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Clean Air Testzone

Reduction of emissions from wood stoves
-> from lab to real life

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Background

- ~700,000 wood stoves in Denmark (population 6m)
  - Acounts for up to 70% of BC and PM2.5 pollution
- Regulation:
  - Emission only regulated for type approval in laboratory
  - Stoves from before 2003 replaced when change of ownership
  - Intensive political discussions at the moment…
- Stove operation has a huge impact on emissions
- Recent development in wood stove technology
- Real-life effect on emissions?

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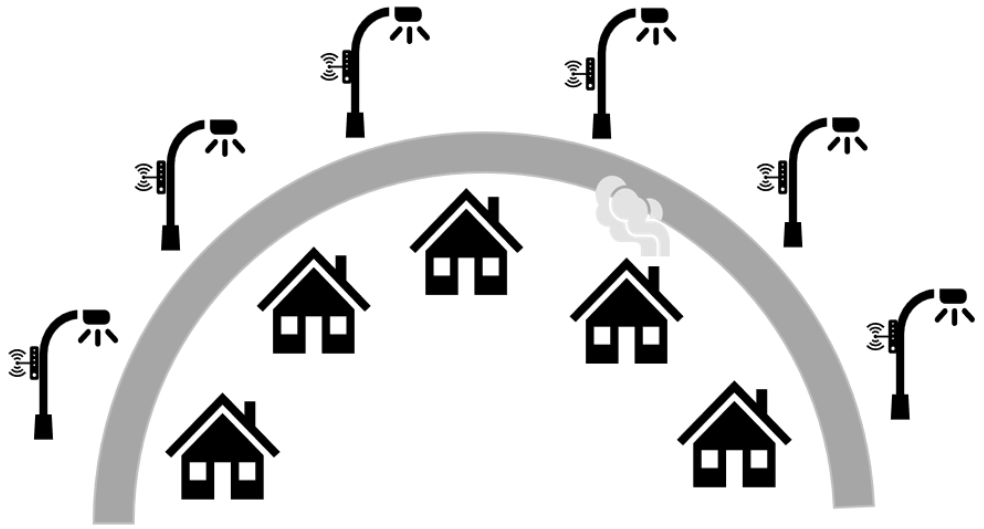
Clean Air Test zone – Reduction of emissions from wood stoves

- Effect of interventions on emissions in real life situations
- Impact on indoor environment and neighborhood

! Identify measures that provide most environmental impact from a cost-benefit perspective (cost/effect)

How?

- Carefully selected residential area
- Technological approaches:
  - New stoves
  - Filter
  - Draft booster / new chimney
  - Education
- Documentation of effect:
  - Outdoor air quality sensors – main focus on PM
  - Indoor air quality sensors
  - Direct emission measurements in chimneys with state-of-art equipment



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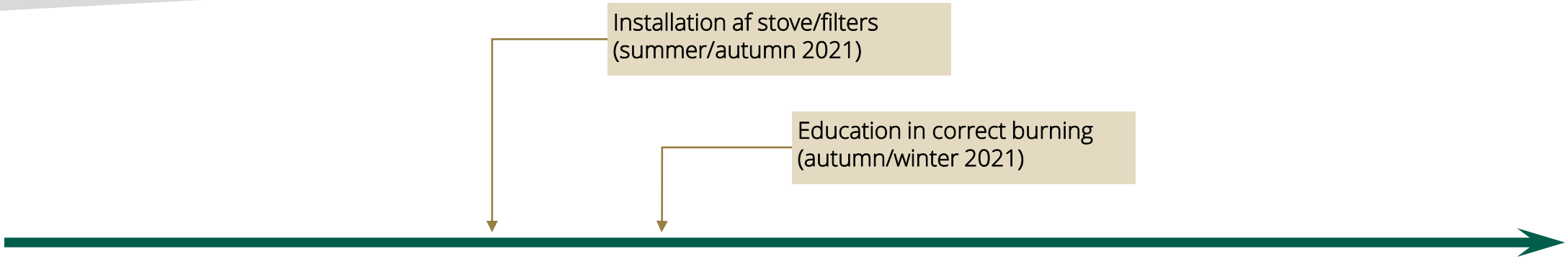

Winter 2020/21

- Sensor installation
- Baseline:
  - Air quality measurements (indoor + outdoor)
  - Direct emissions (selected stoves)

Winter 2021/22

- Year 1 with initiatives
  - New stoves
  - Filters
  - Education

Winter 2022/23

- Year 2 with new/further initiatives:
  - Chimneys
  - Draft booster
  - Education
  - (new stoves)

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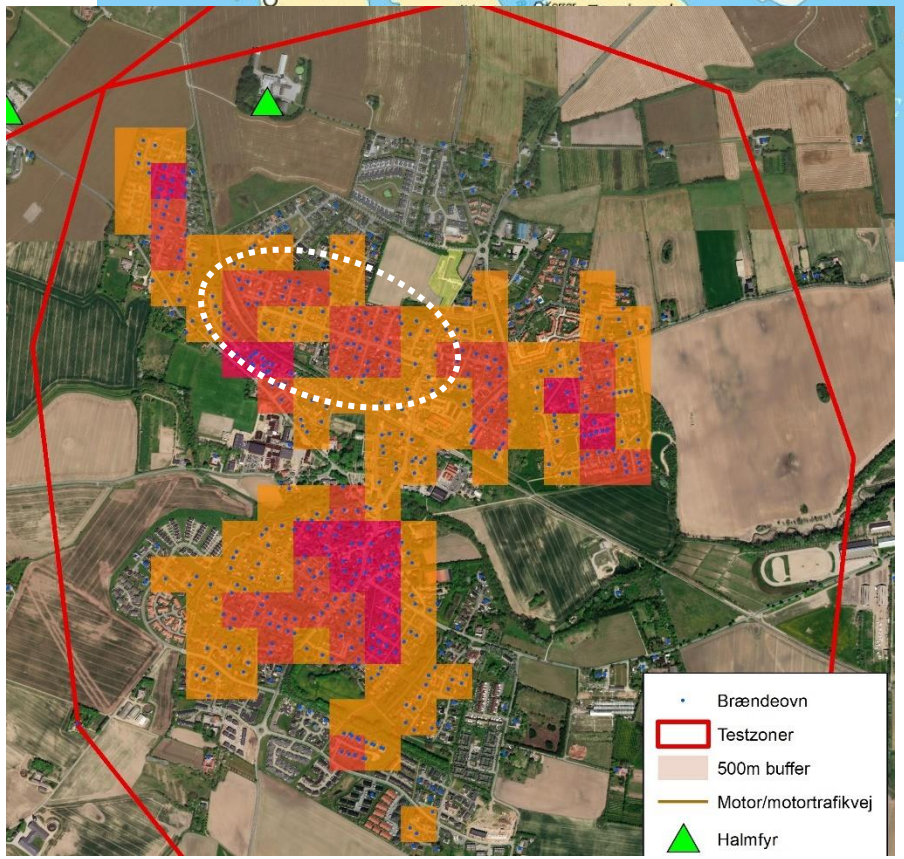
Mårslet, Denmark

- Sufficient number of wood stoves – and active in use
- Little ecpected background pollution (roads, industry, etc.) for dominating wind direction
- Criteria for selection:
  - Frequency of use and age of stoves
  - Density and placements of participants
  - Lamp-posts for adequate sensor placements



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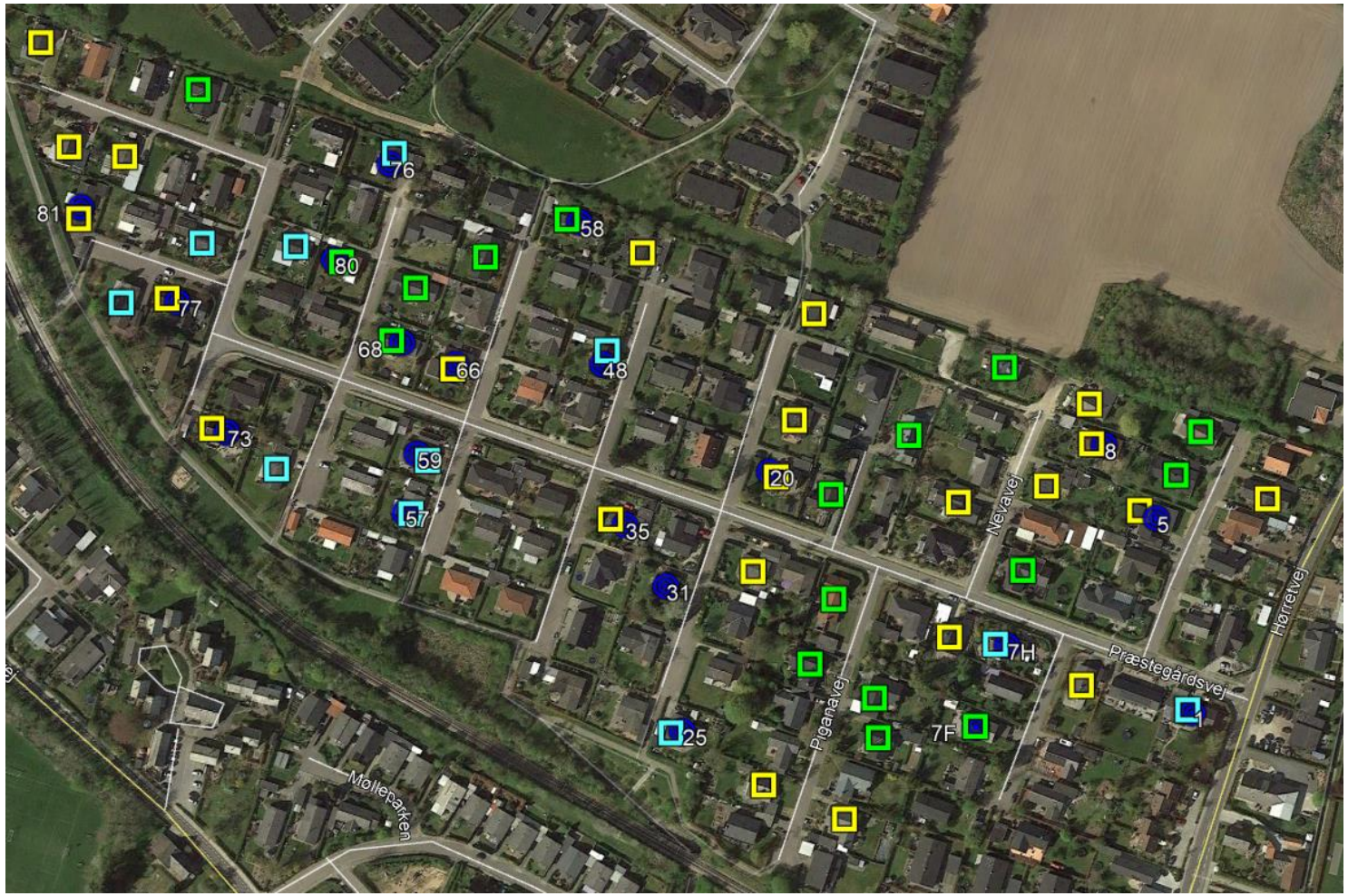
Præstegårdsvej, Mårslet

- 25 participating households
- ~20 indoor sensors installed
- 4 outdoor sensors + 1 background sensor



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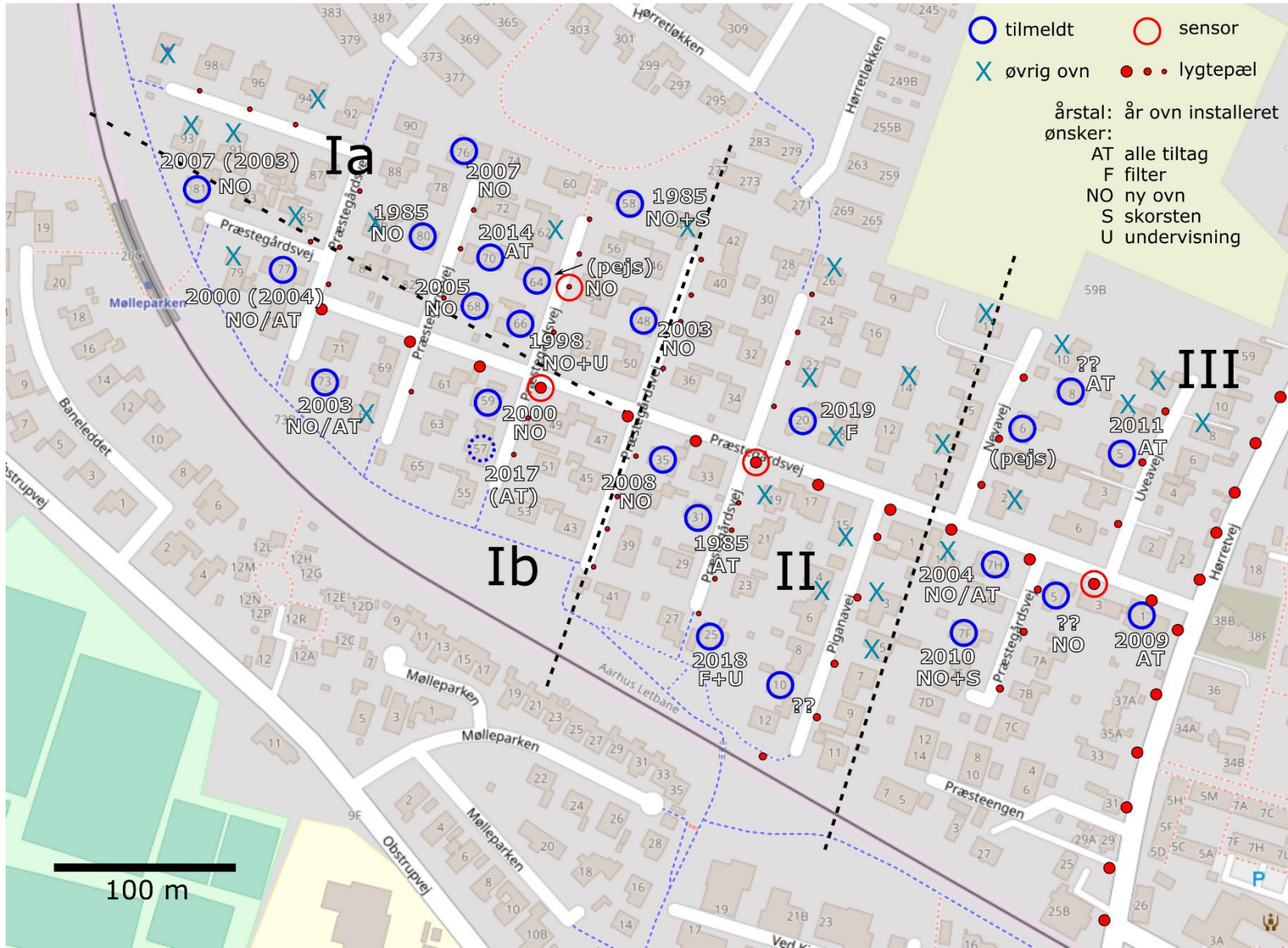
Præstegårdsvej, Mårslet

- Divided into 4 main zones:

	Year 1	Year 2år *(tentative)*
Ia	New stove	-
Ib	New stove	New chimney / draft booster
II	Filter	New stove and/or education
III	Education	(new technology)



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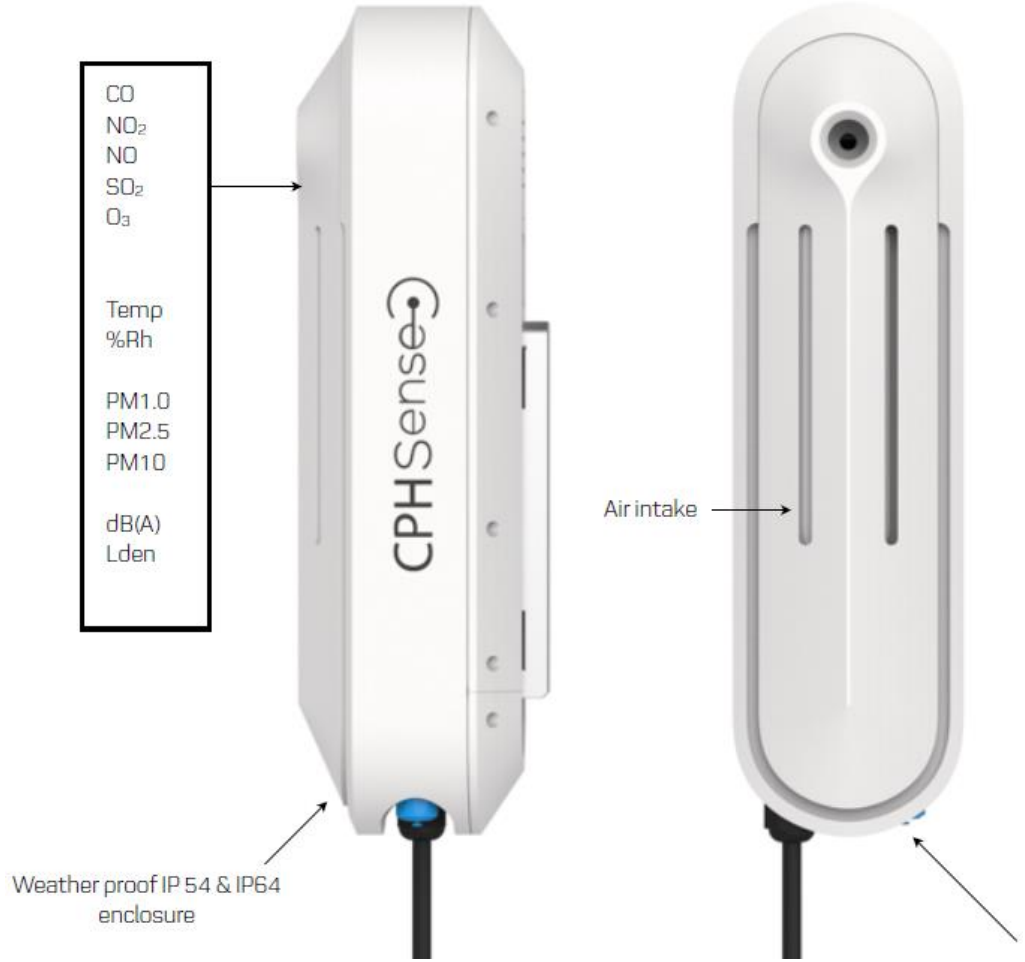
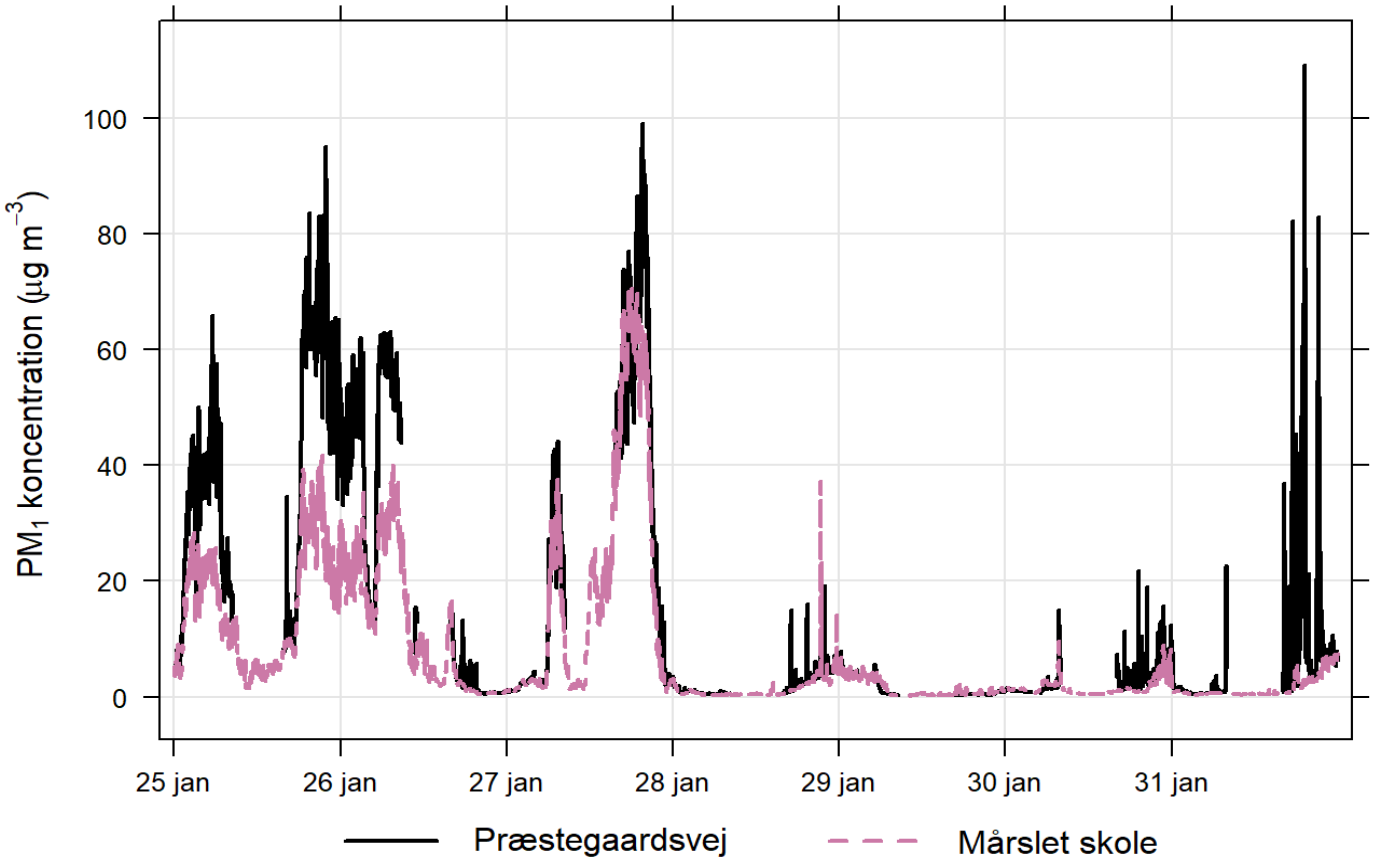
Local interviews during a pandemic and installing indoor sensors – not an easy job!

Type ildsted, stand:	
Type skorsten, stand:	
Rumbeskrivelse, størrelse, åben til køkken:	
Brug:	
Brændsel: type, opbevaring, fugt, størrelse, mængde:	
Typisk opstart:	
Typisk genfyring:	
Spjæld-håndtering:	
Fyring ved flammer eller gløder?:	
Føler I der er træk nok?:	
Generer den varme nok til rummet?:	
Giver ovnen gener i boligen?:	Klager fra nabober?:
Er der husdyr:	Rygning i hjemmet:
Brug af levende lys:	Bruges ovn samtid. med emhætte:
Åbnes vindue eller slukkes emhætte ved opstart?:	
Indeklima sensor, SN:	Egnet til online målinger: (J/N)
Manuel log over tidspunkt for opstart og genfyring første 4 måneder:	
Øvrig:	

Data collection – outdoor sensors



Raw data from Test zone – background sensor (red) vs. local (black)



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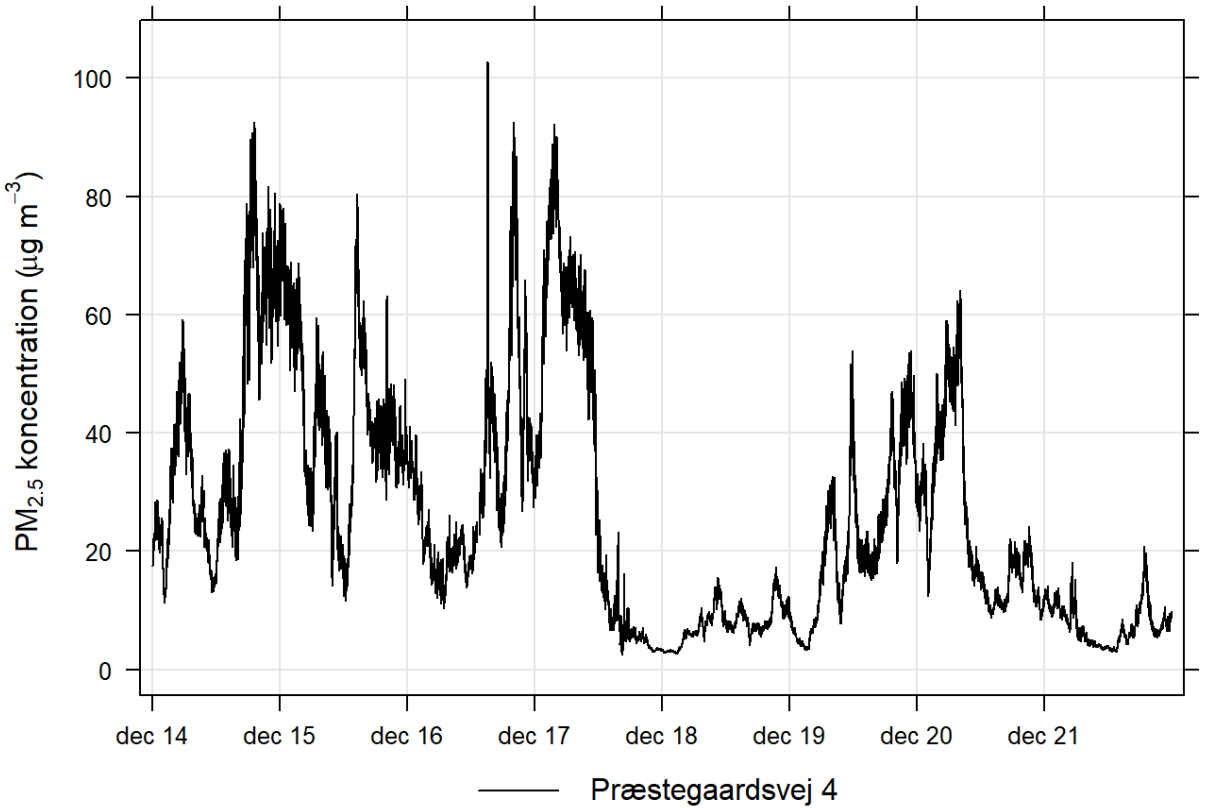
Example: Præstegaardsvej sensor 4 ($pm_{2.5}$)



Observed variations can be due to many different effects, such as:

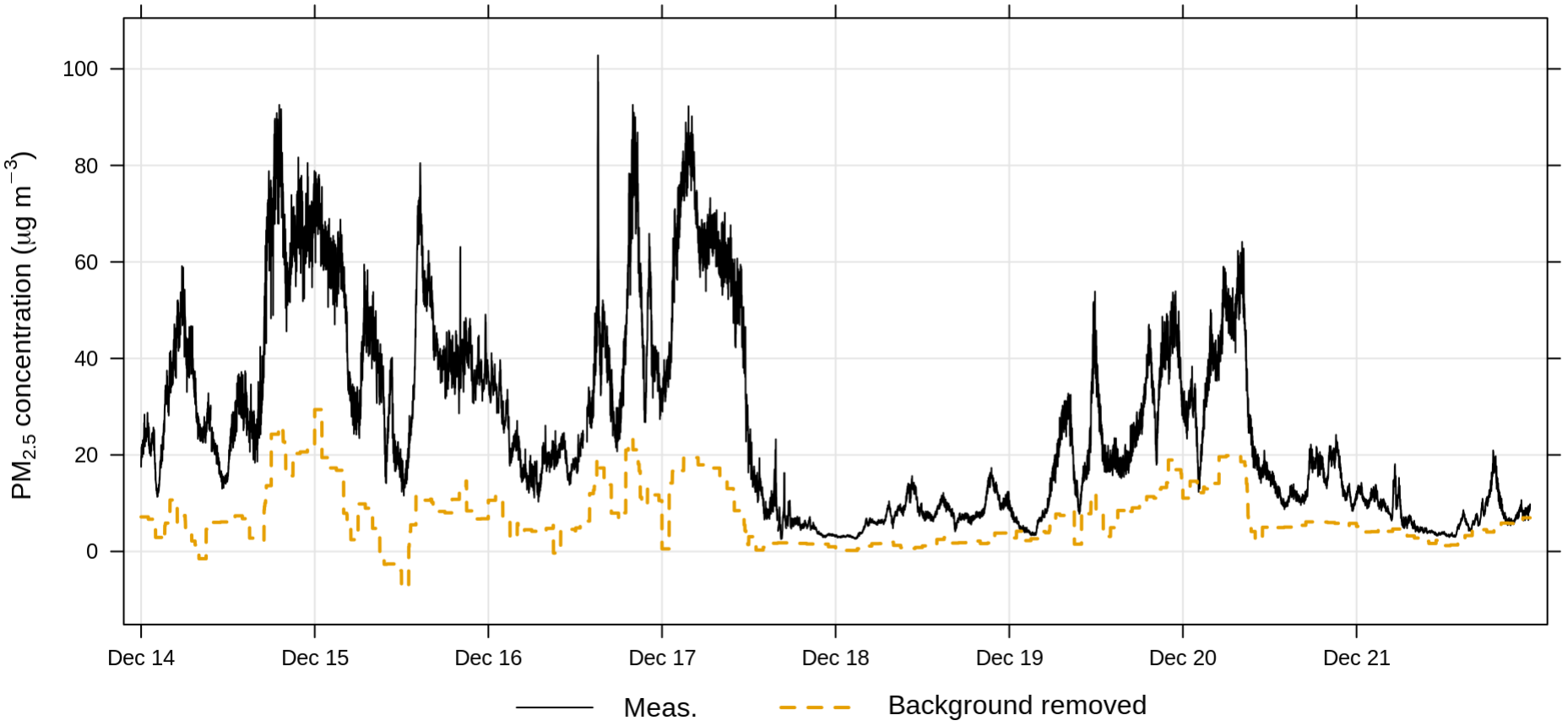
- Local emissions (incl. wood stoves)
- Wind (direction, dilution, speed, turbolence, …)
- Background (long distance transport)
- …

Analysis approach – met. normalization:*

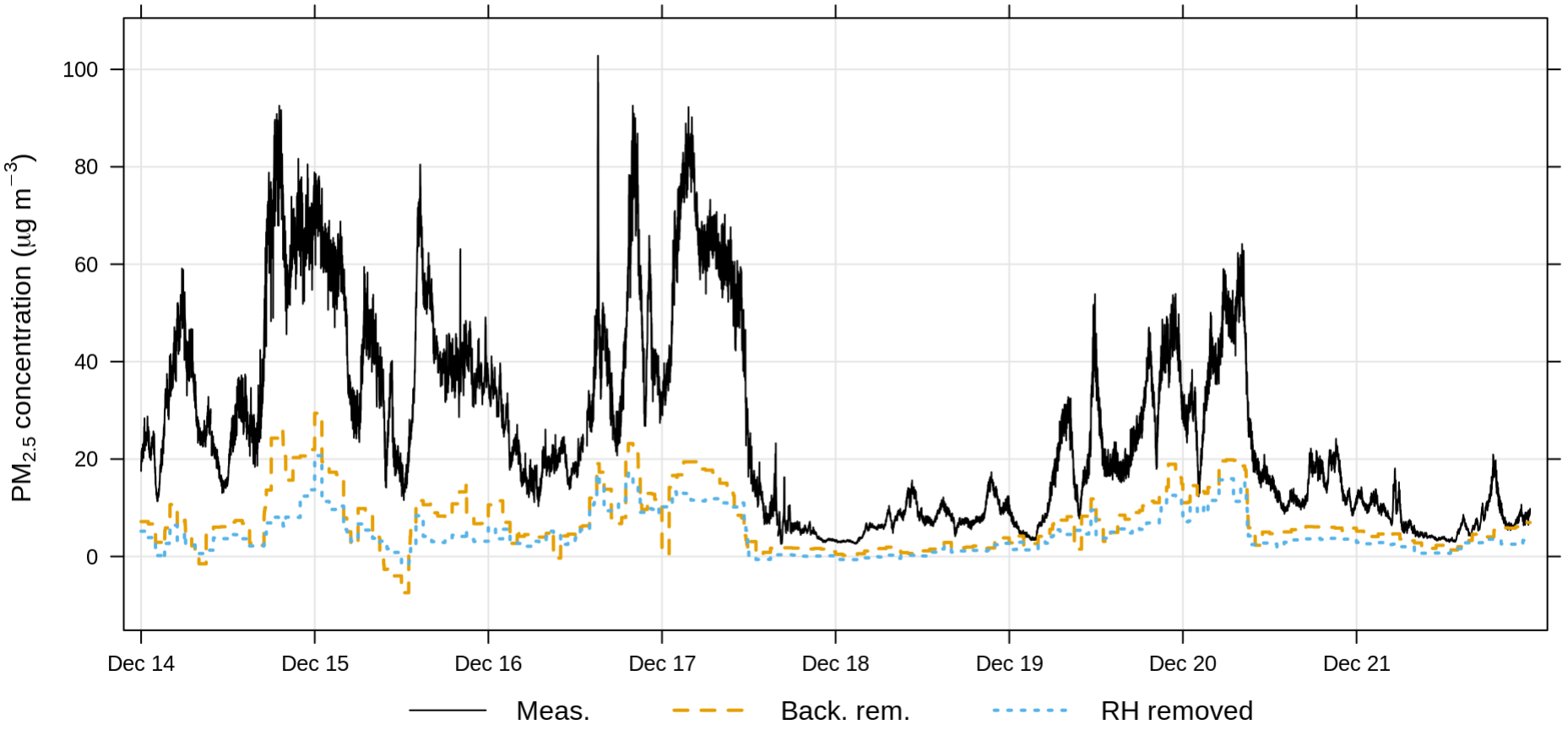
- Fit concentrations based on input (wind speed, wind direction, diurnal variation, etc.)
- Non-linear fit performed through random forest (machine learning)

* See Grange & Carslaw (2019) for further information

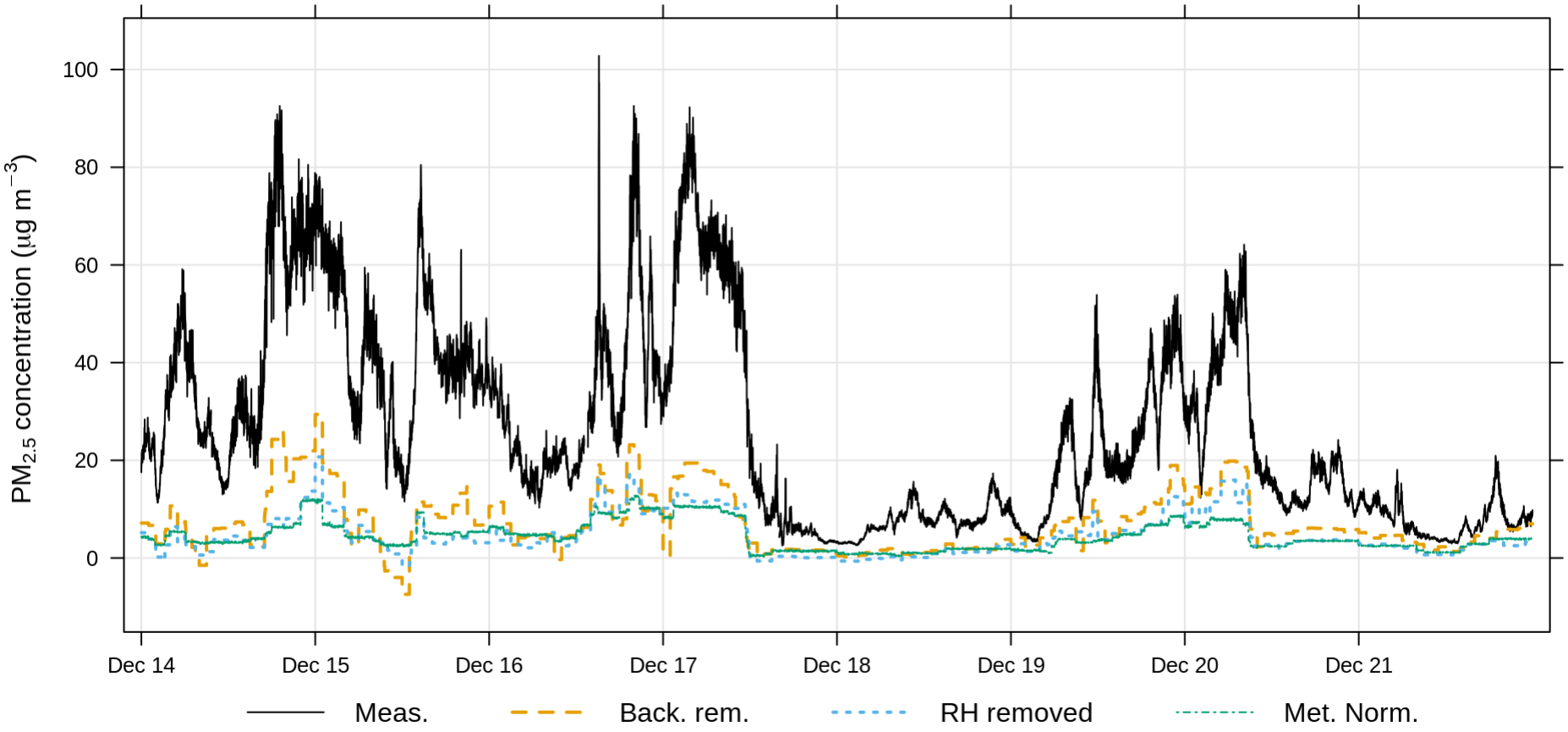
Prel. results



Prel. results



Prel. results



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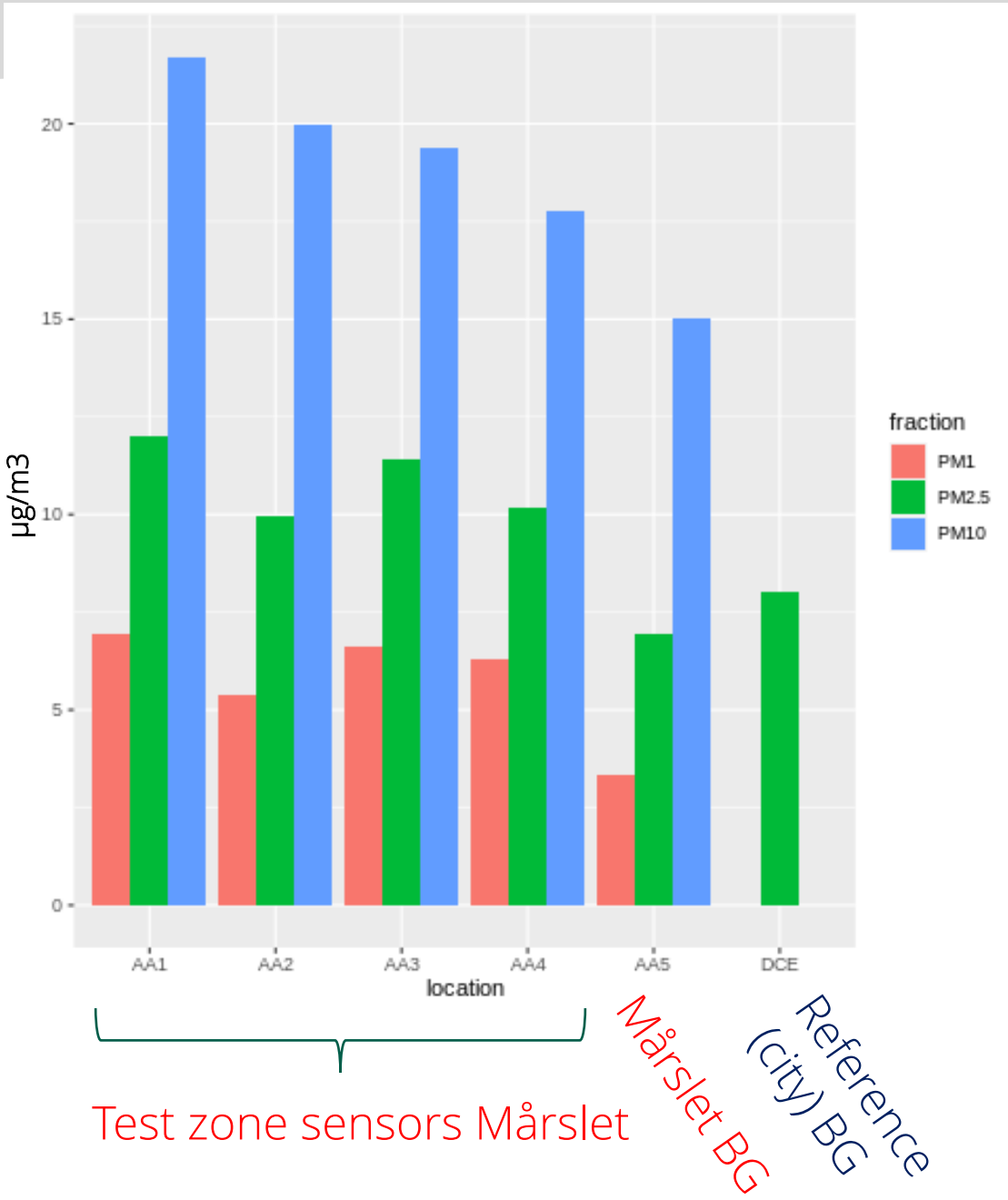
Prel. results - summary

- Substantial contribution from wood stoves (and other local sources) in all size fractions
- Largest relative contribution for PM1
- 25-50 % increase in PM2.5 as compared to BG (average for a 3 month period)
- Comparing results with reference city monitoring station (Botanic garden, Aarhus) provides a good sanity check of data for now



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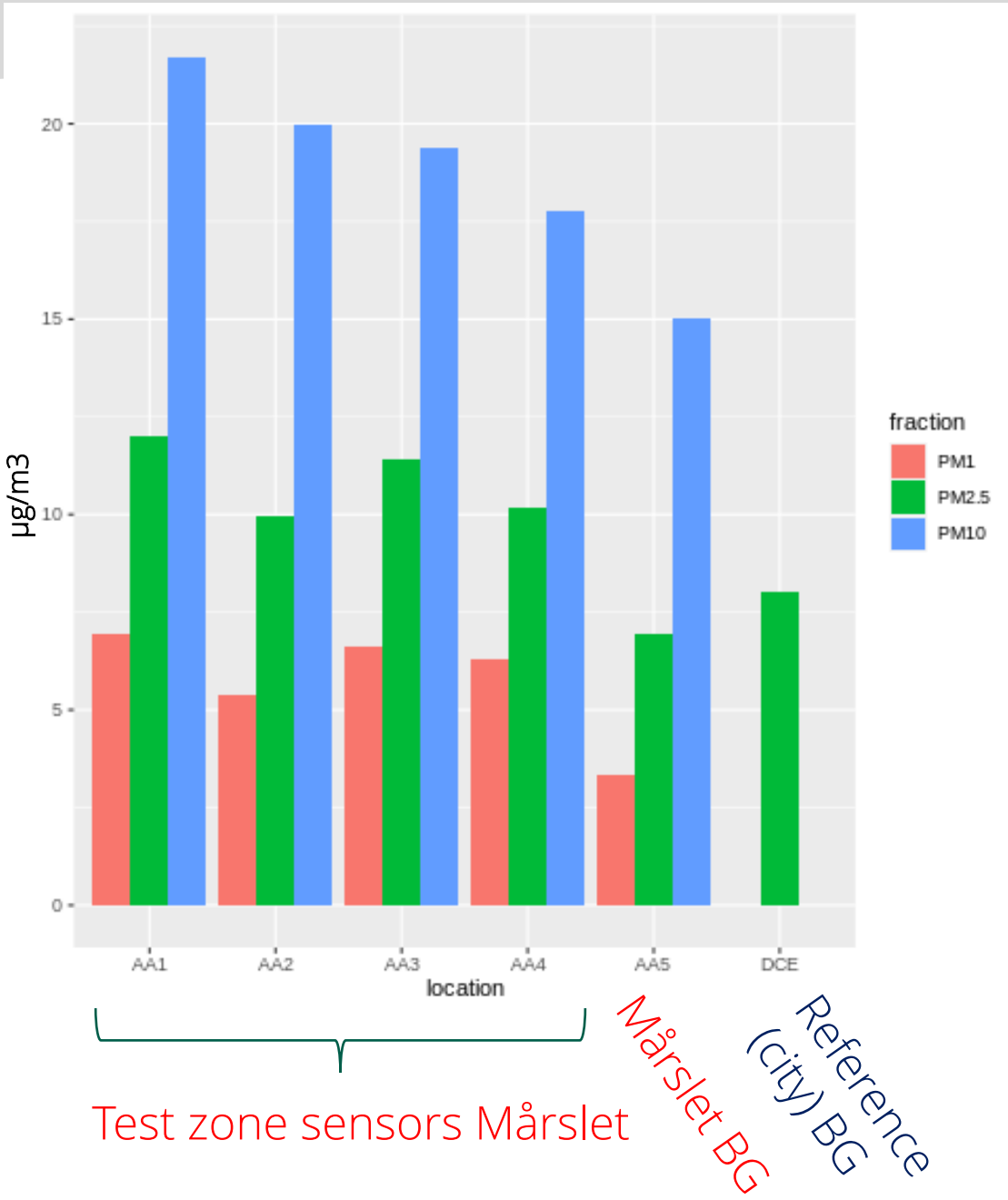
Uncertainties

- Separation between wood stoves and other local sources
- Correction for sensor artefacts (e.g. spikes at high RH)
- Potential systematic biases between sensors

Next steps:

- Explore temporal variation and coupling with fuel logs / chimney temperature profiles
- On-site calibration of sensors (scheduled fall 2021)
- Add subsequent measurements to explore source attribution (e.g. summer vs. winter contributions)
- Improve on sensor artefact identification



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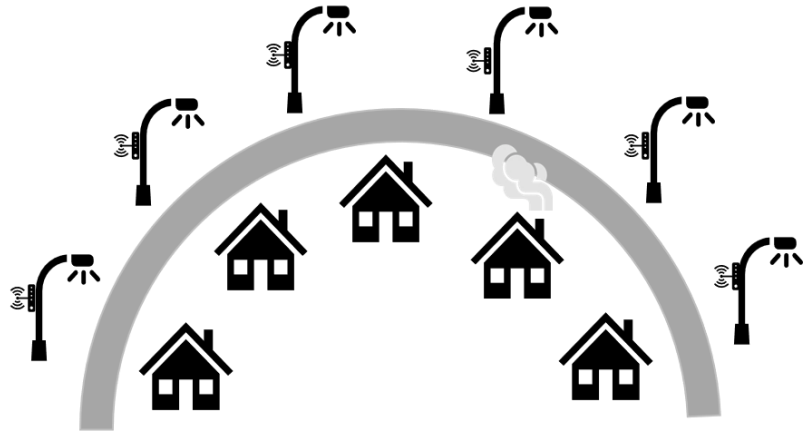
Reference measurements

- Selected households (2 per zone)
- Onsite measurements (1-2 days)
- Measurements before/after intervention

- Measurement of:
  - Temperature [°C]
  - CO2 [%-vol]
  - CO [%-vol og mg/Nm3 v/13% O_2]
  - OGC [mgC/nm3 v/13% O_2]
  - NOx [mg/nm3 v/13% O_2]
  - Dust (PM in hot exhaust)
  - PM2.5 (with developed ambient sensor)

Summary

- Emission reducing steps demonstrated in real life test zone
- 25 participating households in Mårslet, Denmark
- Focus on baseline so far – main challenge is separating wood stove signal from other local sources (ambient measurements)
  - To be coupled with direct emission measurements
- Effect of different interventions to be demonstrated the next two heating seasons
- Measurements indicate a 25-50% increase in PM2.5 during heating season 20/21 as compared to surburban background.



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