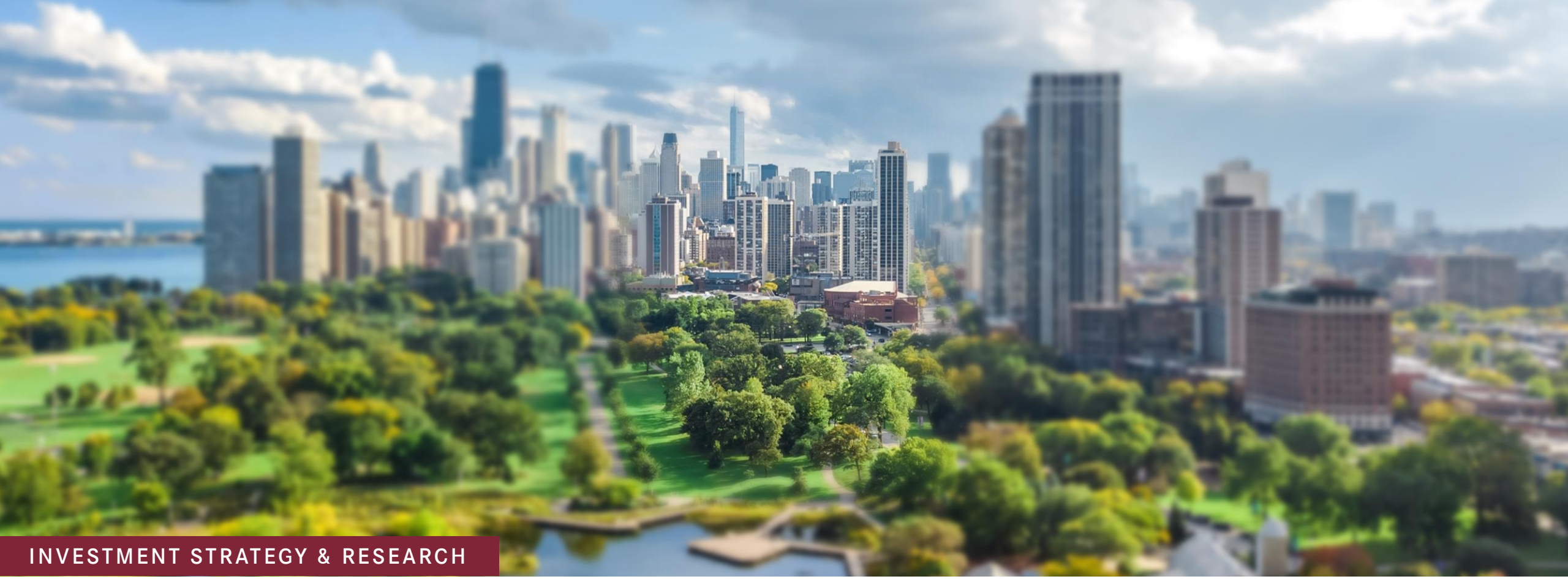
E-CREDA 40’ Research Update

The price of clean air: Quantifying air pollution exposure in real estate investment decisions

By PD Dr. Marcelo Cajias – PATRIZIA SE / IREBS

20th of April
15:00 – 15:40 CET
Online seminar

E-CREDA improves the access to and understanding of available CRE data to facilitate higher quality applied research and more frequent interaction between investors, data providers and academics to achieve data parity with other major asset classes, like stocks and bonds



INVESTMENT STRATEGY & RESEARCH

RESEARCH BRIEF

PD Dr. Marcelo Cajias
M.Sc. Rebecca Restle

The price of clean air – Quantifying air pollution exposure in real estate decisions

PATRIZIA

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PATRIZIA

Air pollution – a hidden threat in Berlin?

Source: PATRIZIA, Google

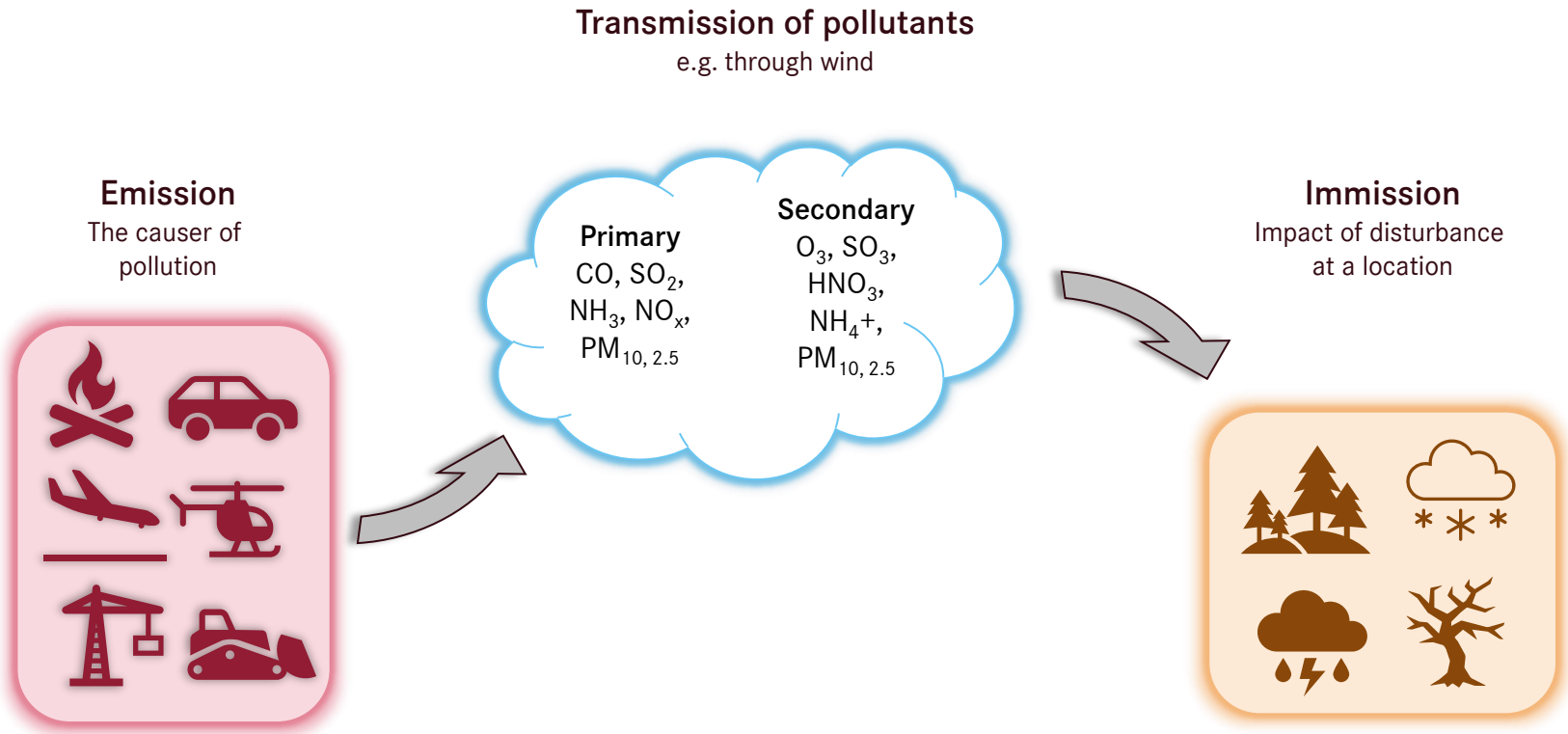
Air pollution – a hidden threat in Berlin?

Best air quality

Worst air quality

Source: PATRIZIA, Google

Air pollution: What is it and where it comes from?



Source: PATRIZIA

Why does air pollution matter and what are the effects on health and environment?

Risk and size of particulates

- For particulates: health risks can be caused by the dust itself as it can damage the organs depending on the size.
- The bigger the particle, the more likely it is for the dust to be exhaled or stay in the nose.
- The smaller the particle, the more dangerous, as they can penetrate deeper organs, e.g., lungs and bronchial tubes.
- Heavy metals can adhere to the surface of the particles, which would produce toxic air. Short-term studies showed higher risks of hypertension and heart rhythm variability for high concentrations.

In 2016, it was estimated that ~37,000 premature deaths in Germany were attributable to air pollution (WHO 2022)

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Causality and evidence

- Causality is not always conclusively evident: It is important to note that even if most epidemiological studies found significant relationships between certain diseases and air pollution.
- Harmfulness of each component is not always possible to understand as there is exposure to a combination of substances (Brook et al. 2010).
- Fine particulates PM2.5 have the most severe health effects, and short- and long-term exposure have effects on the human body, European Environment Agency (EEA 2019).

Long-term studies revealed a serious risk of organ damage, but also short-term effects on the cardiovascular system can occur

Source: PATRIZIA

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We only touch the surface

- Greenhouse gas CO2 is a prominent contributor to climate change. But pollutants like NO2 or SO2 also cause effects on ecosystem through acid rain (US EPA 2016).
- Black carbon is relevant: High warming potential due to its ability to absorb sunlight. it can influence regional cloud formation and rainfall patterns.

Environmental impacts include acid rain and contribution to the greenhouse effect

Source: PATRIZIA

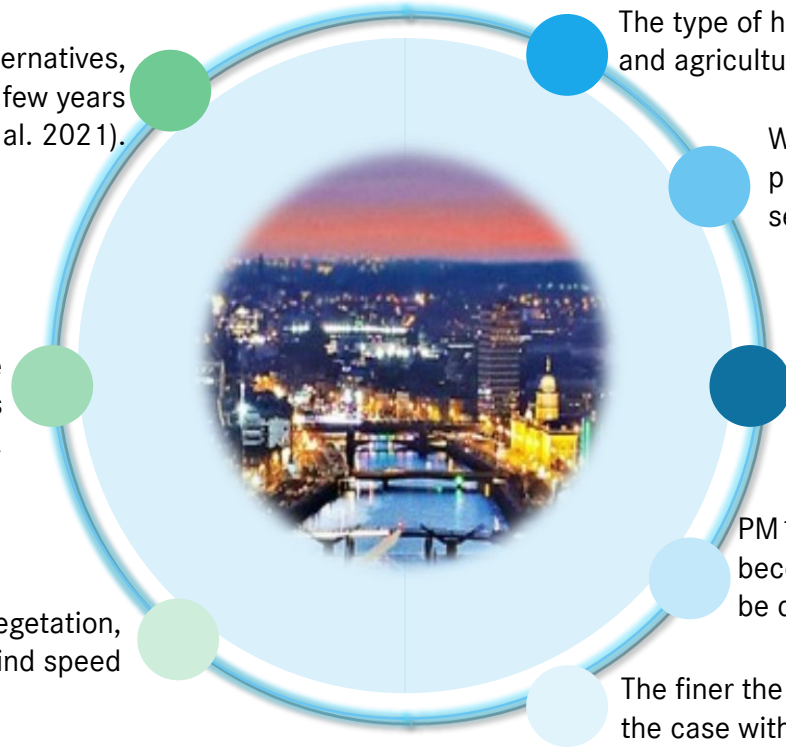
The causes of high pollution levels reveal where we need to act

Mitigation chances

With the rise of the electric-powered car or other alternatives, traffic will have a smaller share in air pollution in the next few years (Eichlseder et al. 2021).

The European Commission (2019) claims that half of particulate matter pollution in the EU comes from heating systems. This points to seasonal variations in concentration levels.

Responsible for decreasing pollution concentrations are vegetation, distance to emission sources, altitude, and wind speed



Negative effects

The type of heating has a negative impact, as do construction sites and agriculture.

Wind speed can have a strong influence, followed by air pressure, humidity, and temperature, depending on the season (Yang et al. 2020).

The combustion of fuels mainly causes PM10 and NO2, in addition to the chemical reaction of oxygen gas with ambient nitrogen gas.

PM10 is negatively correlated with humidity since the particles become heavier as they absorb water and can therefore no longer be distributed (Rumaling et al. 2021).

The finer the particle size, the less affected by humidity, which is the case with PM2.5 (Munir et al. 2017).

Source: PATRIZIA

The willingness to pay for clean air – international empirical evidence

The hedonic regression revealed that in the city of Nantes, noise has a significant negative impact on rent prices, air pollution does not. Pollution values were derived from an *Atmospheric Dispersion Modelling System* (Le Boennec and Salladarré 2017) .

Sun and Yang (2020) analyzed the behavior of $PM_{2.5}$ on housing prices in several Chinese cities. They conclude that there is a negative relationship between $PM_{2.5}$ and housing prices and that cities with rapid growth and increased industrial activity experience a real estate boom.

In Quito, Ecuador Borja-Urbano et al. 2021 found a significant negative relationship between housing price and air pollutants like CO, PM2.5, and NO2 values. Based on their results an increase of 1% of PM2.5 leads to a reduction of 15 US$/m2 ceteris paribus.

Source: PATRIZIA

Our statistical approach: everything is related to everything else, but near things are more related than distant things

Measurement of the dynamics behind the distribution of pollutants is complex

Approach 1: Use physical and chemical processes to calculate the distribution starting from the pollution source (e.g., Knote et al. 2015).

Approach 2: estimate values by applying geoinformatic and geostatistical interpolation methods on the measurement network through the city (Deligiorgi and Philippopoulos 2011).

The selected method: Spatial interpolation

"[...] the process of using points with known values to estimate values at other unknown points" (QGIS Project 2022).

The transformation equation

$$\hat{X}(s_0) = \sum_{i=1}^{N} \lambda_i X(s_i)$$

The predicted position is indicated by s_0. N is the number of measured values and $X(s_i)$ is the observed value at Position i, with λ_i as an unknown weight.

More weight λ_i is given to points closer than those located further away; this is known as the inverse distance weighting.

Thus, the weighting is solely dependent on the distance to the predicted location, and the output is a surface raster with weighted averages.

Source: PATRIZIA

The hedonic model for isolating price differentials to changes in air quality

The semiparametric hedonic model

$$log(Rent_{i,t}) = \sum_{p=1}^{P} s_p\left(log(X_{p,i,t})\right) + \sum_{b=1}^{B} \beta_b \cdot X_{b,i,t} + \sum_{m=1}^{M} s_m\left(log(X_{m,i,t})\right) + \sum_{d=1}^{D} s_d\left(log(X_{d,i,t})\right) + \sum_{l=1}^{L} s_l\left(X_{l,i,t}\right) + error$$

- Interpolated pollutant variables
- Binary hedonic characteristics
- Metric hedonic characteristics
- Distance to relevant amenities
- Socioeconomic variables
- Estimation error

Variable	Unit	Mean 2018	Mean 2021
Refurbished	Binary	0.18	0.13
Built-in kitchen	Binary	0.51	0.48
Balcony	Binary	0.63	0.63
Parking	Binary	0.22	0.21
Elevator	Binary	0.40	0.49
Terrace	Binary	0.13	0.12

The apartment contains a bathtub, a built-in-kitchen, a balcony, but neither a parking slot nor an elevator or a terrace.

Source: PATRIZIA, Valuemarktdaten

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- **Metric hedonic characteristics**
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Variable	Unit	Mean 2018	Mean 2021
Rent	EUR/month	788.41	788.31
Size	sqm	70.88	66.31
Rent sqm	EUR/sqm	10.94	11.68
Age (relative to 2017)	Integer	63.6	57.77

An average apartment in 2018 has an asking rent of 10.94 EUR/sqm/p.m. and is 64 years old relative to 2017.

Source: PATRIZIA, Valuemarktdaten

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$$error \quad \text{Estimation error}$$

Variable	Unit	Mean 2018	Mean 2021
City centre distance	Km.	7.90	7.60
Bus stop	Km.	0.19	0.19
Post box	Km.	0.21	0.19
Bar	Km.	0.48	0.53
School	Km.	0.32	0.33
Fast food	Km.	0.31	0.31
Park	Km.	0.27	0.27
Restaurant	Km.	0.23	0.25
Café	Km.	0.37	0.39
Playground	Km.	0.19	0.18
Supermarket	Km.	0.28	0.29
Atm	Km.	0.54	0.55

On average, it is 7.9 km away from the CBD, 370 meters to the nearest café and 280 meters to the closest supermarket. The bus station is 190 m away, whereas the nearest school is located 320 meters nearby.

Source: PATRIZIA, Valuemarktdaten

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Variable	Unit	Mean 2018	Mean 2021
Purchasing Power	EUR/HH/ZIP	36.2k	38.3k

Source: PATRIZIA, Valuemarktdaten

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Variable	Unit	Mean 2018	Mean 2021
PM10	$\mu m/m^3$	17.35	14.32
NO2	$\mu m/m^3$	25.00	16.37

Source: PATRIZIA, Valuemarktdaten

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Variable	Unit	Mean 2018	Mean 2021
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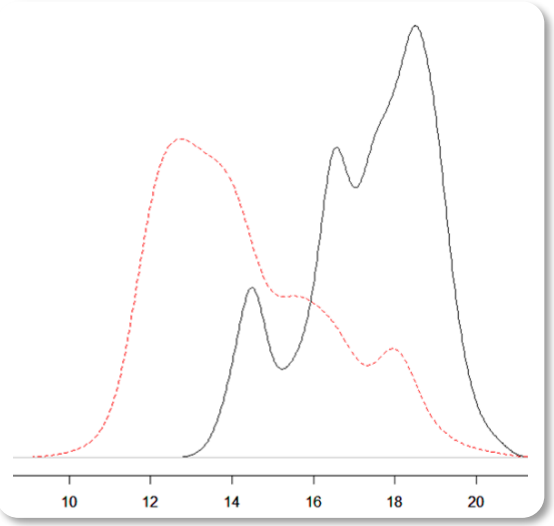
PM10 concentration

2018 and 2021



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NO2 concentration

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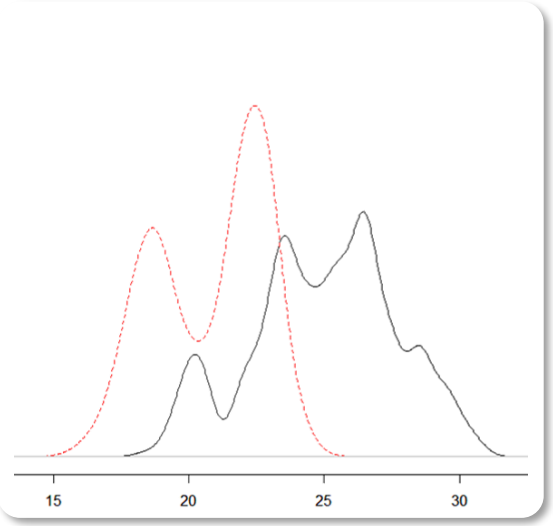

Source: PATRIZIA, Valuemarktdaten

The hedonic model explains the willingness to pay for clean air

The hedonic model

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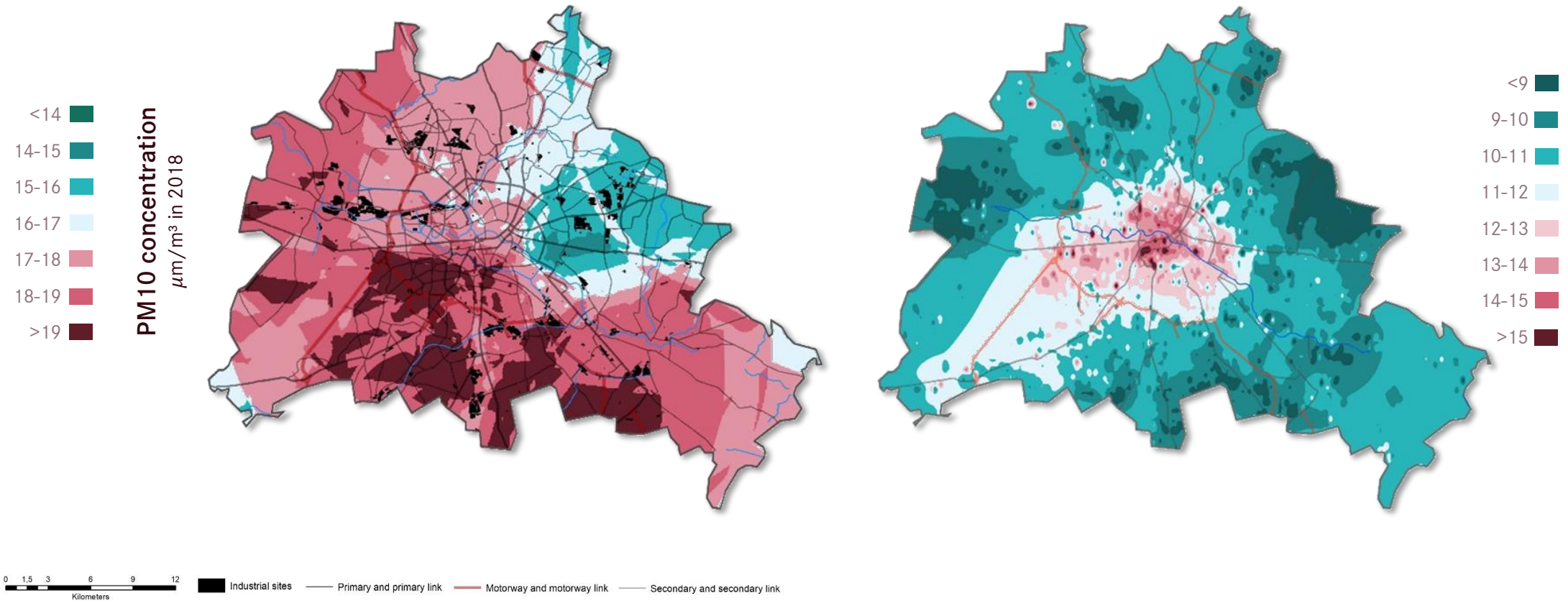
Source: PATRIZIA

Particulate matter and rents 2018



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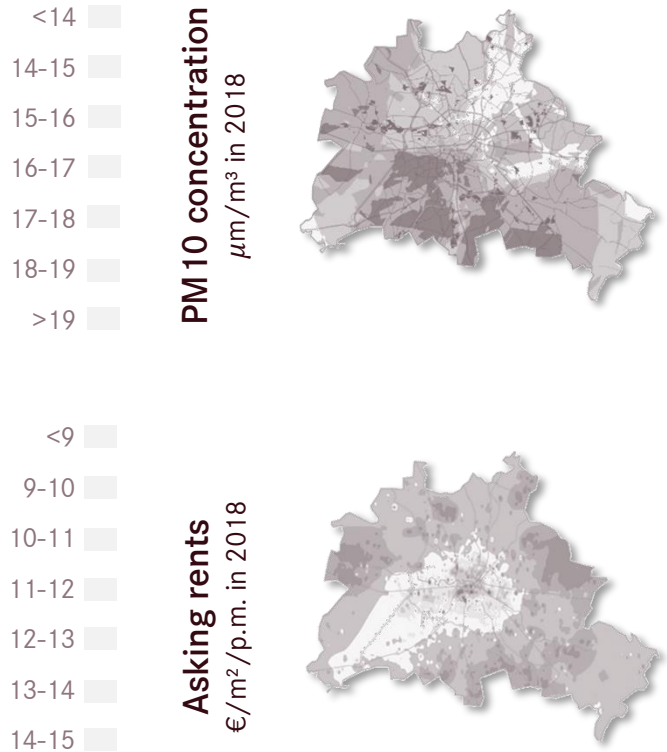
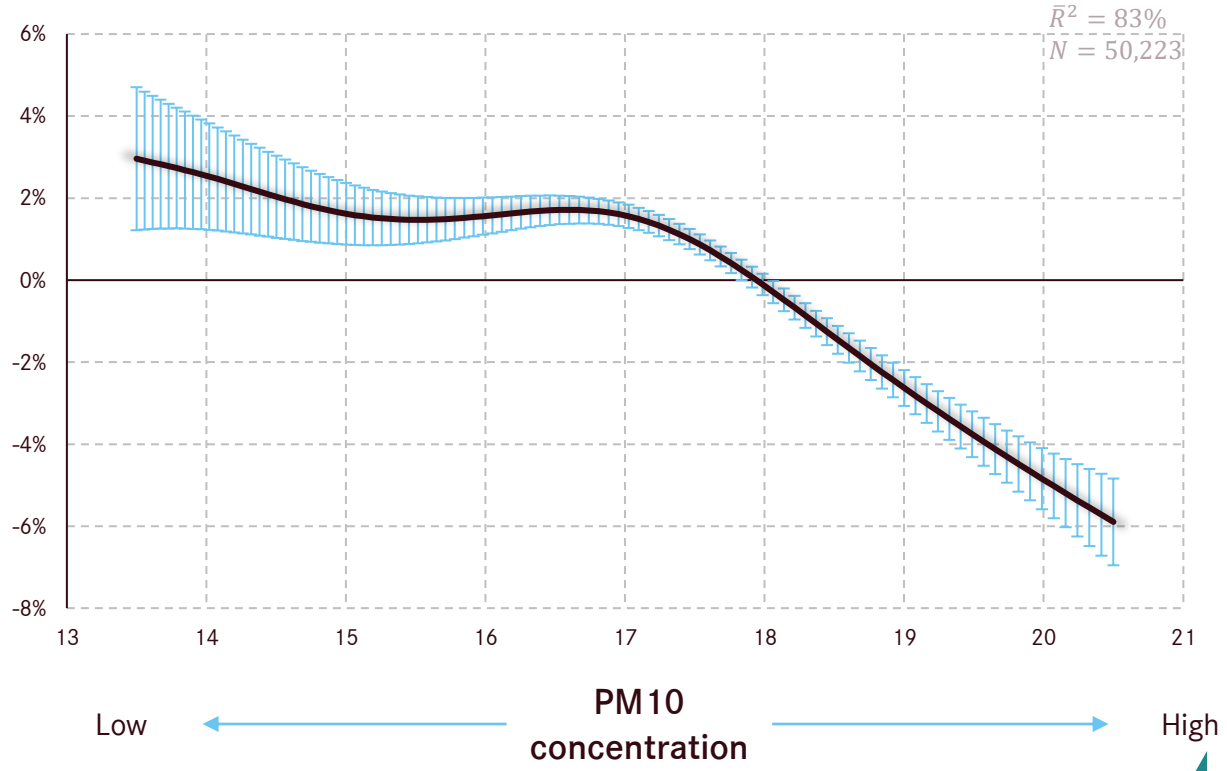
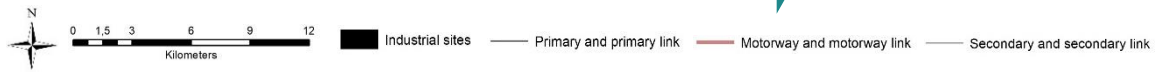


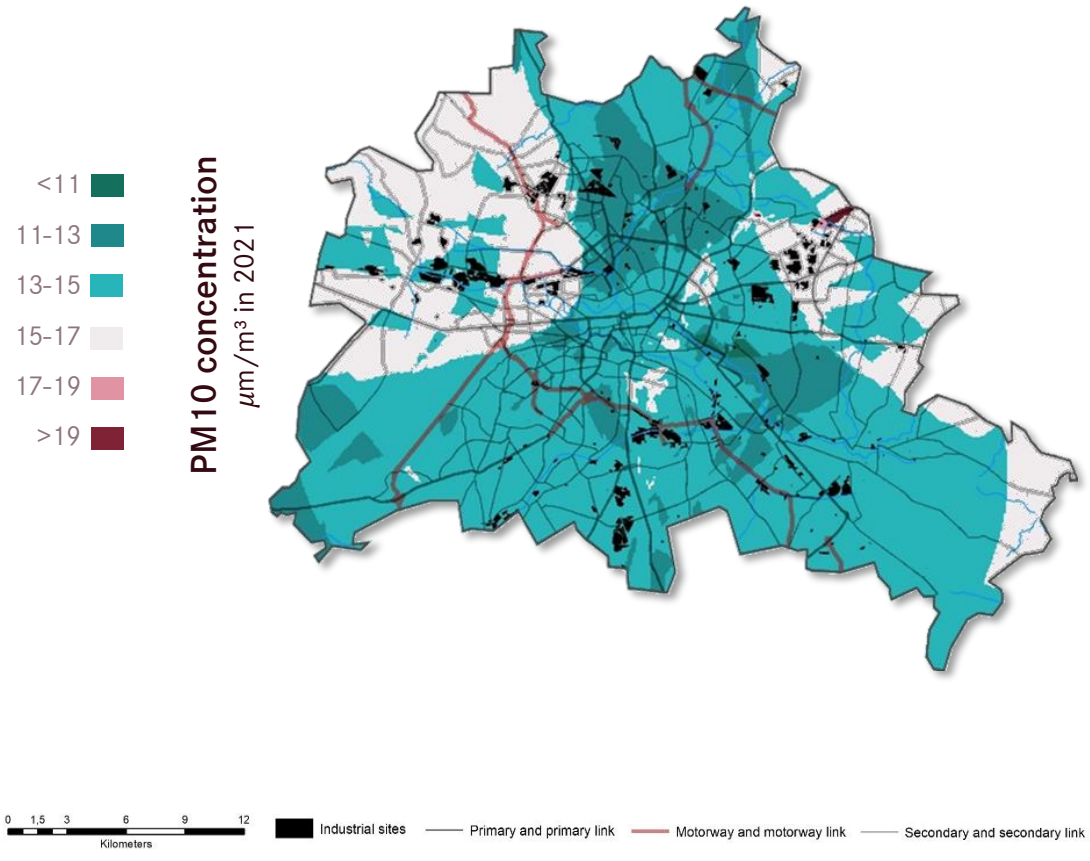


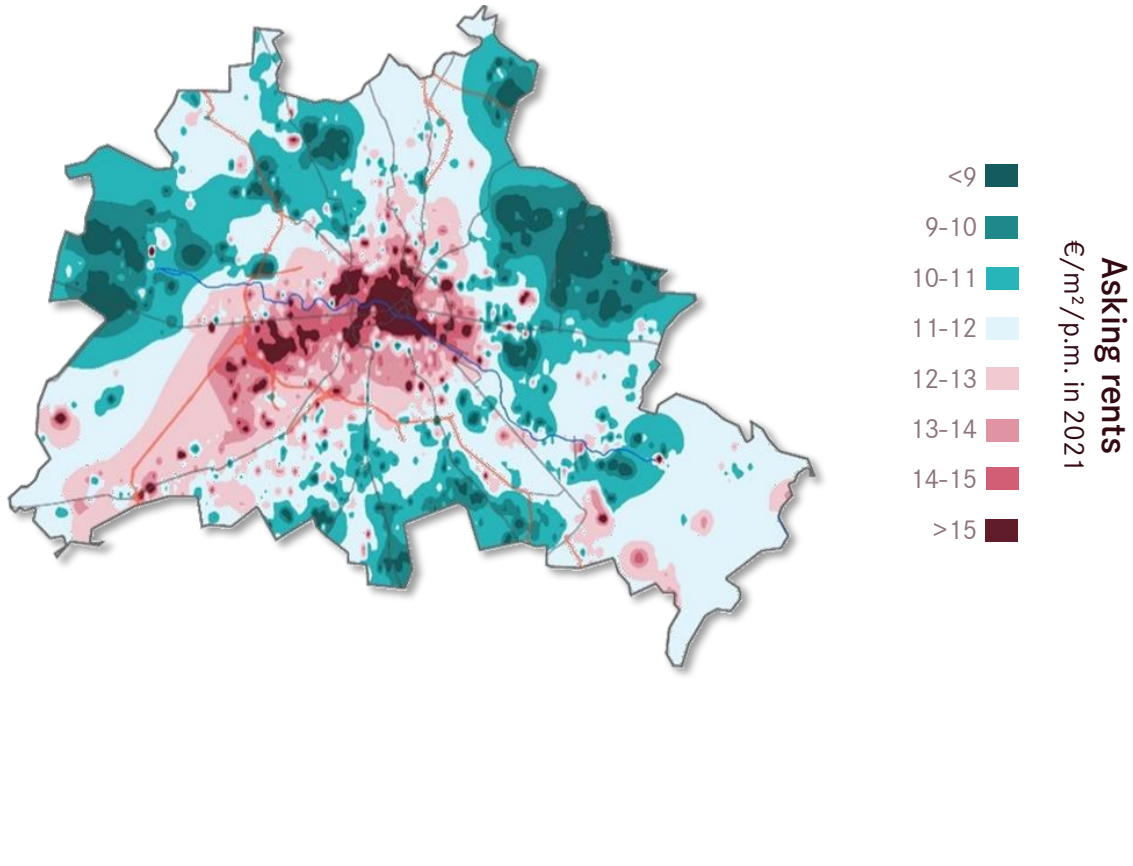
The rental income of apartments located in areas with low pollution was 2% higher than market average. Assets in areas with high pollution were offered at a discount between –2% and 6% in comparison with average assets.



Source: PATRIZIA, Valuemarktdaten

Particulate matter and rents 2021





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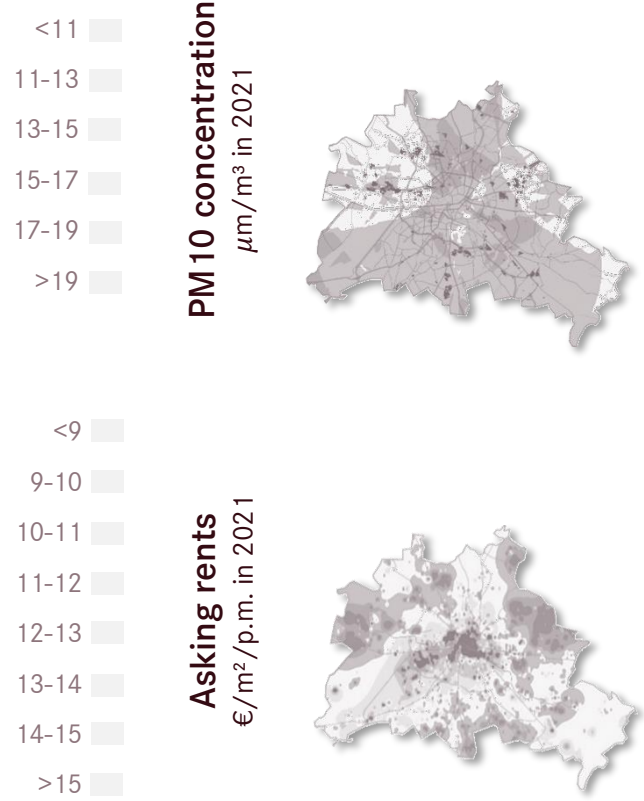
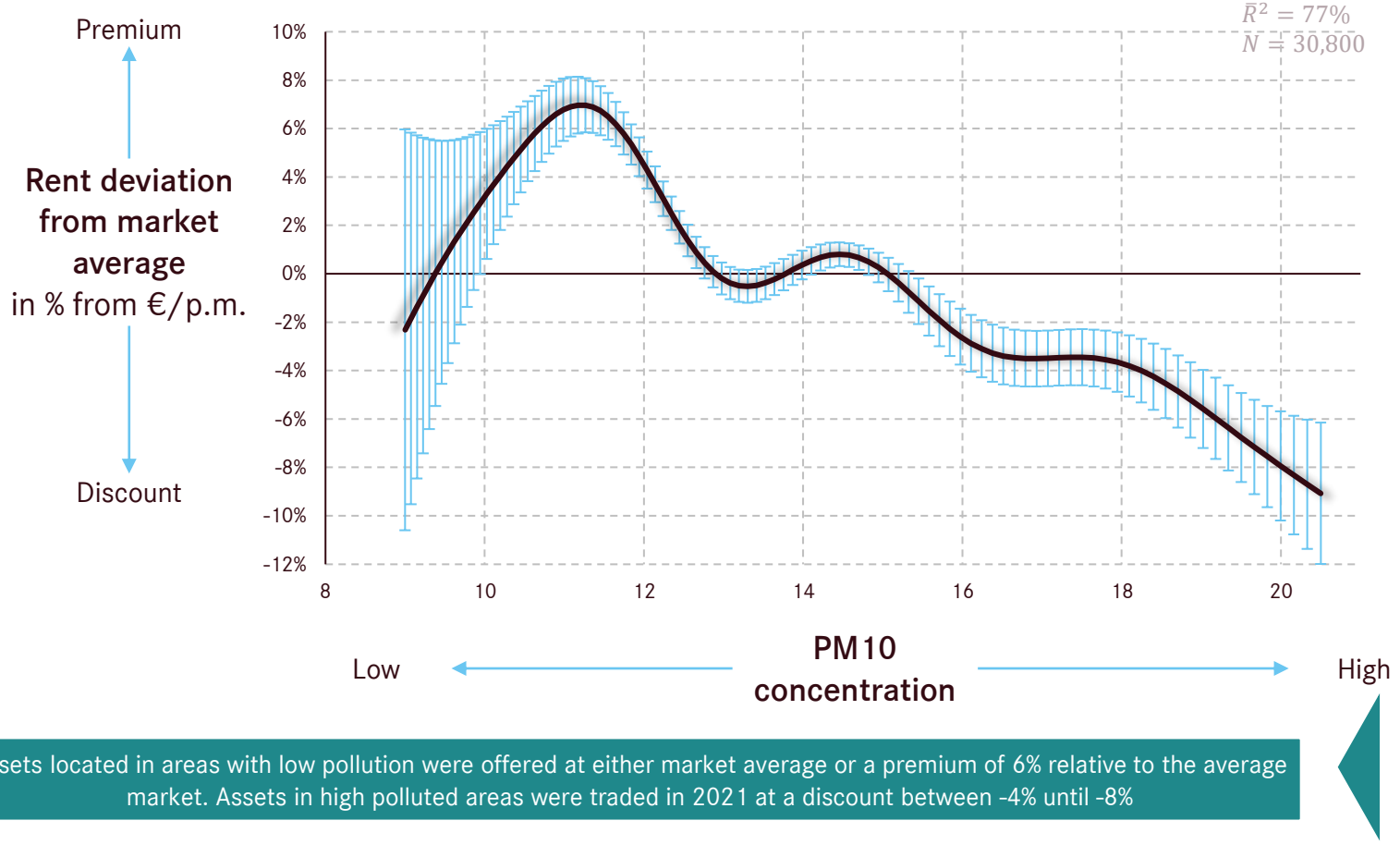
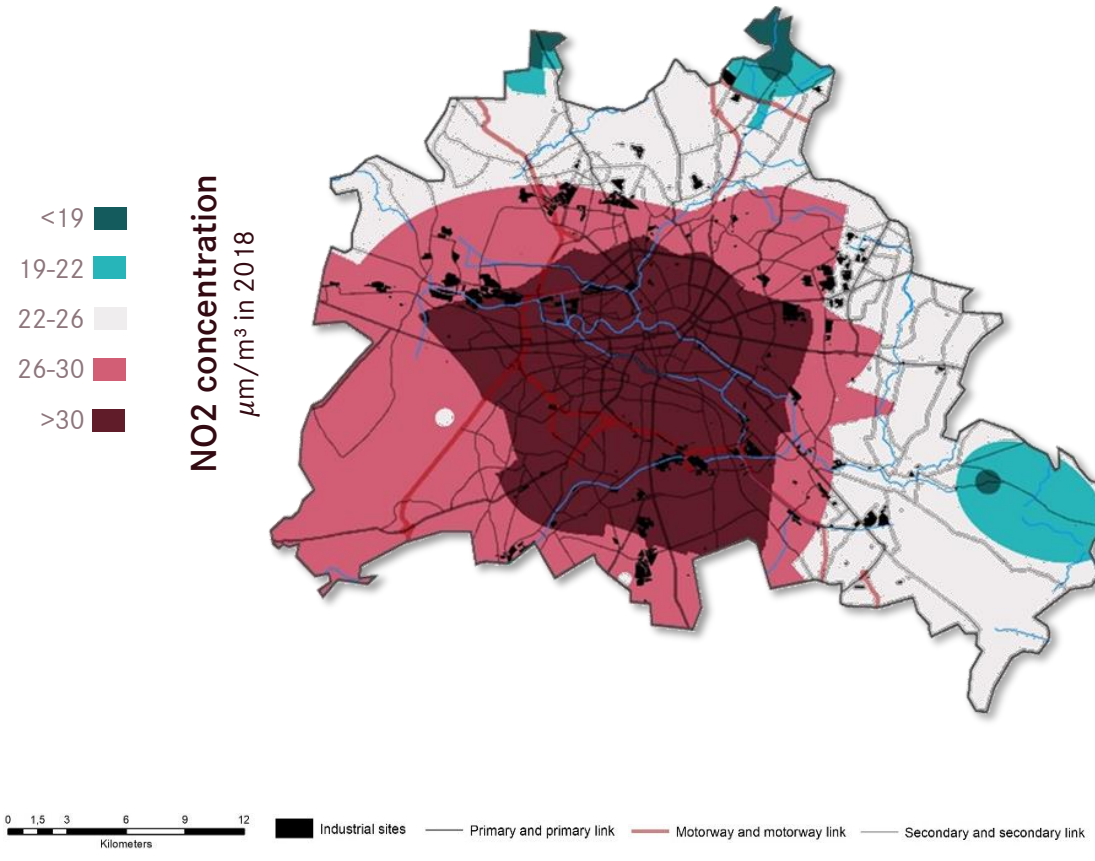


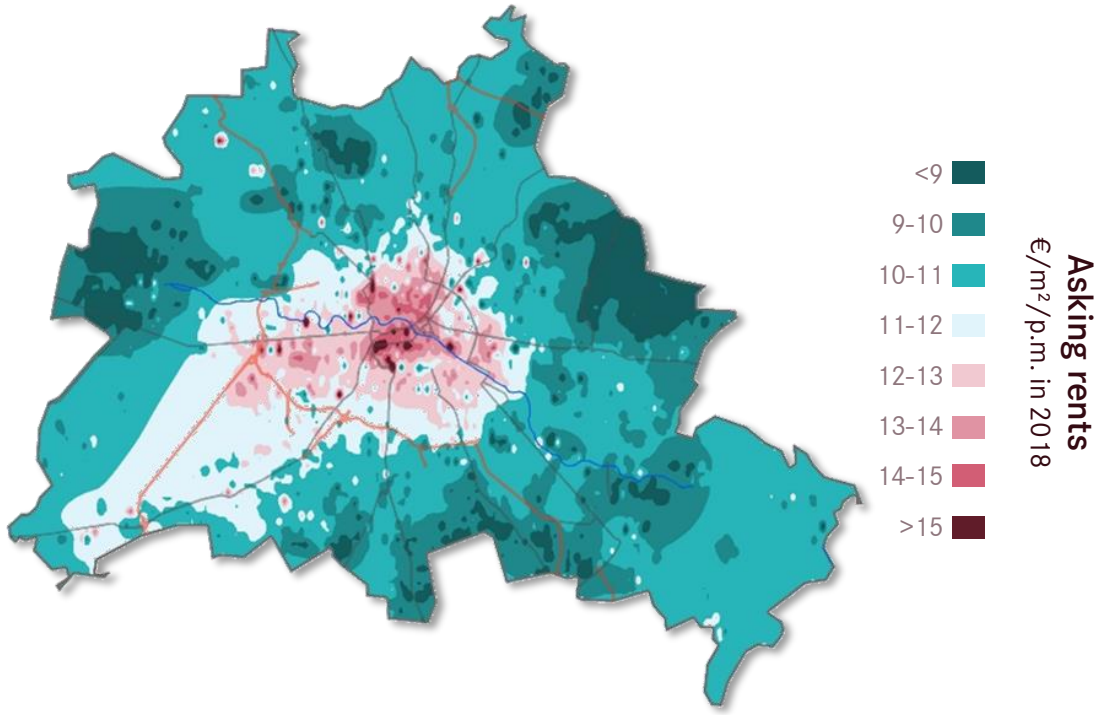


Assets located in areas with low pollution were offered at either market average or a premium of 6% relative to the average market. Assets in high polluted areas were traded in 2021 at a discount between -4% until -8%

Source: PATRIZIA, Valuemarktdaten

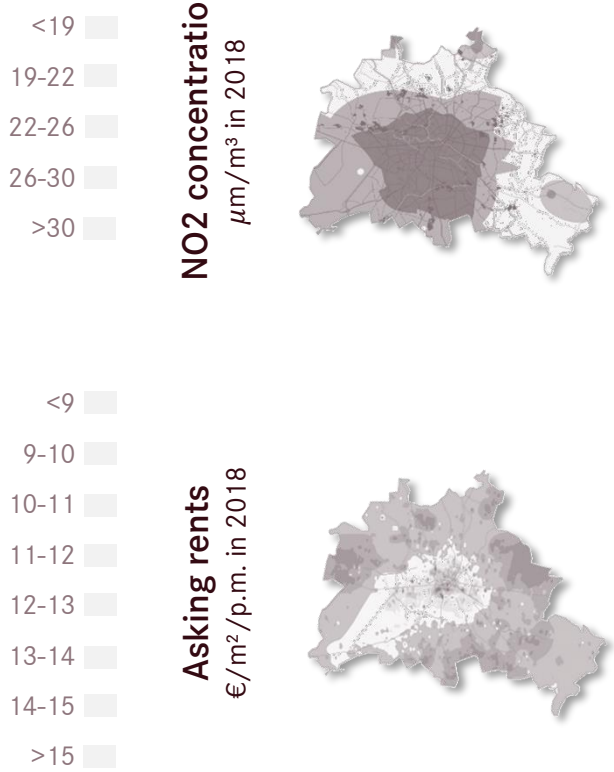
Nitrogen dioxide and rents 2018

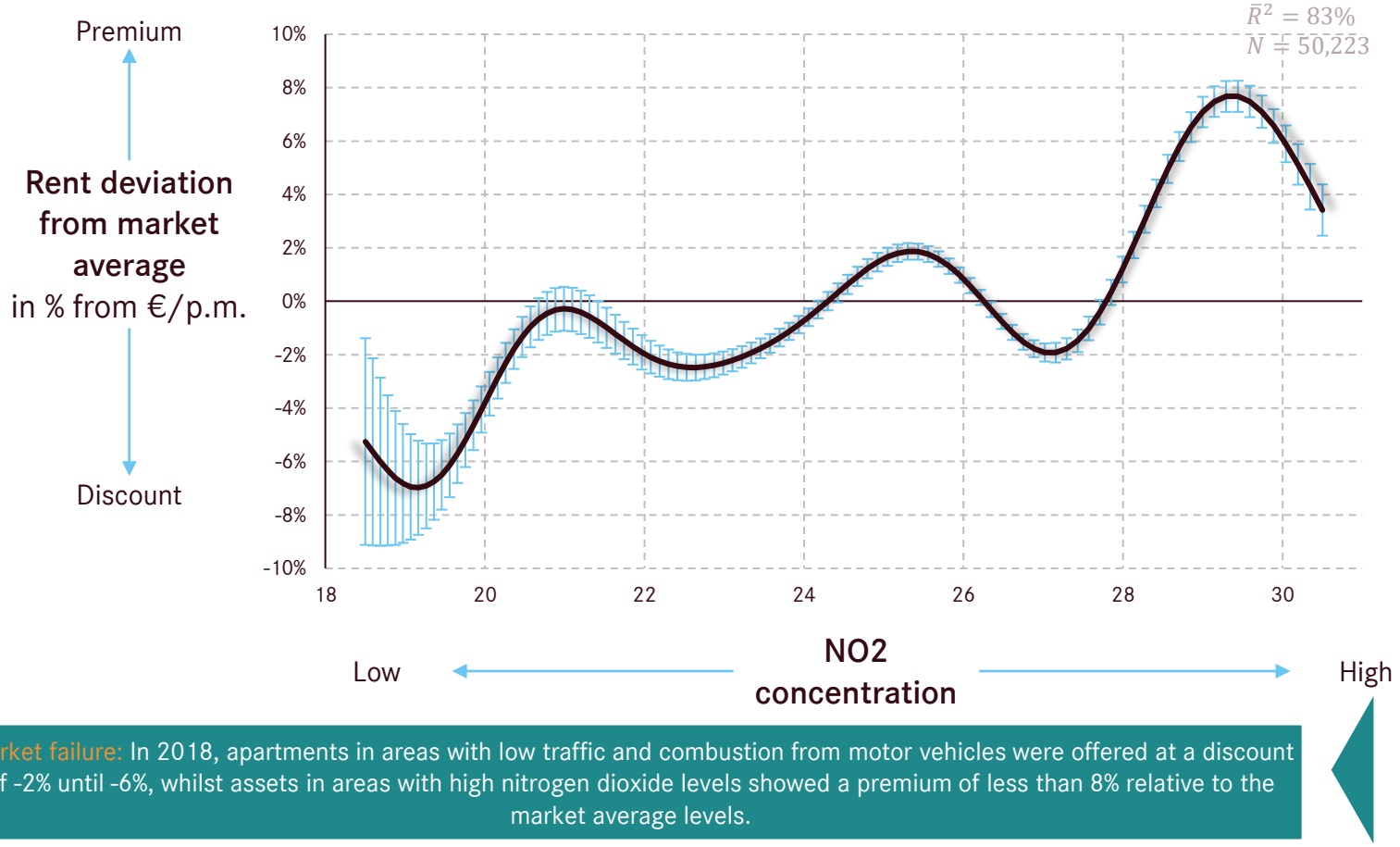




Source: PATRIZIA, Valuemarktdaten

Nitrogen dioxide and rents 2018

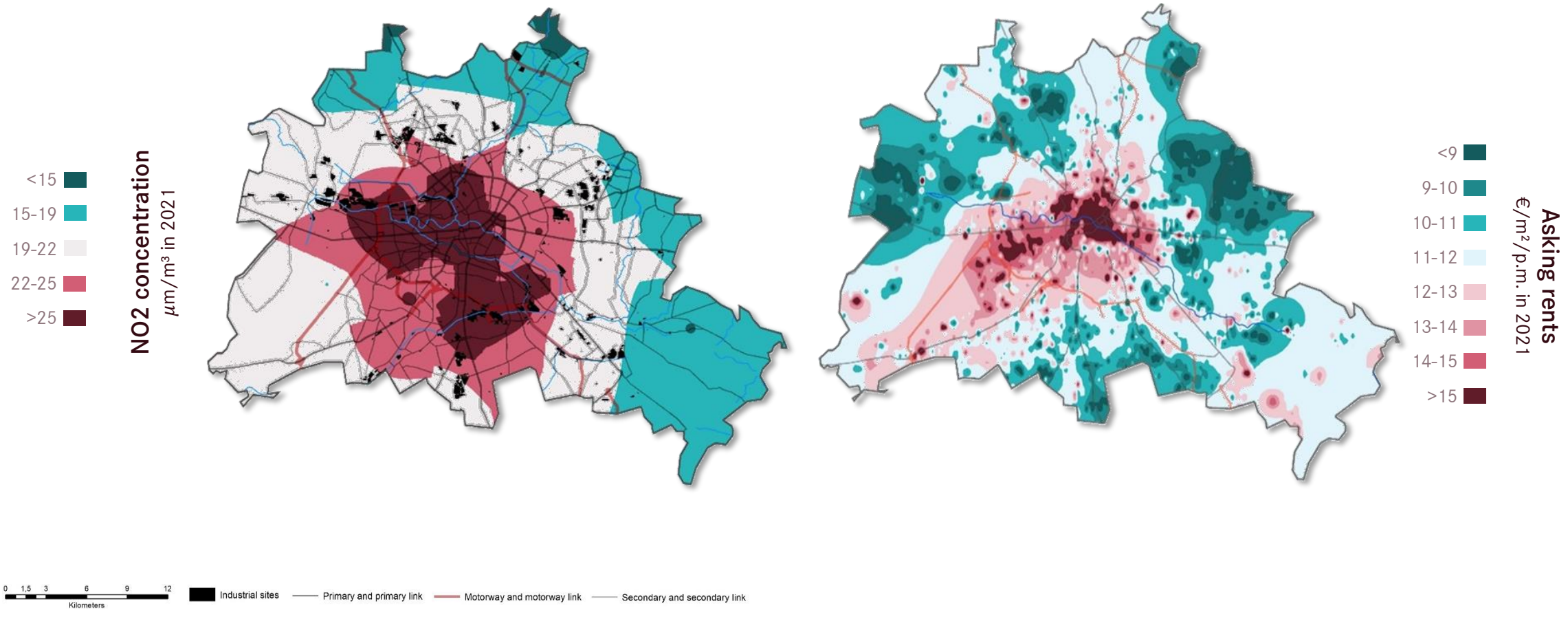




Market failure: In 2018, apartments in areas with low traffic and combustion from motor vehicles were offered at a discount of -2% until -6%, whilst assets in areas with high nitrogen dioxide levels showed a premium of less than 8% relative to the market average levels.

Source: PATRIZIA, Valuemarktdaten

Nitrogen dioxide and rents 2021



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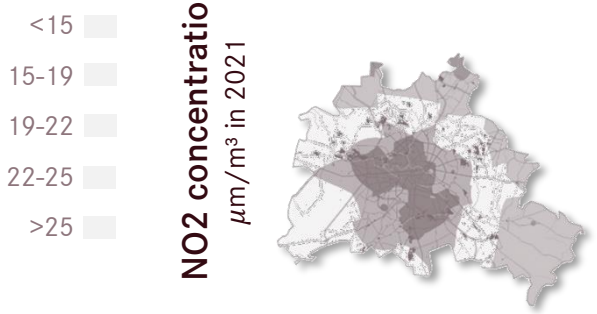
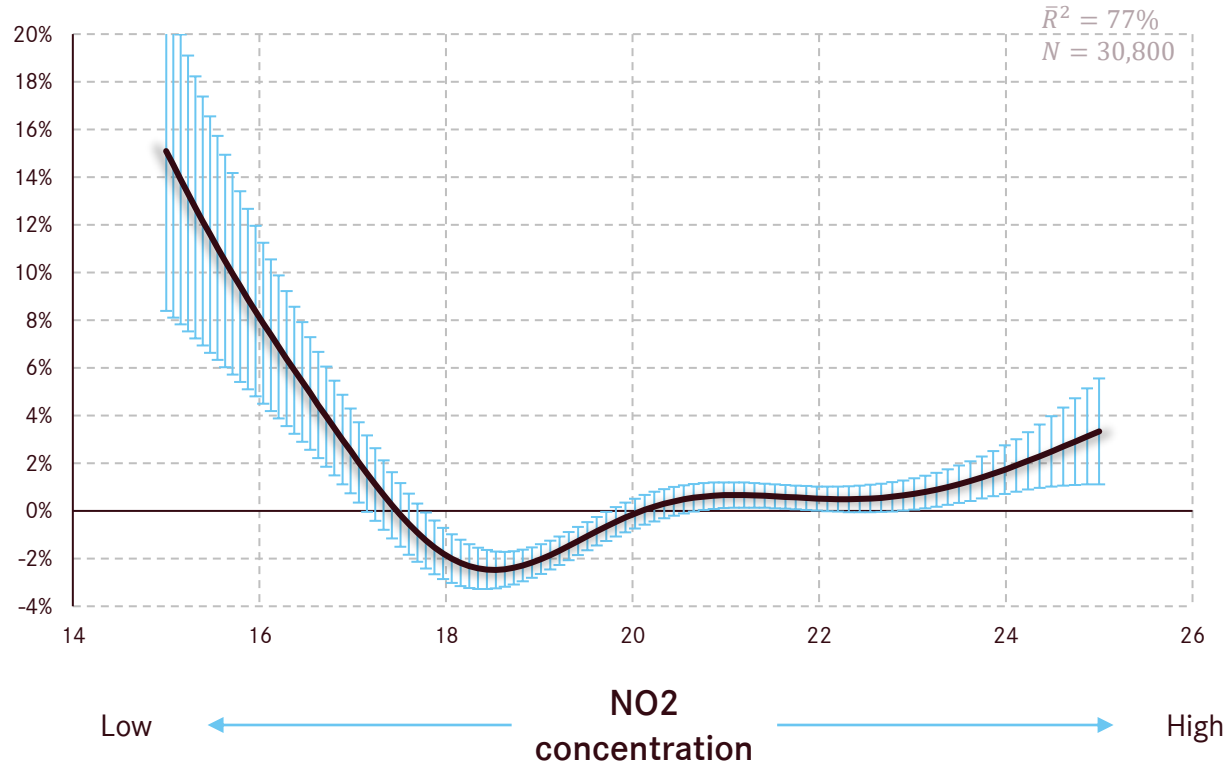
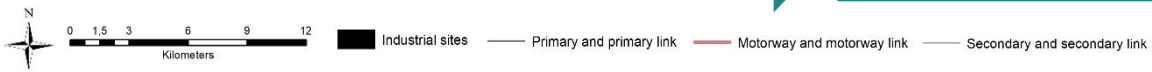
Nitrogen dioxide and rents 2021





Market correction: In 2021, areas with low traffic and combustion from motor vehicles were offered at a premium of up to 14% relative to the market average.



Source: PATRIZIA, Valuemarktdaten

Key takeaways

1. Short- and long-term exposure to air pollutants poses a serious threat to human health, wellbeing, and the environment
2. Air quality matters when optimizing rental income in a residential portfolio
3. In Berlin, air quality has improved since 2018 pointing to a change in human behaviour and mobility
4. The econometric models explain more than 80% of the variation of rents and identify air quality as an essential influencing factor
5. Tenants are willing to pay up to 5% higher rents for assets located in areas with low pollution levels

PD Dr. Marcelo Cajias

Head of Data Intelligence

M.Sc. Rebecca Restle

GeoData Scientist

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E-CREDA 40’ Research Update

The price of clean air: Quantifying air pollution exposure in real estate investment decisions

By PD Dr. Marcelo Cajias – PATRIZIA SE / IREBS

20th of April
15:00 – 15:40 CET
Online seminar

E-CREDA improves the access to and understanding of available CRE data to facilitate higher quality applied research and more frequent interaction between investors, data providers and academics to achieve data parity with other major asset classes, like stocks and bonds