Modelling the Energy Transition in the Ruhr: a Multi-Level Approach

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Model Integration
Model integration

The integration of spatial models has four *dimensions*:

- **Spatial levels**: The model should recognise processes at different spatial levels: national/regional/local.

- **Subsystems**: The model should integrate subsystems: demography/economy/land use/mobility/environment.

- **Dynamics**: The model should recognise different speeds of change: slow/medium/fast.

- **Software**: The model should be executed in one unified software system.

Here a modelling approach is presented addressing all four dimensions of integration.
The Energy Transition
The energy transition

The history of cities is a history of energy transitions:
- In the medieval city heating and cooking occurred with wood and peat.
- The growth of the industrial city in the 19th century was built on coal and electricity.
- The sprawling metropolis of the 20th century was made possible by oil and gas.

How will the city of the 21st century look after the next energy transition from fossil to renewable energy?
The energy transition

The challenges of the energy transition affect all fields of urban development:

- settlement structure
- landscape/water
- socioeconomic structure
- person travel and goods transport
- environment

Until now measures to achieve the energy transition have been mostly dealt with in isolation from each other. But it is necessary to consider the interactions and positive and negative synergies between them.
The Mercator Project
The Mercator Project

This is why the private Mercator Foundation located in Essen, Germany, launched a four-year programme to enhance knowledge and awareness of the need for the energy transition in the municipalities of the Ruhr Area.

With a population of more than five million, the Ruhr Area is one of the major urban agglomerations in Europe. Through its industrial past and polycentric settlement structure it has a particular potential for the development of transport-reducing settlement structures on former industrial brownfields.
The Mercator Project

The Mercator *programme* consists of a *combination* of empirical surveys, research projects, citizen participation and implementation studies.

The project reported here is part of this larger programme. In it a *computer simulation model* of *urban land use, transport and environment* will be applied to *assess the impacts* of policies to *reduce energy consumption* and promote the *transition to renewable energy* on economy, mobility, quality of life and environment in the Ruhr Area.

Project partners are the *Wuppertal Institute for Climate, Environment and Energy*, the *University of Wuppertal* and *Spiekermann & Wegener*.
The Mercator Project

Through the project two kinds of *questions regarding the energy transition* are to be answered:

- **Conditional forecasts**: "Which impacts would have to be expected if a certain combination of measures to improve energy efficiency and save energy were implemented?"

- **Backcasting**: "Which combination of measures to improve energy efficiency and save energy would have to be implemented to achieve the energy conservation targets of the government?"

In answering these questions different assumptions about possible *decisions processes* and *strategies* in the Ruhr Area can be made.
The Mercator Project

To answer these questions scenarios were defined which differ in their assumptions about the policies and combinations of policies implemented:

- **Economy**: investments, taxes, user fees
- **Land use**: densification, mixed-use development, building restrictions
- **Transport**: pricing, infrastructure improvements, speed limits, car-sharing, alternative fuels/vehicles
- **Buildings**: energy retrofitting, combined heat and power, solar energy, wind energy

The forecasting horizon of the scenario simulations is the year 2050. Simulations start in 1990.
Method
Method

In the project the simulation model of urban land use, mobility and environment developed at the Institute of Spatial Planning of the University of Dortmund called the IRPUD model will be applied. The model addresses all four dimensions of integration:

- **Spatial levels**: The model works in a three-level spatial hierarchy: European, regional and local.
- **Subsystems**: The model integrates demography, economy, land use, mobility and environment.
- **Dynamics**: The model applies recursive dynamics with slow and fast feedbacks.
- **Software**: The regional and local models will be executed in a single unified executable.
Urban change processes

- Networks
- Travel
- Population
- Workplaces
- Land use
- Housing
- Goods transport
- Employment

Speed of change

- Very fast
- Medium speed
- Slow
- Very slow

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Land-use transport feedback cycle
Model levels

SASI model

IRPUD model

Raster model
Model integration

**European (NUTS-3 regions)**

- SASI model
  - Economy
  - Demography
  - Migration

**Regional (Zones)**

- IRPUD model
  - Land use
  - Transport
  - Buildings
  - Population
  - Employment
  - Environment

**Local (Raster cells)**

- Raster model
  - Environment

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Level 1:
European (1,347 NUTS-3 regions)
SASI model

European developments

Transfer policies

Transport policy

Migration policy

GDP

Accessibility

Production function

Transport network

Regional endowment

Employment

Migration function

Accessibility

Unemployment

Population

Income

Cohesion indicators

Regional quality of life

Regional fertility mortality

Regional education

Labour force

Socio-economic indicators

Regional labour force participation

Labour force
Level 2:
Regional (687 zones)
External zones

Ruhr Area

Bocholt
Krefeld
Mönchengladbach
Düsseldorf
Cologne
Wuppertal
Arnsberg
Münster

134 municipalities
Centroids
IRPUD model

SASI model results

Microsimulation
IRPUD model

The IRPUD combines three kinds of theories:

- **Technical theories** of urban development interpret cities as urban mobility systems, i.e. that trip decisions and location decisions co-determine each other.

- **Economic theories** of urban development focus on the economic foundations of city growth: it is their market function that distinguishes cities from the countryside.

- **Social theories** of urban development interpret cities as the result of individual or collective appropriation of space within capacity, coupling and institutional constraints.
IRPUD model

The IRPUD model forecasts over a period of sixty years
- location decisions of firms, housing investors and households,
- household moves and commuter and other travel flows resulting from them,
- construction activity and the resulting changes in land use,
- impacts of land use and transport on energy use and the environment,
- impacts of policies in the fields of land use, economy, housing, infrastructure and transport.
IRPUD model

The IRPUD-Model permits to influence the decisions of the private actors through *policies*:

- **Land use**
  - zoning, landscape protection, ...

- **Economy**
  - economic promotion, industrial/commercial areas, ...

- **Housing**
  - social housing, mixed-use housing, ...

- **Infrastructure**
  - schools, hospitals, roads, tramways, buses, ...

- **Transport**
  - fuel taxes, public transport fares, ...
Model extensions (1)

In the project the model is being extended by submodels of building energy and solar/wind energy.

In addition existing model submodels will be made more responsive to energy issues, e.g. the transport model to car-sharing, electromobility and cycling.

The model will be more closely linked with existing high-resolution models of environmental impacts of land use and transport (air quality, traffic noise, biodiversity).

This will allow to model not only environmental impacts but also their effects on location decisions of households and firms ("environmental feedback").
Level 3: Local (840,000 raster cells)
Raster model

$1,200 \times 700 = 840,000$ raster cells
Air quality (mgNO₂/m³)
Traffic noise (dB(A))
Accessibility of workplaces
Polycentricity
Energy Efficiency of Residential Buildings
Energy efficiency of residential buildings

The first new submodel is the model of energy efficiency of residential buildings (Fuerst and Wegener, 2012). The submodel predicts the probability that home owners in response to

- market developments
- energy price increases
- subsidies

energetically retrofit their residential buildings.

The basic assumption is that home owners are the more prepared to invest in the energy efficiency of their buildings, the shorter the payback period in which they recover their initial investment through energy cost savings.
Scenarios

Four *scenarios* are considered:

0 **Base**: floorspace: 100 sqm; retrofitting cost: 200 €/sqm; interest rate: 3%/year; energy consumption before retrofitting: 200 kWh/sqm, after retrofitting: 80 kWh/sqm; energy costs: 0,20 €/kWh, increase +1% p.a.

A **Subsidies**: 33% of retrofitting cost subsidised.

B **Higher energy cost**: energy costs increase +4% p.a.

C **Rental market**: 50% of energy cost savings recouped from tenants.
Share of energy-efficient residential buildings

- 000: Base scenario
  - Energy costs +1% p.a.
- 00A: Subsidies
  - 33% of investment
- 00B: High energy prices
  - Energy costs +4% p.a.
- 00C: Rental market
  - 50% savings recouped

Years:
- 1970
- 1980
- 1990
- 2000
- 2010
- 2020
- 2030

Share of energy-efficient residential floorspace (%): 0 to 50
Energy use of residential buildings

- 000: Base scenario
  - Energy costs +1% p.a.
- 00A: Subsidies
  - 33% of investment
- 00B: High energy prices
  - Energy costs +4% p.a.
- 00C: Rental market
  - 50% savings recouped
Conclusions
Conclusions

In the face of epochal challenges, such as globalisation, climate change, energy transition, population ageing and immigration, and the foreseeable limits of economic growth of the richest countries, projections of the long-term future of cities are becoming more and more important.

Only integrated models can cope with the complexity of urban and regional systems.

Integrated models need to be multi-level, incorporate all relevant subsystems, consider different speeds of change and be efficient in computation.
Transit-oriented development

Densification and concentration of future development at existing commuter rail stations
More information


