Specification of Zero-Impact Vehicle Emissions & Demonstration of Zero Impact

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Aim & Outline

Aim: Assessment of air quality driven zero impact vehicle emission levels

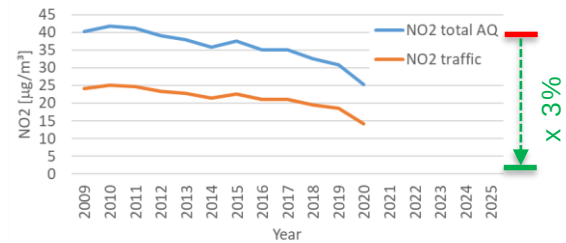
Outline:

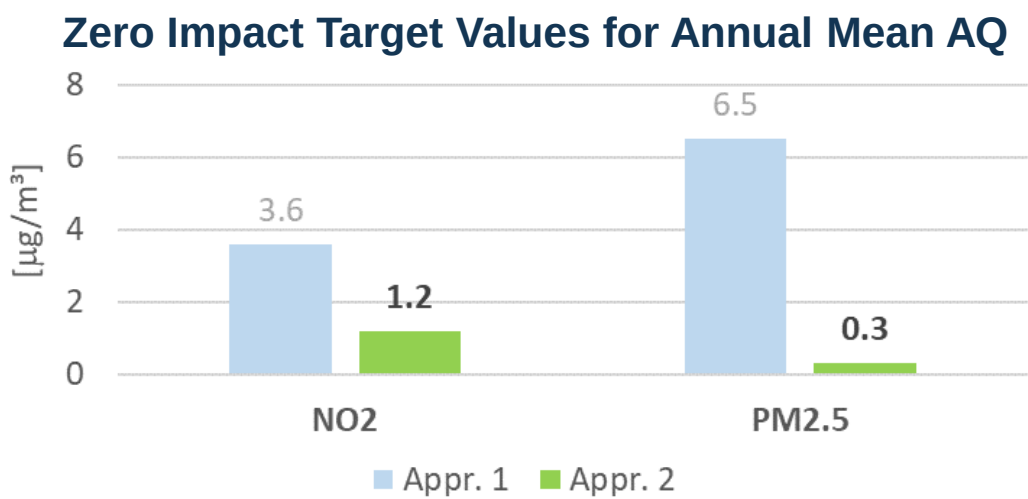
- How to define “Zero Impact” on air quality (NO_2, PM, PN)?
- Assessment of “**Z**ero **I**mpact **V**ehicles” exhaust emissions
- Demonstration of ZIV emission targets with air quality simulations
  - Modelling Approach & Validation NO_x/NO_2 & PN
  - Results from case studies
- Summary & Conclusions

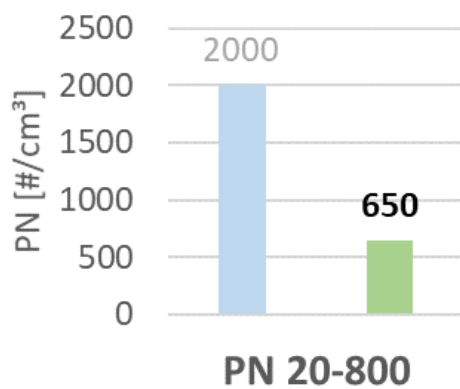
How to define “zero impact” on air quality?

Approach 1: stay below today’s clean urban background levels
→ Lowest conc levels from stations > 900 m a.s.l.

Approach 2: stay below 3% of WHO-2005 targets (“3% irrelevance criterion”)
= selected approach







For PN no AQ limit value nor target
→ analogy NO_2:

PN = 2000#/cm³ * 1.2µg/m³ / 3.6µg/m³

Method to calculate “Zero Impact Vehicle” exhaust emission levels

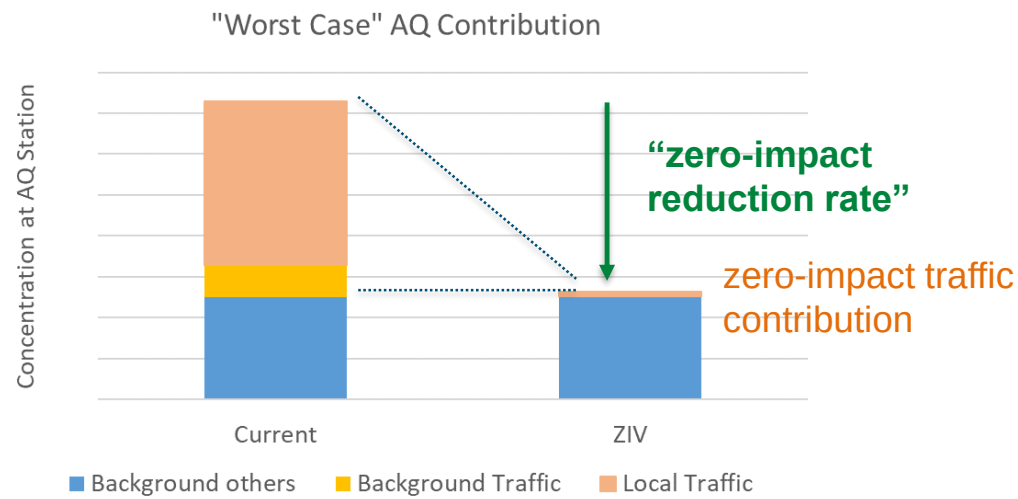
Current emissions → Resulting concentration levels

→ Necessary reduction to meet ZIV target

@ „worst case“ traffic and dilution conditions

AQ Moni-toring & Simula-tion

EIA



ZIV emission level [g/km] = current fleet emission level [g/km] * “zero-impact reduction rate”

Vehicle type	unit (activity)	EF NO_x (mg/unit)	EF PM2.5 (mg/unit)	EF PN20-800 (10^{11} #/unit)
PC	km	6.7	0.4	1.2
LCV	km	7.9	0.5	1.5
HDV	kWh	28.1	1.6	4.8

Demonstration of ZIV emission targets with AQ simulations

- Four case studies – important validation of base cases - focus here: NO_x/NO_2 & PN
- GRAMM/GRAL modelling system for high resolution urban scale flow (Vienna Δx,y 10 m, Augsburg Δx,y 4 m, Graz Δx,y 2 m) dispersion computations, simplified Chemistry (NO_2, NO, O_3) or empirical Romberg NO-NO_2 conversion
- All case studies detailed traffic emissions available
- Vienna & Augsburg detailed HR emission data for various sources

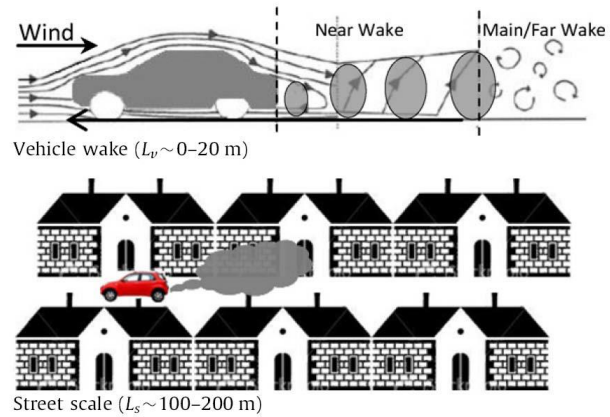
Case study	Domain size	Δx,y	Air pollutant focus	# Monitoring
Stuttgart-Neckartor	1.4 km x 1.7 km	2 m	NO_x/NO_2	2 AQ stations hotspot & bg
Vienna	30 km x 24 km	10 m	NO_x/NO_2, PM2.5	17 AQ stations
Augsburg CAZ	4 km x 6.2 km	4 m	NO_x/NO_2, PM10, PN	4 AQ stations, 2 SMPS
Graz Plüddemanngasse	1.1 km x 0.8 km	2 m	NO_x/NO_2, PN	NO_x, PN4nm, PN23nm, CO_2

Dispersion Modelling PN & accounted processes:

Kumar et al. (2011): Dynamic and dispersion modelling of nanoparticles from road traffic in the urban atmospheric environment—A review

Process	Veh wake	Street Sc	City	LPM
emissions	++	++	++	++
dilution	++	++	++	++
nucleation	++*	+*	+*	approx/bg
coagulation	0	0	+	negl
condensation	++*	0	+	approx
evaporation	++	+	0	approx
dry deposition	++	+	+	+
wet deposition	0	0	+	negl

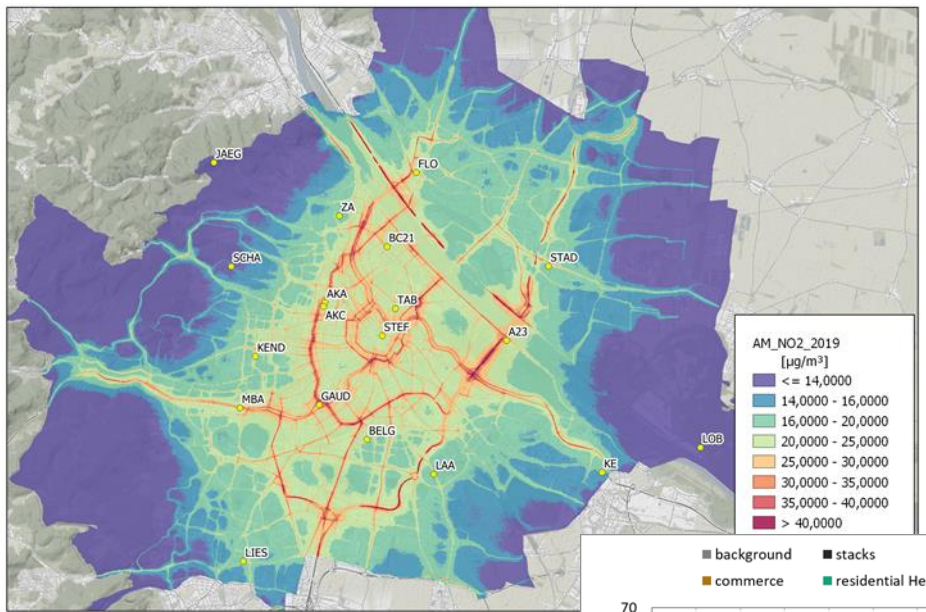
++: very important; +: important; 0: unimportant
++ well represented, 0 neglectable
neglected * high uncertainties bg: background monitoring

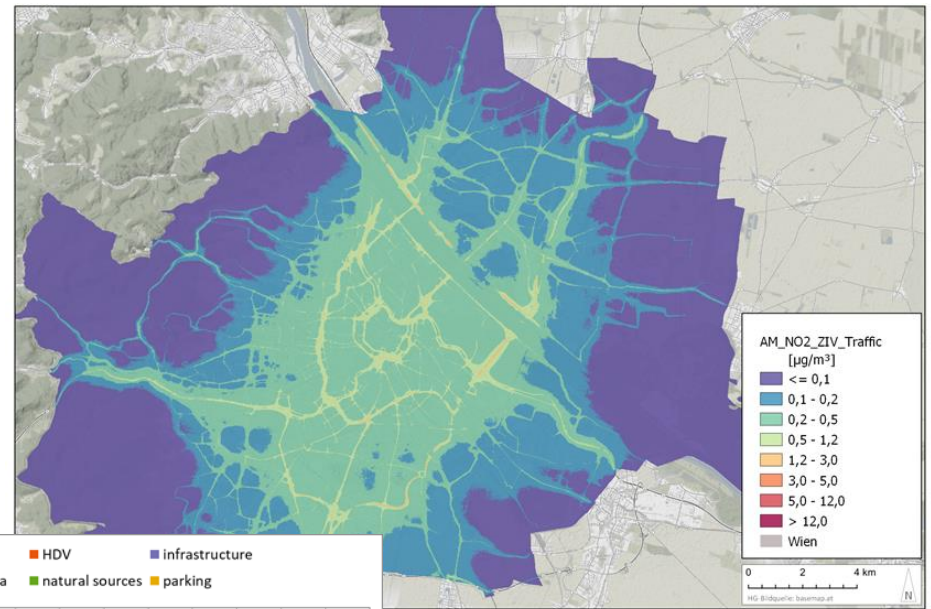


Air Quality Modelling:

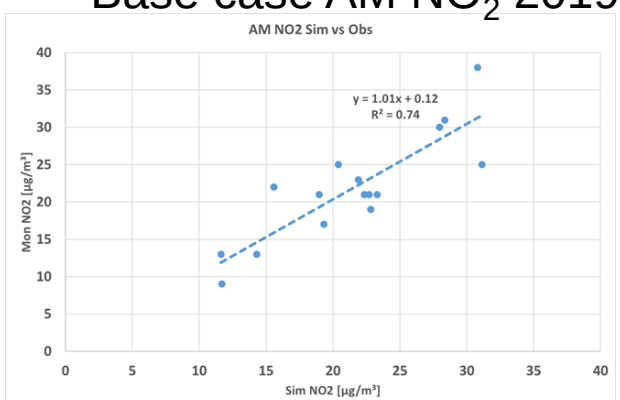
- Scale issue
- Conservative approach: Sink processes less critical

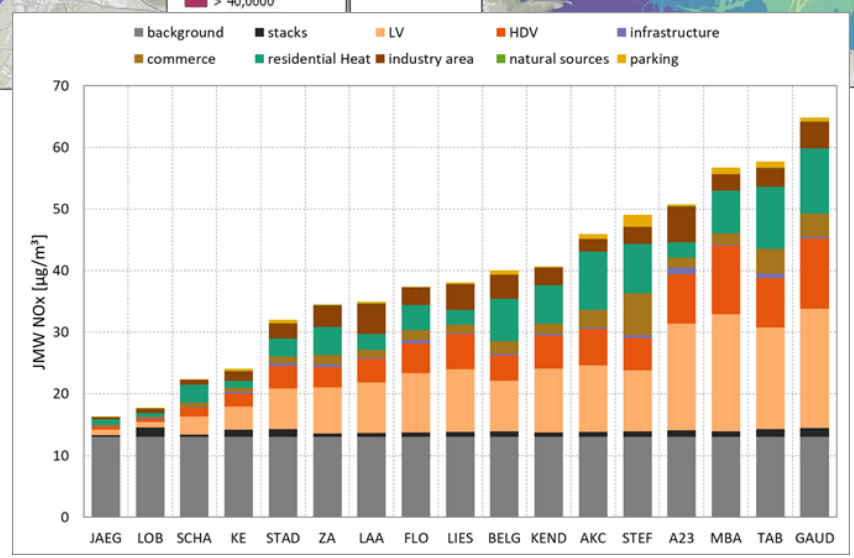
Vienna dispersion modeling case study AM NO_2





Base case AM NO_2 2019





AM NO_2 < 1.2 µg/m³ criteria kerbside & at AQ stations fulfilled

PN monitoring & simulations Graz Plüddemanngasse (street canyon like)

- 10 min PN, NO_x & CO_2 kerbside monitoring in Street Canyon/Graz 1 / 3 / 5 m distance
- 10 min Traffic counted → 30 min for meteo emissions & GRAL Sim

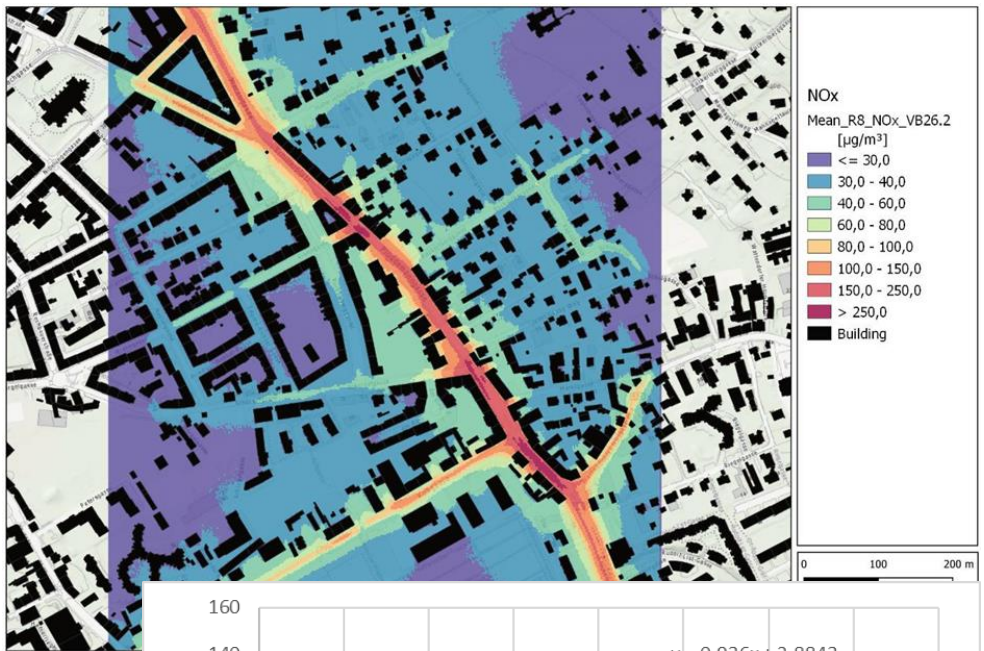
Monitored 7-h mean conc profiles

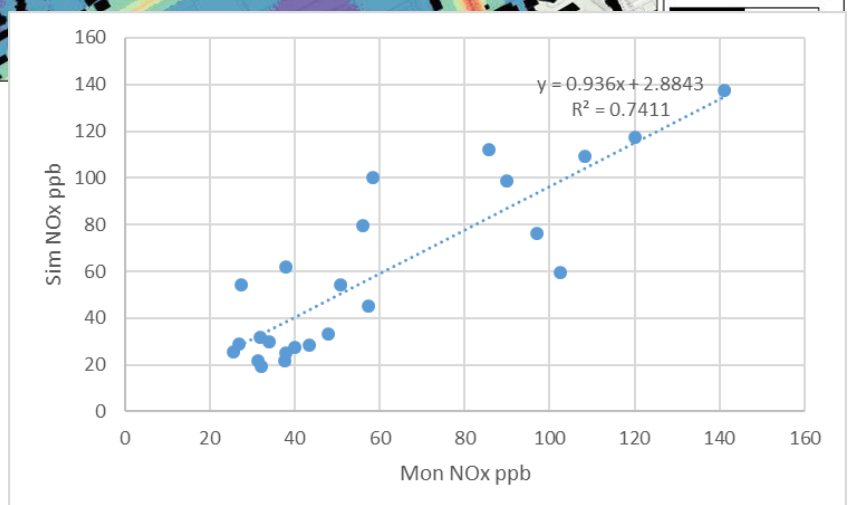
	ΔMINCO₂ ppb	NOx ppb	TPN23 #/cm³	TPN4 #/cm³	NO₂ ppb
1m	31.3	110.8	10378	20788	23.5
3m	26.6	80.7	11778	23529	18.0
5m	20.9	71.3	9494	20642	17.6

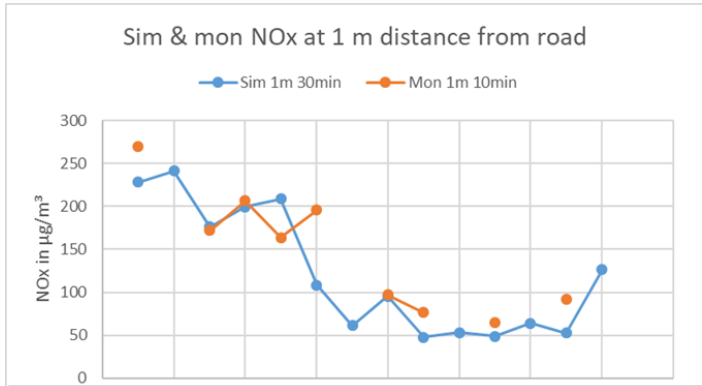
TPN: Total Particle Number dp>23 nm/4 nm

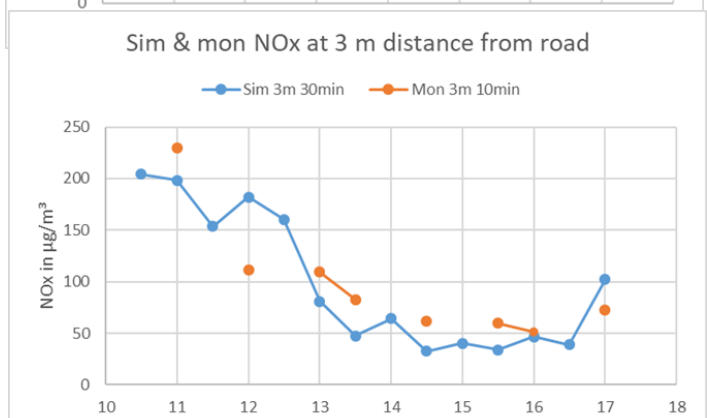
Wind monitoring Graz Schlossberg, radiation, NO_x & O_3 background nearby

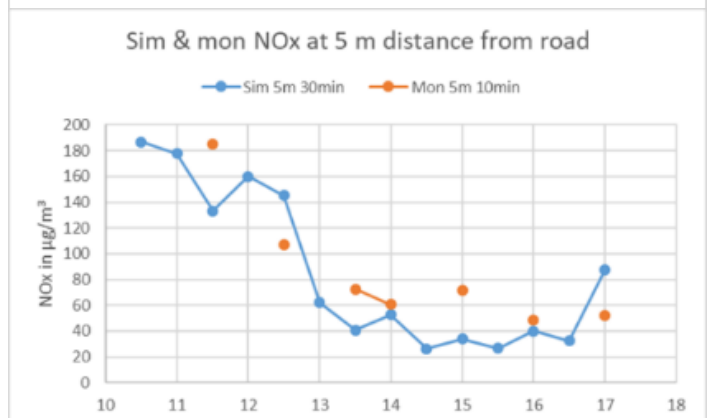
Validation dispersion NO_x Graz case study





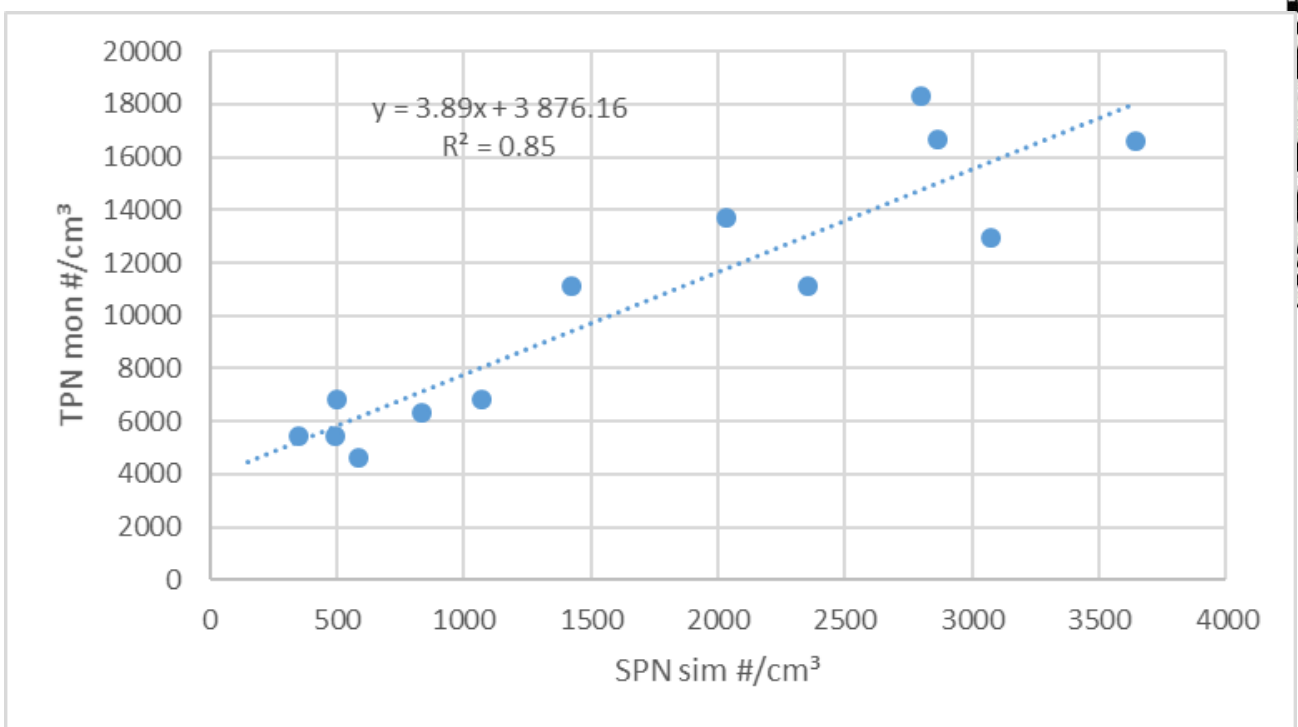


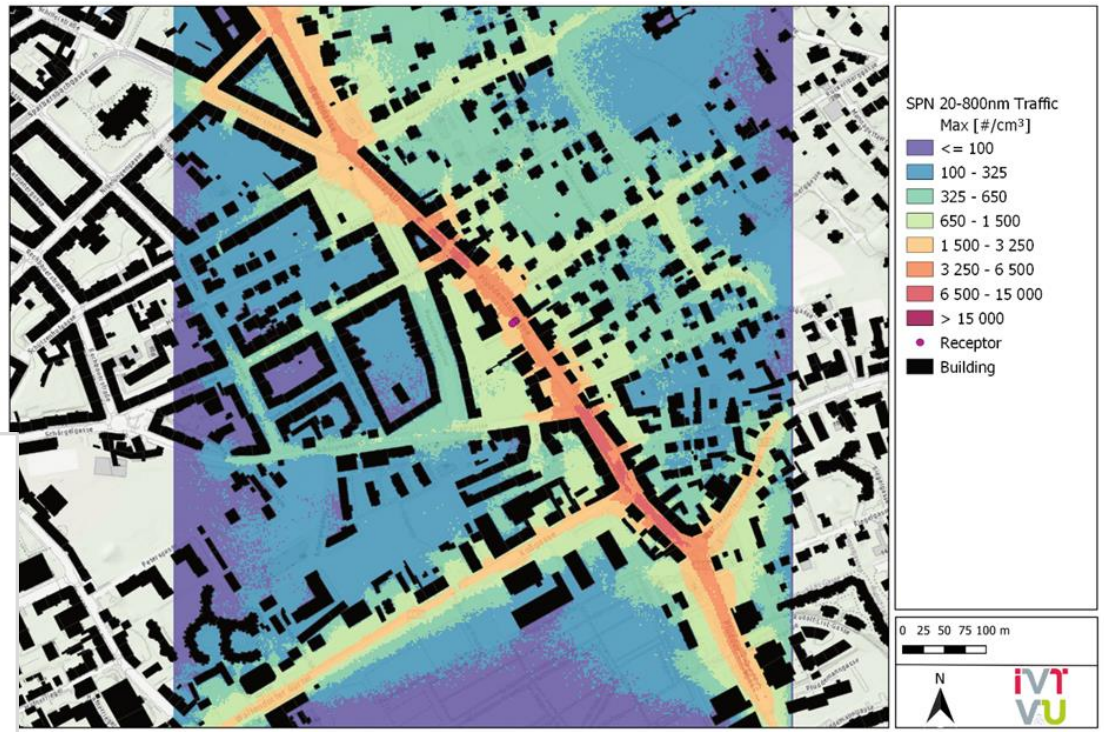




Validation dispersion PN Graz case study

- PN Emissions HBEFA traffic exhaust - SPN!
- No background → regression



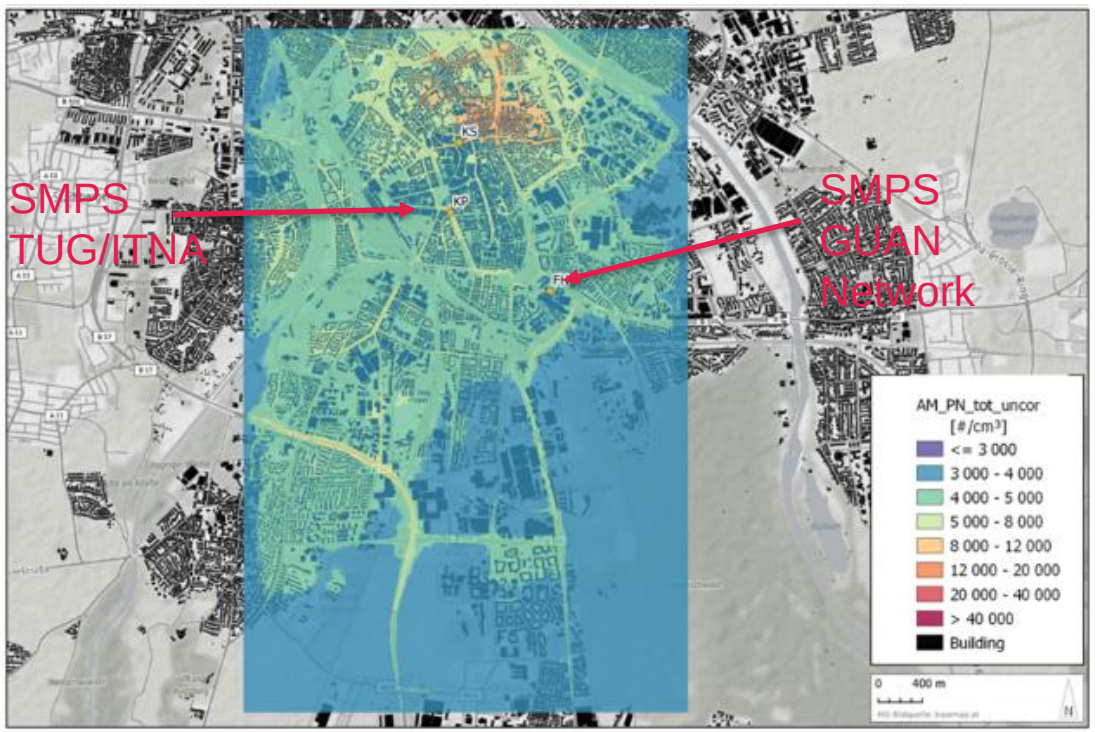


BG: 3876 #/cm³ - all other sources + atm. NPF

m=3.89 → TPN = SPN+VPN+Bg

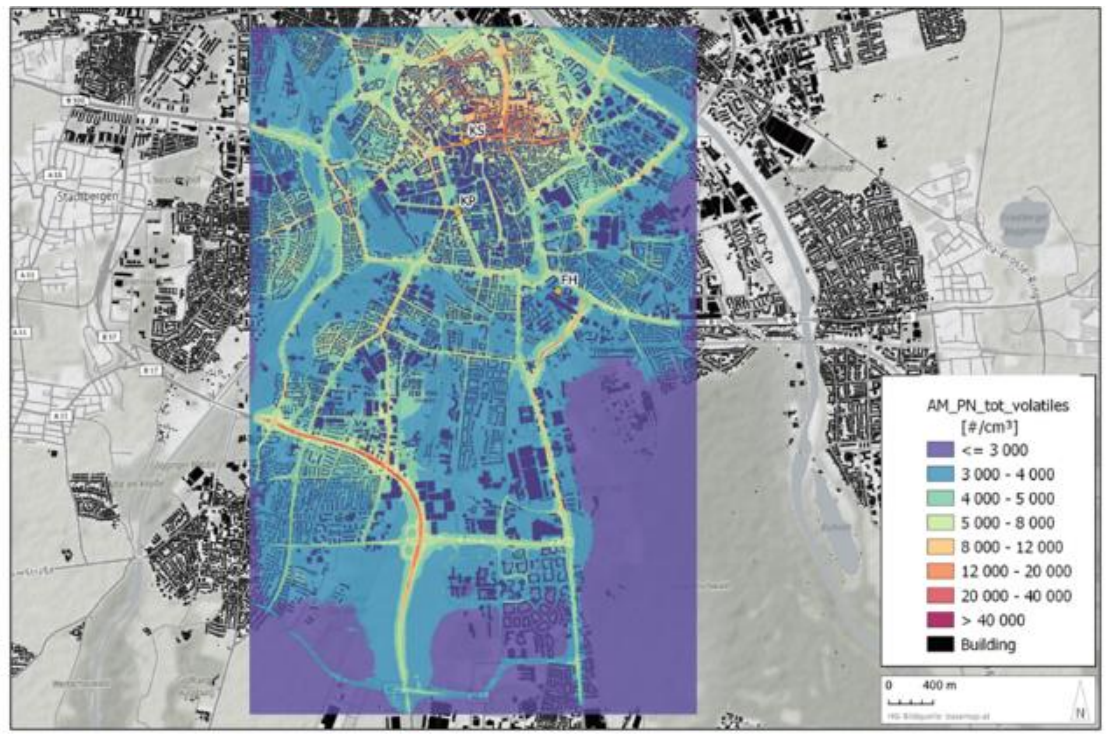
PN simulations & monitoring in Augsburg 2020/21

Emissions: Traffic SPN (exhaust + brake + tire) +Residential heating (gas + oil + solid)



Base case w/o $PN_{20\text{-}800}$ corrections

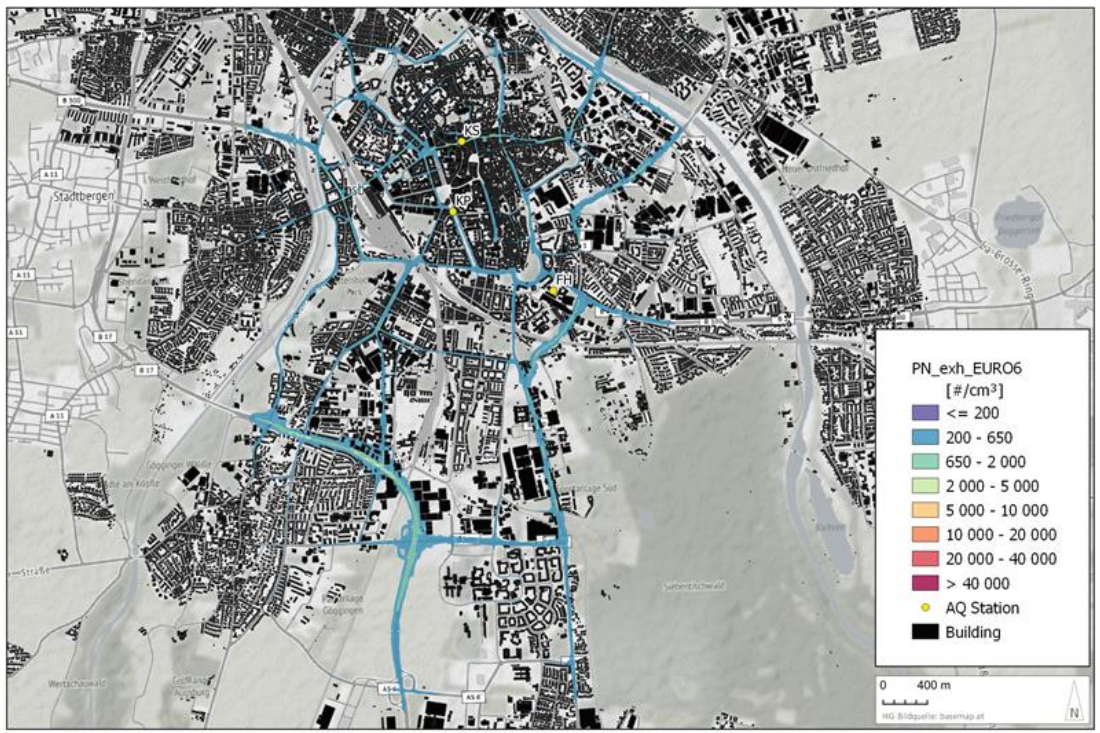
- Very low PN at KP & main arterial roads ?
- High $PN_{20\text{-}800}$ Background 3200 #/cm³ ?



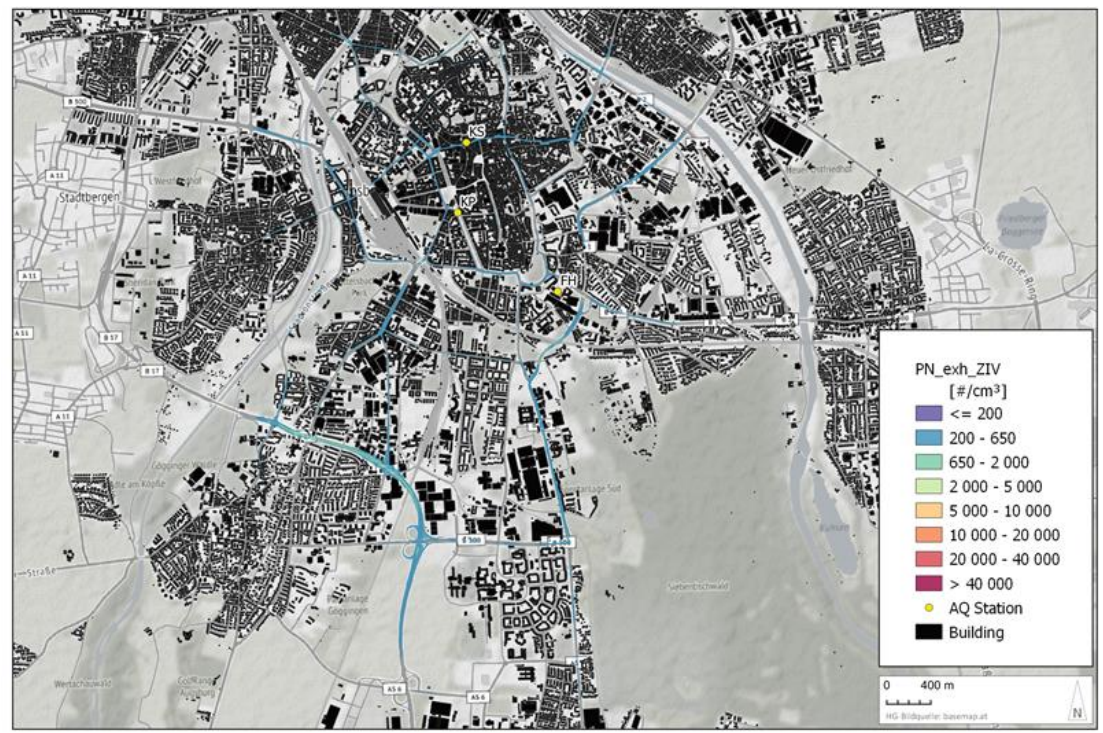
Base case exhEF PN23 corrected by 3.8

- Realistic PN @ KP & main arterial roads
- Realistic $PN_{20\text{-}800}$ Bg 2300 #/cm³

Scenarios Euro 6d/VI & ZIV Augsburg CAZ for PN

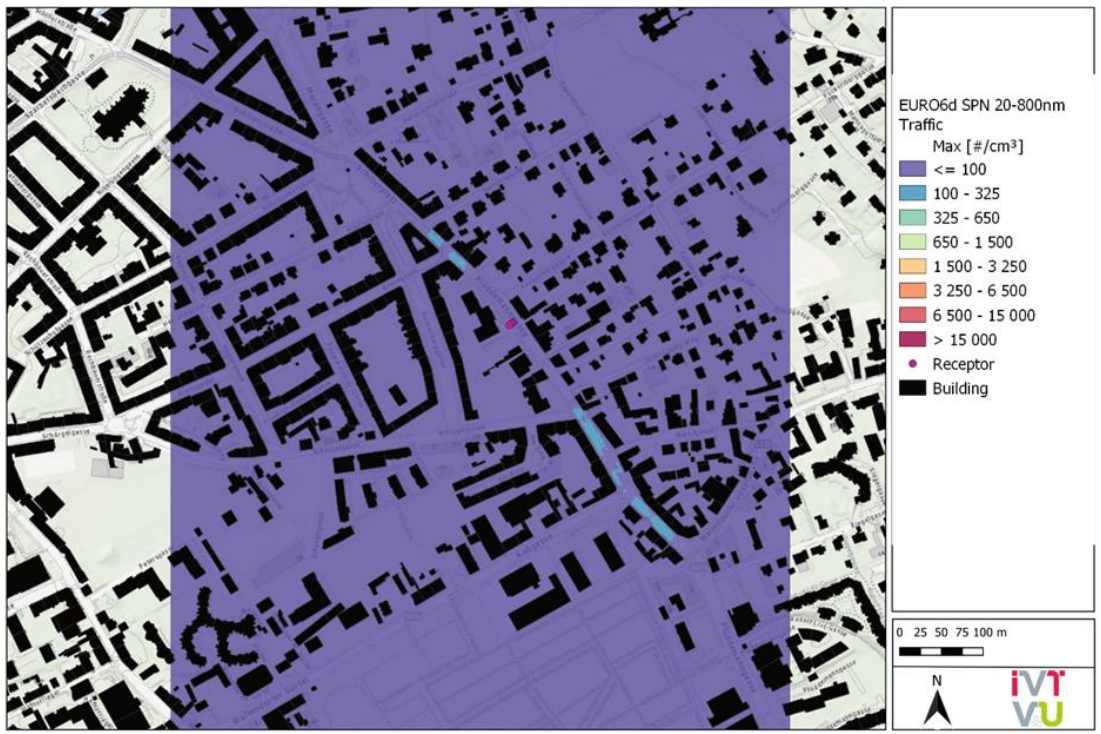


Scen Euro 6d/VI exh-SPN

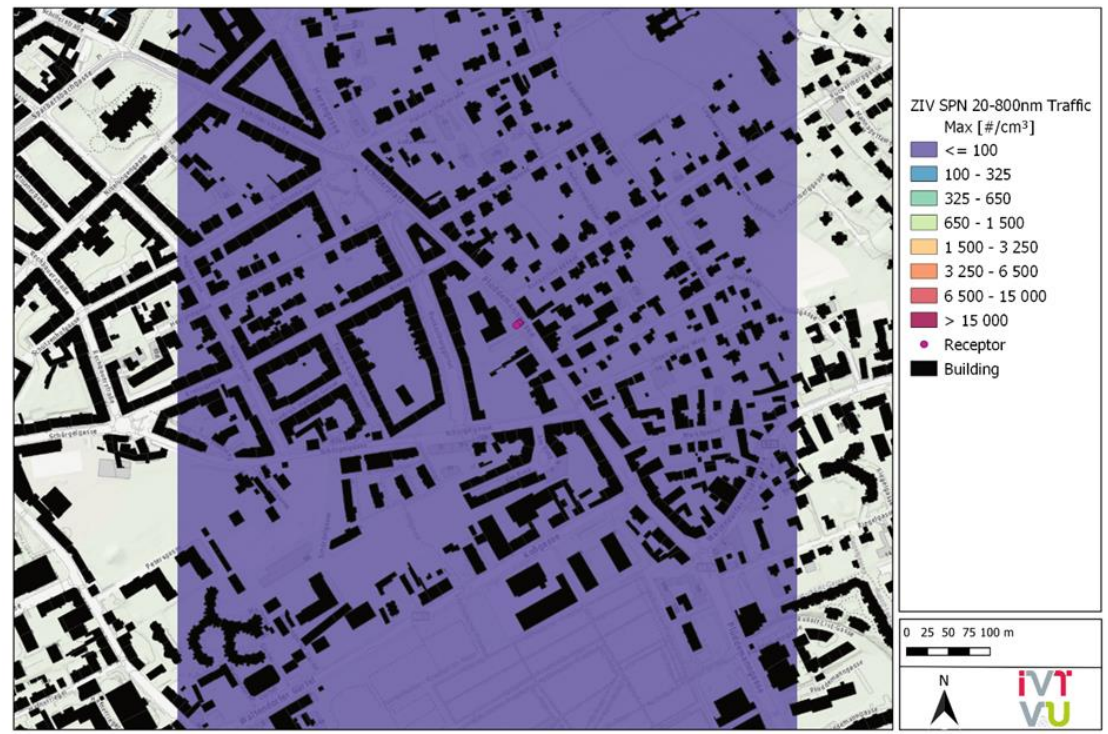


Scen ZIV exh-SPN

Scenarios Euro 6d/VI & ZIV Graz Plüddemanngasse for PN



Scen Euro 6d/VI exh-SPN



Scen ZIV exh-SPN

Summary and Conclusion

- Max Zero impact traffic contributions defined from AQ perspective:

	NO_2	PM2.5	PN_{20-800}
3% crit. WHO 2005 AQ limits	1.2 µg/m³	0.3 µg/m³	650 #/cm³

- Necessary reductions & ZIV emission levels specified
- Validation on the basis of AQ simulations base cases - revealed particularly for PN several challenges:
  - metrics emissions & ambient air (size range, composition – “SPN, VPN & TPN“)
  - aerosol dynamics – dominant role of Volatiles at hot spots, background (SPN/VPN)? → **role of Volatiles in scenarios?**
- Demonstration Zero-Impact Scenarios
  - 1.2 µg/m³ for NO_2 challenging at AQ hot spots kerbside and extreme driving conditions
  - Scenario SPN levels are very low

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