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Energy Efficiency and Real Estate

The Green Premium

ERES, Milano – 22th-25th June 2022

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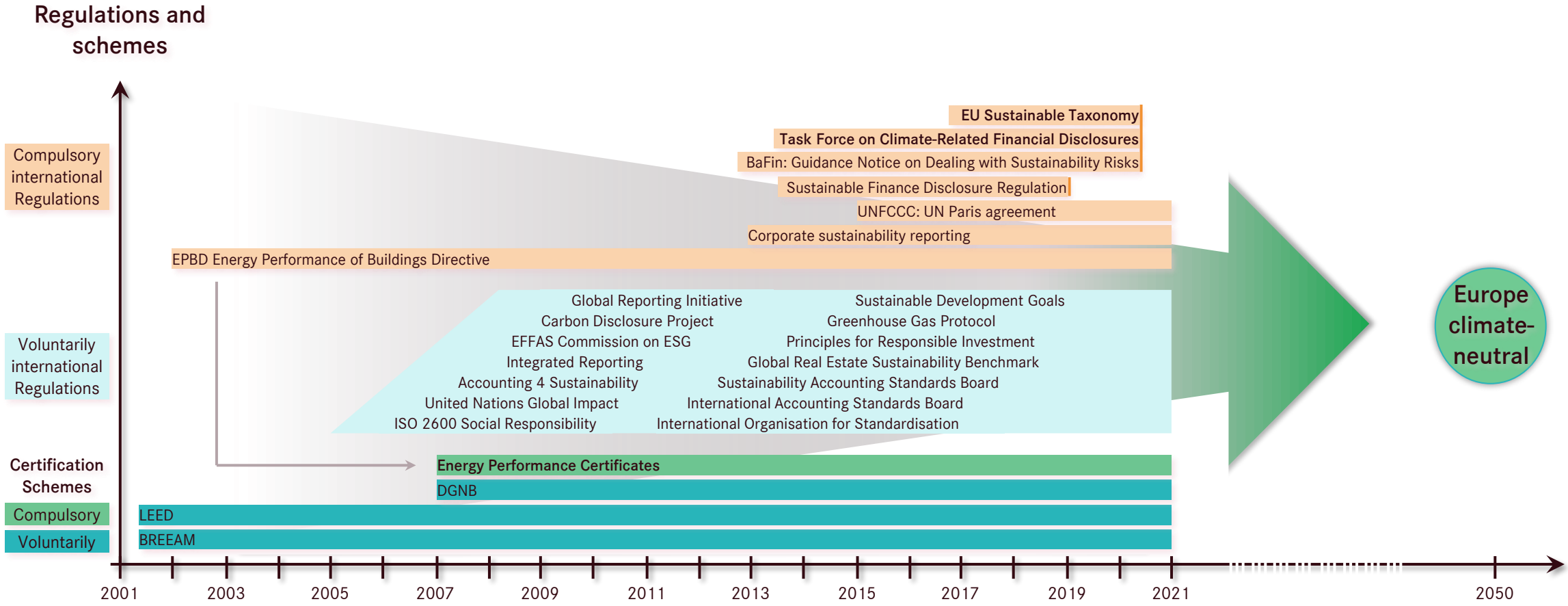
Agenda

1. **Introduction: Sustainability in Real Estate**
2. **Database: Descriptive Statistics**
3. **Generalized Additive Models: Predicting Apartment Rental Prices**
4. **Empirical Results: Model Performance and Willingness to Pay**

Sustainability in the real estate industry: Quo vadis

The path to follow is clear: we will need to ***Identify → Adapt → Change*** our economic activities



Source: PATRIZIA, M. Cajias, D. Piazolo, (2013); K. Kholodilin, C. Michelsen, (2014); & M. Cajias, F. Fuerst, S. Bienert, (2019)

Energy demand & performance certificates are the core control instrument

Clear goal: increase transparency within investment decisions in providing buyers and occupiers detailed information about the energetically quality of the building and possible energy-saving potential

EU Sustainable Taxonomy

Criteria for companies and investors to determine whether an economic activity is “environmentally sustainable”

Goals

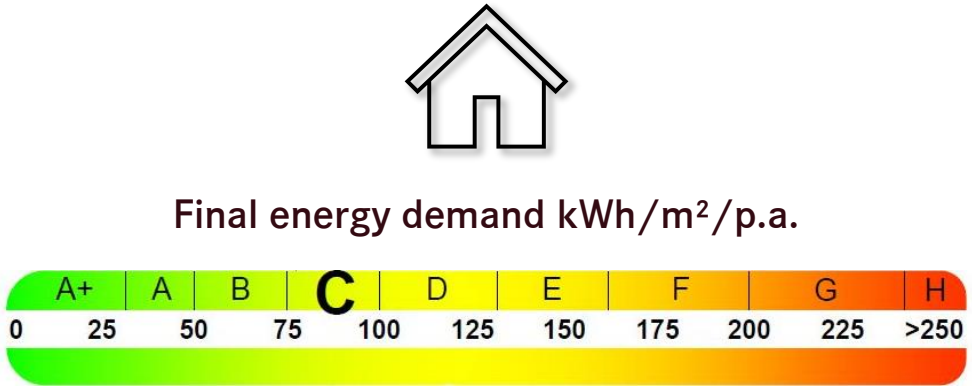
- Mitigation
- Adaptation
- Usage & protection of resources
- Transition to circular economy
- Pollution prevention
- Protection of ecosystems

Impacted activities	Control instruments
New buildings	Primary energy demand ≤10 % than threshold set for the nearly zero-energy building, e.g. Germany ≤ 50 kWh/m²/p.a.
Renovation	Savings in primary energy demand of at least 30 %
Energy equipment	Installation, maintenance or repair of energy efficiency equipment and charging stations.
Electric charging stations	
Measurement of energy	Measuring, regulation and controlling energy performance of buildings
Renewable energy	Installation of renewable energy technologies
Acquisition of buildings	Buildings built before 31/12/2020, the building has at least an EPC class A *or* belongs to the top 15% of the national or regional building stock expressed as operational Primary Energy Demand.

Source: PATRIZIA, M. Cajias, D. Piazolo, (2013); K. Kholodilin, C. Michelsen, (2014); & M. Cajias, F. Fuerst, S. Bienert, (2019)

Energy consumption in real estate in simple words

How to interpret an energy performance certificate?



100 kWh/m²/p.a.

100 m²

= **667** Lightbulbs

≈15 kWh/p.a.

= **100** TVs

≈100 kWh/p.a.

A house with 100 m² and an energy consumption of 100 kWh/m²/p.a. consumes on average the same amount of energy as 100 TVs *or* 667 lightbulbs per year.

Source: Based on 15 kWh/1000 hours per year, November 2021

Theoretical and empirical evidence: The capitalisation of energy efficiency in rents

Scientific studies on the topic "Green premium" in Europe

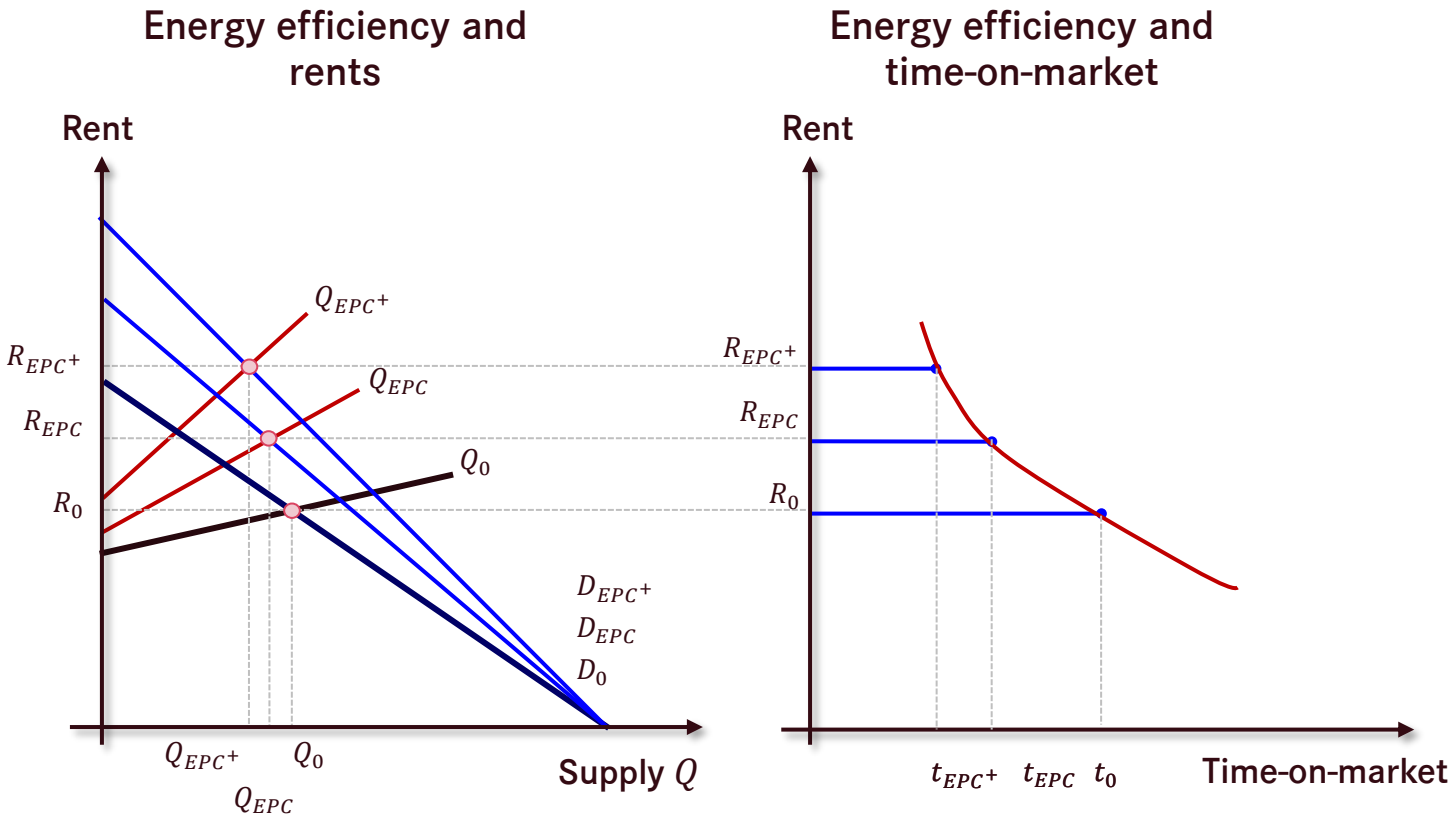
NL	D. Brounen, N. Kok, (2010) & N. Kok, M. Jennen, (2012)
IE	M. Hyland, R.C. Lyons, S. Lyons, (2013)
AT	European Commission, DG Energy, (2013)
FR	European Commission, DG Energy, (2013)
UK	F. Fuerst, P. McAllister, A. Nanda, P. Wyatt, (2015)
PO	A. Ramos, A. Pérez-Alonso, S. Silva, (2015)
Wales	F. Fuerst, P. McAllister, A. Nanda, P. Wyatt, (2016)
ES	A. de Ayala, I. Galarraga, J.V. Sparado (2016)
FI	F. Fuerst, E. Oikarinen, O. Harjunen, (2016)
BE	L. Dressler, E. Cornago, (2017)
RO	P. Taltavull, A. C. Ciora, (2017)
IT	E. Fregonara, D. Rolando, (2019)
DE	M. Cajias, D. Piazolo, (2013)
	K. Kholodilin, C. Michelsen, (2014)
	C. Pommeranz, B. Steininger, (2017)
	M. Cajias, F. Fuerst, S. Bienert, (2019)

Market participants take energy efficiency into account from the energy certificates in their decisions.

Studies confirm a rent premium for energy-efficient residential assets.

Source: PATRIZIA, November 2021

The capitalisation of energy efficiency on residential rents? - The theory



- Decrease in energy costs leads to a market segmentation of apartments.
- Tenants increasingly consider energy efficiency in their letting decisions and demand in this segment increases.
- Increase in demand for energy efficient apartments leads to:
  - higher willingness to pay
  - higher demand, i.e. lower time-on-market

Q = Supply **D** = Demand $\mathbf{Q_0}$ = Initial supply **EPC** = Energy performance certificate **R** = Rent

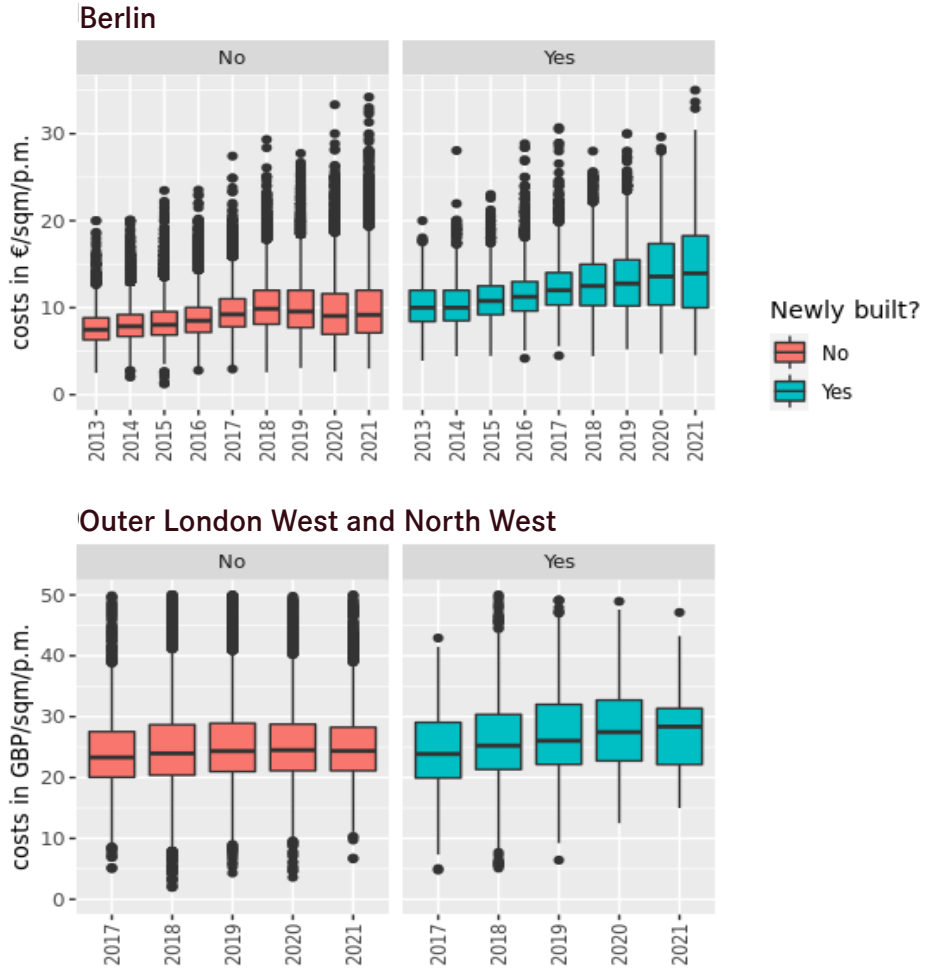
Source: PATRIZIA, F. Fuerst, P. McAllister, A. Nanda, P. Wyatt, (2015)

Database: Value Marktdaten (DE) and REalyse (UK)

Asking rents depend on time and space and are influenced by various characteristics

- Observations/Listings:
  - DE: 990,249 in top 7 and secondary 13 markets
  - UK: 67,523 in London (inner and outer) and secondary 4 markets

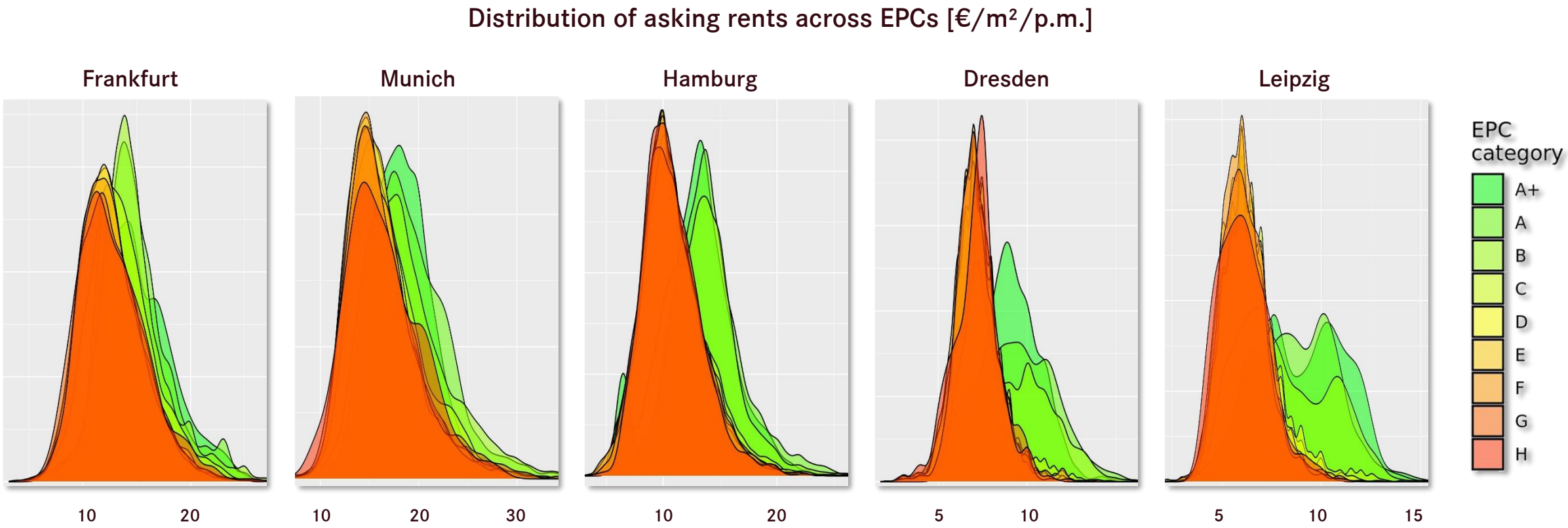
- Variables:
  - hedonic characteristics
  - EPC category A+ to H
  - socioeconomic criteria
  - temporal and spatial controls



Source: PATRIZIA, Value Marktdaten, REalyse, November 2021

The distribution of rents shows a clear pattern (1/2)

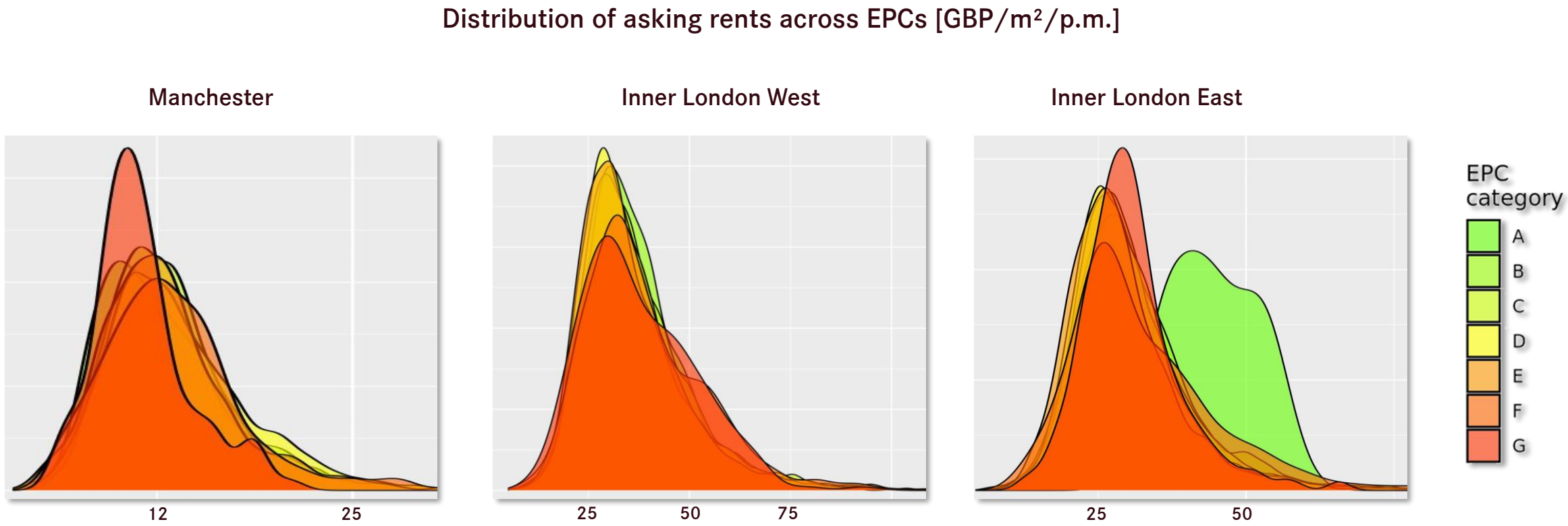
The lower the energy consumption the higher is the asking rent - Germany



Source: PATRIZIA, Value Marktdaten, November 2021

The distribution of rents shows a clear pattern (2/2)

The lower the energy consumption the higher is the asking rent - United Kingdom



Source: PATRIZIA, REalyse, November 2021

Predicting apartment rental prices: from statistical modeling to Machine Learning (ML)

The performance-transparancy – trade-off

$$\log(Rent_{i,j,t}) = \alpha_0 + \underbrace{\sum_{p=1}^{P} X_{i,t}^{p} \cdot \alpha_p}_{\text{hedonic characteristics (property level i)}} + \overbrace{\sum_{k=1}^{K} EPC_{i,t}^{k} \cdot \theta_k}^{\text{EPC categories (ref. D)}} + \underbrace{\sum_{m=1}^{M} W_{j,t}^{m} \cdot \beta_m}_{\text{socioeconomic criteria (ZIP-code level j)}} + \overbrace{\sum_{t=1}^{T} \mu_t \cdot \delta_t + \sum_{g=1}^{G} Z_i^{g} \cdot \rho_g}^{\text{temporal and spatial control variables}} + u_{i,j,t}$$

Predicting apartment rental prices: from statistical modeling to Machine Learning (ML)

The performance-transparancy – trade-off

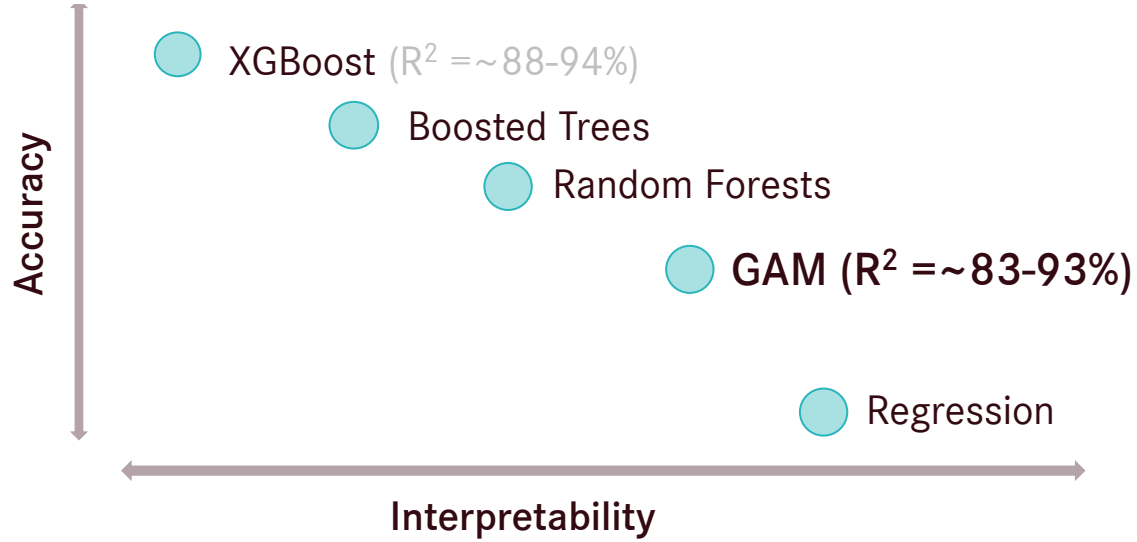
EPC categories (ref. D)

temporal and spatial control variables

$$\log(Rent_{i,j,t}) = \alpha_0 + \sum_{p=1}^{P} X_{i,t}^{p} \cdot \alpha_p + \sum_{k=1}^{K} EPC_{i,t}^{k} \cdot \theta_k + \sum_{m=1}^{M} W_{j,t}^{m} \cdot \beta_m + \sum_{t=1}^{T} \mu_t \cdot \delta_t + \sum_{g=1}^{G} Z_i^{g} \cdot \rho_g + u_{i,j,t}$$

hedonic characteristics (property level i)

socioeconomic criteria (ZIP-code level j)



Generalized Additive Models (GAMs)

Model equation: taking nonlinearities and spatial dependencies into account

$$\log\left(E\left(Rent_{i,j,t}\right)\right) = \alpha_0 + \sum_{b=1}^{B} X_{i,t}^{b} \cdot \alpha_b + \sum_{p=1}^{P} s_p\left(X_{i,t}^{p}\right) + \sum_{k=1}^{K} EPC_{i,t}^{k} \cdot \theta_k + \sum_{m=1}^{M} s_m\left(W_{j,t}^{m}\right) + \sum_{t=1}^{T} s_t\left(Y_i^{t}\right) + \sum_{g=1}^{G} s_g\left(Z_i^{g}\right) + f\left(Z_i^{lon}, Z_i^{lat}\right)$$

hedonic characteristics (property level i)

EPC categories (ref. D)

socioeconomic criteria (ZIP-code level j)

temporal and spatial control variables

Where:

- $s(.)$: 1-dimensional smoothing function to capture nonlinearities in the data (here: thin plate regression splines)
- $f(.)$: 2-dimensional smoothing function to capture the spatial dependencies (longitude, latitude) (here: tensor product/Gaussian process smoother)

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GAMs: Model Performance

Fitted GAMs perform better for German regions than for British regions

Germany

City	Model performance 50%	60%	70%	80%	90%	R^2
Berlin						87%
Cologne						89%
Dusseldorf						91%
Frankfurt						91%
Hamburg						88%
Munich						90%
Stuttgart						88%
Bonn						90%
Bremen						90%
Dortmund						84%
Dresden						91%
Duisburg						83%
Essen						87%
Hannover						87%
Leipzig						93%
Mainz						92%
Mannheim						90%
Munster						90%
Nuremberg						88%
Wiesbaden						92%

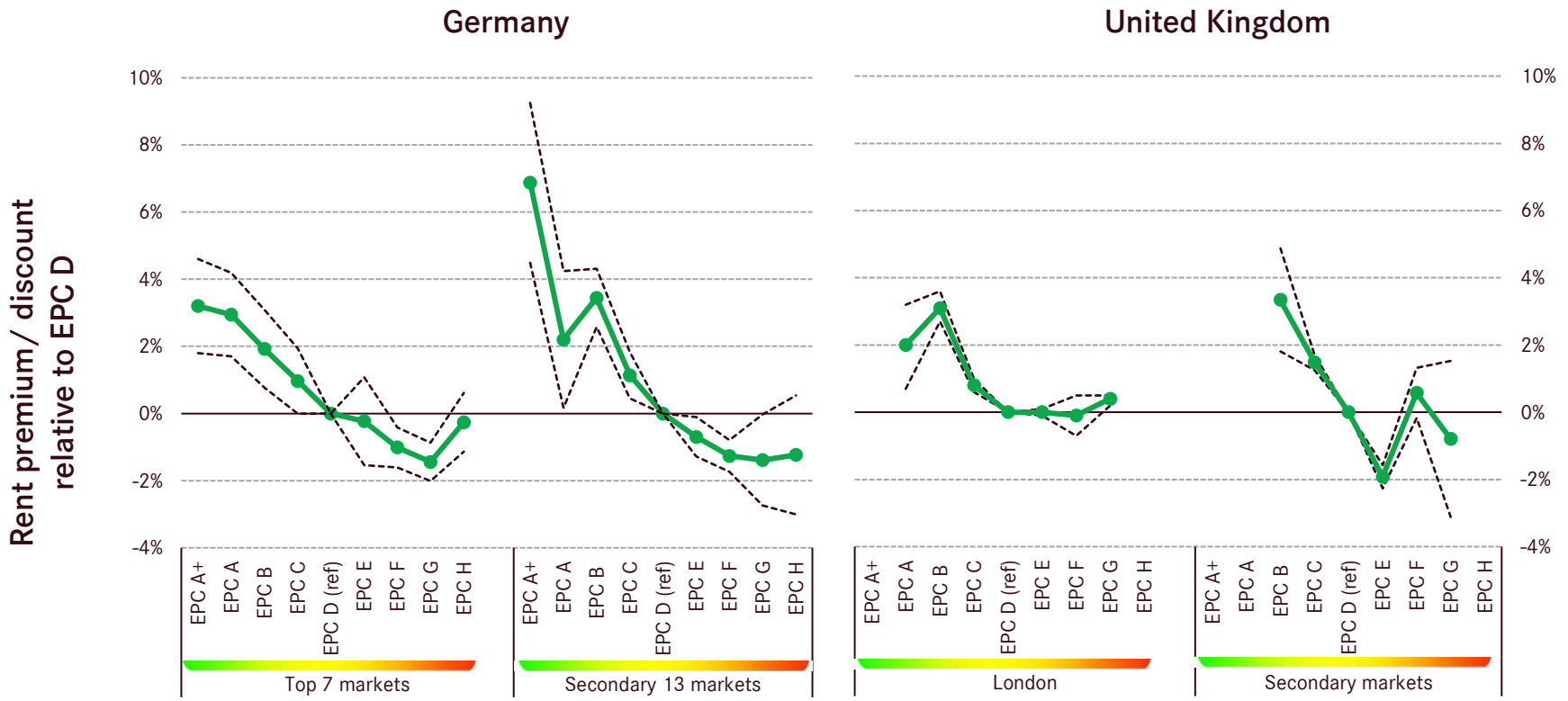
United Kingdom

City	Model performance 50%	60%	70%	80%	90%	R^2
Inner London						62%
Outer London						
East and North						67%
West and North						70%
Birmingham						64%
Leeds						52%
Manchester						75%
Sheffield						52%

- Model Performance:
  - Germany: R^2 = 83% -93%
  - United Kingdom: R^2 = 52% -75%

The green rent premium is not a hypothesis, it exists: the PATRIZIA evidence

Energy savings pay off whenever the financial benefits are higher than the lost investment opportunities



- A market response to climate change has been observed since the establishment of certification labels.
- Thus, the willingness to pay for energy savings may be transferred to diminished operational costs affecting the property value positively.
- The higher the energy efficiency class, i.e. the higher the energy savings, the higher is the asking rent on average, ceteris paribus.
- Rents in residential assets in the EPC class A have >3% higher asking rents than assets in the EPC class D.

Source: PATRIZIA, Value Marktdaten, REalyse, November 2021

The comparative benefits of an energy retrofit: “win-win” for tenants and landlords

By how much would the net rent of old assets increase if they were retrofitted?

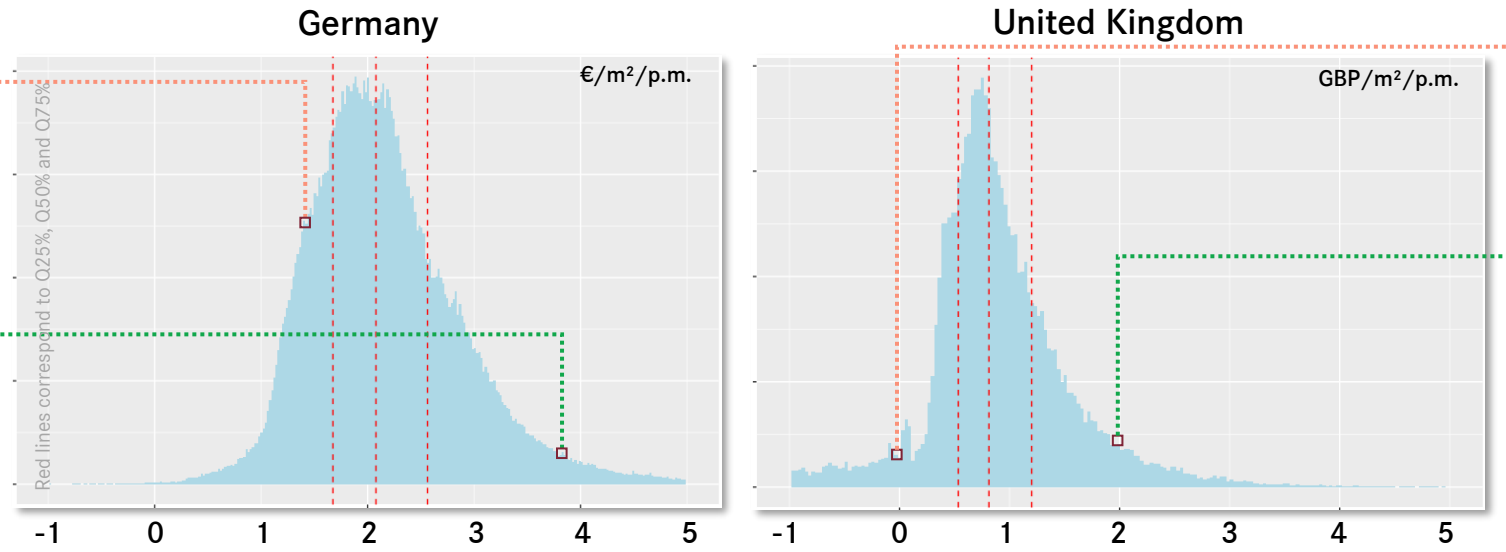
Approach: We simulate the willingness to pay for all apartments built before 1995 if they were offered today with a construction year of 2010 and an EPC category of B ceteris paribus, i.e. with all other characteristics of the apartments remaining identical, e.g. the living area, the number of rooms, or the availability of a build-in kitchen or a balcony.

+1.5ø €/m²/p.m.

Apartments in areas with purchasing power less than 59k € p.a. per household constructed after 1990

+3.9ø €/m²/p.m.

Apartments built between 1965 and 1985 in areas within 7 km. from the city centre



0.0ø GBP/m²/p.m.

Apartments with a living area greater than 24 m² in areas with purchasing power below 49k € p.a. per household

+2.0ø GBP/m²/p.m.

Apartments with a living area between 33 and 50 m² in areas with purchasing power greater than 49k € p.a. per household

The change in the willingness to pay for green retrofitted apartments is more pronounced in Germany than in the UK. Year of construction, the size of apartments, and the average disposable household income in the ZIP-code regions are the main drivers for possibly outstanding benefits.

Source: PATRIZIA, Value Marktdaten, REalyse, November 2021

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THE GREEN PREMIUM

- **Instruments that mitigate and adapt the environmental impact of buildings will increasingly shape our understanding of real estate investments.**
- **Details about the environmental performance of assets lessen the information asymmetry between landlord and tenant which is compensated by higher rents. The willingness to pay for energy savings may be transferred to diminished operational costs affecting the property value positively.**
- **Apartments with an EPC category A+ or A achieve on average about 3% higher rents compared to apartments of EPC reference category D whilst holding all other factors fixed.**
- **Year of construction, the size of apartments and the average disposable household income in the ZIP-code regions are the most important factors for potential for green retrofits.**
- **Energy efficient retrofit of buildings economically pays off if rent increase compensates landlords' costs for refurbishment and equals tenants' energy savings. The shared benefit is a reduction of the carbon footprint.**

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GAM Results: Model Performance & Willingness to pay for energy efficiency

Germany

	Model performance						Willingness to pay for energy efficiency relative to EPC category D								
City	50%	60%	70%	80%	90%	R^2	EPC A+	EPC A	EPC B	EPC C	Reference EPC D	EPC E	EPC F	EPC G	EPC H
Berlin						87%	0.9%	0.6%	0.6%	0.0%	-	-0.9%	-1.2%	-1.5%	-0.8%
Cologne						89%	5.5%	-0.3%	-0.4%	-1.2%	-	-0.9%	-1.9%	-1.9%	-0.3%
Dusseldorf						91%	4.6%	6.4%	3.9%	2.3%	-	-0.9%	-1.5%	-1.8%	-3.2%
Frankfurt						91%	5.6%	4.4%	6.0%	4.5%	-	5.4%	0.9%	-0.5%	1.7%
Hamburg						88%	-1.6%	5.2%	1.8%	0.4%	-	-0.3%	-0.9%	-0.4%	1.3%
Munich						90%	2.0%	2.7%	1.8%	1.5%	-	-1.0%	0.1%	-0.4%	0.9%
Stuttgart						88%	5.3%	1.7%	-0.3%	-0.7%	-	-2.9%	-2.6%	-3.5%	-1.5%
						Mean	3.2%	2.9%	1.9%	1.0%	-	-0.2%	-1.0%	-1.4%	-0.3%
						0.5*SD	1.4%	1.2%	1.2%	1.0%	-	1.3%	0.6%	0.6%	0.9%
Bonn						90%	7.0%	3.7%	3.0%	-0.1%	-	-2.4%	-1.7%	3.8%	-4.2%
Bremen						90%	12.6%	9.6%	5.7%	3.2%	-	-1.3%	-1.1%	-2.6%	-0.4%
Dortmund						84%	-6.4%	-1.2%	5.8%	3.4%	-	-2.1%	-3.5%	-3.2%	-0.2%
Dresden						91%	3.6%	2.3%	1.7%	-0.3%	-	-2.3%	-1.4%	-0.8%	-0.7%
Duisburg						83%	3.6%	-3.6%	3.9%	1.3%	-	0.1%	0.4%	0.2%	-0.5%
Essen						87%	7.9%	3.4%	4.0%	1.1%	-	0.3%	-0.8%	0.8%	2.7%
Hannover						87%	6.9%	7.6%	4.5%	0.4%	-	-1.0%	-1.2%	-1.5%	-1.7%
Leipzig						93%	9.5%	4.1%	4.1%	0.4%	-	-1.4%	-2.5%	-0.8%	-8.1%
Mainz						92%	10.9%	0.7%	4.3%	3.2%	-	0.1%	-0.7%	-1.0%	2.9%
Mannheim						90%	10.1%	0.2%	1.4%	-0.8%	-	-0.2%	-0.6%	-3.6%	1.8%
Munster						90%	7.4%	6.1%	2.7%	1.5%	-	1.4%	-1.4%	-7.8%	-8.0%
Nuremberg						88%	9.5%	-0.7%	3.8%	1.3%	-	-0.7%	-0.9%	0.0%	-0.2%
Wiesbaden						92%	6.8%	-3.5%	-0.3%	0.4%	-	0.4%	-1.0%	-1.5%	0.7%
						Mean	6.9%	2.2%	3.4%	1.1%	-	-0.7%	-1.3%	-1.4%	-1.2%
						0.5*SD	2.4%	2.0%	0.9%	0.7%	-	0.6%	0.5%	1.4%	1.8%

Source: PATRIZIA, Value Marktdaten, November 2021

GAM Results: Model Performance & Willingness to pay for energy efficiency

United Kingdom

	Model performance						Willingness to pay for energy efficiency relative to EPC category D								
City	50%	60%	70%	80%	90%	R^2	EPC A+	EPC A	EPC B	EPC C	Reference EPC D	EPC E	EPC F	EPC G	EPC H
Inner London						62%	-	0.2%	3.6%	0.3%	-	-0.2%	-1.4%	0.6%	-
Outer London															
East and North						67%	-	-	2.0%	1.0%	-	-0.1%	0.7%	0.5%	-
West and North						70%	-	3.8%	3.7%	1.1%	-	0.2%	0.6%	0.0%	-
						Mean	-	2.0%	3.1%	0.8%	-	0.0%	-0.1%	0.4%	-
						0.5*SD	-	1.3%	0.5%	0.2%	-	0.1%	0.6%	0.2%	-
Birmingham						64%	-	-	5.6%	2.1%	-	-1.9%	-0.7%	-0.6%	-
Leeds						52%	-	-	6.0%	1.6%	-	-1.1%	1.6%	-6.9%	-
Manchester						75%	-	-	2.2%	1.0%	-	-1.9%	-0.8%	0.0%	-
Sheffield						52%	-	-	-0.5%	1.3%	-	-2.8%	2.1%	4.4%	-
						Mean	-	-	3.3%	1.5%	-	-1.9%	0.6%	-0.8%	-
						0.5*SD	-	-	1.5%	0.2%	-	0.3%	0.7%	2.2%	-

Source: PATRIZIA, REalyse, November 2021