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MARIBOR, 18. - 19. SEPTEMBER 2013

www.pminter.eu

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Chemical characterization of PM10 emissions from small-scale domestic wood combustion – factors for the macro-tracer concept

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MINISTRY OF ECONOMIC DEVELOPMENT AND TECHNOLOGY

University of Maribor

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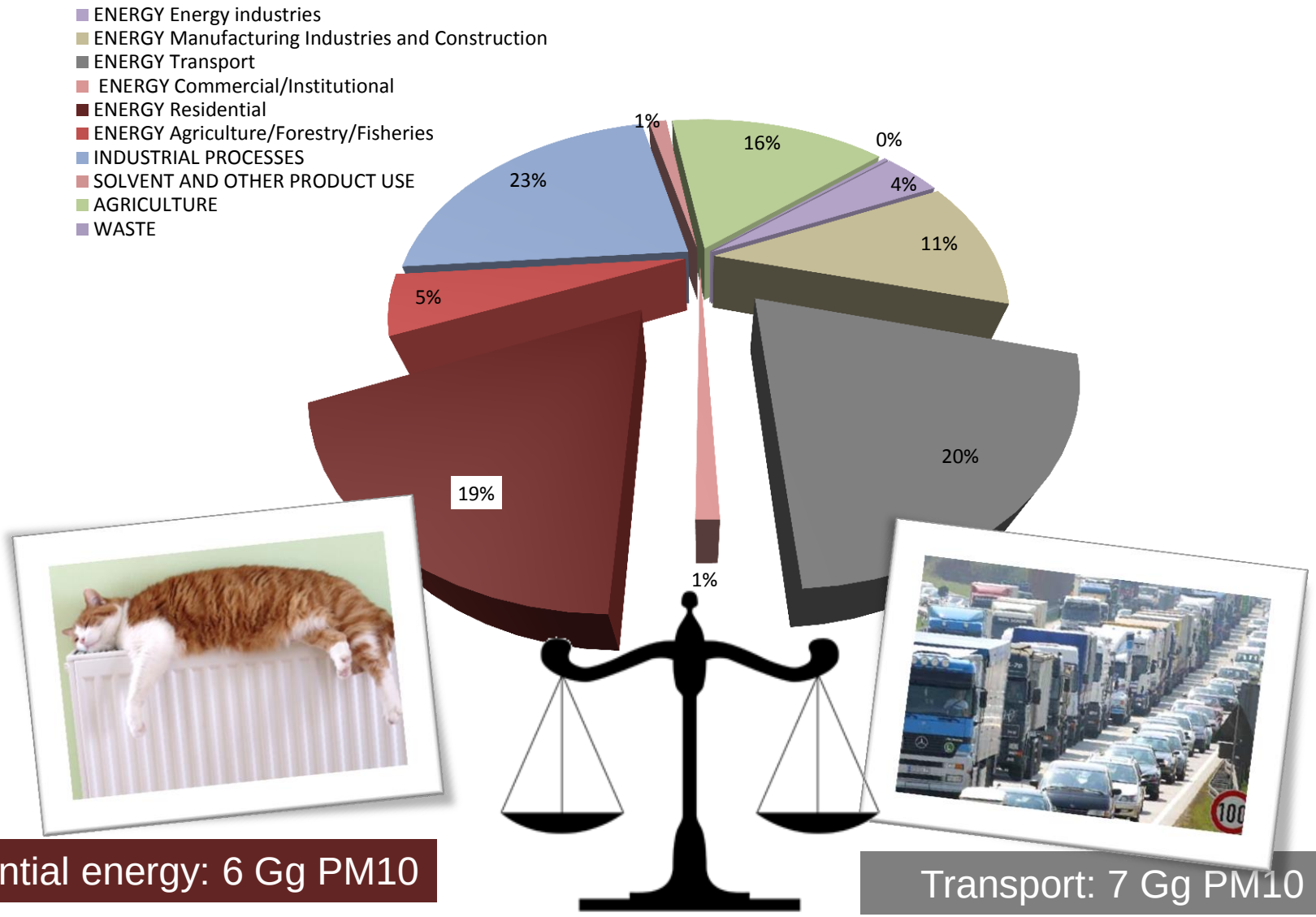
PM10 Emission sources (Austria, 2011)

Emission Inventory Report 0414, UBA AIIR 2013



Residential energy: 6 Gg PM10

Transport: 7 Gg PM10

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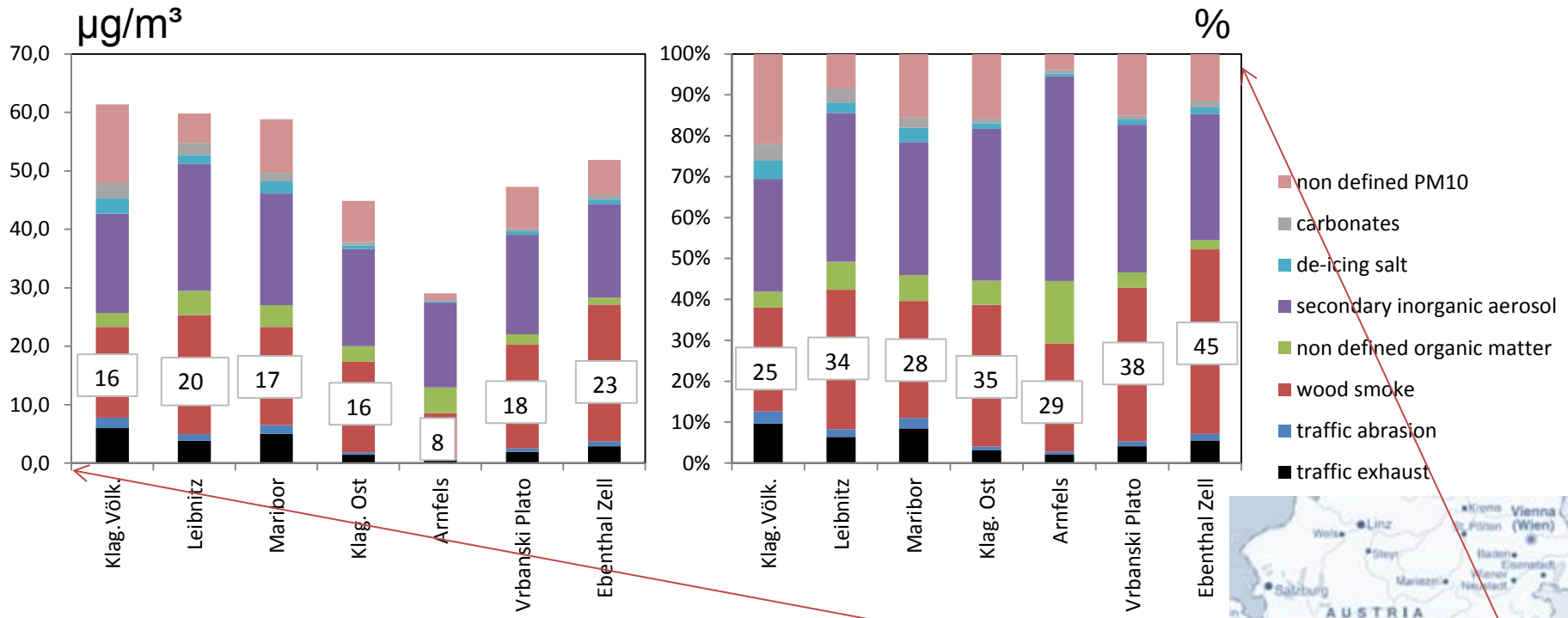
WB contribution @ *PMinter* sites

Average WB contributions

PM 25-45% OM 55-86%



Is it a lot? Where do those numbers come from?

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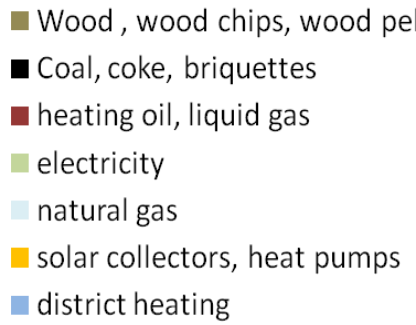
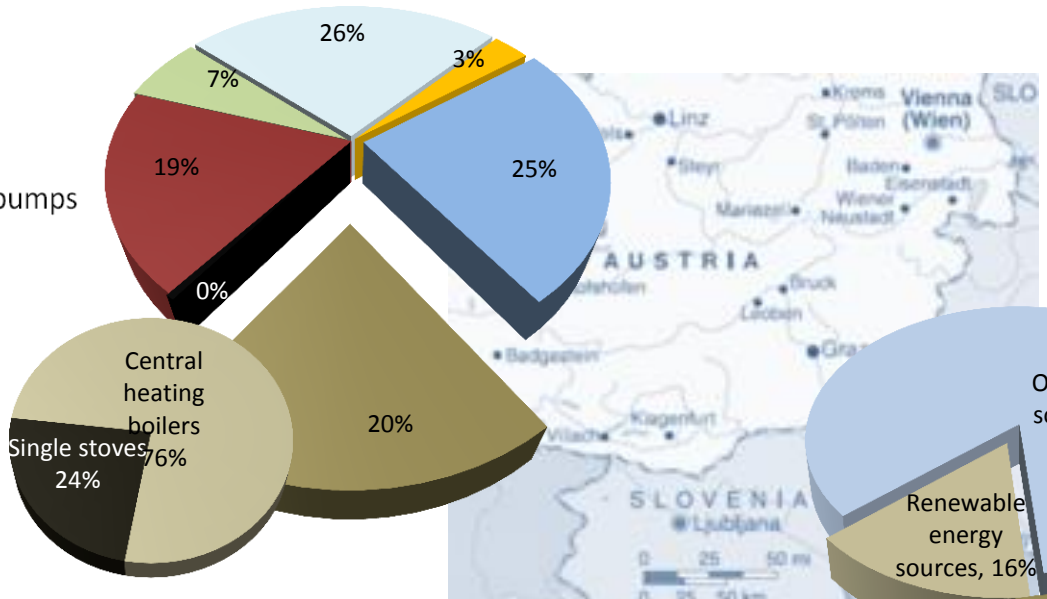
Is it a lot? Energy statistics

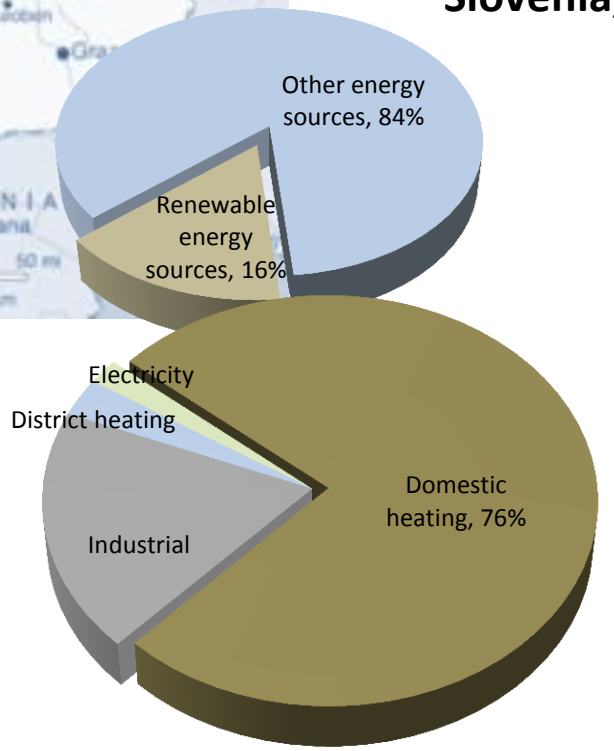
(Statistik Austria, www.agriforenergy.com, EC 2001)



Austria, 2011/2012



Slovenia, 2009



Austria	Slovenia
> 1 mio. households	> 300000 households
> 4 mio. inhabitants	> 1000000 HH get therir own biomass
87 PJ/year	14 PJ/year

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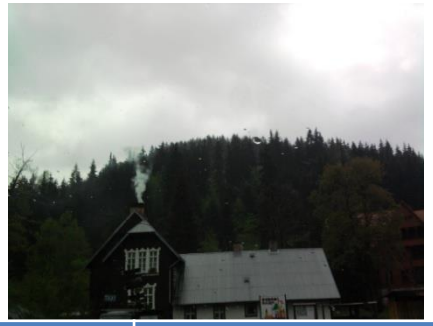
Is it a lot?

Wood Burning contribution to atmospheric aerosols






Reference	Component	Contribution	Place
Puxbaum et al., 2007	OM	20-50%	European background sites
Szidat et al., 2007	OM	88%	Closed alpine valley (Switzerland)
Caseiro et al., 2009	OC	70%	Graz, Austria, cold season
Bari et al., 2011	OM	50%	„wood burning community“ (Germany)

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Is it a lot?

Perception of wood burning smell

Ever smell wood burning on autumn evening in residential area?

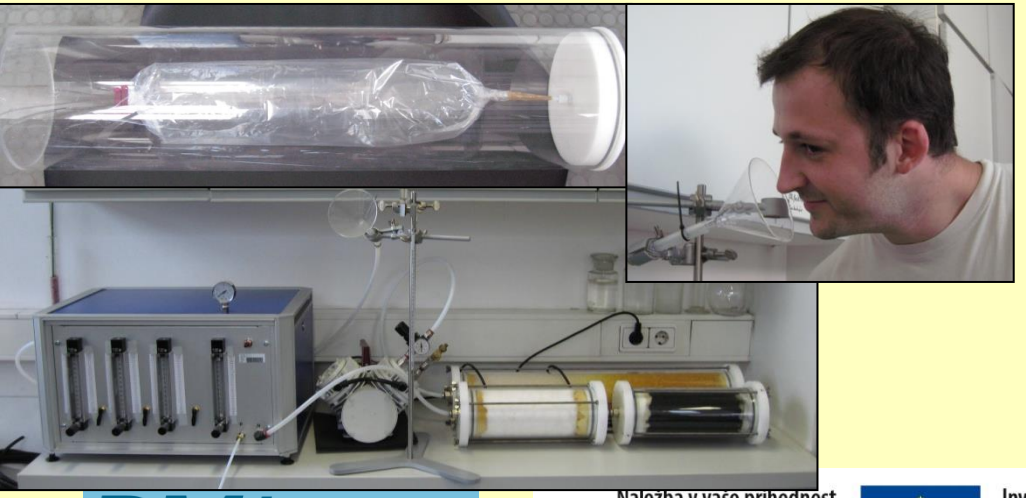
due to VOC, SVOC – gas and particulate phase

Average ambient wood smoke PM10 concentrations @ Pminter sites: 8- 23 µg/m³
but short-time peaks peaks even 100 times higher!

Odor nuisance can be measured and related to PM10 burden

Dynamic dilution olfactometry

European Odor Unit (1 OU/m³) dilution at which odor nuisance can be recognized by human nose



Pellets: not detected

Logwood: ~500-5000 OU/m³

Garden waste ~3500-19000 OU/m³

1 OU/m³ (perception level)

Beech burning → 60 µg/m³ $PM10_{WB}$

Spruce burning → 20 µg/m³ $PM10_{WB}$

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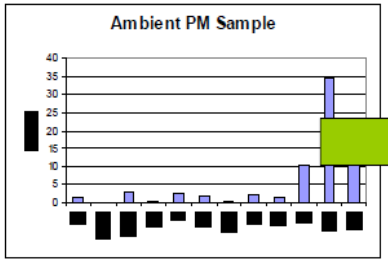
Where do the numbers come from?

Wood burning PM in ambient air

Source contributions to ambient PM10 on base of filter measurements? Yes! What is needed?

„macro“ tracer – unique, stable, significant contribution

chemical characterization of ambient sample



Calculation:

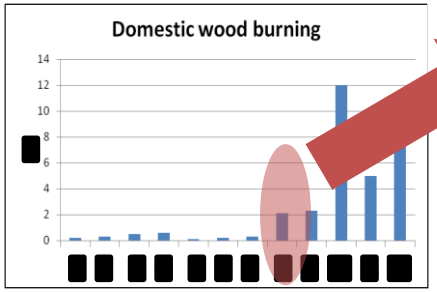
% of Source A

% of Source B

% of Source C

concentration of „macro“ tracer in source emissions in relation to total PM10

chemical characterization of emission sample



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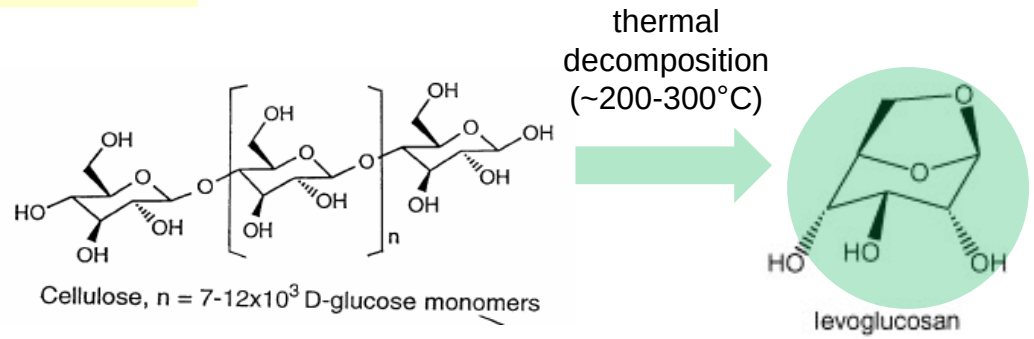
Wood burning tracers

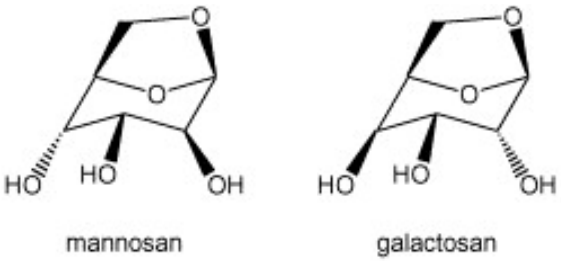
<u>Levoglucosan:</u>

- formed from cellulose (pyrolisis)
- stable
- released in significant amounts



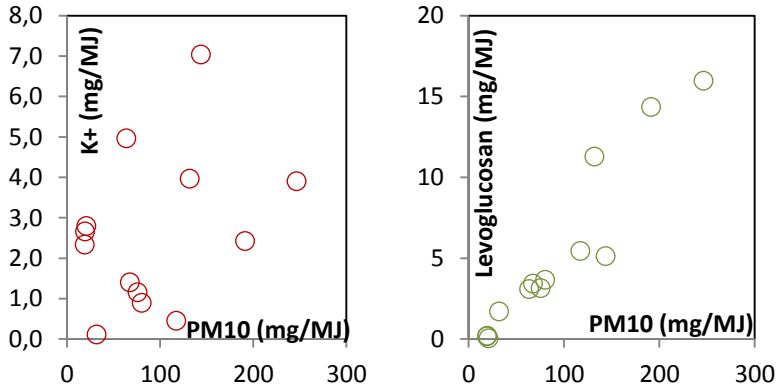
<u>Mannosan and Galactosan:</u>

- formed from hemicelluloses
- variable amount



<u>Potassium:</u>

- released at high temperatures
- amount dependant on burning conditions
- released also from solid fossile fuels (coal)



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Emission sampling – stoves and biomass

- Small-scale residential heating: devices with nominal power output < 50 kW

  (except „old wood boiler“ – 125 kW)
- Over 30 fuels (wood, briquettes, wood/straw pellets, paper, biomass waste, coal)

Modern pellet stove

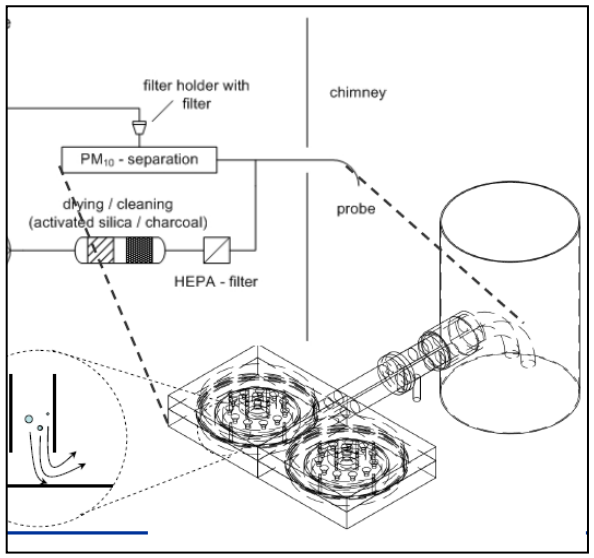
Modern chimney stoves

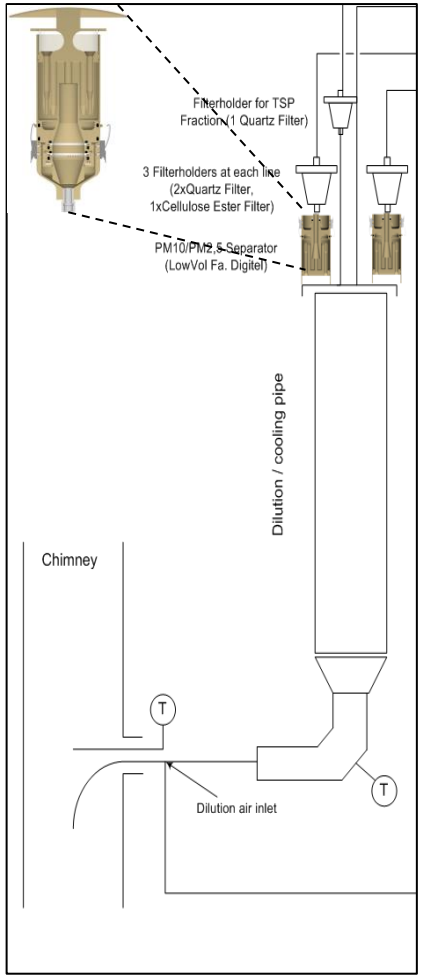
Traditional tiled stove

Automatic (modern) biomass boiler

Old biomass boilers

Emission sampling





Sampling systems:

- Dilution sampling
- Quartz filters
- Duration: all burning phases (2 or 3 full stove loadings)
- Size separation (one-stage impactor)
- Continuous gas emission measurement (CO, NOx, VOCs)
- Operation due to stove instructions, extra experiments with false settings

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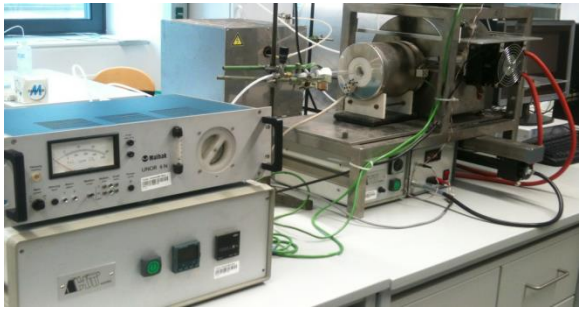
PM10 Analytics

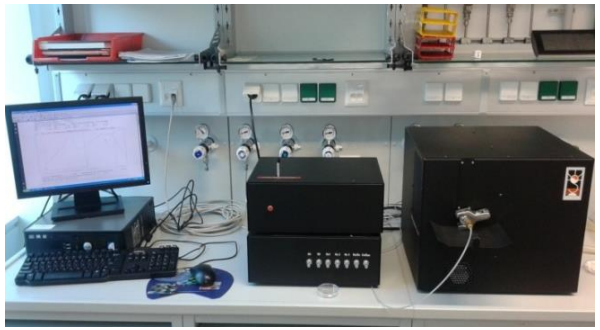
Gravimetry

filter pre-cleaning: T=500°C, 5h

conditioning and weighing

T= 20°C±1°C, RH=50%±5%





T-OT - Carbon parameters

- O_2 atmosphere, linear temperature ramp, NDIR detection, laser
- He/O_2 atmosphere, different temperature steps, CO_2 reduction to CH_4, FID detection, laser

HPAEC-PAD - Anhydrosugars

Ion chromatography with alkaline eluent gradient (NaOH), electochemical detection

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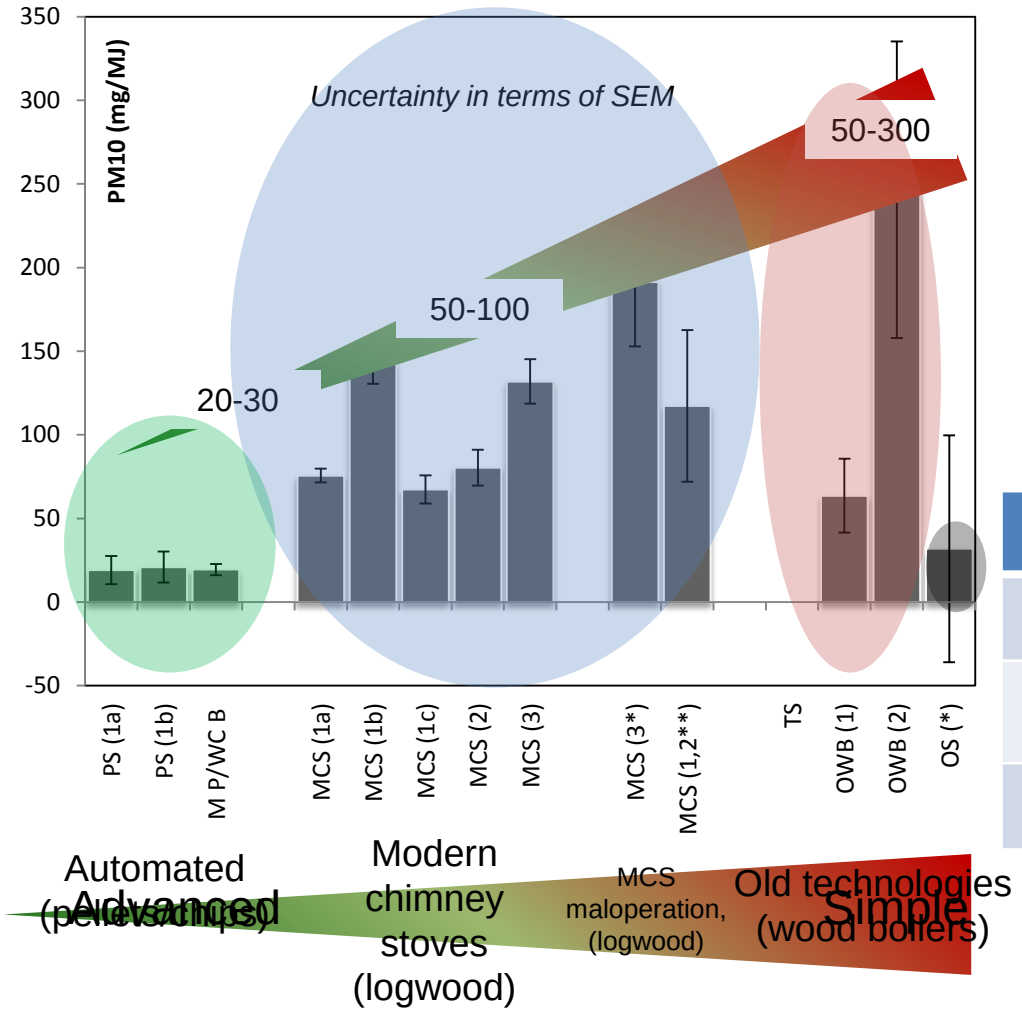
PM10 Emissions



Emission factors:

- standardized (0°C, 1 atm and 13% O_2)
- 1 kg wood (12% H_2O) ~ 16 MJ
- high variability among manually operated devices
- constant low values for automatically fired devices

Ef (mg/MJ)	Chimney stove	Pellet stove	Boiler manual		Boiler automatic	
Nominal Power	<15 kW		4-25 kW	25-50 kW	4-52 kW	25-50 kW
Austria *(Spitzer, 1998)*	134		90			
Germany *(Struschka, 2008)*	106	57	90	52	23	13

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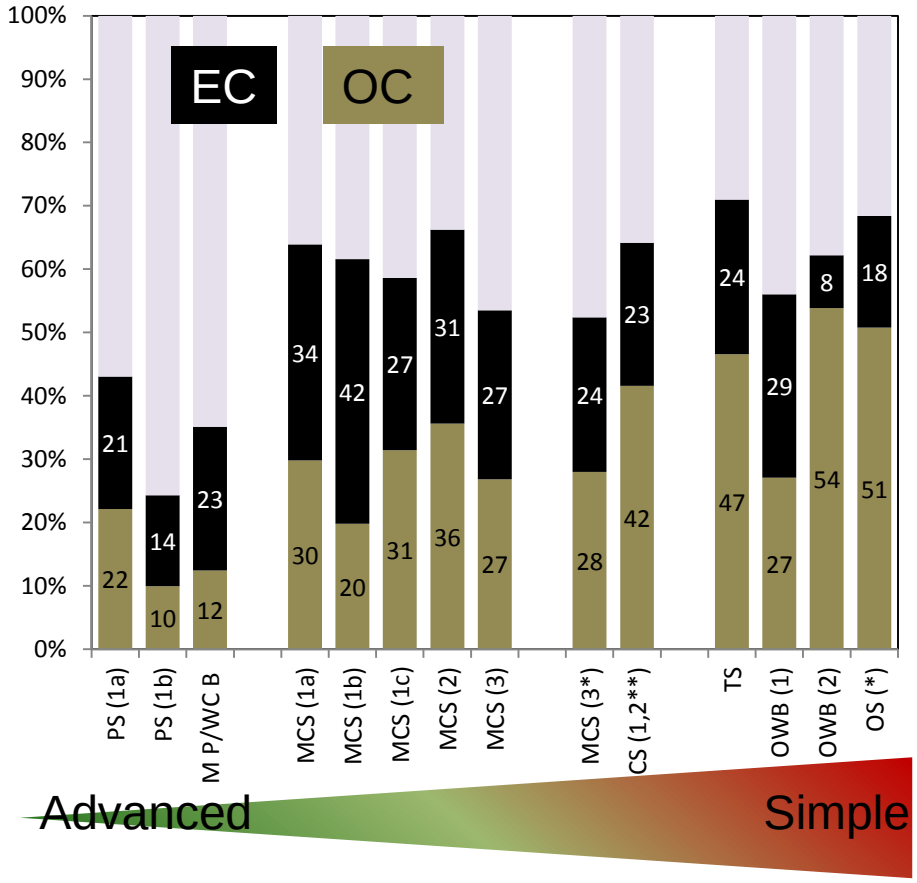
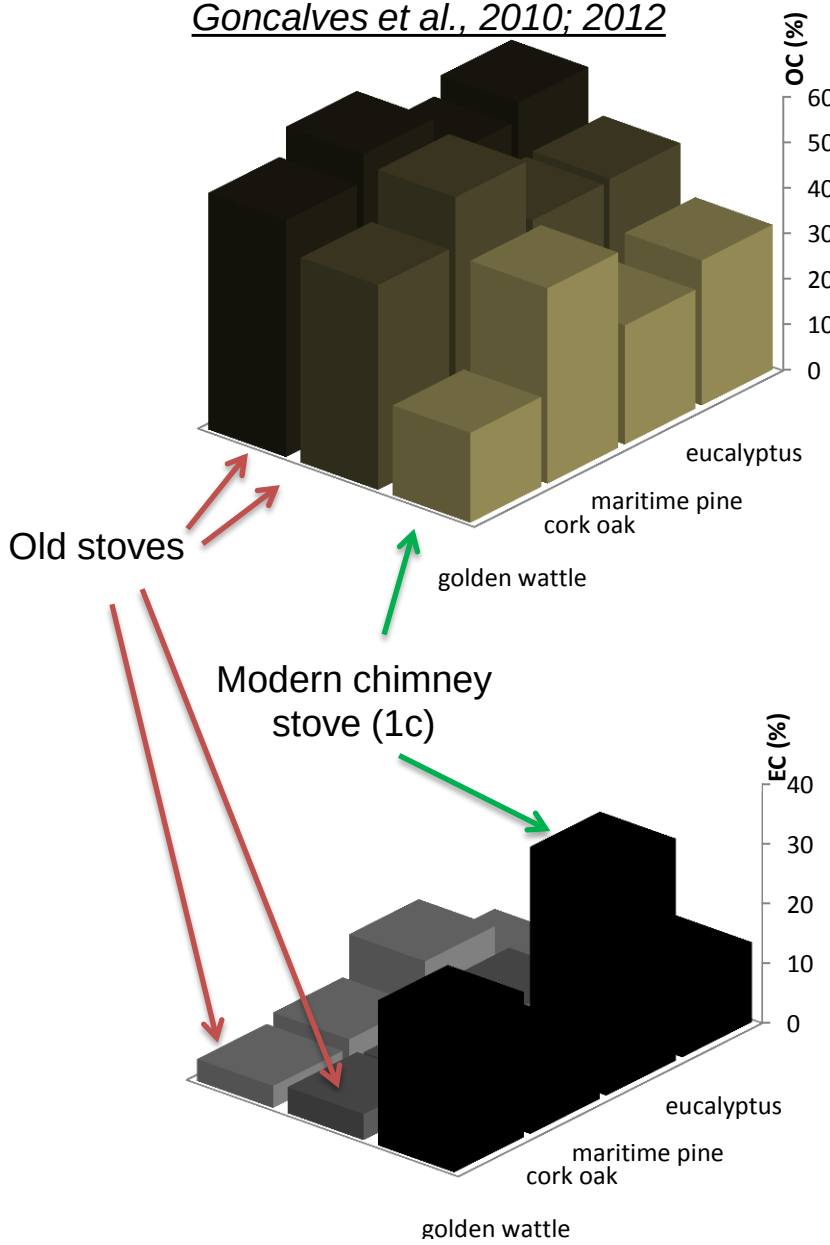
Carbonaceous material



Goncalves et al., 2010; 2012



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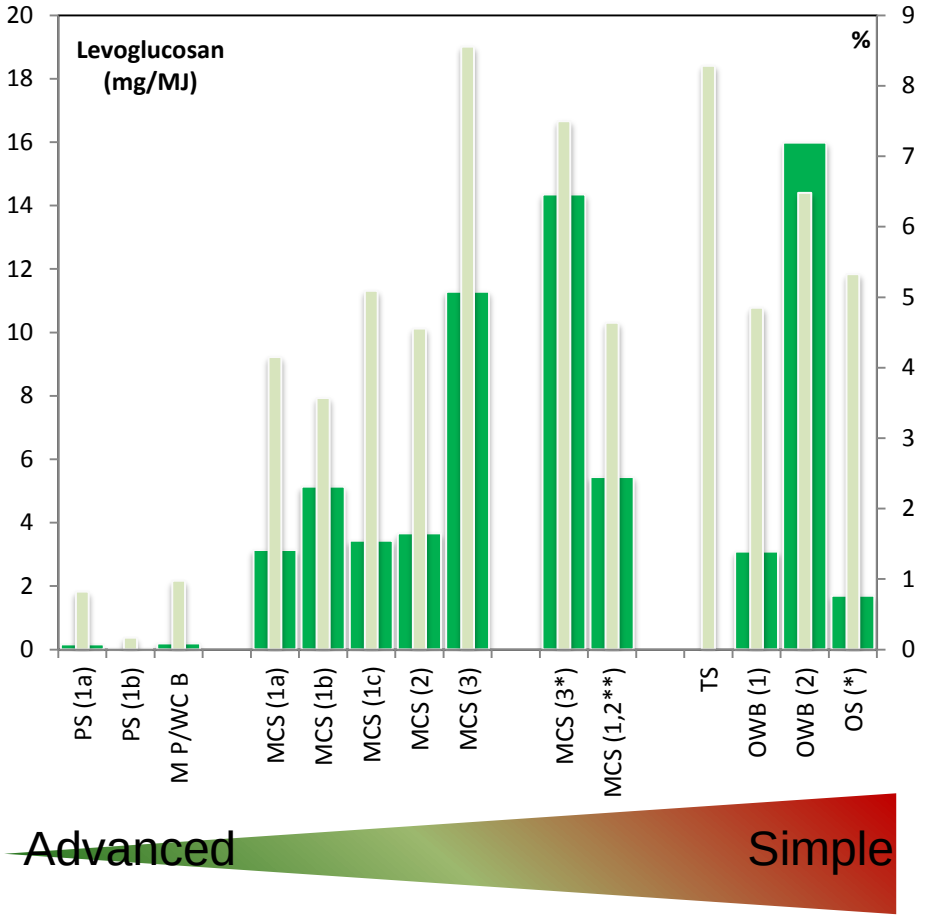
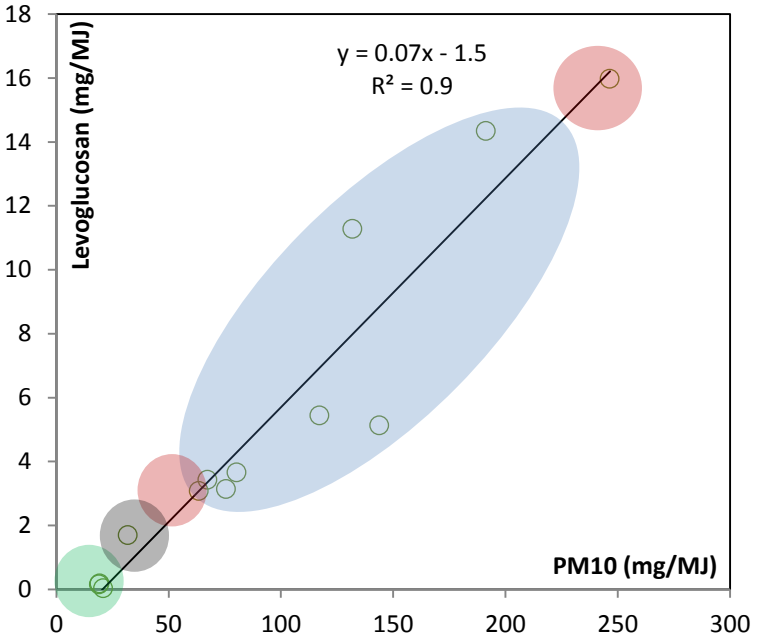
Levoglucosan in PM10





PM/Levoglucosan rates

Traditional tiled stove	12.1
Wood boilers	18.0
Modern chimney stoves	20.1

MCS (oak)	11.3
MCS (beech)	21.6
MCS (spruce)	17.3
MCS (briquetes)	19.9

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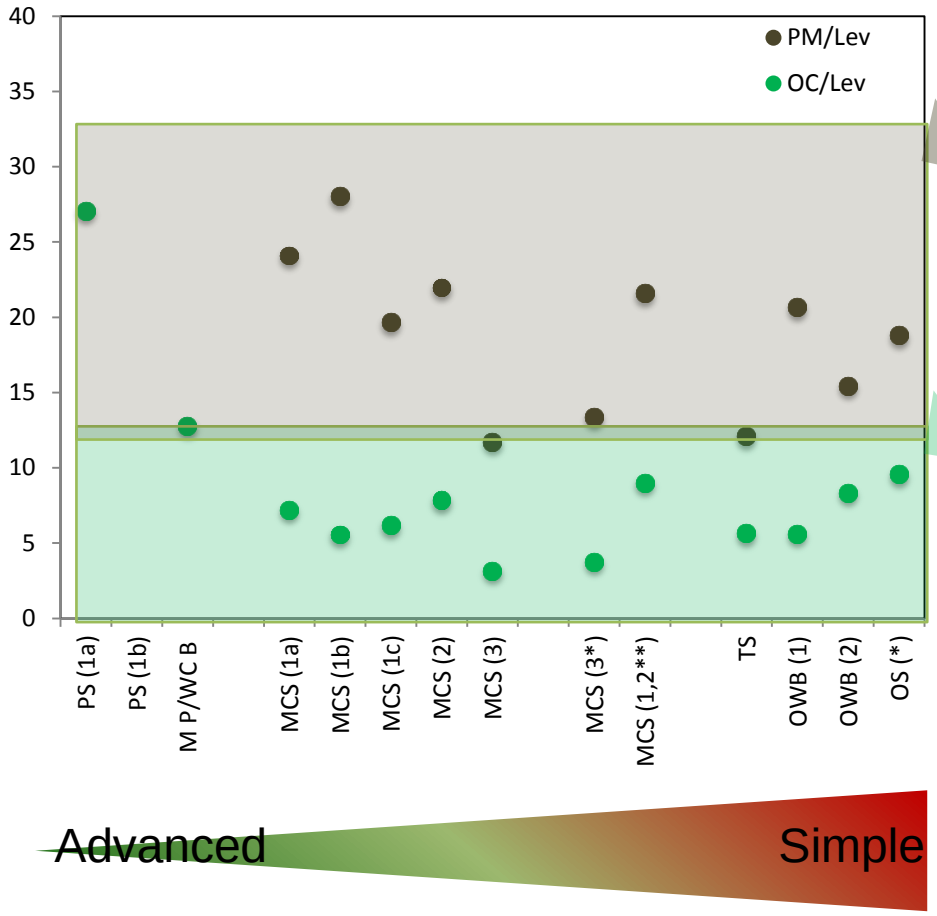
Levoglucosan in OM



variability among different stoves an species

good stability

OC/Levoglucosan rates

Traditional tiled stove	5.6
Wood boilers	7.0
Modern chimney stoves	6.1

MCS (beech)	6.7
(* excluding 2 extreme values)	
MCS (oak)	5.2
MCS (spruce)	5.7
MCS (briquetes)	7.4

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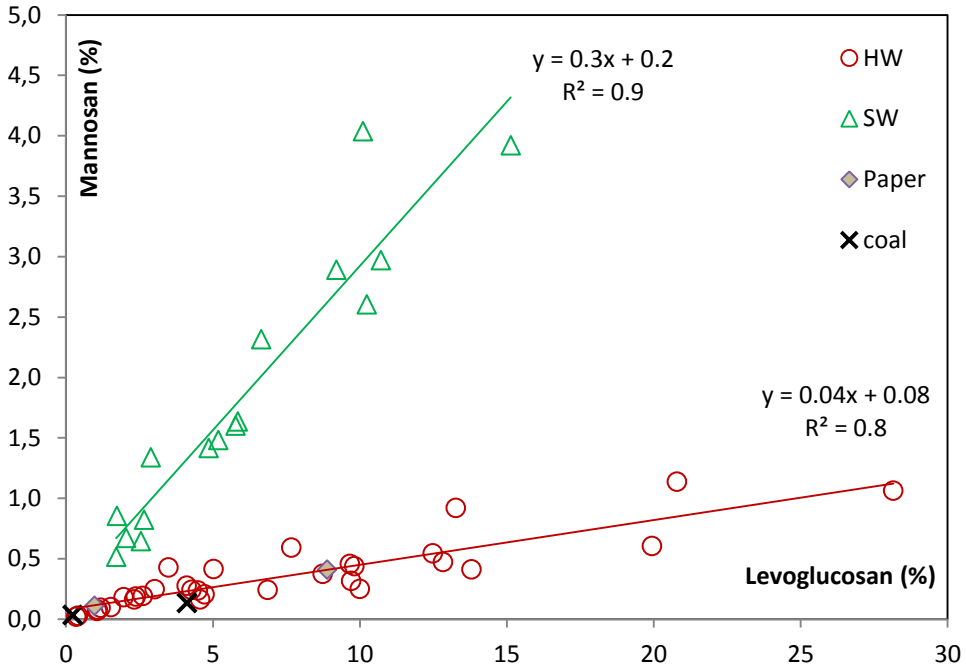
Levoglucosan/Mannosan ratios



Significant lev/man ratio difference for different biomass types

Hardwood (HW): 19.8 (8-40)
Softwood(SW): 3.2 (2-4)

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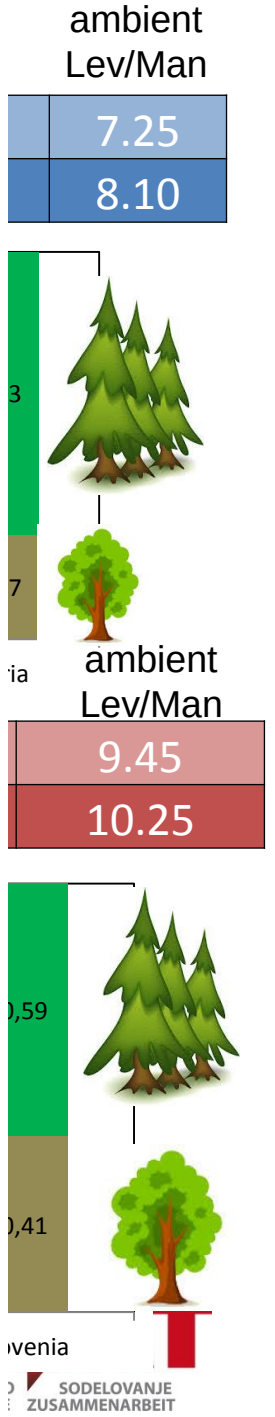
Kistler et al., 2012

ee species in forests of selected Central European countries. (Sources: see text).

Wood		Austria	Baden-Württemberg and Bavaria (Germany)	Czech Republic	Hungary	Slovak Republic	Slovenia	South Tyrol (Italy)	Switzerland
Total forest cover [% of land area]		47	37	36	20	41	60	45	30
Botanic name	Common name		(% of woodland area)						
Carpinus betulus	European hornbeam			1	**5**	**6**		3	
Fagus sylvatica	European beech	**10**	**16**	**7**	**6**	**31**	**31**	1	**18**
Populus nigra	Black poplar				4(**11**)*		0		
Quercus cerris	Turkey oak				**11**	3		0	
Quercus petraea	Sessile oak	2[a]	**7**[a]	**7**[a]	**21**[b]	**11**[b]	**7**[a]	1[b]	2[a]
Quercus robur	Pedunculate oak								
Robinia pseudoacacia	Black locust				**24**	2			
Other deciduous		12	13	9	11	7	14	2	13
Total deciduous		24[d]	36	24	88	59	52	7	34
Abies alba	Silver fir	2	4	1		4	3	1	**13**
Larix decidua	European larch	**5**	2	4		2		**28**	**6**
Picea abies	Norway spruce	**54**	**42**	**53**		**23**	**32**	**53**	**42**
Pinus nigra	Austrian black pine	1	**15**[c]	**17**[c]		**7**[c]	**6**[c]	0	4[c]
Pinus sylvestris	Scots pine	**5**						**11**	
Other coniferous		1	1	0	12	1	2	0	1
Total coniferous		67[d]	64	75	12	41	48	93	66

*...4% correspond to Black poplar, while 11% is a contingent of all poplar types (including Hybrid poplar), [a]...sum of all oak species, [b]...sum of temperate oak species (*Q.petraea, Q.robur*), [c]...sum of all pine species, [d]... remaining 9% is dedicated to blanks, gaps and shrubs, for abbreviations see text.



PMinter calculation factors - conclusion

ambient Levoglucosan → ambient wood burning PM10 concentrations

$Lev_{ambient}[\mu g/m^3] * PM/Lev_{WB} = PM_{WB\ ambient}$

Factor PM/Lev based on the ambient Lev/Man ratios

ambient Levoglucosan, ambient OC → Share of wood burning OC in ambient OC

$OC_{ambient}[\mu g/m^3] * OC/Lev_{WB} = OC_{WB\ ambient}$

Factor OC/Lev based on the same pattern as PM/Lev

ambient Levoglucosan, ambient EC → Share of wood burning EC in ambient EC

Share of wood burning – EC assessed as 10% of $PM_{WB\ ambient}$ 10% (old technology scenario)

Conclusions

- Old technologies - low efficiency and high PM10 emissions, OM dominates
- Modern logwood chimney stoves variable PM10 emissions according to both biomass type and operation conditions – due to manual operation
- Modern devices - generally higher EC and inorganic ash contribution

- Automatically operated combustion devices - constant low emissions with much lower carbonaceous matter mass

- Levoglucosan correlates well with PM and is a robust basis for modeling of WS share
- Levoglucosan/Mannosan ratios are useful to assess the share of HW/SW in burned biomass and can be succesfully applied to the ambient observations

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Thank you for your attention!

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„FWF-WOODSMOKE“

„PMinter“

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