



From neighbourhood to city (energy) simulation

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- Part I: Some simple toys
 - Resource availability
 - Energy modelling and simulation
- Part II: City energy micro-simulation
- Part III: The bigger picture



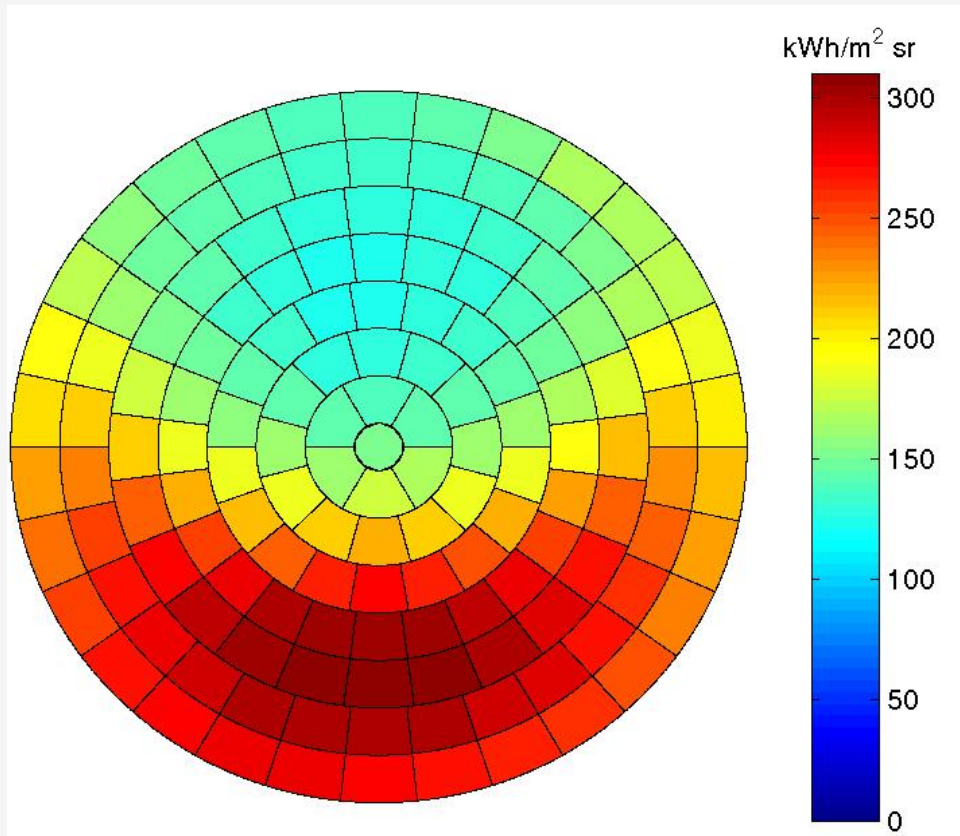
Some toys...

Cumulative Sky Modelling (2004)



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$$\ell_i = f(Z, \theta)$$

$$\chi = I_{dh} / \sum_{i=1}^p \ell_i \Phi_i \sin \bar{\gamma}_i$$

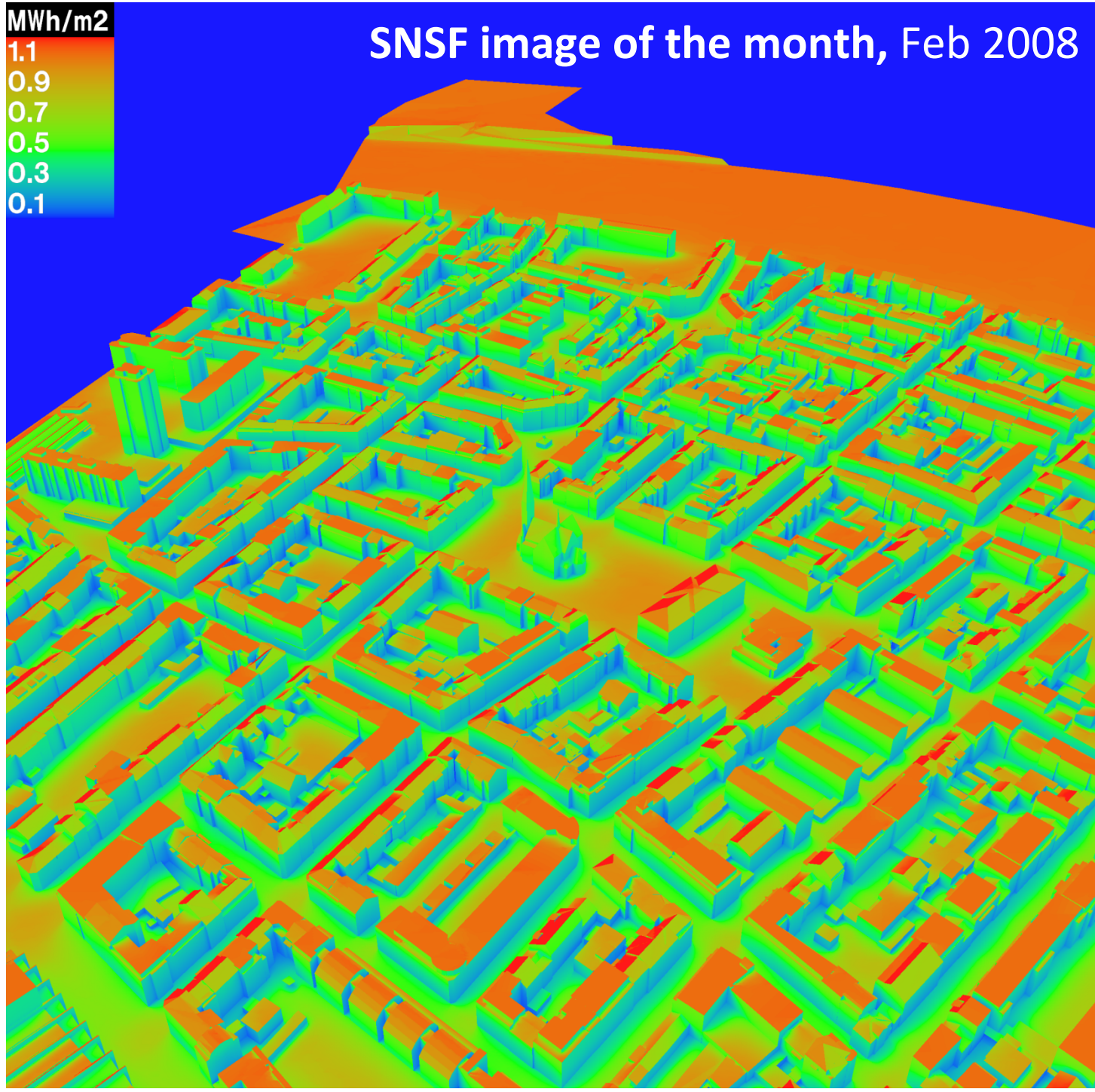
$$R_i = \ell_i \chi$$

$$R_i^T = \sum_{h=1}^n R_{i,h}$$

We can also add to this the cumulative **solar** radiance.

Robinson and Stone, PLEA 2004.

Radiance: **GenCumulativeSky** (2004)



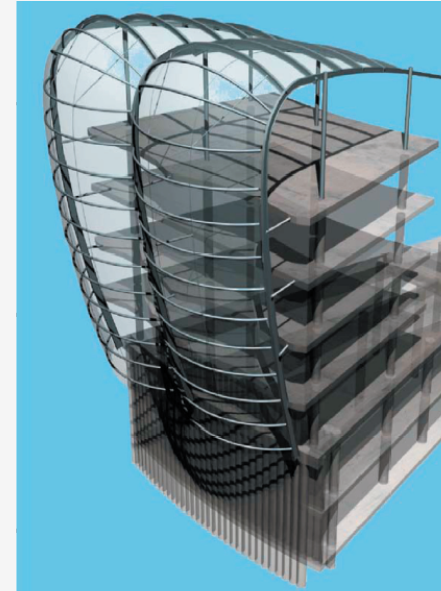
Rhino: **DIVA** (2011), **UMI** (2013);
Grasshopper: **Ladybug** (2012)

Pelham place – Hastings [F+P]: external irradiation

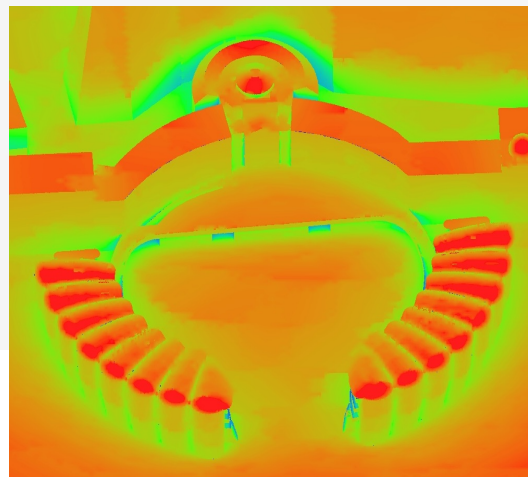
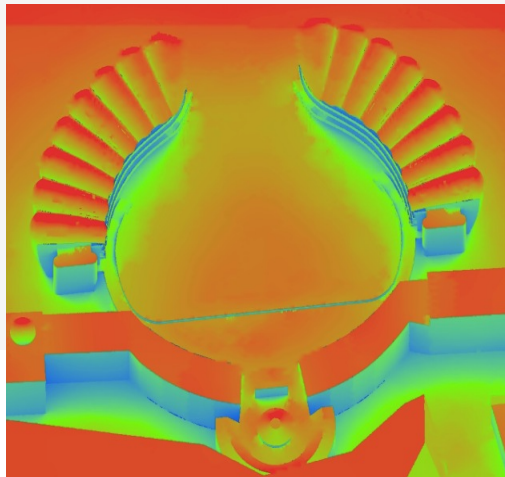


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Wh/m²
950000
850000
750000
650000
550000
450000
350000
250000
150000
50000

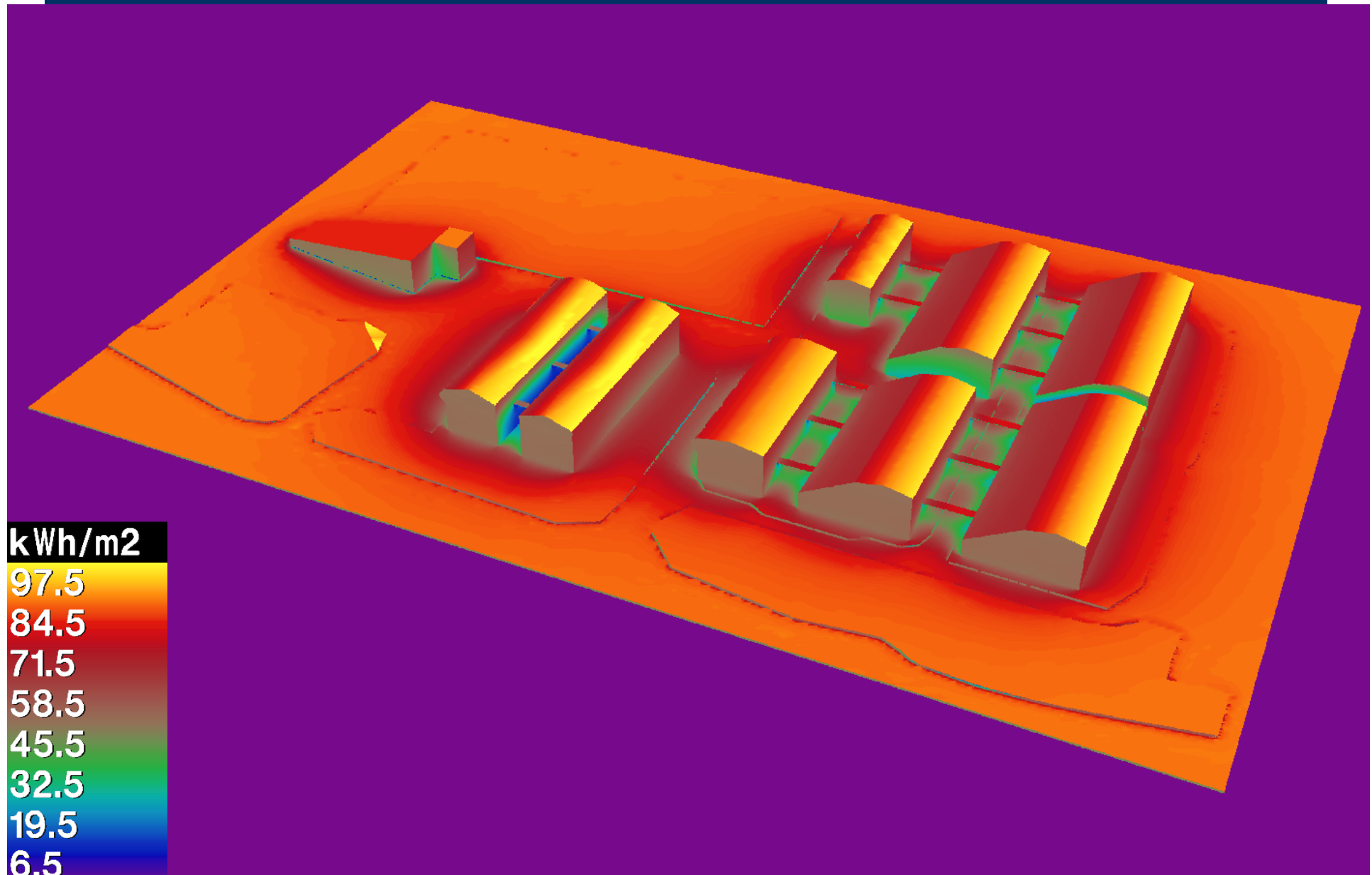


Winter irradiation: BedZed



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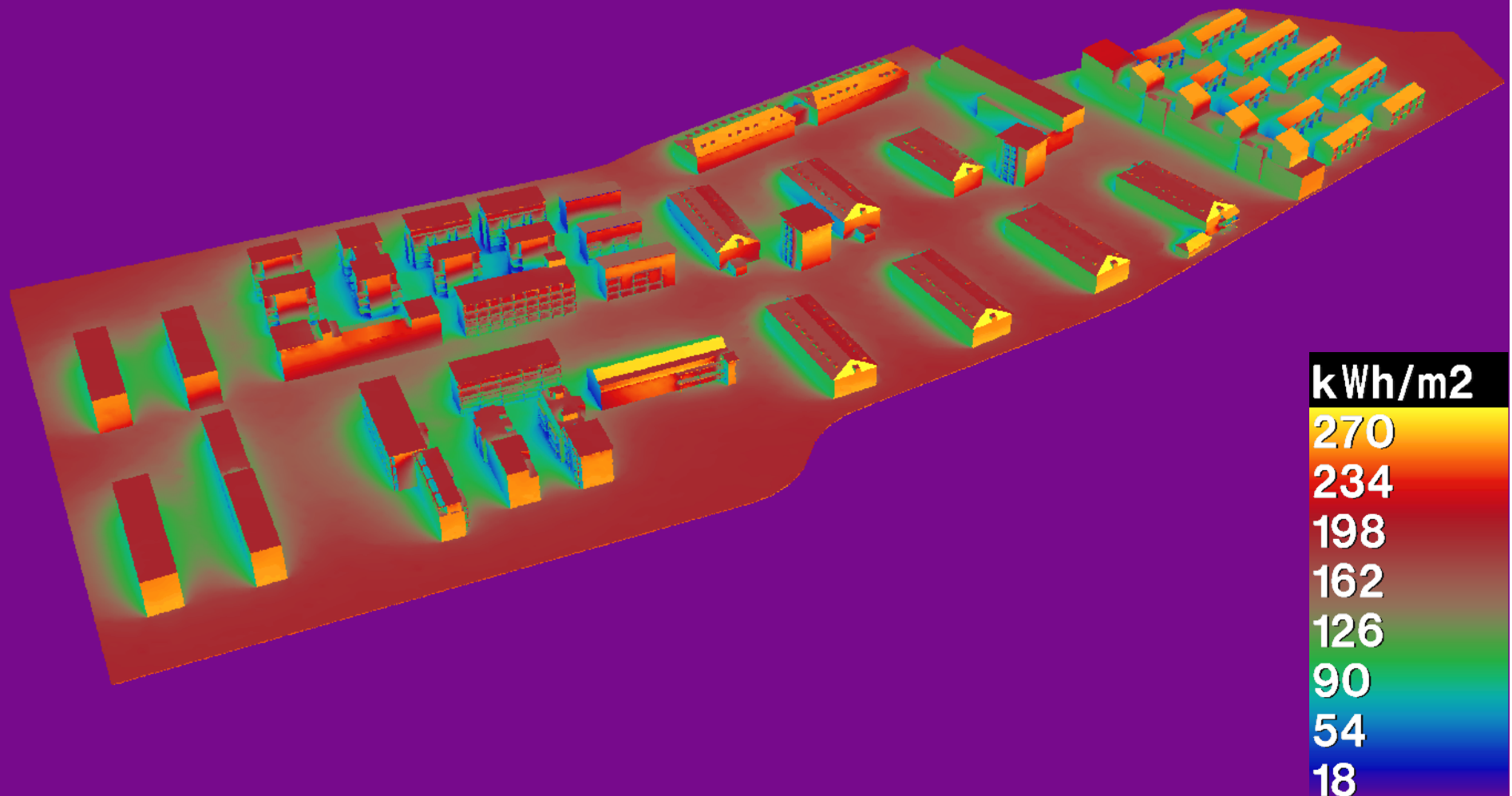


Winter irradiation: Freiburg / Vauban

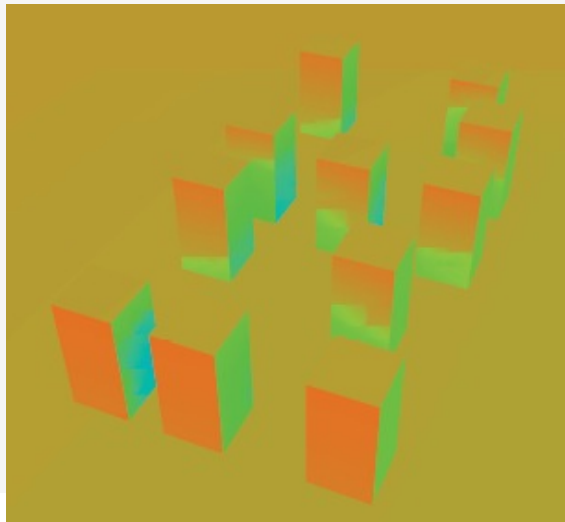
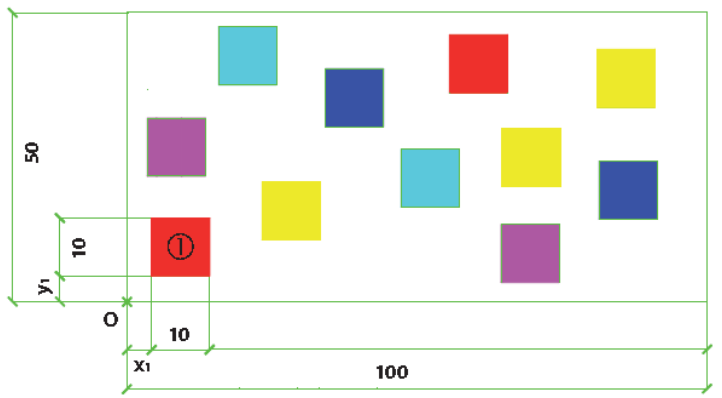


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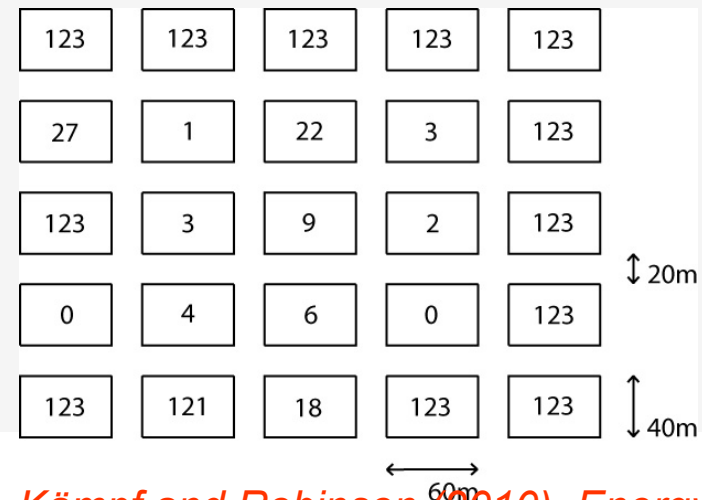
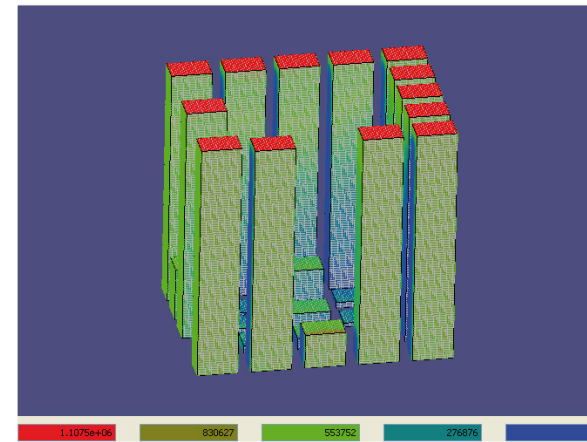


Position:



Kämpf and Robinson (2009), Applied Soft Computing, 2(9): 738-745

Height:



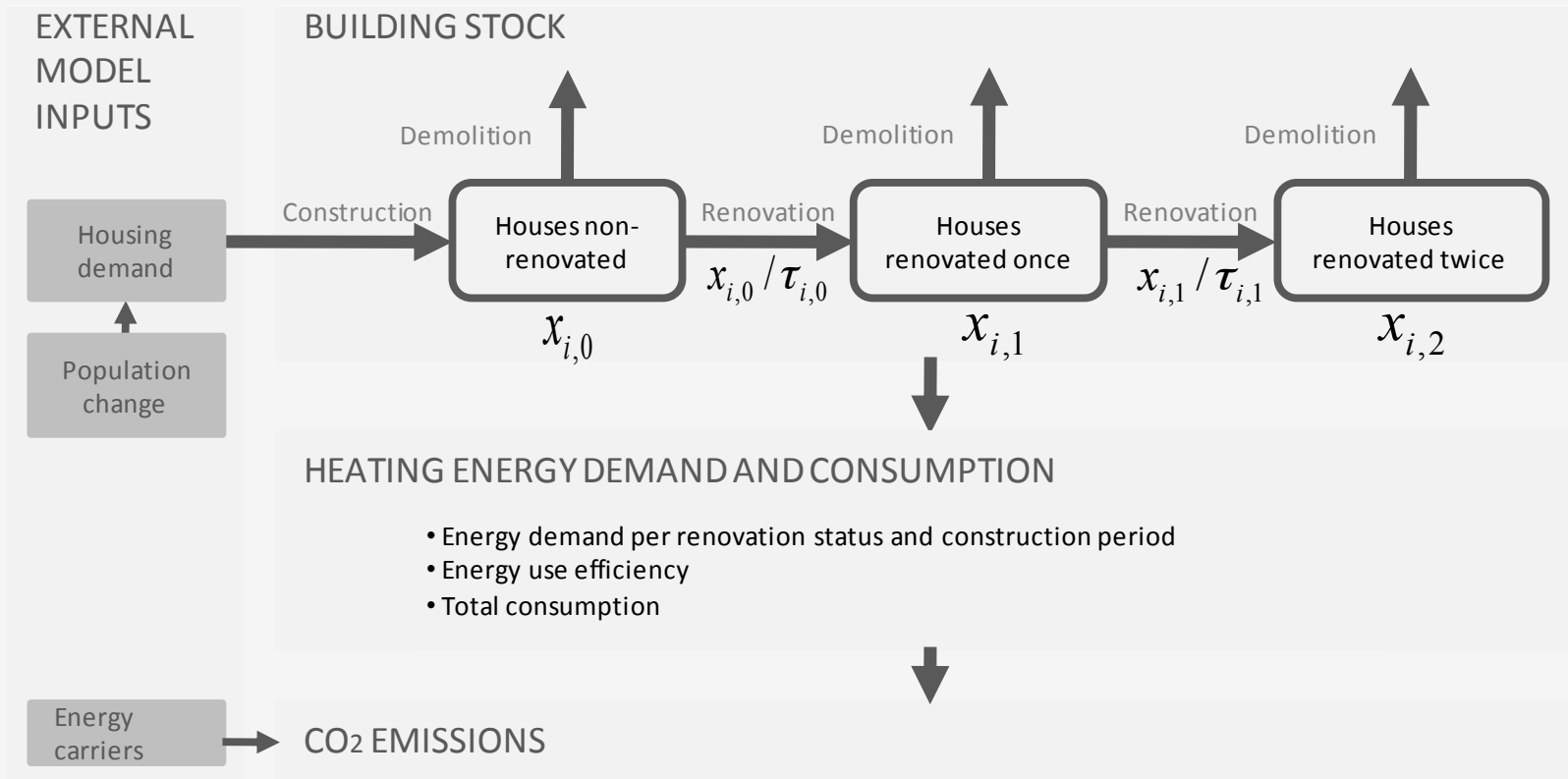
Kämpf and Robinson (2010), Energy and Buildings 42(6), 807-814.

Energy: Macro-simulation (2009)



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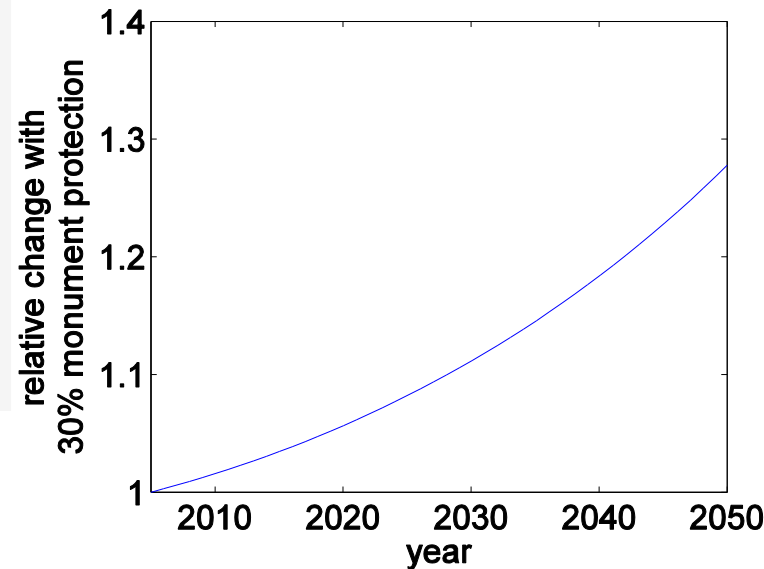
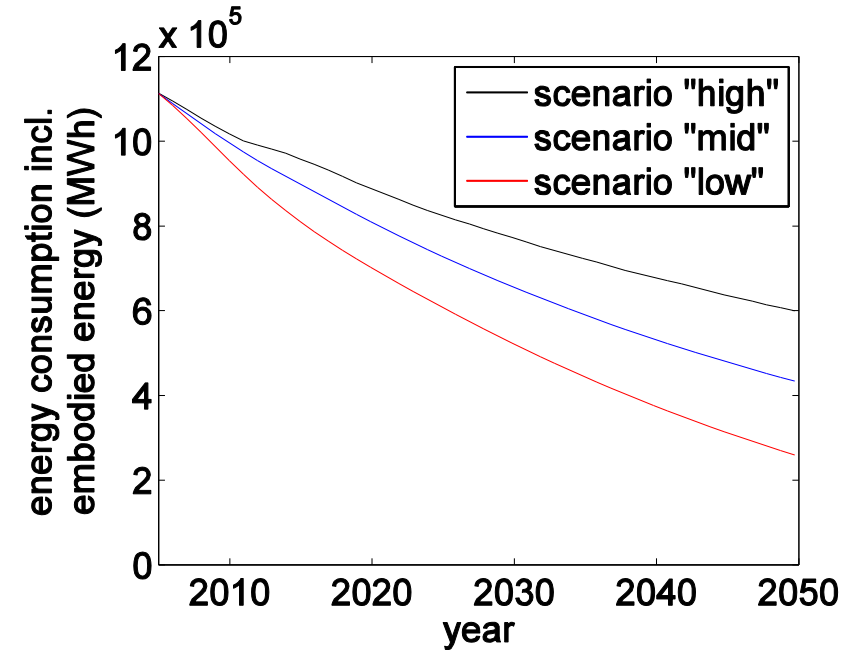
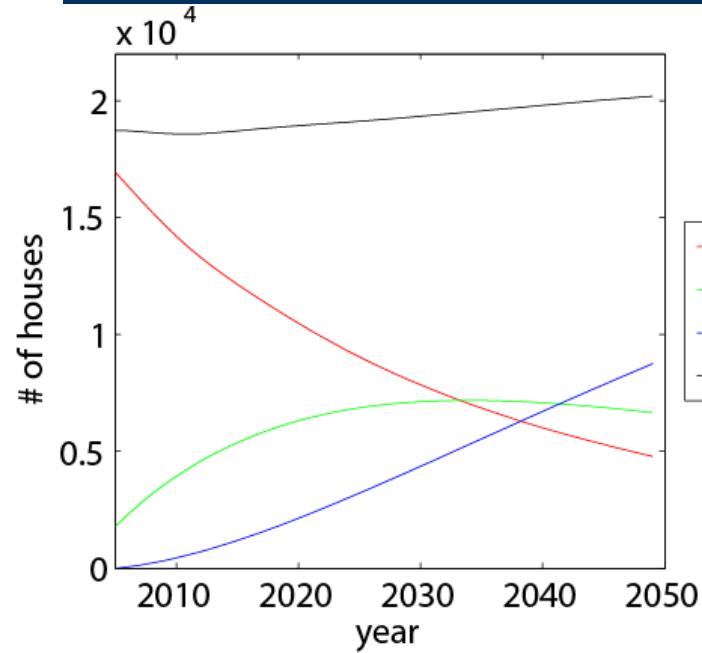


Macro-simulation (2009)



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Typological sampling: InSmart (2014+)



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Data and GIS preparation

- Prepare **distributions of typologies** (and their attributes) in an area: GIS database
- **Collate survey data** of homes' features

Sensitivity Analysis

- **Sensitivity analysis** of model outputs to input parameters (homes' features)
- **Rank** in order of sensitivity index (measure of how sensitive output is to a given input)
- **Select** highest ranking parameters

Synthetic Stock Creation

- Randomly **sample distributions** of the selected parameters to assign these features to a sub-stock of buildings; **simulate** their energy use
- Sample from this sub-stock, **assign** energy use to the stock of buildings in GIS

Scenario Testing

- **Define scenarios, alter sub-stock inputs, simulate and re-assign**
- **Rank scenarios by effectiveness**: cost and impact on total energy use

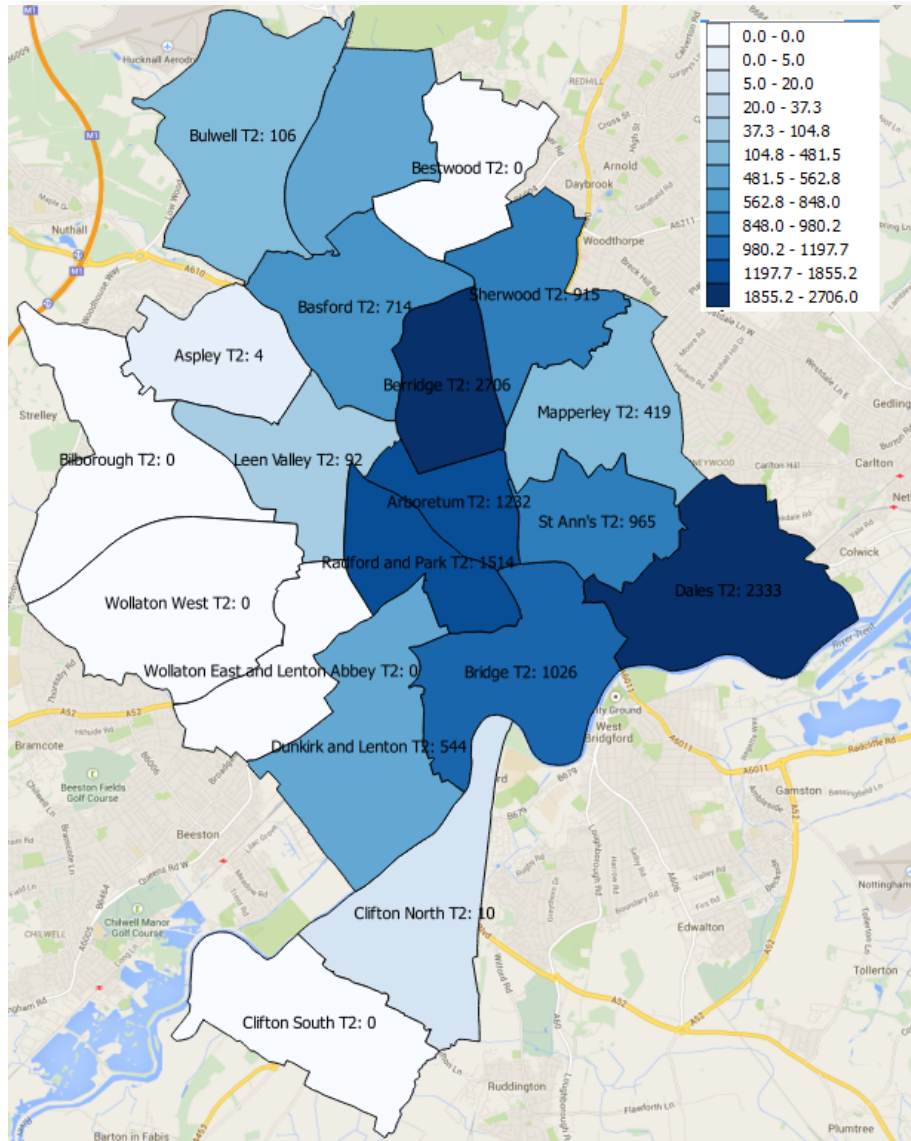
Alalwany, Long & Robinson, Energy Policy, 2016 (in preparation).

Typology and energy use distributions

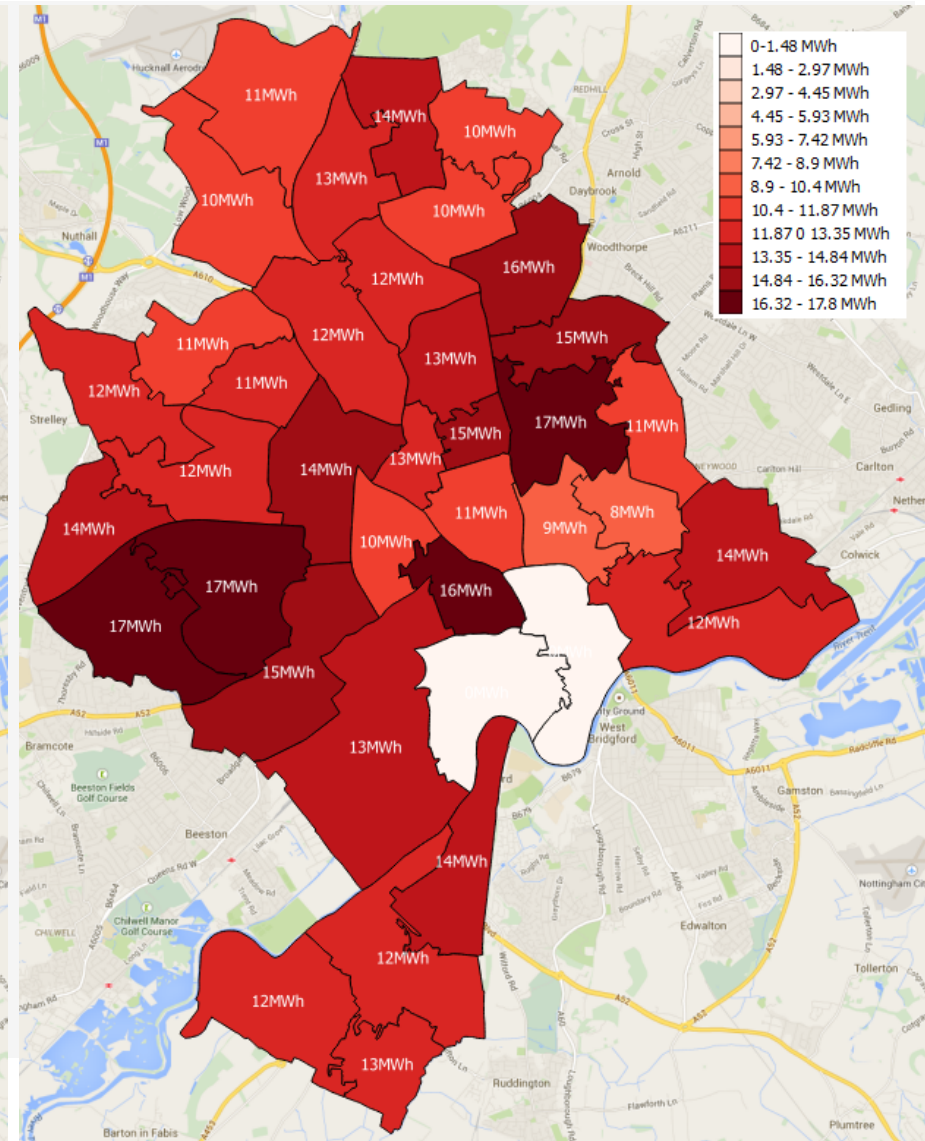


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Distribution of typologies (Ward)



Distribution of energy use (MSOA)

Typology visualisation (we can do the same for energy use)



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Micro-simulation: SUNtool (2002 +)



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The screenshot displays the SUNtool software interface, which is used for micro-simulation of building energy performance. The interface is divided into several panels:

- Top Panel:** Contains the menu bar (File, Edit, Layer, Model, View, Window, Help) and a toolbar with various simulation and visualization tools.
- Location Panel:** Shows the location set to Prague, with coordinates 50.1N and 14.3E. Location files are listed as Catalog_0_0 and Prague TRY.
- Properties Panel:** Includes a 'Site' tab and a 'Plant' tab. It displays the 'Total No of Buildings' as 29. The 'Use Summary' table is as follows:

Use	%	A[m2]	V[m3]
Residential	100	227069	681207
Office	0	0	0
Total		227069	681207

The 'Planning Parameters' section includes: Entire Site (dropdown), Plot Ratio (0.227), Habitable Rooms per Hectare (392), Dwellings per Hectare (93), Residential Occupants (4657), and Office Occupants (0). The 'Parking' section has a table:

Required Parking	x	Parameter	Total Parking
	x	Residential Area	0
	x	Office Area	0
- Simulation Parameters Panel:** Located at the bottom left, it shows a color-coded 3D perspective view of the building model. A color scale on the left ranges from 60 (blue) to 240 (red). The date and time are shown as 01-01-2006 12:30:00.
- Layers Panel:** Located at the bottom right, it lists the building and context layers: Building 1 (blue), Building 2 (green), Building 3 (purple), Context 1 (grey), and Context 2 (grey). Each layer has visibility and lock icons.

Robinson et al, Solar Energy, 2007.



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Urban energy micro-simulation: **CitySim**

CitySim (a successor to SUNtool)

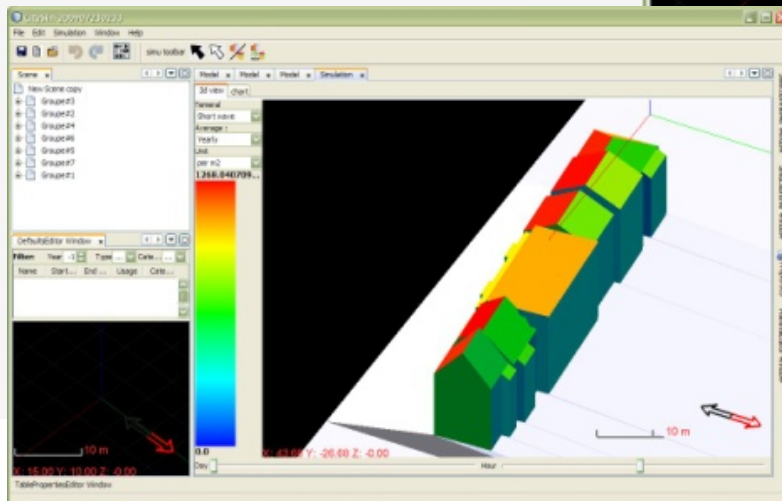
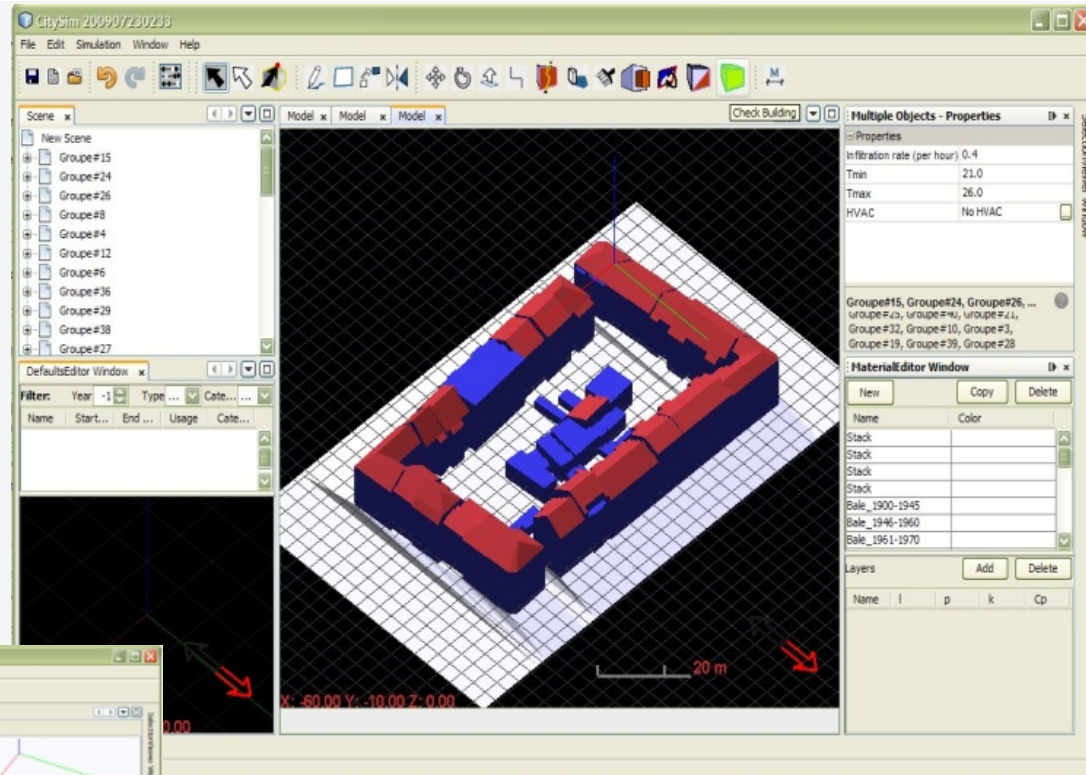


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- **CitySim**: a **detailed decision support** tool to support sustainable urban planning and design
- **Micro-simulation** for flexibility; breadth of scenarios
- Based on modelling of **urban energy** and matter **flows**
- Accounting for:
 - Occupants' **behaviour**
 - **Urban (radiative) climate**
 - **Synergetic** energy & matter **exchanges**
- Applicable at the **range of scales**
- **Productive and intuitive**

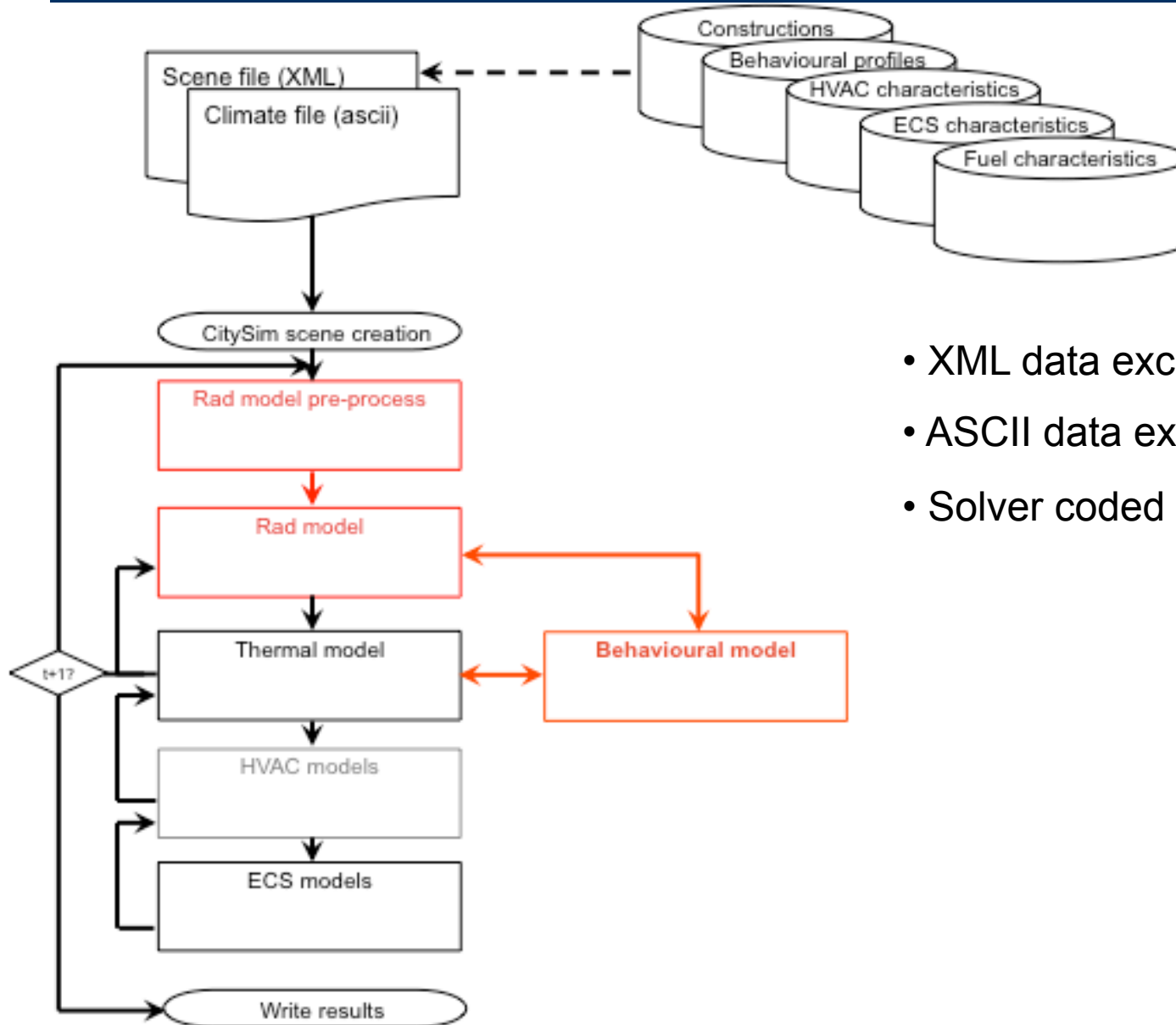
- 1) Create or import **3D model** and its clones
- 2) Describe **envelope composition**
- 3) Describe **occupancy and appliance** schedules



- 4) Describe **HVAC and ECS** systems

- 5) **Simulate and analyse**

CitySim solver



- XML data exchange: GUI to solver
- ASCII data exchange: solver to GUI
- Solver coded in C++

Radiation Exchange: Basis of the Simplified Radiosity Algorithm (SRA)



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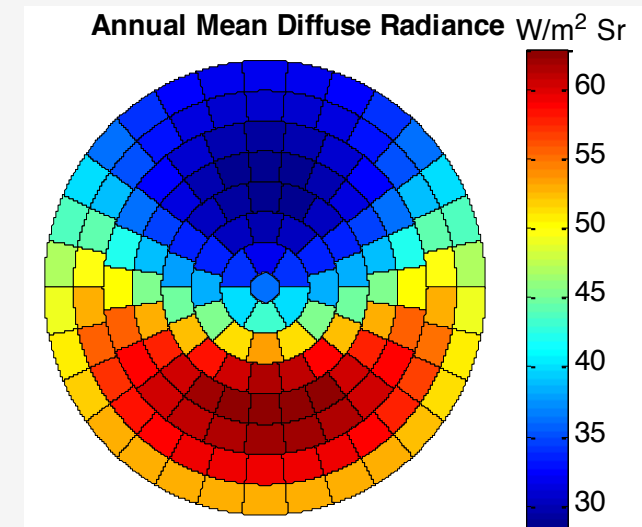
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1. Calculate a sky radiance distribution for a discretised sky vault

$$\ell v = f(Z, \theta) \quad R_i = f(Z, \theta) \chi$$

$$\chi \cong I_{dh} / \sum_{i=1}^p (\Phi \ell v \sin \bar{\gamma})_i$$

$$I_{d\beta} = \sum_{i=1}^p (R \Phi \sigma \cos \xi)_i$$



$p = 145$ (we use the Tregenza discretisation scheme)

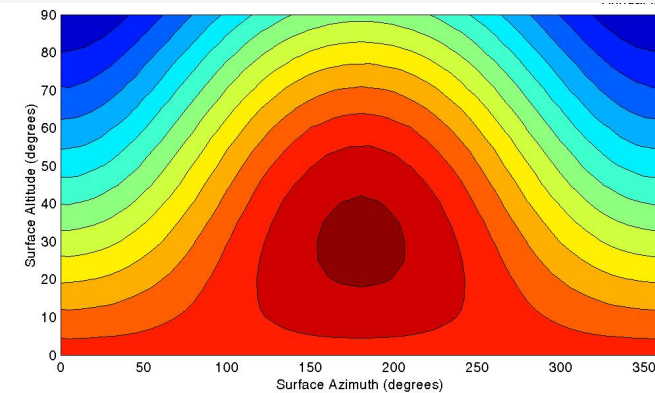
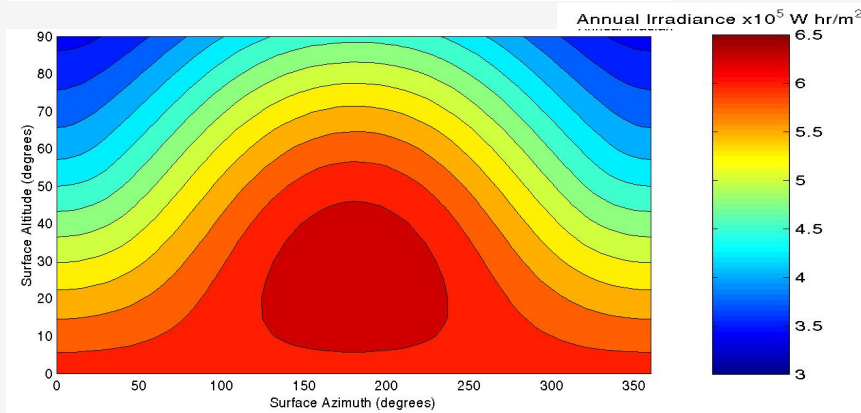
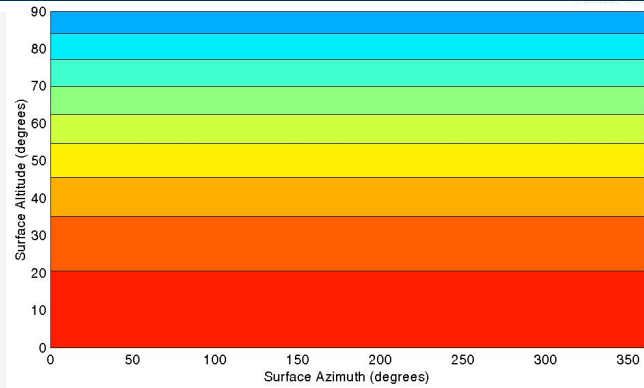
*Robinson and Stone, SEJ, 2004;
BSER&T 2005.*

Comparisons

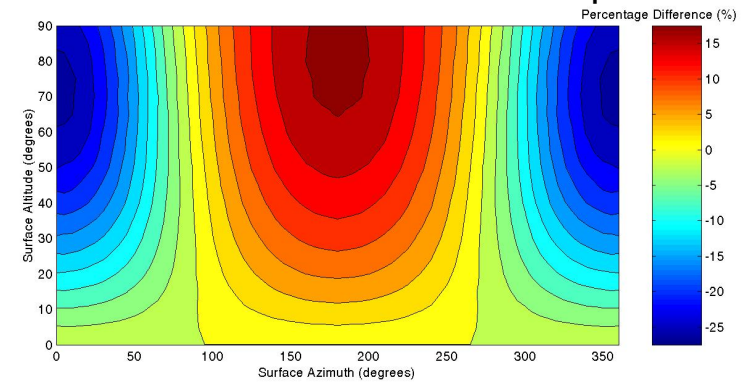


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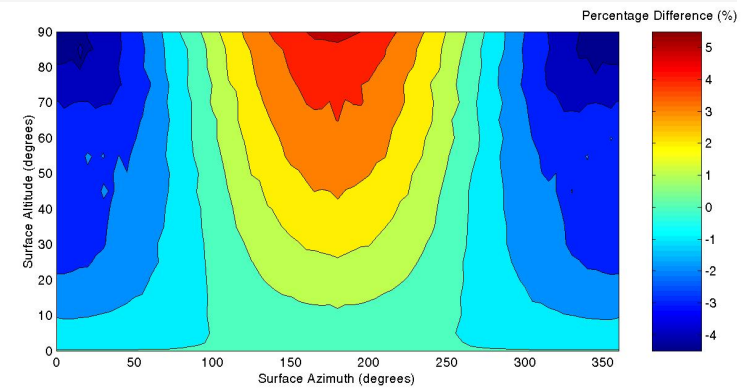


Radiance distribution v's isotropic



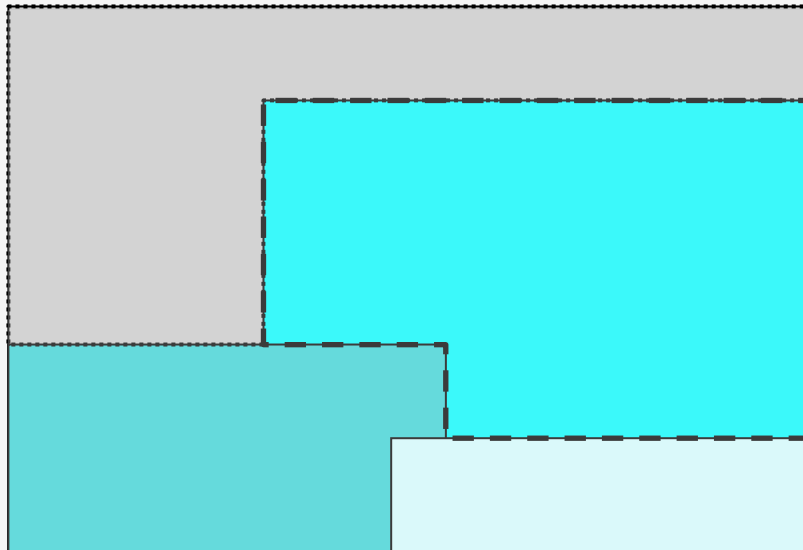
max=18.2%, min=-26.3%

Radiance distribution v's Perez



max=5.2%, min=-4.4%

2. Combine obstructions (angular neighbours) within each patch, representing the radiance by the dominant obstructing surface



The dominant obstruction is that which provides the largest contribution to:

$$\Phi \omega \cos \xi = \cos \xi . d\Phi$$

3. Calculate irradiance due to obstructions

$$I_{\rho\beta} = \sum_{i=1}^p \left(R^* \Phi \omega \cos \xi \right)_i$$

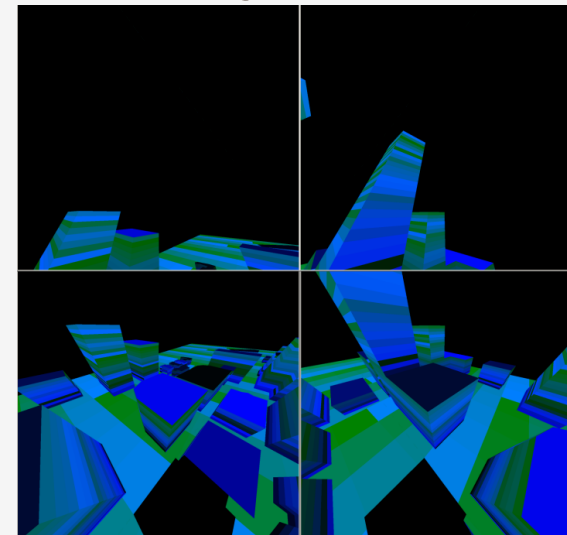
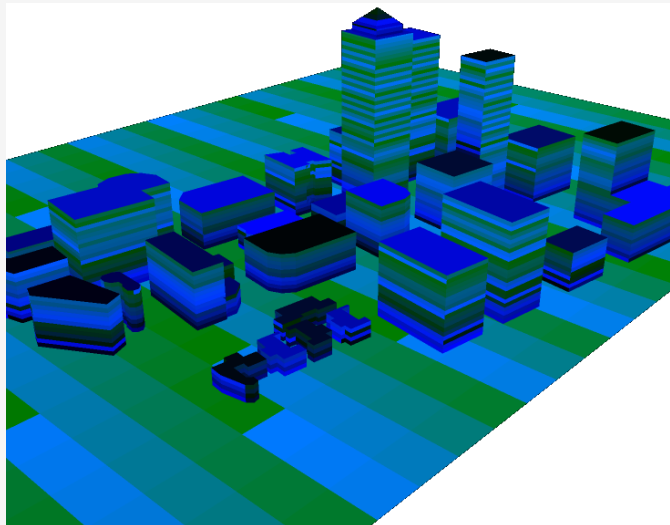
But we also have obstructions below the horizontal plane. For this we can simply define another discretised vault and invert it (upside-down sky), so that:

$$I_{\rho\beta} = \sum_{i=1}^{2p} \left(R^* \Phi \omega \cos \xi \right)_i$$

For each i th patch we need the radiance of the dominant occlusion:

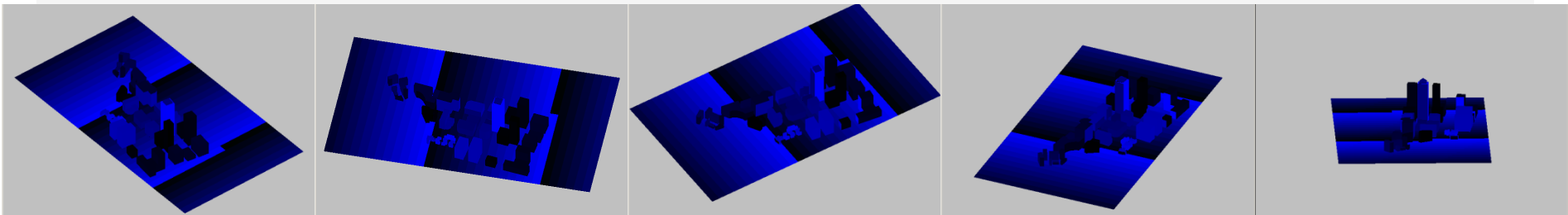
$$R = \left(I_{b\xi} + \sum_{i=1}^p \left(R \Phi \sigma \cos \xi \right)_i + \sum_{j=1}^{2p} \left(R^* \Phi \omega \cos \xi \right)_j \right) \rho / \pi$$

- **Step 1 – Patch view factors:** determine patch view factors and identify dominant obstruction.
 - Colour each surface uniquely (blue → red; 256^3-1)
 - Render four wide angle perspective views from each surface's centroid to capture the entire 180° visible range



- Calculate the coordinates and solid angle of each pixel
- Determine sky / obstruction view factors from the surface centroid to the sky / dominant obstructing surface

- **Step 2 – Solar view factors:** determine the proportion of each surface that is directly insolated at each hour.
 - For each sun position, render the scene from the sun's view point (using parallel projection).



- Calculate the area of each pixel.
- Sun View Factor = Number of pixels occupied by surface * area of each pixel / area of surface projected perpendicular to sun direction
- Incident beam irradiance is then simply: $I_{b\xi} = I_{bn}\psi_t \cos \xi$

- **Step 3 – Build matrices and solve:** determine energy contribution from sun, sky and reflections.

$$\underline{I_d} = A \underline{I_g} + B \underline{R}$$

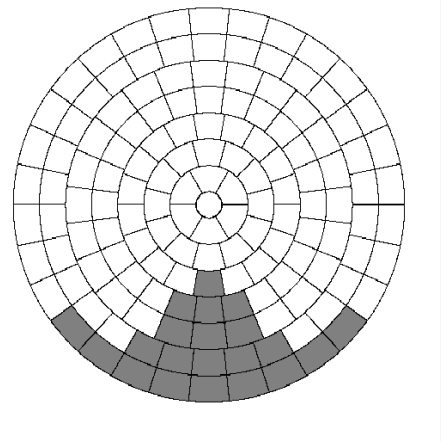
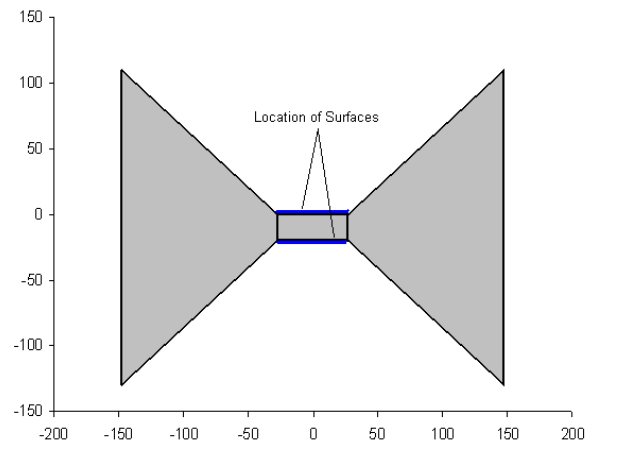
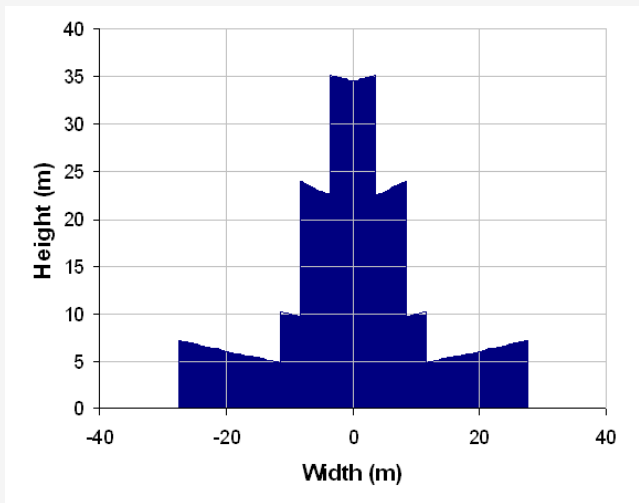
$$\underline{I_g} = \underline{I_d} + \underline{I_b}$$

$$B = \begin{bmatrix} \Phi_{1,1} \sigma_{1,1} \cos \xi_{1,1} & \Phi_{1,2} \sigma_{1,2} \cos \xi_{1,2} & \cdots & \Phi_{1,p} \sigma_{1,p} \cos \xi_{1,p} \\ \Phi_{2,1} \sigma_{2,1} \cos \xi_{2,1} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ \Phi_{n,1} \sigma_{n,1} \cos \xi_{n,1} & \Phi_{n,2} \sigma_{n,2} \cos \xi_{n,2} & \cdots & \Phi_{n,p} \sigma_{n,p} \cos \xi_{n,p} \end{bmatrix} \quad n \times p$$

$$A = \begin{bmatrix} \frac{\rho_1 k_{1,1}}{\pi} & \frac{\rho_2 k_{1,2}}{\pi} & \cdots & \frac{\rho_n k_{1,n}}{\pi} \\ \rho_1 k_{2,1} & \ddots & & \vdots \\ \pi & & \ddots & \vdots \\ \vdots & & & \vdots \\ \frac{\rho_1 k_{n,1}}{\pi} & \frac{\rho_2 k_{n,2}}{\pi} & \cdots & \frac{\rho_n k_{n,n}}{\pi} \end{bmatrix} \quad n^2$$

$$k_{i,j} = \sum_{k=1}^m \Phi_{i,x_k} \omega_{i,x_k} \cos \xi_{i,x_k}$$

SRA verification

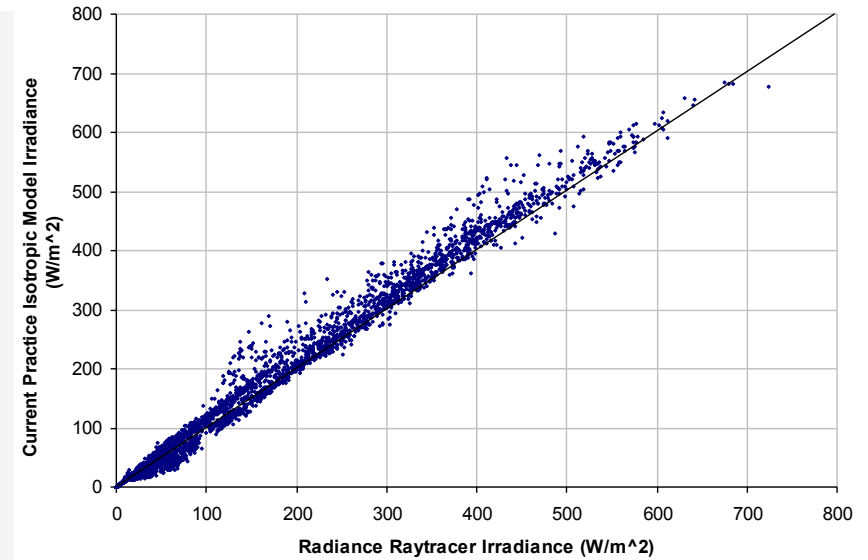
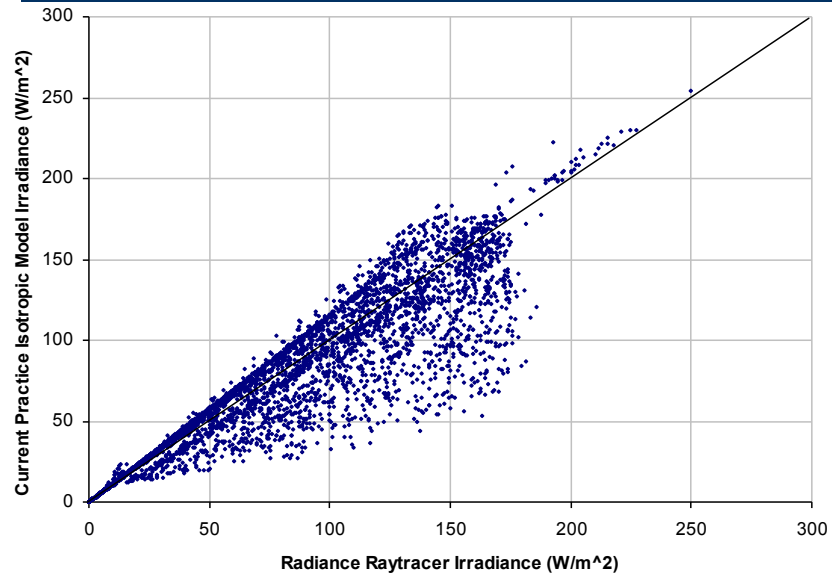


SRA verification

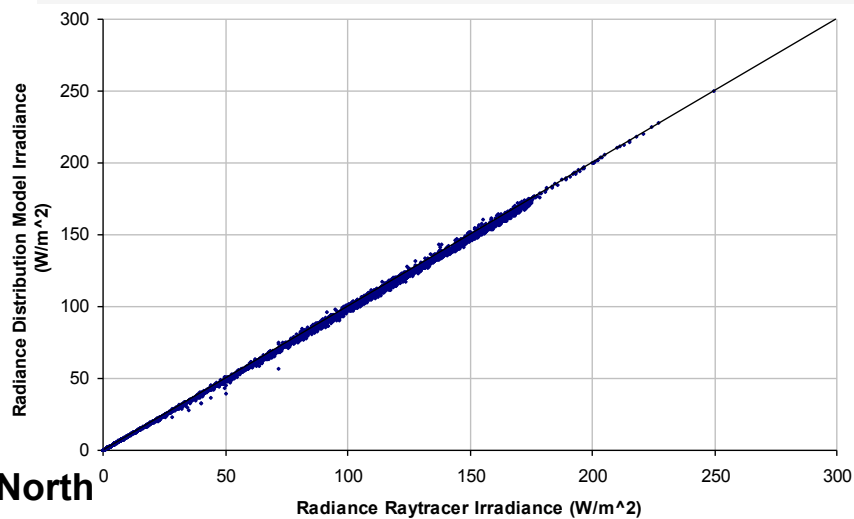


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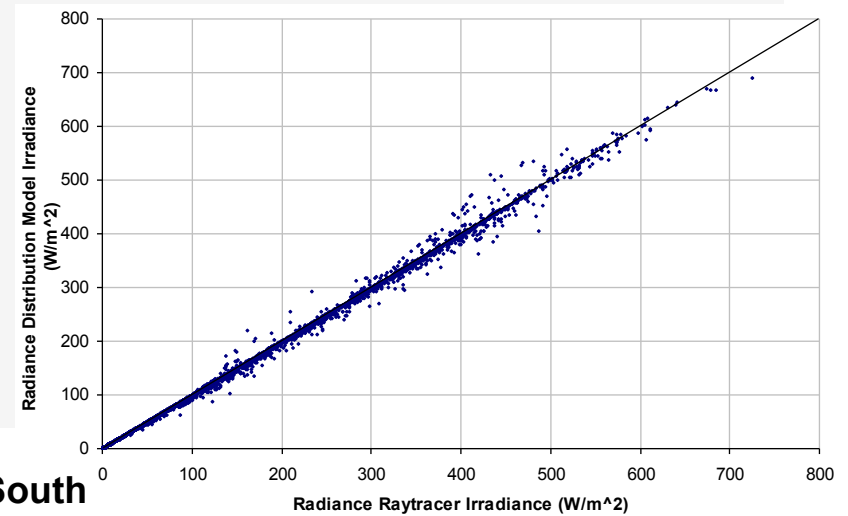
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Current practice (Perez tilted surface) versus RADIANCE (gendaylit)



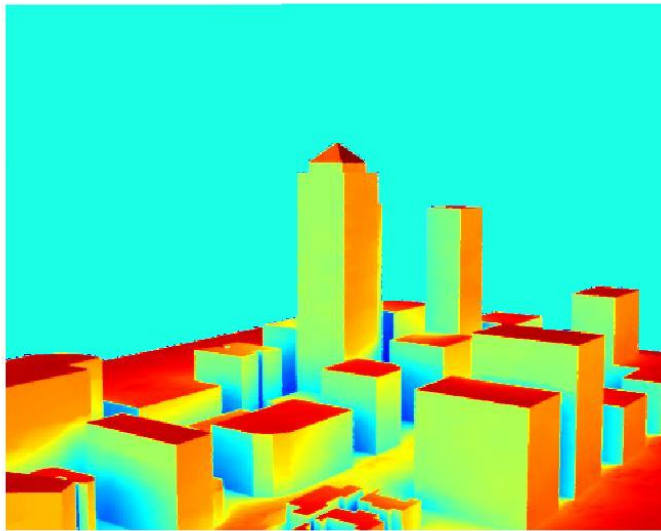
North



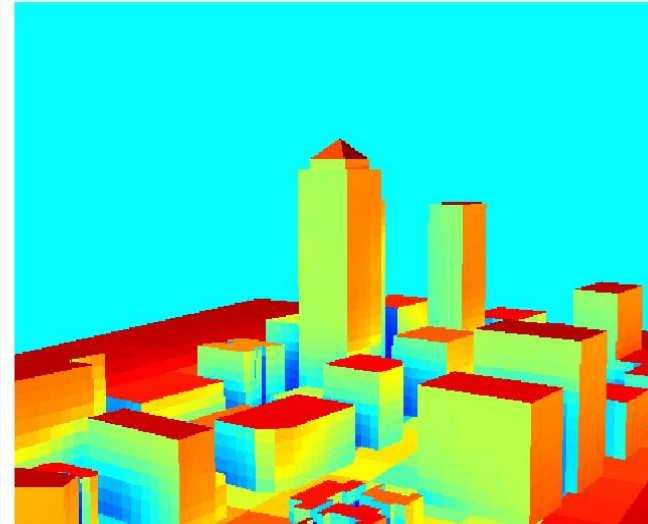
South

SRA versus RADIANCE (gendaylit)

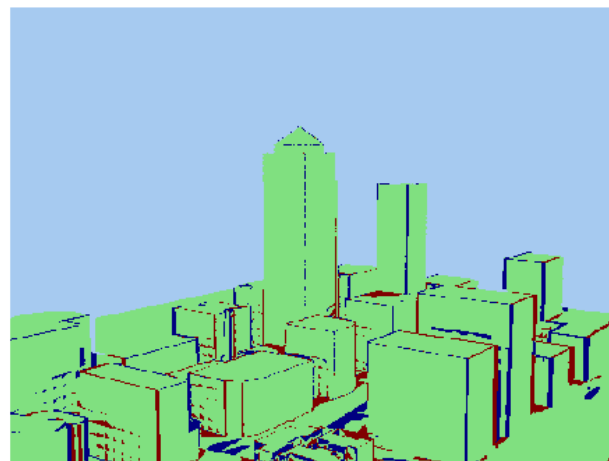
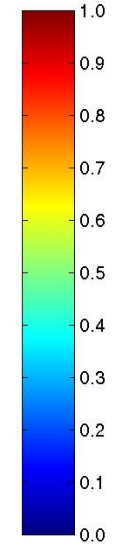
SRA verification



Radiance



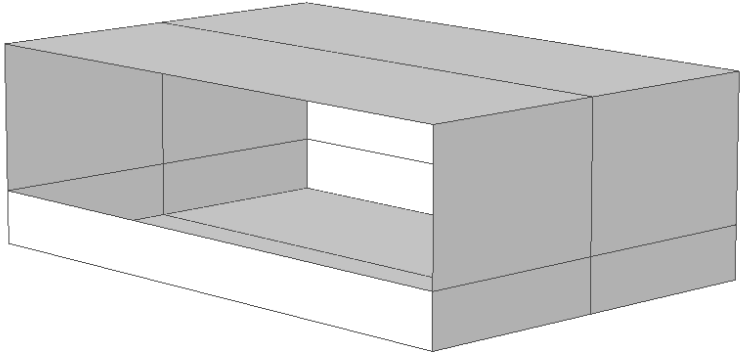
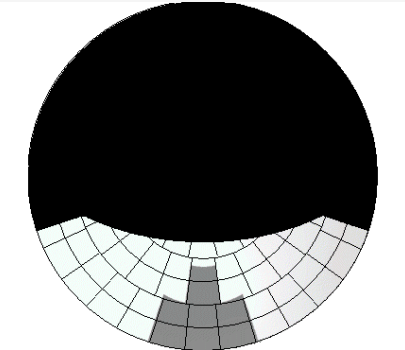
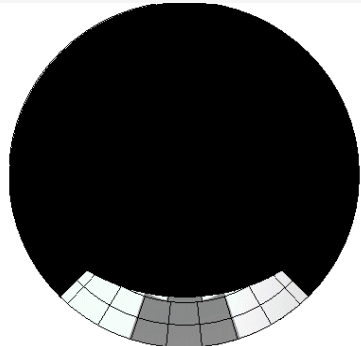
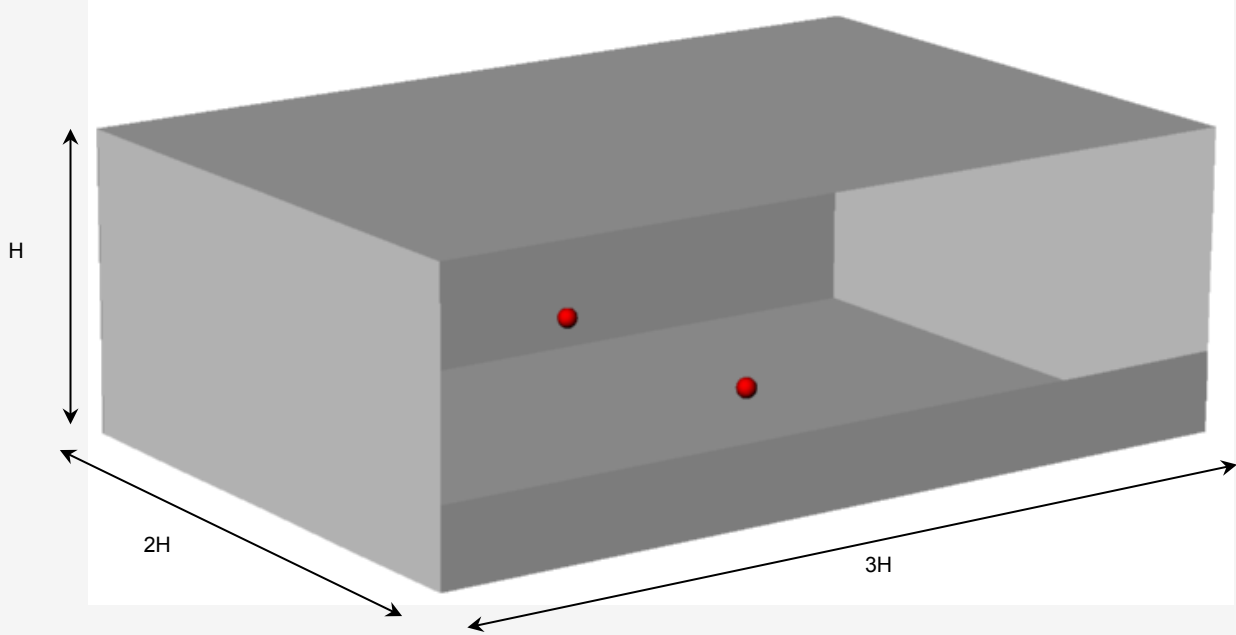
SRA for 10m x 10m facade discretisation:
6500 surfaces



Difference plot: green is within 10%

*Napier-Shaw Medal,
CIBSE 2007*

Daylight



Robinson and Stone (2006), Solar Energy 80(3)

- Calculate an approximate sky temperature

$$\varepsilon_0 \approx 0.741 + 0.00062T_d$$

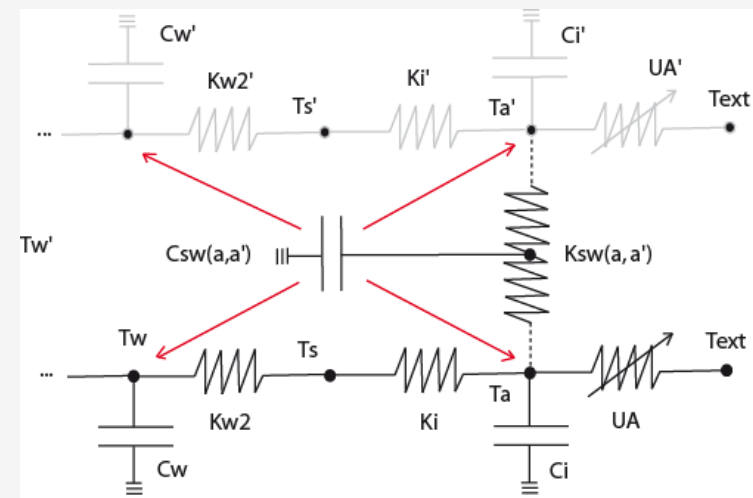
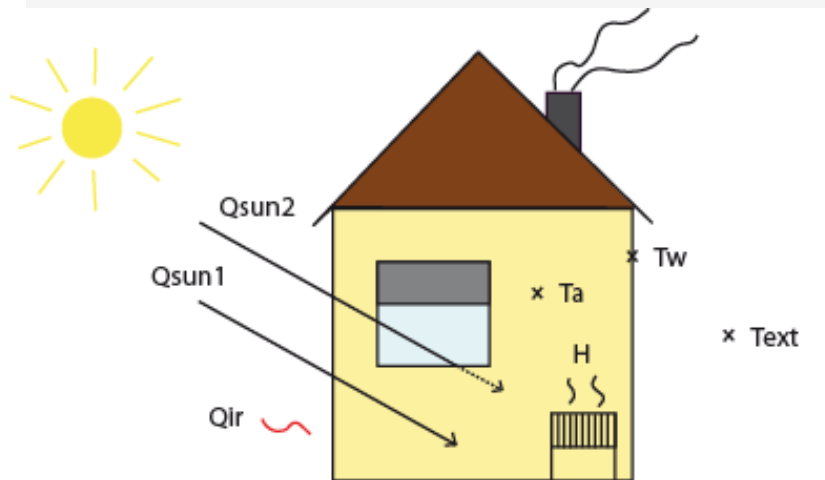
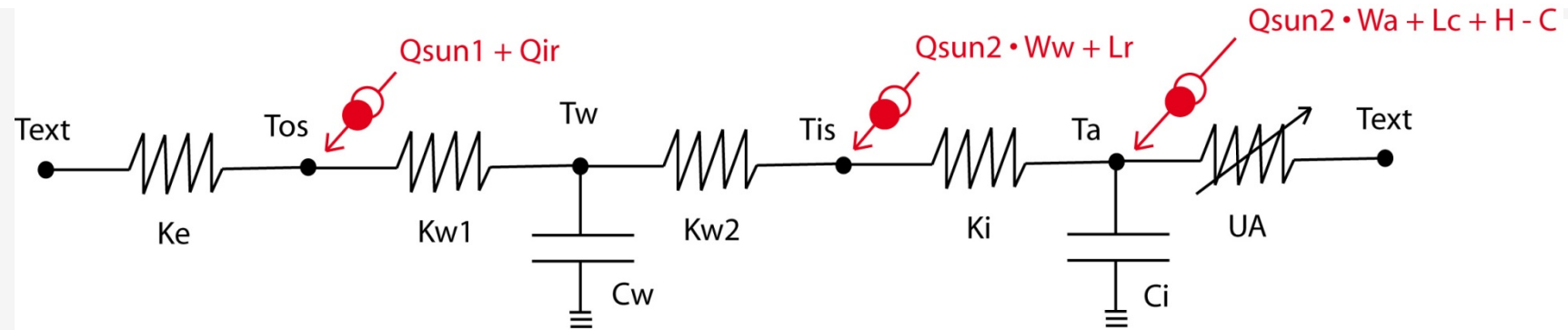
$$T_{sky}^4 \approx T_a^4 \varepsilon_0 n^{5/2} \quad (\text{accounting for cloud cover in the sky emittance})$$

- Take surface temperatures from a thermal model (for the previous time step)
- Define a solid angle weighted equivalent temperature.

$$T^{*4} = \frac{1}{\pi} \left(T_{sky}^4 \sum_{i=1}^{145} (\Phi \sigma \cos \xi)_i + \sum_{j=1}^{290} (\Phi \omega \cos \xi T^4)_j \right)$$

- Calculate the longwave exchange: $I_L = \varepsilon A \sigma (T^{*4} - T_s^4)$

Simple RC network thermal model

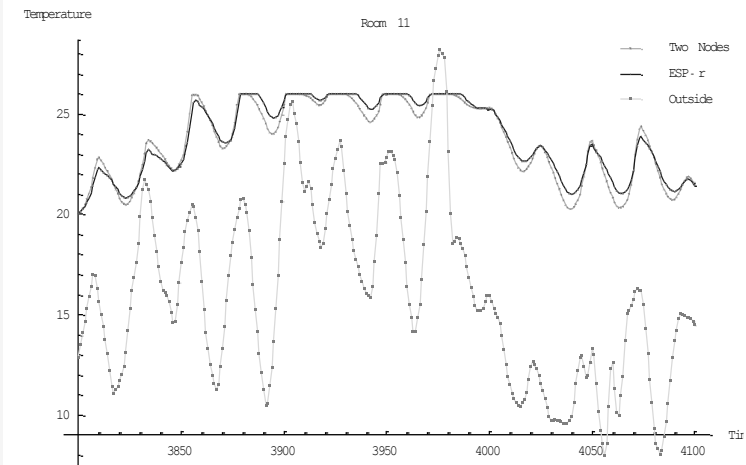
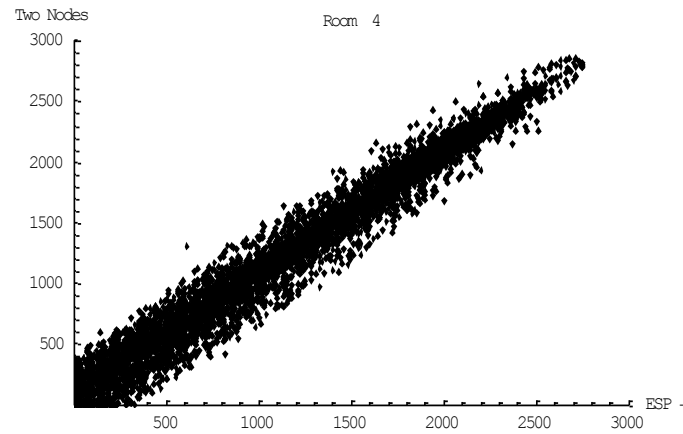
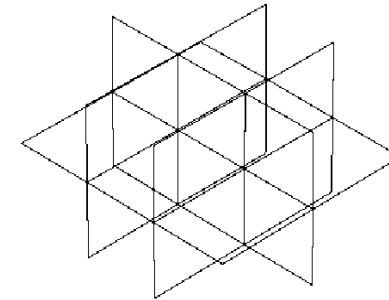
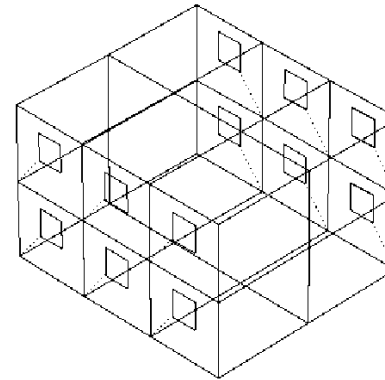
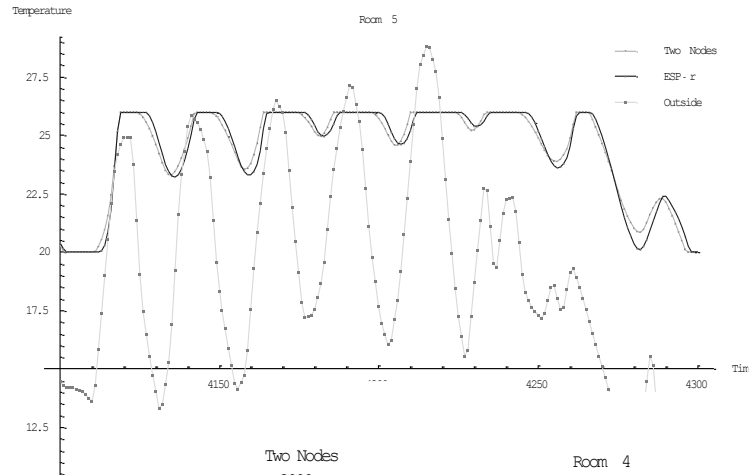


Inter-model comparison: ESP-r



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Good dynamic behaviour compared to ESP-r

HVAC systems

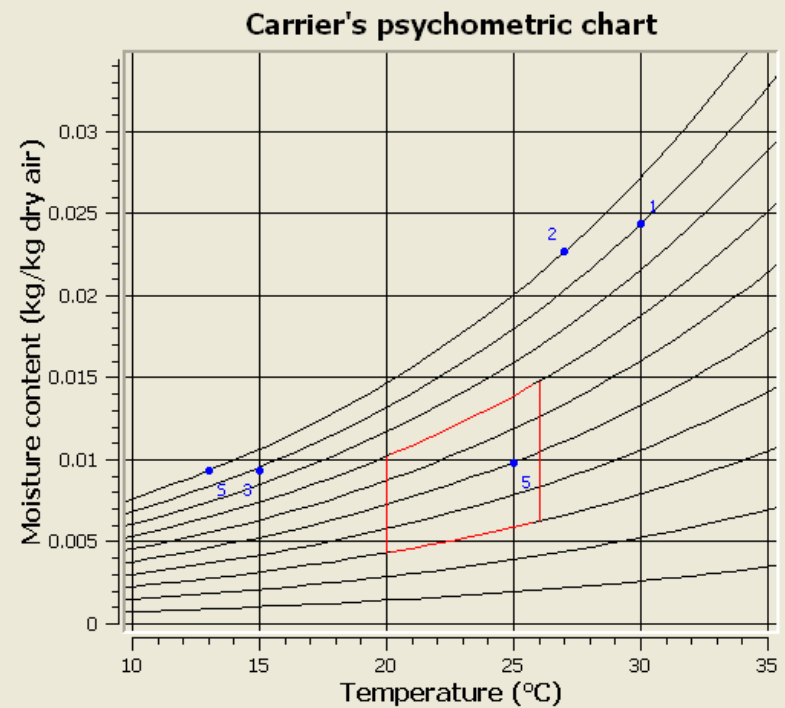


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Psychometrics - by Jérôme Kämpf, LESO-PB, EPFL, Switzerland

External temperature (°C)	<input type="text" value="30"/>	Moisture content (g/kg dry air)	<input type="text" value="24.3814"/>		
Relative humidity (%)	<input type="text" value="90"/>				
Atmospheric pressure (Pa)	<input type="text" value="101325"/>				
Coil efficiency	<input type="text" value="0.6"/>	Temperature after coil (°C)	<input type="text" value="27"/>		
Set point temperature (°C)	<input type="text" value="25"/>				
Sensible Load (W)	<input type="text" value="-1000"/>	Supply air temperature (°C)	<input type="text" value="13"/>		
Latent Load (W)	<input type="text" value="100"/>	Flow rate (kg/s)	<input type="text" value="0.0976395"/>		
Number of persons	<input type="text" value="1"/>	Total moisture content (g/kg dry air)	<input type="text" value="23.1656"/>		
Change in supply air temperature (°C) fans and ductwork	<input type="text" value="2"/>	Controlled moisture (g/kg dry air)	<input type="text" value="9.33436"/>		
<hr/>					
Heating load (W)	<input type="text" value="0"/>	+ COP	<input type="text" value="3.5"/>	=	<input type="text" value="0"/>
Cooling load (W)	<input type="text" value="4729.05"/>	+ COP	<input type="text" value="5.5"/>	=	<input type="text" value="859.828"/>
Humidification load (W)	<input type="text" value="0"/>			=	<input type="text" value="0"/>
Reheat load (W)	<input type="text" value="0"/>			=	<input type="text" value="0"/>
<hr/>					
<input type="button" value="Calculate"/>			Total	<input type="text" value="859.828"/>	



Heating Ventilation and Air Conditioning Model

Mixture of Ideal Gases (Air and Vapour)

- enthalpy changes

Energy Conversion Systems



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PV - by Jérôme Kämpf, LESO-PB, EPFL, Switzerland

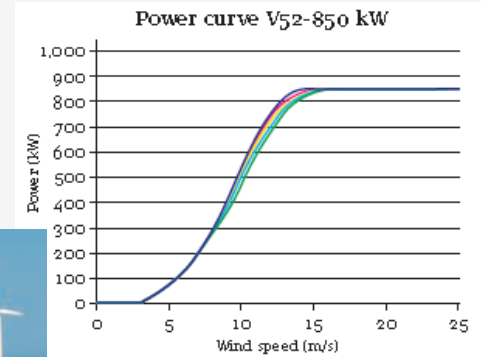
Panel surface (m ²)	<input type="text" value="0.1"/>	Ambient temperature (°C)	<input type="text" value="30"/>
Irradiation on panel (W/m ²)	<input type="text" value="800"/>		
Max power efficiency @ Tref (%)	<input type="text" value="12.2"/>	Cell NOCT (°C)	<input type="text" value="40"/>
Reference temperature Tref (°C)	<input type="text" value="18.6"/>	Air NOCT (°C)	<input type="text" value="20"/>
Temp coeff voltage μVoc (V/K)	<input type="text" value="-0.05"/>	Irradiation NOCT (W/m ²)	<input type="text" value="800"/>
Voltage @ max power (V)	<input type="text" value="12.5"/>		
Power conditioning efficiency (%)	<input type="text" value="92"/>		

Calculate

Efficiency @ max power (%)	<input type="text" value="11.6437"/>
Power (W)	<input type="text" value="8.56975"/>



Water and/or Air



Solar collectors (PV + thermal)

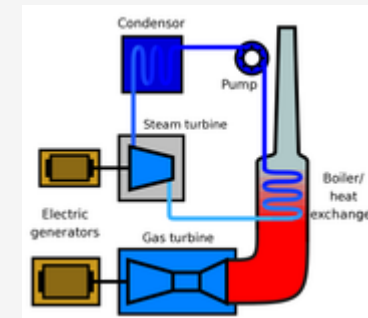
Wind turbines

Boilers and co-generation systems

Heat pumps (air + ground: hoz / vert)

Sensible + latent heat storage

**Co-generation of
heat and
electricity**

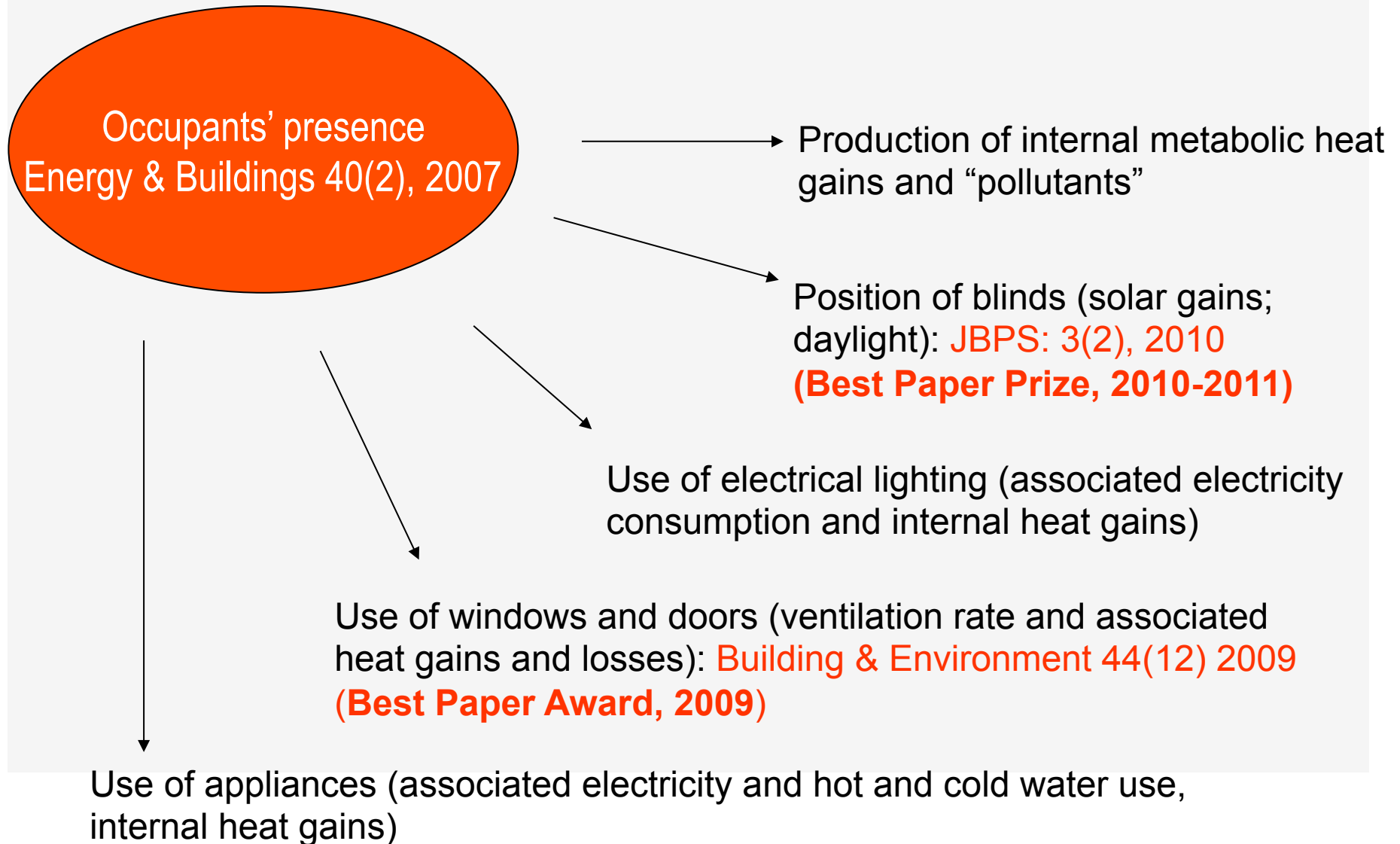


Key behavioural models (2001 - 2011)



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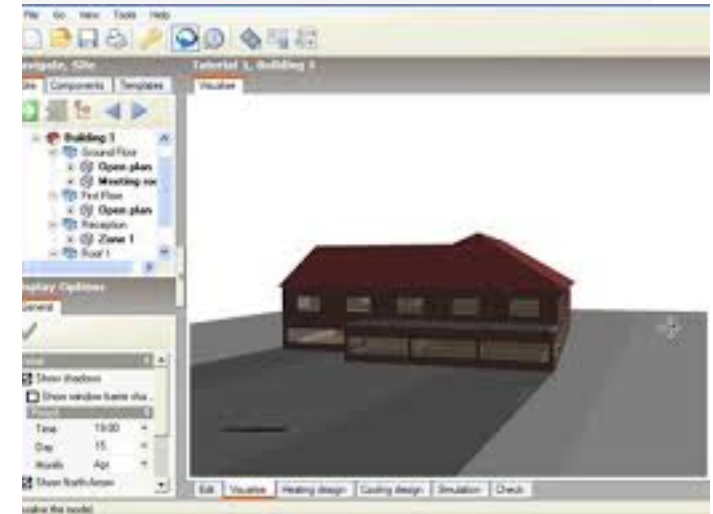
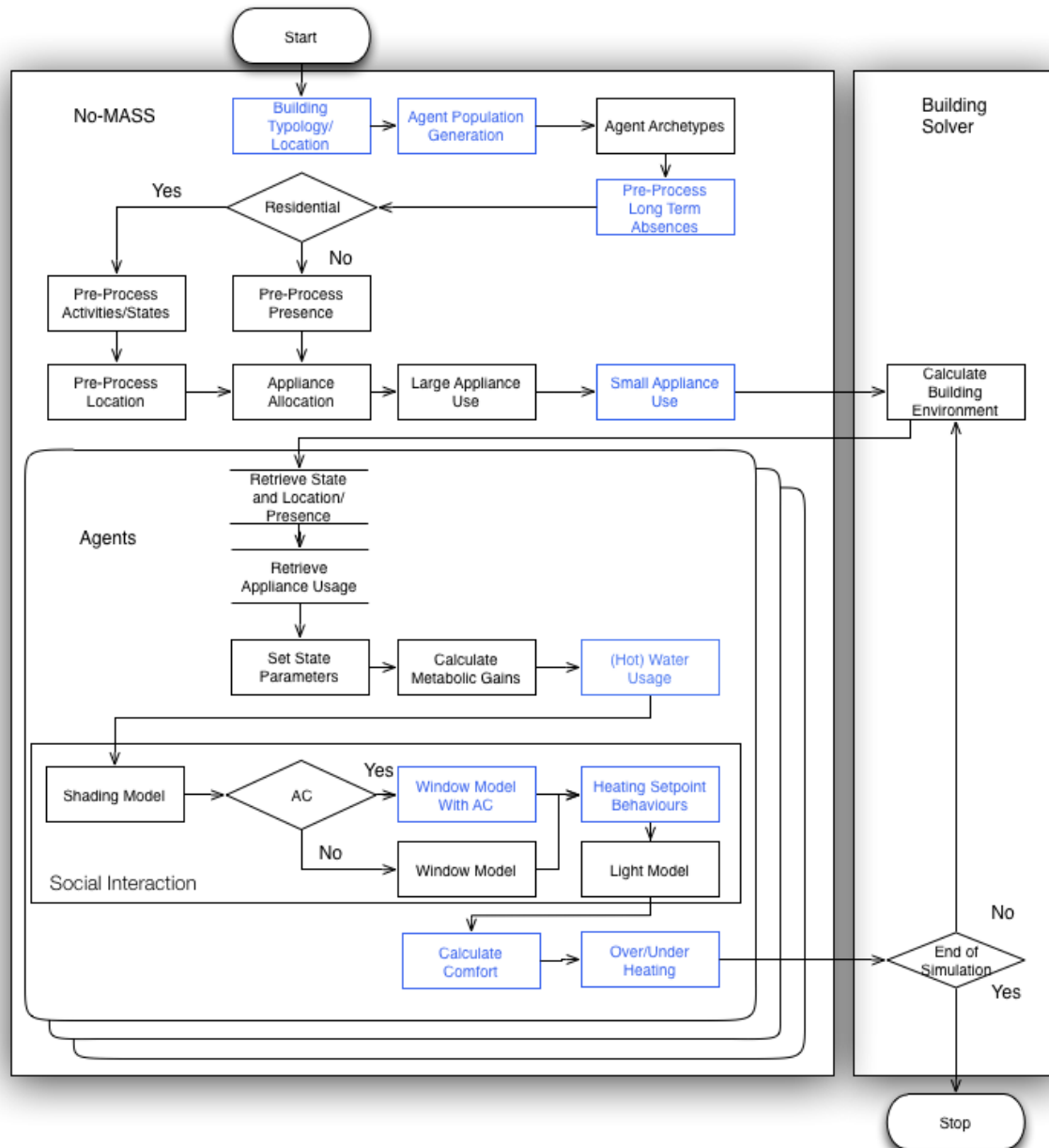


No-MASS (2013-15): E+ → CitySim

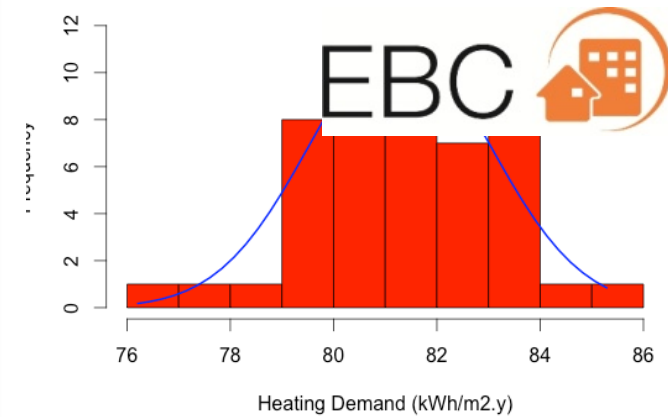


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Distribution of yearly heating demand

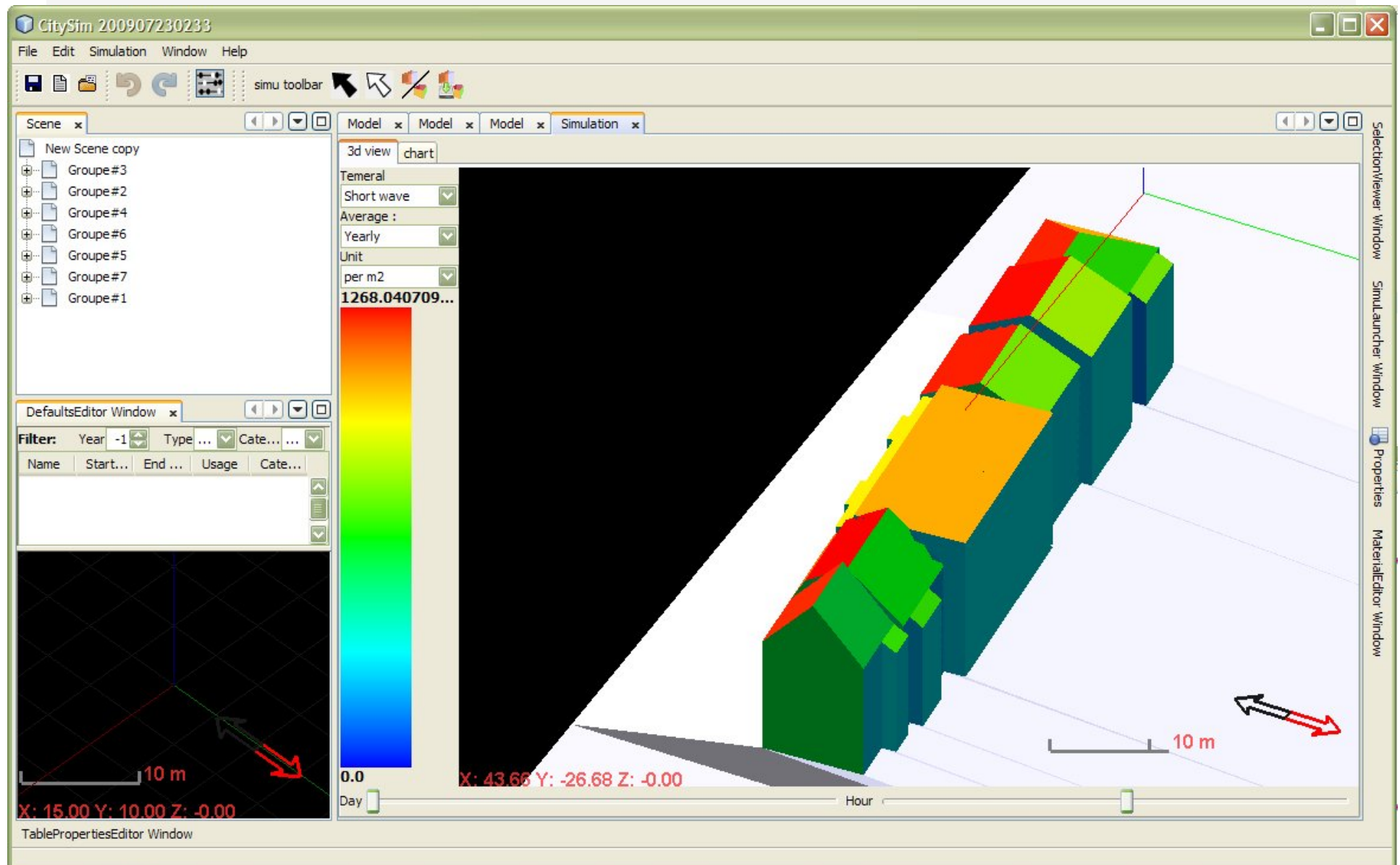


Falsecoloured images



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Tables, line graphs & results export...



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CitySim 201006101454

File Edit Simulation Window Help

simu toolbar

Scene Editor - New Scene Lausanne x Simulation x

3d view chart Summary

temporal resolution: Hourly, **Daily**, Weekly, Monthly

X axis variable: Time, HeatStockTemperature(celsius), ColdStockTemperature(celsius), MachinePower(W), FuelConsumption(J), ElectricConsumption(J), Ta(celsius), Heating(Wh), Cooling(Wh)

Y axis variable: HeatStockTemperature(celsius), ColdStockTemperature(celsius), MachinePower(W), FuelConsumption(J), ElectricConsumption(J), Ta(celsius), **Heating(Wh)**, Cooling(Wh), Qs(Wh)

Variable	Year consumption
HeatStockTempe...	23.67 °C
ColdStockTempe...	18.71 °C
MachinePower(W)	10.44 MW
FuelConsumption...	39.13 GJ
ElectricConsumpt...	0.00 J
Ta(celsius)	24.26 °C
Heating(Wh)	9.44 MWh
Cooling(Wh)	-41.16 MWh
Qs(Wh)	9.32 MWh

Heating(Wh)

Heating(Wh)

Days

ToolsOptions Window

Properties

Vertex 1	x: 0 y: 0 z: 0
Vertex 2	x: 0 y: 0 z: 0

Rectangle Floor

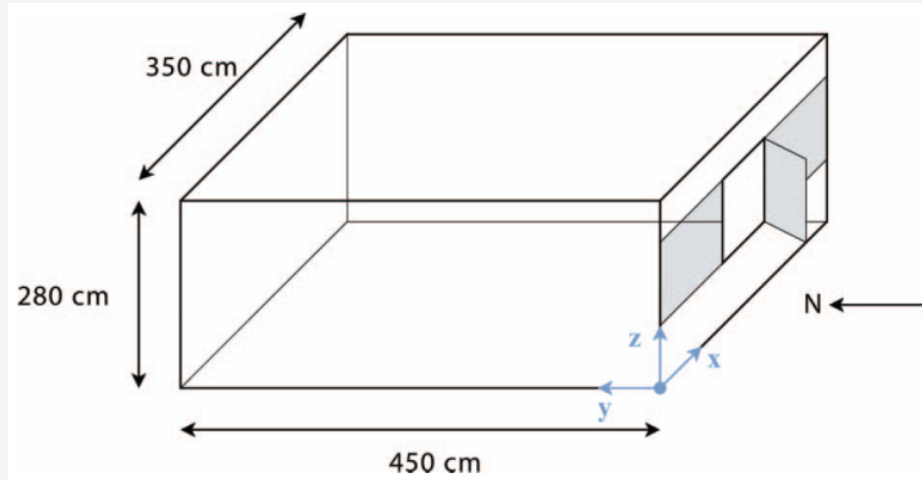


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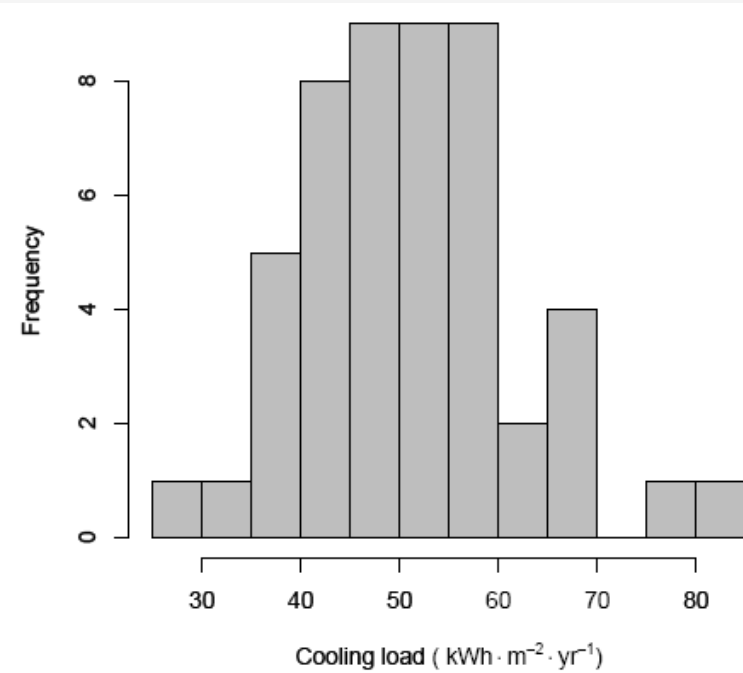
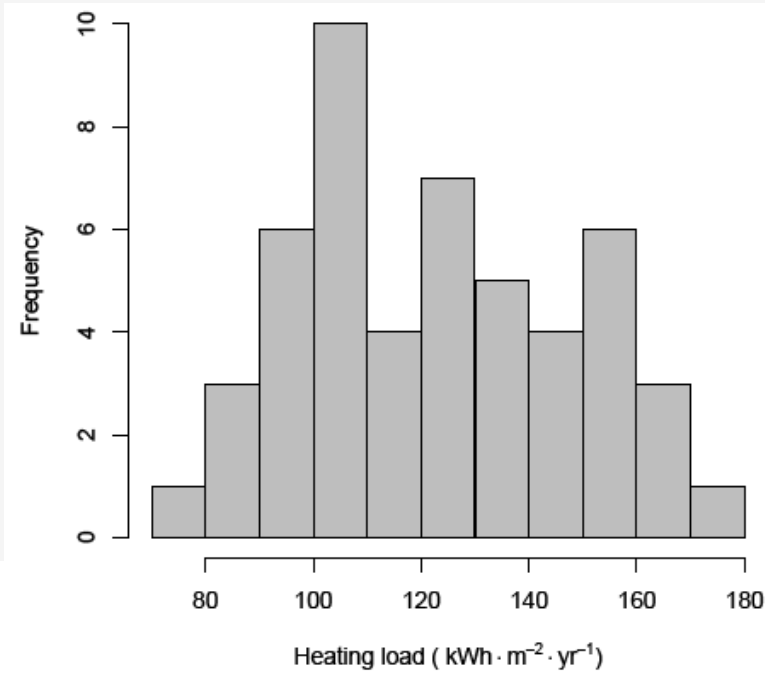
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Some CitySim applications

A shoebox



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

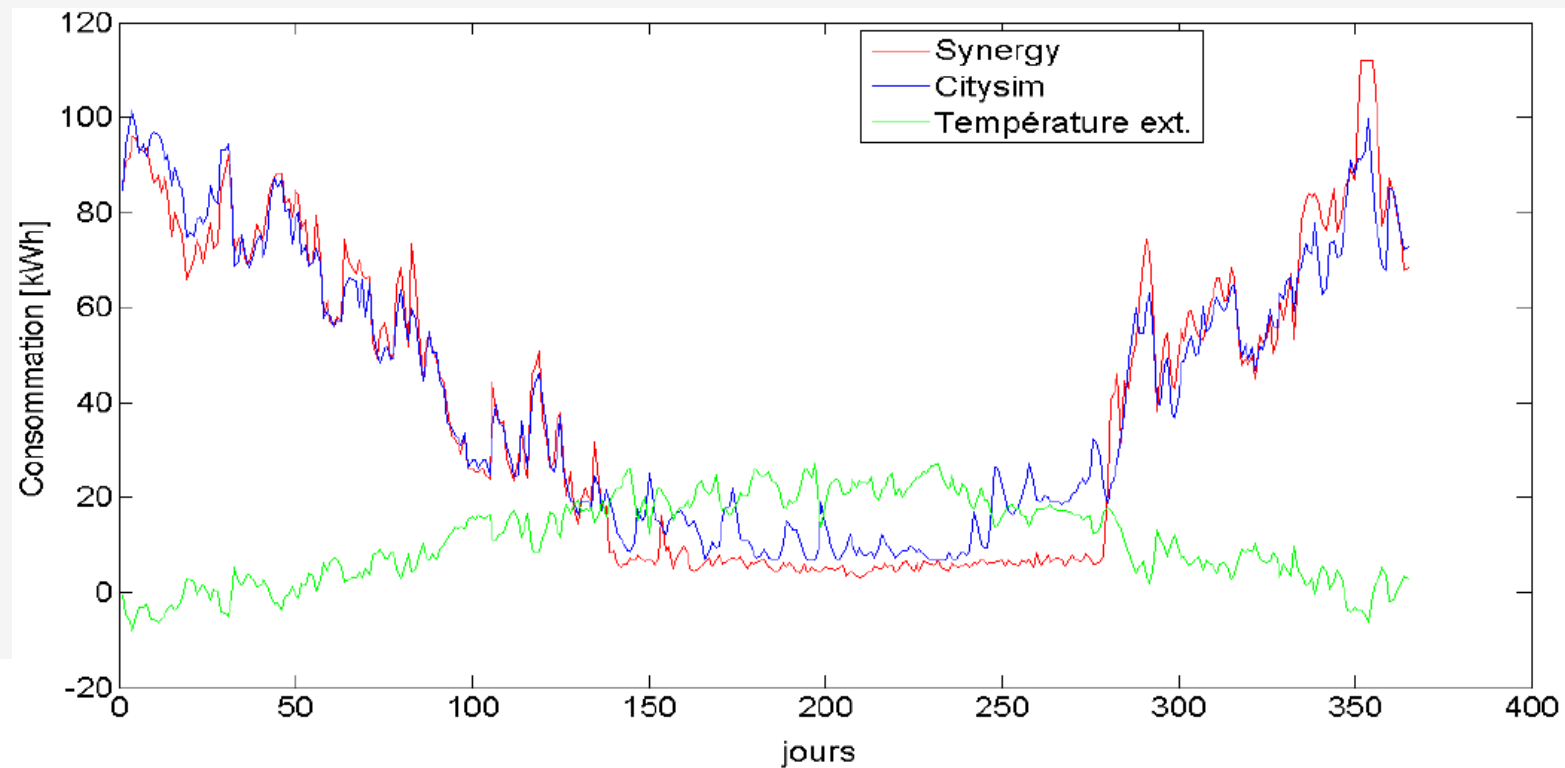
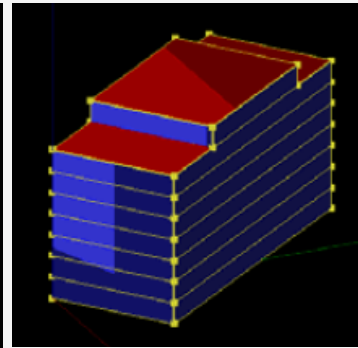
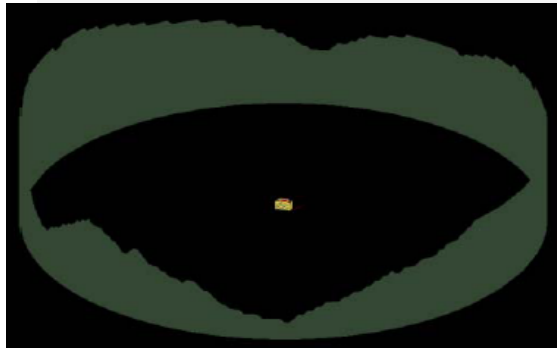


A single building: **Martigny**



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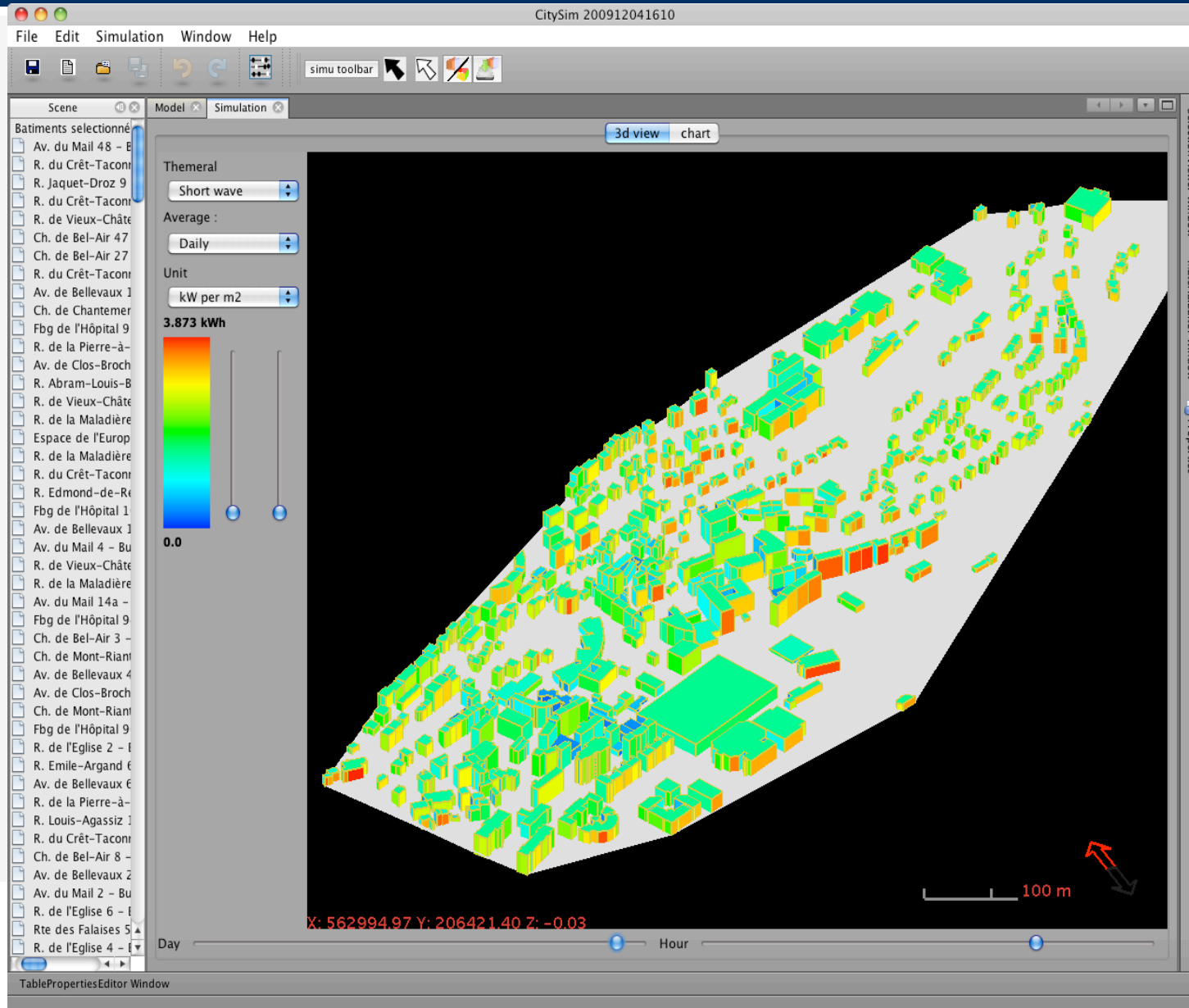


A district: Neuchâtel



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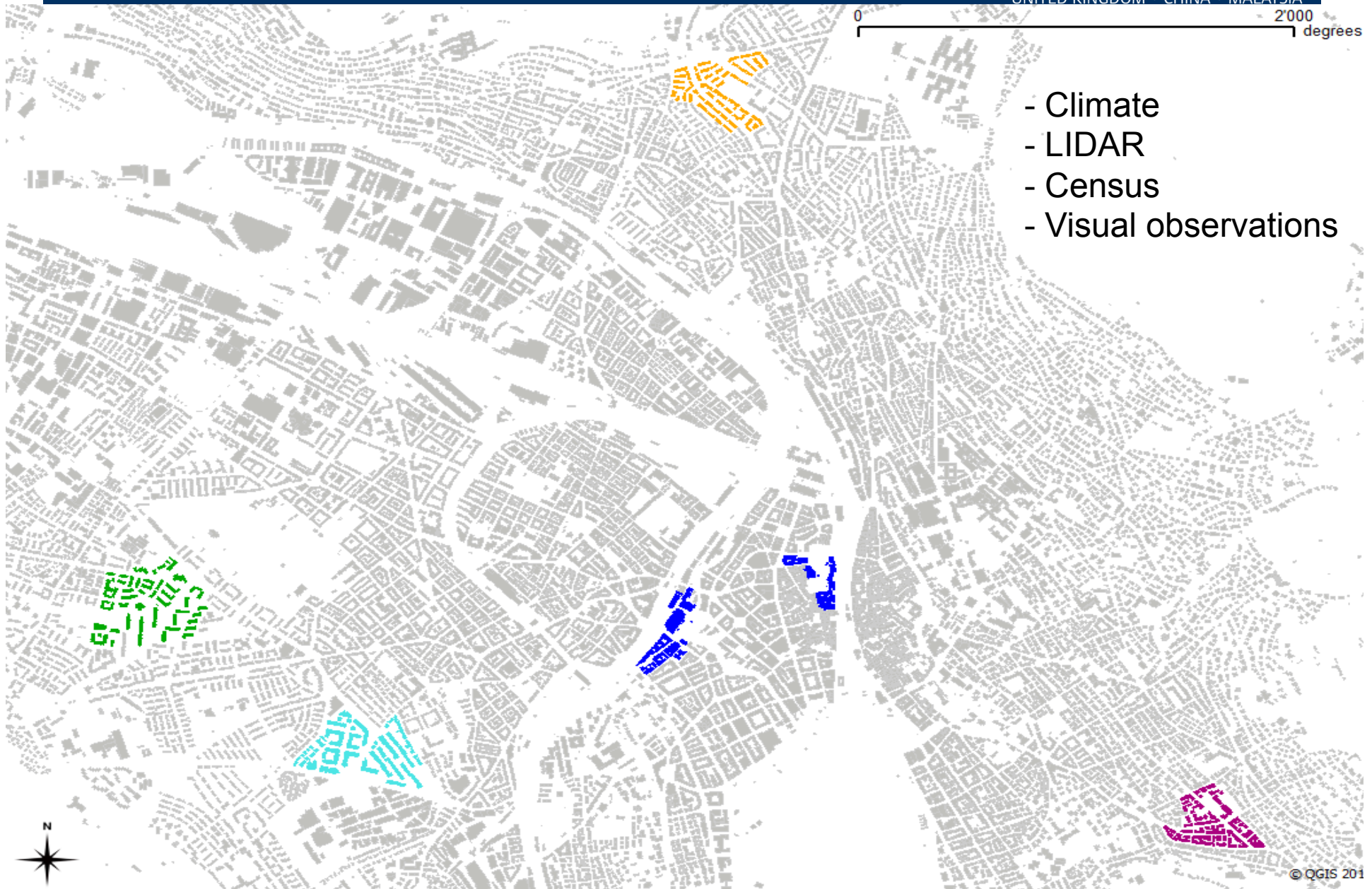


A City: **Zürich** (Nottingham is en-route)



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Q-GIS interface to PostgreSQL database



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The screenshot shows the QGIS 1.6.0 interface. The main map area displays a vector map of buildings in red and green. A scale bar indicates 200 degrees. The 'Couches' (Layers) panel on the left shows two layers: 'building' and 'cadastre_interse'. An 'Identifier les résultats' (Identify Results) dialog box is open, displaying a table of data for a selected building.

Donnée	Valeur
0	building
description	Bürogebäude
(Actions)	
(Dérivé)	
address_fk	Im Tiergarten 7,
altitude	426.8
avuvale	
building_id_fk	302047384
description	Bürogebäude
gastw	6
gbauj	1991
gbaup	8018
grenj	9999
grenp	
gstat	

© QGIS 2011

Coordonnée : 681069,246839 Échelle : 1:216263612 Rendu

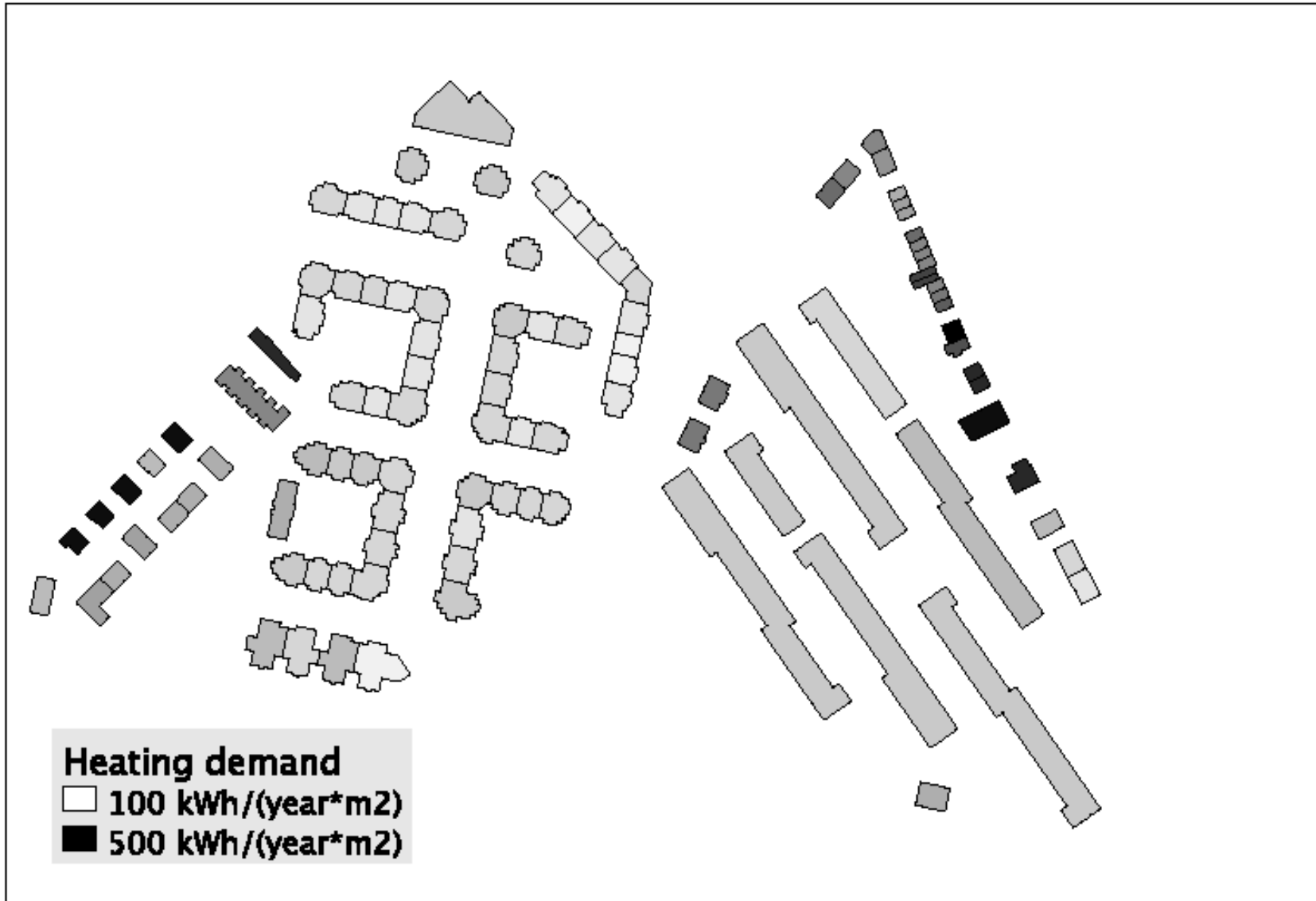
Kreis 3 – Alt-Wiedikon

Pre-renovation: old buildings dominate



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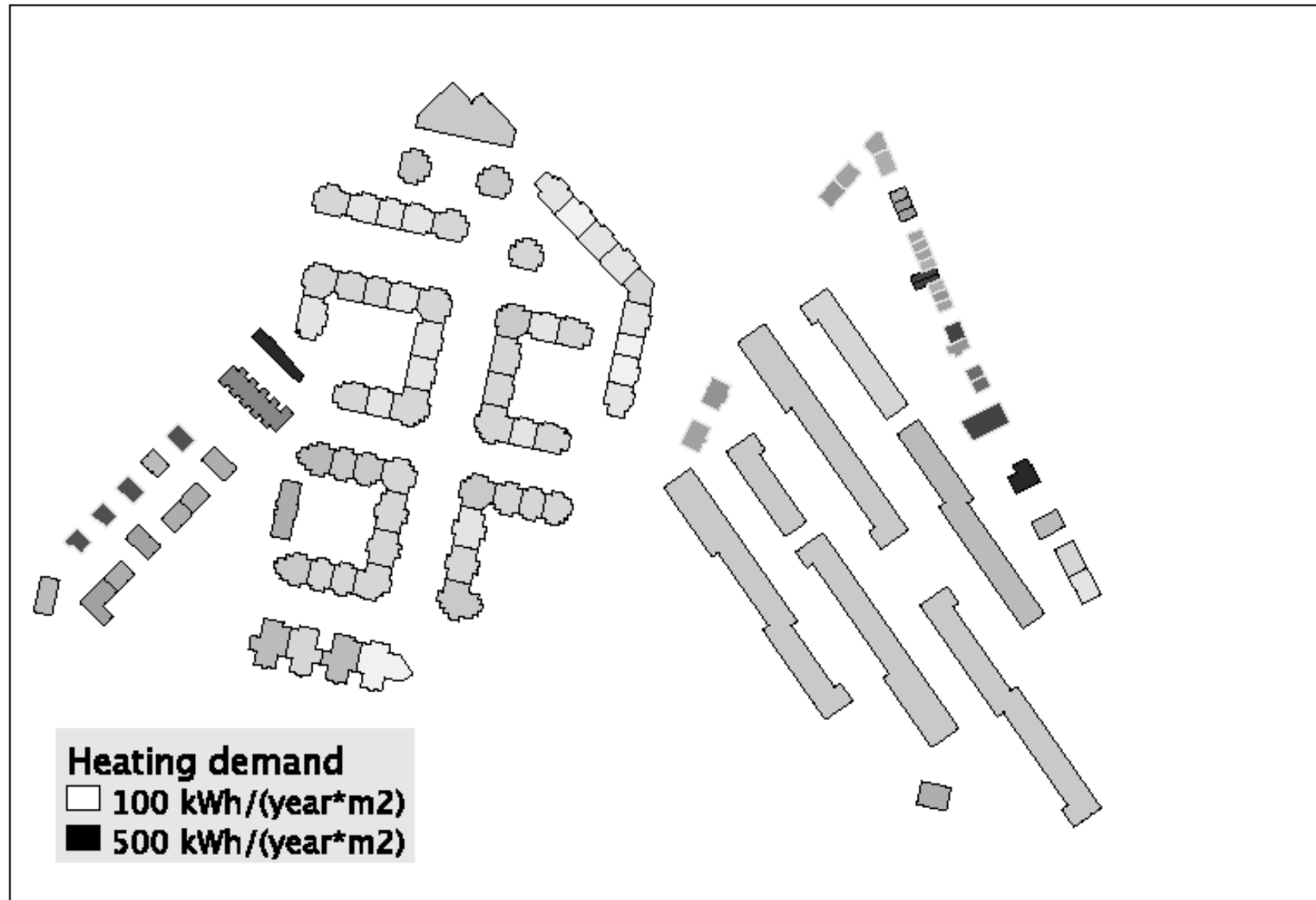


Post-renovation: 8% total heating reduction



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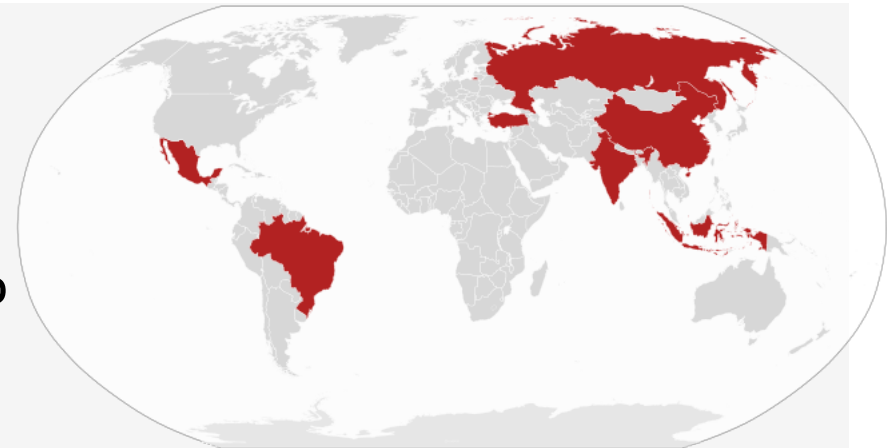


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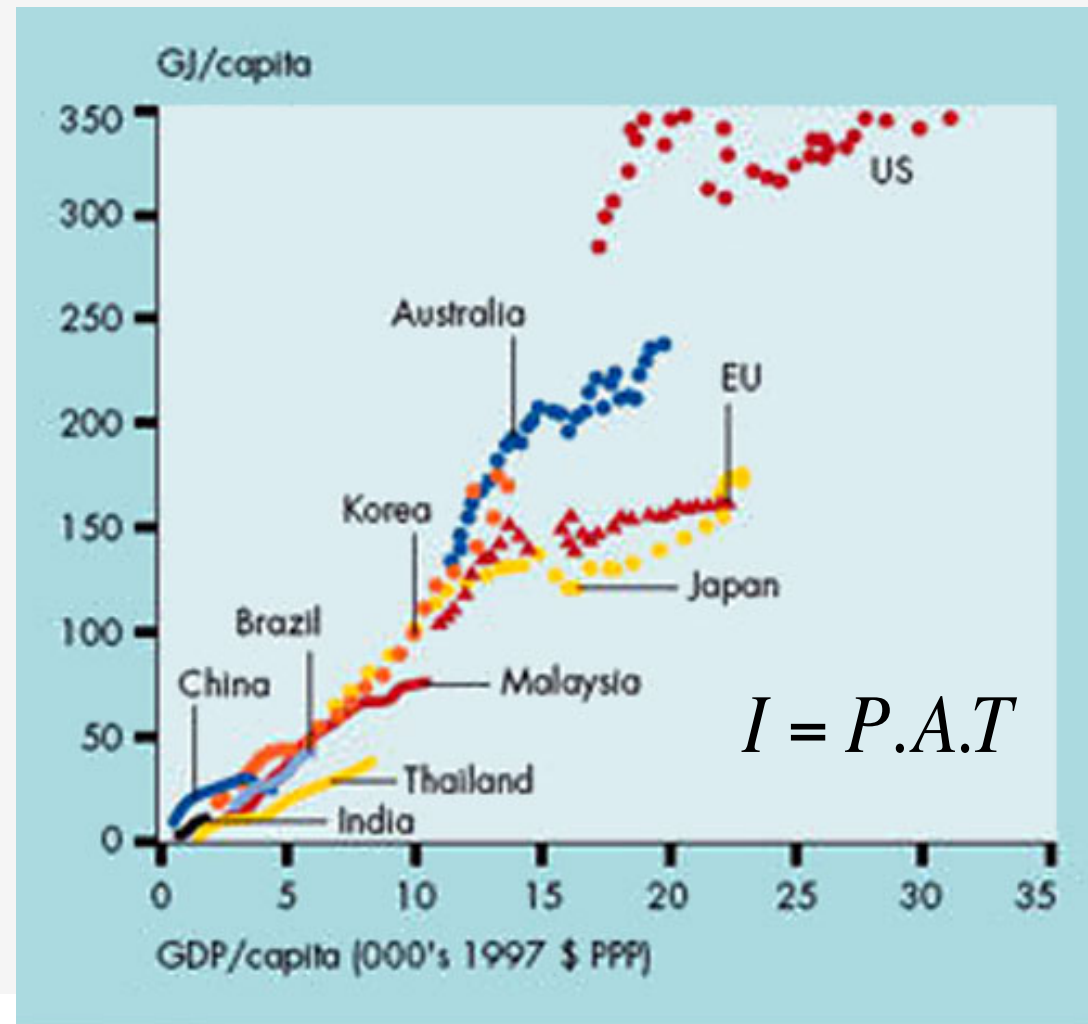
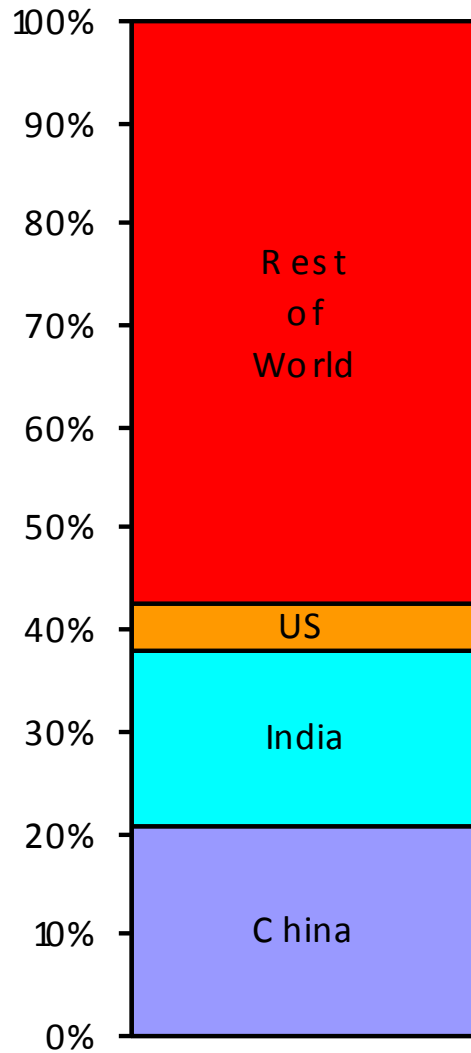
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The bigger urban picture...

- **E7** states are experiencing **unprecedented growth**.
- E7 economies may be 75% larger than G7 by 2050.
- **Mass rural->urban migration**.
- In **2050** we may have:
 - **2.7B more urban dwellers**.
 - **80% of urban population living in developing economies**.



Global environmental tendencies



Cities are complex systems



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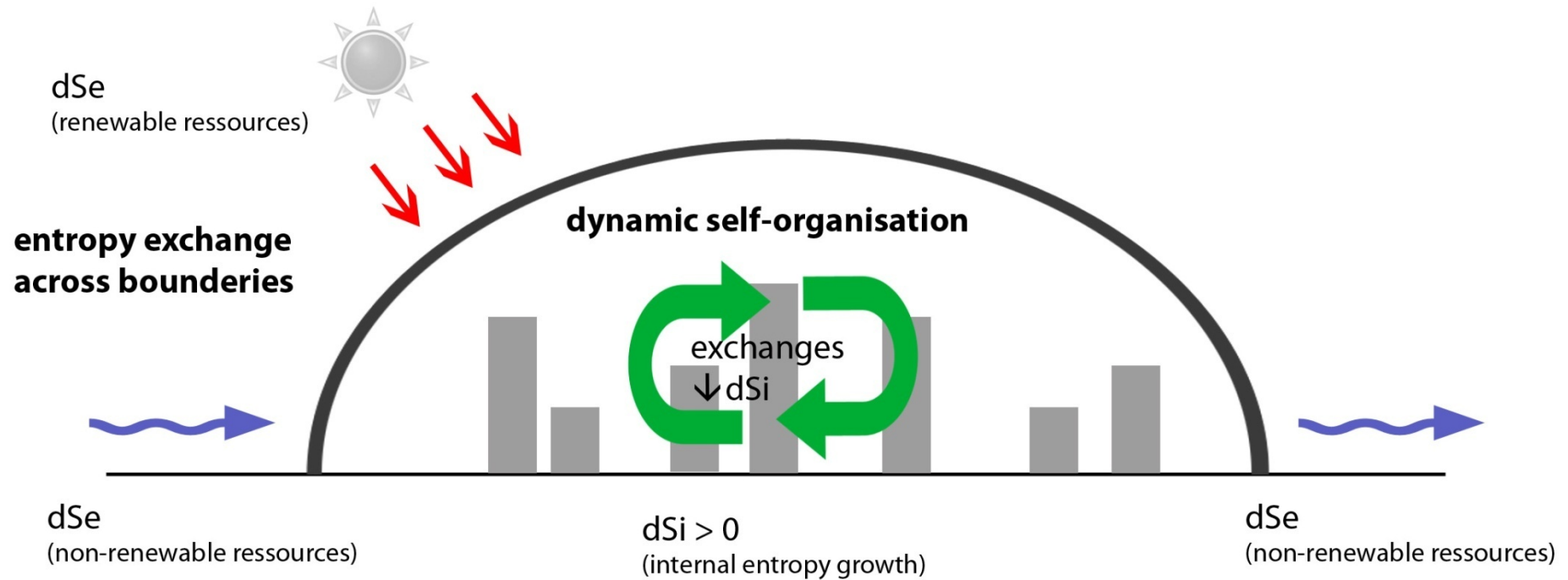
- Cities are **self-organising systems**, expressing macroscopic structural pattern (**emergent behaviour**) based on microscopic **interactions of their actors** (individuals, firms):
 - Actors respond to **financial, regulatory, technological and educational stimuli** and to the actions of their peers.
- This emergent behaviour is **non-linear**.
- Cities are **far from equilibrium** and **open systems**:
 - Internal entropy production (dS_i) is counteracted by entropy exchange (dS_e) across the city boundaries: $dS = dS_i + dS_e$
 - Entropy is produced internally, but order may be increased
 - Equilibrium implies the absence of change: death.
 - « **Sustainable city** » is an **oxymoron!**

A conceptual model



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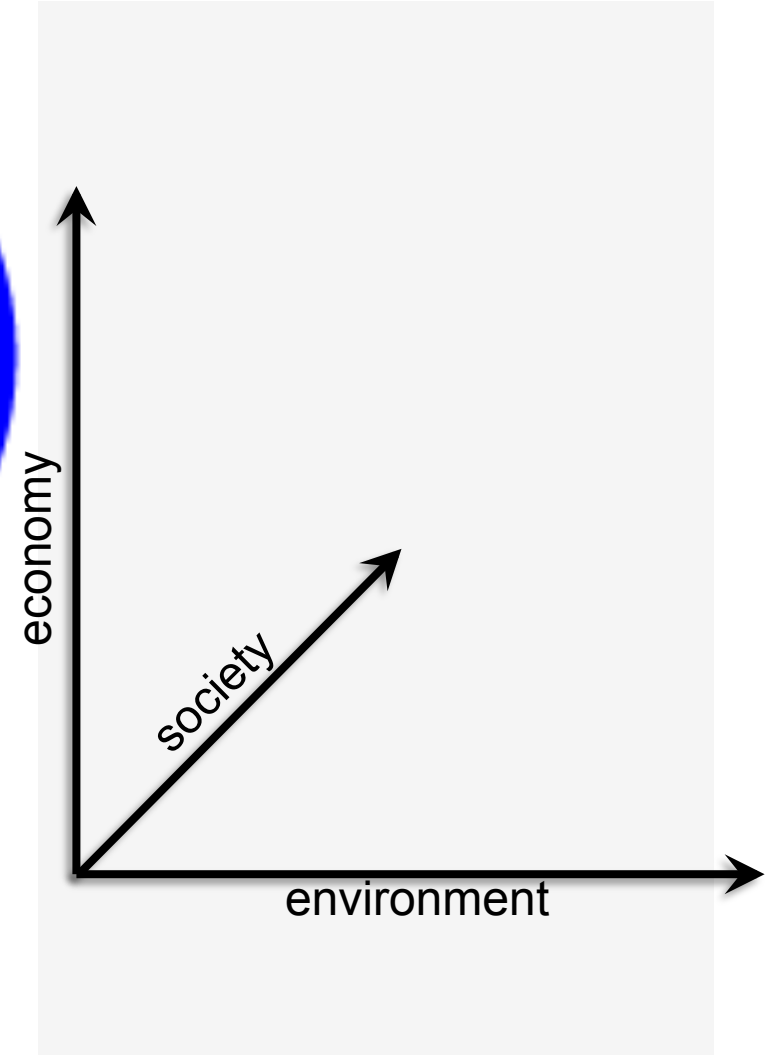
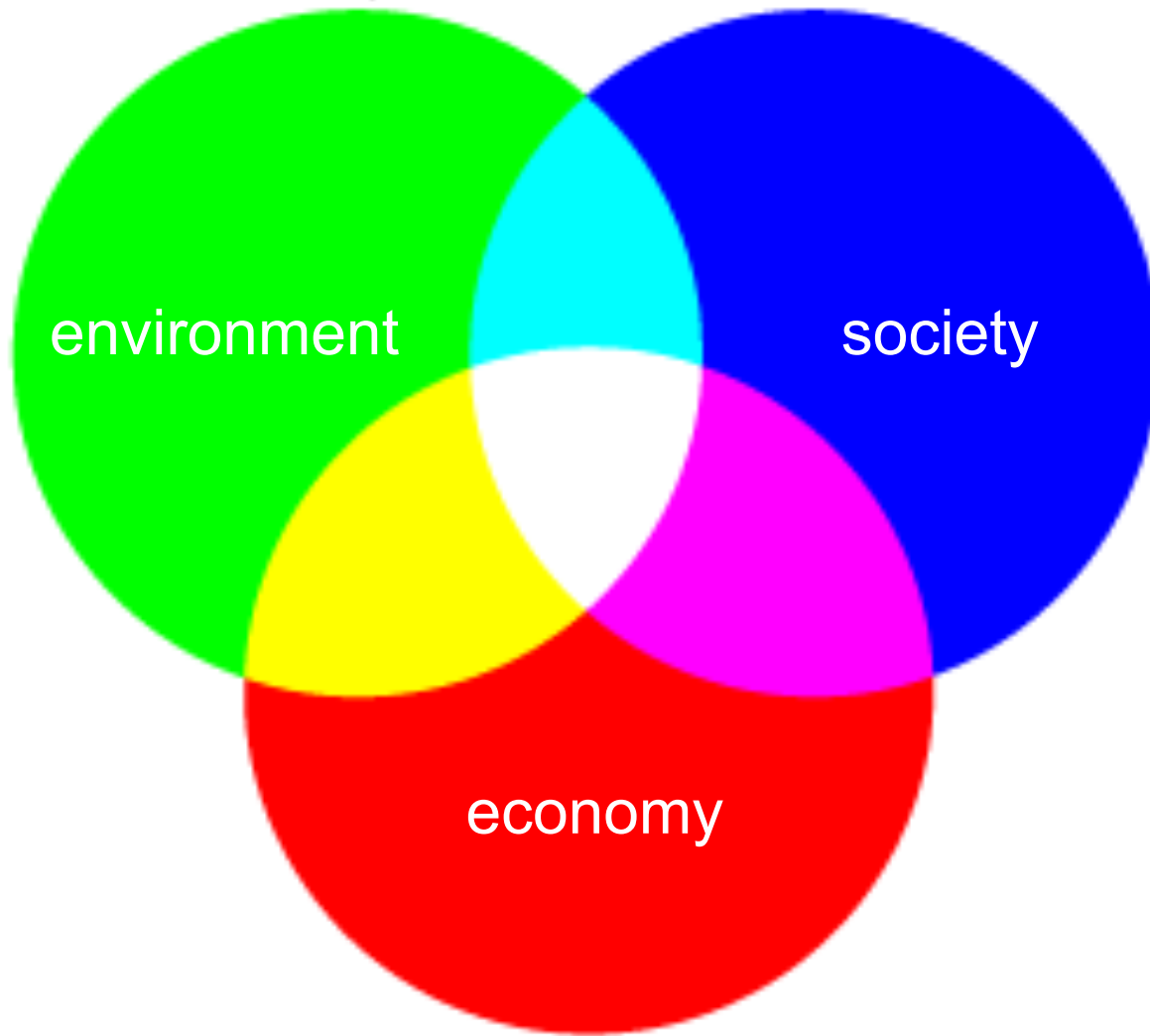


What's sustainability?: interrelationships, conflict and competition



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Sustaining Urban Habitats: An interdisciplinary approach



The Leverhulme Trust



The University of
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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



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European *transition* cities

Asian *growth* cities

Sustaining Urban Habitats: An **interdisciplinary** approach

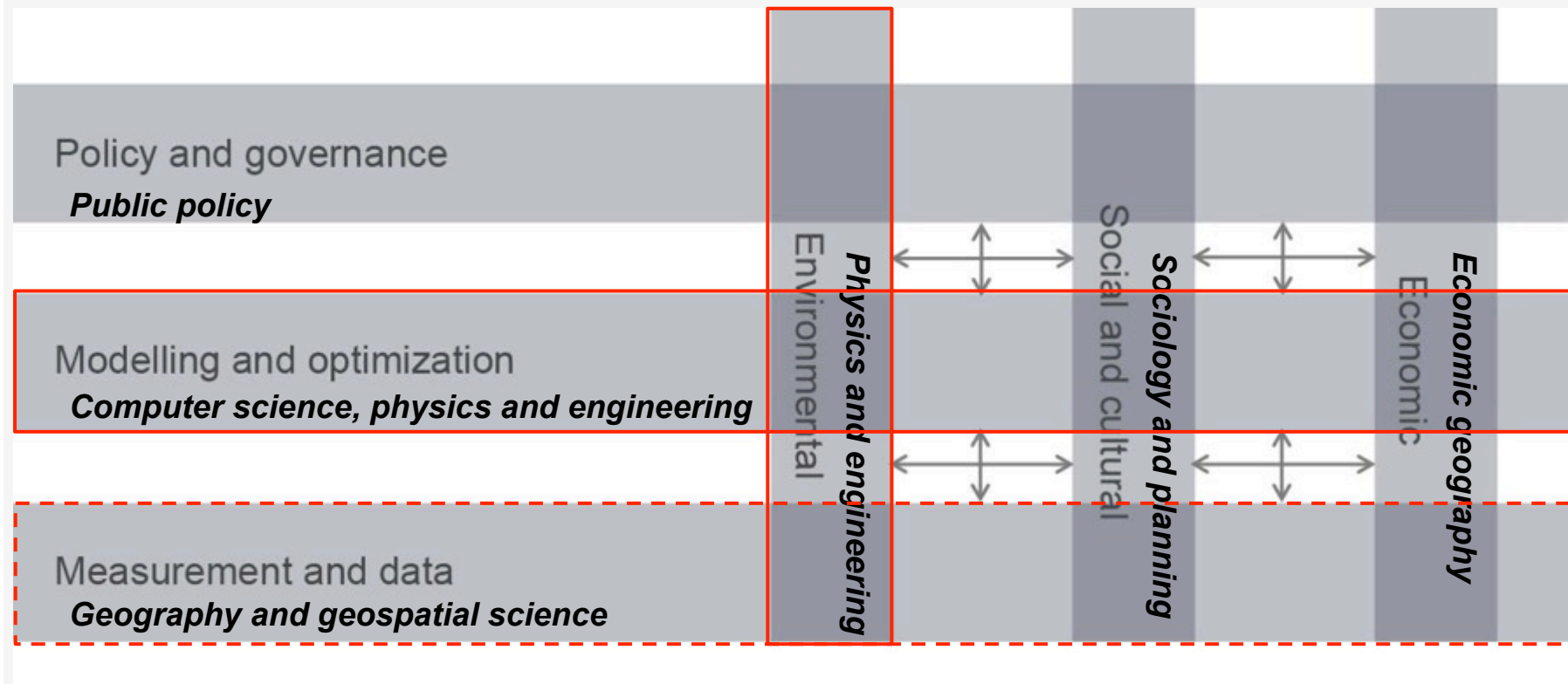


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Theme #1: Environment



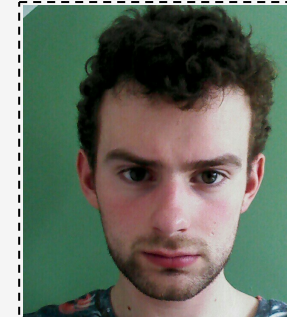
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- **How do we define environmental sustainability** in a measurable, predictable and realistic way, which also deepens our insights into the functioning of the city, to identify where there is scope for improvement?
- Taking a conceptual model of a hypothetical city as an open system, to what extent can we maximise resource flow circularity: **how sustainable can a city system be?**
- Can we prepare a **city sustainability label** and associated assessment method; a new **vocabulary?**



Me



Ben Purvis (PhD)



Dr Yong Mao



Phillip Heyken (PhD)
+ A N other (IDIC)



Dr Andrew Allen (RF)



Tim Whiteley (PhD)

Theme #2: Society



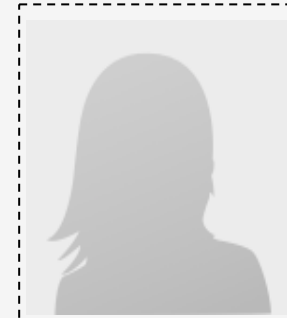
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- How does the **ecological footprint** vary between social groups? Which factors are important for the variation in ecological footprint? How do different social groups respond to **strategies to reduce it**?
- Which factors define our **perceptions of social sustainability** in its broader sense (e.g. capital, cohesion, equity, inclusion) in increasingly diverse communities? What **levers** can be employed to improve upon it?
- **Can this understanding be modelled; how?**



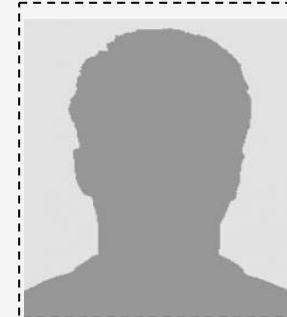
Prof. Reiner
Grundmann



Hannah Keding (PhD)



Dr Jenni Cauvain



A N other (IDIC)

Theme #3: Economy



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- What constitutes **economic sustainability**?
- What are the **dominant factors** influencing a city's economy; to what extent can corresponding **levers** be modified to bring about change? Can this be modelled?
- How should these be achieved through **policy and stimulation** of public and private investments?
- *What drives **migration** and how can this be managed?*
- What are the factors influencing firms' and individuals' **investment decisions more broadly**: location; infrastructure; buildings and systems; appliances...



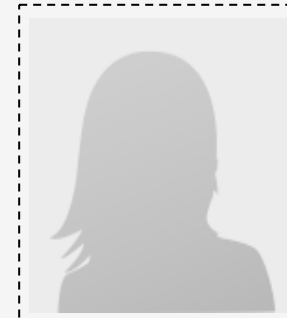
Prof. Sarah Hall



Phil Northall (PhD)



Dr Pelin Demirel



A N other (IDIC)



Stephen Parkes (RF)

Theme #4: Data



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- Can we combine the outcomes from themes #1 to #3 to **indicate city sustainability** in a comprehensive way?
- What are the most effective means for **acquiring and managing diverse** [traditional and crowd-sourced] **urban data for monitoring and modelling** purposes?
 - CityGML (and its ADEs) & 3DcityDB
 - OSM
 - NASA WorldWind...



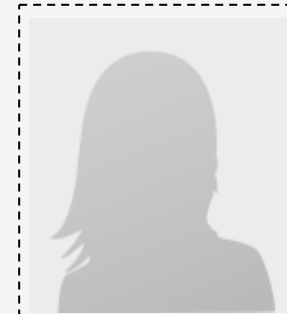
Dr. Doreen Boyd



A N other (PhD)



Dr Ant Beck



A N other (IDIC)



A N other (PhD)

Theme #5: Modelling



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- What form should our [physical and social] **modelling framework** take?
- What would a **utopian** (maximally sustainable) city look like in the case of transition and growth cities?
- Based on abstract representations of real cities, what is the **optimal combination of policy measures** to maximise some integrated measure of city sustainability?
- How robust is this **transition pathway** to key (initial and time varying) input **uncertainties**? **Or** how should we **backcast** from this target future state?



Me



Dr Sam Zakhery (RF)



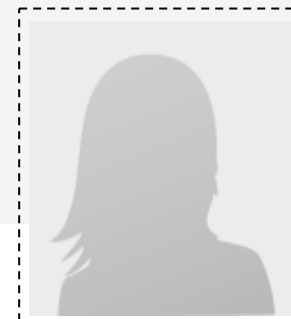
Prof. Paul Nathanail



3 x A N other (PhD)



Dr Peer-Olaf Siebers



A N other IDIC

Theme #6: Policy



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- Who are the **main interested actors** in policy-decision making?
- How do they use information and evidence to **make** their **decisions**?
- **Which** specific **policies and strategies** are required in our case study cities to improve their sustainability?
- **What role does the public** (want to) **play** in the decision-making process?



Dr Stephen Cope



A N other (PhD)



A N other (RF)



A N other (IDIC)

- 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 four case study cities.
- The types of **policy and governance structure** needed to implement the recommended development / transition pathways.



Candidate modelling strategies

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

Some open questions...



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

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

Some open questions...



- 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...***



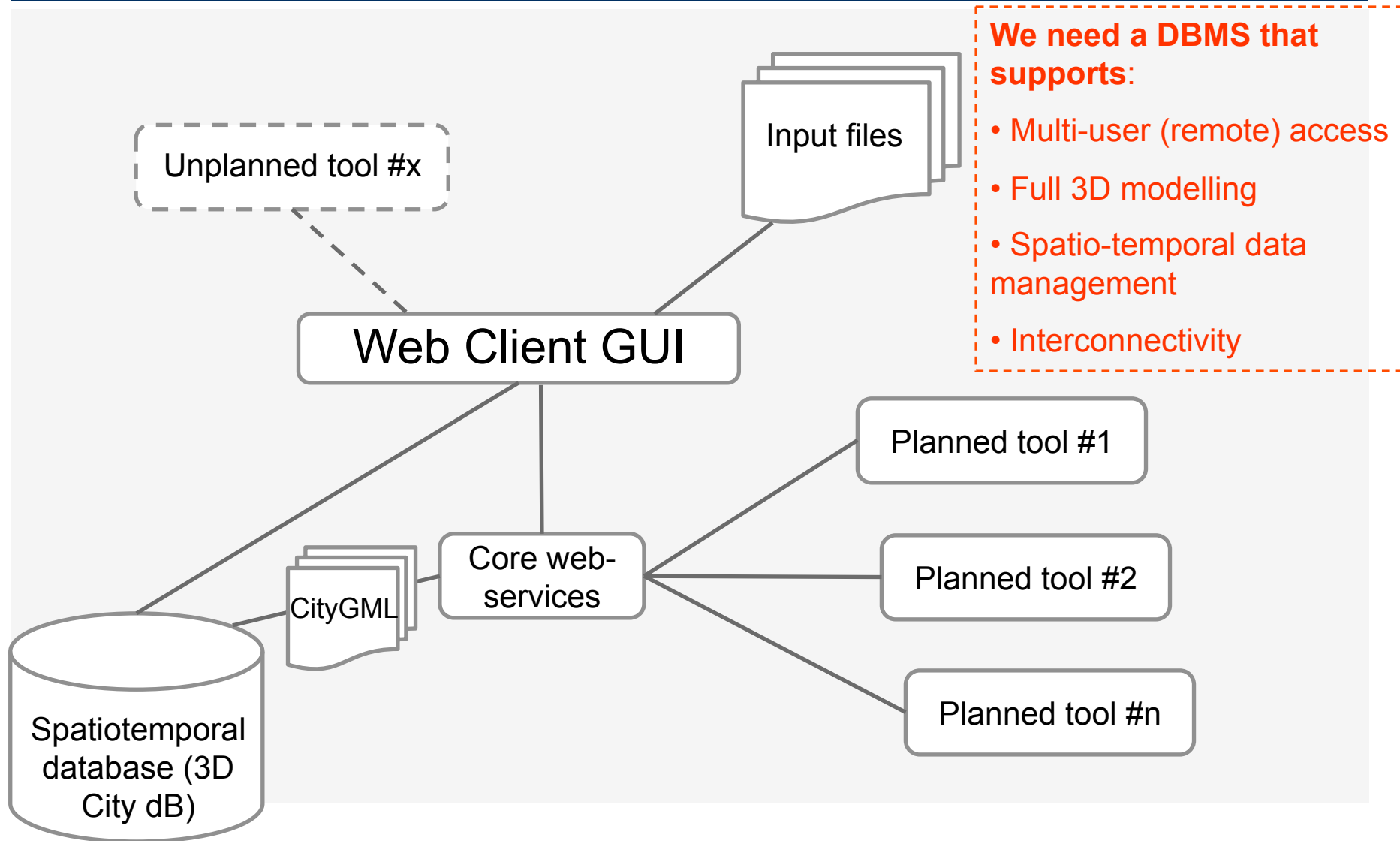
- We require explicit spatial considerations to answer these questions, but at what **spatiotemporal and functional resolution**?
- Should our modelling approach be scale dependent: an **adaptive framework**?
- **Data implications:**
 - Quantity and existence / availability of data
 - Administrative boundaries
- **Computational implications:**
 - Hardware acceleration

City scale simulation: Integration



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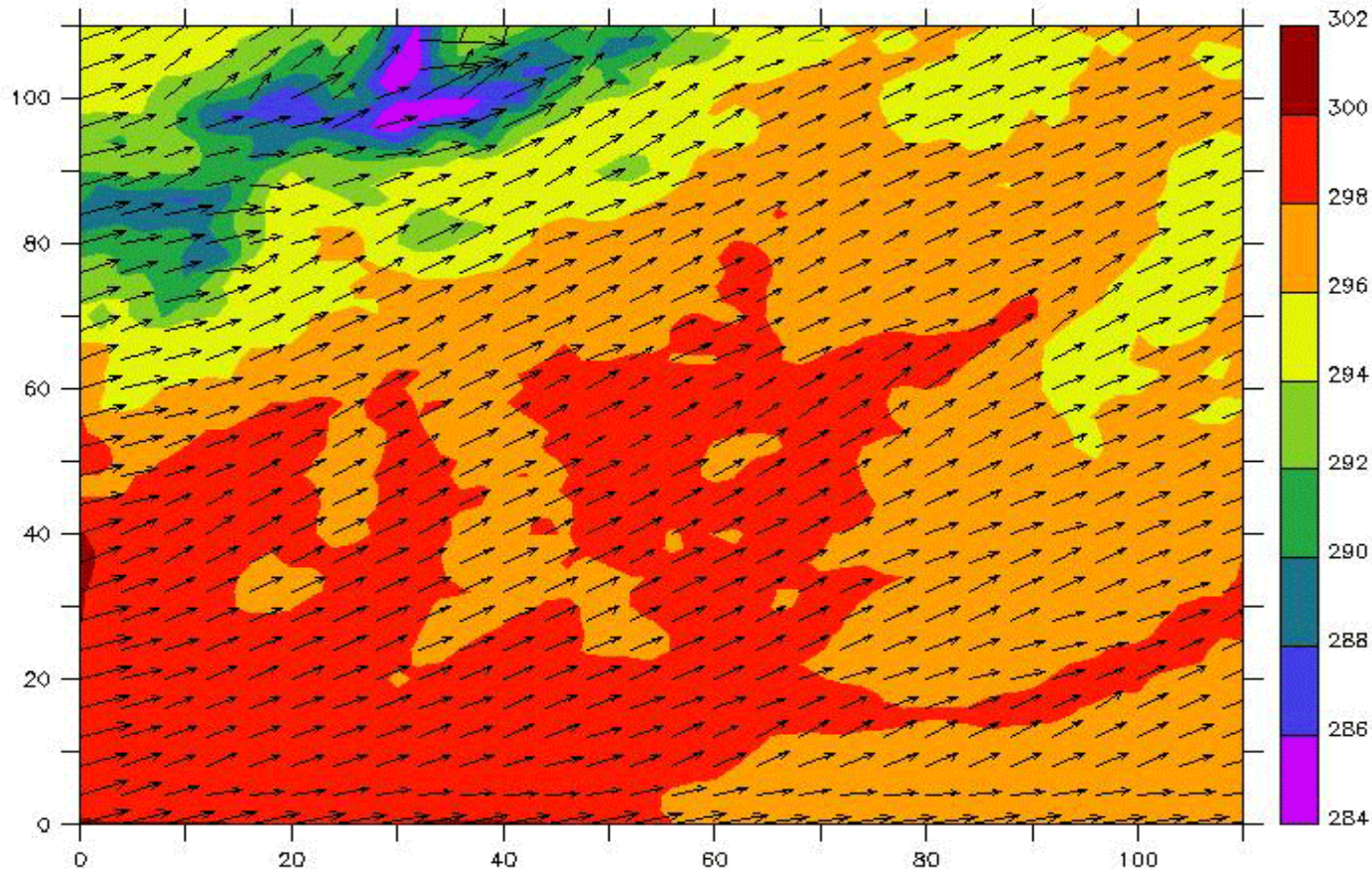


Urban and future climate modelling



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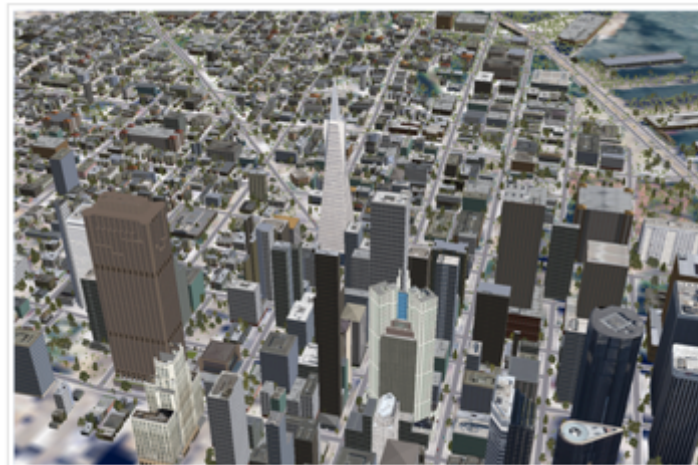
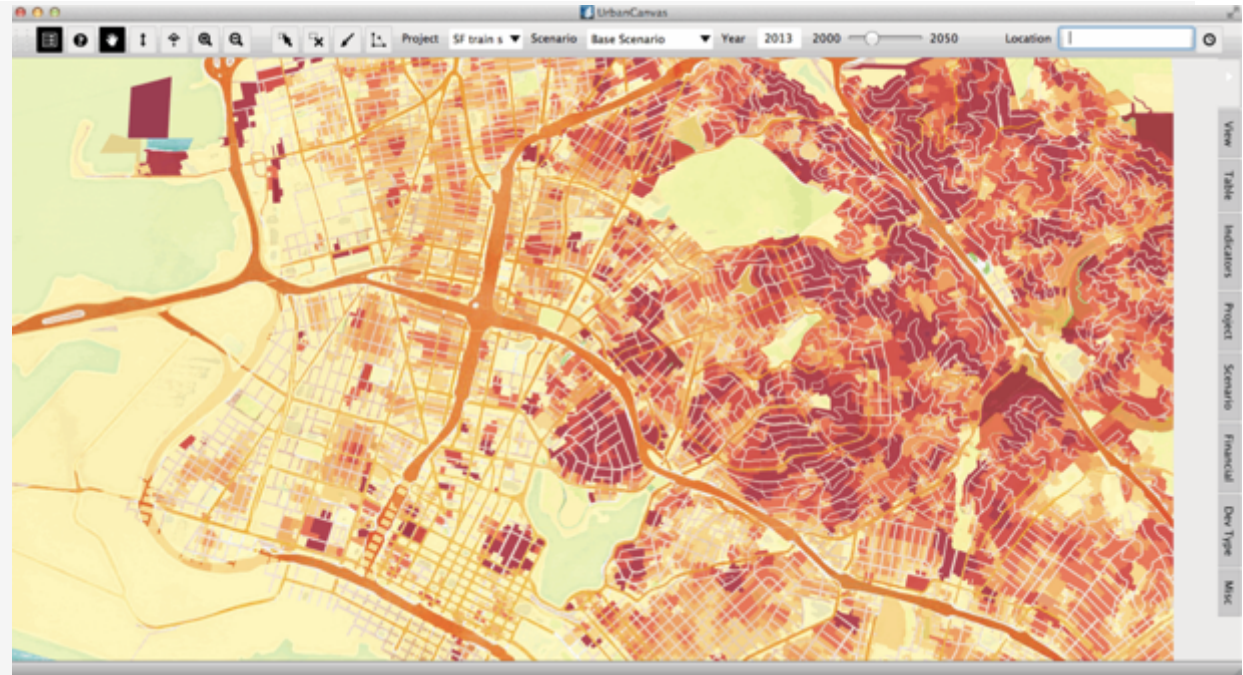
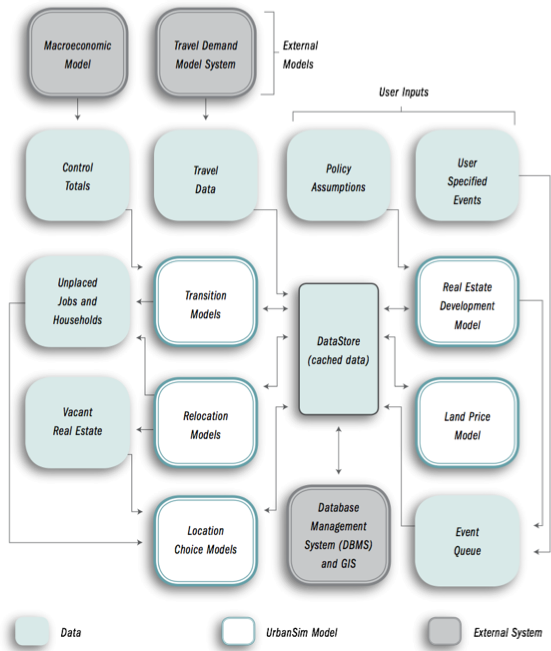
18:00

Spatial dynamics: UrbanSim: UrbanCanvas: UrbanVision



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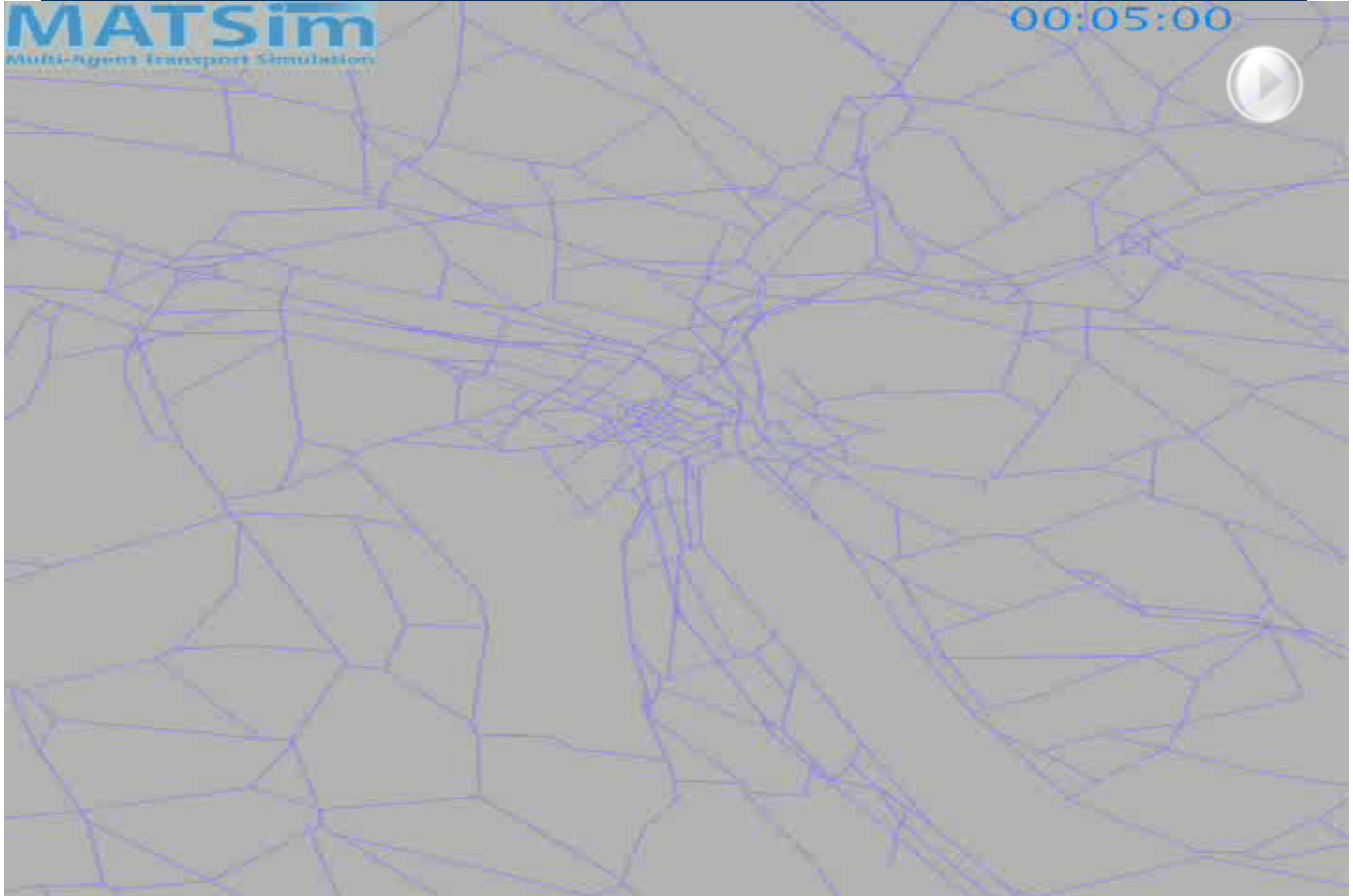
Transport microsimulation



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MATSim
Multi-Agent Transport Simulation

00:05:00



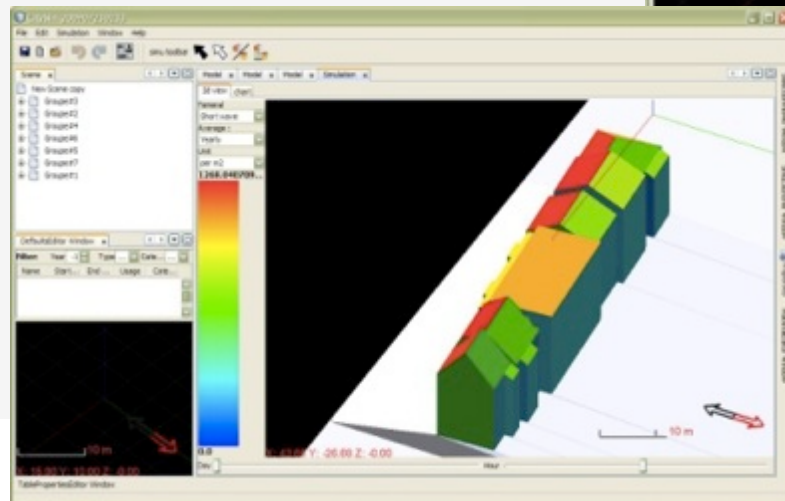
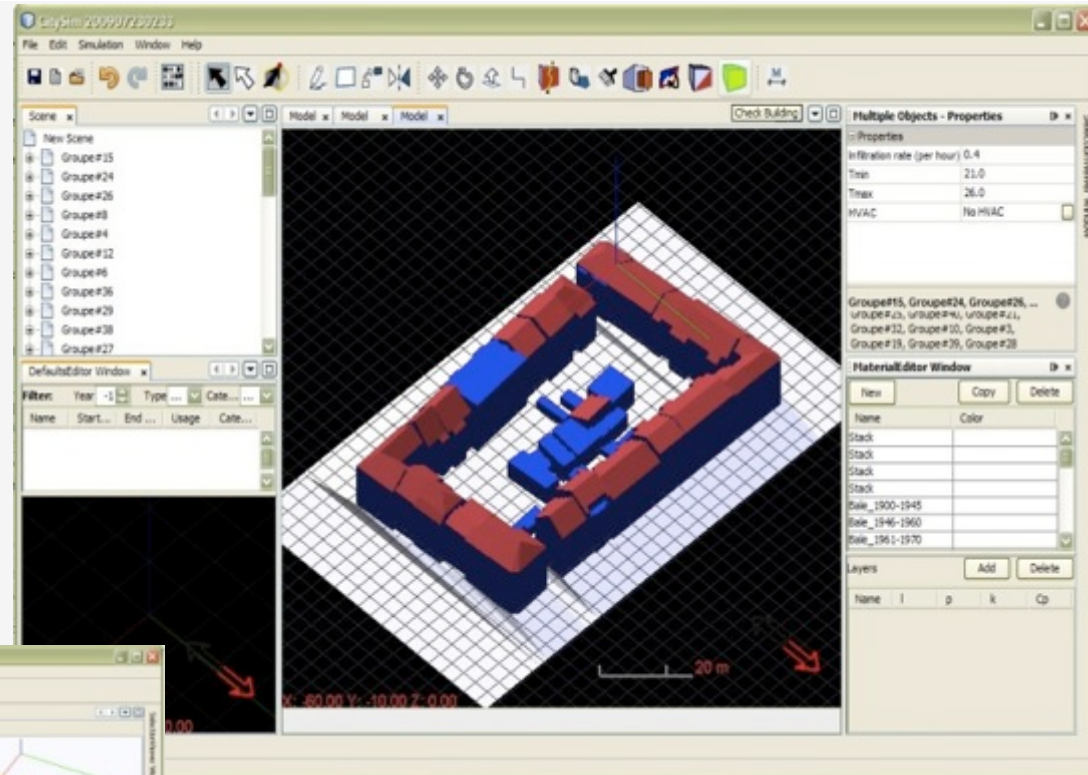
Energy in buildings: CitySim



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- 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

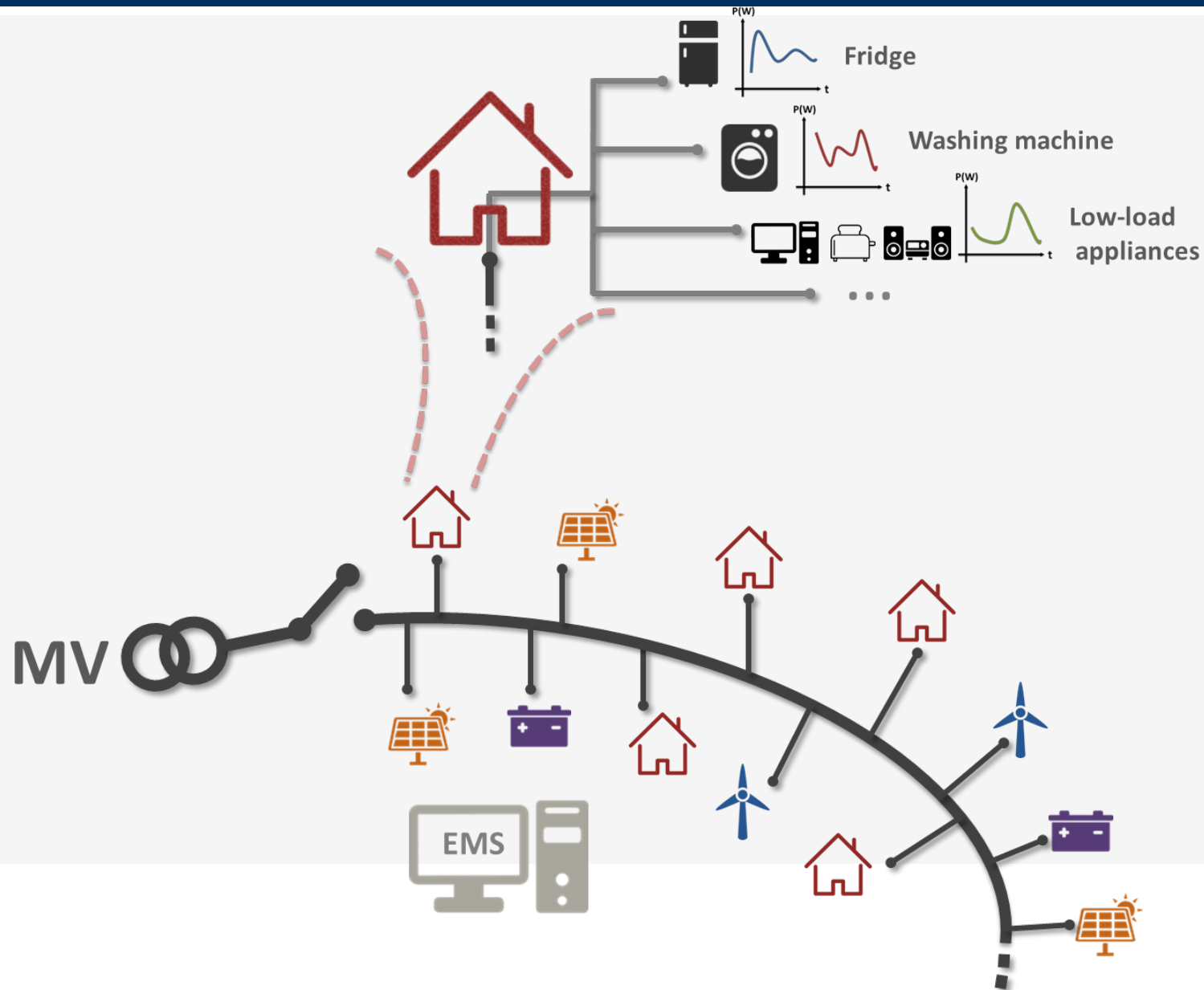
- 5) **Simulate and analyse**

Towards smart (power, heat, matter) grid simulation...



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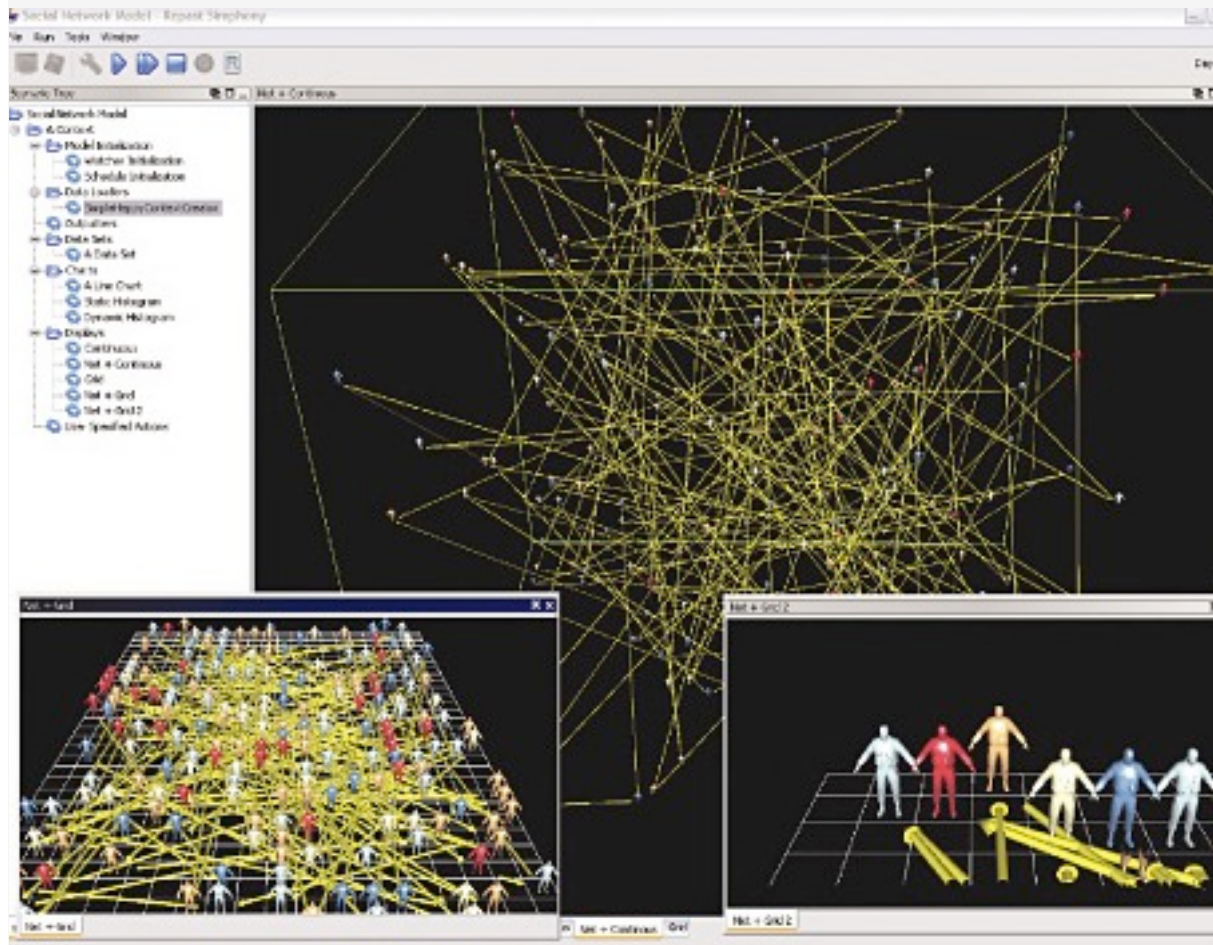


Empirically based social simulation



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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

Finally: To summarise...



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- **Cities are the crucial** piece in the sustainability jigsaw
- **Cities** and their sustainability **are complex**
- They are also functionally and spatially **diverse**
- Transition planning requires an **integrated urban modelling architecture** that accommodates this diversity
- A flexible architecture could be applied to **multiple spatial scales and time horizons**
- Urban **energy modelling** is now **fast evolving**
- ...we still have a very long way to go...
- **...but this stuff is fun!**



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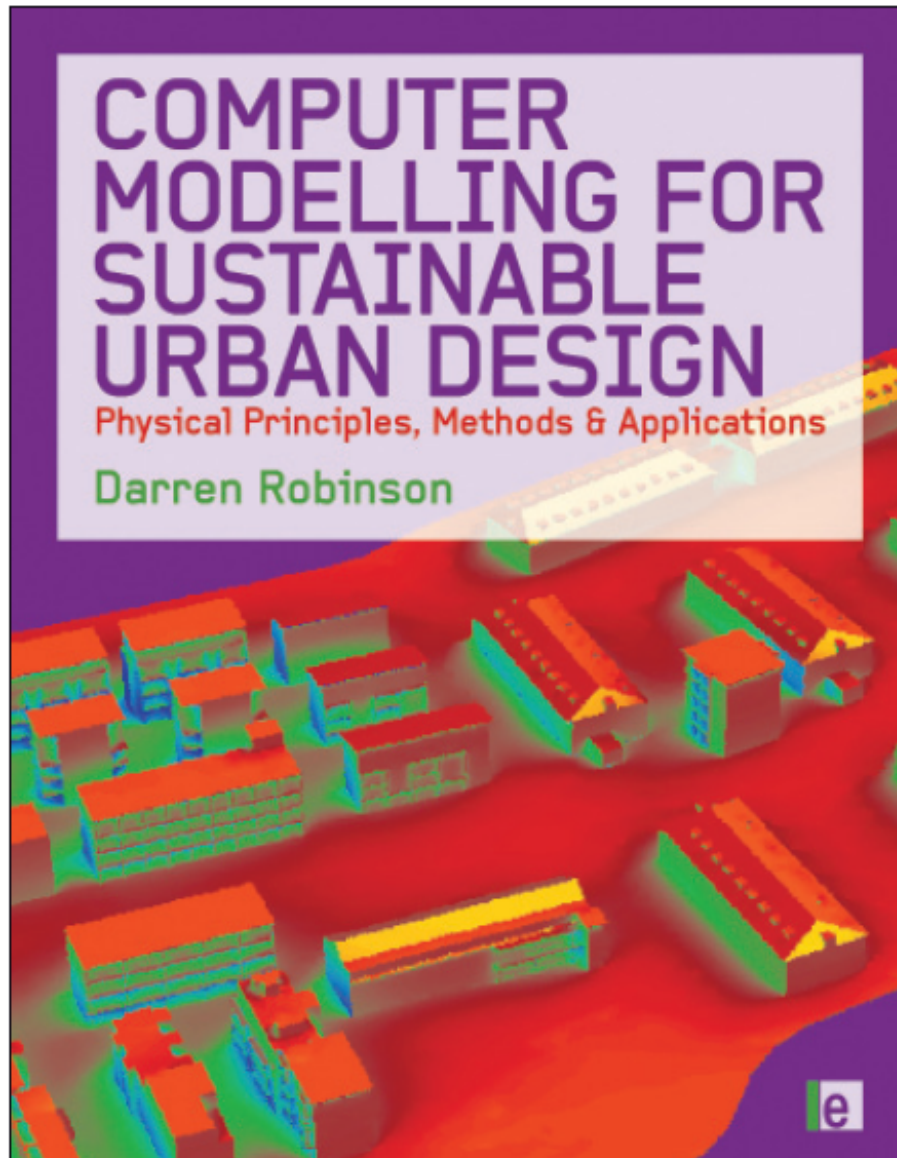
LUCAS outreach

Insomnia cure (Taylor & Francis, 2011)



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CONTENTS

1. Introduction

Part I Climate and Comfort

2. The Urban Radiant Environment

3. The Urban Climate

4. Pedestrian Comfort

Part II Metabolism

5. Building Modelling

6. Transport Modelling

Part III Measures and Optimisation of Sustainability

7. Measures of Urban Sustainability

8. Optimisation of Urban Sustainability

Part IV An Eye to the Future

9. Dynamics of Land -Use Change and Growth

10. Conclusions

LUCAS www, open resources and seminars



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Laboratory for Urban Complexity And Sustainability

Home

Projects

Events

LUCAS

Directed by [Professor Darren Robinson](#), the Laboratory of Urban Complexity and Sustainability (LUCAS) is a cross-faculty interdisciplinary team of natural and social scientists working to better understand how cities function, socially and physically, and how this functioning and its consequences for social, economic and environmental sustainability can be improved upon.

At the core of our activities in LUCAS is the Leverhulme Research Programme Grant "Sustaining urban habitats: an interdisciplinary approach, to which are aligned a number of satellite projects.

LUCAS is also a key component of the University's *Sustainable and Resilient Cities* Research Priority Area (RPA).



Sustaining Urban Habitats: an interdisciplinary approach

The hub of our activity is the Leverhulme Research Programme Grant *Sustaining urban habitats: an interdisciplinary approach*. The ambitious aim of this project is to transform our understanding of how sustainable cities, and by extension our species, can be.

Our objectives in achieving this aim are to:

- Confront and understand the complex interrelated and competing factors influencing urban sustainability.
- Holistically define, measure and model urban sustainability.
- Identify pathways to transition developed cities and accommodate growth in developing cities in minimally unsustainable ways.
- Define policy and governance structures to implement these pathways in practice.

To find out more about the Sustaining Urban Habitats project please visit the dedicated project page linked below.

The LUCAS seminar series

LUCAS seminar series brings together both high profile speakers, early career researchers and other stakeholders, e.g. industry speakers from diverse backgrounds on topics that relate to urban sustainability.

For upcoming seminars, please visit the [events](#) page. For any enquiries about the seminars, please contact Jenni Cauvain at jenni.cauvain@nottingham.ac.uk.

Research team

We are a team with backgrounds in the physical, computational, economic and social sciences:

Director

- [Darren Robinson](#)

Academic Staff

- [Doreen Boyd](#)
- [Stephen Cope](#)
- [Pelin Demirel](#)
- [Reiner Grundmann](#)
- [Sarah Hall](#)
- [Yong Mao](#)
- [Paul Nathanael](#)
- [Peer-Olaf Siebers](#)

Research Staff

- [Andrew Allen](#)
- [Matthew Ashmore](#)
- [Anthony Beck](#)
- [Jenni Cauvain](#)

Urban Transitions 2016



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Nottingham

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TRANSITIONS** 2016

Towards a better urban future
in an interconnected age

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Towards a better urban future in an interconnected age

5-9 September 2016 | Shanghai, China

Cities are incredibly vibrant centres of innovation, education, employment and commerce. They are the heart of the modern global economy and as such they continue to attract rural migrants seeking a better quality of life for themselves and their families. Today, more than half of the world population lives in urban areas, and each week, the urban population increases globally by 1.3 million.

As we become a mainly urban species, we have significant challenges and exciting opportunities ahead of us, as we try to transition towards more:

- Economically competitive urban futures
- Sustainable and resilient urban futures
- Equitable and inclusive urban societies
- Digitally supported urban futures

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Committee

Conference Chair

Karen C. Seto, *USA*
Darren Robinson, *UK*

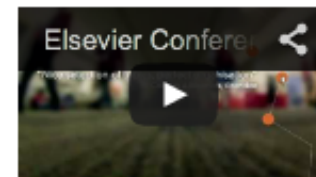
Committee

Christopher Boone, *USA*
Harriet Bulkeley, *UK*
Neha Sami, *The Netherlands*
Hassan Virji, *USA*
Wei-Ning Xiang, *China*

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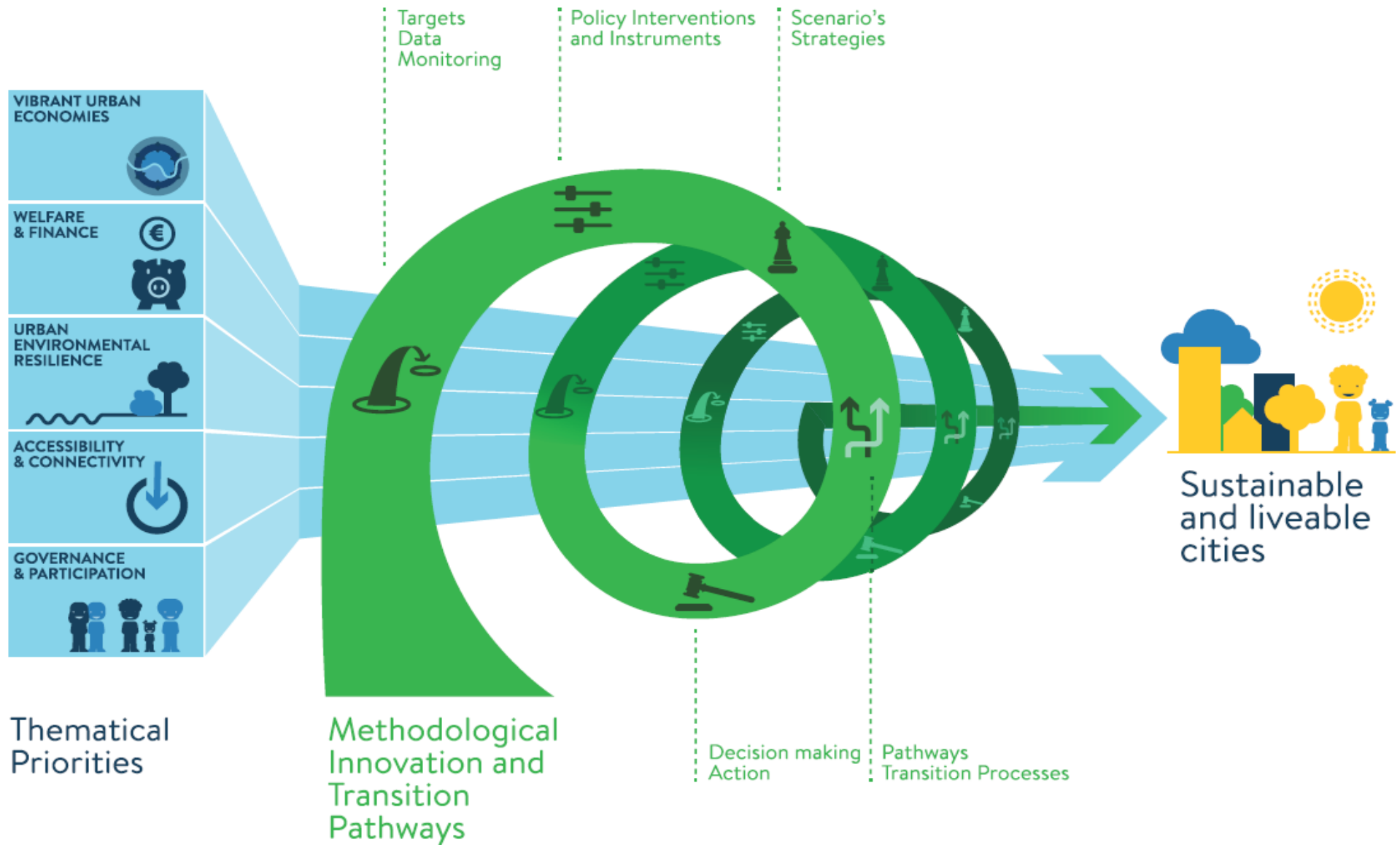
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Thank you!