Coupling urban growth and energy demand through GIS-based cellular automata

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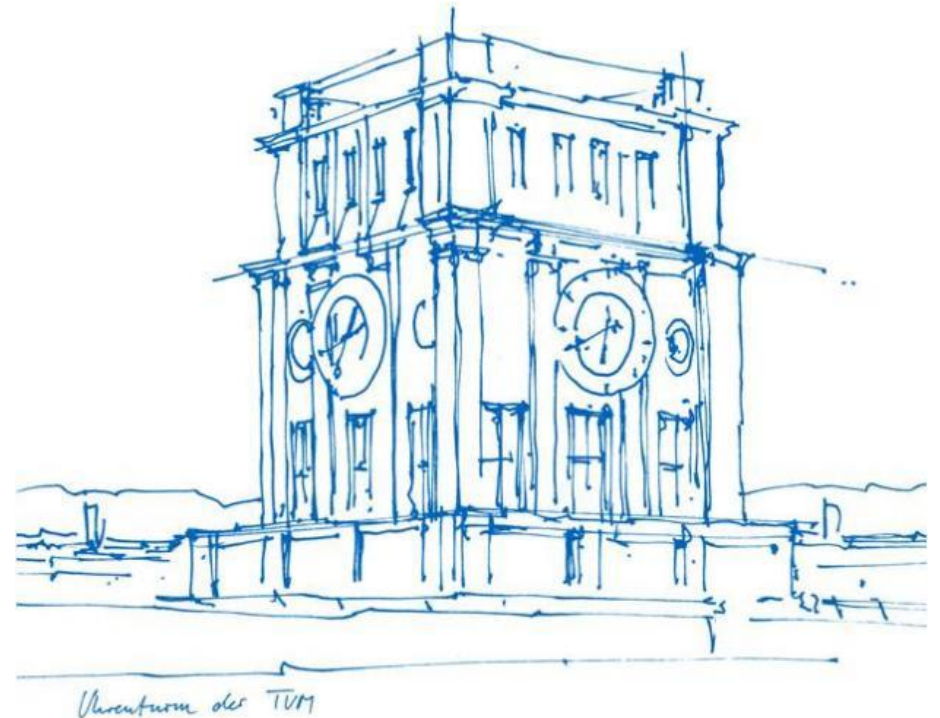
Faculty of Electrical and Computer Engineering
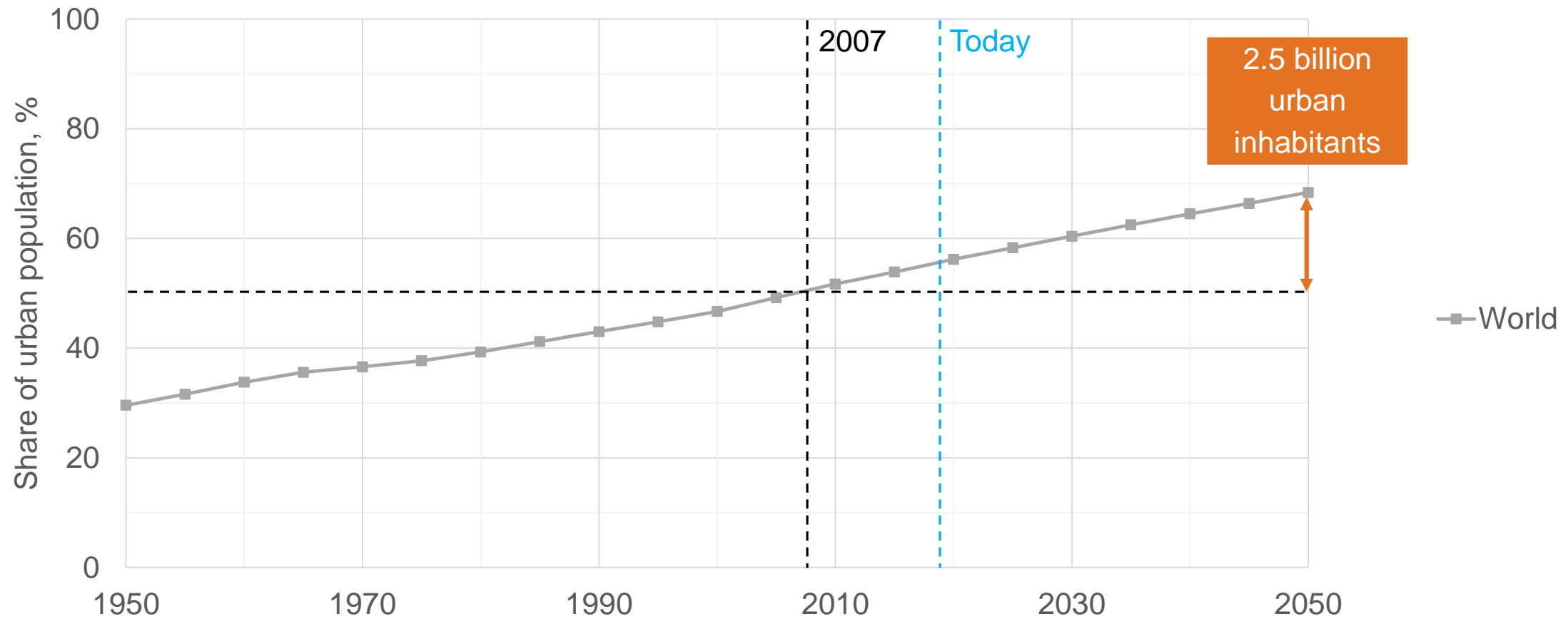
Chair of Renewable and Sustainable Energy Systems
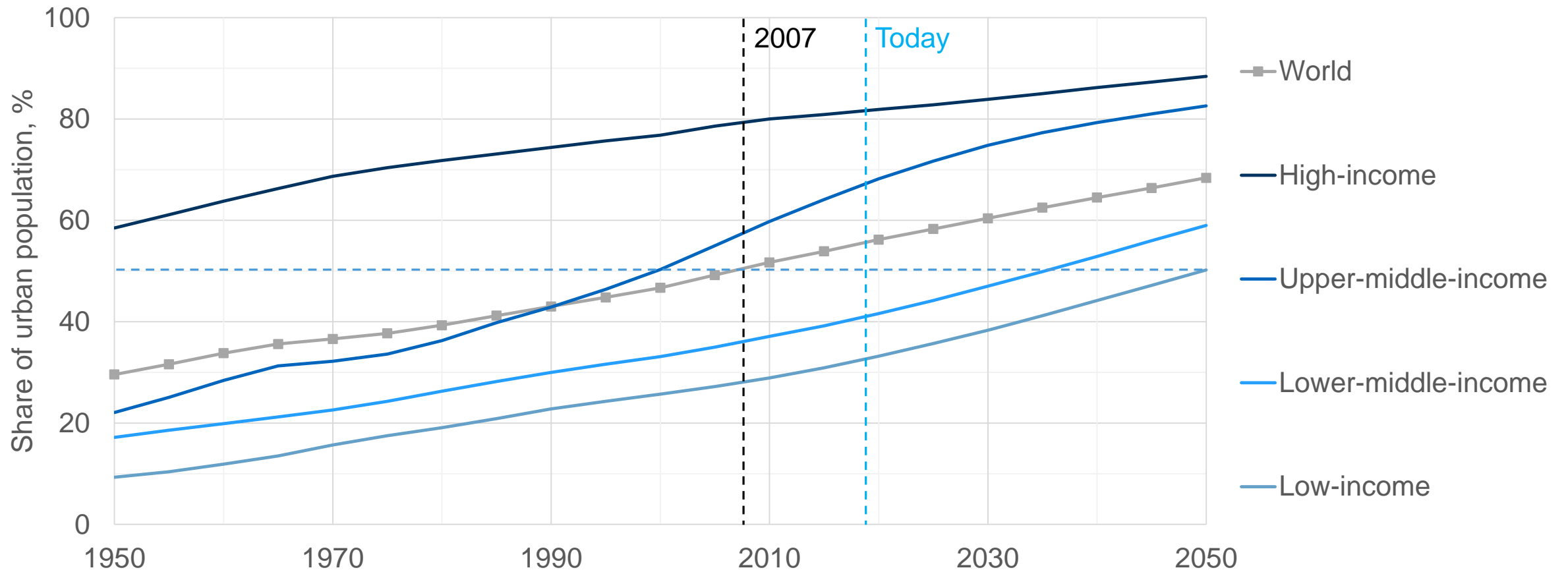
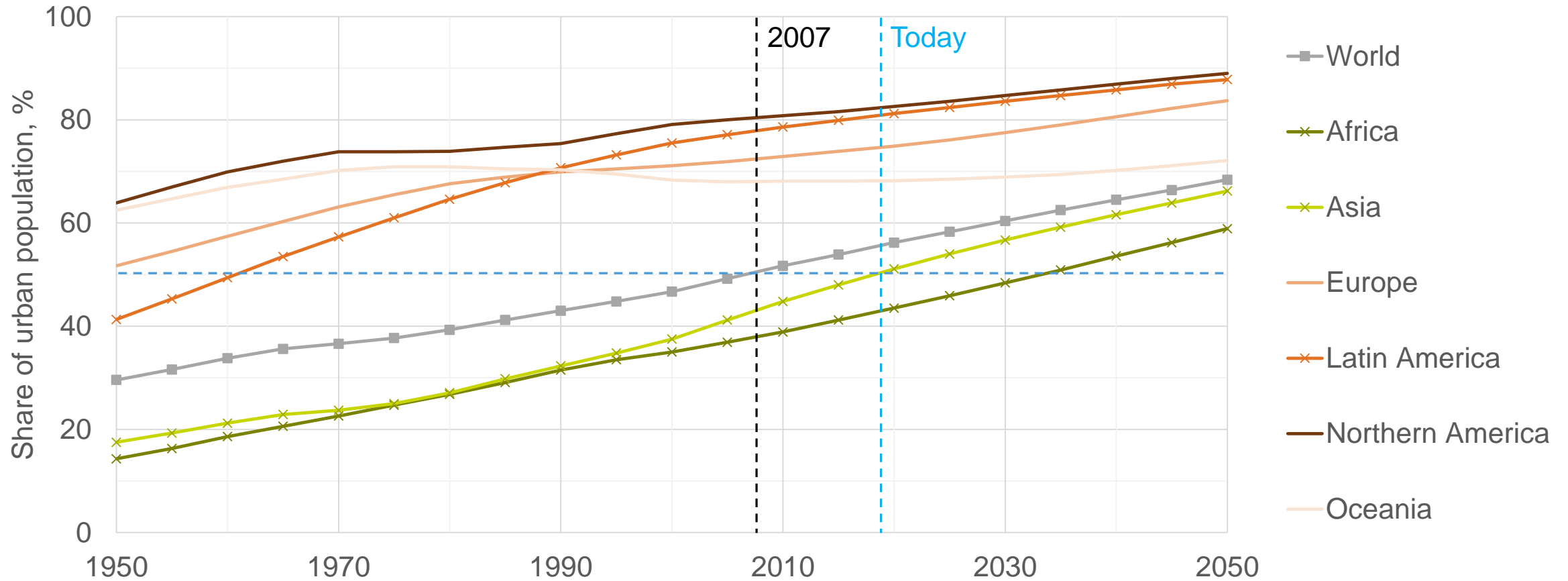# Our urban world

Source: UN Urbanization prospects (2018)

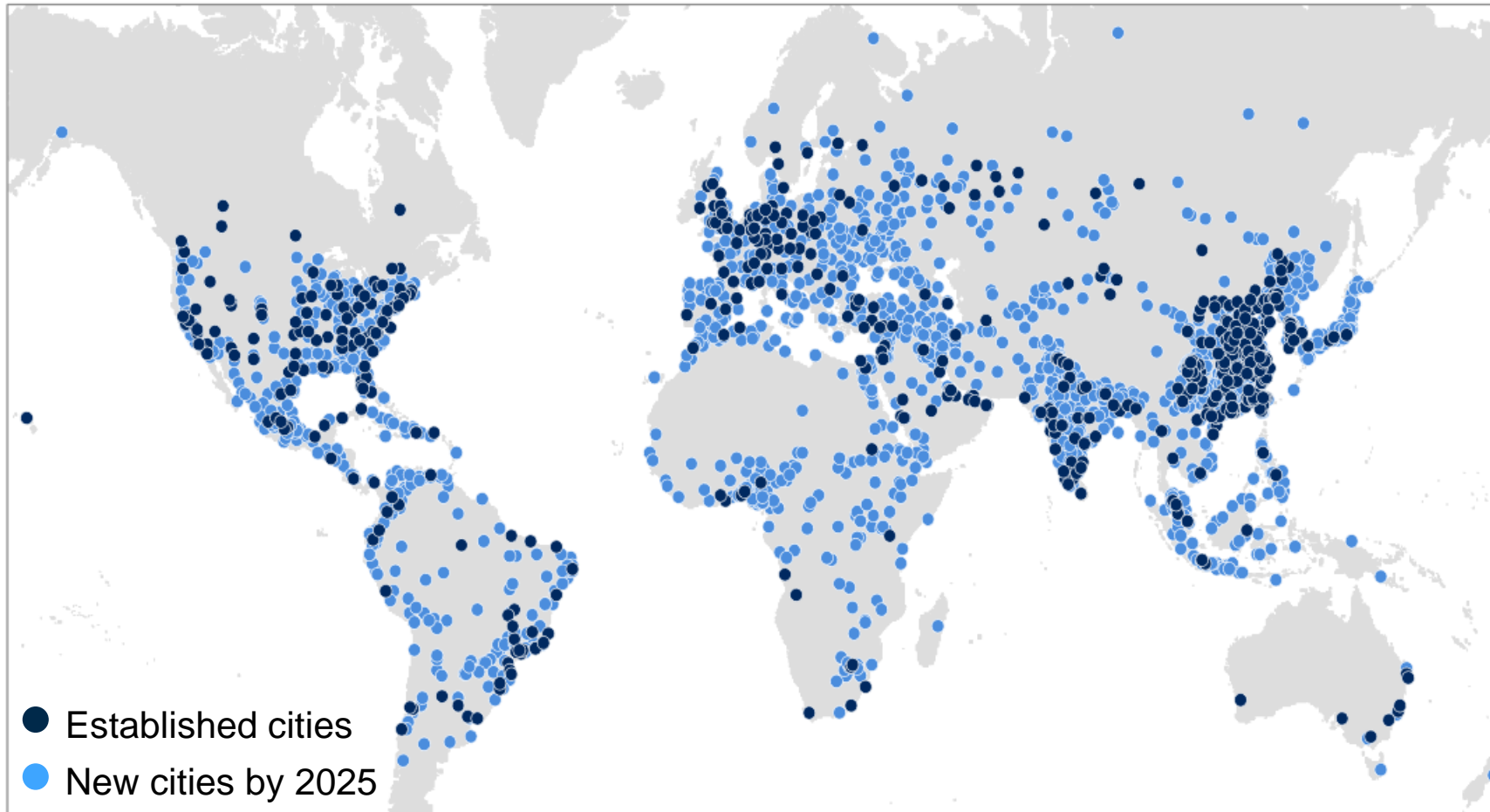# Our urban world

Source: UN Urbanization prospects (2018)

Our urban world

Source: UN Urbanization prospects (2018)

Our urban world (2025)

Established cities

New cities by 2025

Source: MGI Cityscope (2012)

- 1 out of 8 people will live in one of the 43 **megacities** (>10 mio. inh.)

- ca. 50% of the population will live in **medium-sized settlements** (<1 mio. inh.)

- 1 billion inh. will enter the „**consuming class**" by 2025

- Growth in **demand of goods and services**, especially in emerging markets.

The key towards a sustainable future is the effective management of emerging cities

Content

The City

Source: Sino-Singaore Tianjin Eco-city (2011)

The engineered system
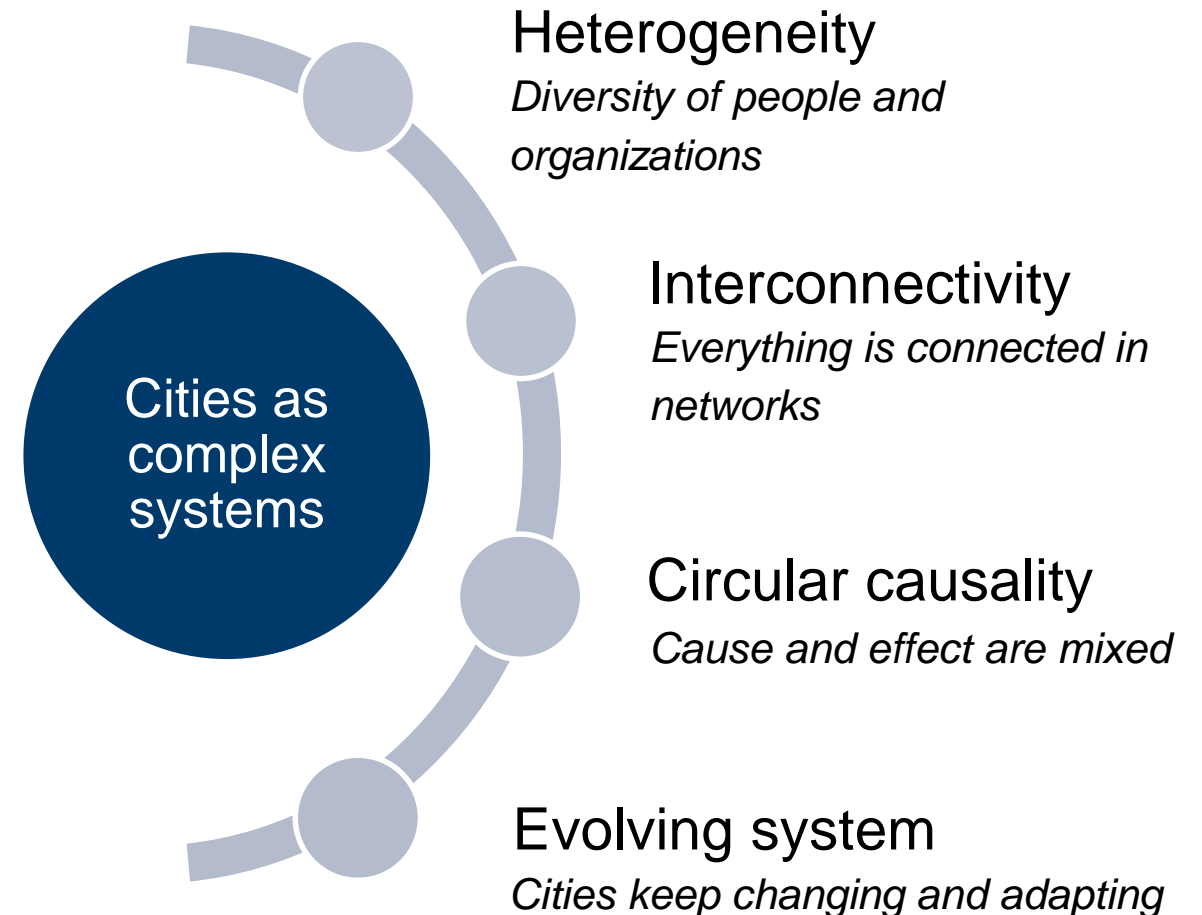

Source: rioonwatch.com (2018)

The self-organized system

Studying real cities

"[Real cities present] situations in which several dozen quantities are all varying simultaneously and in subtle connected ways".
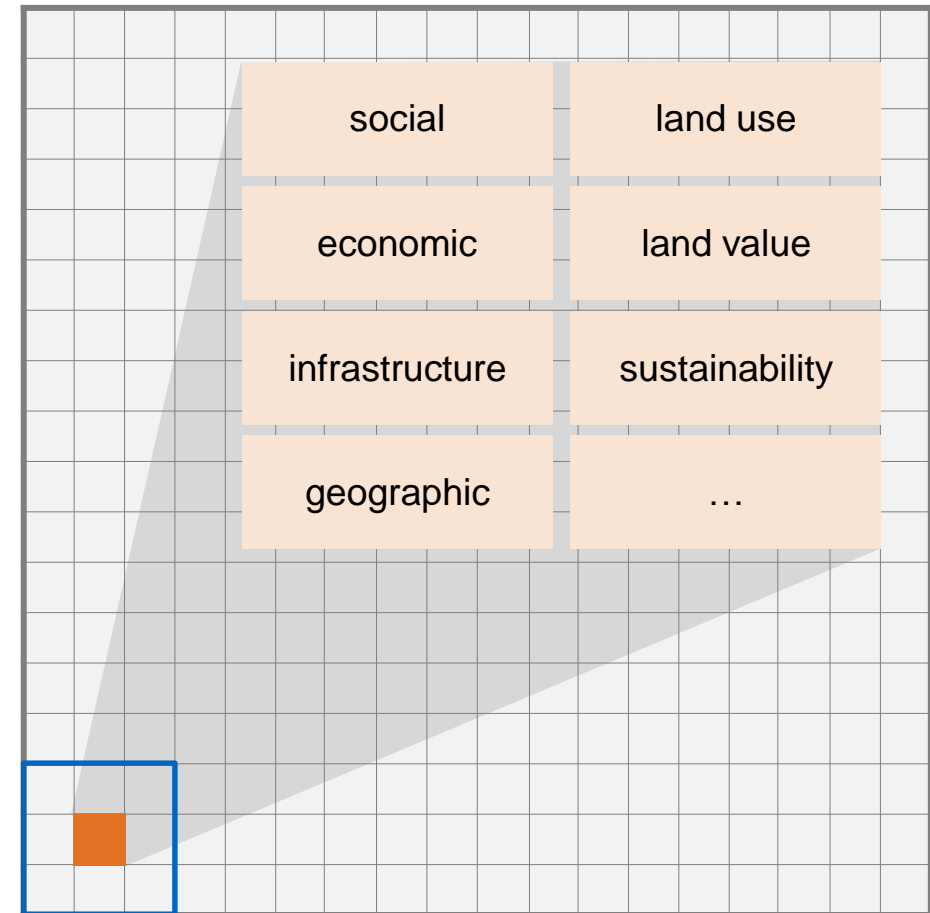
Jane Jacobs

The death and life of great American cities

1961

Cities as complex systems

Heterogeneity
Diversity of people and organizations

Interconnectivity
Everything is connected in networks

Circular causality
Cause and effect are mixed

Evolving system
Cities keep changing and adapting

The city as a grid

Guadalajara, Mexico Source: Google Earth (2016)

social · land use
economic · land value
infrastructure · sustainability
geographic · …

intus: integrated modelling of urban systems

Environmental impact
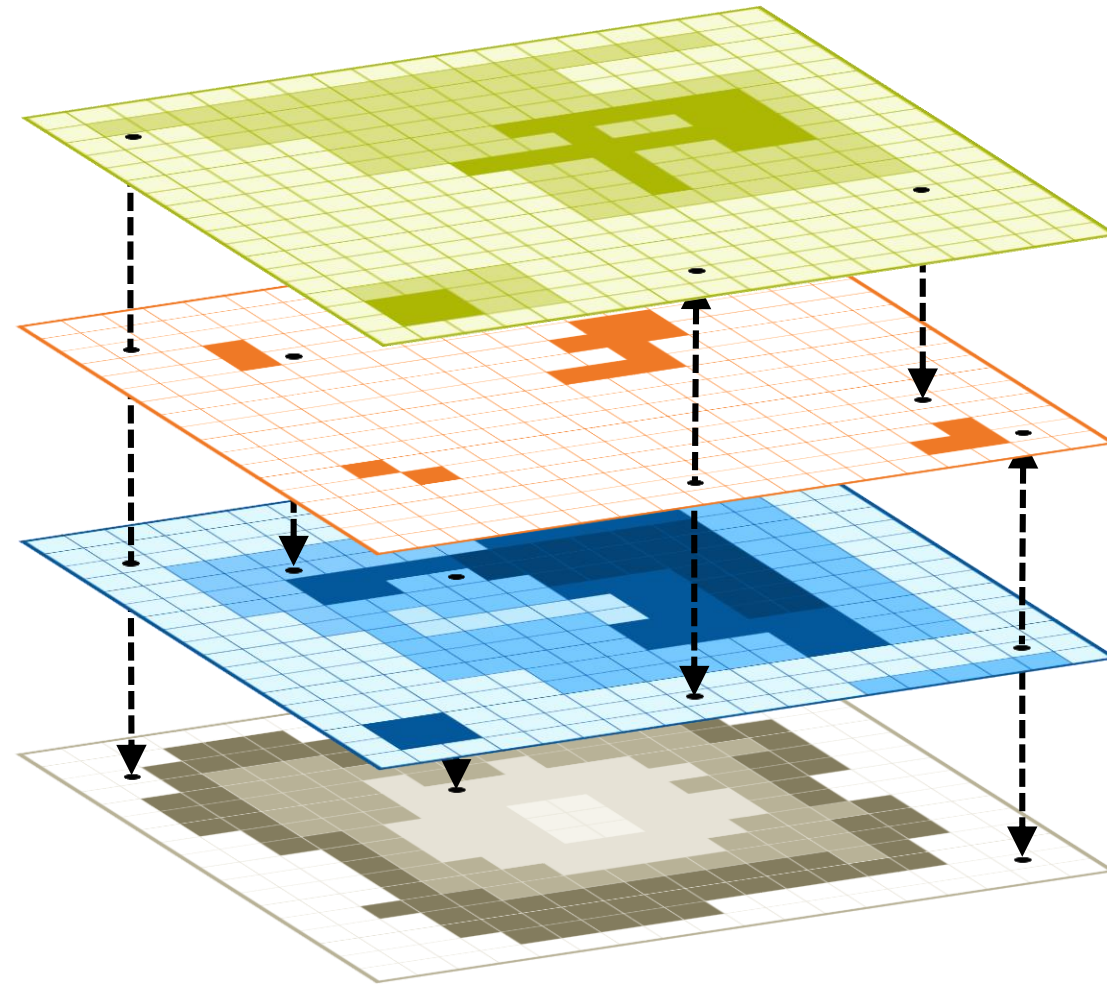
Renewable resources

Energy demand

Urban expansion and densification
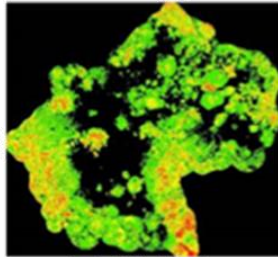
Coupling urban growth and energy demand
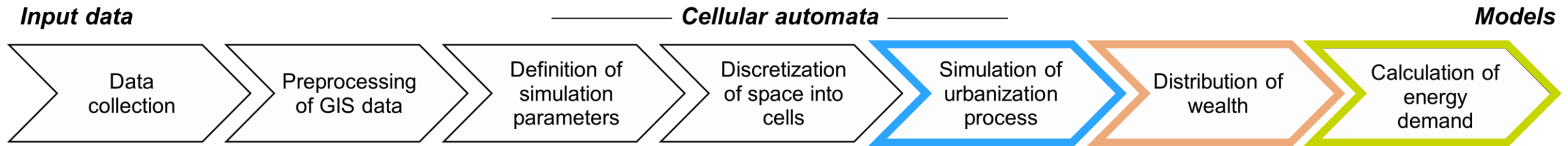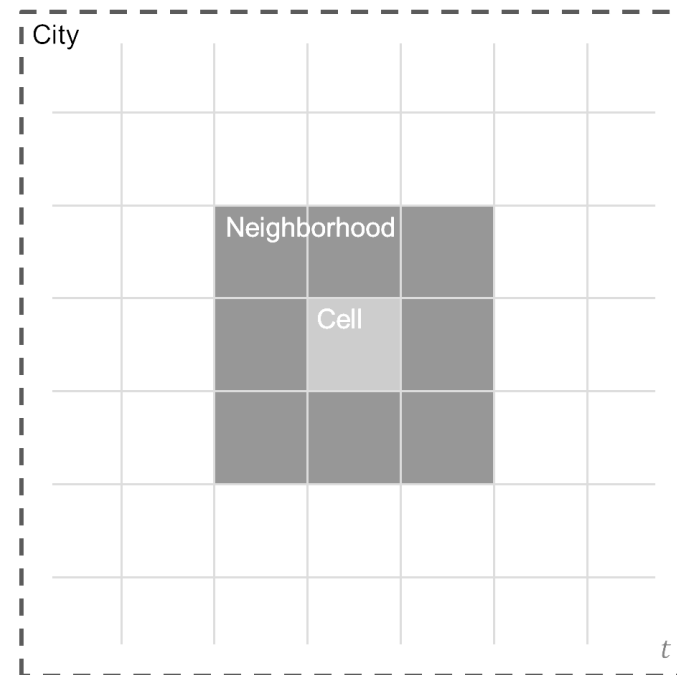
Modeling urban growth: SLEUTH model (adapted)

Slope
(0: flat
1: critical slope)

Urban
(0: not urbanized
1: urbanized)

Land cover
each color
represents a
different land
use
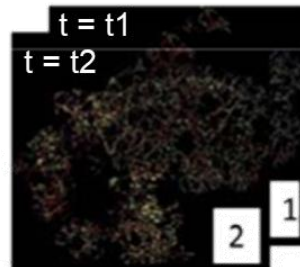
Transportation
(0: no transportation network
1: transportation network)

Excluded
(0: suitable for
urbanization
1: not suitable
for urbanization)
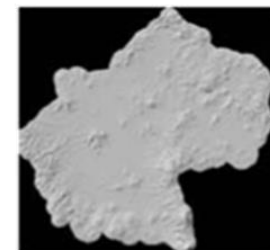
Hillshade
(0: not shaded
1: heavily shaded)
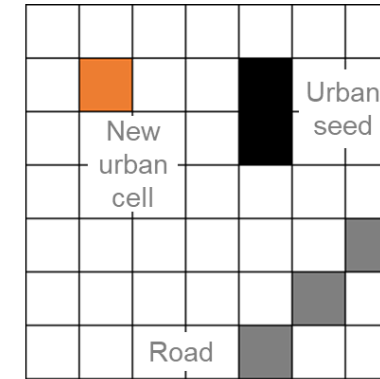
1. Spontaneous growth
2. Growth of new spreading center
3. Edge growth
4. Road-influenced growth
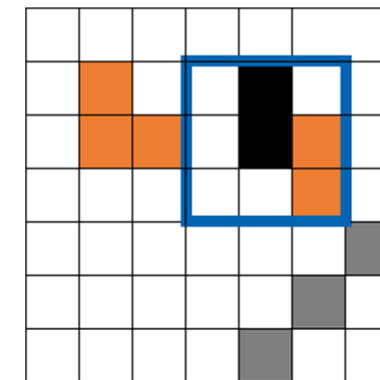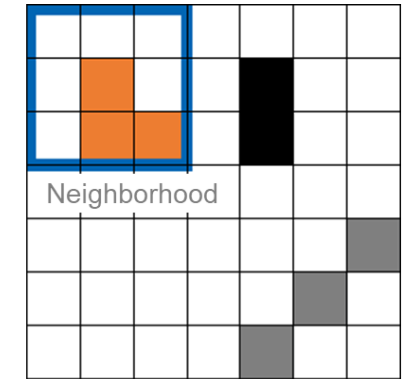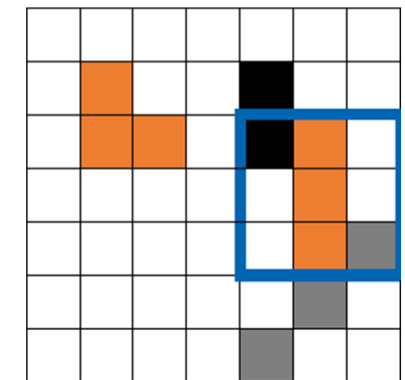
New urban cell

Urban seed

Neighborhood

Road

Source: Mohar and Galindo (2016)

Who settles where? Learning the value of land

Machine Learning:

$$Y = f(X) + \epsilon$$

Output variable „label"

Function mapping

Input variable „feature"

Noise

Socioeconomic level as label
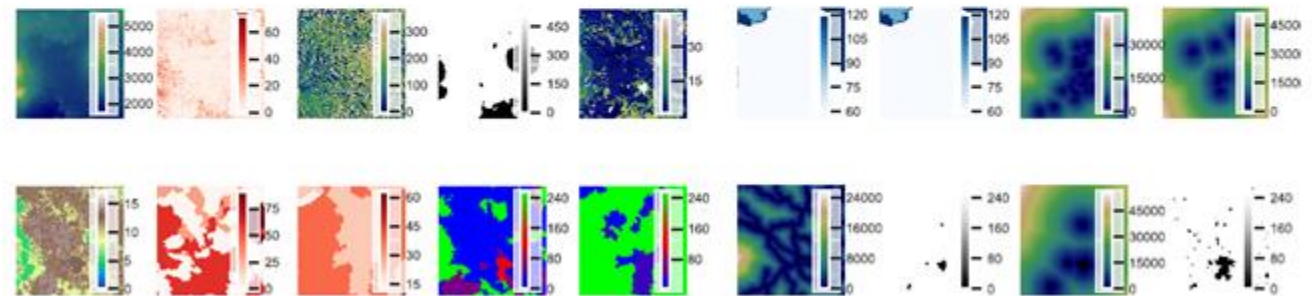
Environmental characteristics as feature

Modeling energy demand

Energy expenditure in energy services in Mexican households (Rodriguez-Oreggia & García, 2014)
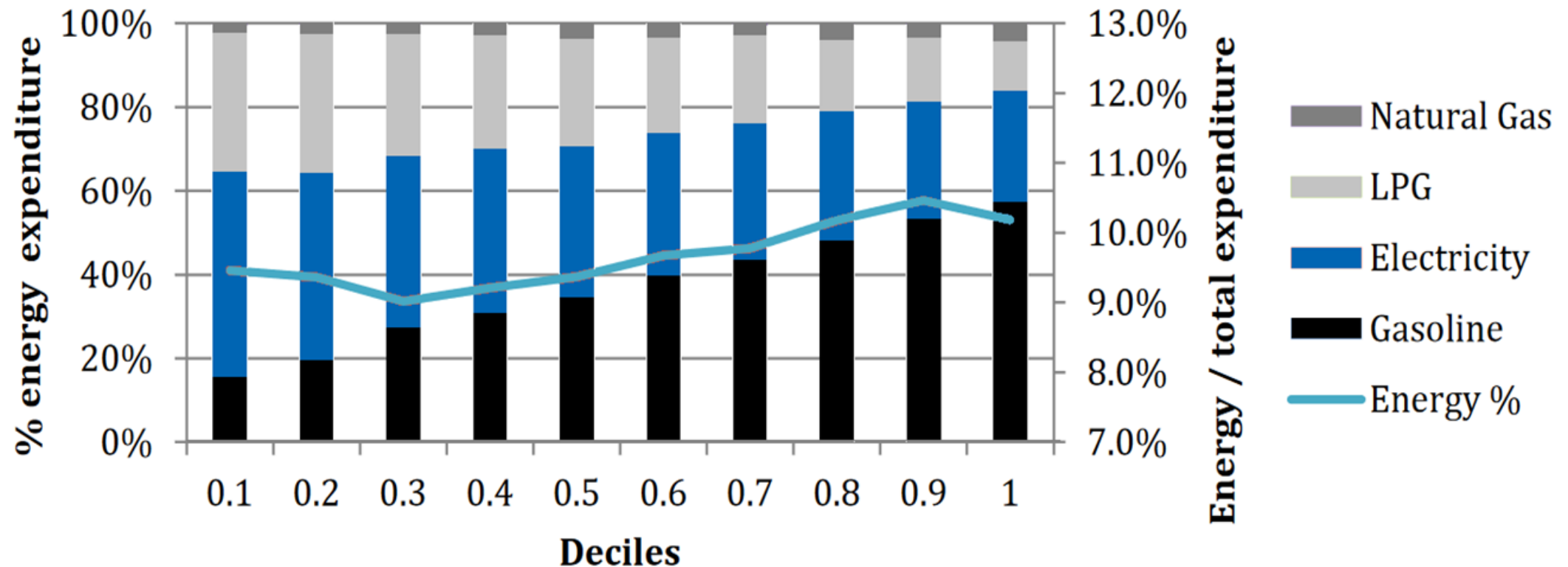
Study case: Metropolitan Area of Guadalajara
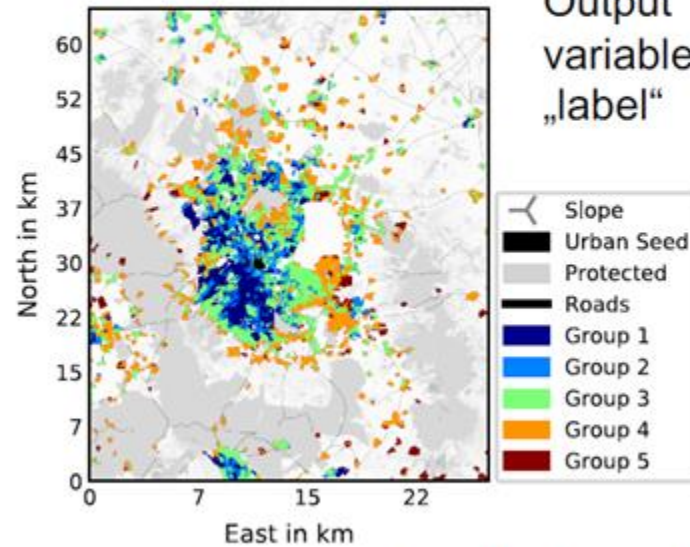
Guadalajara
Jalisco, Mexico

- Second largest urban area in Mexico

- Population: ~ 5 mio.

- 70% of the state population is projected to live in Guadalajara by 2030

- Wealth distribution:

Decil 1 (High)

Decil 0.1 (Low)

Results: Land value map

Study case: Guadalajara

Electricity demand in MWh/a

| 1 | 10 000 | 15 000 | 20 000 | 25 000 | 30 000 |

1970 | 7.2 TWh
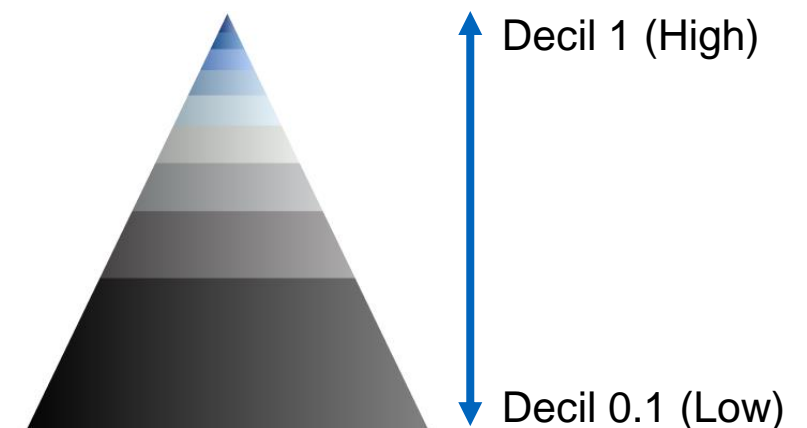Consolidation of a multi-nuclei urban center including three municipalities.

1990 | 20.4 TWh
Urban expansion in all directions. Industry is allocated in the south.

1999 | 22.8 TWh
City expands towards the south following the main roads.

2014 | 27.1 TWh
New isolated residential zones in the periphery. Consolidated industrial area.

Key messages

1. **Integrative modeling** is necessary to capture the **complexity of cities.**

2. **Coupling** urban growth and energy demand models allows a better understanding of the **energy use patterns** in cities.

3. The inclusion of the **spatially explicit urban transformations** expands the possibilities for incorporating other **dynamic urban processes** relevant for the shaping of a **sustainable future.**

4. Focus on **emerging cities** is currently under-represented but tools and solutions for an **effective urban planning** are needed.

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