Impacts to emissions and air quality of electric vehicles in Denmark in 2030

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Aim

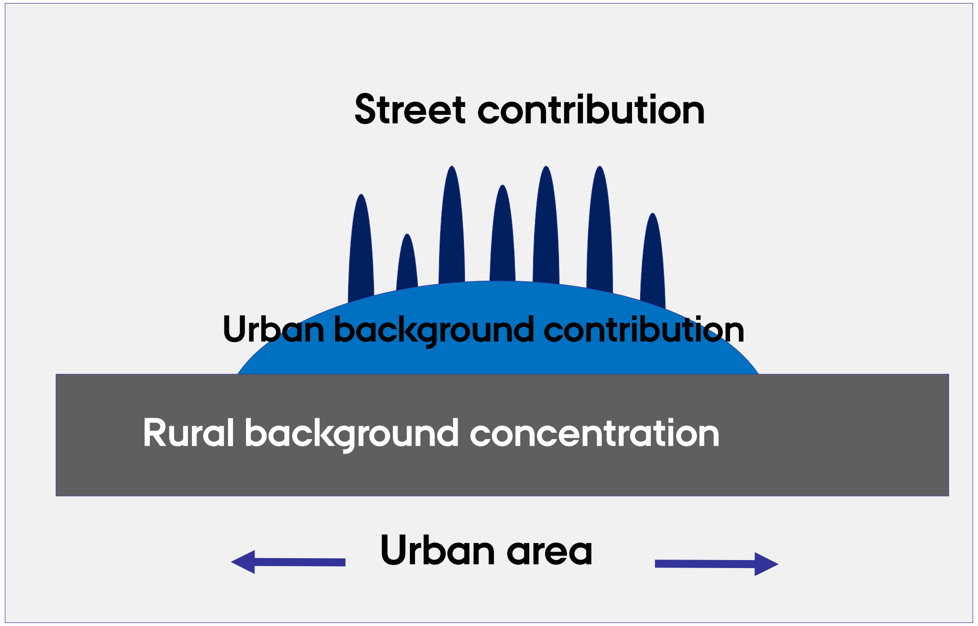
- Impact assessment of the Danish Government's Climate and Air Proposal launched in 2018 for emissions and air quality
- Three measures for road transport and two measures regarding scrappage of wood stoves
- Named climate scenario
- Focus is on the impact of the three measures for road transport
- Study funded by Ministry of Environment and Food of Denmark

Three climate measures for road transport

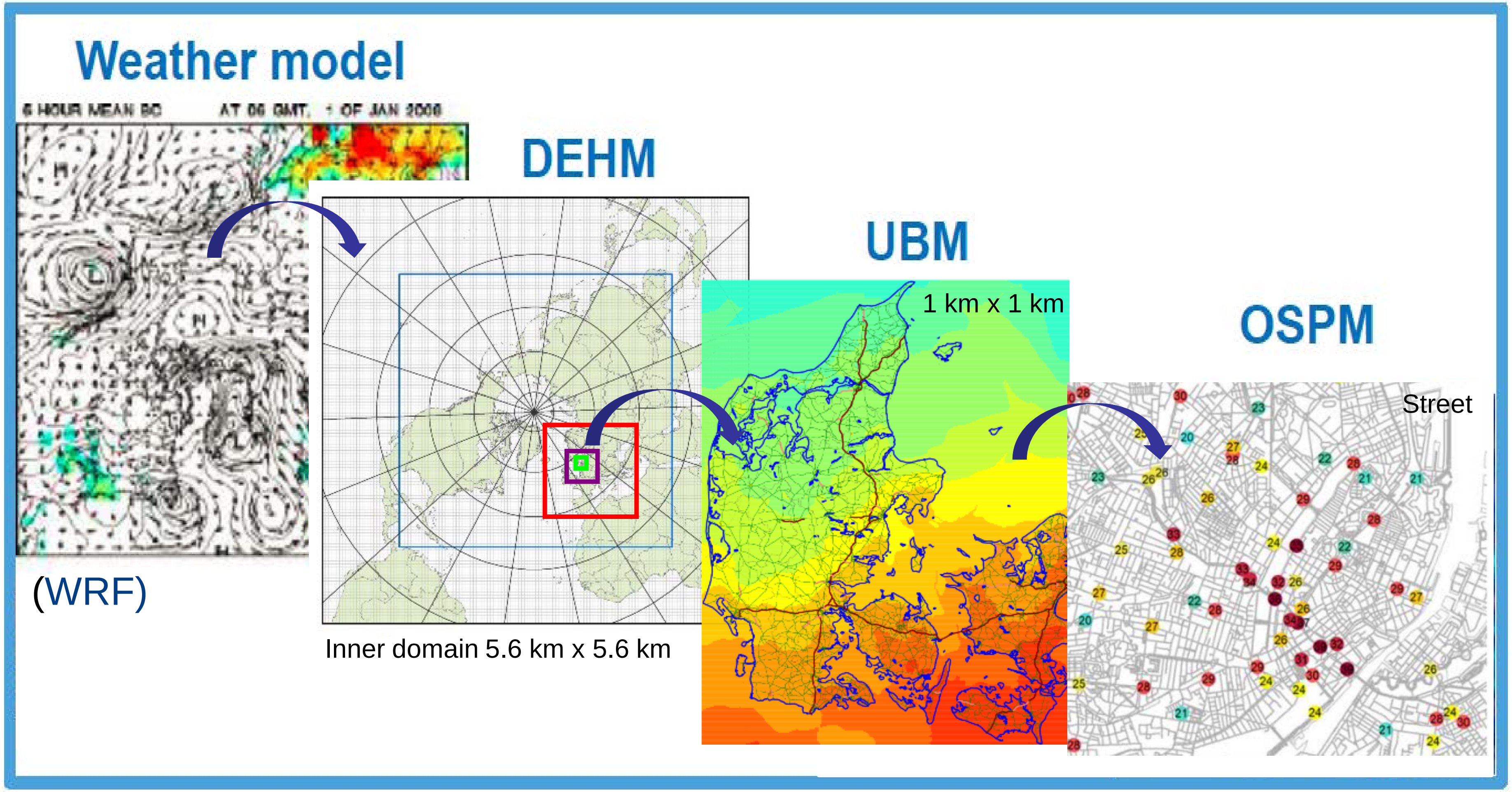
- **1 mill. electric cars in 2030**
  - 1 mill. EVs in 2030 are about 1/3 of all passenger cars
  - No sale of new petrol and diesel cars in 2030
- **100% electric urban buses in 2030**
  - No CO_2 emissions and air pollution from urban buses in cities from 2030
- **100% electric taxis in 2030**
  - No petrol and diesel taxis in 2030

Assessment of air quality in 2016 and 2030

- **Background concentrations**
  - Rural background concentrations in regions of Denmark
  - Urban background concentrations in four largest cities
  - $PM_{2.5}$ and NO_2 assessed due to largest health risk
  - Includes emission reduction from both road and woodstove measures
- **Street concentrations**
  - 98 streets in Copenhagen for $PM_{2.5}$ and NO_2



Multi-scale air quality modelling

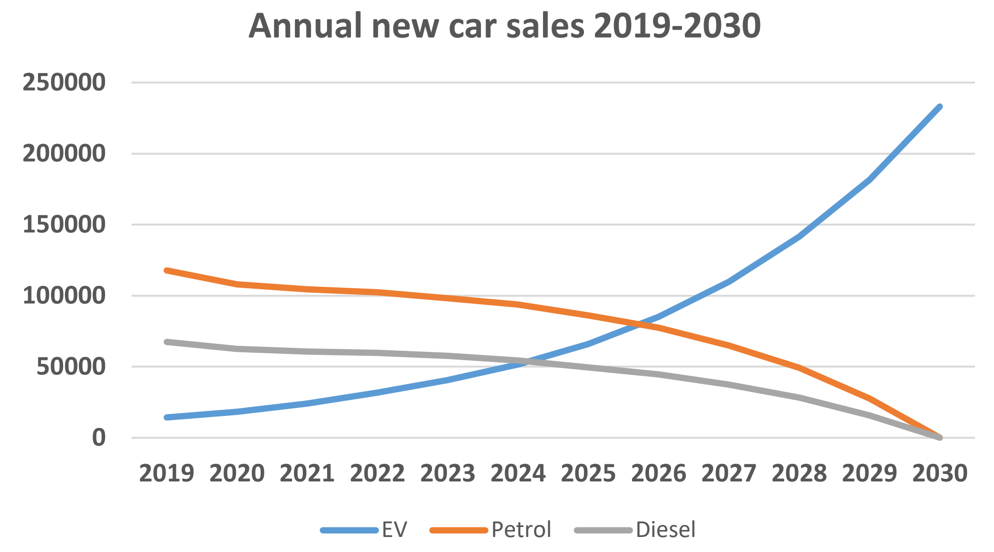


Assumption for emissions

- **Baseline development for NO_x and $PM_{2.5}$**
  - European emissions - member states baseline emission projections
  - Danish emissions - baseline projection of the Danish Energy Agency (With Measures (WM) - ‘frozen policy’)
- **Climate scenario for NO_x and $PM_{2.5}$**
  - European emissions - baseline if the national emission ceilings are met (NEC), otherwise the NEC emission ceiling for the country
  - Danish emissions from Danish Energy Agency - With Additional Measures for the energy and transport sector (WAM)
- **Road transport**
  - Emission factors taken from COPERT V
  - Non-exhaust emissions are assumed to be unchanged when shifting from fossil fuelled cars to EVs
  - Development in the vehicle fleet and mileage based on data from the Technical University of Denmark

Scenario 1 - One mill. EVs in 2030

- Exponential growth in EV sales assumed from 2019 to reach one mill. EVs in 2030
- No new sales of fossil cars in 2030
- 30% of all cars are EVs in 2030
- EVs increase by 766% compared to baseline (876,000 EVs)
- Petrol cars decrease by 26% and diesel cars by 27%
- Fleet of cars increase from 2019 to 2030 by 22% (604,000 cars)
- Sales in 2020 are 14,200 for EVs and 18,300 for PHEV



Car fleet of passenger cars in 2030 by fuel type for baseline and one mill. EV scenario

Scenario	Petrol	Diesel	EV	PHEV	CNG	Total
Baseline 2019	1761208	947605	11939	2590	200	2723542
Baseline 2030	2038595	1121571	114331	52213	490	3327200
One mill. EVs in 2030	1500380	815533	990390	20552	344	3327200
Difference, total	-538215	-306038	876059	-31660	-145	0
Difference, %	-26	-27	766	-61	-30	0

Scenario 1 - Impacts to emissions of one mill. EVs

- Emission savings are 19 % for NO_x and 25 % for $PM_{2.5}$-exhaust
- No change in $PM_{2.5}$ non-exhaust assumed between EVs and fossil cars
- Non-exhaust - brake/tire/road wear – dominant total $PM_{2.5}$
- Consequently, total $PM_{2.5}$ only reduced by 3.4 %

Pollutant	Baseline	One mio. EVs	Emission savings	
Units	Tonnes	Tonnes	Tonnes	%
NOx	9173	7460	1713	19
PM2.5-exhaust	104	79	26	25
PM2.5-non-exhaust	654	654	0	0
PM2.5-total	759	733	26	3.4

Scenario 2 - 100% electric urban buses in 2030

- **5,600 diesel and 400 CNG buses (baseline) are replaced in 2030**
- **Emission savings are 100% for NO_x and 100% for $PM_{2.5}$-exhaust, and 6% for total $PM_{2.5}$**

Pollutant	Baseline	Electric urban busses	Emission savings	
Units	**Tonnes**	**Tonnes**	**Tonnes**	**%**
NOx	178	0	178	**100**
PM2.5-exhaust	2.5	0	2.5	**100**
PM2.5-non-exhaust	38	38	0	**0**
PM2.5-total	40	38	2.5	**6.2**

Scenario 3 - 100% electric taxis in 2030

- **4,192 diesel and 153 gasoline taxis (baseline) are replaced**
- **Emission savings are 100% for NO_x and 100% for $PM_{2.5}$-exhaust, and 10 % for total $PM_{2.5}$**

Pollutant	Baseline	Electric taxis	Emission savings	
Units	Tonnes	Tonnes	Tonnes	%
NOx	77	0	77	100
PM2.5-exhaust	0.78	0	0.78	100
PM2.5-non-exhaust	6.9	6.9	0	0
PM2.5-total	7.7	6.9	0.78	10

Scenario reductions compared to total baseline in 2030

- **Compare the total effect of all three scenarios to baseline emissions in 2030 for road transport (including all light-duty and heavy-duty vehicles)**
- **Emissions of NOx are reduced by 14%, $PM_{2.5}$-exhaust by 19% and total $PM_{2.5}$ by 2%**
- **The largest emission reductions are obtained in Scenario 1 (one mill. EVs).**

Pollutant	One mio. EVs	Electric taxis	Electric urban	Total
	%	%	%	%
NOx	12	0.6	1.3	**14**
PM2.5-exhaust	17	0.5	1.6	**19**
PM2.5-non-exhaust	0	0	0	**0**
PM2.5-total	2.0	0.1	0.2	**2.3**

Emission reduction in climate scenario

Scenario	NOx (tons)	PM2.5 (tons)
Transport	-1,968	-29
Wood stoves	+41	-979
Total	-1,927	-1,008

- **NO_x reduction driving by transport measures**
  - **Modern wood stoves increase NOx emissions**
- **$PM_{2.5}$ reduction driving by wood stove measures**
  - **old stoves before 2000 scrapped when home ownership is changed**
  - **and subsidy to scrap old stoves before 2000**

Rural background concentrations

Rural background concentrations af NO_2 and $PM_{2.5}$ modelled with DEHM/UBM

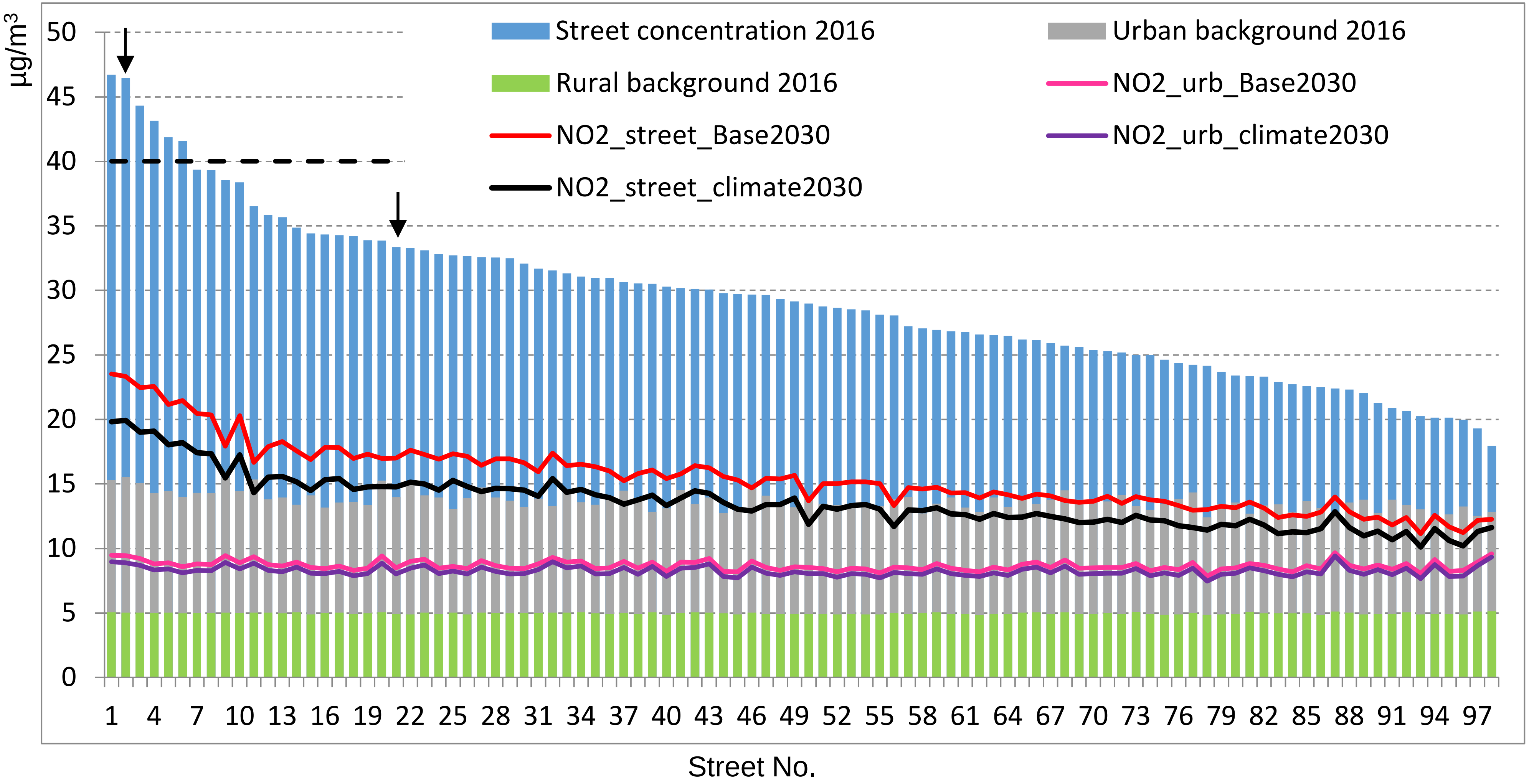
$\mu g/m^3$	Location	2016	2030	Difference 2030/2016	2030	Difference 2030/2016
Region			**Base**	**Base**	**Climate**	**Climate**
NO_2						
Nordjylland	Average	5.8	4.6	-20%	4.6	-22%
Midtjylland	Average	6.3	4.6	-27%	4.5	-28%
Syddanmark	Average	7.0	5.1	-27%	5.0	-29%
Hovedstaden	Average	11.2	7.7	-31%	7.4	-34%
Sjælland	Average	8.7	6.6	-24%	6.5	-25%
$PM_{2,5}$						
Nordjylland	Average	6.4	5.3	-18%	5.1	-21%
Midtjylland	Average	7.2	5.7	-20%	5.5	-23%
Syddanmark	Average	8.3	6.4	-22%	6.2	-25%
Hovedstaden	Average	8.2	6.5	-20%	6.2	-24%
Sjælland	Average	8.4	6.6	-22%	6.3	-25%

Urban background concentrations

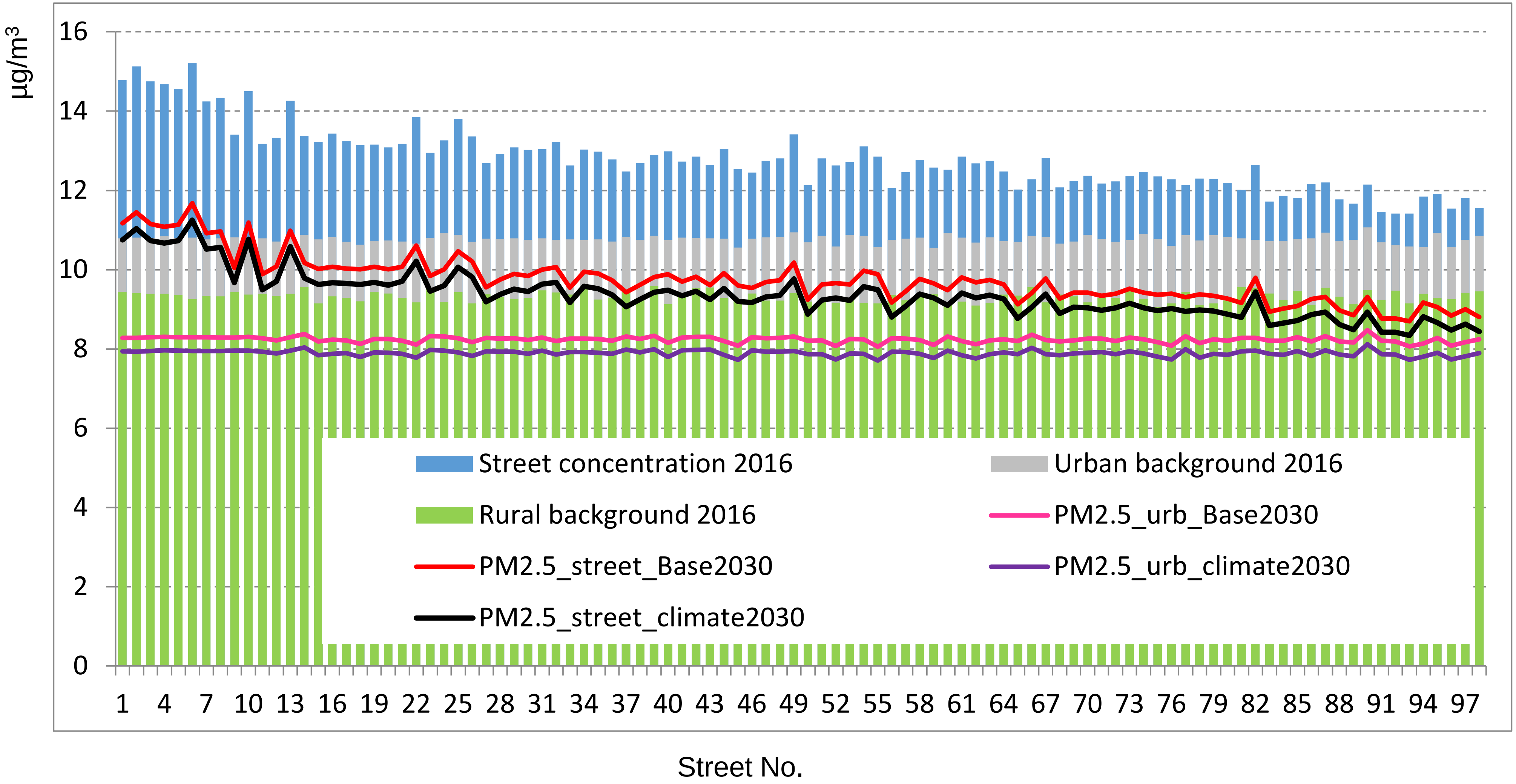
Urban background concentrations af NO_2 and $PM_{2.5}$ modelled with DEHM/UBM

µg/m³	Location	2016	2030	Difference 2030/2016	2030	Difference 2030/2016
City	**Monitor station**		**Base**	**Base**	**Climate**	**Climate**
NO_2						
Copenhagen	H.C. Ørsted	13.8	8.5	-39%	8.0	-42%
Odense	Rådhus	12.1	7.9	-35%	7.5	-38%
Aarhus	Botanisk Have	15.8	11.0	-30%	10.6	-33%
Aalborg	Østerbro	13.5	10.5	-22%	10.2	-24%
$PM_{2,5}$						
Copenhagen	H.C. Ørsted	8.1	6.5	-19%	6.3	-23%
Odense	Rådhus	8.6	6.7	-22%	6.4	-26%
Aarhus	Botanisk Have	8.2	6.6	-20%	6.3	-23%
Aalborg	Østerbro	6.9	5.7	-18%	5.5	-21%

Street concentrations of NO_2 at 98 streets in CPH



Street concentrations of $PM_{2.5}$ at 98 streets in CPH



Non-exhaust from EVs

- **We assumed non-exhaust emissions to be unchanged when shifting from fossil fuelled cars to EVs**
- **However, EVs have higher road and tire wear and resuspension due to higher weight but less brake wear and no exhaust**
- **According to Timmers & Achten (2016) EVs and fossil cars have the same total PM emission (sum of exhaust and non-exhaust)**

Table 6
Comparison between expected $PM_{2.5}$ emissions of EVs, gasoline and diesel ICEVs.

Vehicle technology	Exhaust	Tyre wear	Brake wear	Road wear	Resuspension	Total
EV	0 mg/vkm	3.7 mg/vkm	0 mg/vkm	3.8 mg/vkm	14.9 mg/vkm	**22.4 mg/vkm**
Gasoline ICEV	3.0 mg/vkm	2.9 mg/vkm	2.2 mg/vkm	3.1 mg/vkm	12.0 mg/km	**23.2 mg/vkm**
Diesel ICEV	2.4 mg/vkm	2.9 mg/vkm	2.2 mg/vkm	3.1 mg/vkm	12.0 mg/vkm	**22.6 mg/vkm**

Timmers & Achten (2016): Non-exhaust PM emissions from electric vehicles.

Conclusion

- Three climate measures assessed (1 mill. EVS, 100% e-taxis and 100% e-urban buses)
- Impact assessment of emissions and rural, urban background and street concentrations in 2030 using multi-scale modelling
- EV cars increase 766% and constitute 30% of all cars in 2030
- Car fleet increases 22% from 2019 to 2030 and fossil cars remain high in 2030 (70%)
- Climate scenario decreases emissions of NO_x by 14%, $PM_{2.5}$-exhaust by 19%, and total $PM_{2.5}$ by 2.3% (change in non-exhaust assumed to zero)
- Baseline development from 2016 to 2030 decrease rural, urban background and street concentrations significantly and climate scenario adds further decrease
- Impacts to total $PM_{2.5}$ overestimated if EVs have higher non-exhaust than fossil cars