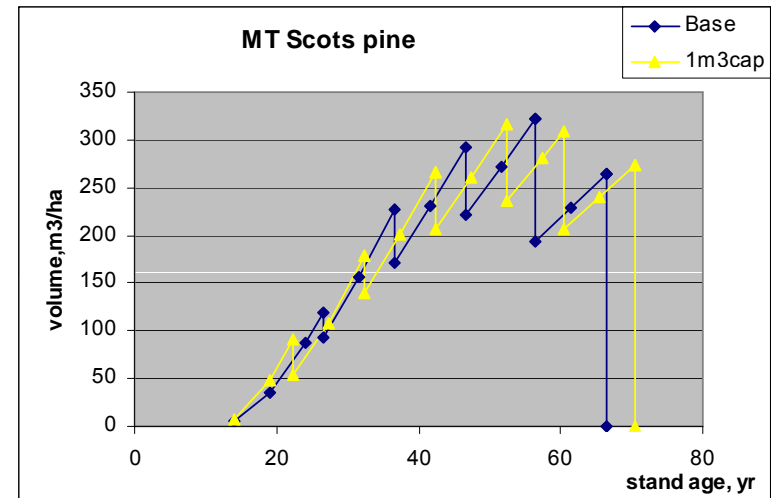
Less fertile stands

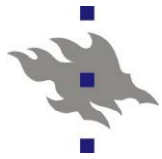
Small differences between objective function values in thinnings number

alternatives \rightarrow In optimal strategies: average carbon stock \downarrow , rotation length \uparrow

But still planting density \uparrow , average volume \uparrow and production of sawlogs / ha

\uparrow , production of pulp wood \downarrow





Conclusions

Gaps, Overlaps and Missing Links

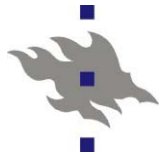
- Timber supply is solved in the market model, in the forest regional model and in the stand model

- Different assumptions
 1. Stand level model: long term steady state
 2. Forest region model: new price in every period
 3. Forest sector model: welfare is maximized with no foresight to the future periods

- No consistency between EFI-GTM and forest system

- Biological descriptions on forest growth, data and the parameters' values differ → different volumes

- Energy wood was not an assortment

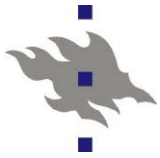


Conclusions

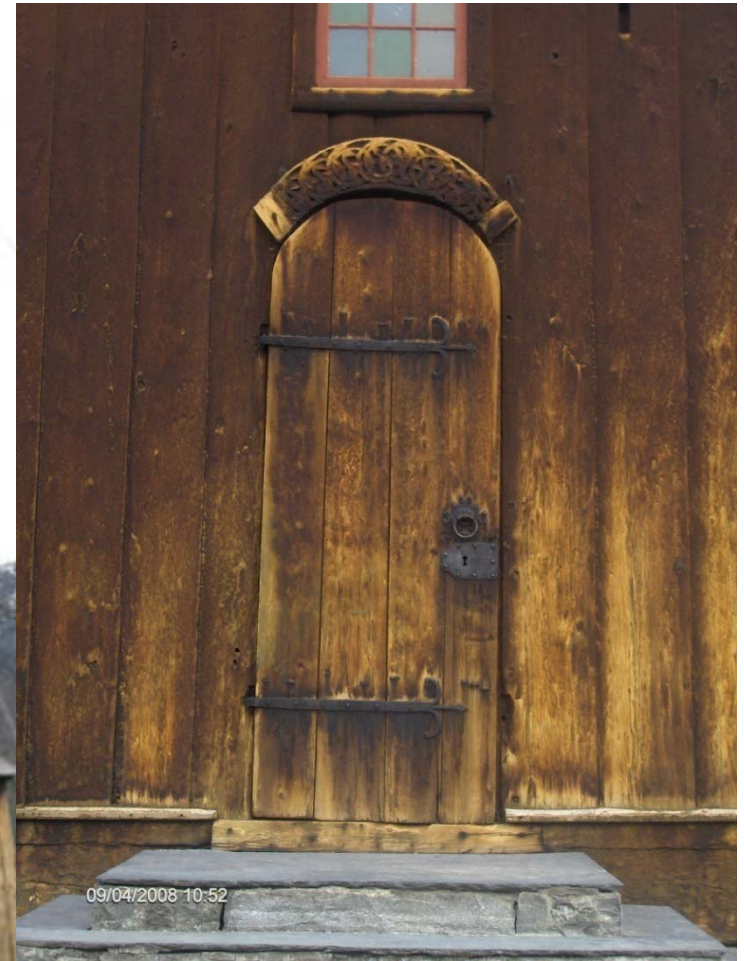
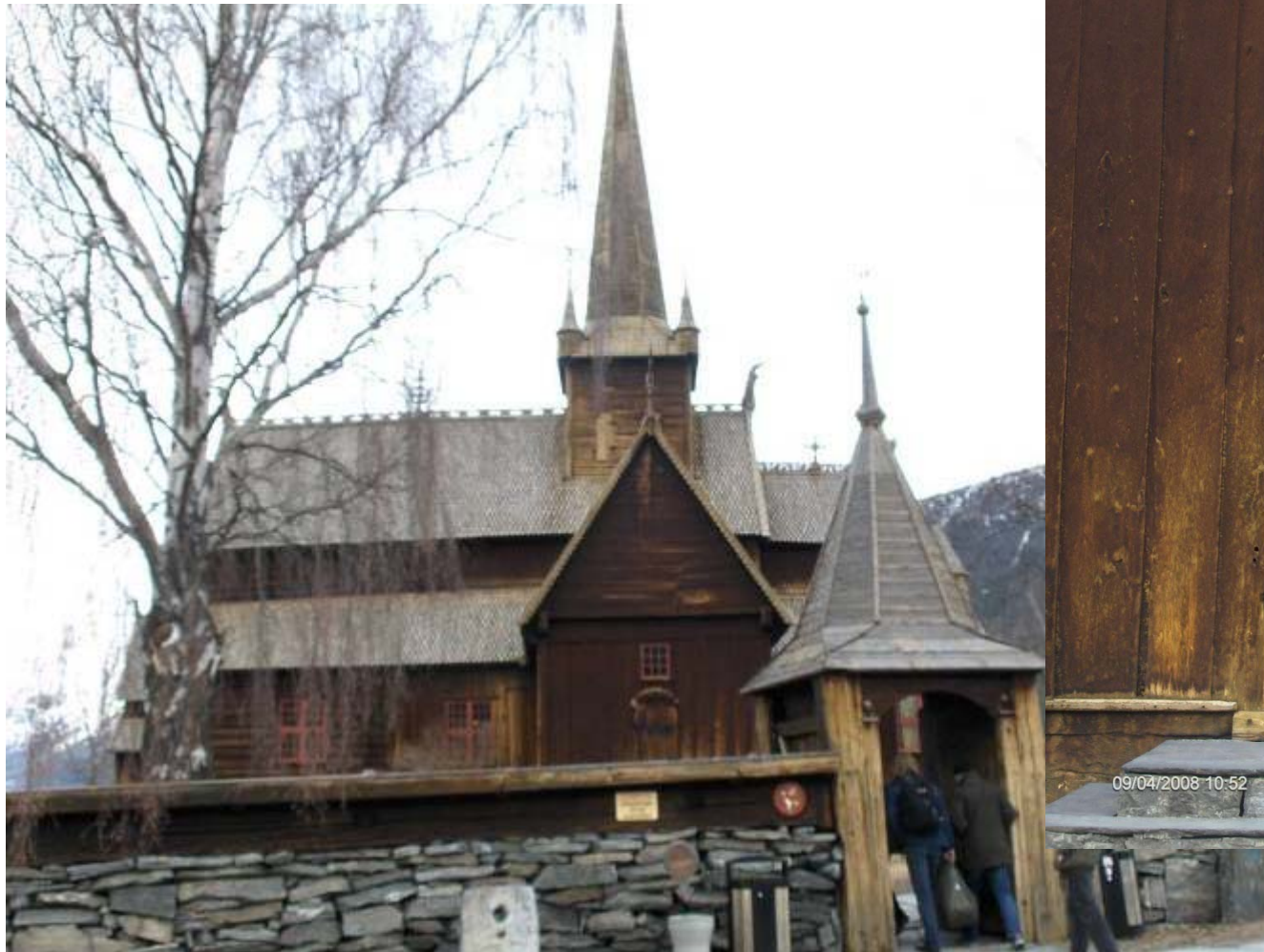
- Emission reductions in scenarios of increased wood use in construction sector are significant
 - Scenarios are extreme
 - Uncertainties

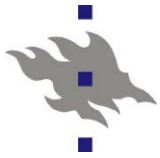
- Scenarios "Swedish House" and "Finnish House" : Even a massive new construction program of 1 million flats in wooden multi-story houses annually would not create especially high demand for roundwood in Sweden

- For consistency, would be an advantage to look at the problem with having **the market mechanism** and **forest management** in the same model



Thank You for Your Attention!





Backup...

With the forest regional model, the harvest levels for sawlogs deviated from those projected by the EFI-GTM. Unlike in the EFI-GTM, the immediate harvests decreased when the sawlog prices increased due to forest owners postponing their harvests in order to increase the future sawlog yield and thereby income. This occurred even though the EFI-GTM projection was based on, for the Swedish market, on elasticity from the SMAC model. However, this elasticity was derived based on a change of the entire timber price level, i.e. an equal relative increase of the sawlog as well as the pulpwood price. Since the EFI-GTM projected different price developments for sawlogs and pulpwood, while the results of the SMAC model are sensitive to the relative prices of sawlogs and pulpwood “ there is a strong cross-price elasticity between the two major assortments “ the consistency between the models were broken.