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Ambient air filter efficiency in airtight, highly energy efficient dwellings – A simulation study to evaluate benefits and associated energy costs

Performed in the framework of IEA EBC Annex 68

Gabriel Rojas, University of Innsbruck, Austria
Unit for Energy Efficient Buildings
October 16th, AIVC 2019

EBC | Bundesministerium Verkehr, Innovation und Technologie | IEA FORSCHUNGS KOOPERATION | FFG Forschung wirkt.

1

Motivation

In very airthight residential housing with MVHR (Passive Houses)…

What is the exposure contribution from outdoor originated and from indoor originated particulate matter?

What filter quality is recommendable?

What impact has the use of a recirculating vs. extracting cooker hood?

Simulation study (CONTAM) accounting…

- filter efficiency
- envelope penetration
- particle deposition
- outdoor air concentration
- indoor sources

$= f\ (particle\ size)$
21 size bins

2

Model assumption – Reference apartment

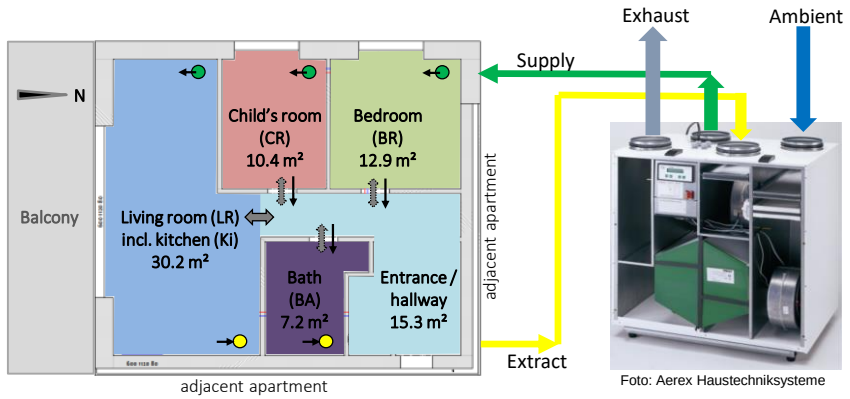


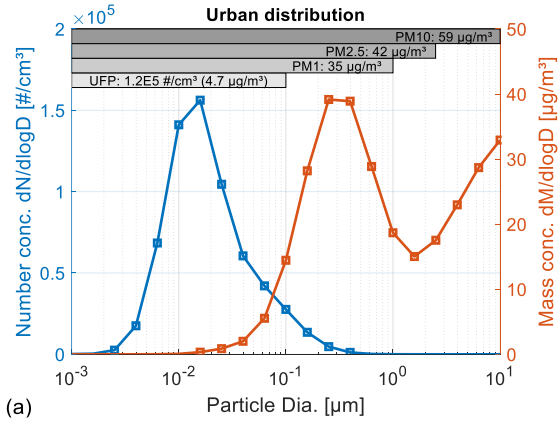
Foto: Aerex Haustechniksysteme

Ventilation air flows in m³/h (l/s)

	BR	CR	LR/Ki	BA	Total
Supply	40 (11.1)	20 (5.6)	30 (8.3)		90 (25)
Extract			60 (16.7)	30 (8.3)	90 (25)

3

Model assumption – Ambient air PM concentration

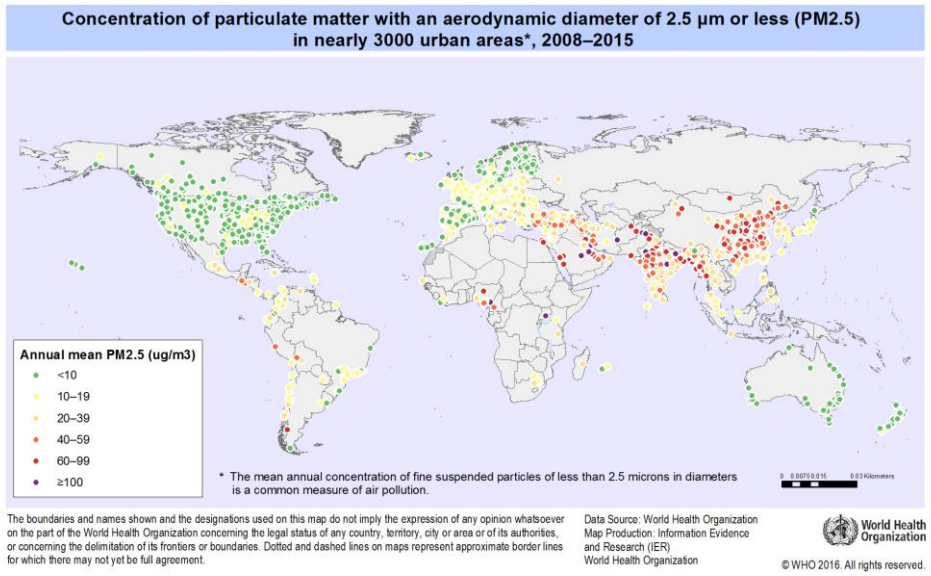


Derived from:Ruprecht, Jaenicke. 1993. "Tropospheric Aerosols." Pp. 1–31 in *Aerosol-Cloud-Climate Interactions*, edited by P. Hobbs. Academic Press

	PM2.5
Low	8.4 µg/m³
Ref	**42 µg/m³**
High	84 µg/m³

4

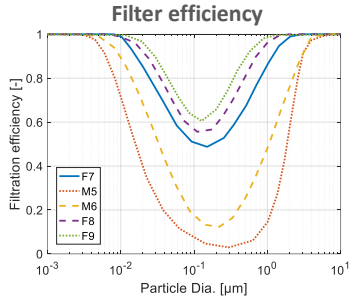
Model assumption – Ambient air PM concentration



Source: https://www.who.int/gho/phe/air_pollution_pm25_concentrations/en/

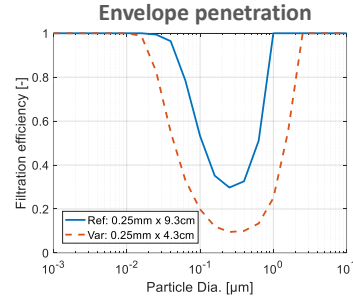
Model assumptions: filter, penetration, deposition

Filter efficiency



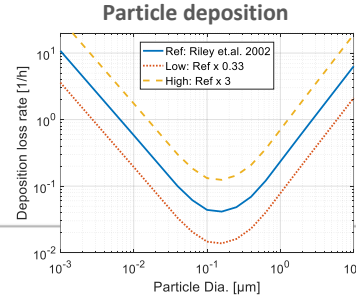
Derived from: Shi, Bingbing. 2012. "Removal of Ultrafine Particles by Intermediate Air Filters in Ventilation Systems - Evaluation of Performance and Analysis of Applications Ventilation Systems." Chalmers University of Technology, Göteborg, Sweden.

Envelope penetration



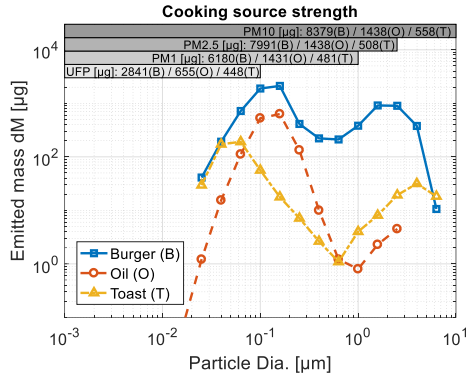
Derived from: Liu, De Ling and William W. Nazaroff. 2003. "Particle Penetration through Building Cracks." *Aerosol Science and Technology* 37(7):565–73.

Particle deposition



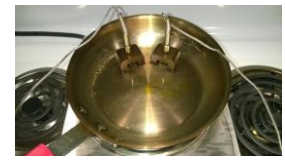
Derived from: Riley et.al. (2002). "Indoor Particulate Matter of Outdoor Origin: Importance of Size-Dependent Removal Mechanisms." *Environmental Science and Technology* 36(2):200–207.

Model assumptions: Cooking source strength



breakfast

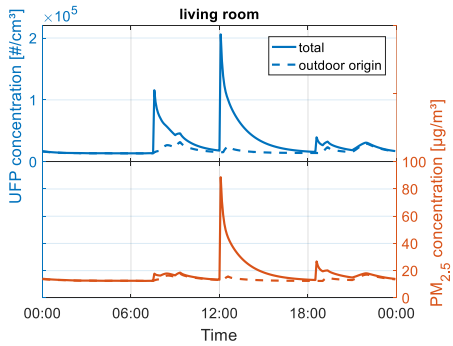
lunch



dinner

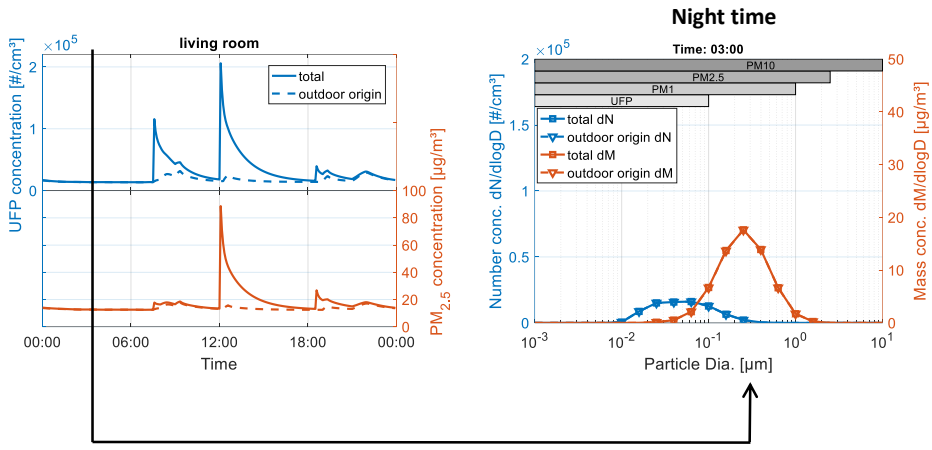
7

Results: Daily evolution



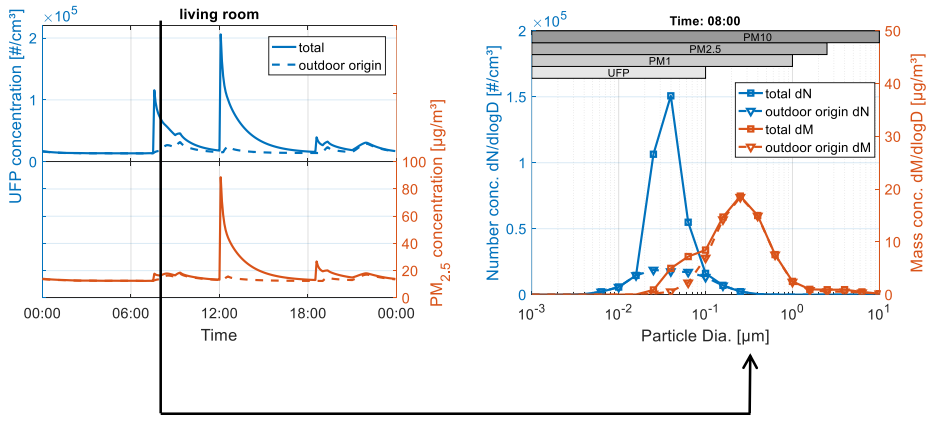
8

Results: Daily evolution



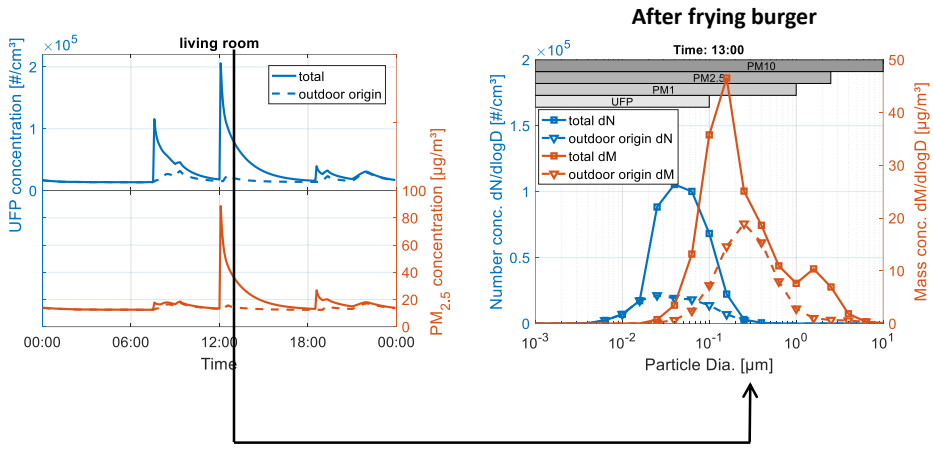
9

Results: Daily evolution



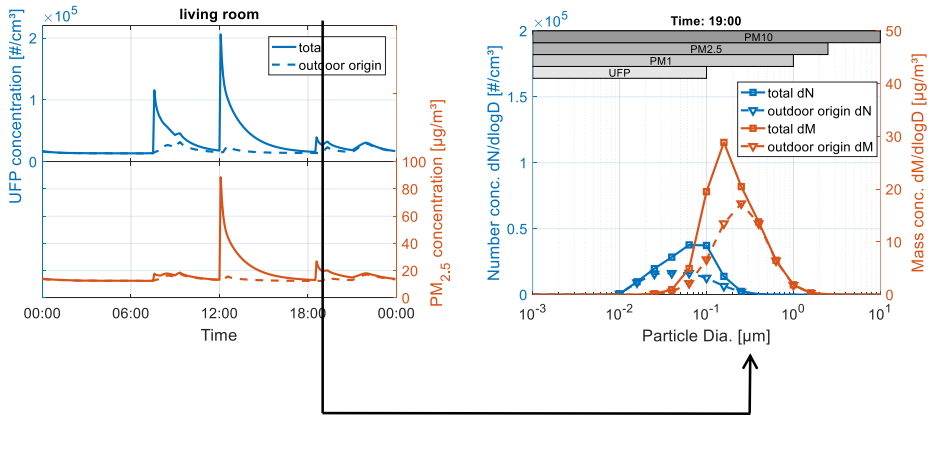
10

Results: Daily evolution



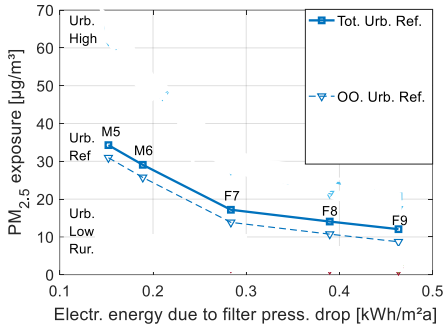
11

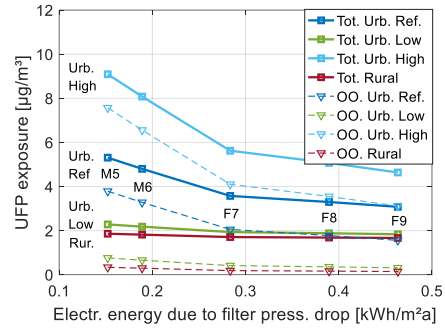
Results: Daily evolution



12

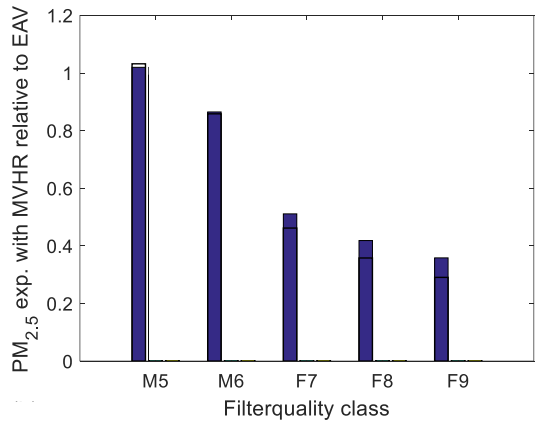
Results: Exposure reduction vs. electr. fan power



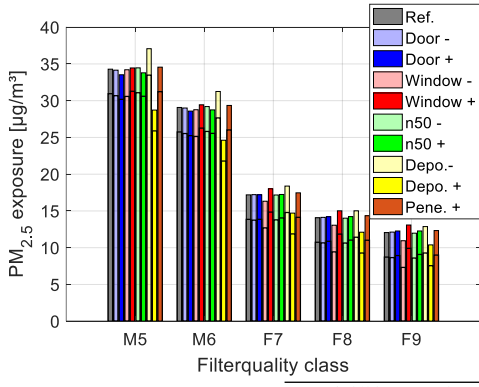


M5	M6	F7	F8	F9
MERV9/10	MERV11/12	MERV13	MERV14	MERV15

Results: Relative to extract air ventilation



Sensitivity on model assumptions



	Reference	Low	High
Bed- / child's room door opening	8am – 10pm	4 x 10 min	0-24 hrs
Window opening (tilted): all	3.6 h/day	0 h/day	6.3 h/day
Kitchen area	3 x 20 min	-	3 x 35 min
Living room area	3 x 10 min	-	3 x 18 min
Bedroom	2 x 56 min	-	2 x 98 min
Childs room	2 x 6 min	-	2 x 11 min
Airtightness / n50	0.6 1/h	0.3 1/h	1.5 1/h
Deposition rate multiplier	1	0.33	3.0
Penetration factor for crack with dimensions	W 0.25 mm x L 9.4 cm	-	W 0.25 mm x L 4.3 cm

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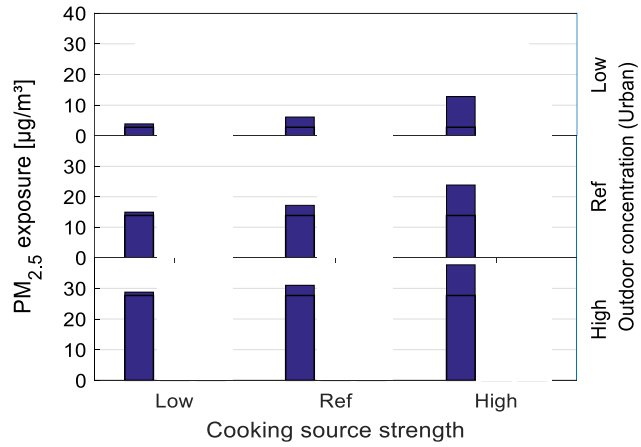
15

Results: Outdoor vs indoor source strength



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16

Recommendations for airtight residential housing with MVHR / Passive Houses

- F7 (ePM1-50% / MERV 13) can be considered a good general recommendation. However, higher quality (F9) are recommended for moderate or high polluted areas.
- Extracting cooker hoods are advisable for household where high cooking induced particle generation (e.g. frying) can be expected. However, in areas with high outdoor pollution, PM introduced with make-up air will be a (more) relevant source.
  -> Further product development is encouraged.
- Recirculating cooker hoods will not notably reduce total PM exposure.
  -> Further product development is encouraged.

Outlook / Further research

- Apply time-resolved recent ambient air data for simulation
- Apply more diverse indoor generation models
- Apply resuspension models
- Eperimental validation
- Measure / apply (fractional) filter efficiency for filter class acc. to ISO 16890
- **Account for potentially different health effects from outdoor originated vs indoor generated particles.**

Thank you!

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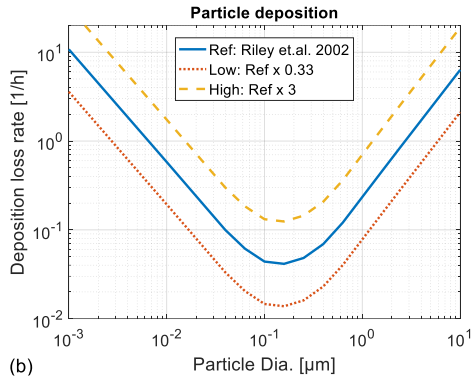
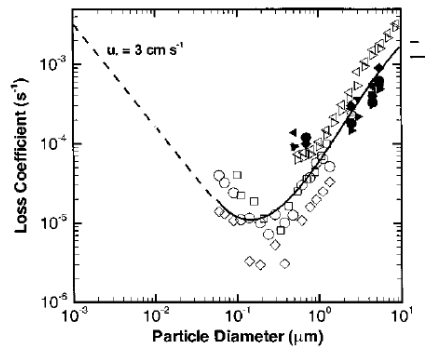
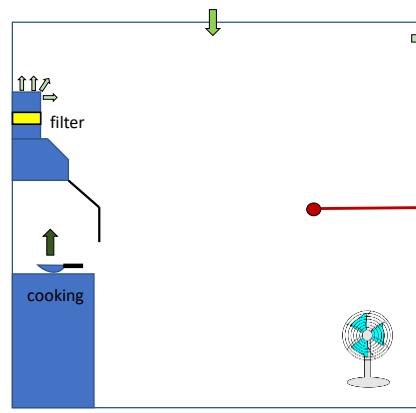
Model assumptions: PM deposition





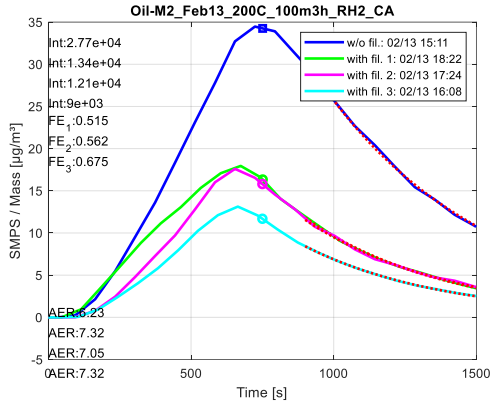
Source: Riley et.al. (2002). "Indoor Particulate Matter of Outdoor Origin: Importance of Size-Dependent Removal Mechanisms." *Environmental Science and Technology* 36(2):200–207.

Measurement method: cooking source strength



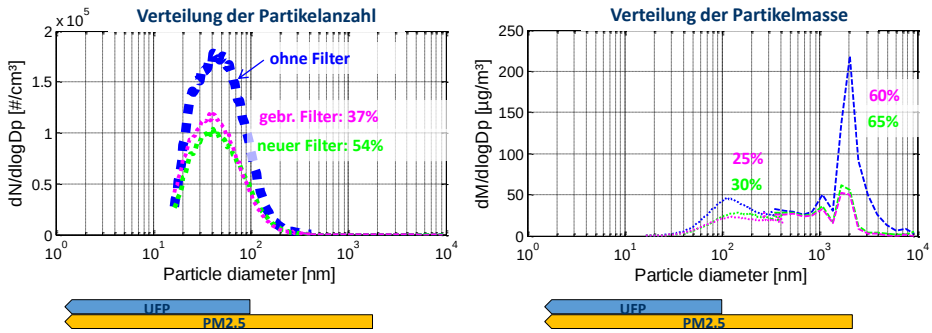
$RE = 1 - \frac{\Delta C_{withFilter}}{\Delta C_{without}}$

Deriving cooking source strength

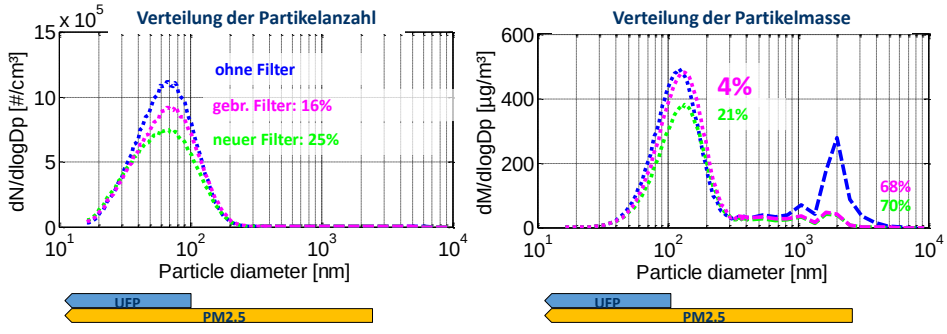


$$m = \int_0^{peak} AER\ V\ c\ dt + V\ c$$

Größenverteilung der Partikel: Zwiebel @ 200 C



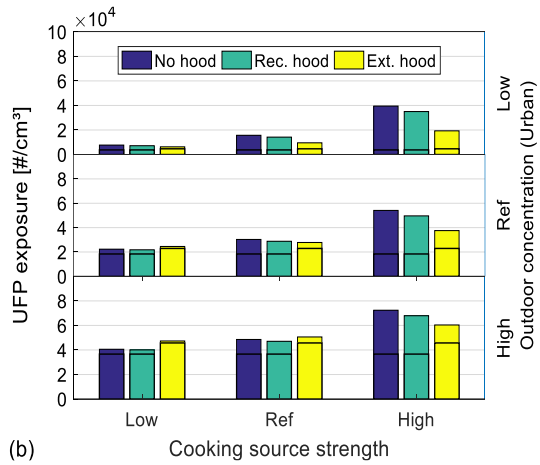
Filter Br1-2, gemessen mit SMPS 3936 (10-400nm) und OPS 3330 (0,3 -10µm), 3 Wiederholungen



Filter Br1-2, gemessen mit SMPS 3936 (10-400nm) und OPS 3330 (0,3 -10µm), 2-3 Wiederholungen

23

Results: Outdoor vs indoor source strength



24