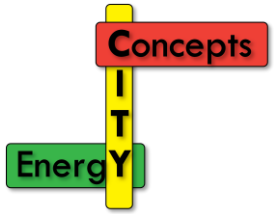
AEE INTEC



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Holistic urban energy planning in spatial and temporal resolution

Workflow coupling spatial modeling with dynamic building simulation

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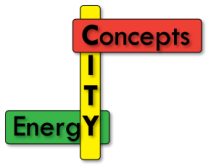
8010 Graz, Inffeldgasse 25b, AUSTRIA

Content



- Introduction to the R&D project „EnergyCityConcepts“
  - Objective
  - Workflow, Methods

- Spatial energy and infrastructure analysis and modeling with GIS

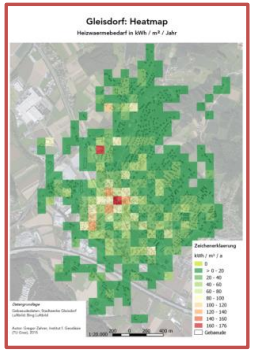
- Combining GIS and dynamic building simulation
- Discussion and outlook

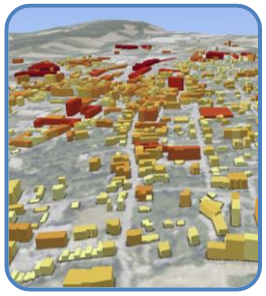
Objective “EnergyCityConcepts”

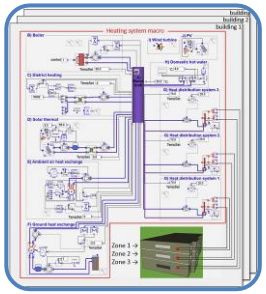
- Development of methodical approaches for local / regional urban energy planning in spatial and temporal resolution
- Development of organizational frameworks for the implementation of energy strategies in communities
- Testing on two Austrian model regions
  - urban district “Salzburg-Schallmoos”
  - city of Gleisdorf

Methods - Workflow

Spatial energy and infrastructure analysis and modeling
GIS, statistics, energy balancing, roadmapping







Data acquisition, geodatabase management

Pre-processing (check, verify, extend database)

Spatial analysis / spatial modeling
- Characterization of existing infrastructures, energy demands and local resources

Renovation and modernization roadmap
- Building renovation roadmap based on hourly HWB* calculation (acc. to EN ISO 13790)
- Scenarios for increased share of renewables in heating sector and DH extension

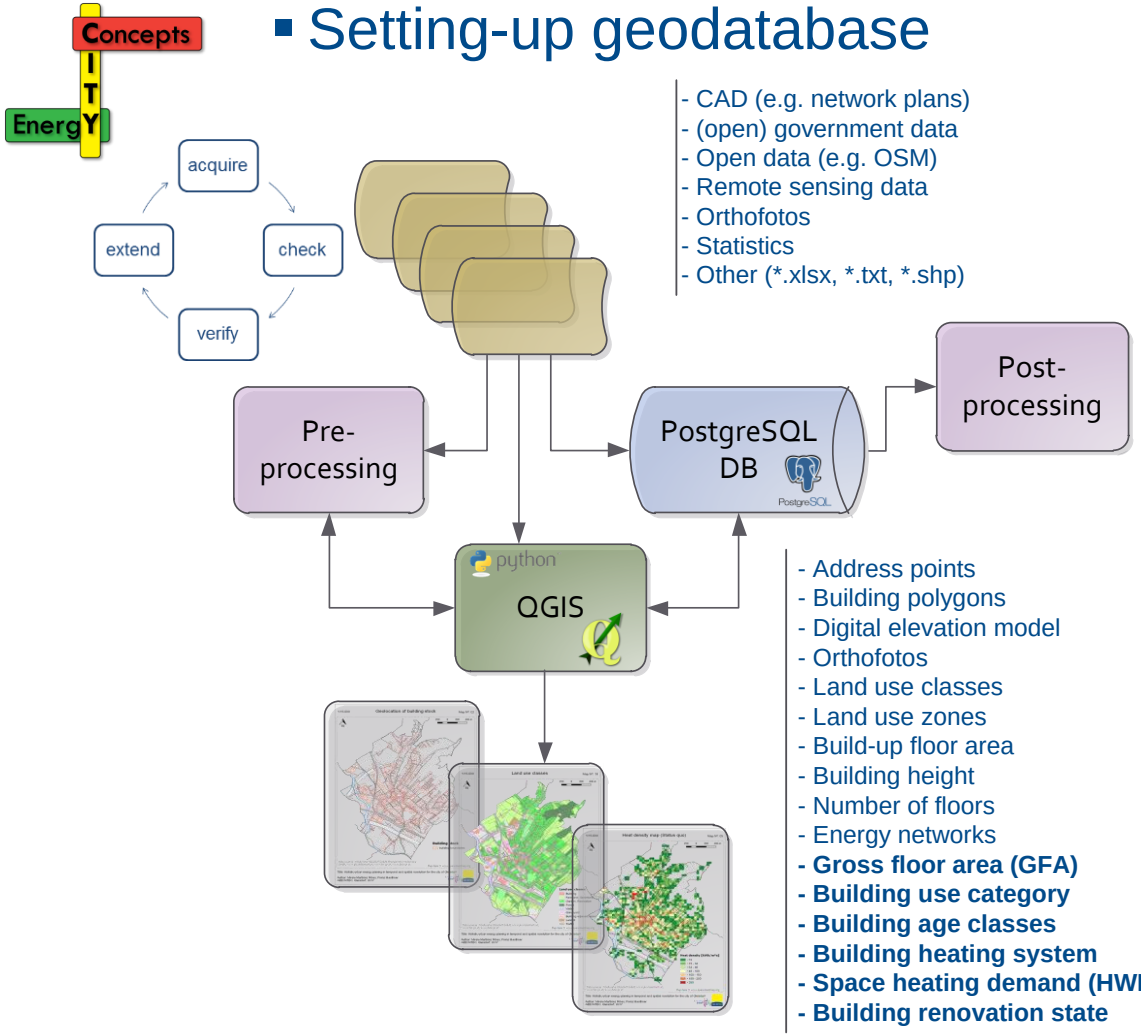
Dynamic building and utility network **simulation**
- Automated workflow coupling geodatabase with IDA ICE building simulation framework

In-depth analysis / simulations in high temporal resolution
physical models, (dynamic) simulation

*HWB = German abbr. for space heating demand

Spatial analysis and modeling

Setting-up geodatabase

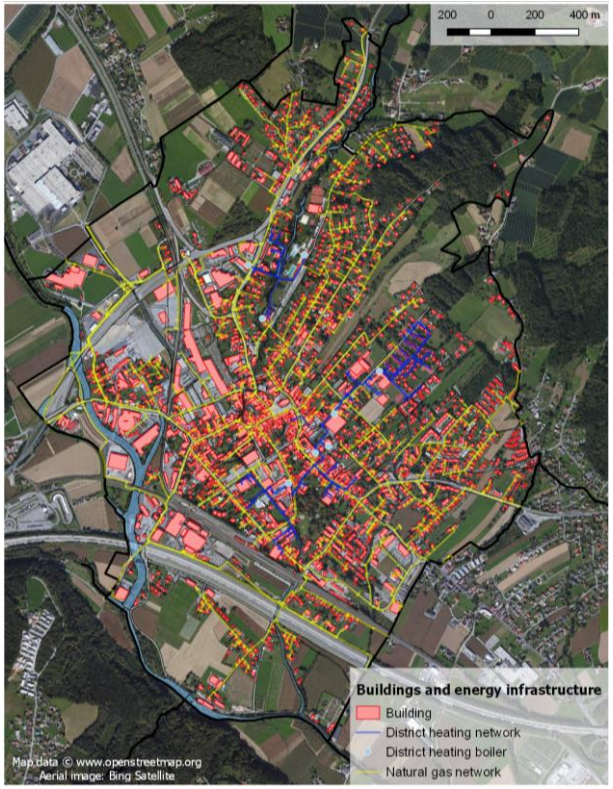


- CAD (e.g. network plans)
- (open) government data
- Open data (e.g. OSM)
- Remote sensing data
- Orthofotos
- Statistics
- Other (*.xlsx, *.txt, *.shp)

- Address points
- Building polygons
- Digital elevation model
- Orthofotos
- Land use classes
- Land use zones
- Build-up floor area
- Building height
- Number of floors
- Energy networks
- **Gross floor area (GFA)**
- **Building use category**
- **Building age classes**
- **Building heating system**
- **Space heating demand (HWB)**
- **Building renovation state**

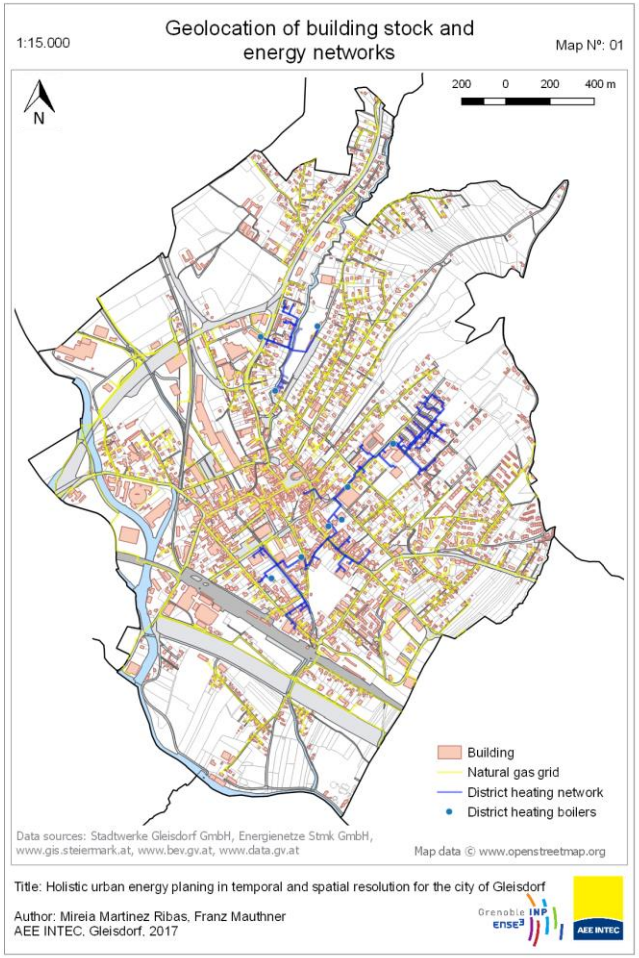
Final geodatabase

- Geolocation of all buildings and energy supply networks
- **Full characterisation of residential sector** for basic energetic analysis
- *Only partial characterisation of industry, commercial and public sector*
- Land use / zoning



Spatial infrastructure analysis

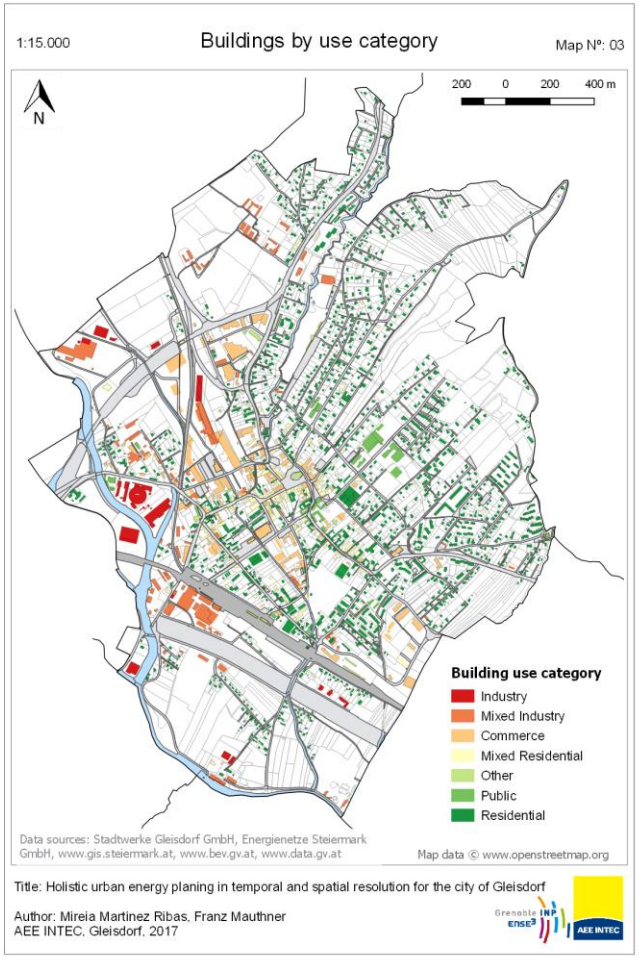
- Building stock and energy networks

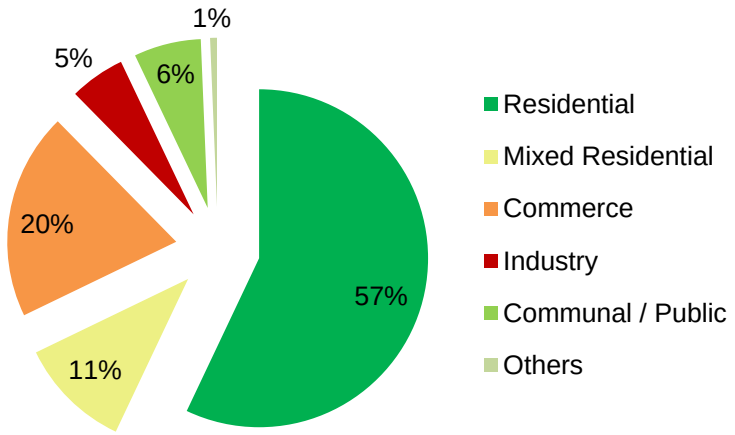


- 6.073 inhabitants
- Urban area: 475.4 ha
  - ~35% built environment (buildings + traffic areas)
- Building infrastructure
  - 1.731 addresses
  - 1.902 buildings
  - 734.000 m² GFA
- Energy networks
  - 50.3 km natural gas network
  - 6.7 km district heating trench

Analysis of building stock

- Building use category



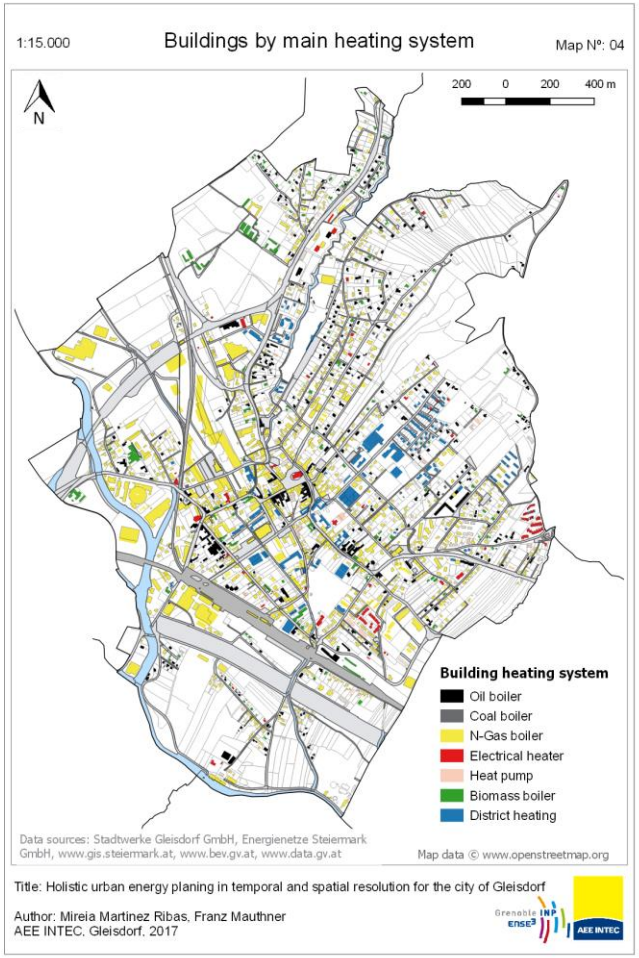


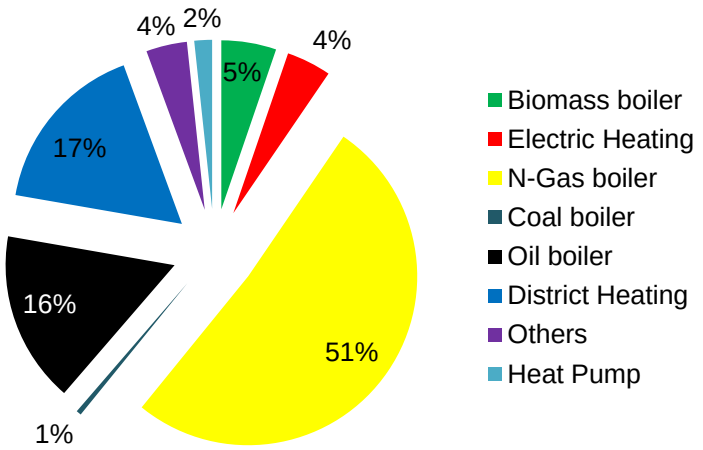
- Distribution by building use category*
  - ~75% residential and public buildings as well as mixed use in city center
  - ~25% industry and commerce

*weighted by heated gross floor area (GFA)

Analysis of building stock

- Building heating system



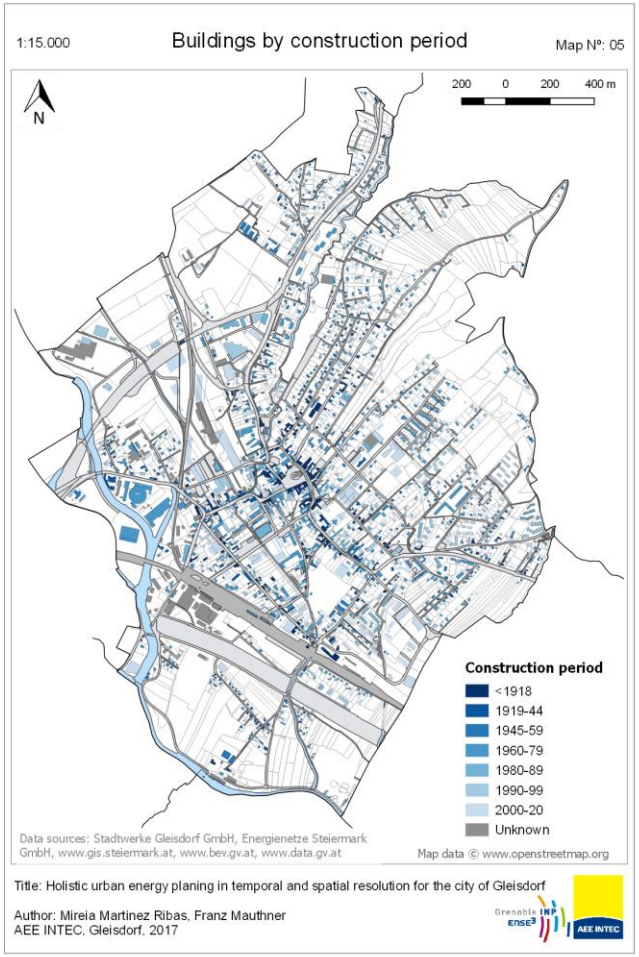


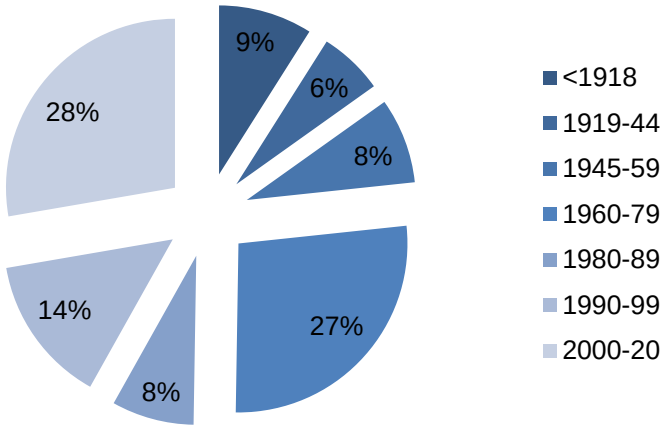
- Distribution by kind of heating system*
  - N-gas: 51%
  - District heating: 17% (mainly biomass based)
  - Oil, coal, electricity: 21%
  - Biomass, HP: 11%

*weighted by heated gross floor area (GFA)

Analysis of building stock

- Building age classes



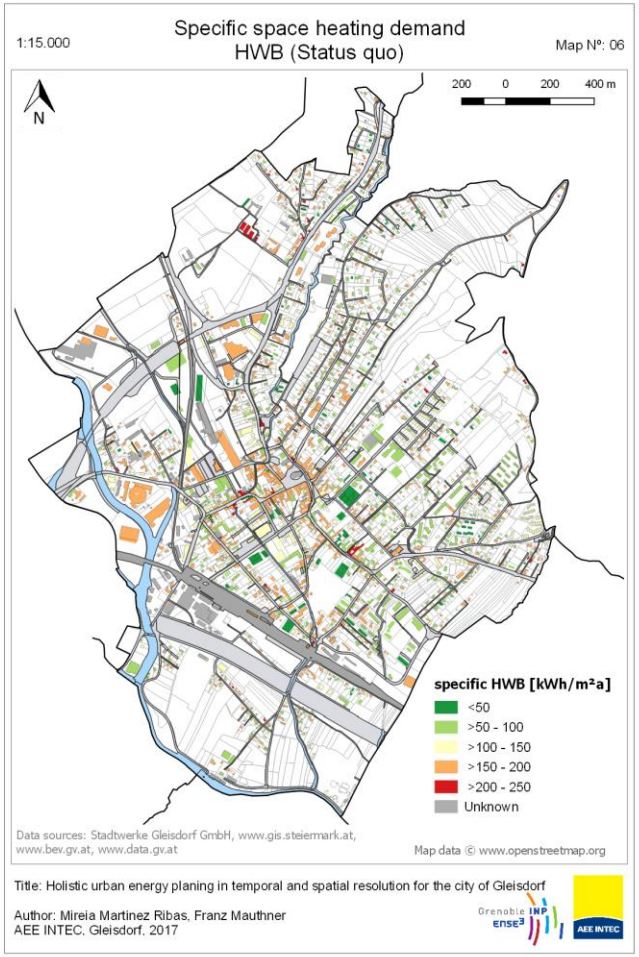


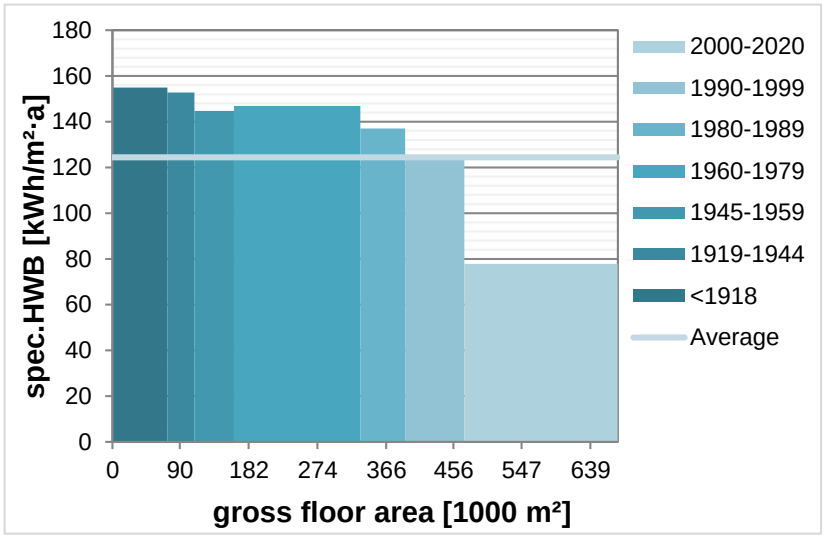
- Distribution by building age classes*
  - Around half of the buildings are from <1980 (low building energy standards)

*weighted by heated gross floor area (GFA)

Analysis of building stock

- Space heating demand (HWB) → kWh per GFA

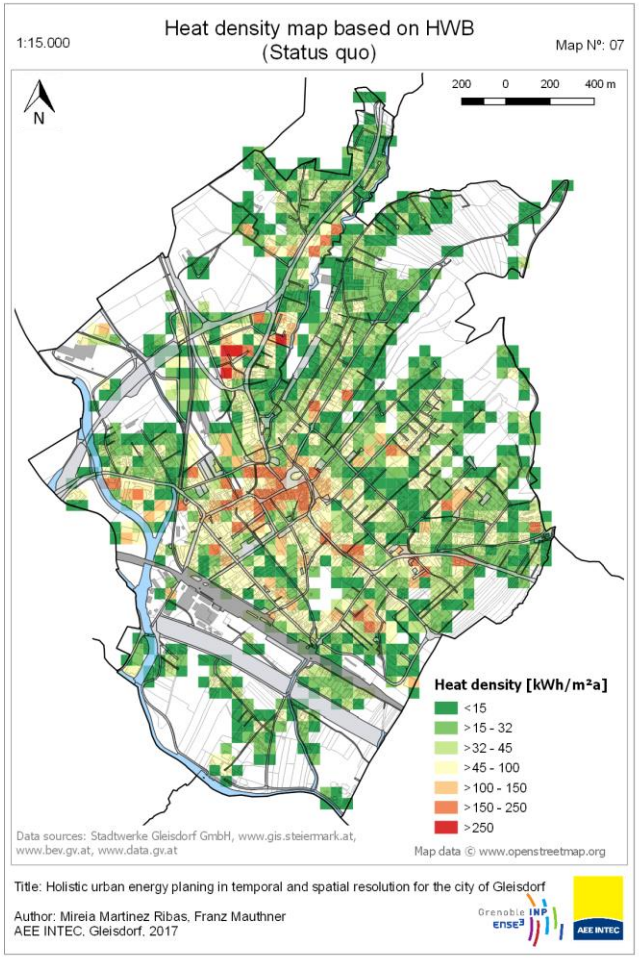


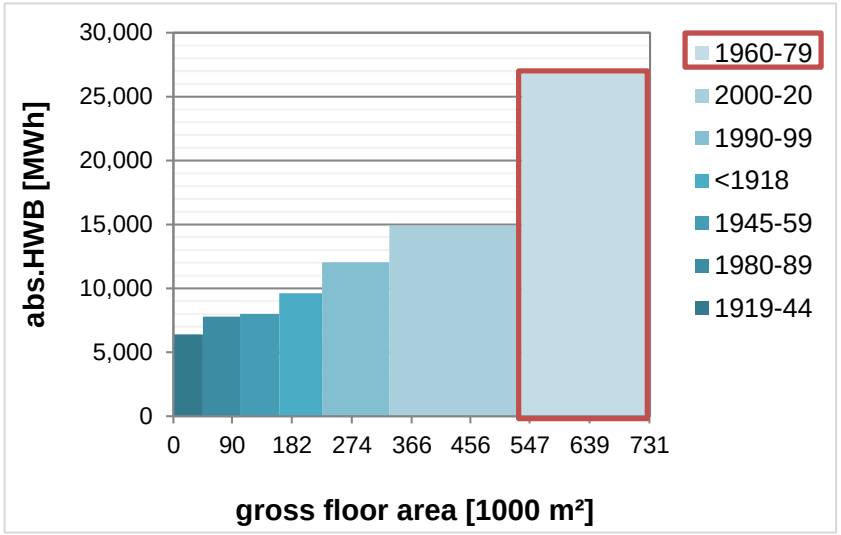


- avg. space heating demand (specific HWB): ~125kWh/(m^2_{GFA}a)

Analysis of building stock

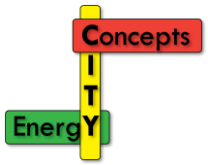
- Heat density map → kWh per raster area



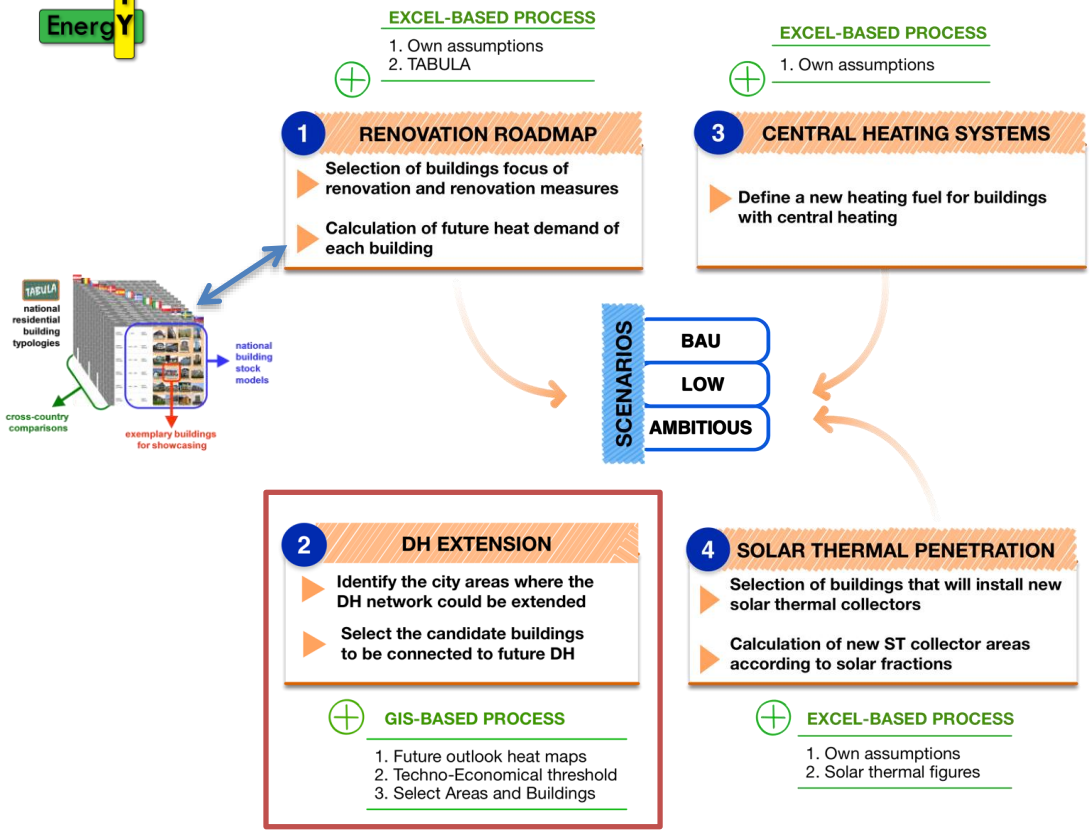


- Buildings built between 1960 and 1979 will account for the highest energy savings
- → starting point for building renovation roadmap

Roadmapping / Scenarios



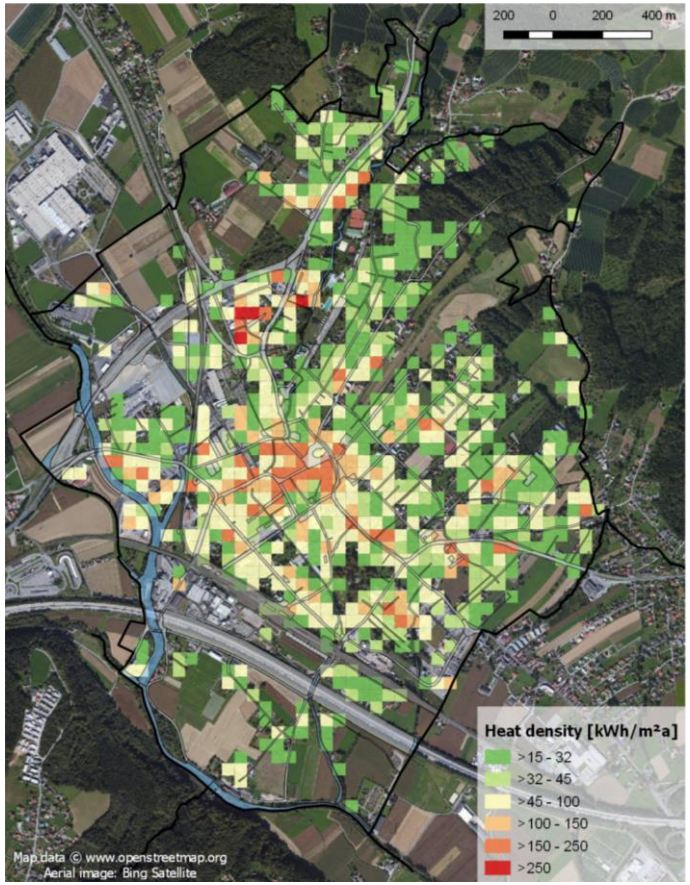
- Workflow

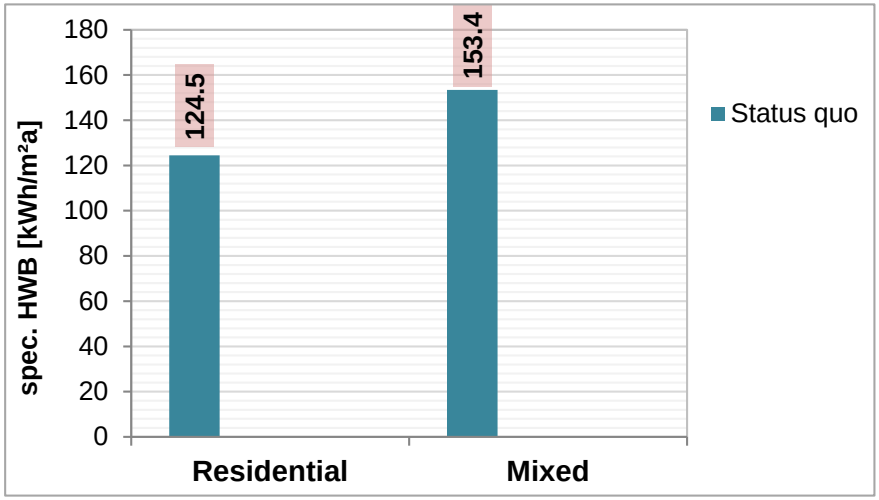


- Building renovation roadmap
  - Only for residential / mixed sector
  - Renovation rates: 1.2% - 2.2%
  - Usual or advanced refurbishment
- Modeling of future space heating demand acc. to EN ISO 13790
  - One zone-model, hourly basis
  - Based on building categories and physical parameters from TABULA
- Modeling of DH priority areas based on future heat densities and techno-economic thresholds
- Assumptions for kind of heating supply and solar fractions for buildings outside of DH areas

Roadmapping / Scenarios

- Heat density map – Status quo

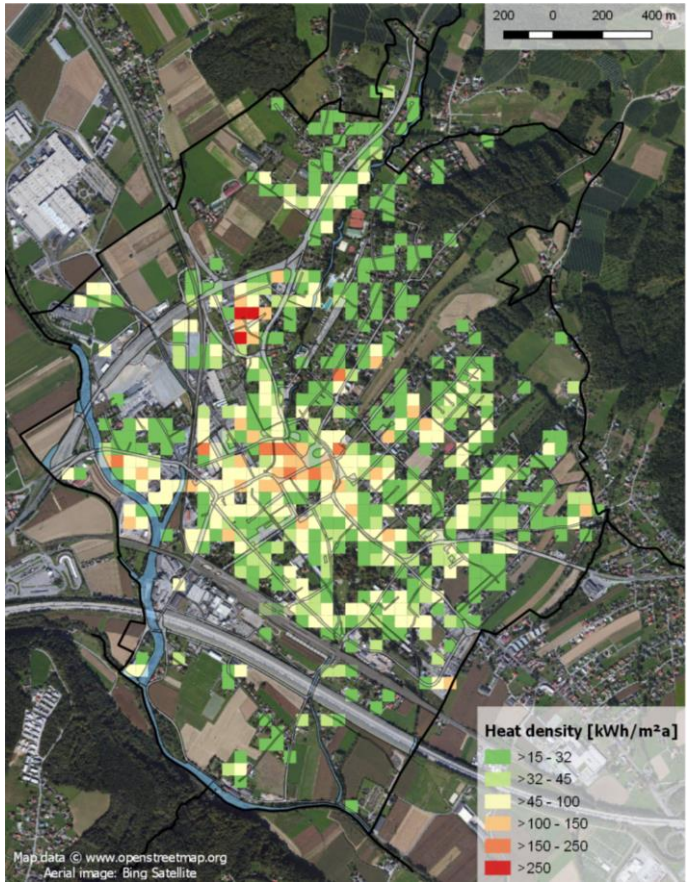


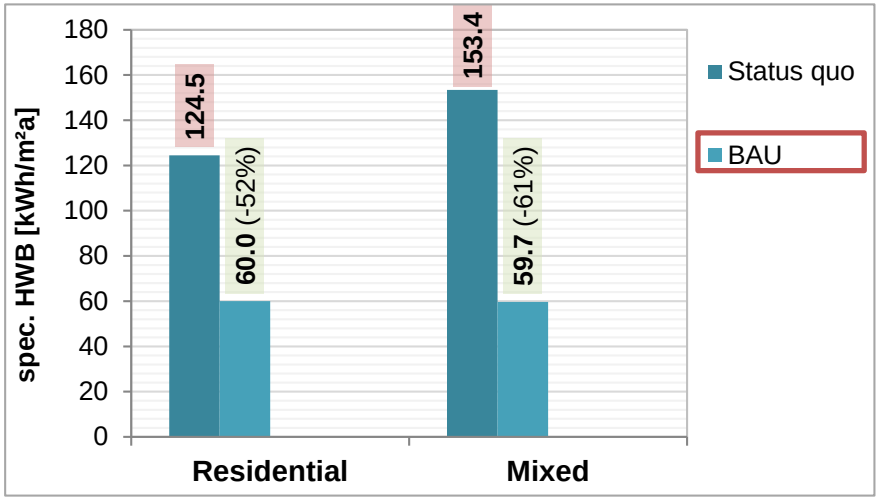


- Status quo
  - Total No. of buildings: 1,902
    - Residential / Mixed residential: 1,599 (447 already refurbished)
    - Other: 303 (industry, commerce)

Roadmapping / Scenarios

- Heat density map – BAU scenario

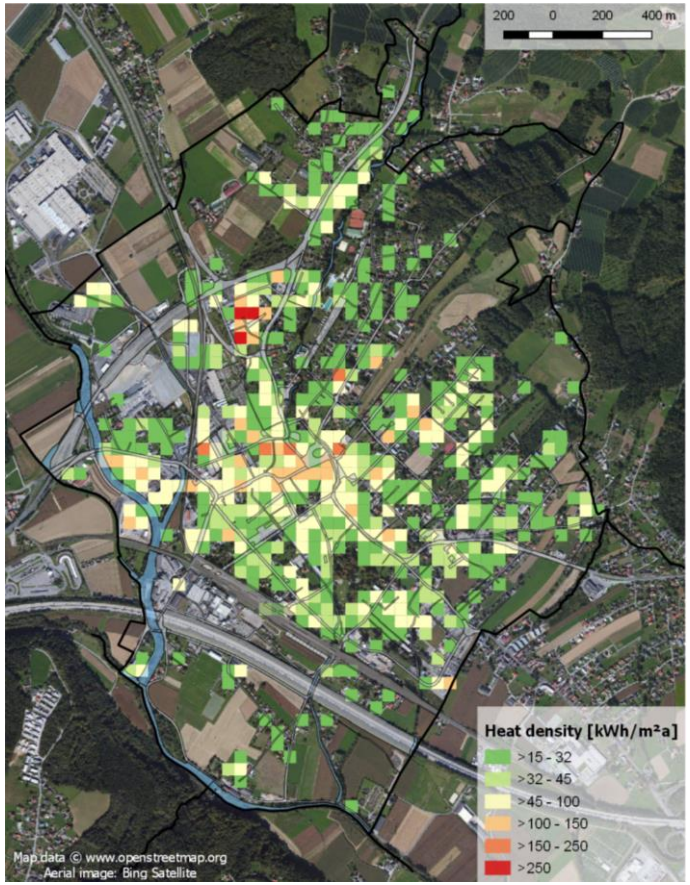


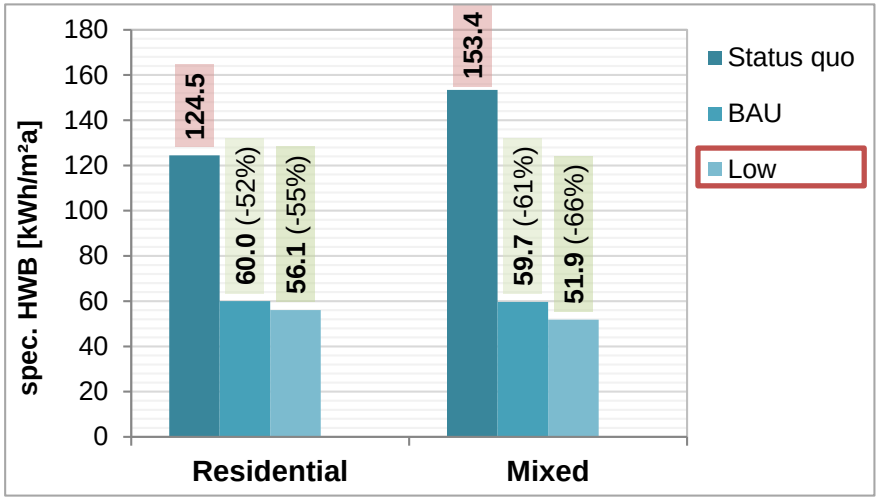


- BAU scenario
  - Renovation rate: 1.21%
    - 761 buildings
  - Refurbishment: usual (<1990)
  - HWB reduction: 52-60%

Roadmapping / Scenarios

- Heat density map – Low scenario

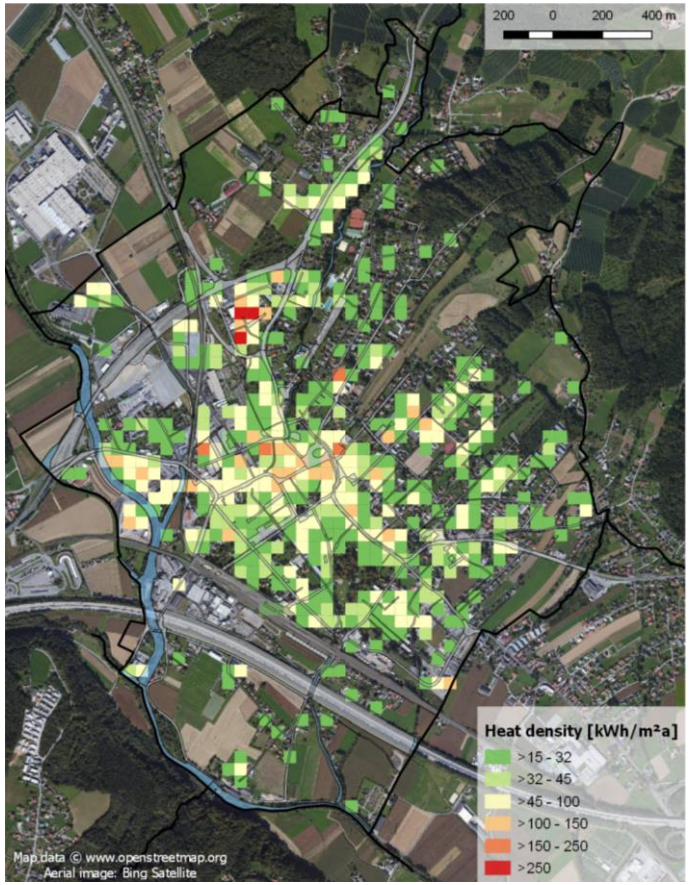


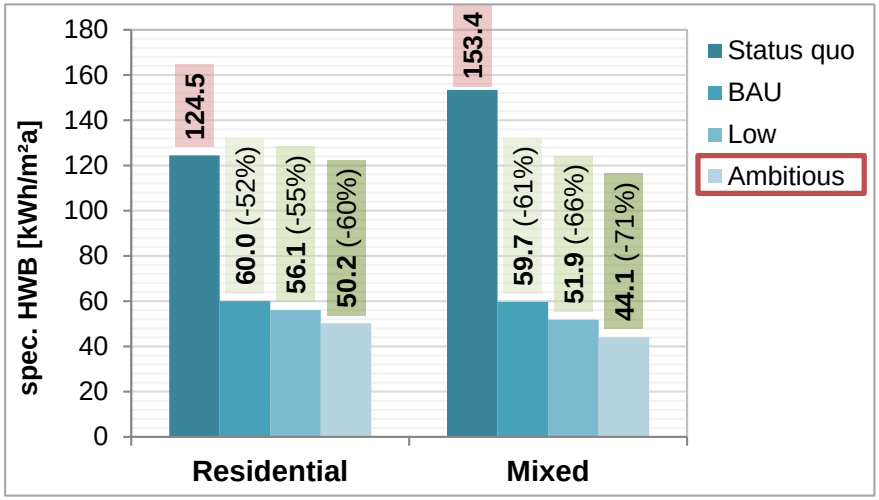


- Low scenario
  - Renovation rate: 1.65%
    - 1,037 buildings
  - Refurbishment: usual (all)
  - HWB reduction: 55-66%

Roadmapping / Scenarios

- Heat density map – Ambitious scenario

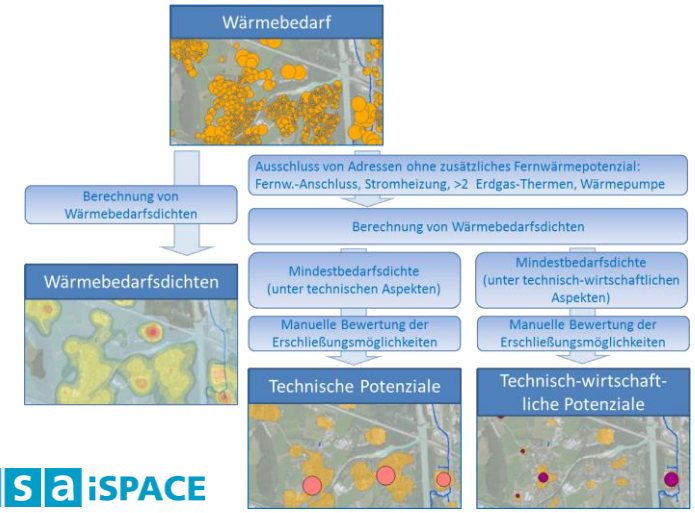


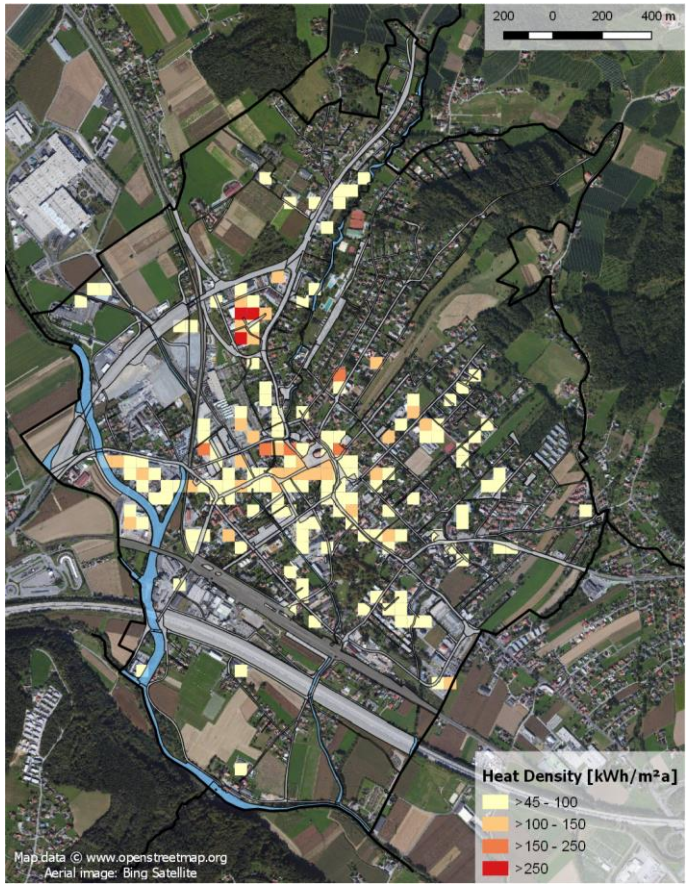


- Ambitious scenario
  - Renovation rate: 2.16%
    - 1,358 buildings
  - Refurbishment : advanced (all)
  - HWB reduction: 60-71%

Roadmapping / Scenarios

- District heating potential areas
  - Technical potential
    > 32 kWh/m²
  - Techno-economic potential
    > 45 kWh/m²





Roadmapping / Scenarios

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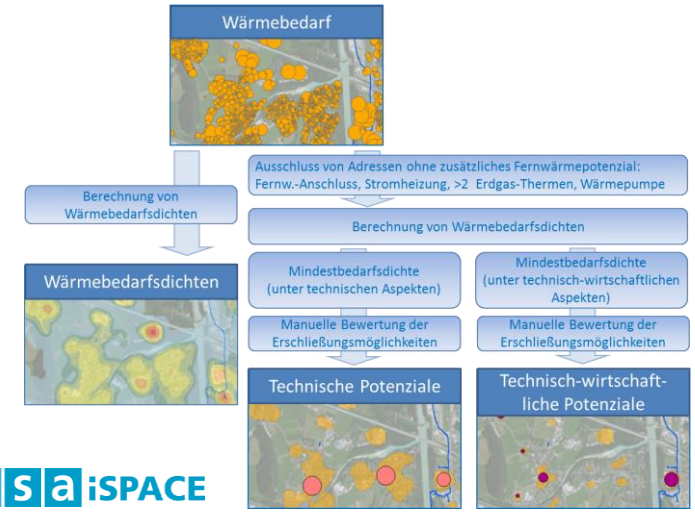
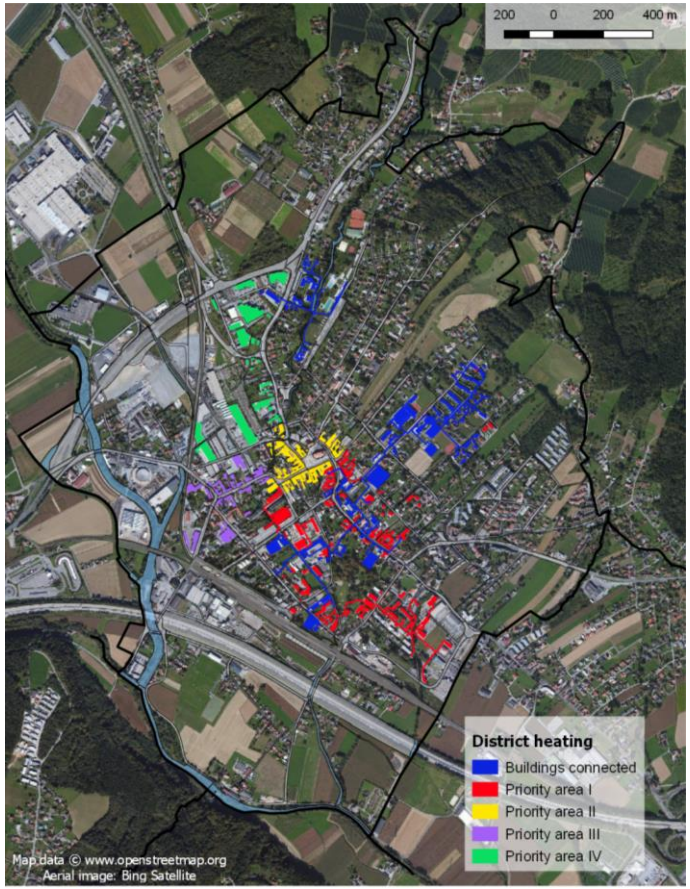
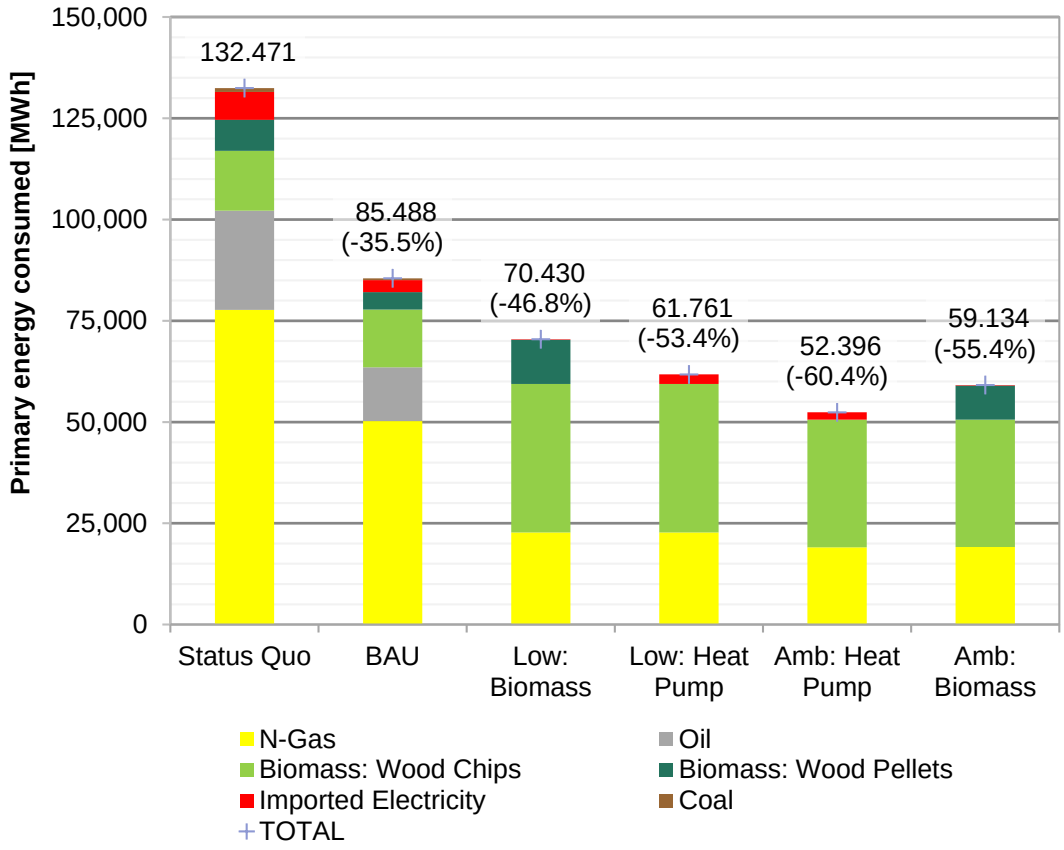




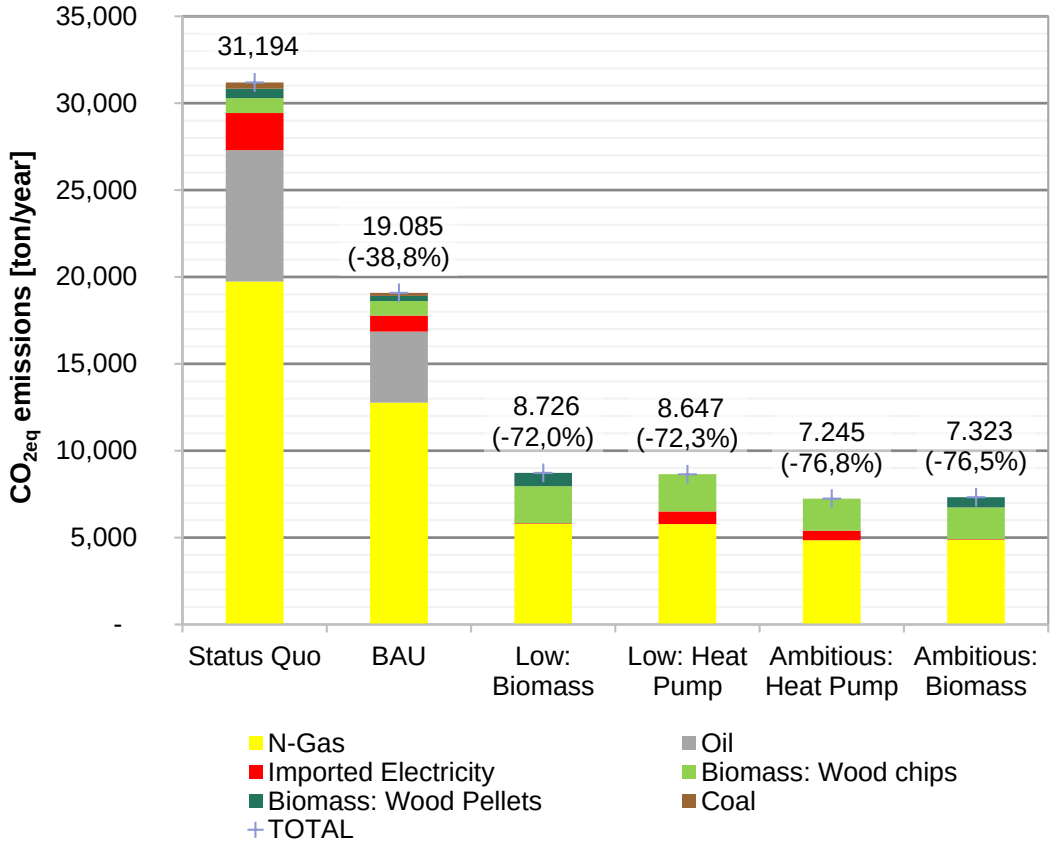
Roadmapping / Scenarios - Results

- Primary energy reduction



Roadmapping / Scenarios - Results

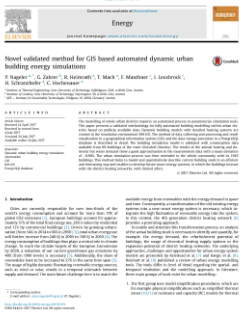
- Emission reduction (CO2eq) and % RES



Renewable fraction [%]	
Status Quo	22,0
BAU	26,2
Low: Biomass	71,3
Low: Heat Pump	68,6
Ambitious: Heat Pump	72,8
Ambitious: Biomass	73,8

Dynamic building simulation

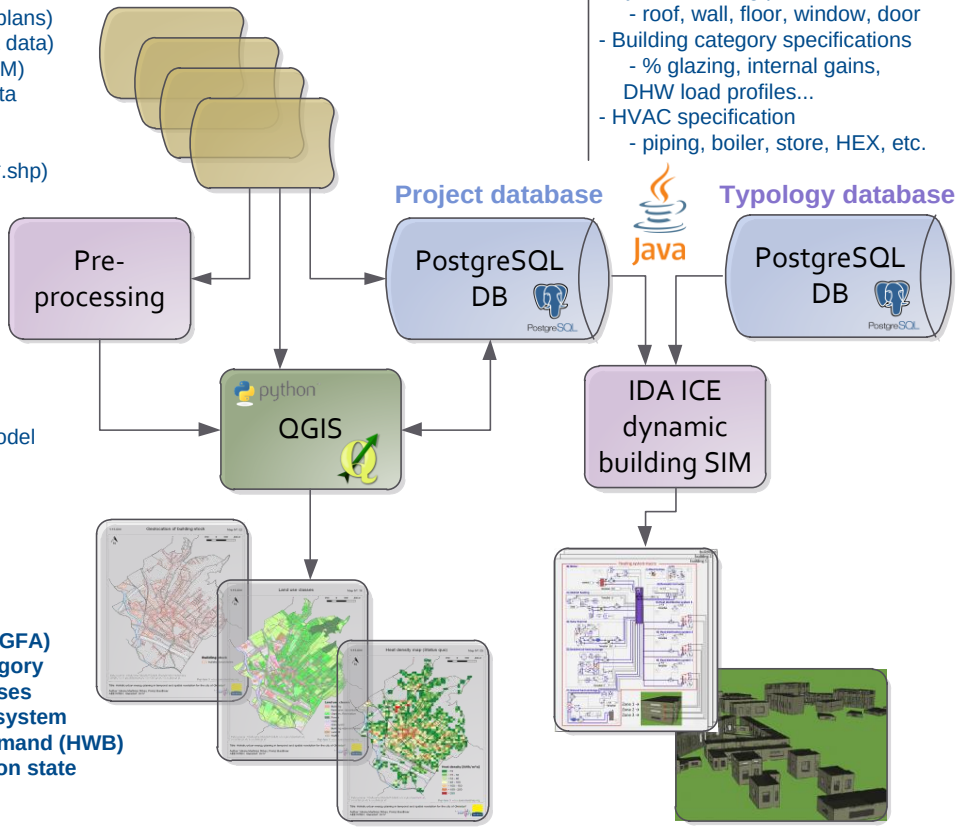
- Coupling spatial modeling with dynamic building simulation*

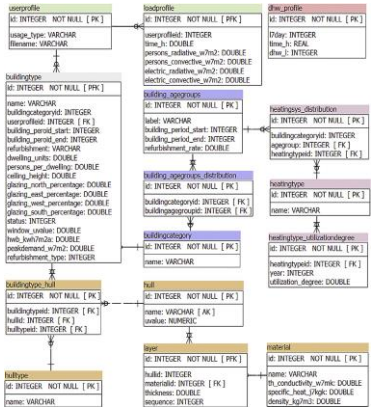


P. Nageler et al, Novel validated method for GIS based automated dynamic urban building energy simulations, Energy 139 (2017) 142-154

- CAD (e.g. network plans)
- (Open) government data)
- Open data (e.g. OSM)
- Remote sensing data
- Orthofotos
- Statistical data
- Other (*.xlsx, *.txt, *.shp)

- Pysical building parameters
  - roof, wall, floor, window, door
- Building category specifications
  - % glazing, internal gains, DHW load profiles...
- HVAC specification
  - piping, boiler, store, HEX, etc.





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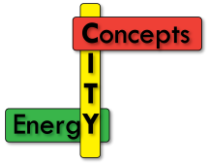
- **Building heating system**
- **Space heating demand (HWB)**
- **Building renovation state**

Wrapping up…



- Summary
  - GIS-based urban energy planning workflow based on existing geo-data, applicable for Austrian communities and cities
  - Simplified approach for future HWB demand estimation (EN ISO 13790) good starting point for roadmapping
  - Detailed building simulation of entire cities can be directly linked to acquired geodatabase (tested for ~2,000 buildings)
  - GIS- maps are self-explaining and as such important documents in urban energy planning processes

- Methodical improvements – ongoing tasks:
  - Further automation of data acquisition and pre-processing
  - Building roadmap not yet considers demolition of existing buildings and / or new building areas
  - Space heating demand for non-residential sector as well as process heat demand not yet sufficiently considered