

# Effects of moisture content on supply costs and CO<sub>2</sub> emissions for an optimized supply network

Christian Kanzian, Martin Kühmaier and Gernot Erber  
University of Natural Resources and Life Sciences Vienna (BOKU)

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## Background

Moisture content of energy wood has an impact on:

- Chip quality
- Heating value
- Demand
- Revenues
- Transport
- Storage
- Chipper performance
- ...



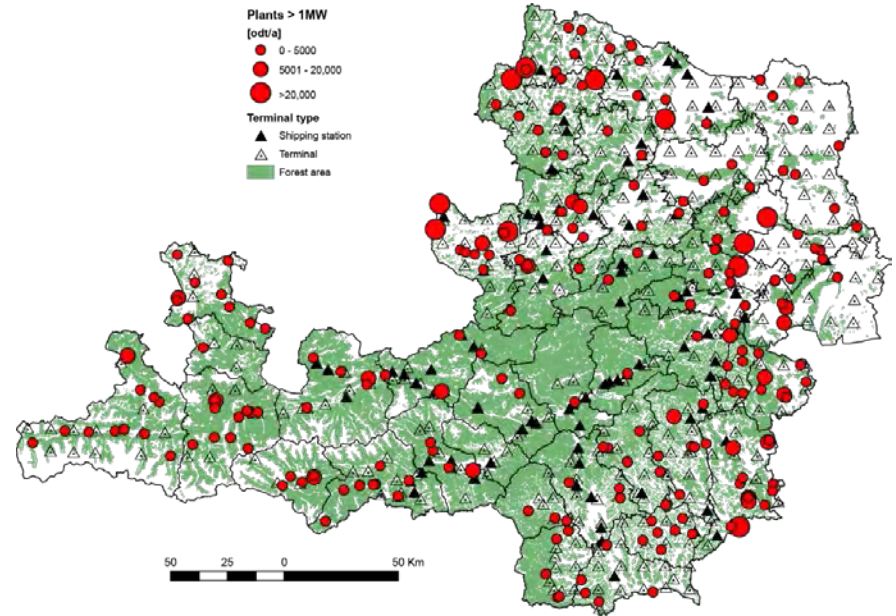
## Background

- Natural drying to decrease water content and increase heating value is wanted
- Series of drying experiments have been done
- Savings on logistics in terms of emissions and costs have not been studies extensively



## Study area

- Resources  $\sim 882,170 \text{ t} \cdot \text{a}^{-1}$  represented by 9,984 resource points
- 228 heating & CHP with a demand of  $\sim 982,000 \text{ t} \cdot \text{a}^{-1}$
- 356 possible terminal location
- 119 Railway shipping stations for round wood

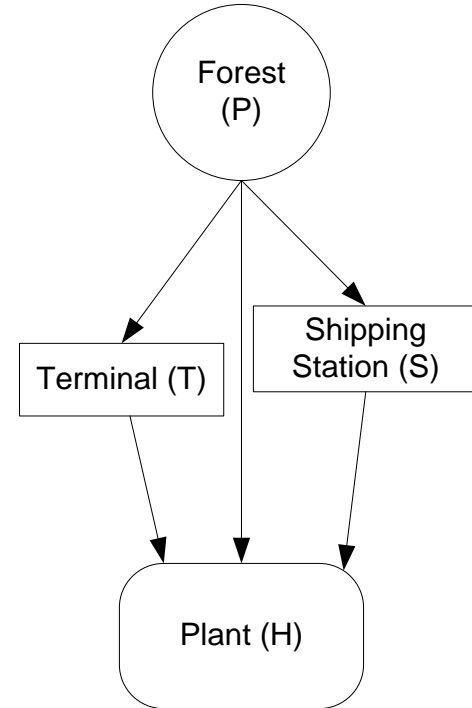


Kanzian et al., 2013

## Problems

- ✓ What terminal locations to chose?
- ✓ Should we transport solid or chipped?
- ✓ Where the chipping should be done?
- ✓ What **profit** and **emissions** can we expect?
  
- **How sensitive is the optimal solution on changing moisture content?**

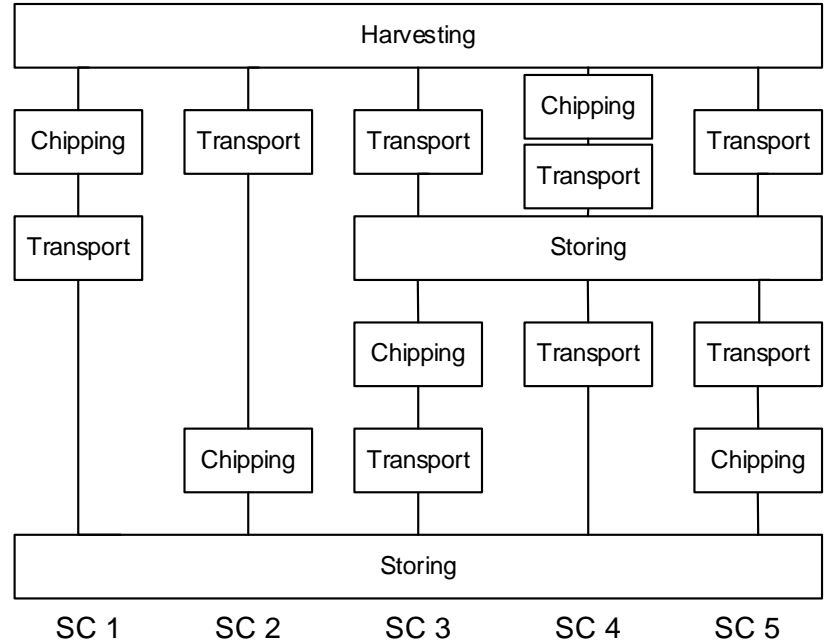
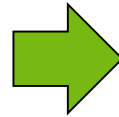
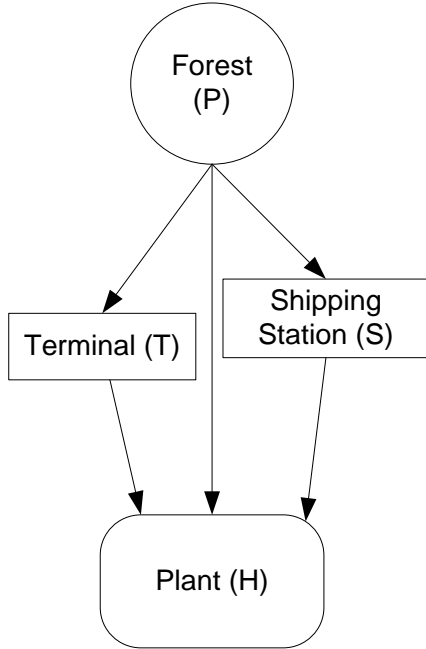
Biomass Supply Network



Kanzian et al., 2013

# Supply chains

Biomass Supply Network

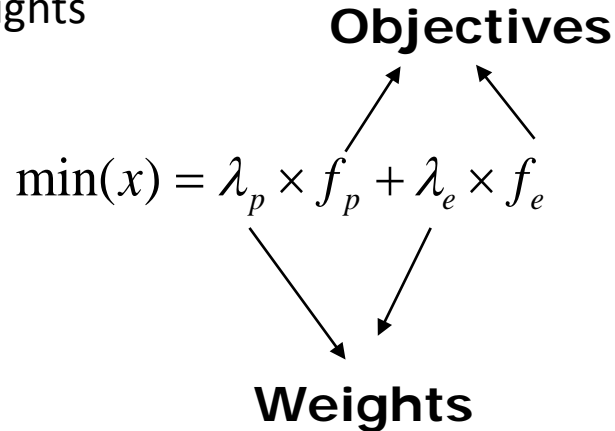


# Multi-criteria optimization MOP

Weighted sum scalarization approach (*Ehrgott 2005*)

Basic idea is it to find Pareto optimal solutions by:

- Scaling different objectives (function) with non-negative weights



Kanzian et al., 2013

# MOP - Moisture content influences?

Weighted sum scalarization approach (Ehrgott 2005)

$$\min(x) = \lambda_p \times f_p + \lambda_e \times f_e$$

$$\max(f_p) = (C^r - C^{harv} - C^{trans} - C^{chip} - C^{lvar} + C^{lfix})$$

$$\min(f_e) = C^{harv} + C^{trans} + C^{chip} + C^{lvar} + C^{lfix}$$

Diagram illustrating the weighted sum scalarization approach. The objective function is  $\min(x) = \lambda_p \times f_p + \lambda_e \times f_e$ . The constraint function is  $\max(f_p) = (C^r - C^{harv} - C^{trans} - C^{chip} - C^{lvar} + C^{lfix})$ . The terms  $C^{harv}$  and  $C^{chip}$  are circled in blue and marked with a red 'X' and a red question mark, indicating their influence on the moisture content.



# MOP - Moisture content influences?

$$r_{j,k=0} = 60.273 + 36.105MC - 99.415MC^2$$

$$r_{j,k=1} = 81.346 + 30.558MC - 86.271MC^2$$

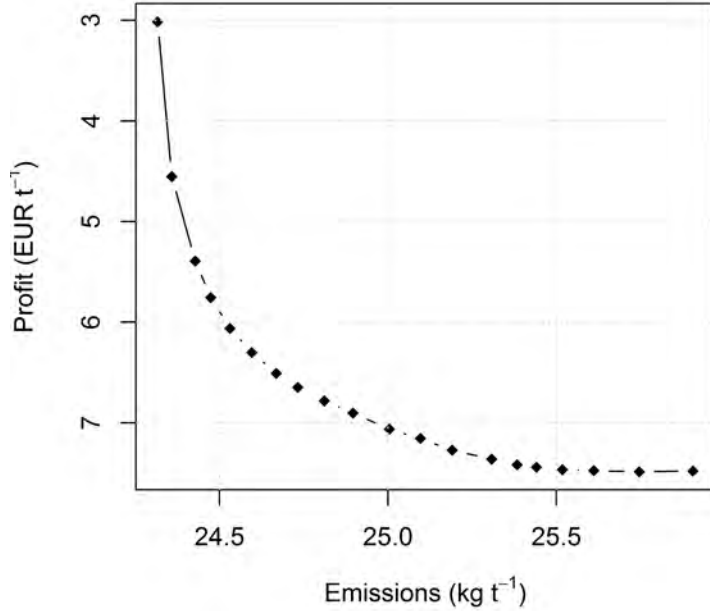
$$\max(f_p) = C^r - (C^{harv} + C^{trans} + C^{chip} + C^{lvar} + C^{lfix})$$

$$c_{ijk} = \frac{((t_k^L + 2t^D + t^U + 2p_k^W t_k^D)c_k^h + 2c_{ij}^{toll})n_{ik}}{s_i}$$

$$n_{ik} = \left\lfloor \frac{s_i}{lv_k} \right\rfloor$$

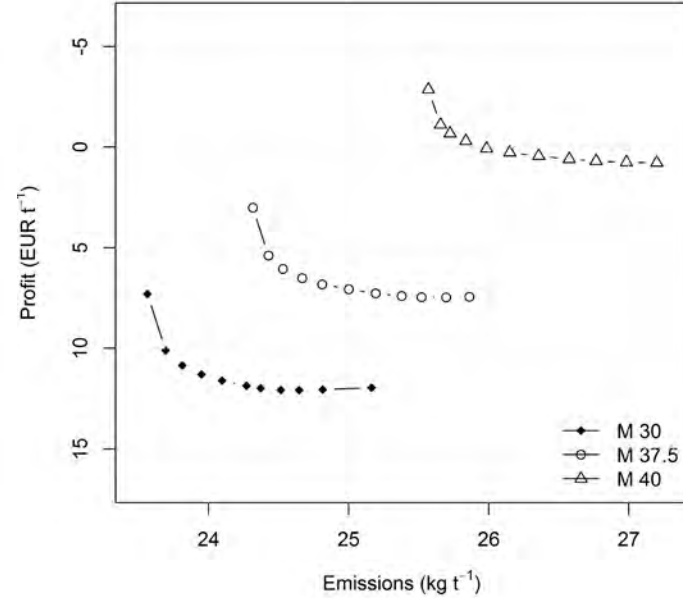
**Number of loads per site**

# Results



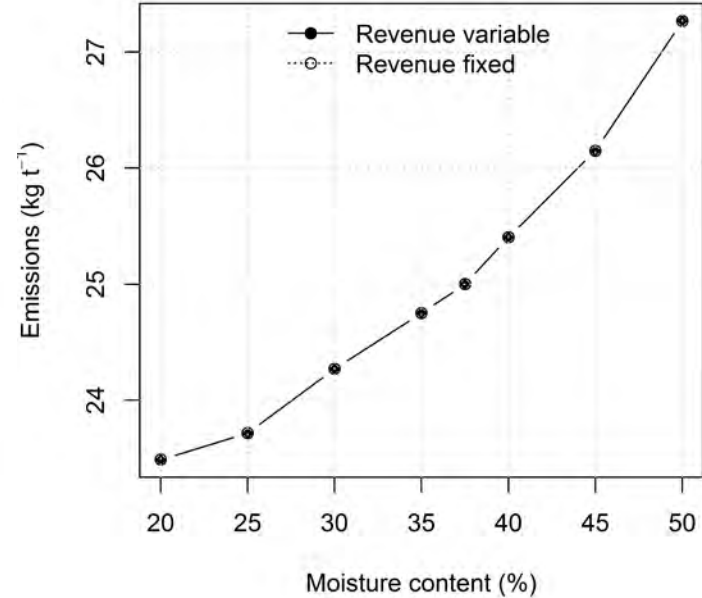
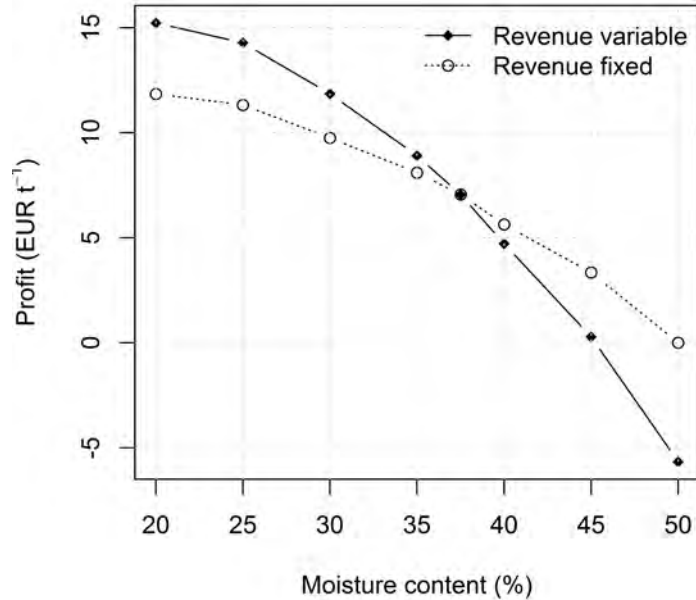
**Increasing profit**

Kanzian et al., 2013



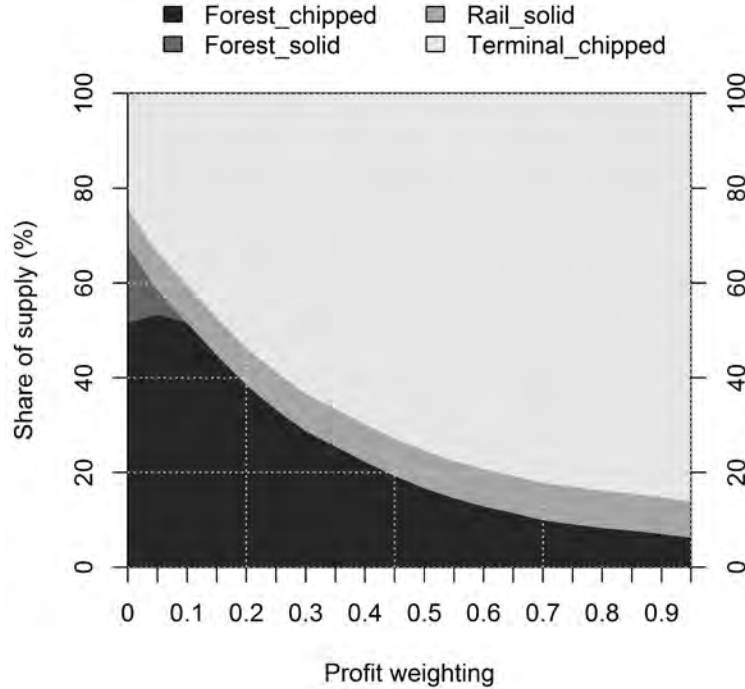
# Results – Revenue related

Profit and emission weighting values of 0.5



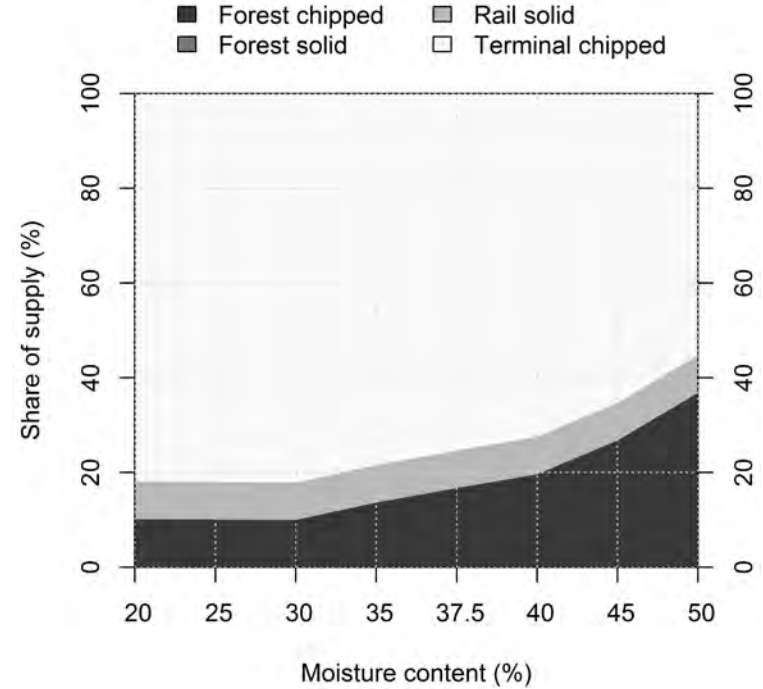
profit from 5 to 12 EUR\*t<sup>-1</sup>

# Results - Supply

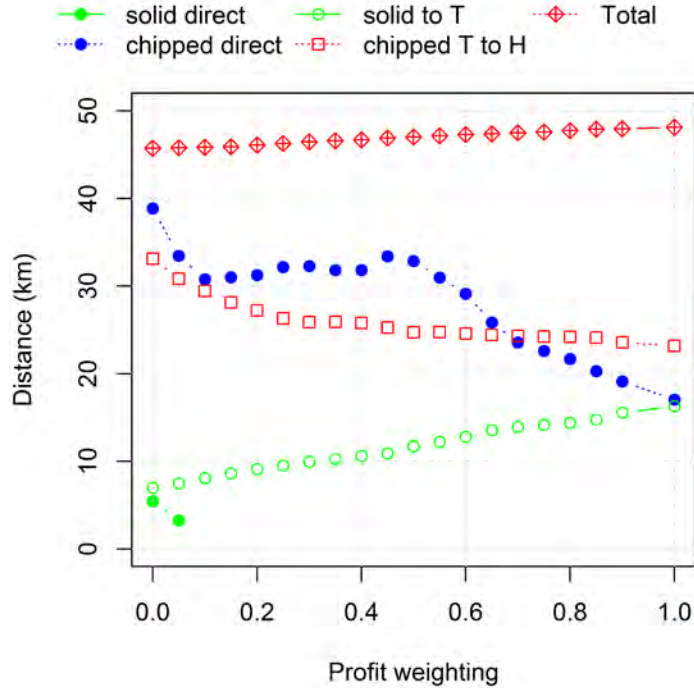


Kanzian et al., 2013

Profit and emission weighting values of 0.5

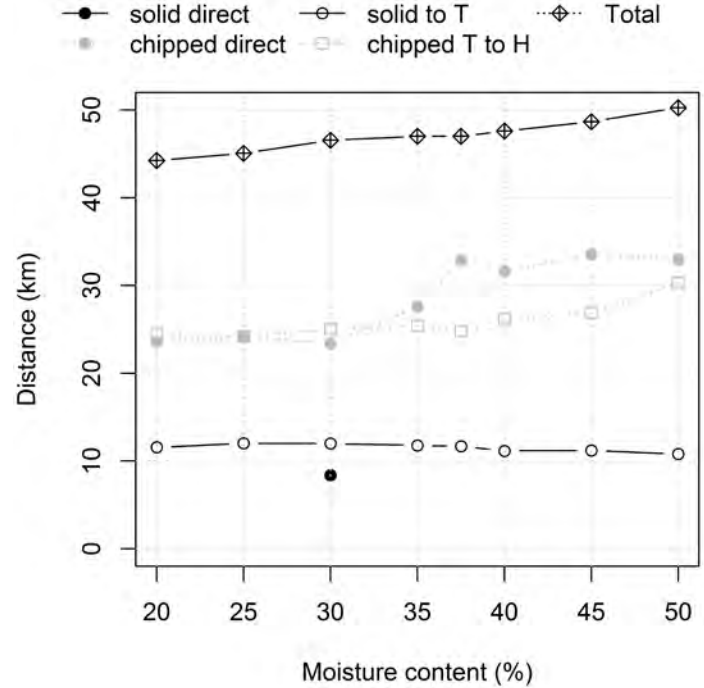


# Results - Distances



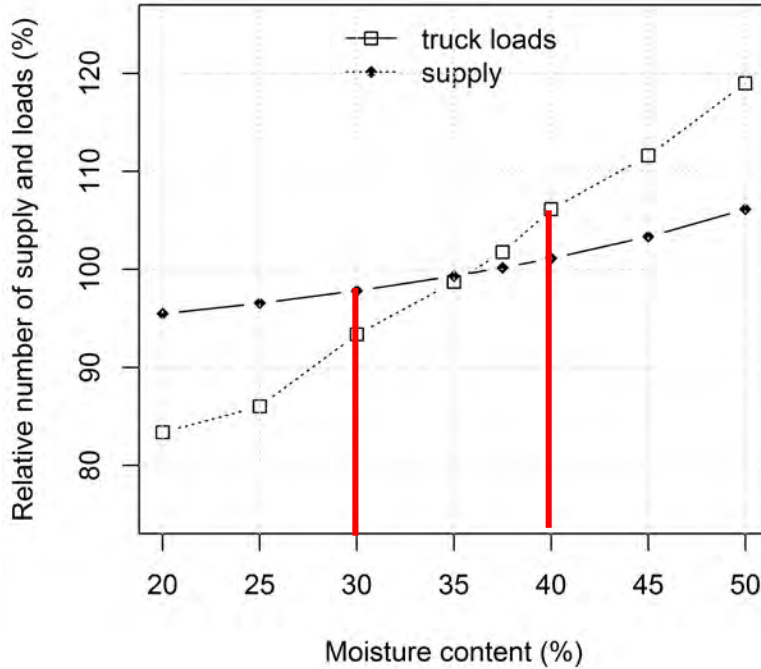
Kanzian et al., 2013

Profit and emission weighting values of 0.5



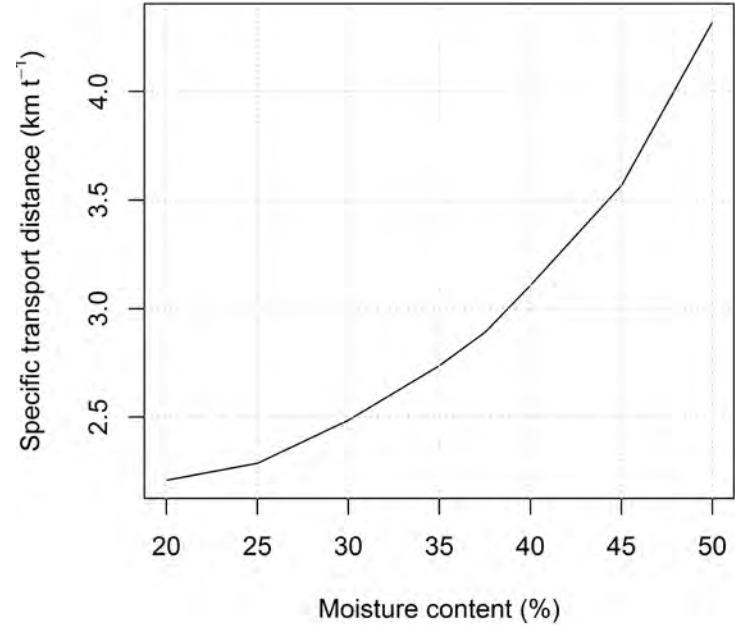
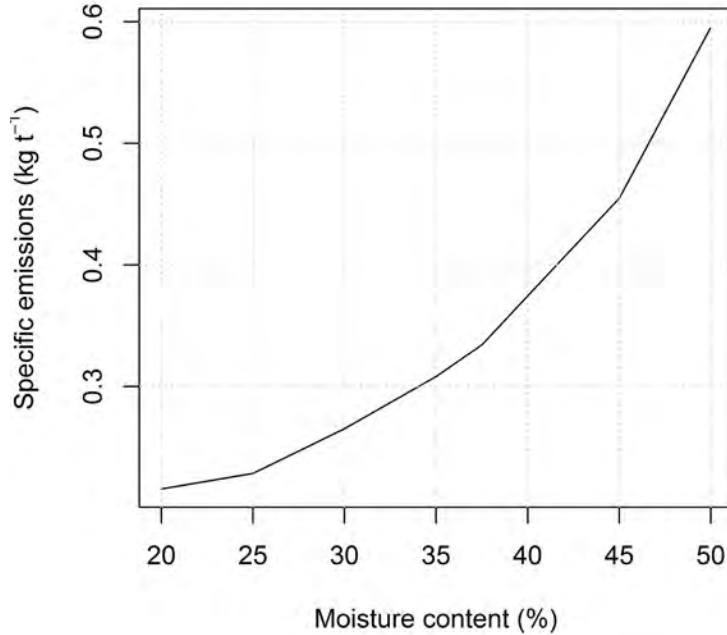
# Results – relative supply & truck loads

Profit and emission weighting values of 0.5



# Results – specific distances and emissions

Profit and emission weighting values of 0.5



## Conclusions?

**10% decrease in moisture content means**

- profit from 5.10 to 12.00 EUR\*t<sup>-1</sup>
- save 4% of CO<sub>2</sub> emissions
- ~7% less truckloads
- ~3% less demand
- Decrease of specific transport distance from 2.9 to 2.5 km\*t<sup>-1</sup>





## Lessons learned

... or what is not written

- **Adopting a model is not enough**
  - Time periods are missing to find optimal storage
  - Include drying models
  - Consider changes of material over time
  - Uncertainty
- **Used commercial solver platforms is powerful but costly for business users**
- **Still a long way to go, but who will be the user**



## Additional information

Christian Kanzian

University of Natural Resources and Life Sciences Vienna (BOKU)

E-mail: [email@boku.ac.at](mailto:email@boku.ac.at)

The “full” paper will be published in the **Croatian Journal of Forest Engineering (CROJFE), Issue 37(1), 2016.**

[www.infres.eu](http://www.infres.eu)

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015) under grant agreement n°311881.


 A large photograph of a forest with tall, thin trees and sunlight filtering through the canopy. In the foreground, there is a pile of forest residual biomass. Below the main image is a row of five small inset images showing various pieces of forestry machinery: a red harvester, a yellow skidder, a blue skidder, a green truck, and a red truck.
 

Innovative, effective and sustainable technology and logistics for forest residual biomass

Summary of the INFRES project results




[www.infres.eu](http://www.infres.eu)