Perkin-Elmer 900, Gas Chromatograph, 1970s

Empa

Materials Science and Technology

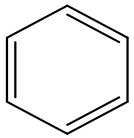
30 years of VOC measurements in Switzerland

long-term monitoring of BTEX

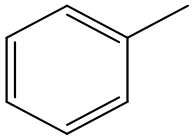
Zoé Le Bras, Stefan Reiman, Pascal Rubli, Paul Schlauri

08.04.2025 – CiGas Community Meeting, online

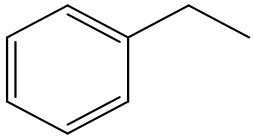
BTEX in urban ambient air



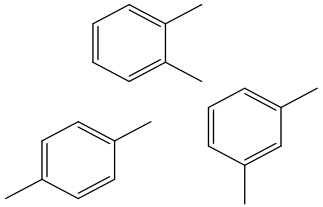
Benzene (lifetime: 10 days)[1]



Toluene (2 days)



Ethylbenzene
(2 days)

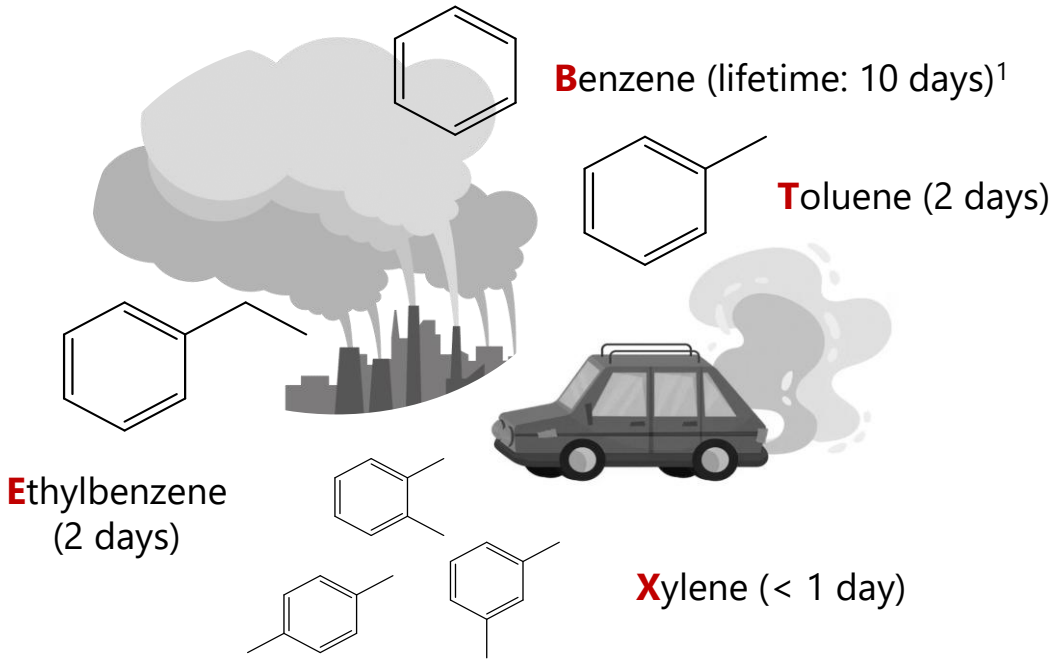


Xylene (< 1 day)

- Human health risks
- Benzene: carcinogen to humans

1. Monod *et al.*, Atmos. Environ., 2001

BTEX in urban ambient air



- Human health risks
- Benzene: carcinogen to humans
- Anthropogenic emissions (cars, solvent, fuel/biomass burning)

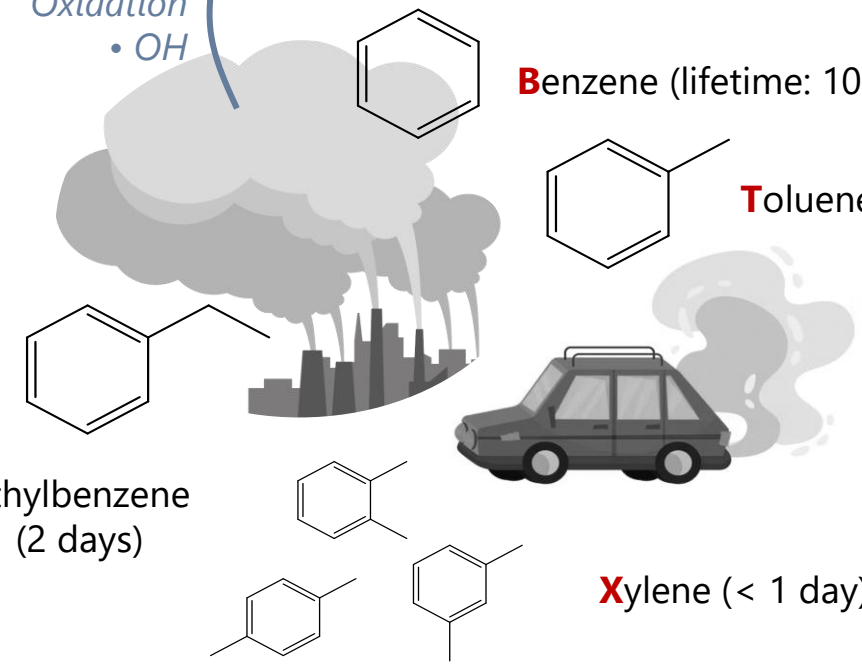
1. Monod *et al.*, Atmos. Environ., 2001

BTEX in urban ambient air

highly oxygenated molecules[2]

O_3
Secondary organic aerosols (SOA)

Oxidation
• OH



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Toluene (2 days)

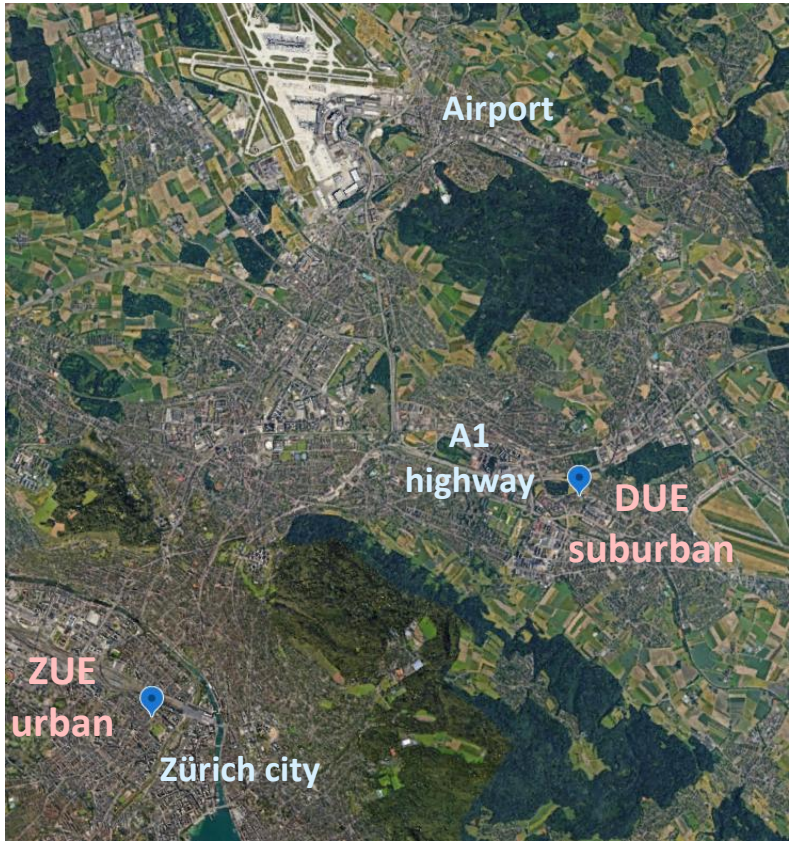
Ethylbenzene (2 days)

Xylene (< 1 day)

- Human health risks
- Benzene: carcinogen to humans
- Anthropogenic emissions (cars, solvent, fuel/biomass burning)
- Air pollution (photochemical smog, fine particles)

1. Monod *et al.*, Atmos. Environ., 2001; 2. Molteni *et al.*, ACP, 2018

1994, the start of a long time series for BTEX in Dübendorf



Dübendorf (DUE), suburban area

BTEX monitoring started in 1994 with gas chromatography flame ionization detector (GC-FID)

Since 2001: GC-Photoionization detector (GC-PID)

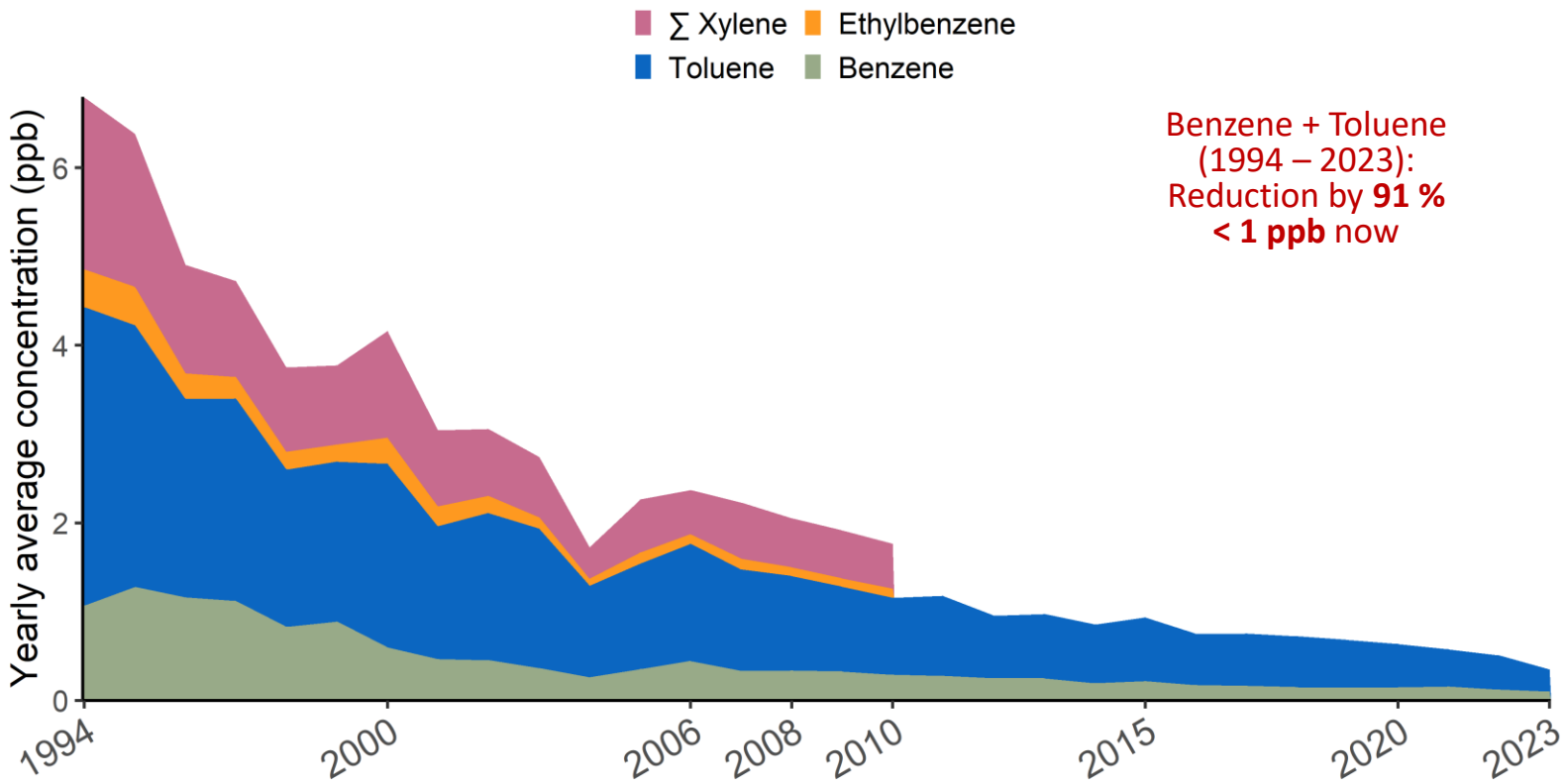
Zürich Kaserne (ZUE), urban area

VOC measurement campaigns since 1993

OVOC measurements from 2005

GC-FID

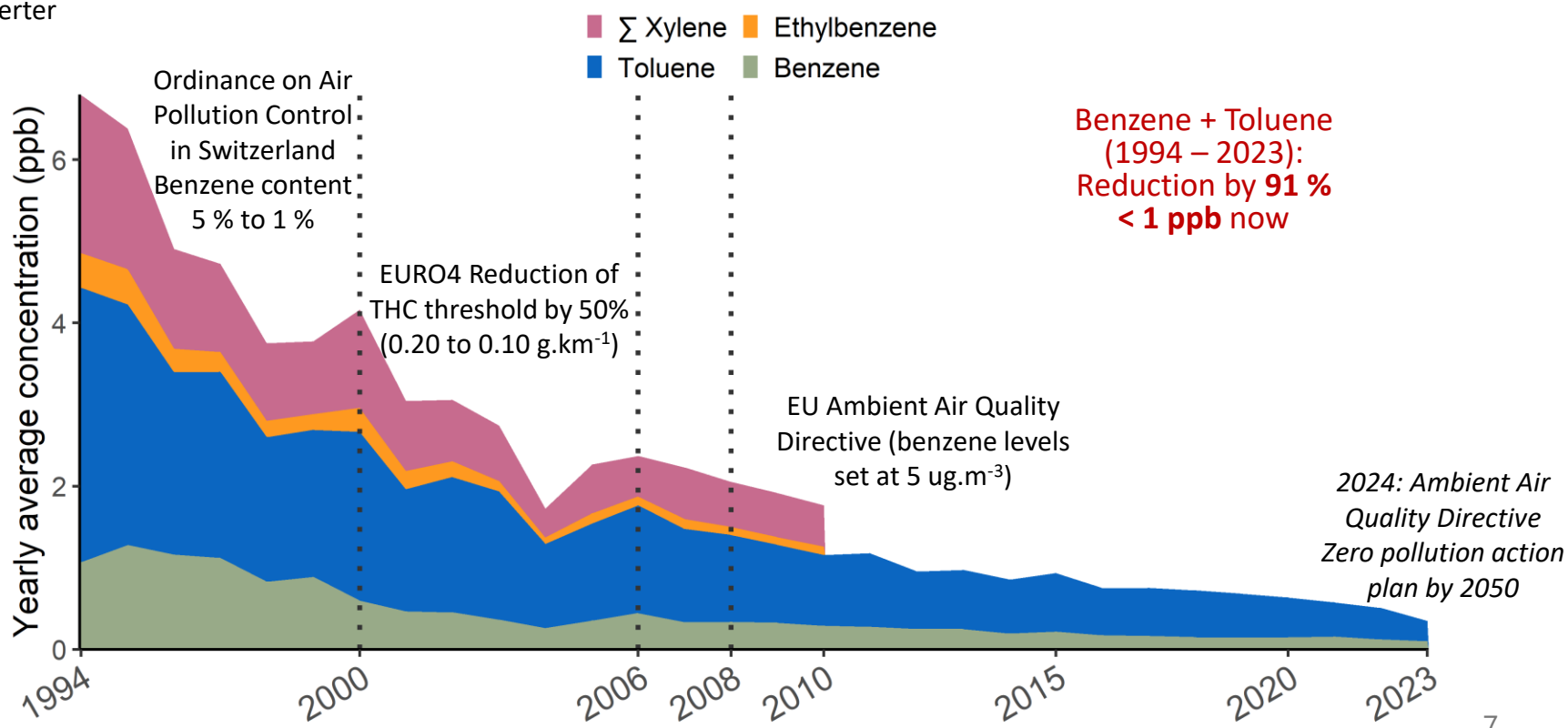
Overall decrease in BTEX concentration in Dübendorf



Benzene + Toluene
(1994 – 2023):
Reduction by **91 %**
< 1 ppb now

Overall decrease in BTEX concentration in Dübendorf

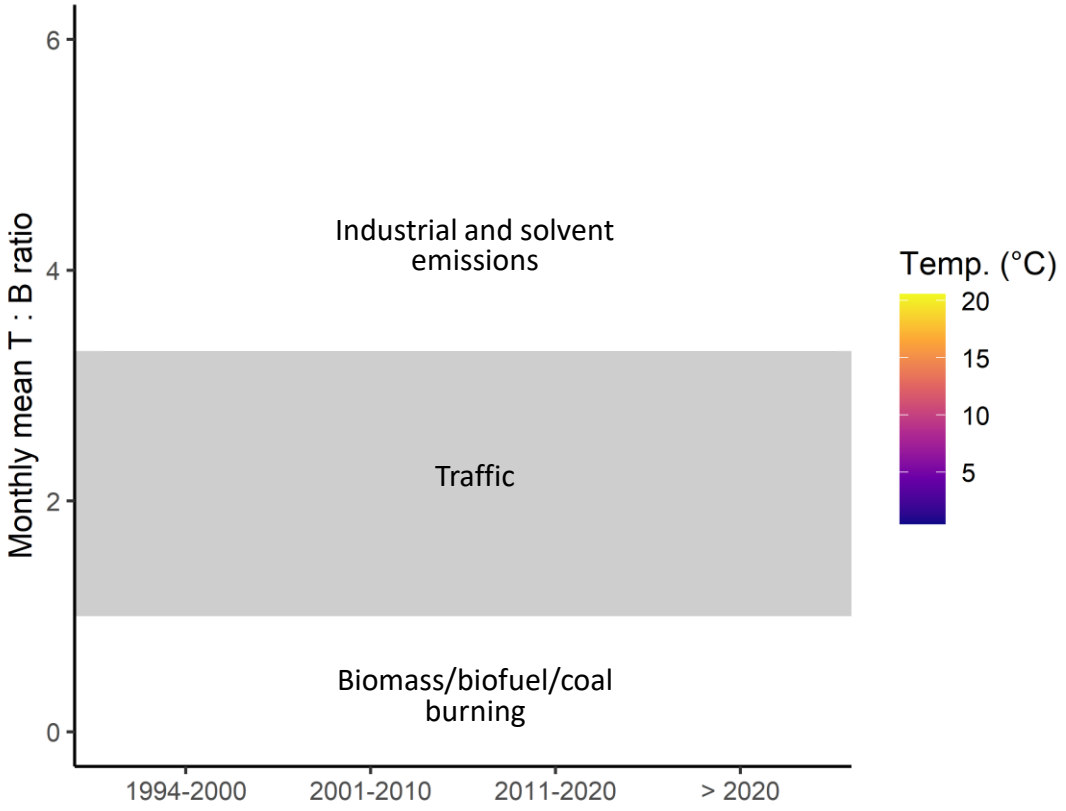
1987: 3-way catalytic converter



Benzene + Toluene (1994 – 2023): Reduction by **91 %** **< 1 ppb** now

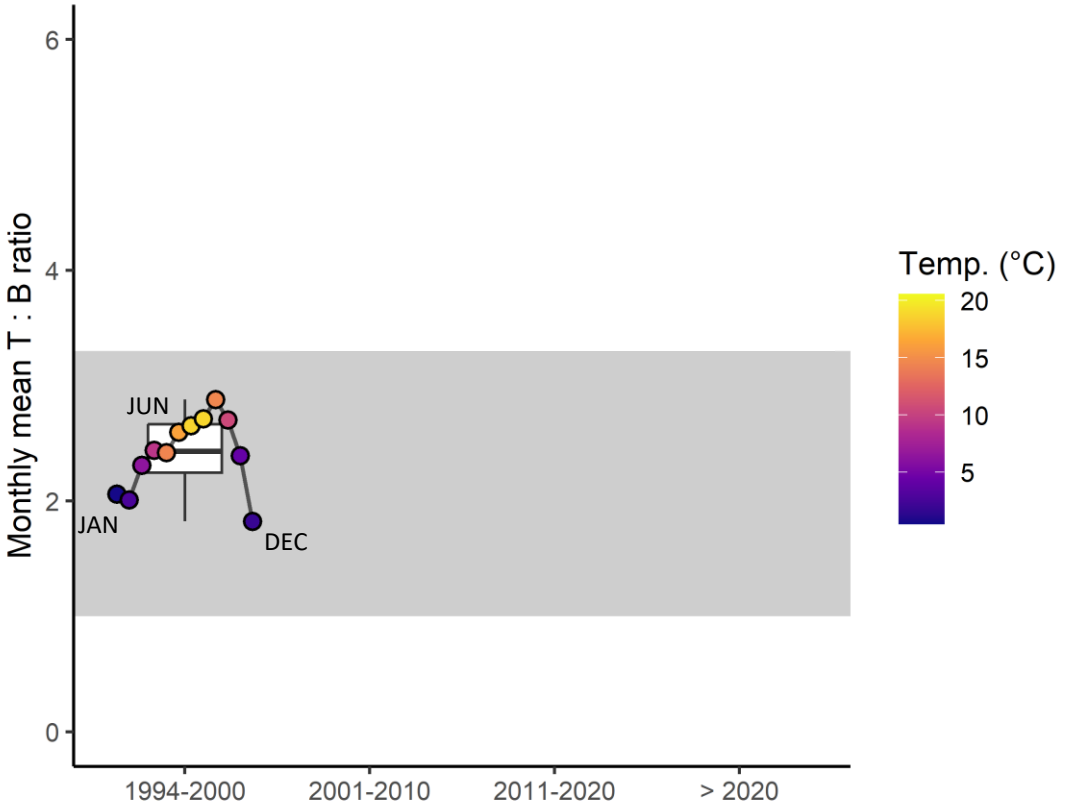
2024: Ambient Air Quality Directive Zero pollution action plan by 2050

T : B ratio used as source identification in Dübendorf



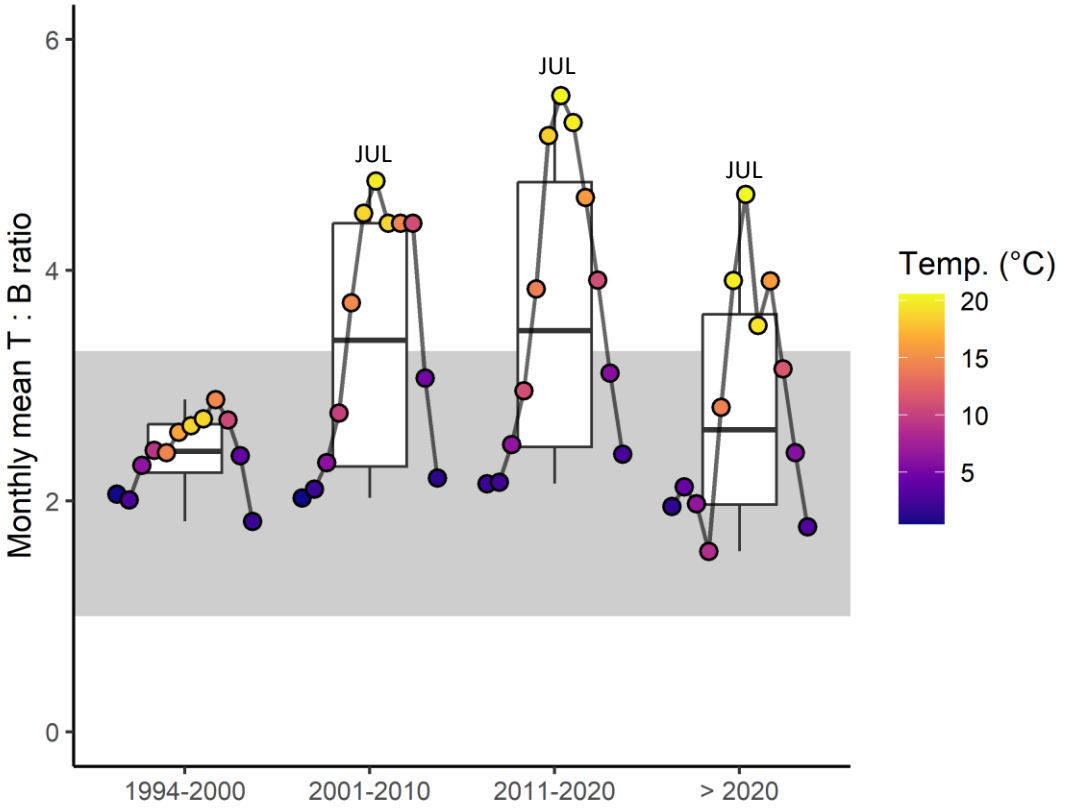
T : B ratio used as source identification in Dübendorf

- Before 2000: dominated by traffic emissions, regardless of the outdoor temperature



T : B ratio used as source identification in Dübendorf

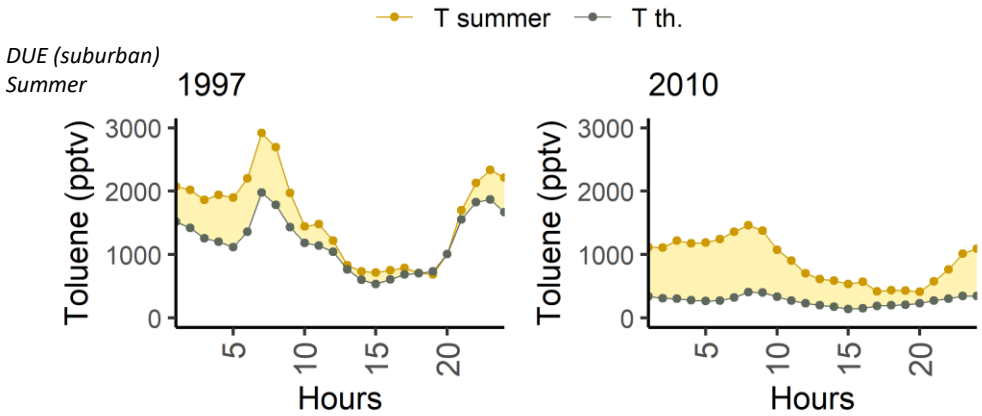
- Before 2000: dominated by traffic emissions, regardless of the outdoor temperature
- After 2000: in the winter dominated by car emissions, in the summer solvent emissions (temperature-dependent source)



Increase of the solvent contribution in the summer

Toluene theoretical concentration estimated for the summer:

- Car emissions contribution: T_{winter} : B_{winter} between 8am and 9am
- Benzene sources: winter ~ summer
- $toluene_{th} = \frac{toluene_{winter}}{benzene_{winter}} . benzene_{summer}$



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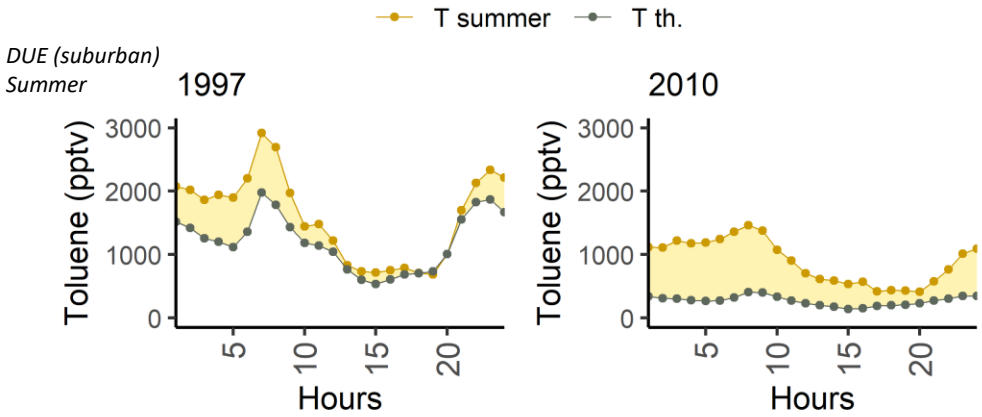
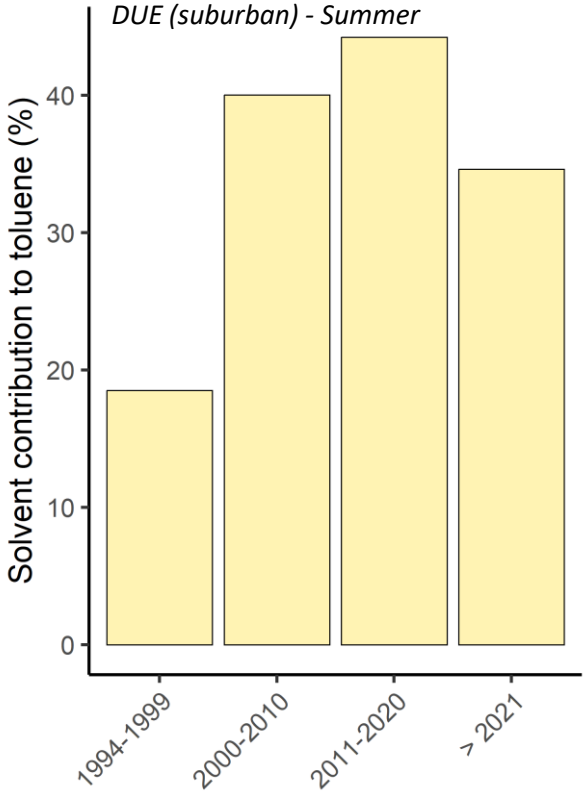
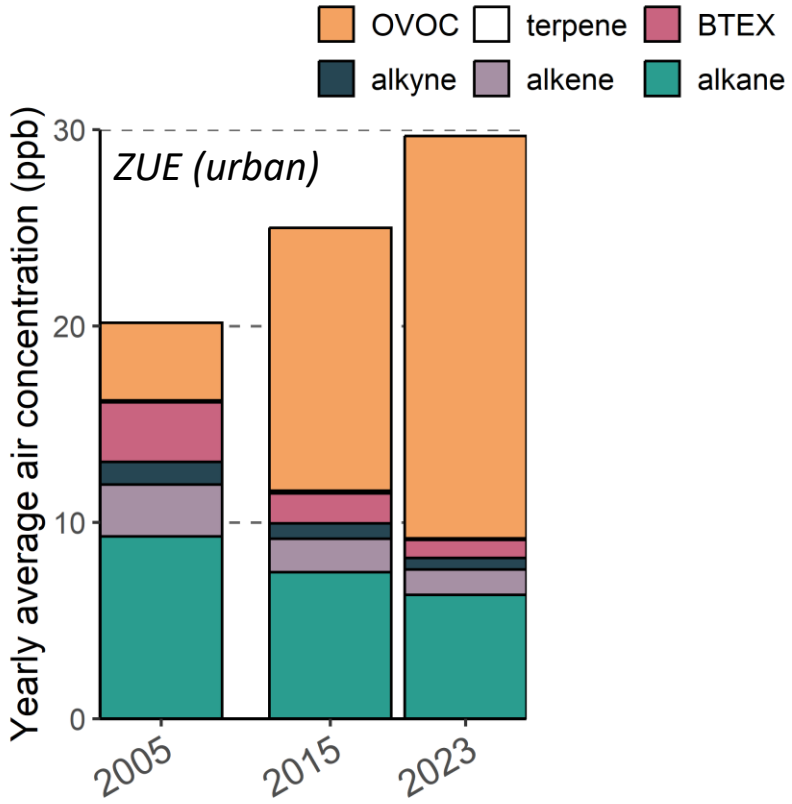




BTEX: A minor contributor to ambient air concentration…

BTEX contribution to total NHMC:

33 % in 1994 at DUE, less than **5 %** today



… but an important player in O_3 production

Ozone formation potential (OFP):

Maximum incremental reactivity (MIR)

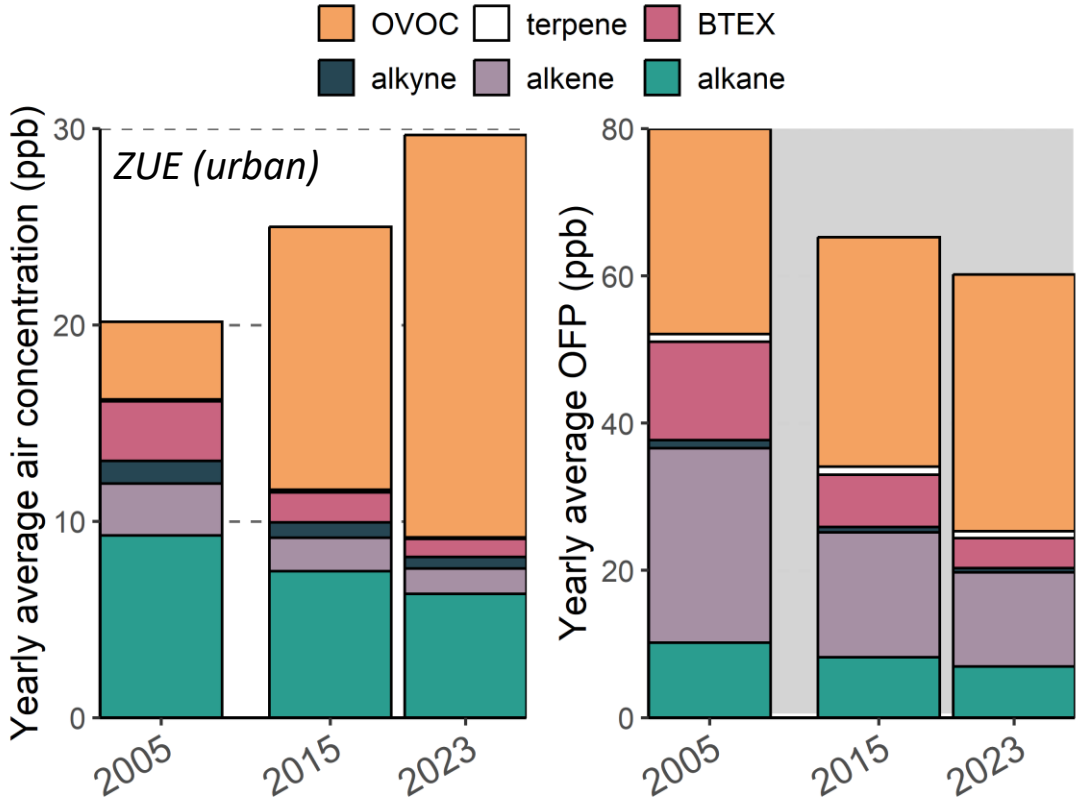
$OFP = [VOC]_i * MIR_i$

Xylene belong to the top 10 of measured VOCs at Zürich with the highest MIR values

(top 3: 1-3-butadiene,

propene, **m-xylene**)

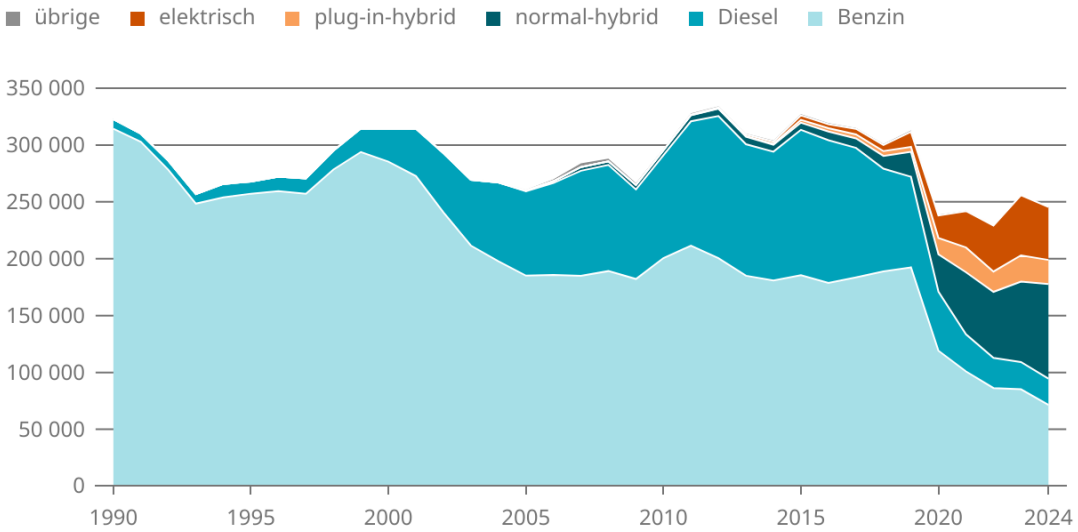
In ZUE, BTEX contributed to **~20 %** (2005) and to **~5%** (2023) to total OFP



Carter (1994), MIR updated values in Carter (2010)

BTEX from car emissions in the future?

New passenger car registrations by fuel type



Hinweis: Elektrische Fahrzeuge werden erst ab 1997 und Hybrid-Fahrzeuge ab 2005 separat ausgewiesen. Davor sind sie in der Kategorie «übrige» enthalten.

Datenstand: 03.01.2025
Quelle: BFS, ASTRA – Neue Inverkehrsetzungen von Strassenfahrzeugen (IVS)

- 1994: 97 % of gasoline cars in Switzerland for passenger car fleet
- 2024: 60 % of gasoline cars

→30 % of new gasoline cars
→20 % of new electric cars

Outlook on BTEX trends and future perspectives

1994 – 2023:
Reduction by 91 % of Benzene + Toluene in DUE

Significant solvent contribution in the summer (> 30 %)

Contribution of the BTEX to ozone potential formation significantly decreased (20 % to 5 %)

→ *How will mobility shift and new air quality directives affect BTEX emissions?*