Towards an integrated platform for the modelling and minimisation of future urban resource flows

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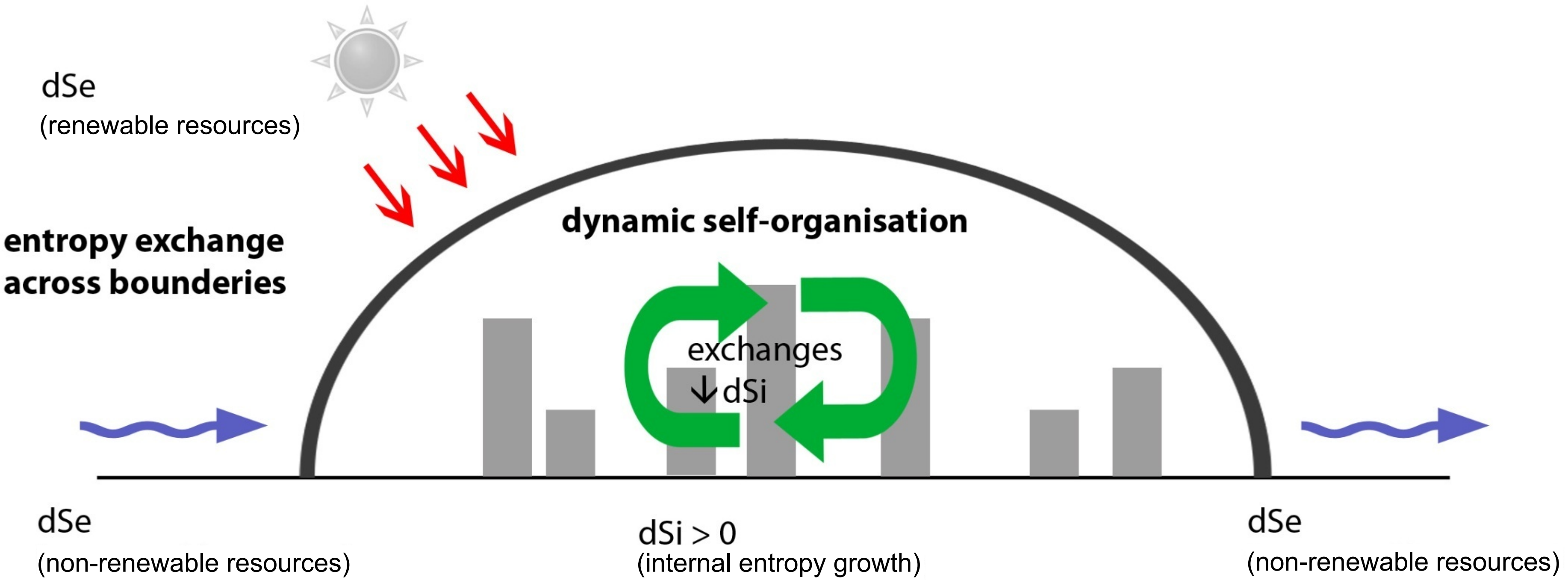
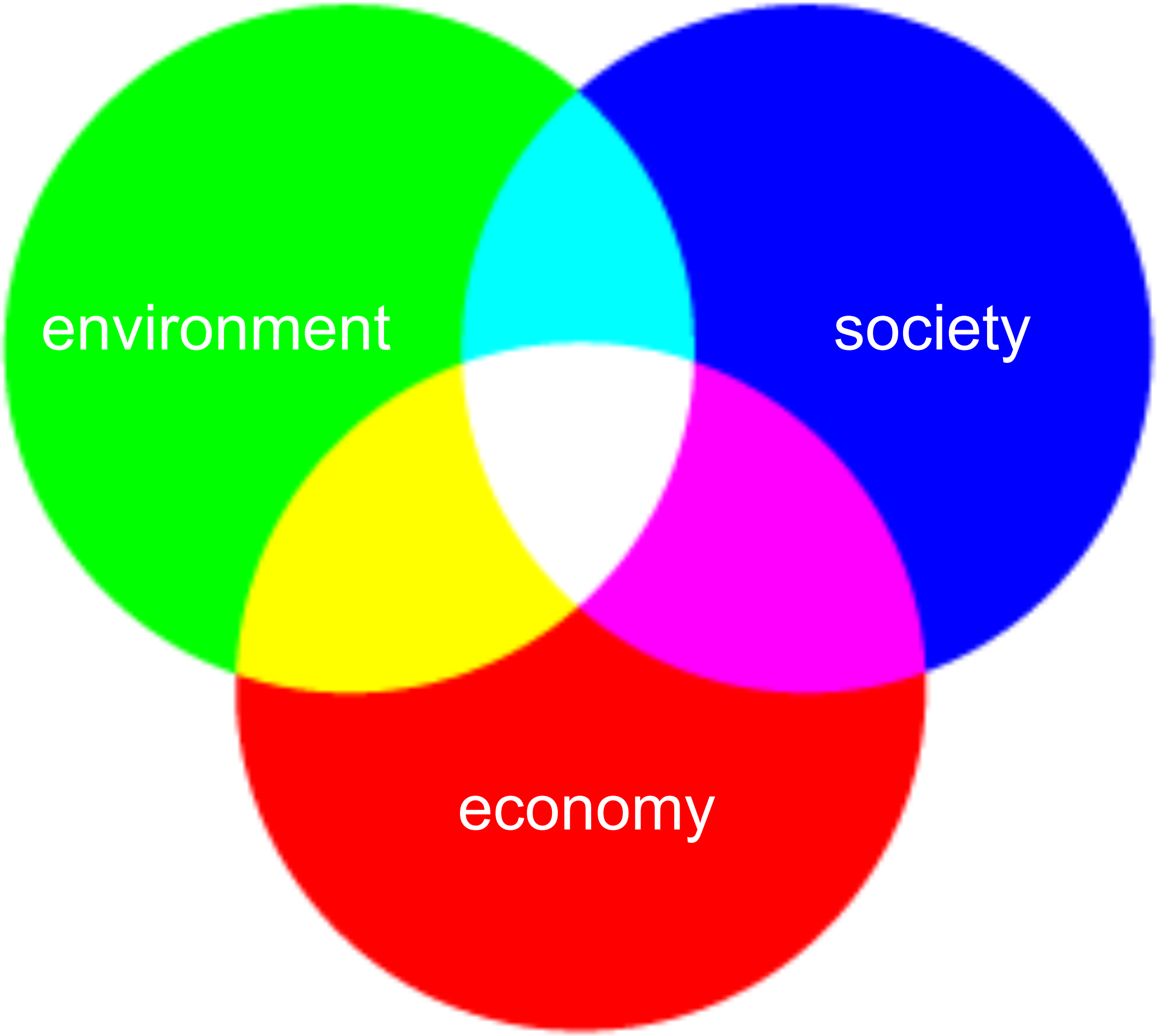
A conceptual model

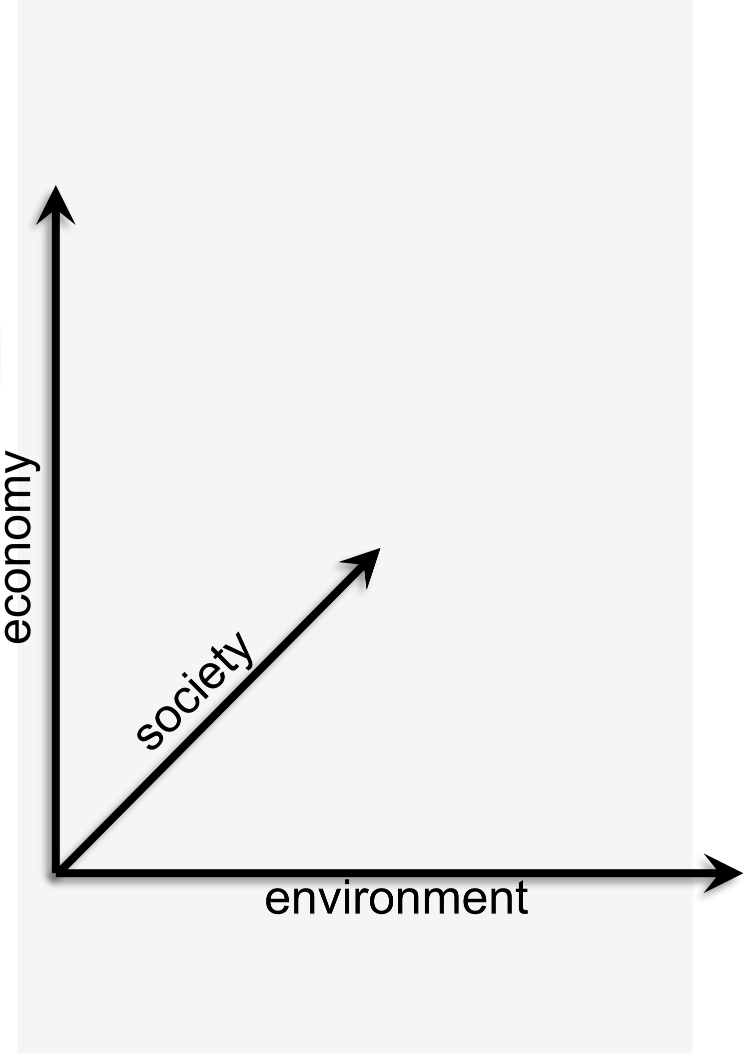


Cities are: Self-organising, non-linear and open.

The environmental unsustainability continuum

What's sustainability?: interrelationships, conflict and competition





Sustaining Urban Habitats: An interdisciplinary approach

The Leverhulme Trust

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Grant: Research Programme Grant, 2014
Funding: £1.75M (£3.4M total: >70PYs [7RF, 16+2PhD])
Duration: 5 years (Feb 2015 – Jan 2020)

Project objectives:

- To **understand** the complex interrelated and competing factors influencing urban sustainability.
- To holistically **define, measure and model** it.
- To identify **pathways** to *transition* developed cities and accommodate *growth* in developing cities in near-sustainable ways.
- To define **policy and governance structures** to implement these pathways in practice.

Case studies

European *transition* cities

Asian *growth* cities

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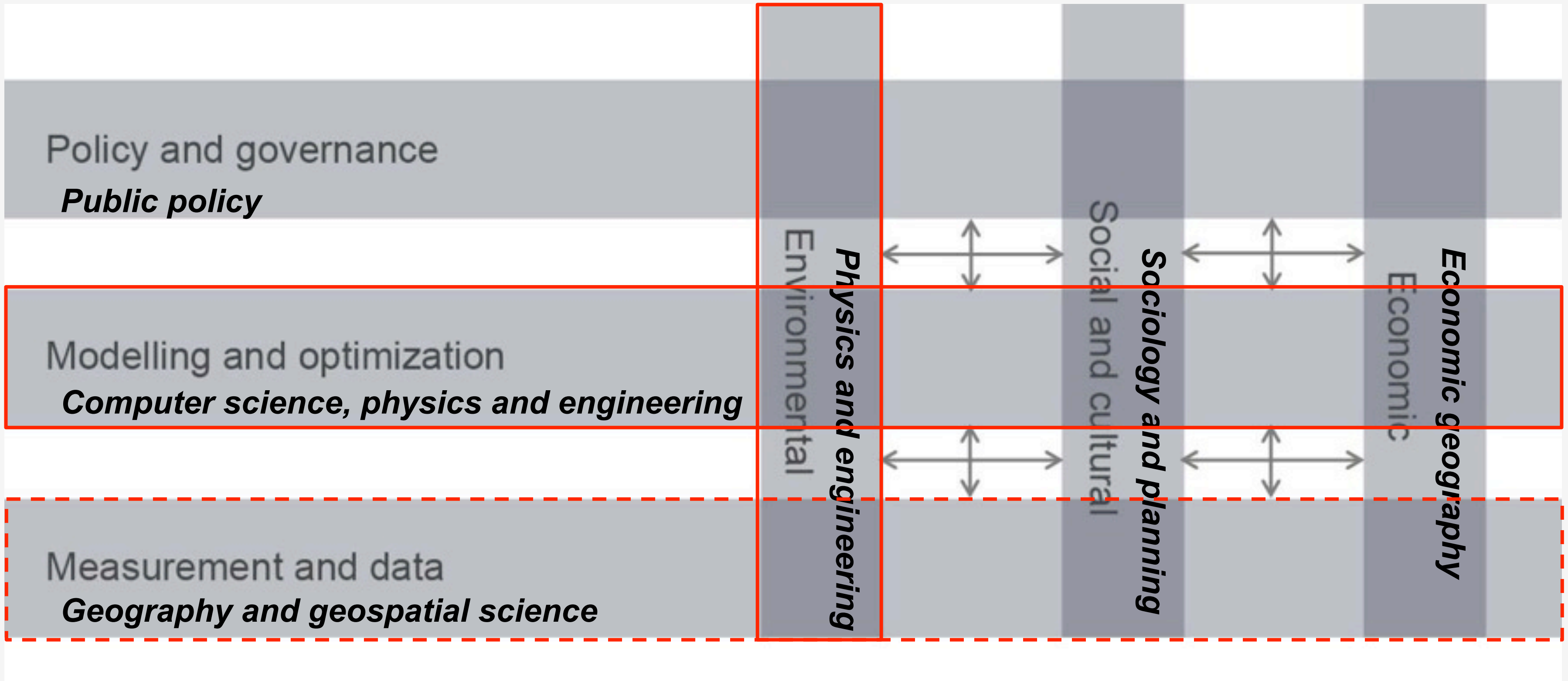

Three core modelling questions:

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- If we were charged with planning a **new city** from scratch, how should we **structure** it?
- How should we **manage** the evolution of an **existing city**?
- How can we address these challenges for cities of very different functions and scales: **generalisability** and **parsimony**.

Some open urban modelling questions…

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Given some objective function characterising environmental **un**sustainability, how should our (**hypothetical**) city be configured to minimise it?:

- How dense or compact?
- How diverse: entropy minimising?
- Which transport modes and technologies?
- Which industries and how tightly coupled?

Some open urban modelling questions…

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- How should buildings be designed to reduce resource demands and of which materials should they be built?
- To what extent can behaviour reduce demands?
- Which (thermal and electrical) energy conversion, storage, distribution and control technologies?
- *Which water treatment / management strategies?*
- *How autonomous can food production be?*
- *…etc*

- ***An integrated urban model should be capable of responding to all these questions, and more…***

Let's flesh out this multiscale socio-technical simulation problem…

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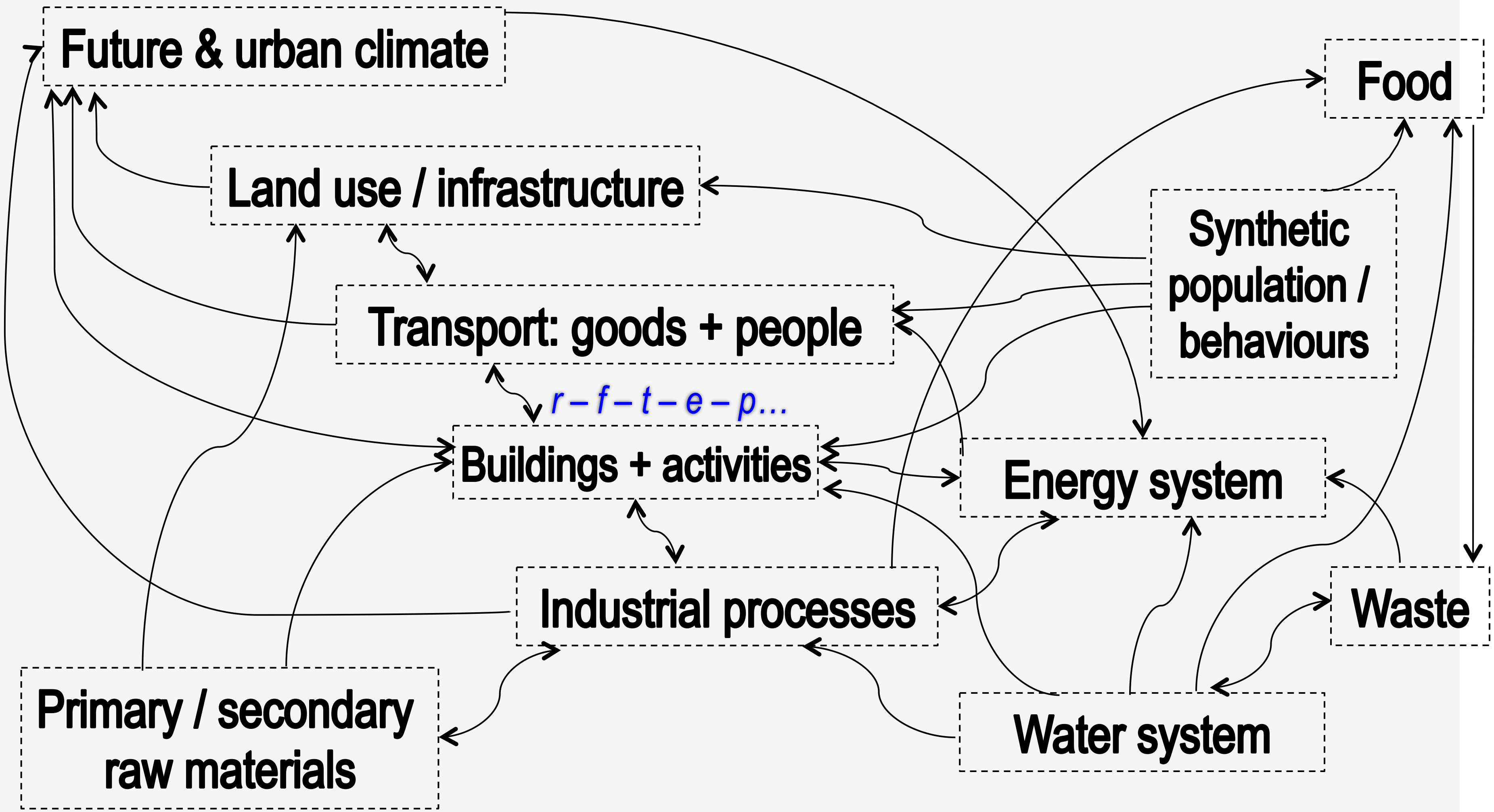

Influencing stimulii: r = regulatory; f = financial; e = educational; t = technological; p = peer

Modelling approach: spatiotemporal scale / scalability; data availability and uncertainty; data exchange; co-simulation; hardware acceleration; contextual questions…

Candidate modelling strategies

“*all models are wrong, but some are useful*”
(Box & Draper, 1987)

Urban and future **climate modelling**
Rural Simulation: Basel-less Basel

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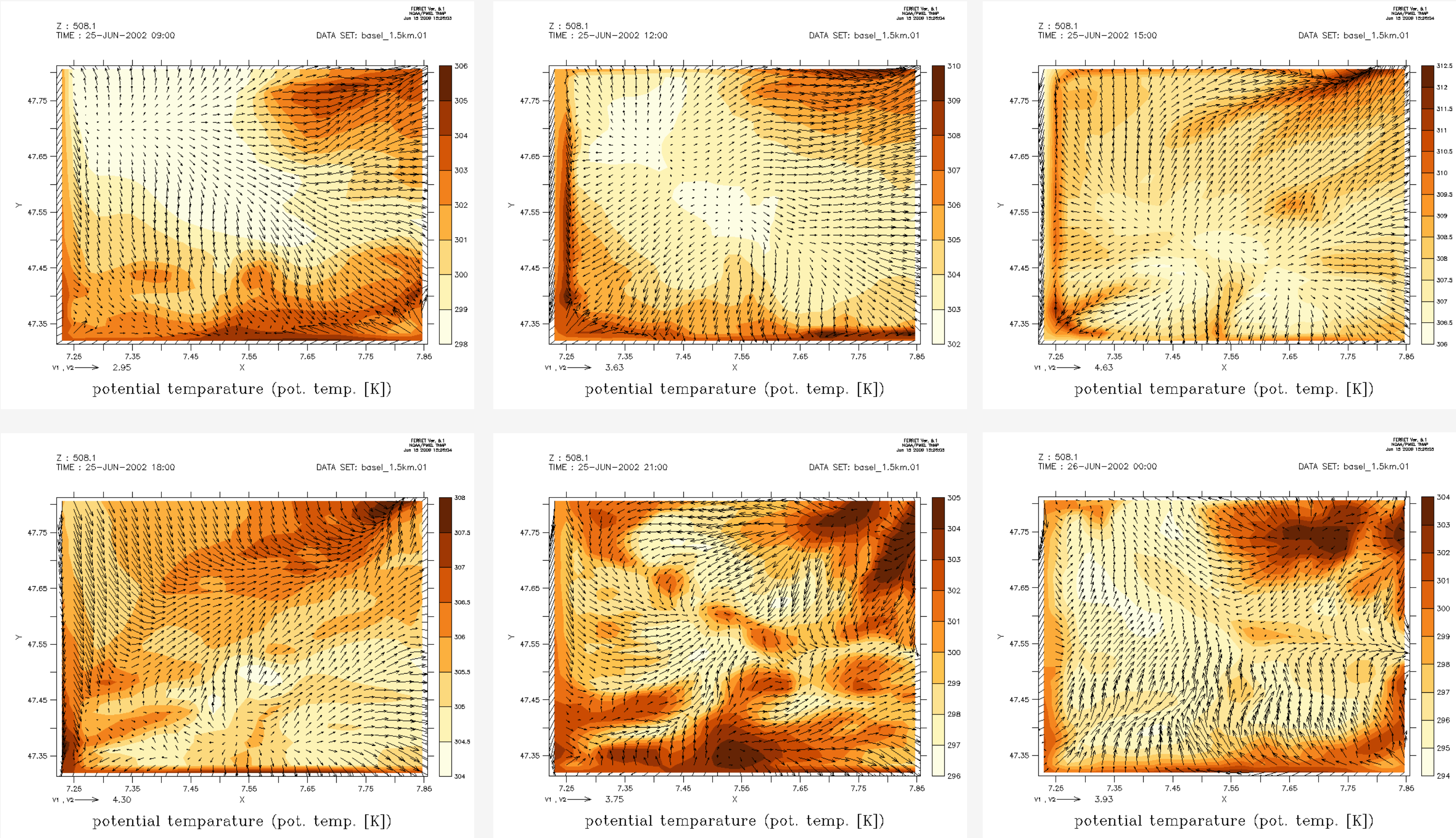
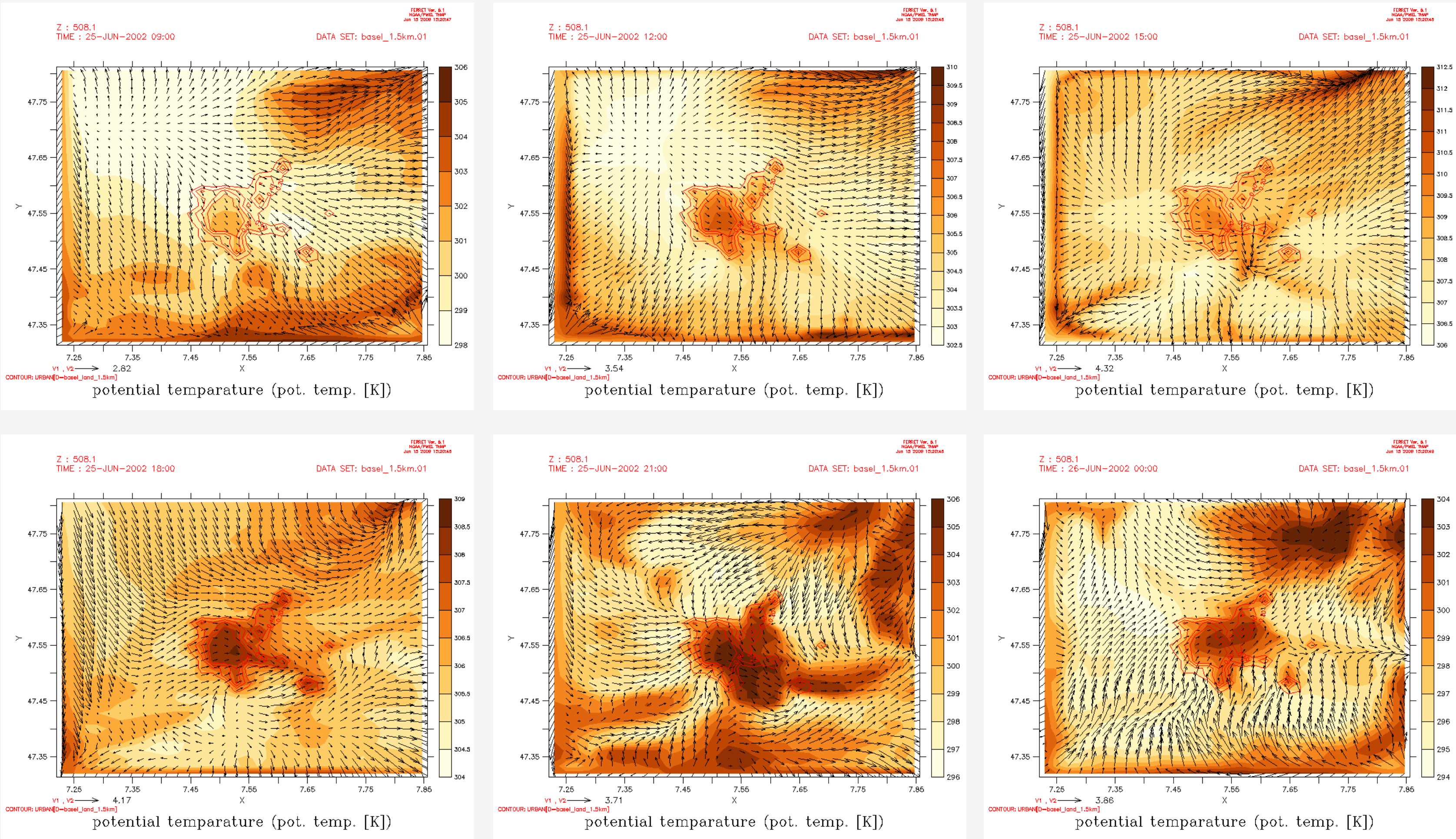


And now **with** Basel…



Airflow retarded by the urban structures, heated city core, entrainment of cool air towards the heated centre, the centre of the UHI is shifted due to wind, temperature drops with radial distance from centre

Air quality

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Population-weighted PM2.5 exposure in China: 52µg/m^3.

This is calculated to contribute to 1.6 million deaths/year, or c17% of all deaths (Berkeley Earth, 2014).

Land use:

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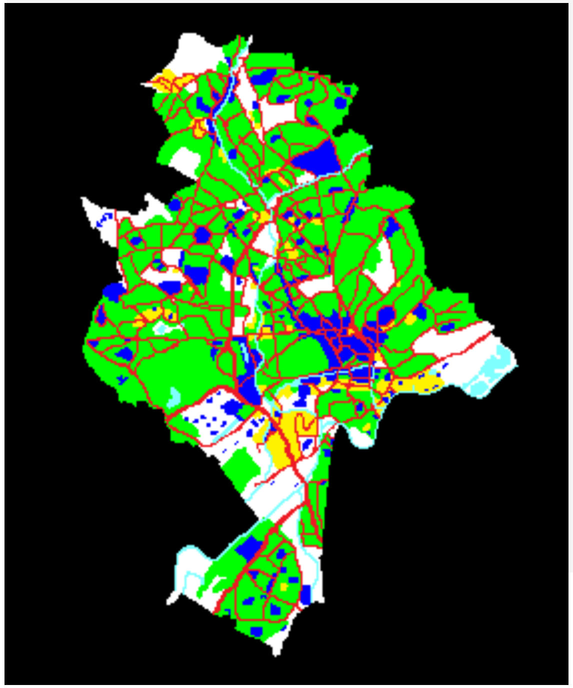
Starting with a simple CA-like model:

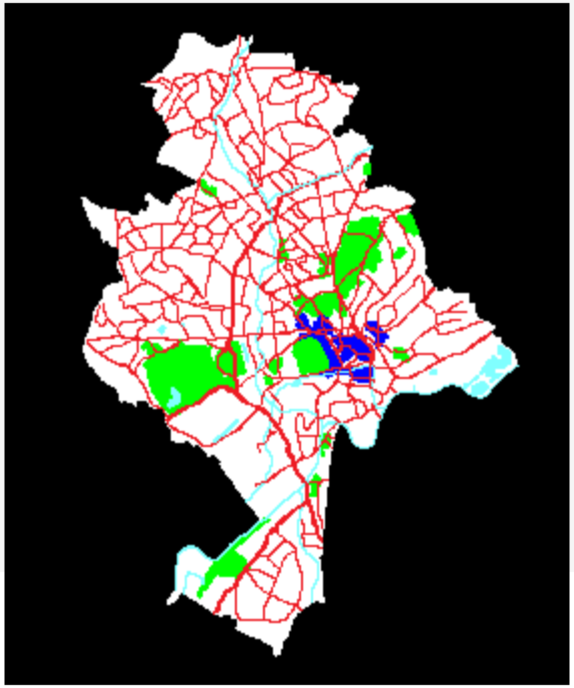
- Three land-use types (Residential/parks-G, Industrial-Y, Commercial-B)
- Land use changed by individual neighbourhood utility optimisation
- Metropolis algorithm used for update

Original Map

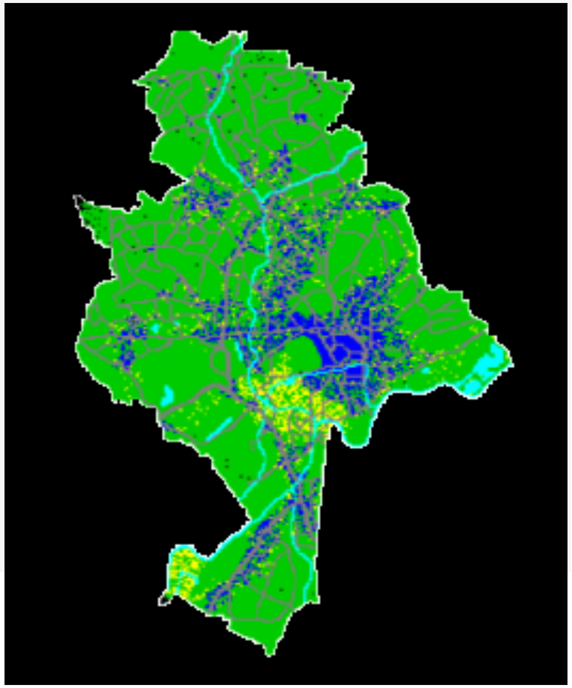


Spatial entropy (comm): 0.64

Initialisation



Result



Spatial entropy (comm): 0.51

Land use (& accessibility interactions):

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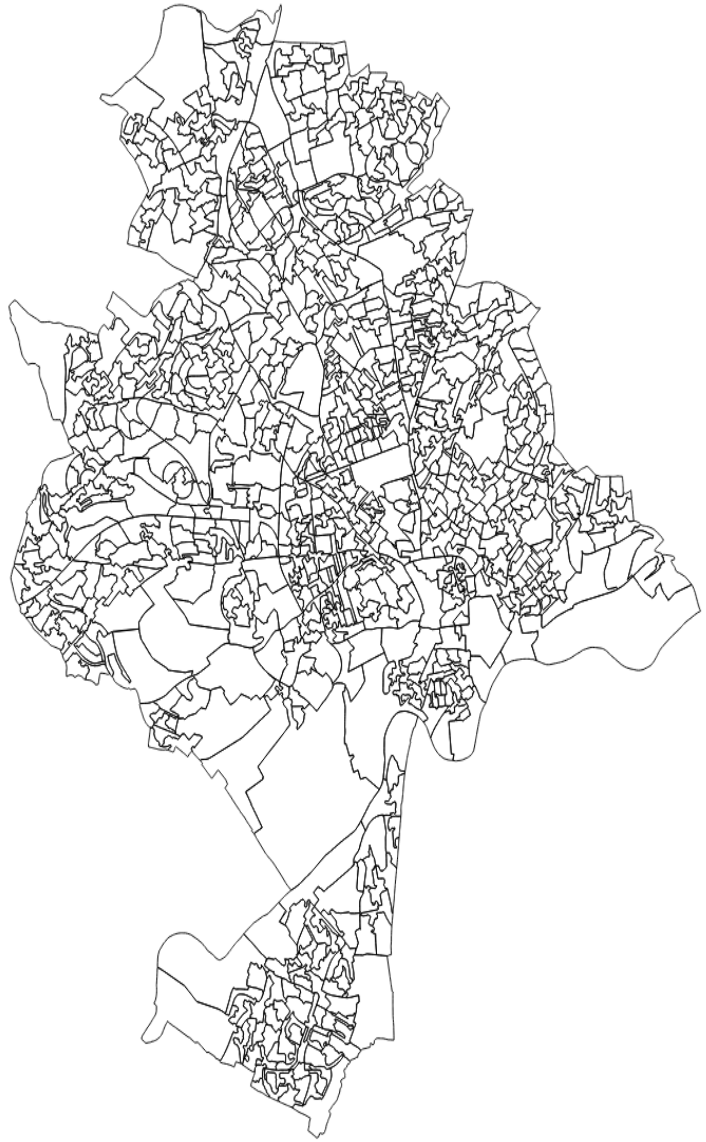
Next steps:

- Regular lattice to irregular zone (output area)
- Optimised utility
- Accessibility
- Discrete to continuous (mixed) land use allocations
  - Plot allocations
    - Demographic composition
  - Corollary of cost
  - Building heights and vertica use distributions
  - Synthetic forms
- Migration



Transport micro-simulation: MATSim

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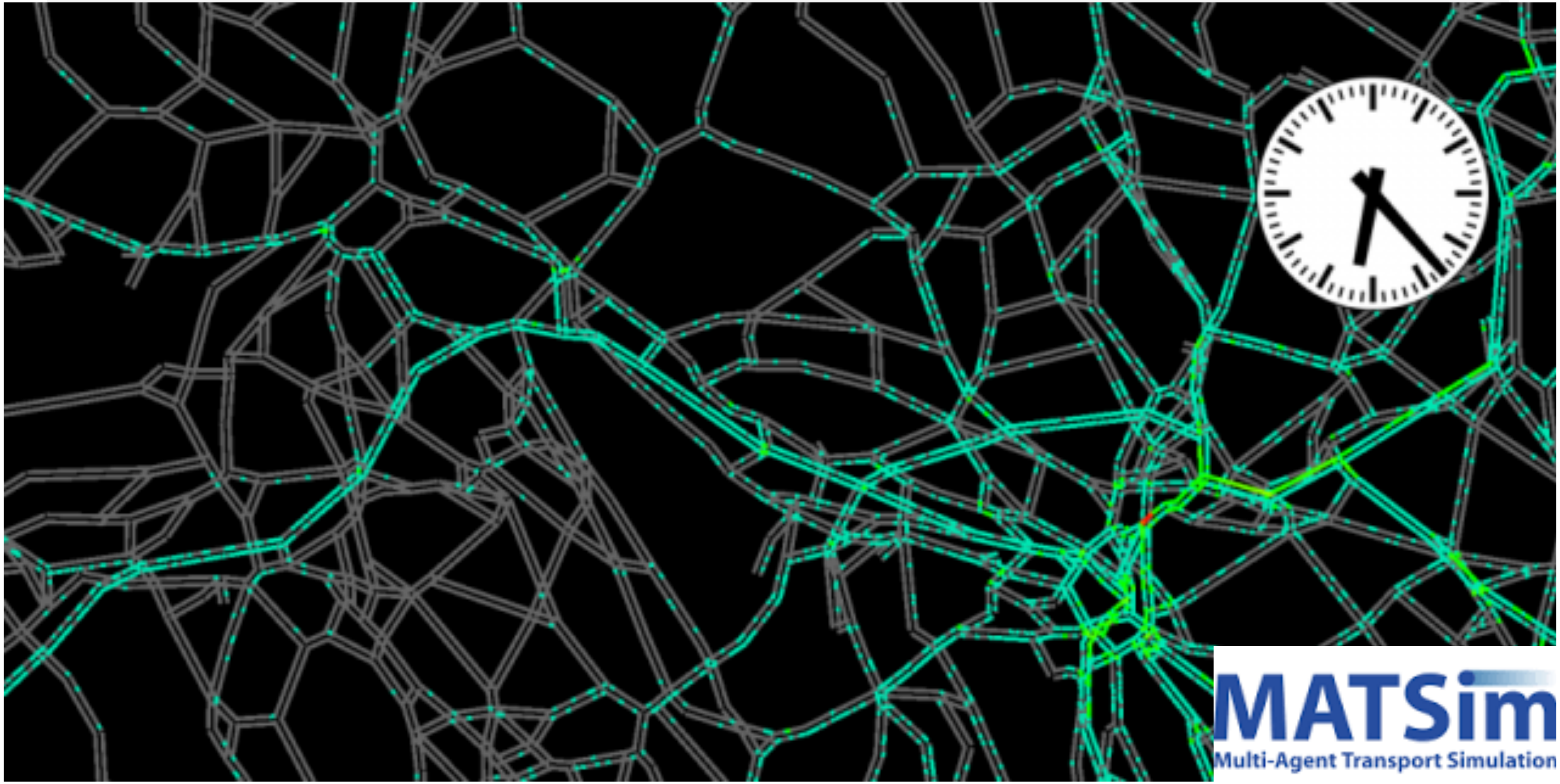

Zonal transport modelling: simplified

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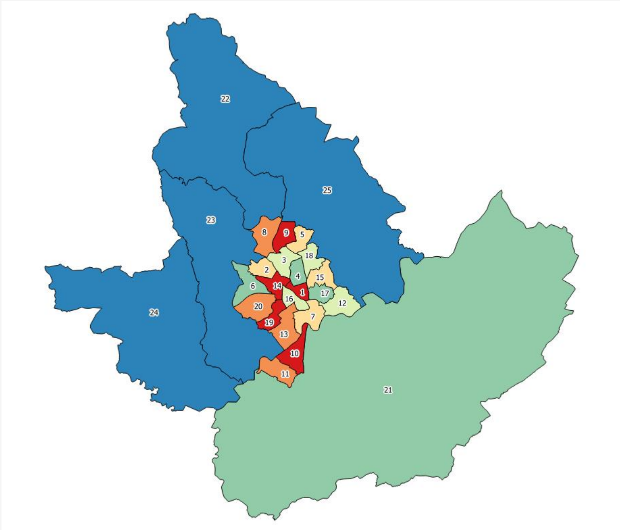


Trip Generation

↓

Trip Distribution

↓

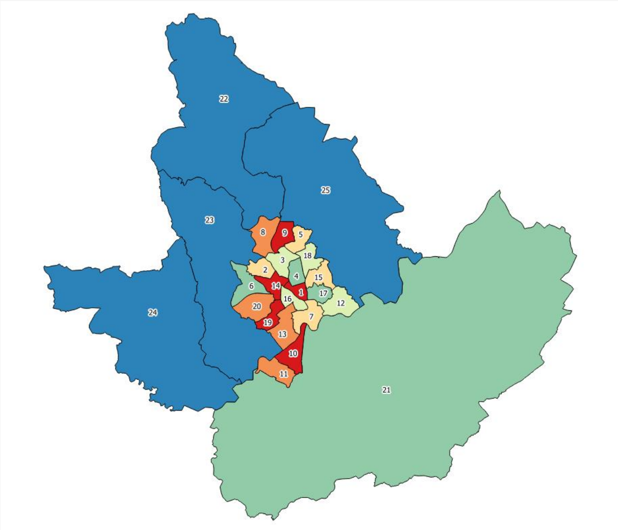
Mode Distribution

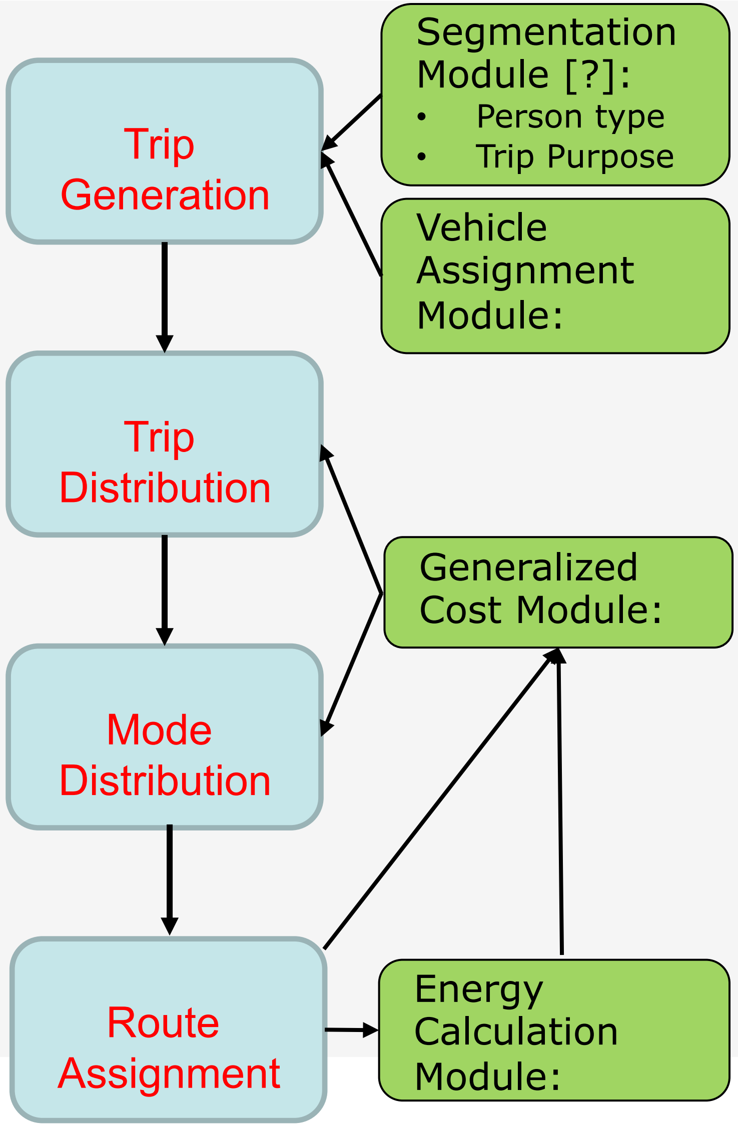
↓

●

Costs:
- Default velocities for modes
- Distance between zones or main route

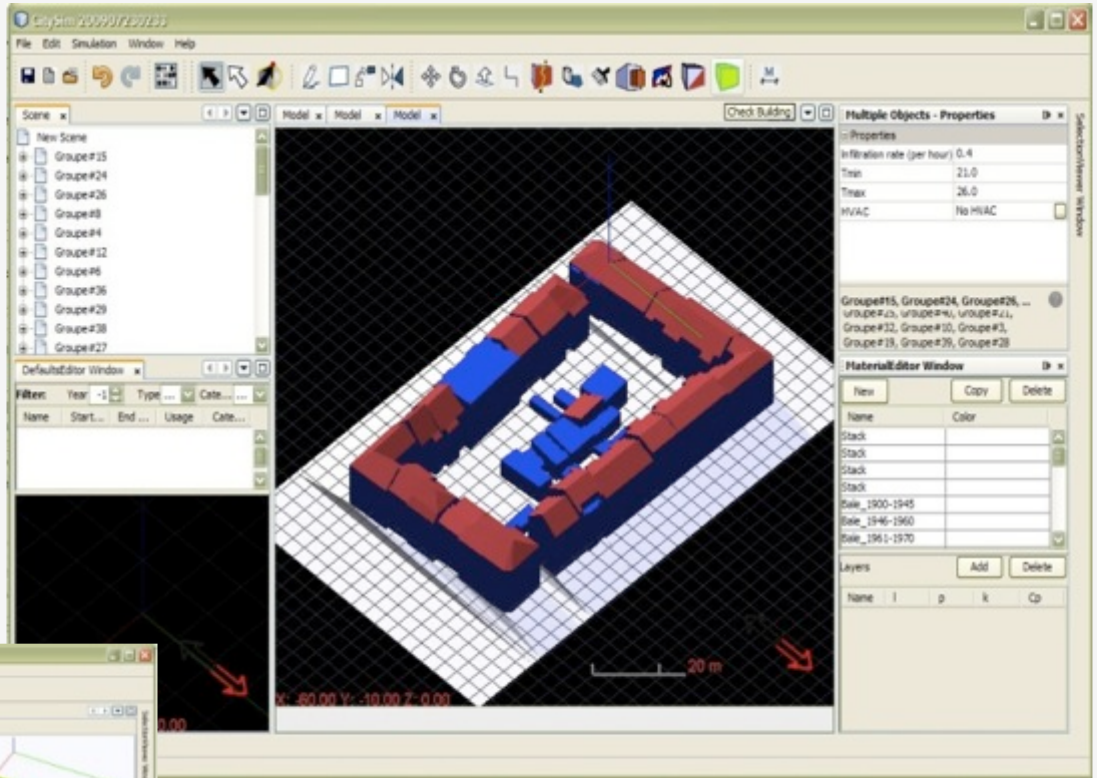
Zonal transport: more elaborate

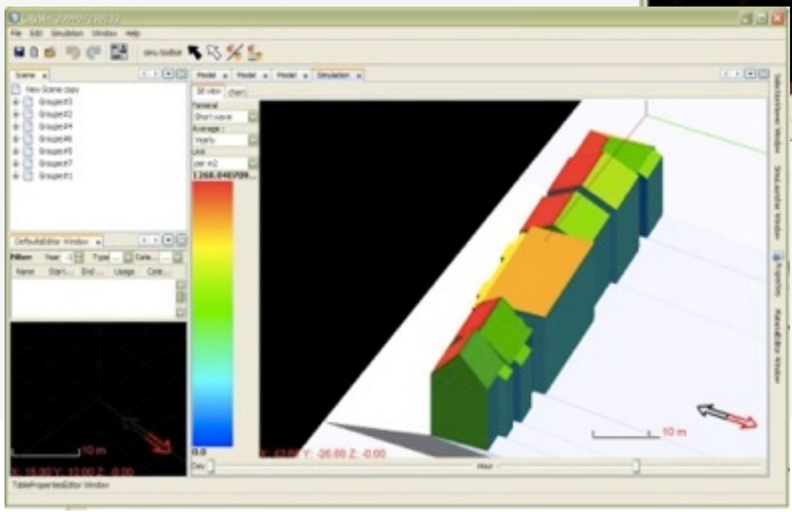




Energy in buildings: micro-simulation: CitySim

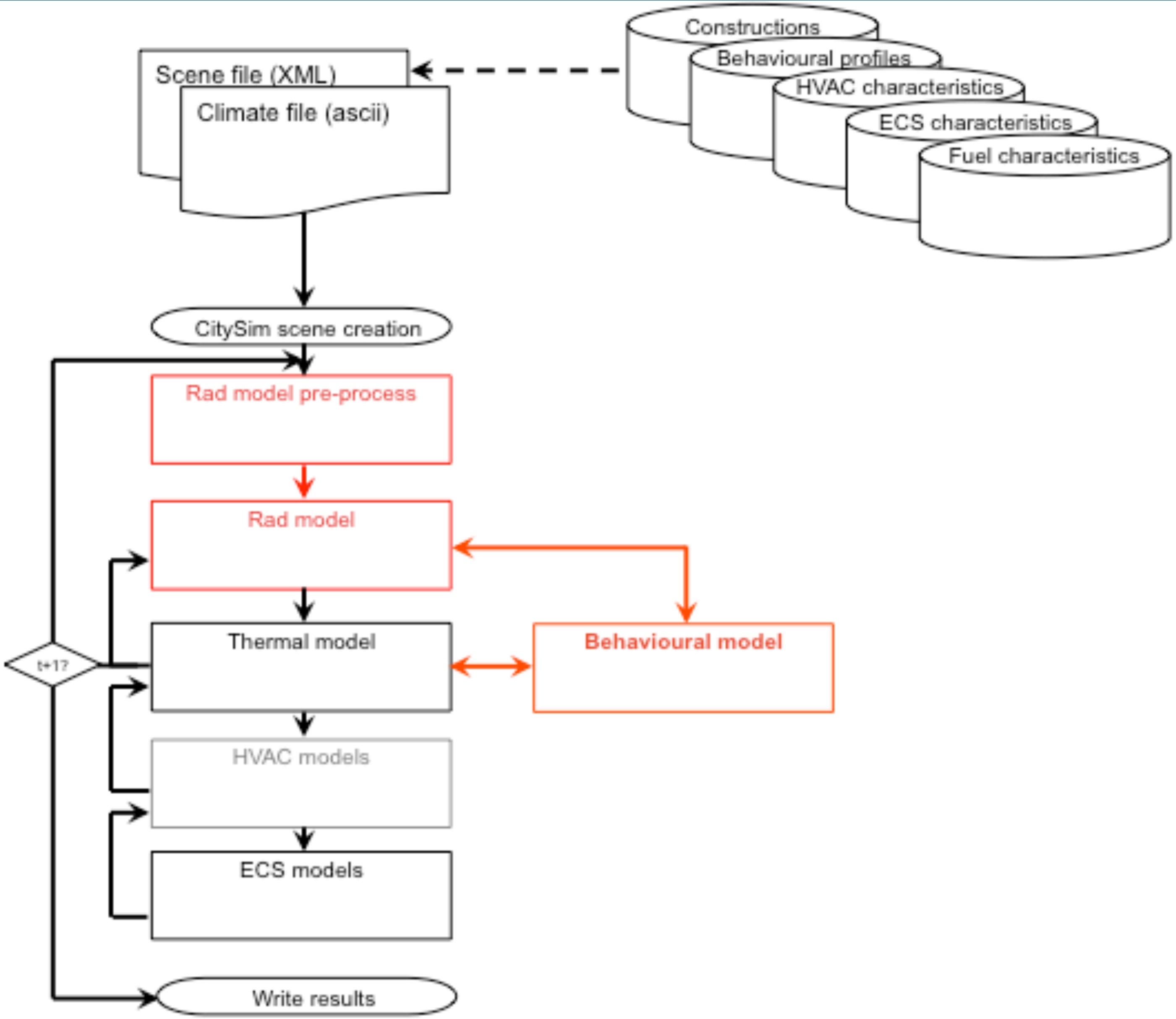
1) Create or import 3D model and its clones
2) Describe envelope composition
3) Describe occupancy and appliance schedules



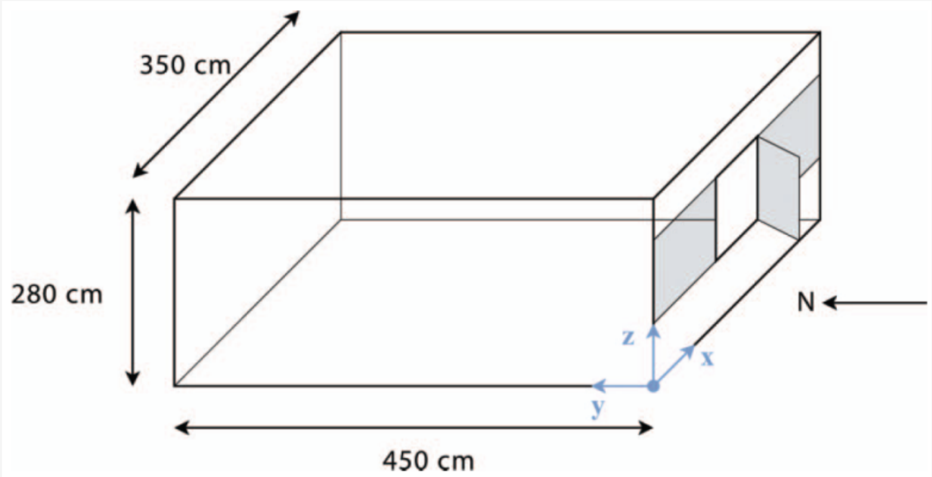


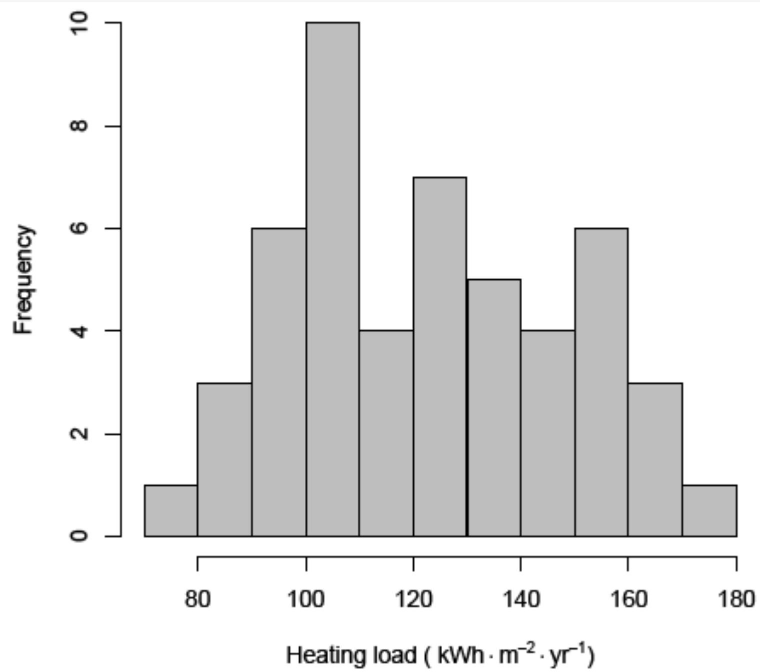
4) Describe HVAC and ECS systems
5) Simulate and analyse

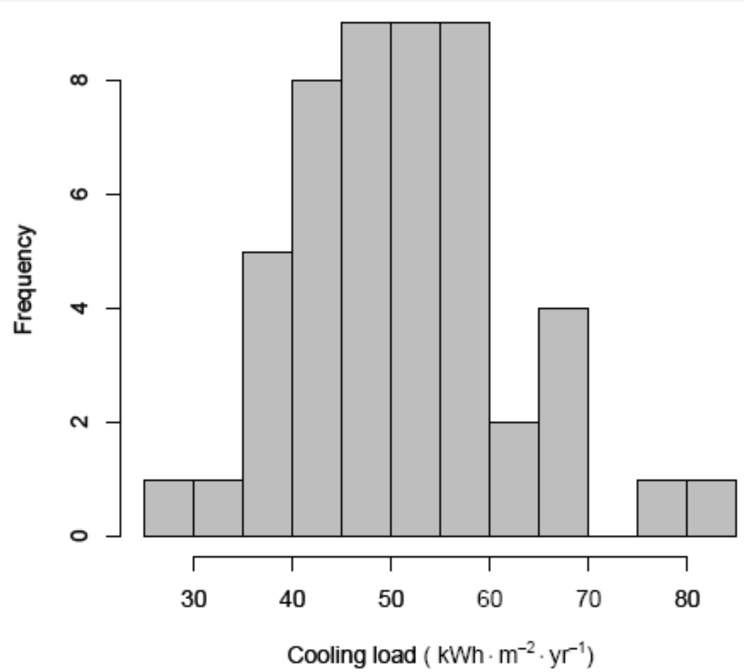
CitySim solver



Results: A shoebox

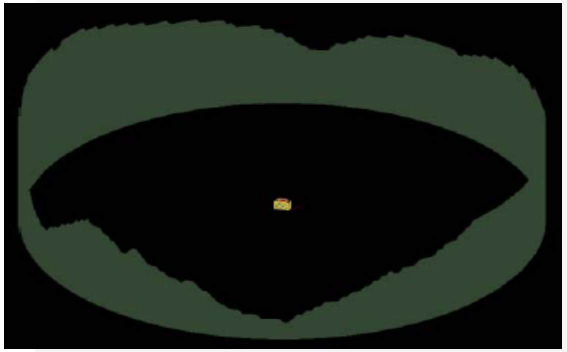
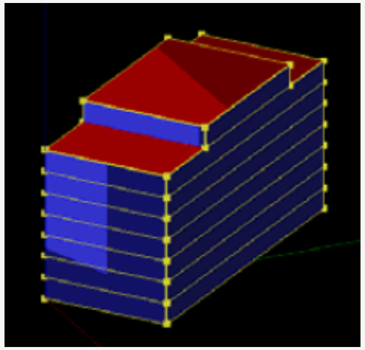


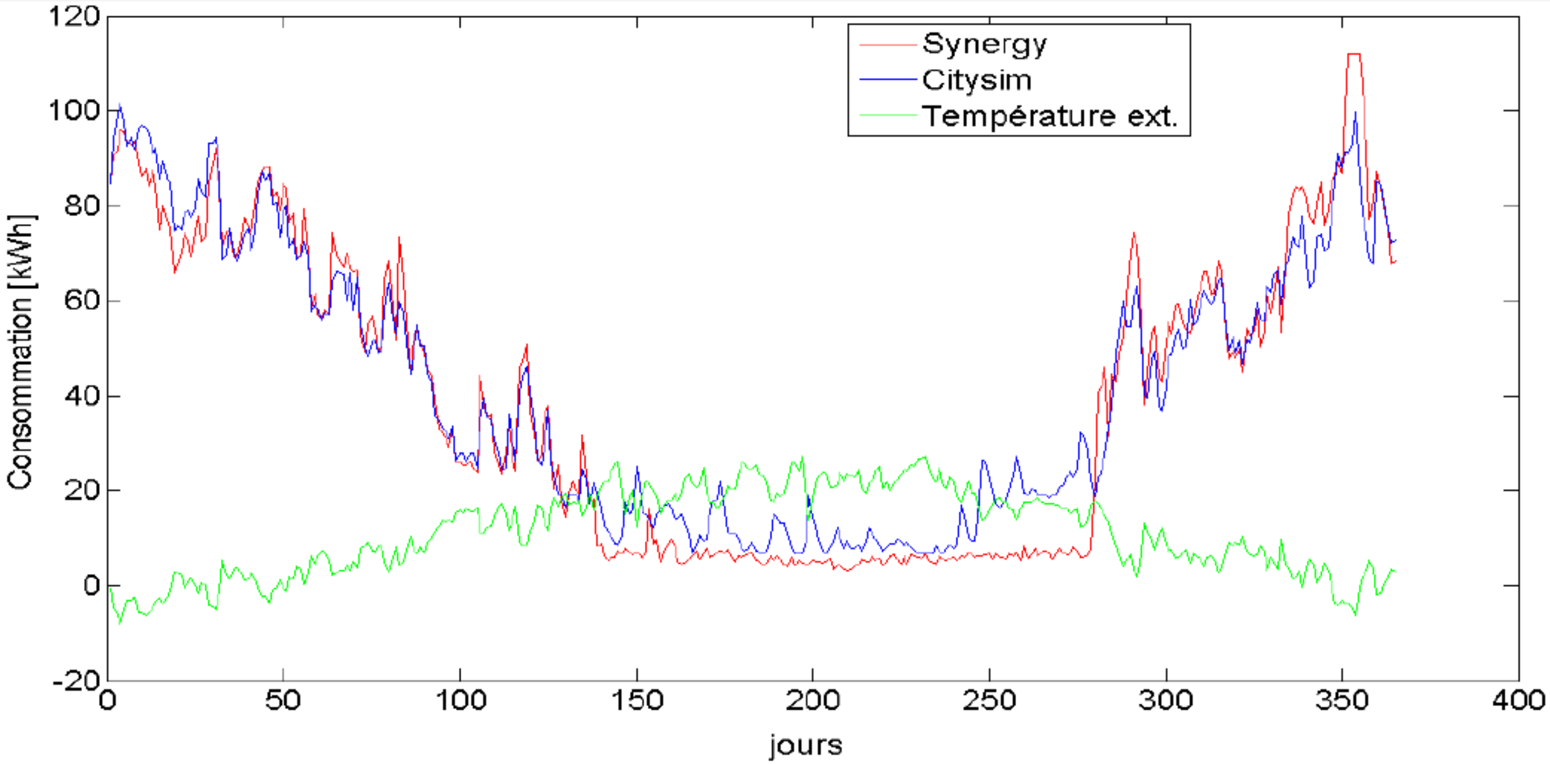




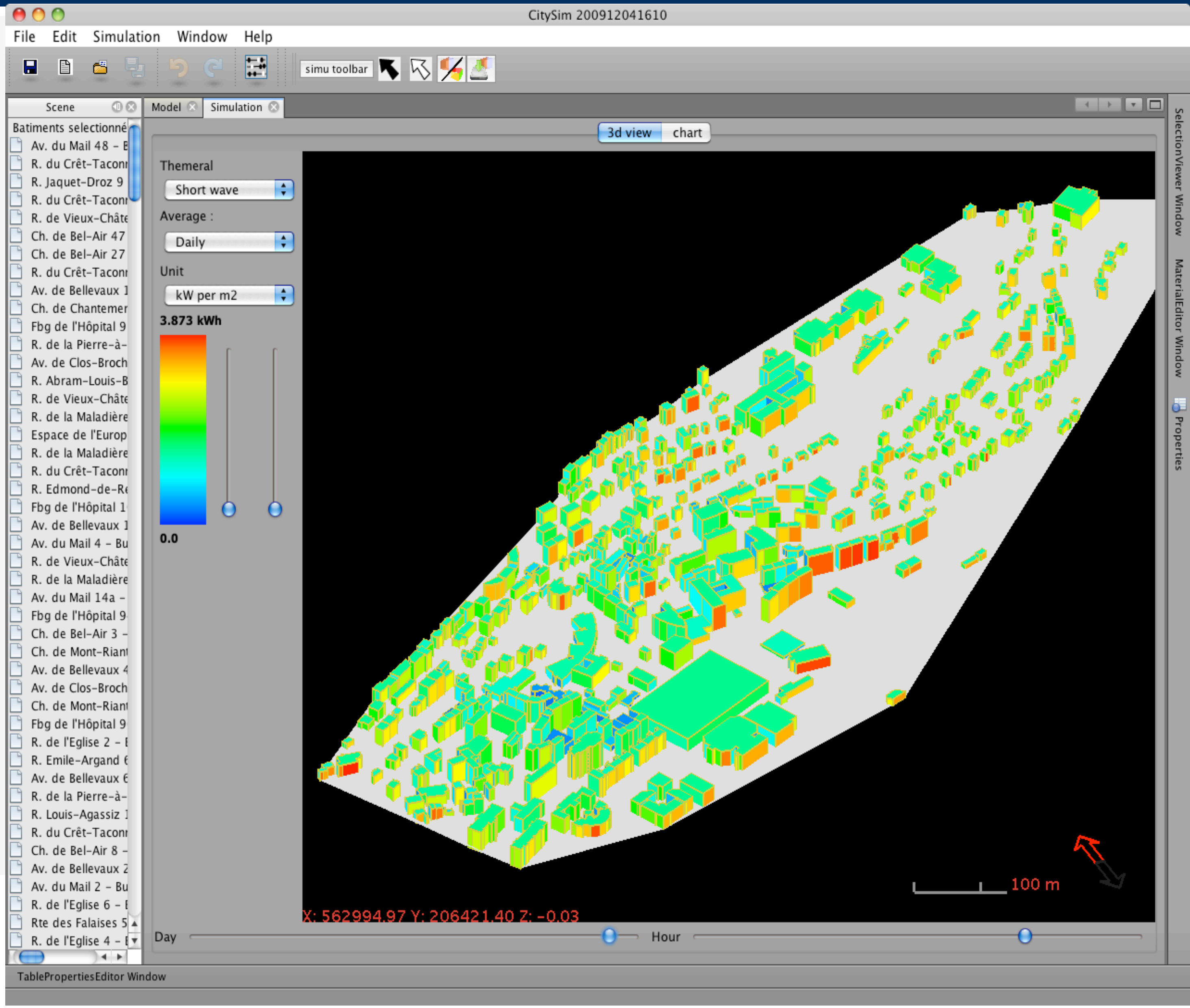
Haldi and Robinson, JBPS : 4(4), 2011

A single building (Martigny)



A district (Neuchâtel)



Energy in buildings: Typological: E+

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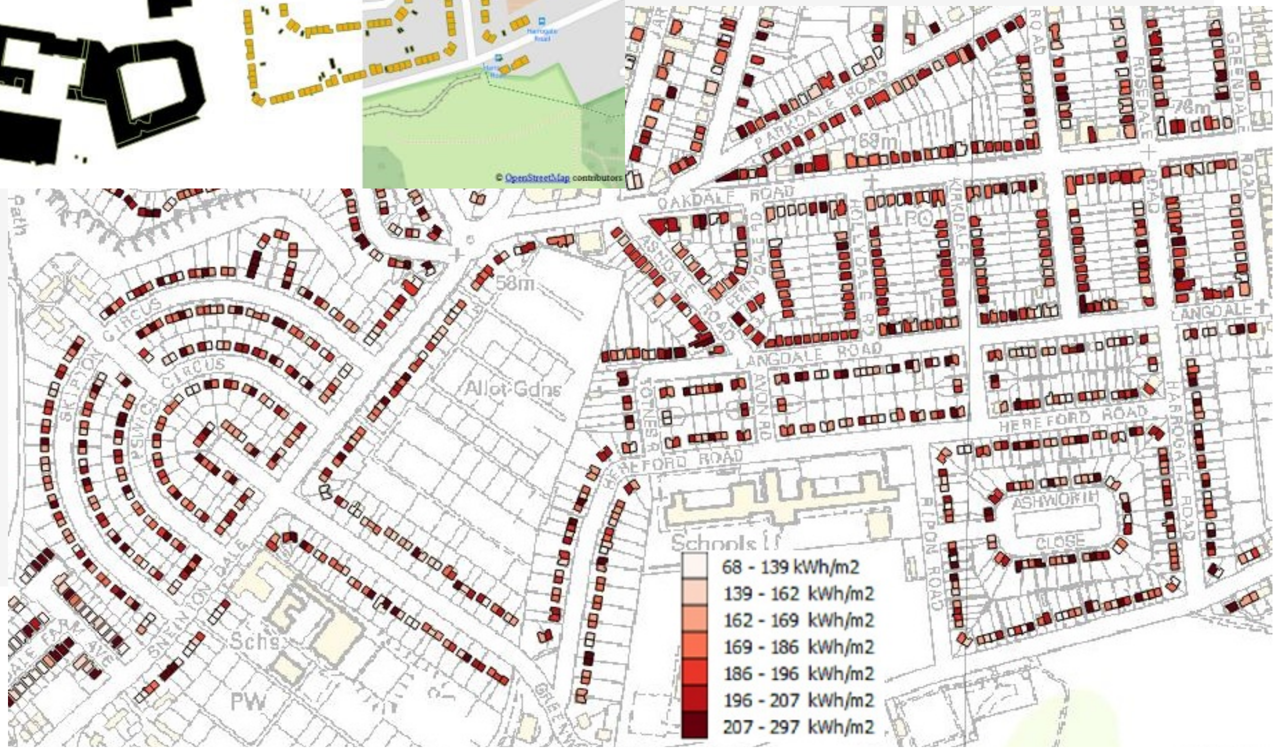
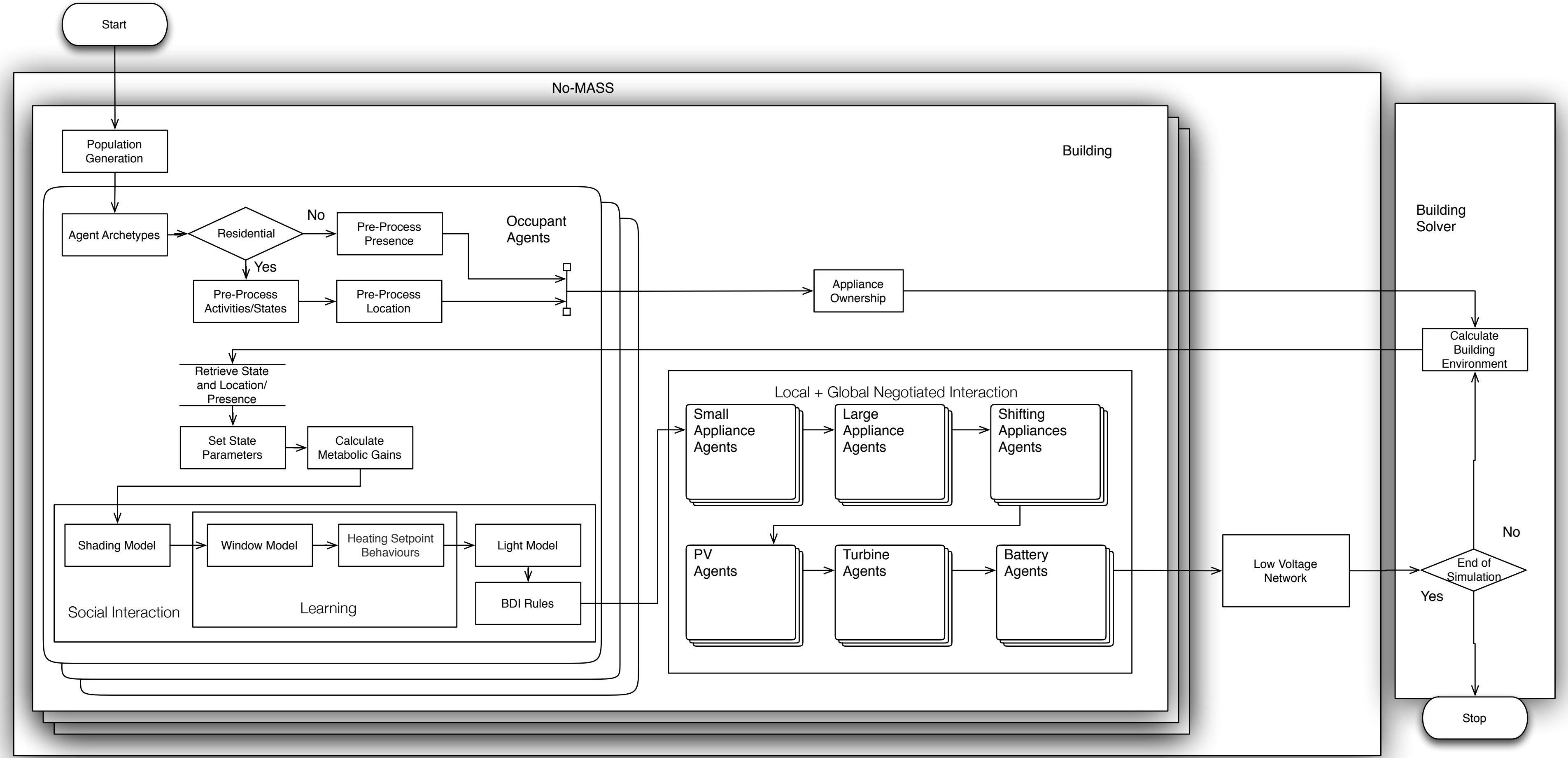


No-MASS+: generalisation for DSM



No-MASS for Demand Response

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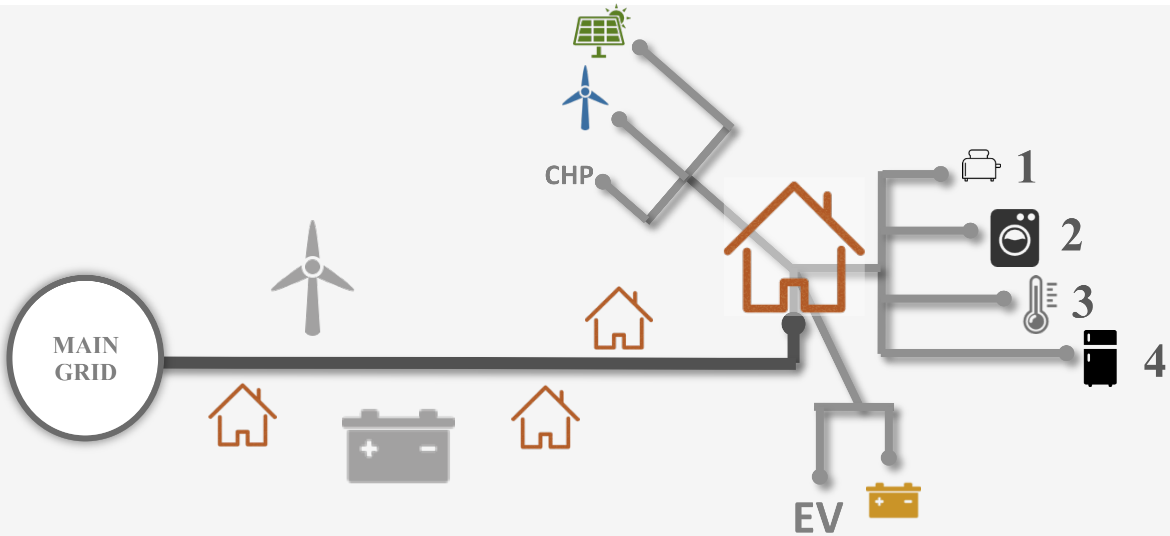
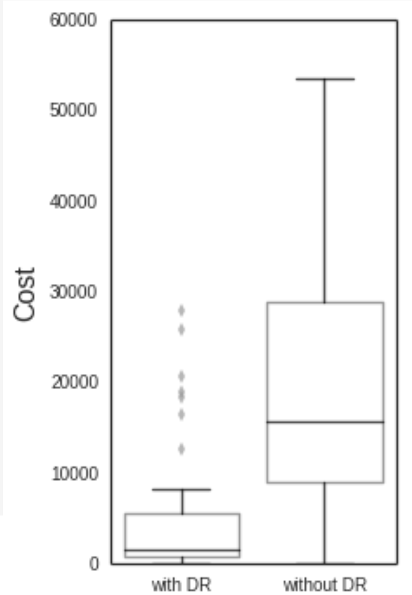


Types of appliance	ON	OFF
1	Human	Human
2	Human	Autonomous
3	Autonomous	Autonomous
4	Always cycling	



Empirically based **social simulation**

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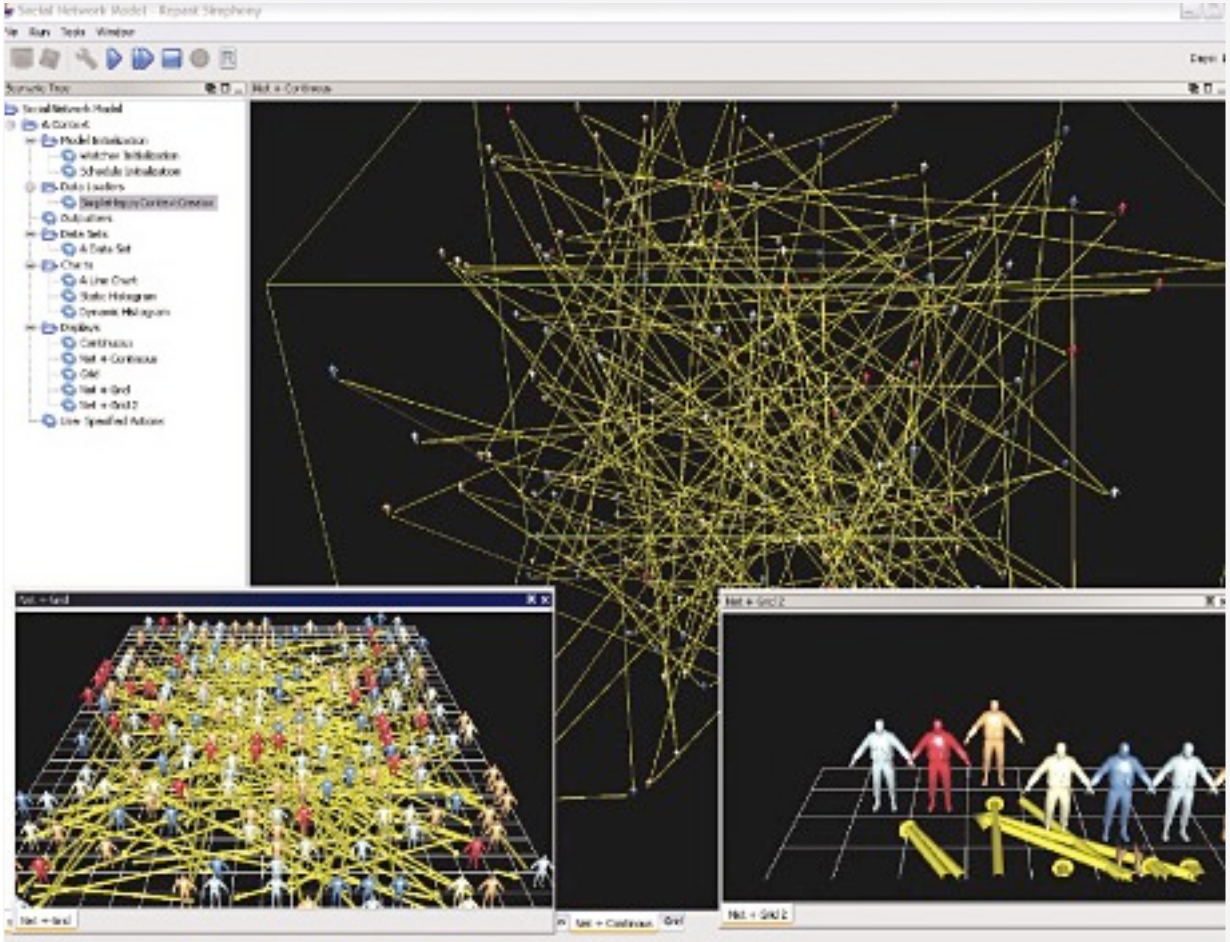

Perceptions of (and labels for) environmental sustainability

Perceptions of social sustainability: cohesion, equity, inclusion…etc

Perceptions of economic sustainability…

Factors **influencing** investments in STs: firms and individuals…etc

Integration: High Level Architecture

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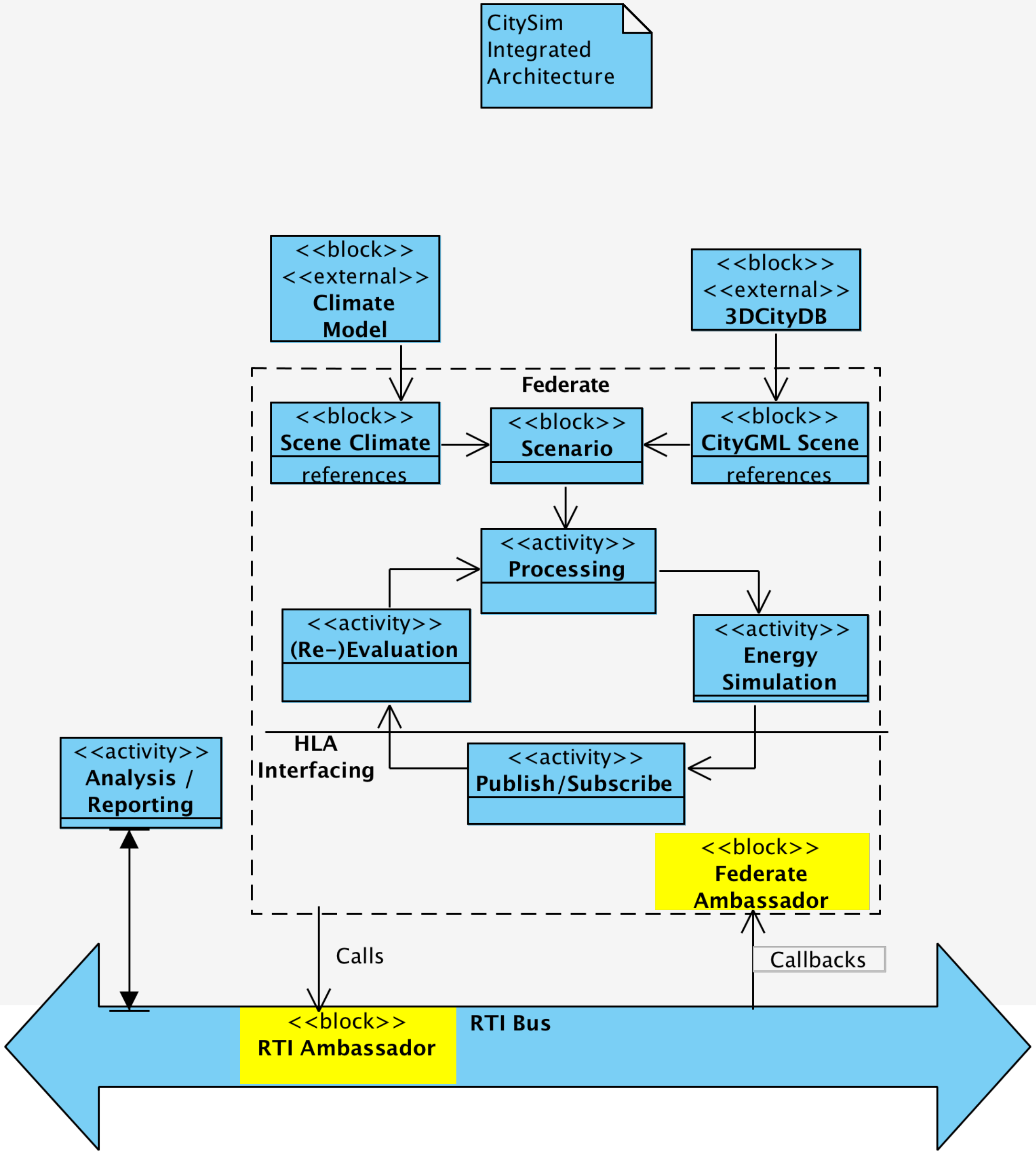
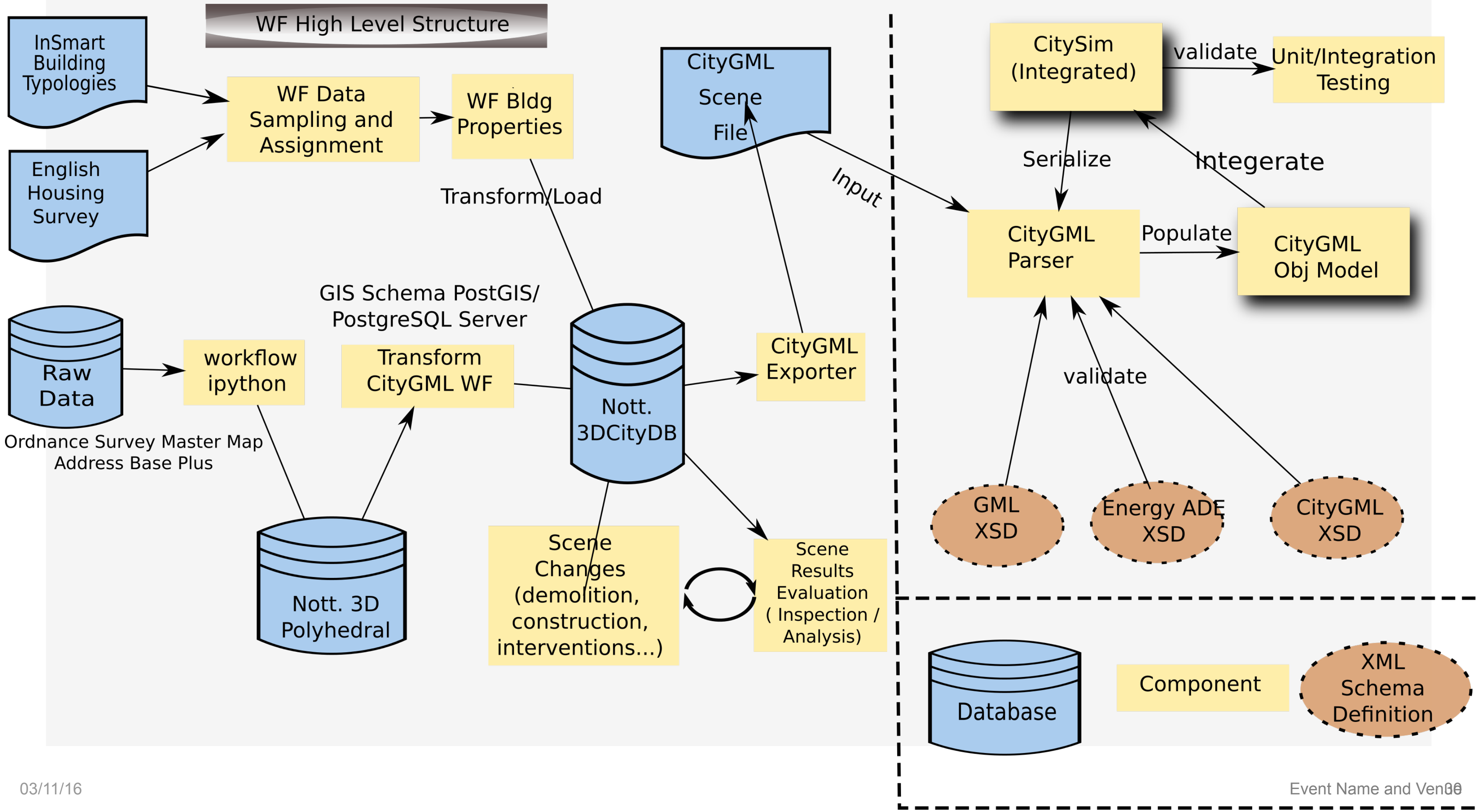


End-to-End workflow



In **conclusion**: planned outcomes

- A comprehensive **theoretical framework** to understand the factors influencing urban sustainability.
- **Visions** for what constitute near-sustainable cities: socially, economically and environmentally.
- A framework for **acquiring, managing and presenting evidence** to characterise and model urban sustainability.
- A **modelling framework** to test strategies to maximise sustainability, applied to **two**/four case study cities.
- The types of **policies, strategies and governance structures** needed to implement the recommended development / transition pathways.

Acknowledgements

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