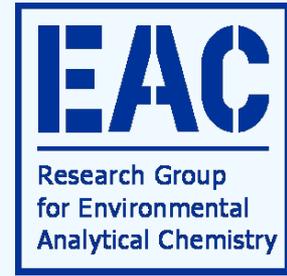




International Conference on  
Carbonaceous Particles in the Atmosphere  
August 12 – 14, Berkeley (CA)

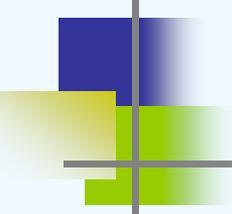


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# Chemical Characterization of Wood Smoke Particle Emissions and its Application to Source Apportionment

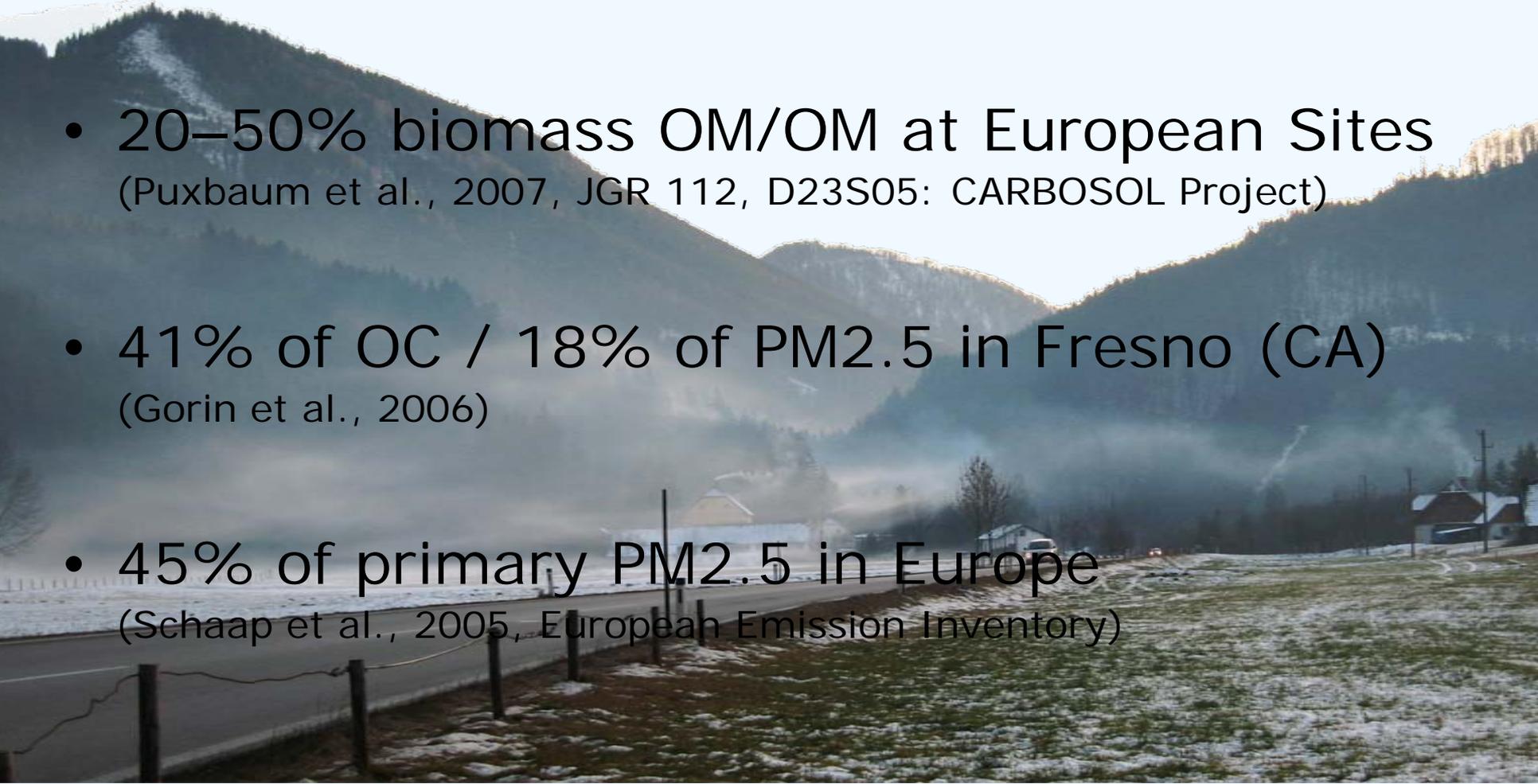
Christoph SCHMIDL, Heidi BAUER, Hans PUXBAUM

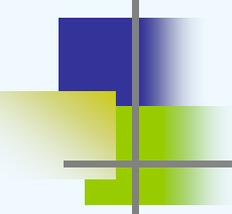
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# Wood Smoke...

... major primary particle source in winter

- 20–50% biomass OM/OM at European Sites  
(Puxbaum et al., 2007, JGR 112, D23S05: CARBOSOL Project)
  - 41% of OC / 18% of PM<sub>2.5</sub> in Fresno (CA)  
(Gorin et al., 2006)
  - 45% of primary PM<sub>2.5</sub> in Europe  
(Schaap et al., 2005, European Emission Inventory)
- 



# Wood-Smoke in Austria

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- 20 – 40% of PM10 in Winter
- Up to 60%(urban)/80%(rural) of OC
- Rural source
- Regional (Continental ?) Scale

*Why is wood smoke so important?*

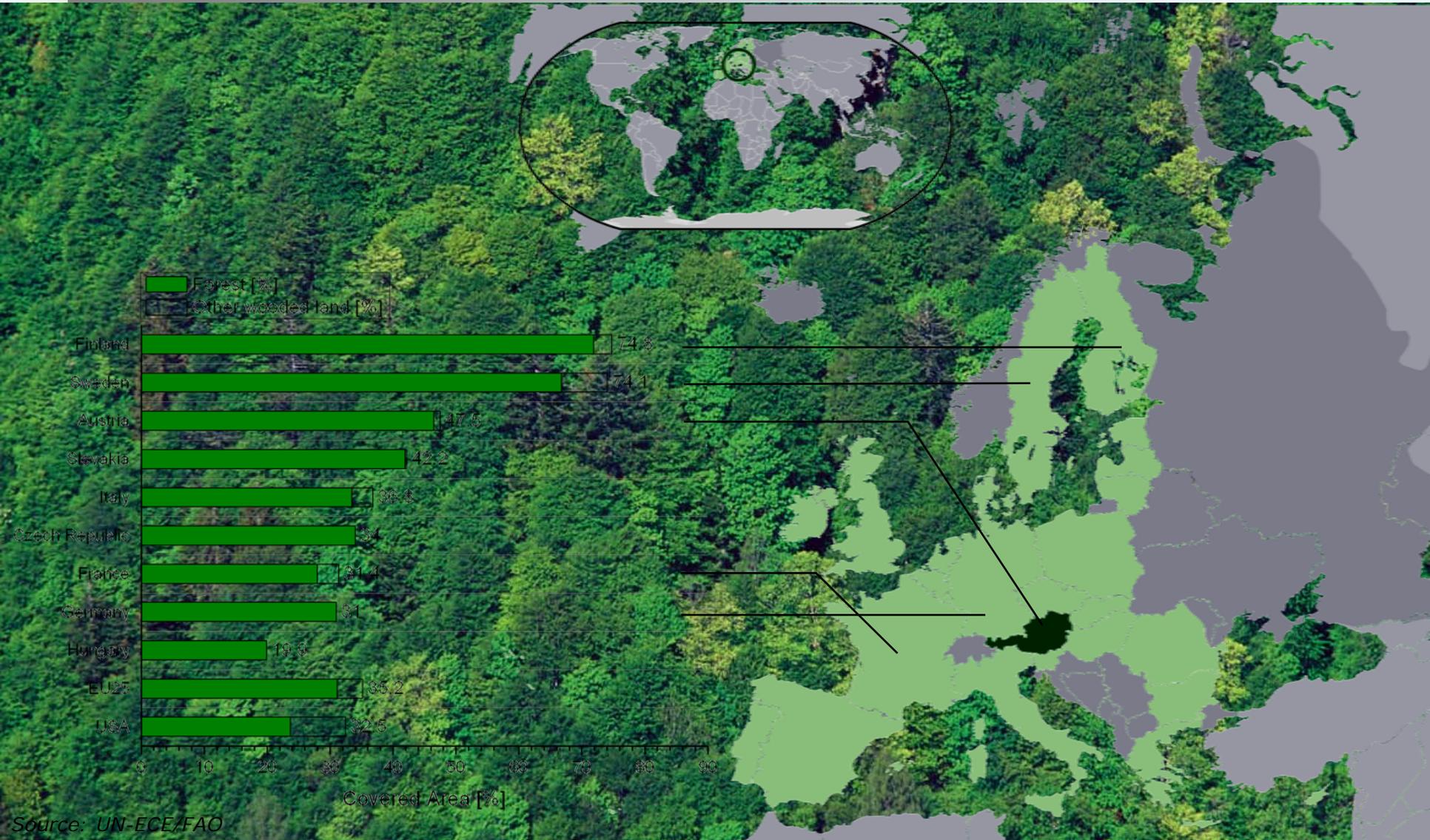
# Importance of Wood-Smoke

- Long Tradition of Wood as Source of Energy



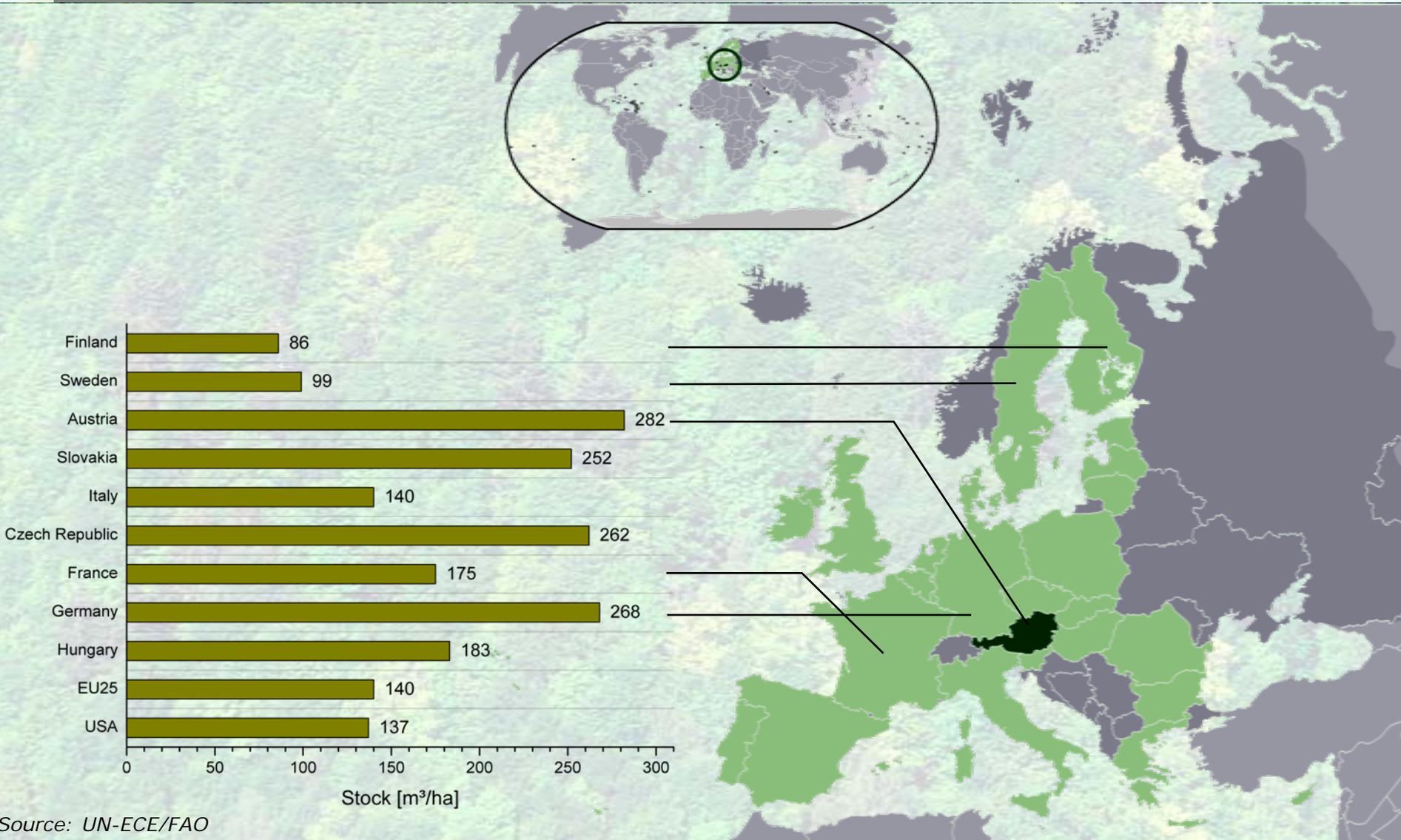
- High Particle-Emission-Factors compared to other Heating Systems (Oil, Gas)
- High availability of Fire-Wood/Population Density

# Forest Coverage



Source: UN-ECE/FAO

# Forest Stock



Source: UN-ECE/FAO

# Residential heating in Austria

## Austrian Provinces:

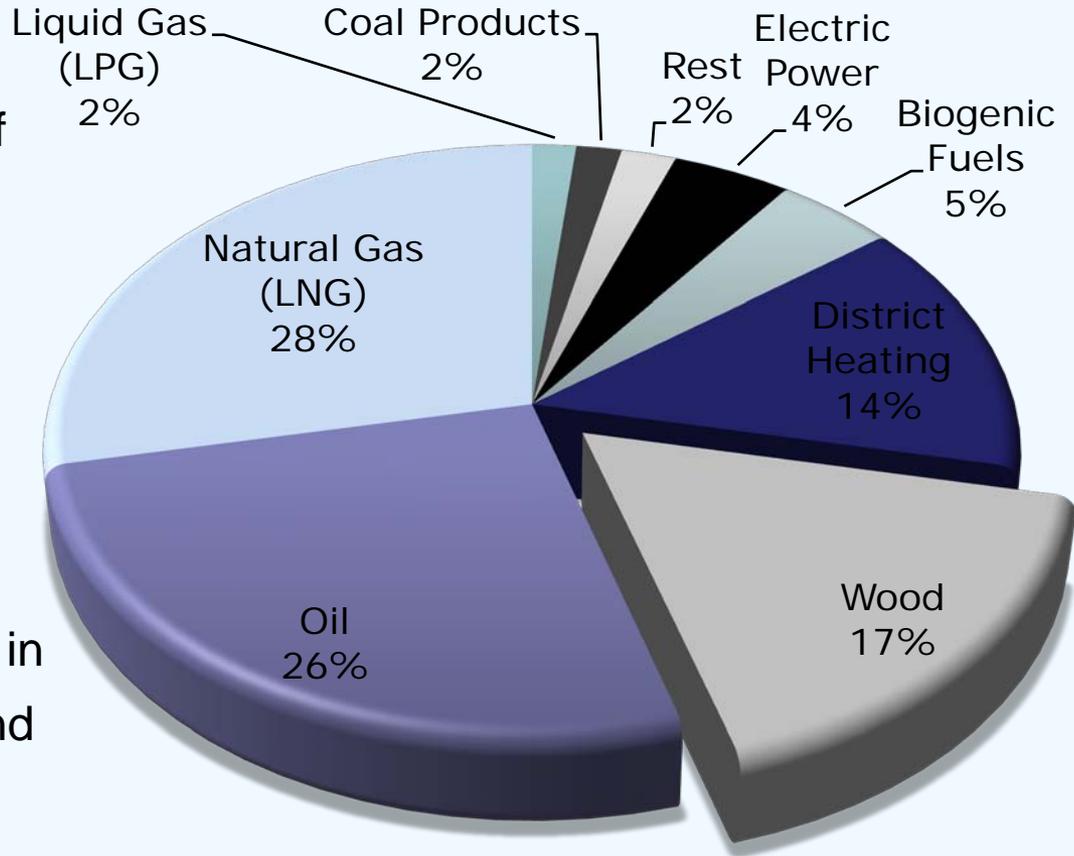
2 – 30% (Vienna - Burgenland) of Households heated with Wood

## Total Austria

17% of Households

## **Not included:**

Wood fired for additional Heating in small Stoves (Spring, Autumn) and esthetic Purposes

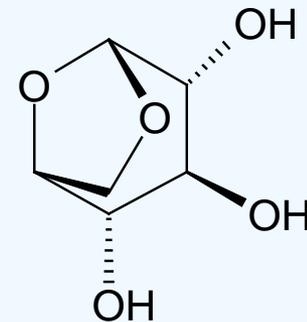


Data for 2004, Source: Statistik Austria

# Assessment of Wood Smoke

- Macrotracer Concept...

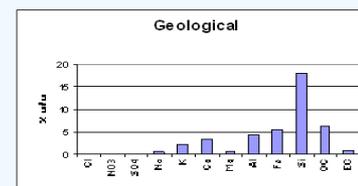
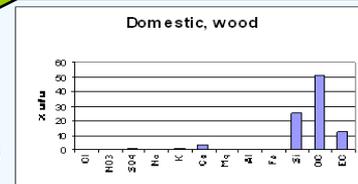
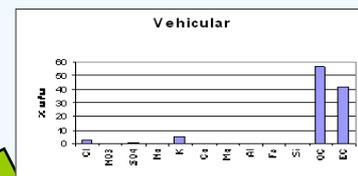
... using the Anhydrosugar Levoglucosan as single Tracer (conversion factor Levo  $\rightarrow$  PM/OC)



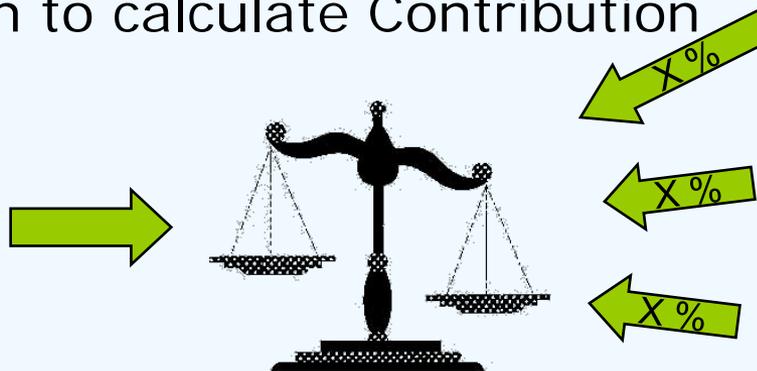
- Chemical Mass Balance (CMB) Model...

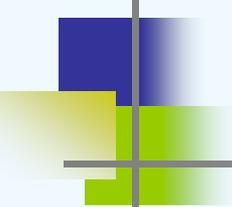
... using a chemical Source Profile and mathematical Equation to calculate Contribution

Source profiles



Ambient profile

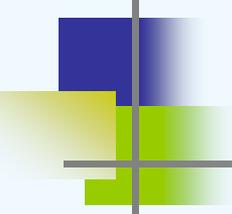




# Pros and Cons

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- Macrotracer Concept
  - ☺ - mostly routine Analysis
    - analytical Errors smaller
    - atmospheric Stability well known
  - ☹ - only one Compound gives Source Contribution
    - no cross-checking with other Compounds
    - Source-specific Tracers necessary
  
- CMB Model
  - ☺ - many Compounds contribute to one Source Result
    - estimation of Uncertainty possible
    - no Tracers necessary, only sufficient difference in Profiles
  - ☹ - detailed Knowledge of Source Profiles
    - analytical Uncertainties for Micro-Compounds higher
    - atmospheric Stability not certain



# „Macro-CMB“

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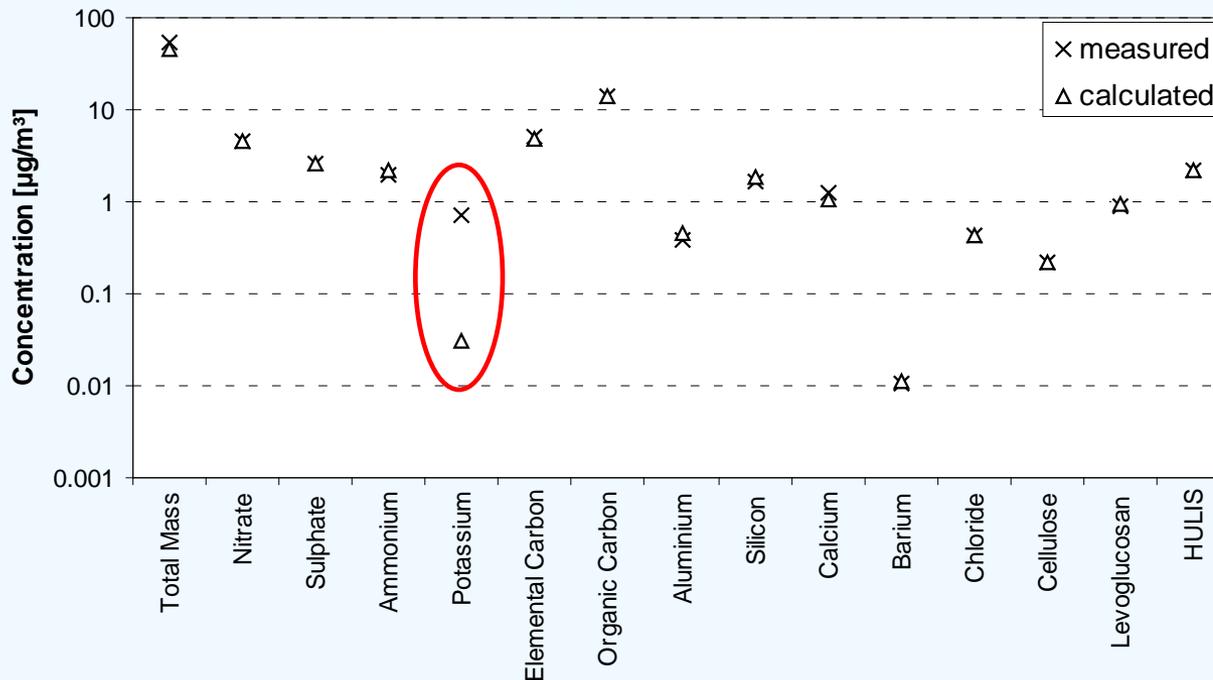
... an Attempt to combine Advantages of Macrotracer and CMB Concepts:

- Reduced Number of Species ( $n=14$ )
- Only Macro-Compounds (omitting organic trace Components)
- CMB Analysis for “Crosschecking” and Estimation of Uncertainties

# Macro-CMB

- Good Fit (measured/calculated) for all Macro – Compounds
- Bad Fit for Potassium (~ one Order of Magnitude)

→ Missing Source/Unsuitable Profiles



Sample:  
January  
Lower Austria

# Source Characterization

- Started with tiled Stove Measurements (Schmidl et al., 2008)
- 2 additional Wood-smoke Projects
  - Dilution sampling System (RT,  $\uparrow$  Sample)
  - Online Gas Analysis ( $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{O}_2$ ,  $\text{NO}_x$ ,  $\text{C}_x\text{H}_y$ )
  - Combustion Efficiency
  - 8 different Appliances (5 – 50kW)
  - > 20 Fuel Types / Wood Types



# Wood-smoke Emissions

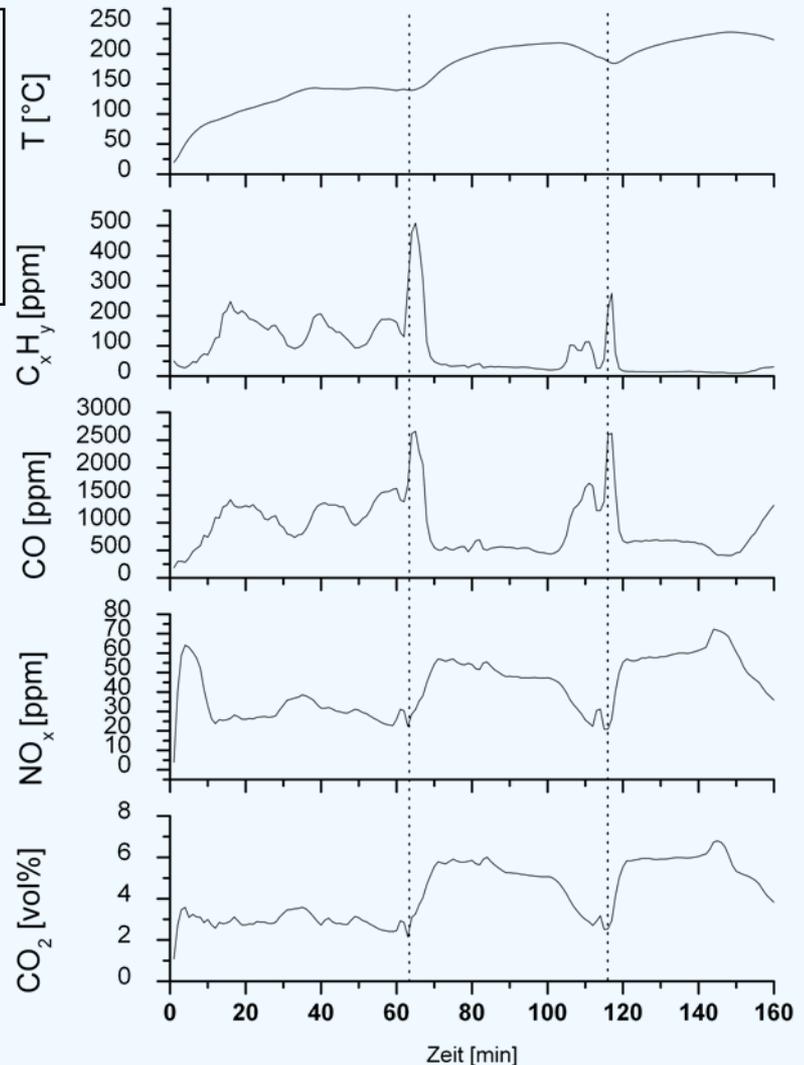
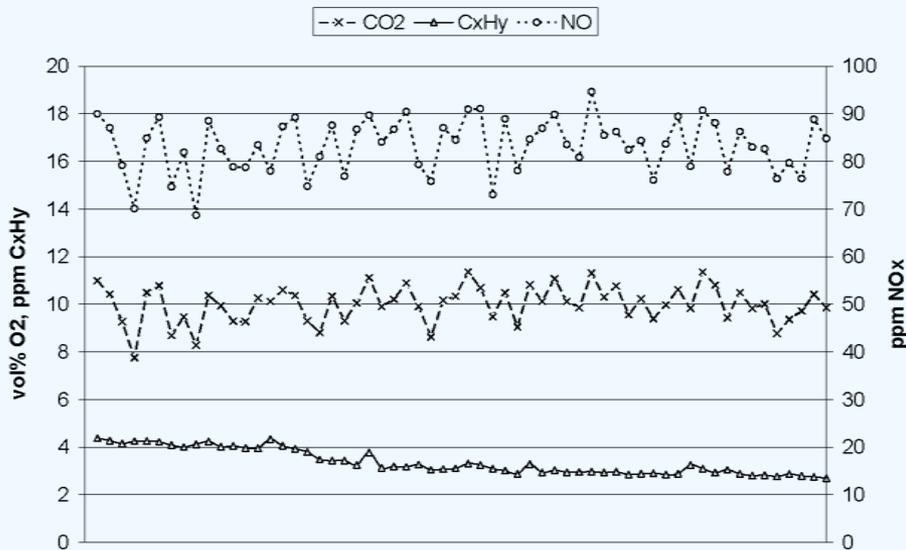
- 2 Groups:

### Manually fired (stove)

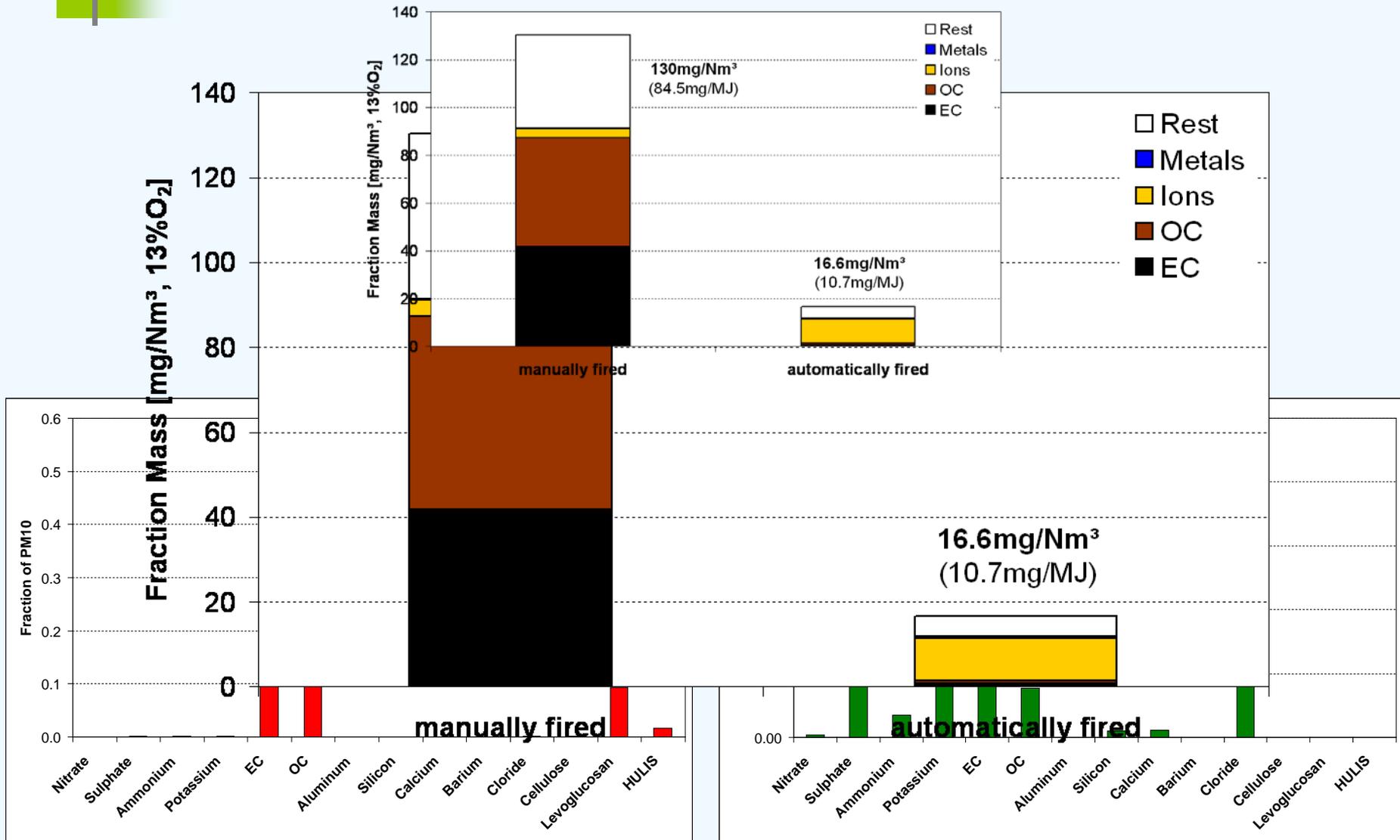
- highly variable
- high Emissions
- Carbon Content 60-80%
- OC, EC, HULIS, Levo

### Automatically fired

- constant Conditions
- low Emissions
- Carbon Content low
- K, Ca, SO<sub>4</sub>, Cl



# Wood-smoke PM10



# Anhydrosugars

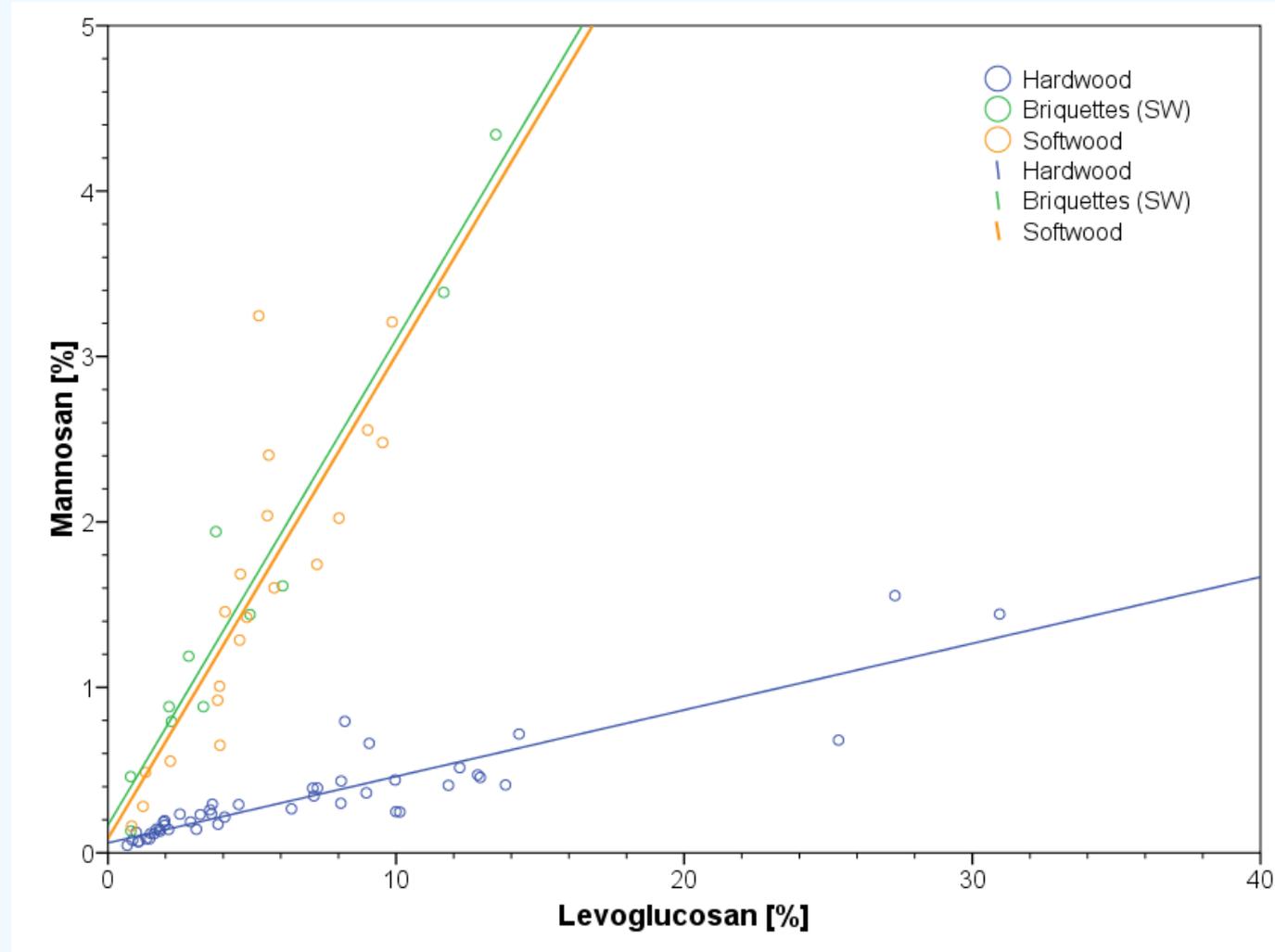
## Lev/Man Correlation:

4 different Stoves

16 Wood Types

## Explanation:

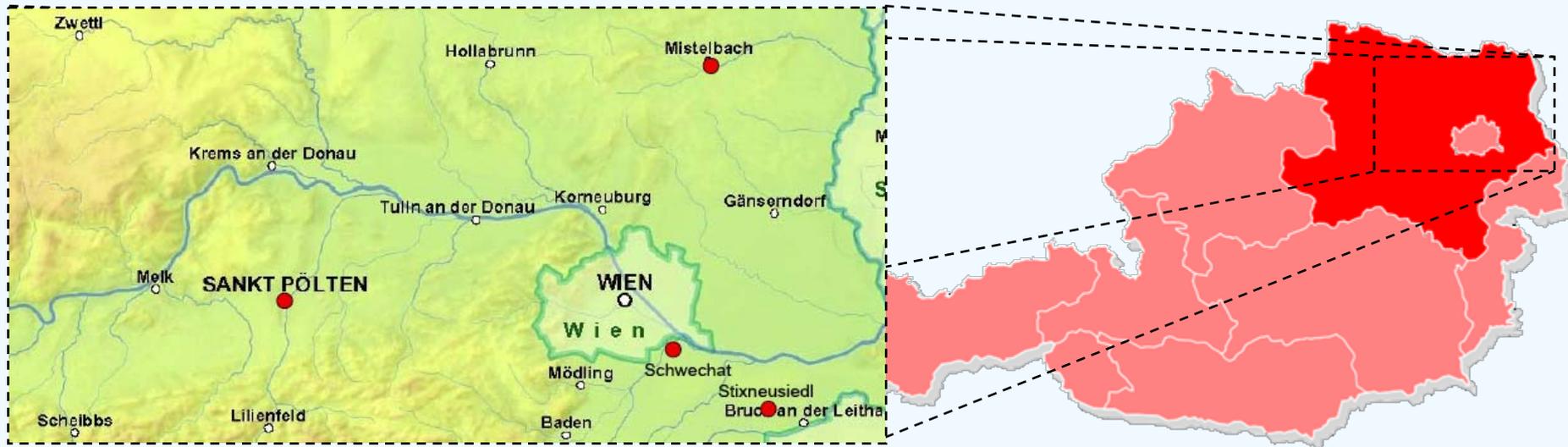
Differences in Structure of Hemicelluloses of Angiosperms (deciduous) and Gymnosperms (coniferous)



Schmidl et al., 2008, AE  
Schmidl et al., in preparation

# Application to Source Apportionment

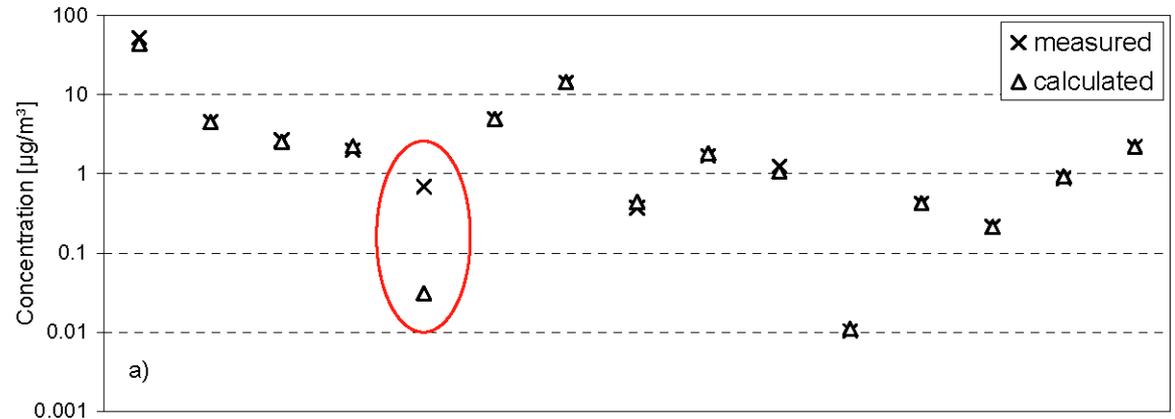
- Use of 2 Wood-smoke Profiles for CMB
  - Automatically fired (Boilers, Pellet Stoves)
  - Manually fired (Stoves)
- Example: Lower Austria



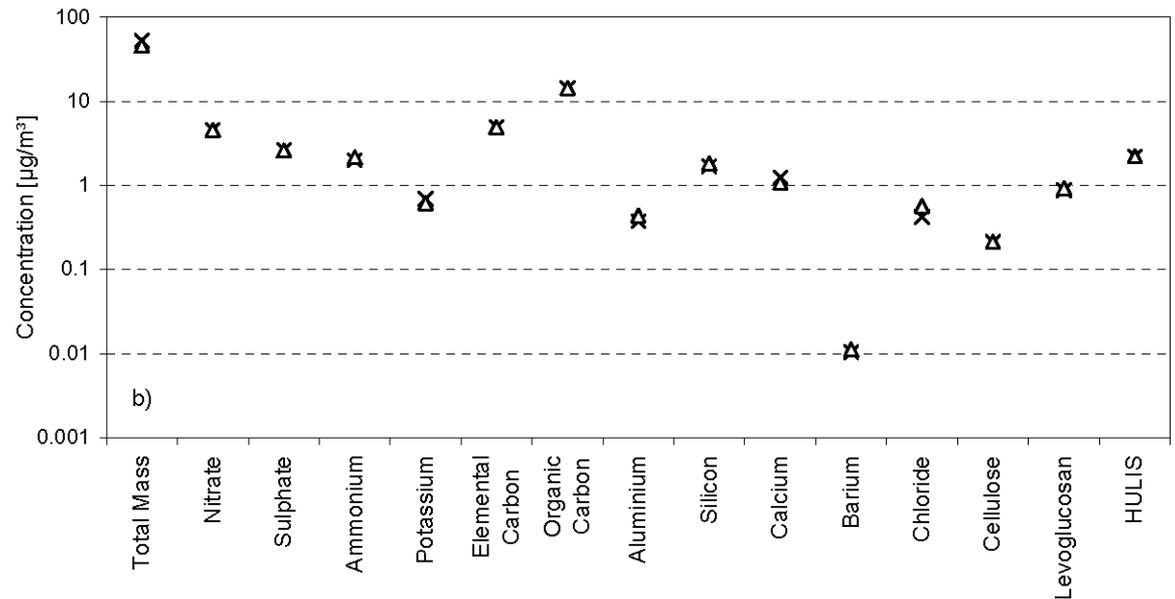
# Measured / Calculated

Same Data – Set:

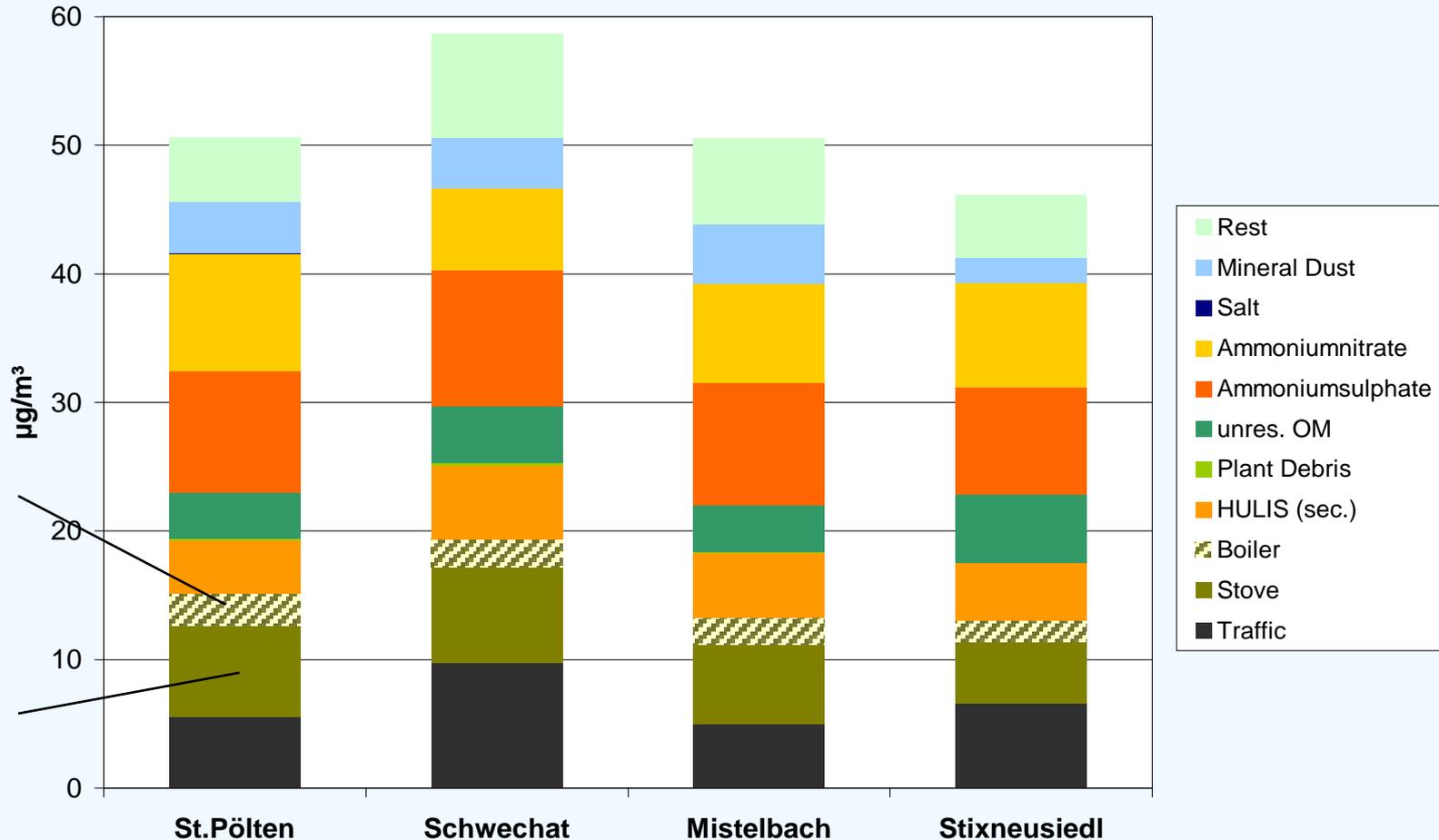
Without Boiler Profile



Including Boiler Profile



# Results CMB (Lower Austria)



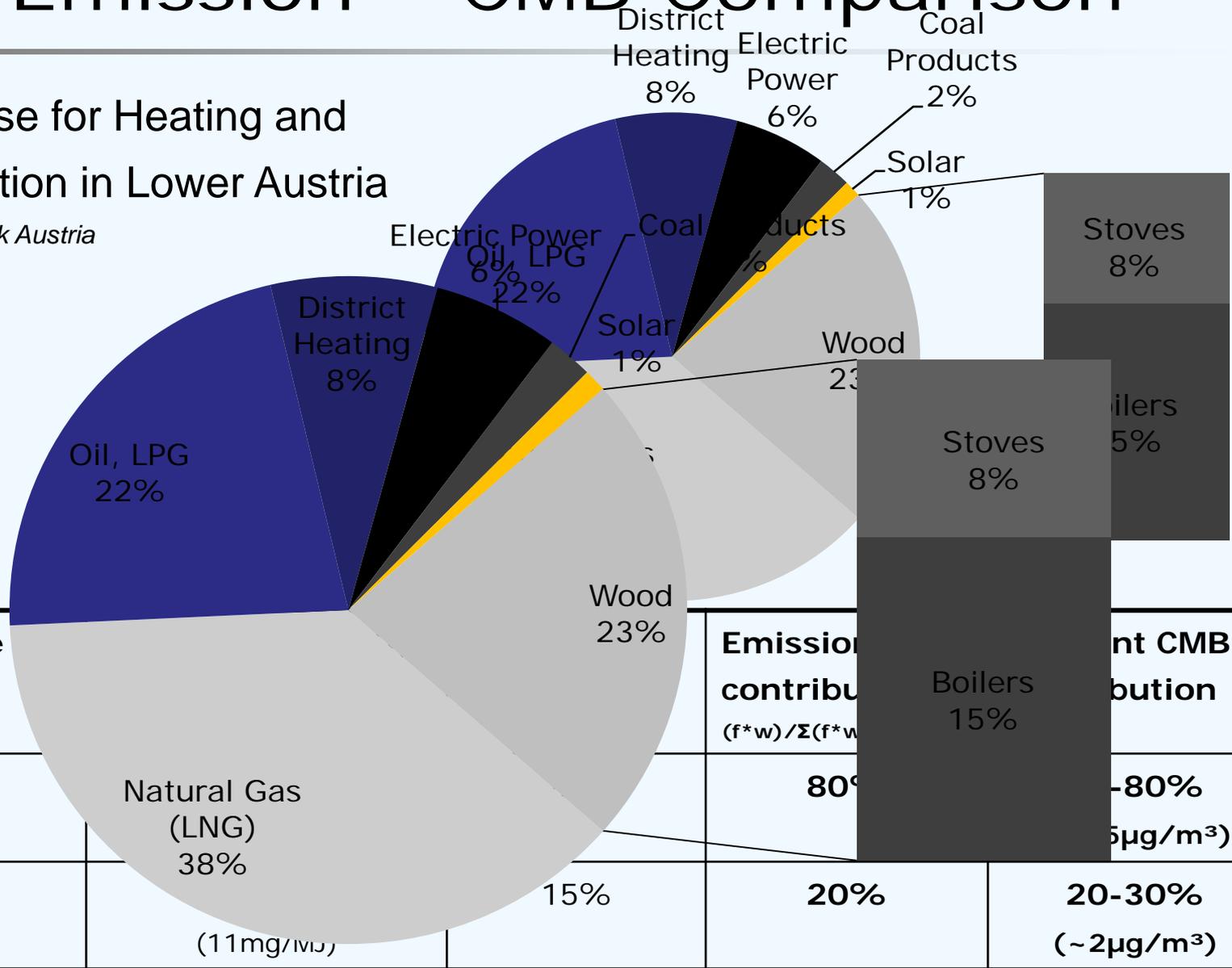
Boiler-Av.:  
2.1  $\mu\text{g}/\text{m}^3$  or  
4% of PM10

Stove-Av.:  
6.4  $\mu\text{g}/\text{m}^3$  or  
12% of PM10

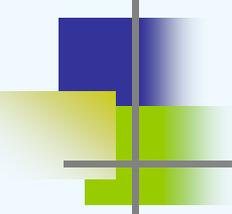
# Emission – CMB Comparison

## Energy use for Heating and Air Condition in Lower Austria

Source: Statistik Austria



Appliance type	Emission contribution (f*w)/Σ(f*w)	Stove contribution
Stove	80%	~80%
Boiler	20%	5µg/m³
		20-30% (~2µg/m³)



# Conclusions

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- Big Effort in Source Characterization is crucial for Quality of Apportionment Studies
- Differentiation between Wood Types seems feasible (using Levoglucosan/Mannosan Ratio)
- Use of 2 different Wood-Smoke Profiles possible and necessary
- „Macro-CMB“ Results show good Correlation with Emission Data

# Acknowledgements

Working Groups „Environmental Analytical Chemistry“ and “Atmospheric Analytical Chemistry” at Vienna University of Technology



## Funding:



lebensministerium.at



# Contribution by Species

