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DIFFUSE PARTICULATE MATTER (PM)

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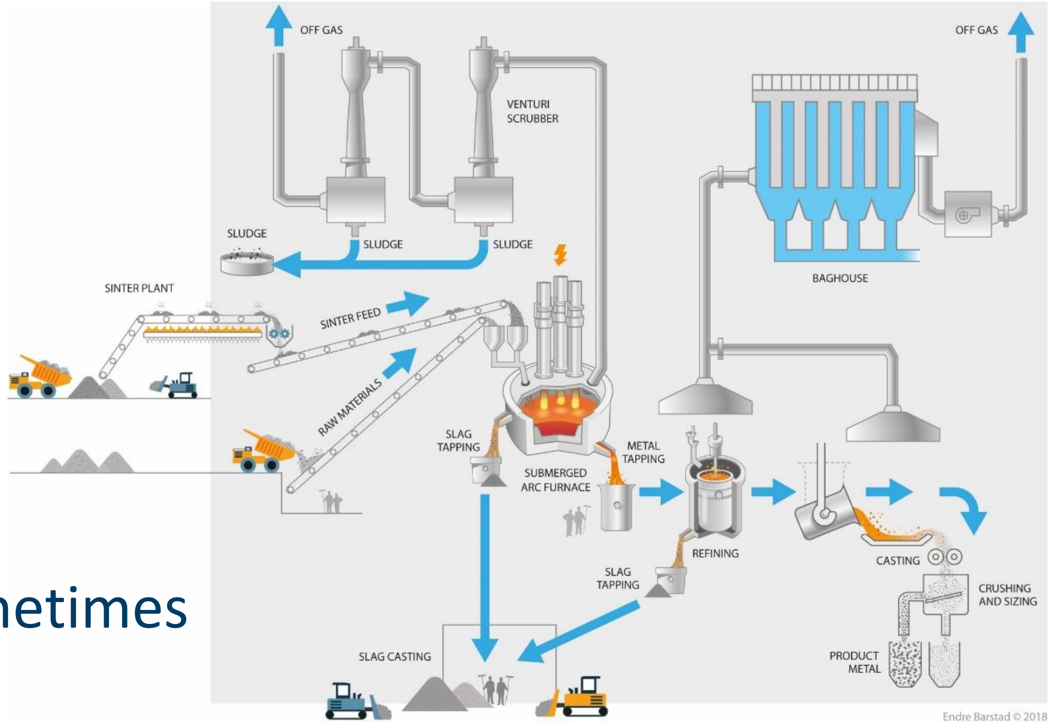
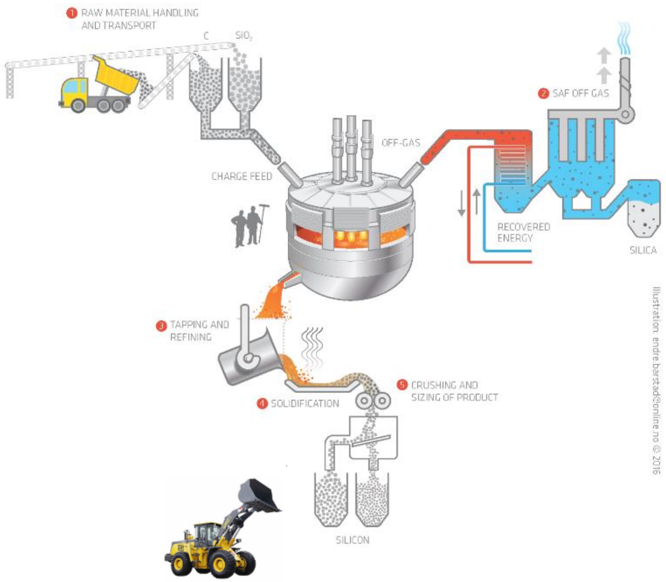
OUTLINE

- Terminology
- Background: PM properties
- PM measurement methods
- Some examples
- Final Remarks

Diffuse PM emissions

- Dust = Airborne particulate matter (PM)
- Small particles suspended in air. The term sometimes includes liquid droplets suspended in air too.
- The PM types and sources are many and varied.
  - In metallurgical processes, we typically distinguish between mechanically and thermally generated PM.
- Most PM types and sources are the same for diffuse and non-diffuse emissions.





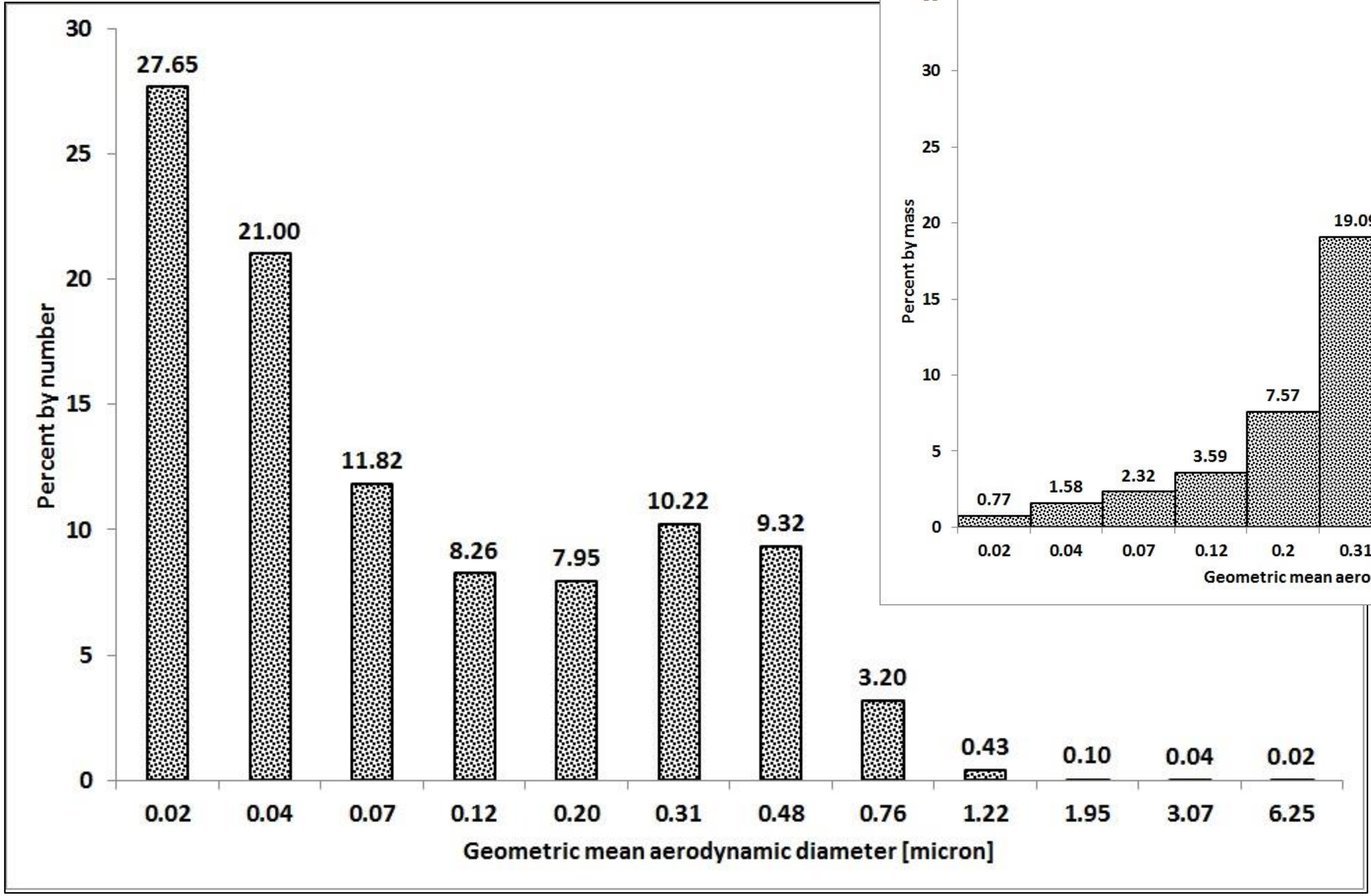
PM properties

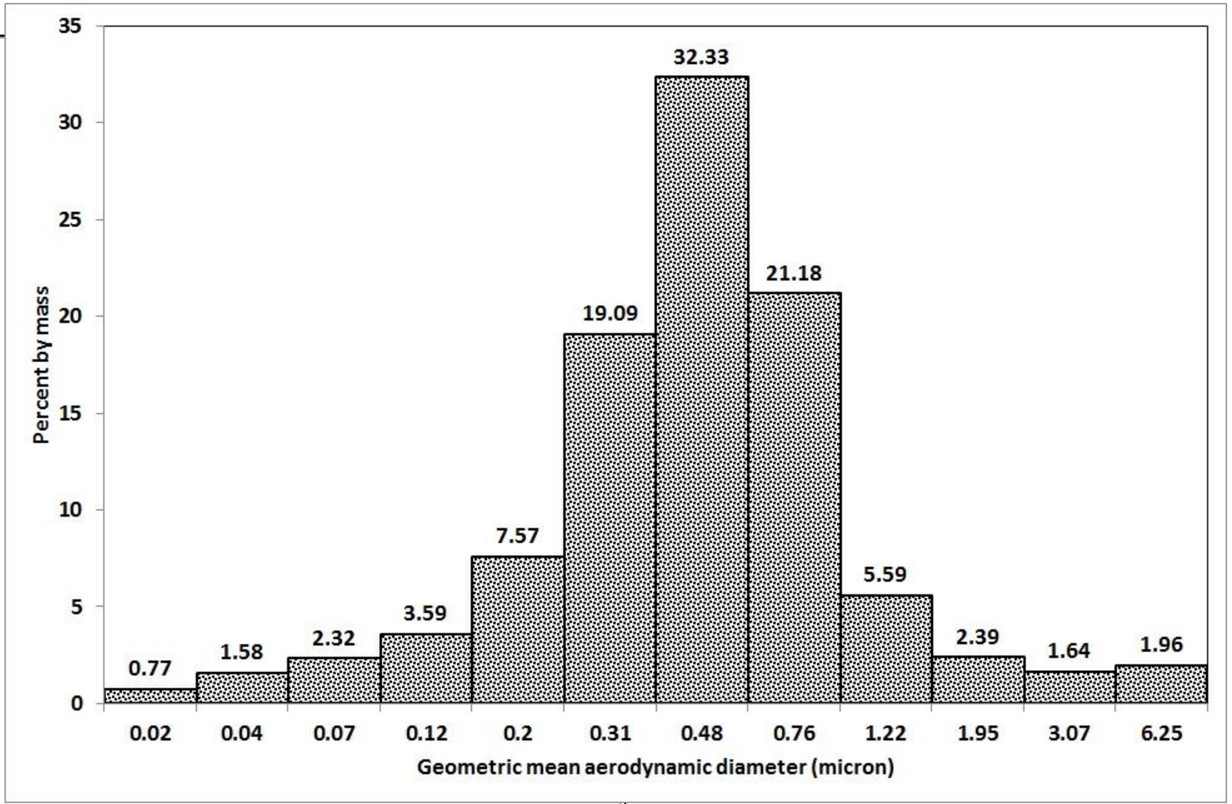
Dynamic system!
Particles deposit, get resuspended, condensate, crystallize, grow, agglomerate, aggregate...

- Concentration
  - All instruments have a conc. -detection range
- Particle Size
  - All instruments have a size -detection range
  - Chemical and Physical Stability (Reactivity, Growth, Settling/Deposition, …)
  - Particle Size Distribution
- Particle Shape (Morphology)
  - Agglomeration and Aggregation
- Composition (Phase and Chemical)
  - Solubility, Bioaccessibility, Toxicity, …
  - Density
  - Surface properties, Optical properties

PM Concentration

Ref: Kero et al: "*Particle size distributions of particulate emissions from the ferroalloy industry…*" *Journal of Occupational and Environmental Hygiene*, **12** 1: p. 37 (2015).





PM from FeSi production

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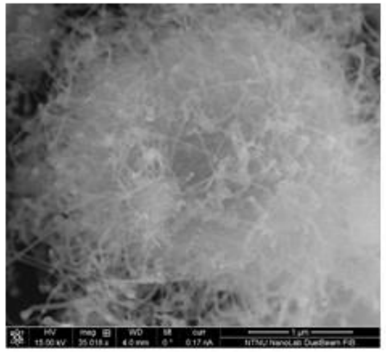
PM Composition

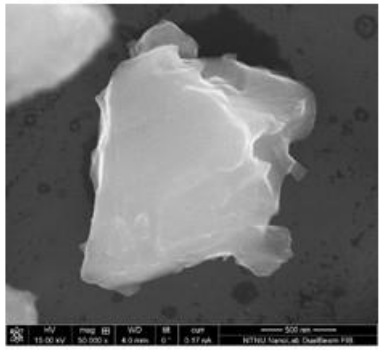
PM from a single source: Primary SiC production (Acheson furnace dust)

Ref: Jørgensen & Kero IJERPH 2017

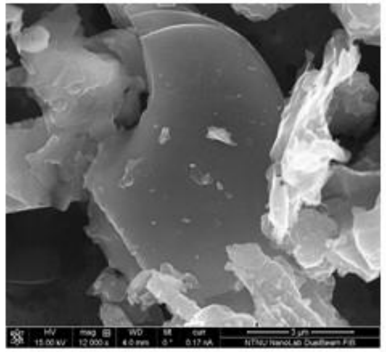
SiC Whiskers



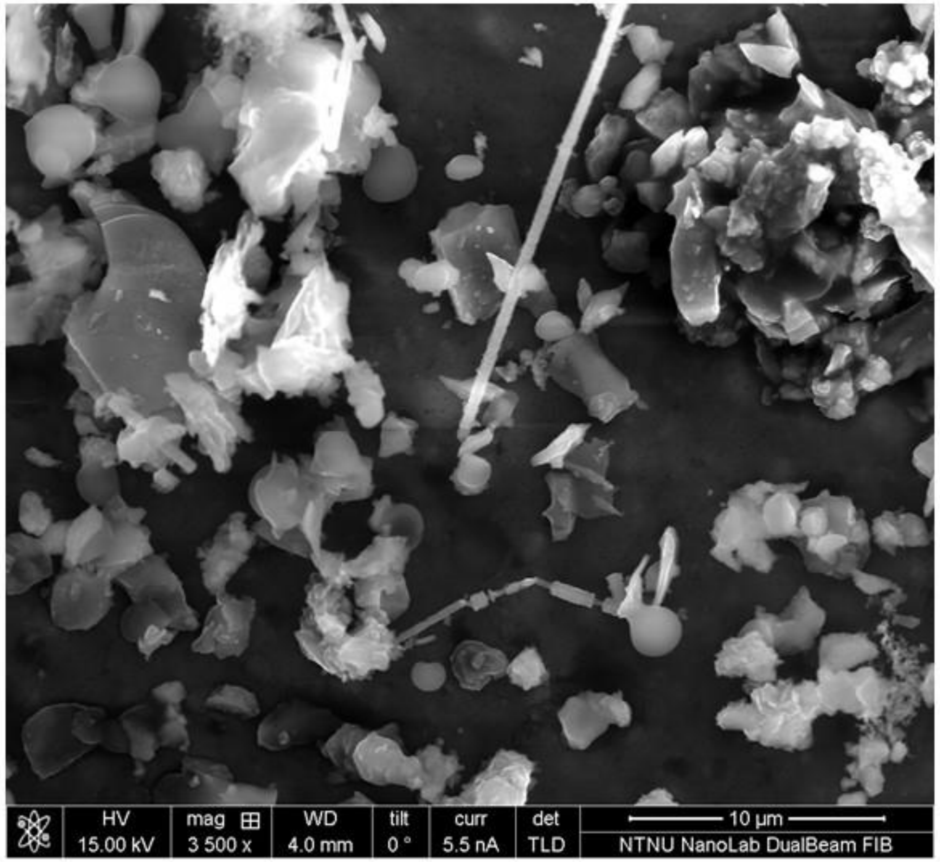
SiO_2 particle



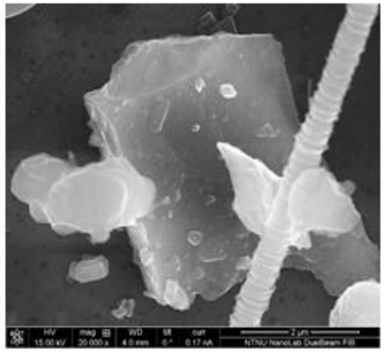
Smooth Si particle



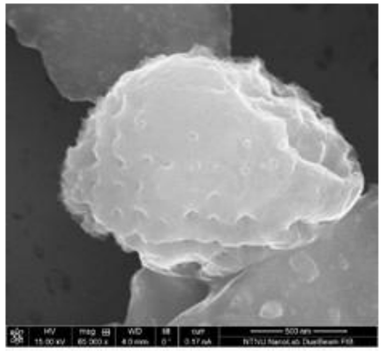
Pilot furnace: ELPI stage #9



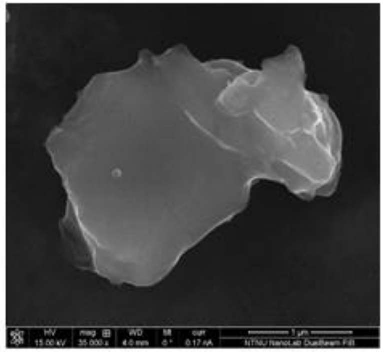
Si particles and SiC rod



SiO_2 particle



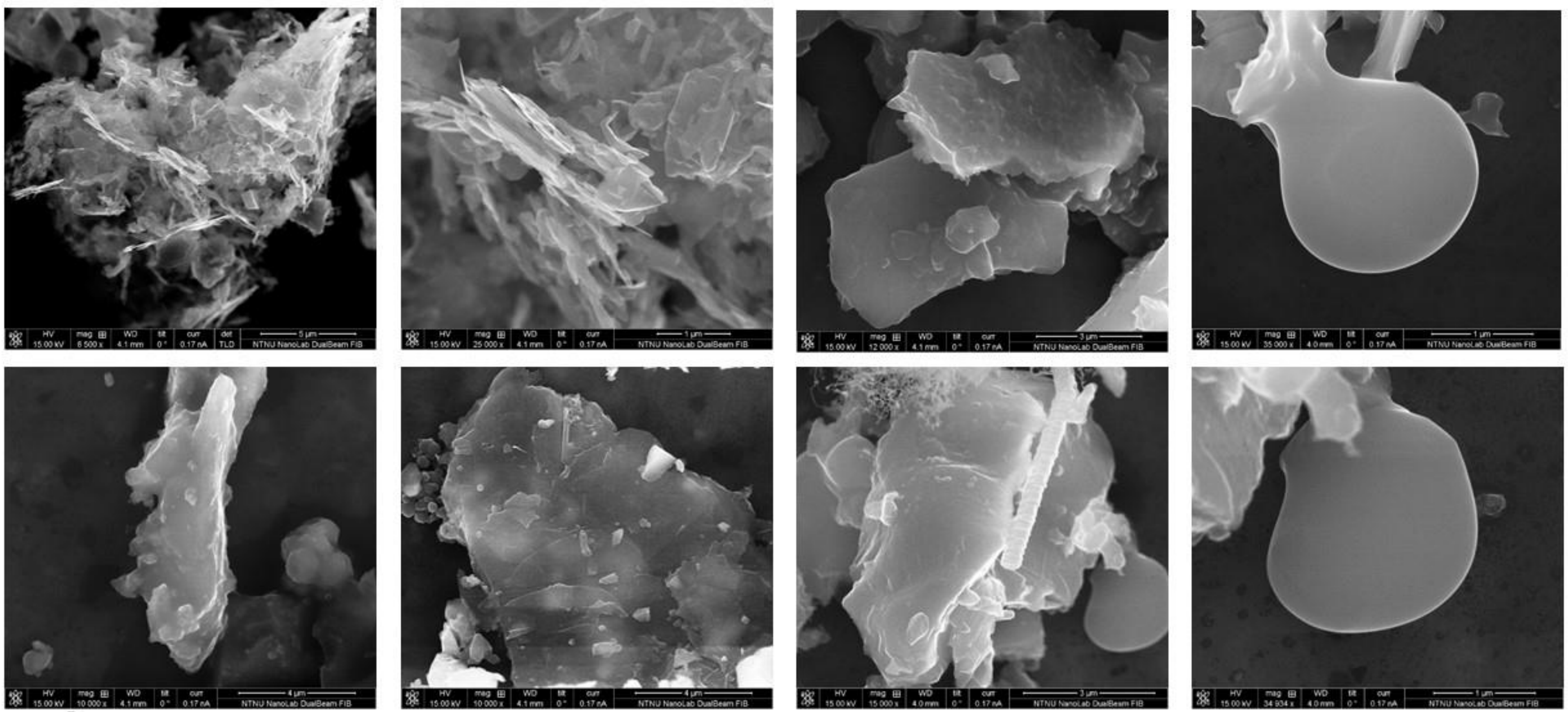
Si particle



PM Composition & Morphology

Carbon particles from a single source: Primary SiC production
Ref: Jørgensen & Kero IJERPH 2017

Carbon-rich particles - illustrating the different morphologies



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PM Size

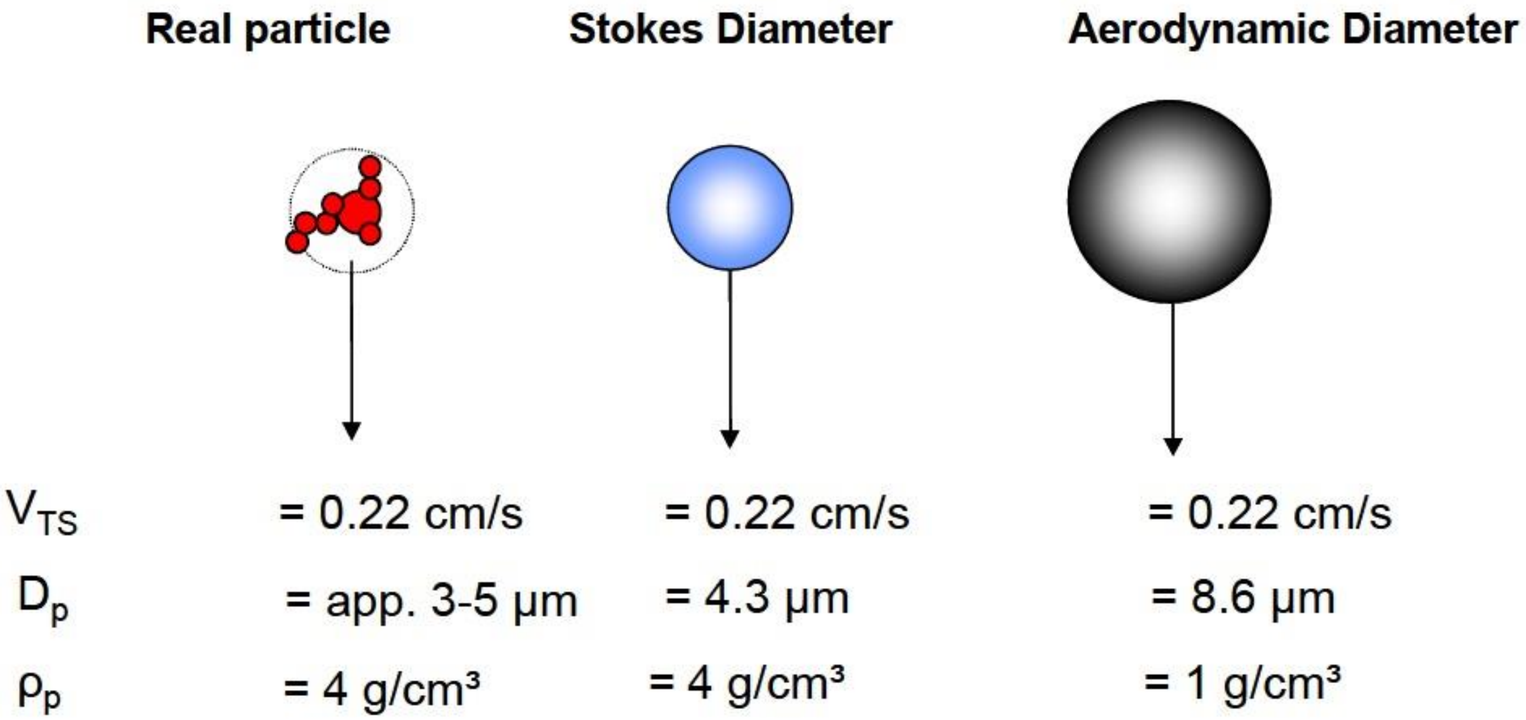
- The PM-scale:
  - *Fine* PM: $D_p \leq 2.5$ µm
  - Mass concentration: gram PM per volume unit air
- Ultrafine Particles:
  - $D_p \leq 100$ nm
  - Number conc.: No of particles per volume unit air

Picture: epa.gov

PM Size

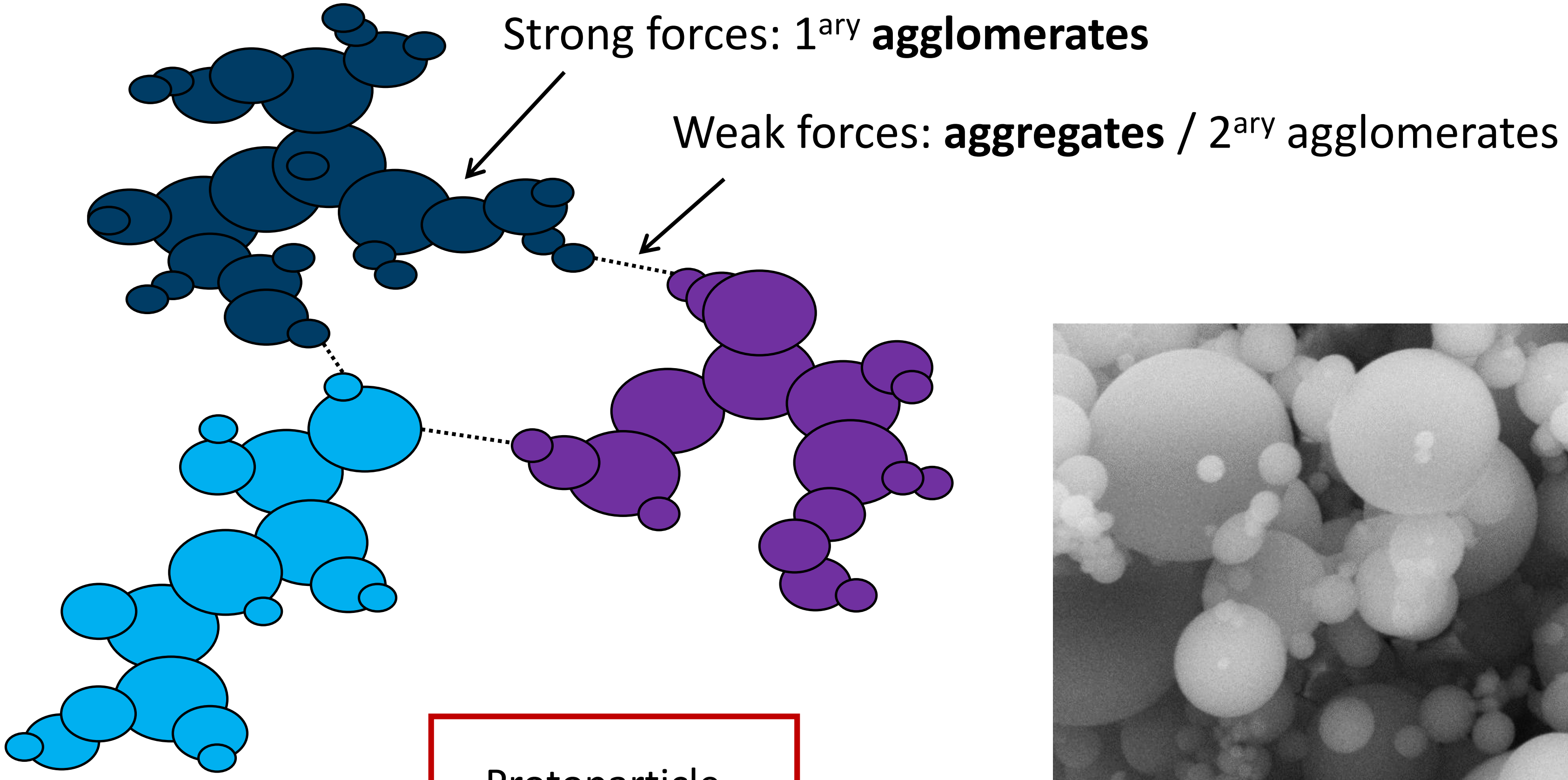
Important parameters for recalculating PM properties, e.g. for comparison between measurement methods:

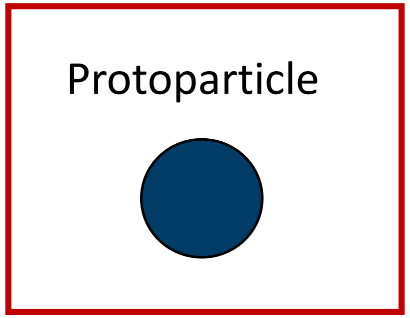
- (Effective) Density, ρ
- Shape factor, χ



Picture: Dekati Ltd

PM Agglomeration





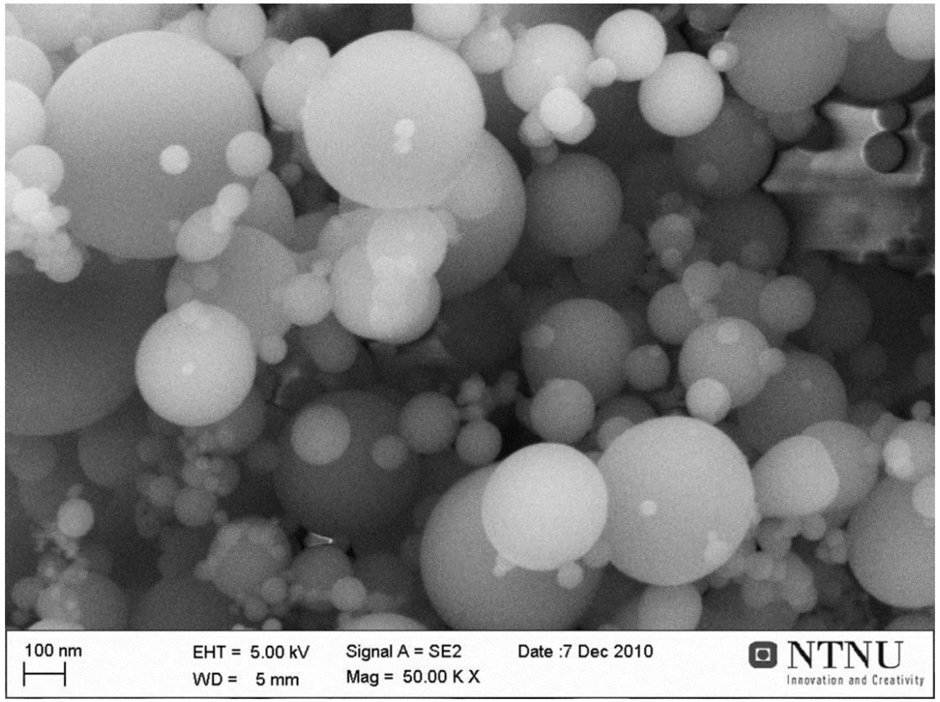
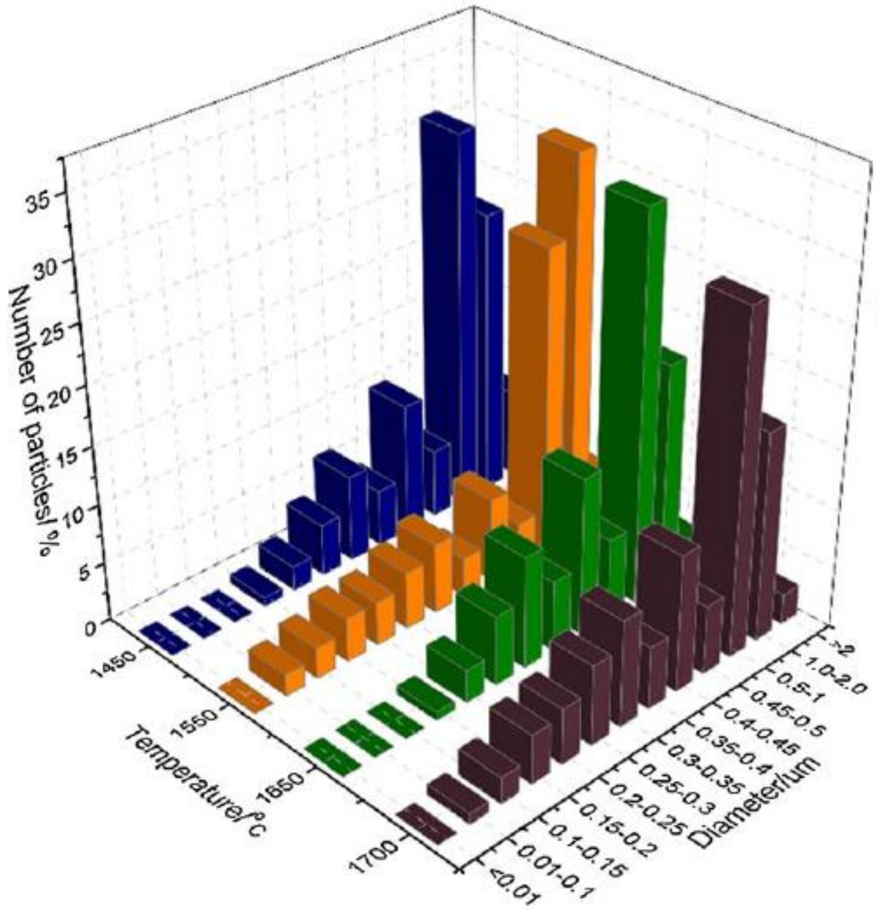


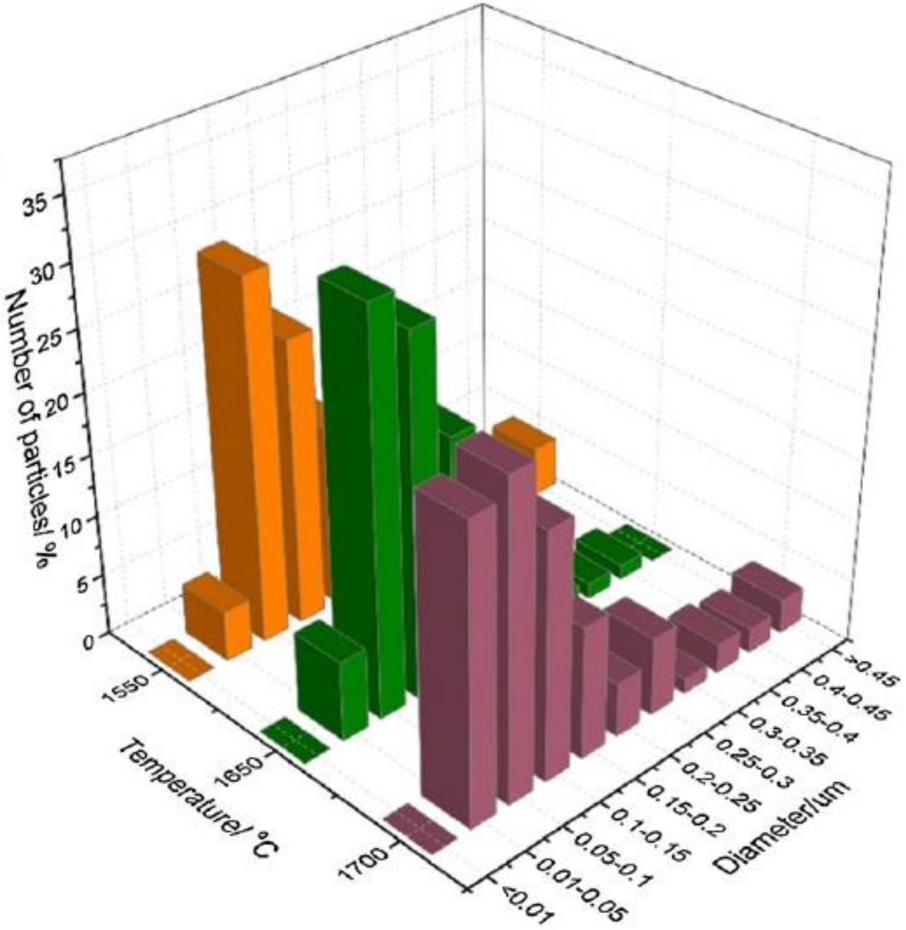
Fig: Næss (2013)

Ref: Ma et al. (2017) "*Fume Formation from Oxidation of Liquid SiMn Alloy*"

Particle size distributions



A) By Laser Diffractometry



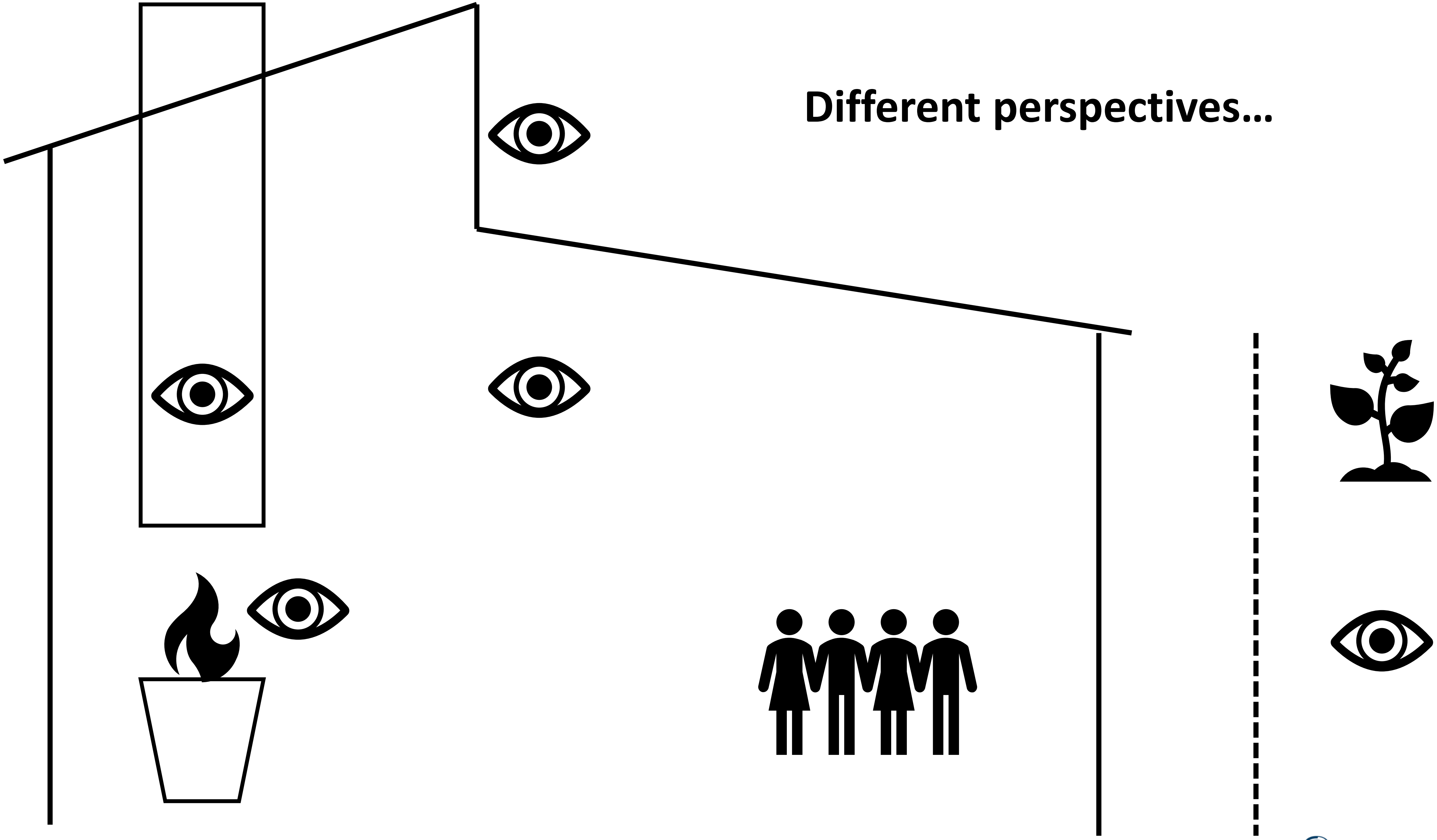
B) By Scanning Electron Microscopy

Why is this important?

- Different measurement methods are based on different PM properties; e.g. optical or aerodynamic properties
- PM properties are interdependent; e.g. settling rate depends on particle size and shape which depends on growth rate and agglomeration, which depends on composition and surface properties
- PM properties are dynamic and may change over time and distances
  - "The atmosphere is one big reactor over which we have absolutely no control"

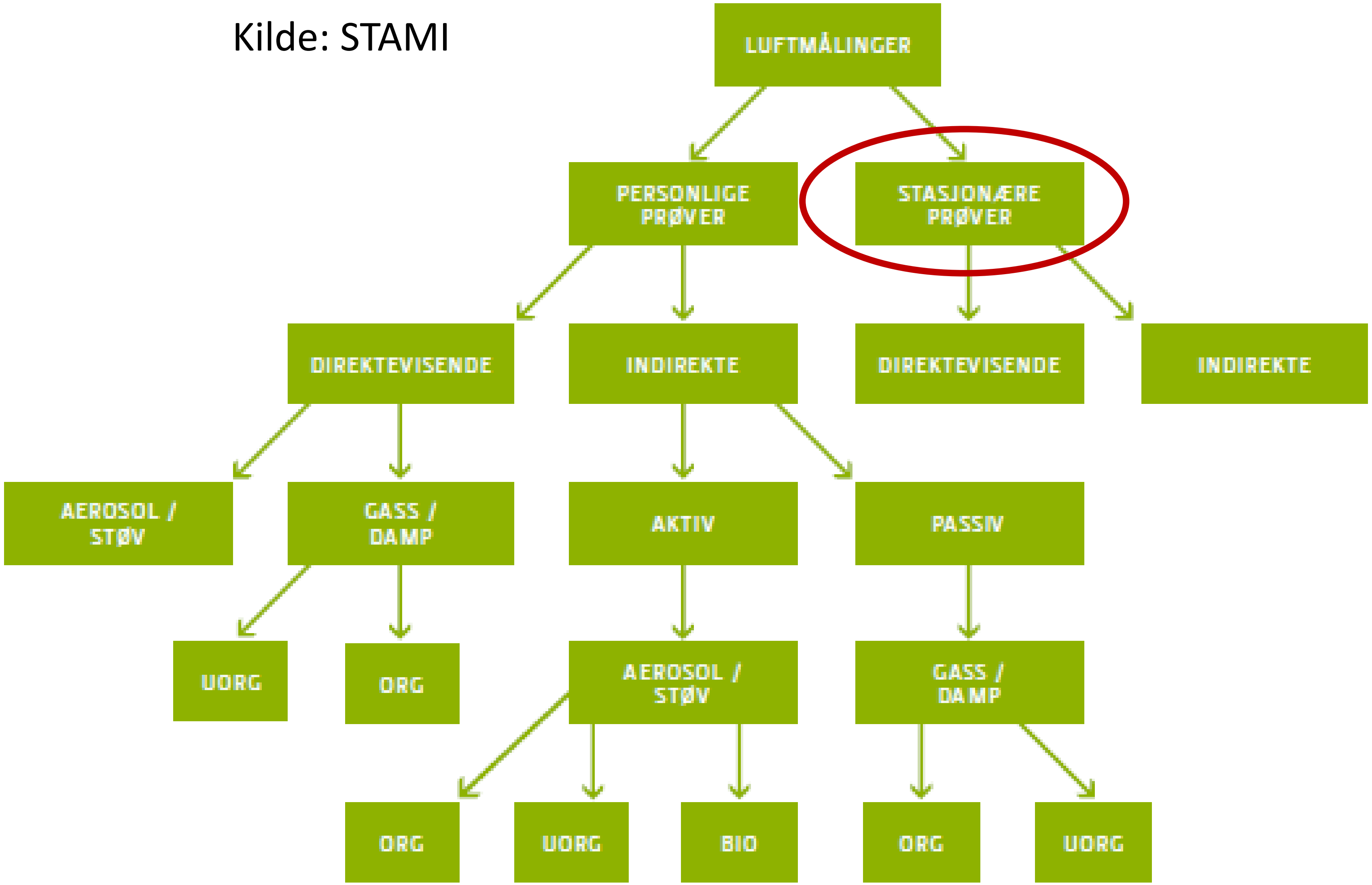
- Comparing results obtained by different methods is non-trivial and may lead to faulty conclusions

Different perspectives…



FIGUR 1. OVERSIKT OVER PRØVETAKINGSPRINSIPPER:

Kilde: STAMI



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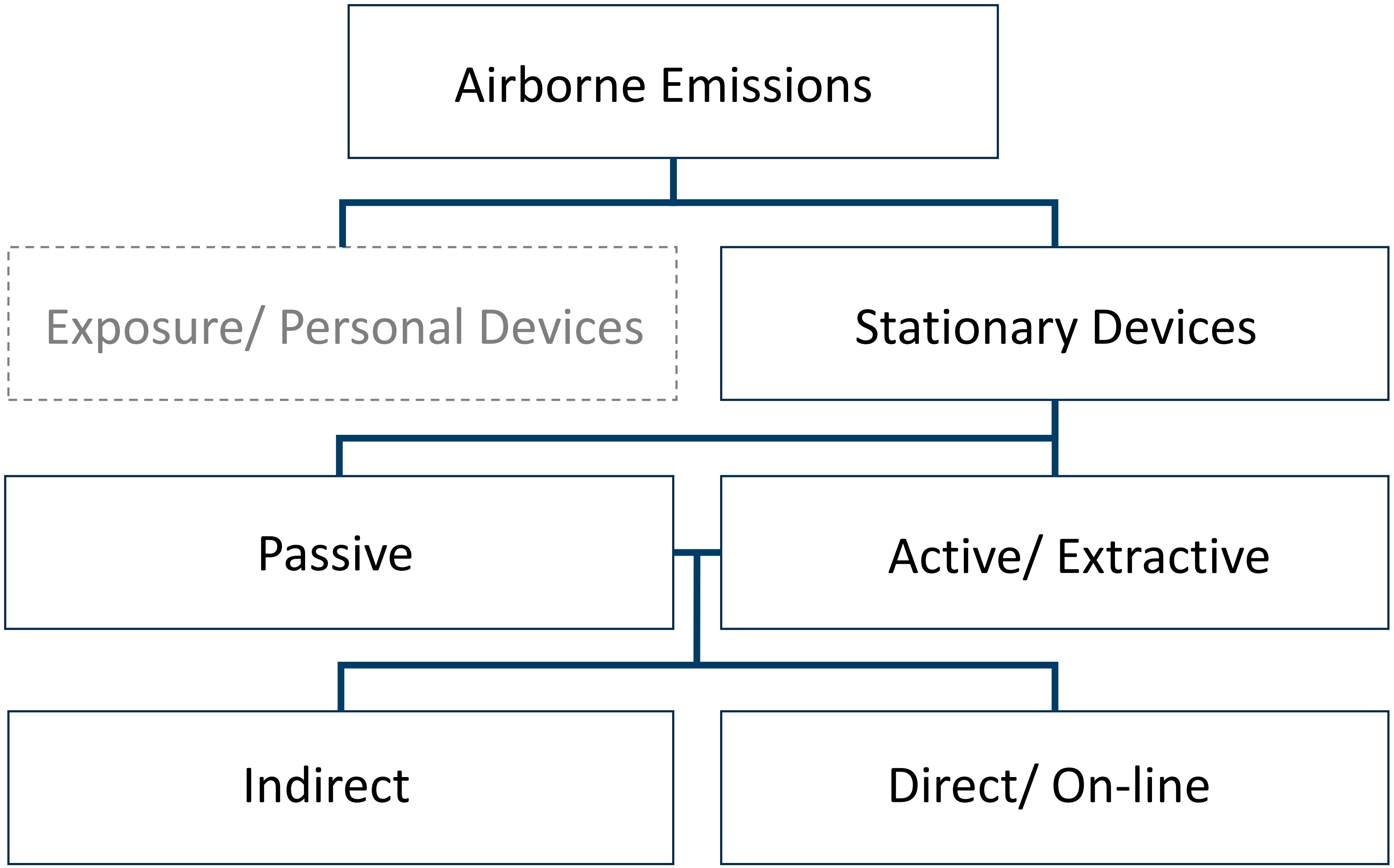

Airborne Emissions
Exposure/ Personal Devices
Stationary Devices
Passive
Active/ Extractive
Indirect
Direct/ On-line

Passive, Direct-reading Devices

Laser Optical Instruments

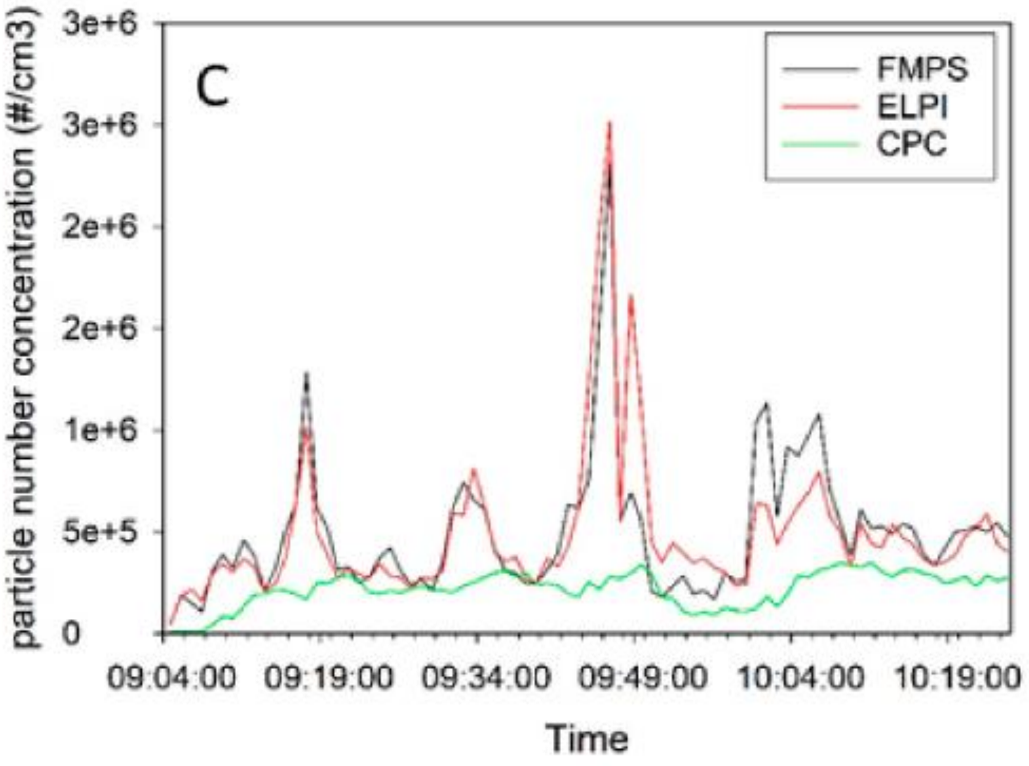
- Versatile: Different ranges, up to many meters
  - Inside ducts, across furnace halls, over roofs, etc.
- Combine with anemometers to estimate emissions
- Site-specific calibration is necessary!
  - Can be acheived by use of gravimetric filters

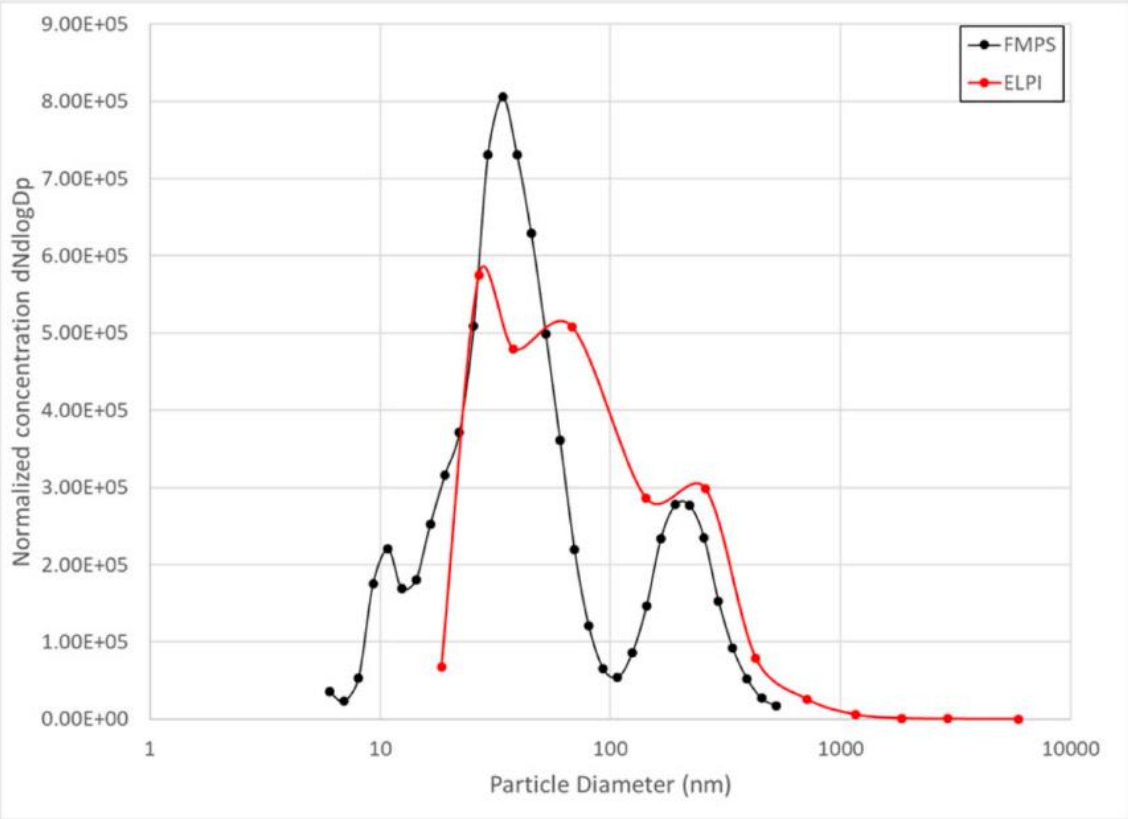
Extractive Devices

- Gravimetric filters
- Optical devices: OPC, CPC, …
- Mobility Sizers
- Impactors
- …




Example: Pilot-Acheson furnace (SiC)





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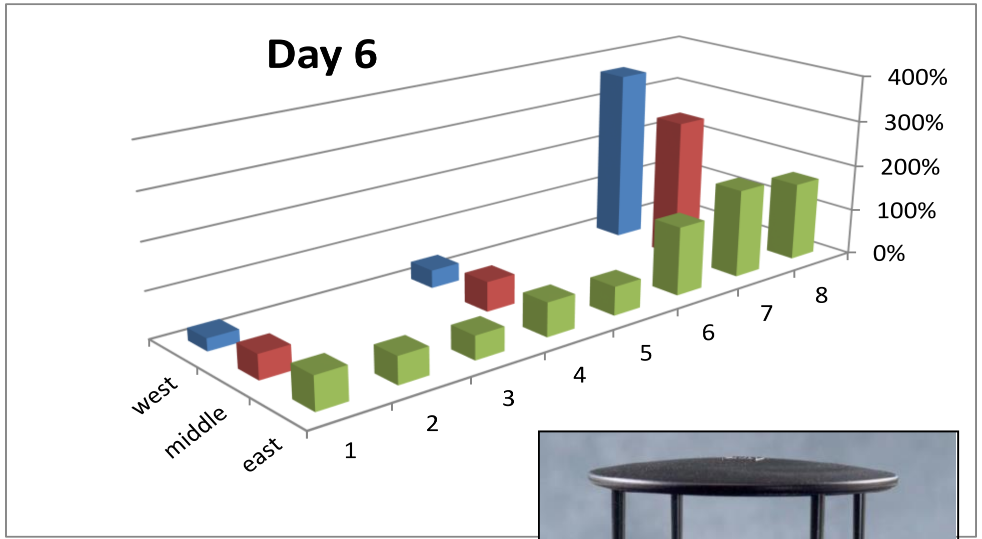
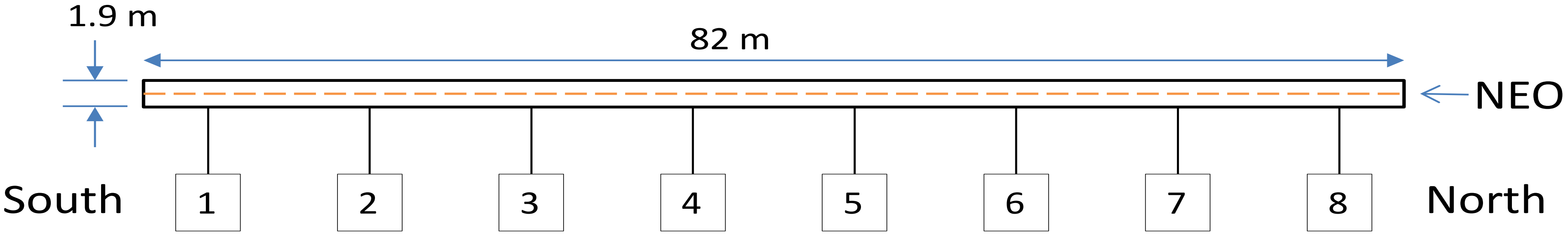
Example: Roof Opening #1





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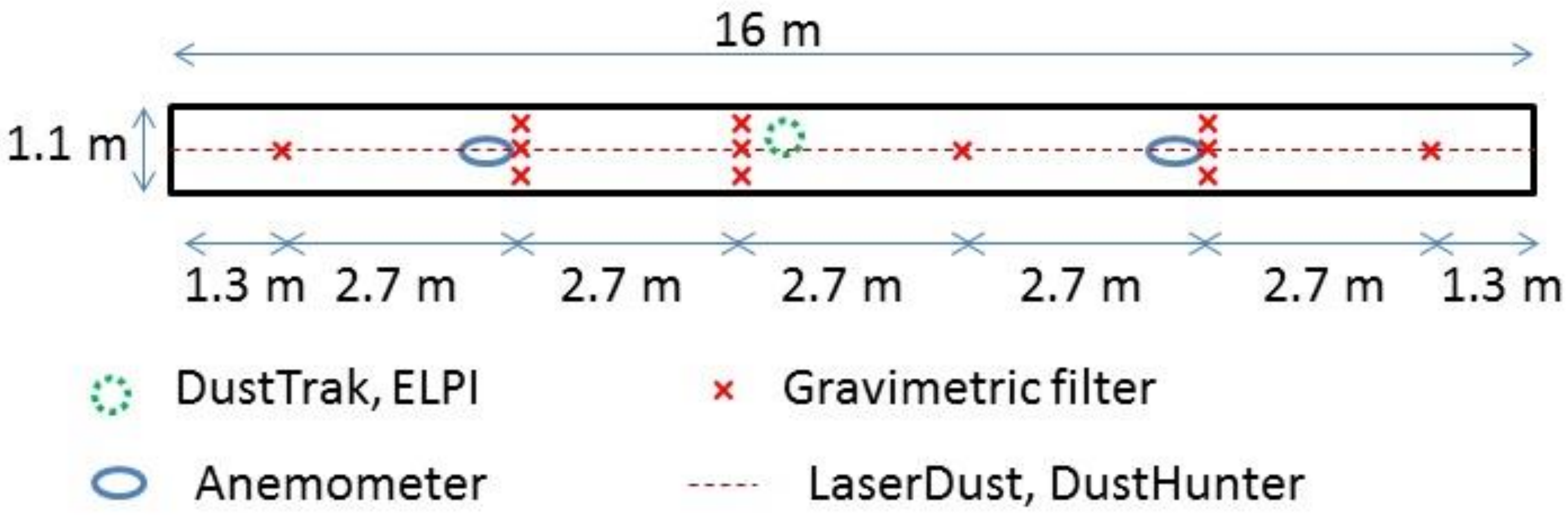
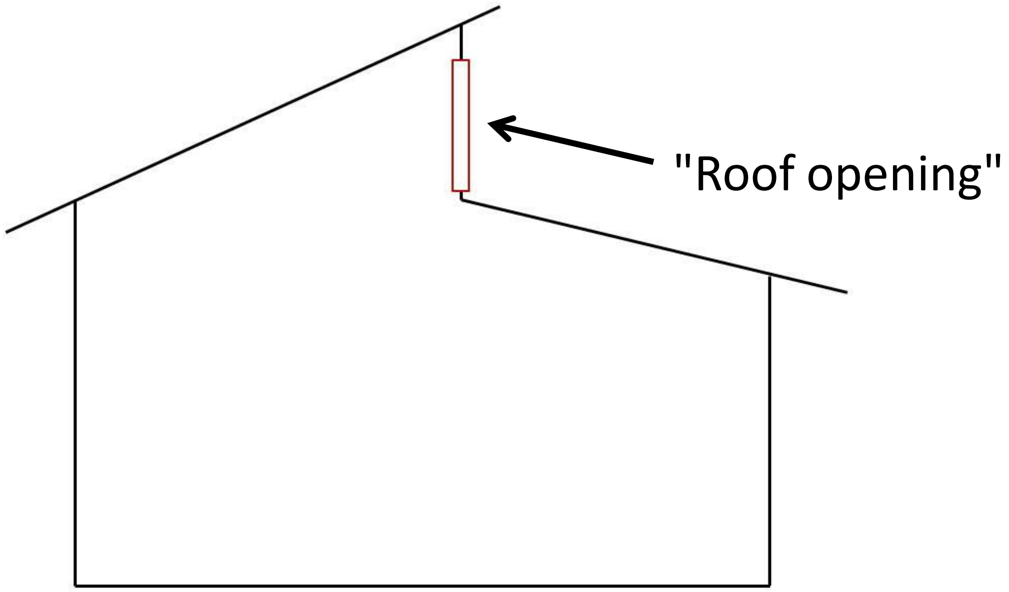
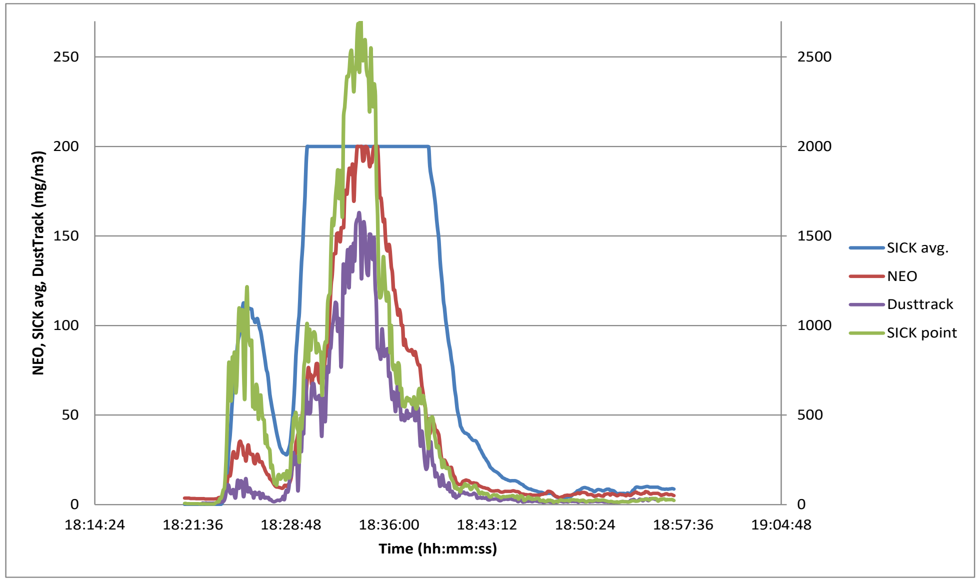
[Kero et al. SIPS 2015]

Example: Roof Opening #2







[Kero et al. SIPS 2015]

Final remarks

- Perspectives: ***Why*** we measure is as important as what we measure.
  - (And ***when***, and ***where*** and ***how***…)
- Beware of faulty conclusions drawn from comparing incomparable data.
  - Agglomerates vs protoparticles sizes
  - Mass- vs. number concentrations
  - Stationary vs. personal samplers
  - Direct-reading vs. indirect analysis of samples with varying averaging times
  - Aged vs freshly generated PM - collected near vs. far from source
  - …

Read more:

- Kero, Eidem, Ma, Indresand, Aarhaug and Grådahl: "*Airborne emissions from Mn ferroalloy production*", Journal of Metals (JOM), 2019. 71 (1): p. 349.
- Kero, Grådahl and Tranell: "*Airborne emissions from Si/FeSi production*", JOM 2017. **69**(2): p. 365
- Jørgensen & Kero: "*Real-time Measurements and Characterization of Airborne Particulate Matter from a Primary SiC Production Plant*", International Journal of Environmental Research and Public Health (IJERPH), 2017. 14 (12): p. 1611
- Ma, Kero & Tranell: "*Fume Formation from Oxidation of Liquid SiMn Alloy*" Oxidation of Metals, 2017. 98 (1-2) p. 211
- Arnoldussen, Ervik, Berlinger, Kero, Shaposhnikov, and Zienolddiny: *"Cellular responses of human astrocytes to dust from the Acheson process: an in vitro study"* Neurotoxicology, 2017. 65 p.241.
- Kero & Jørgensen: "*Comparison of Three Realtime Measurement Methods for Airborne Ultrafine Particles in the Silicon Alloy Industry*", IJERPH, 2016. 13 (9): p. 871
- Kero, Grådahl, Fardal & Wittgens: "*Fugitive dust measurements in the metallurgical industry*" in Sustainable Industrial Processing Summit (SIPS)- Takano International Symposium on Metals and Alloys, 2015. 3 (11) p.123
- Kero, Næss & Tranell: "*Particle size distributions of particulate emissions from the ferroalloy industry evaluated by electrical low pressure impactor (ELPI)*" Journal of Occupational and Environmental Hygiene, 2015. 12 (1): p. 37
- Kero, Naess, and Tranell: Fume characterization in the ferroalloy industry. INFACON XIII 2013. p.945

<u>Where to find'em:</u>

- Researchgate.com
- Google Scholar
- ida.kero@sintef.no

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Teknologi for et bedre samfunn