Simulation of urban environments – some thoughts and experiences

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CIBSE Building Simulation Group

'Simulation of the Urban Environment' Seminar
UCL

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Chapman BDSP

CHALLENGE
INFORM
INFLUENCE

CONTENTS

1. About ChapmanBDSP
2. What is ‘urban simulation’?
3. Engineering perspectives
4. Architectural perspectives
5. Some experiences …
6. Parametrics – responding to the urban context
7. Some thoughts …

ABOUT CHAPMANBDSP

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- Owner lead practice (c200 people)
- Concentration on understanding our Client's drivers
- All services provided in-house
- Directors lead projects
- Offices in London, Kent, Birmingham, Dubai & Abu Dhabi
- Leading edge – heavy commitment to R&D
- Engineers/ environmentalists/ architects/ researchers/ programmers
- We innovate and deliver
- Add value through creative integrated design approach
- Environmental team (c20 people, engineers/architects/environmentalists)

MEP ENGINEERING

ENVIRONMENT & SUSTAINABILITY

INFRASTRUCTURE & MASTERPLANNING

ADVISORY

FACILITIES ENGINEERING

FIRE ENGINEERING

SPECIAL LIGHTING DESIGN

VERTICAL TRANSPORTATION

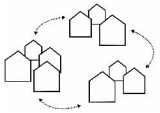
RESEARCH & DEVELOPMENT

What is ‘urban simulation’?

DIFFERENT SCALES:

Building

Masterplan/Neighbourhood



District

City

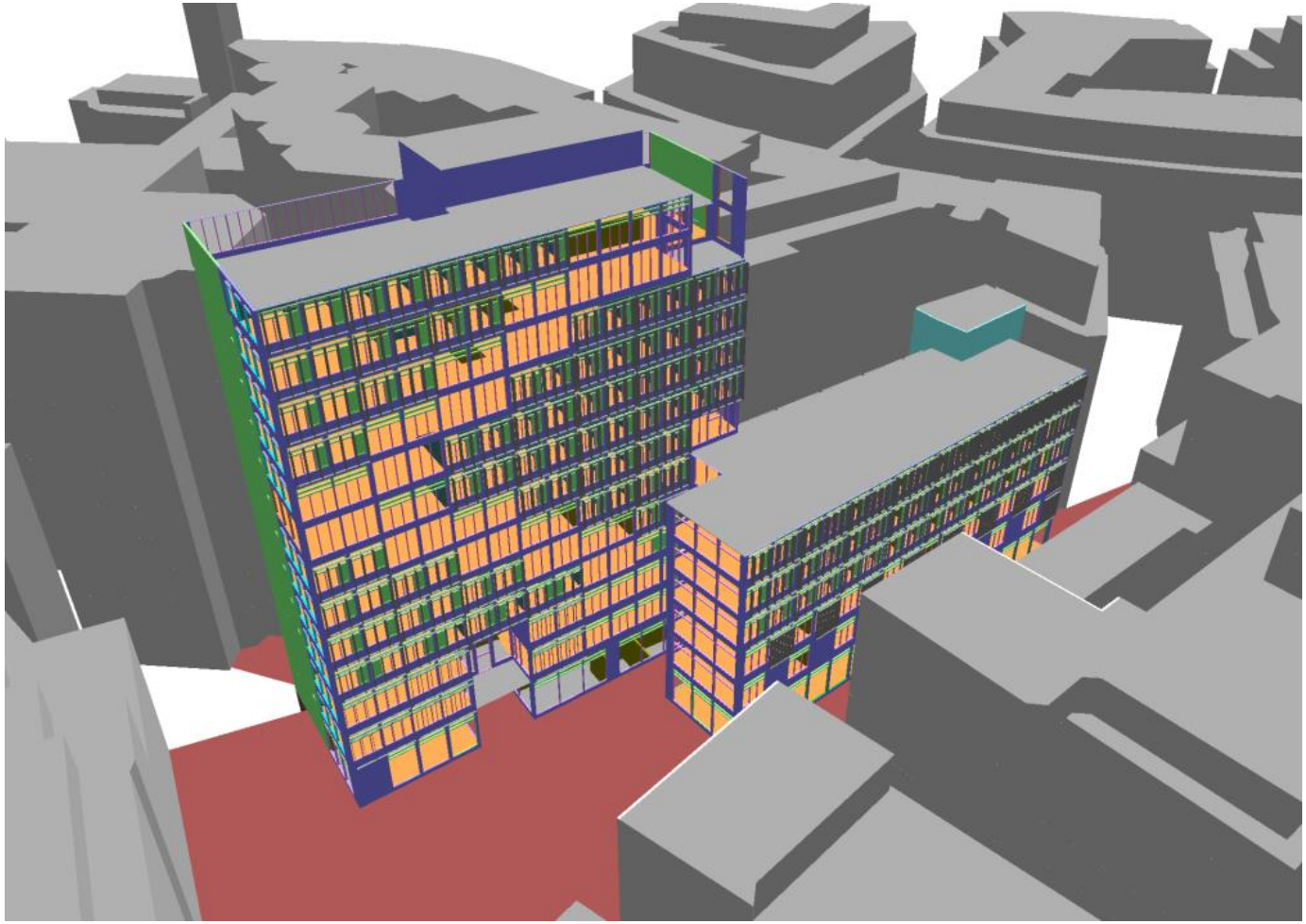
Region

Country

Global

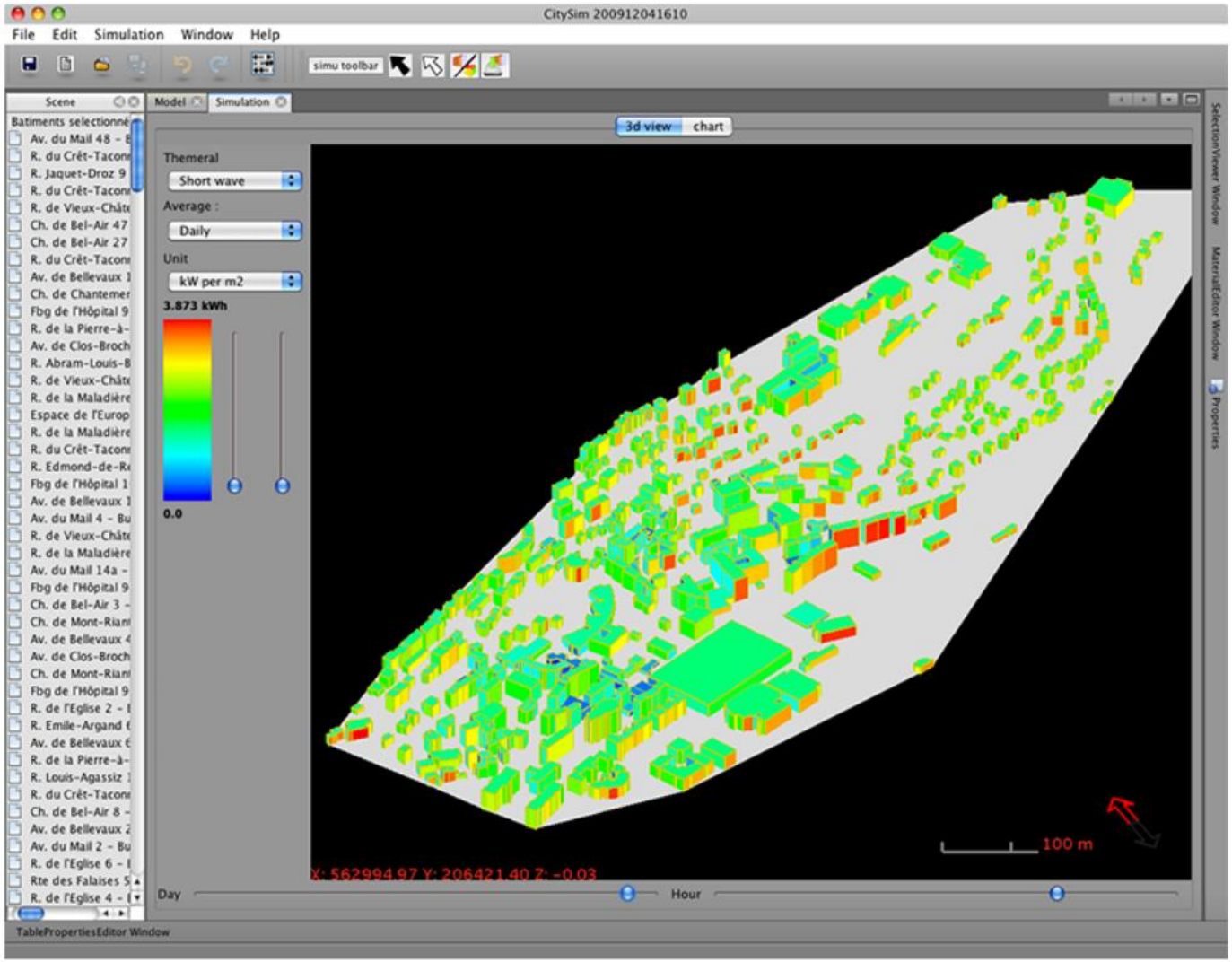
Engineering perspectives

BUILDING LEVEL: Dynamic Thermal Modelling; Daylighting; CFD …

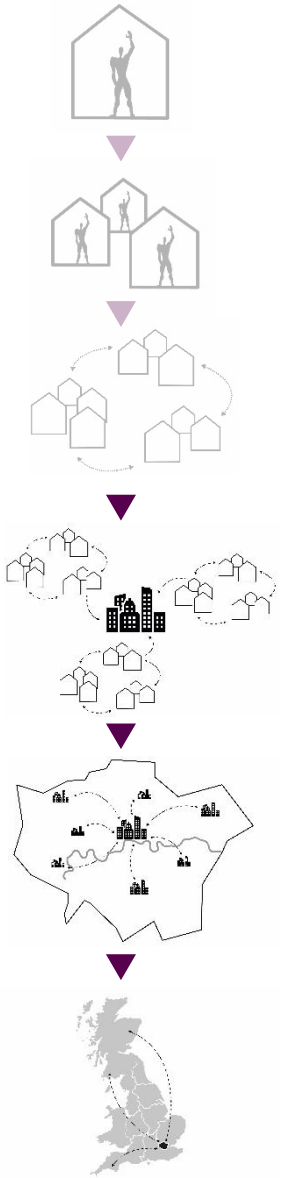


Zero carbon buildings … zero carbon infrastructure … zero carbon grids …

MASTERLAN/NEIGHBOURHOOD: Simulation-based / Decision-based



Source: CitySim (EPFL)



Load Research/Profiling (e.g. electricity industry):

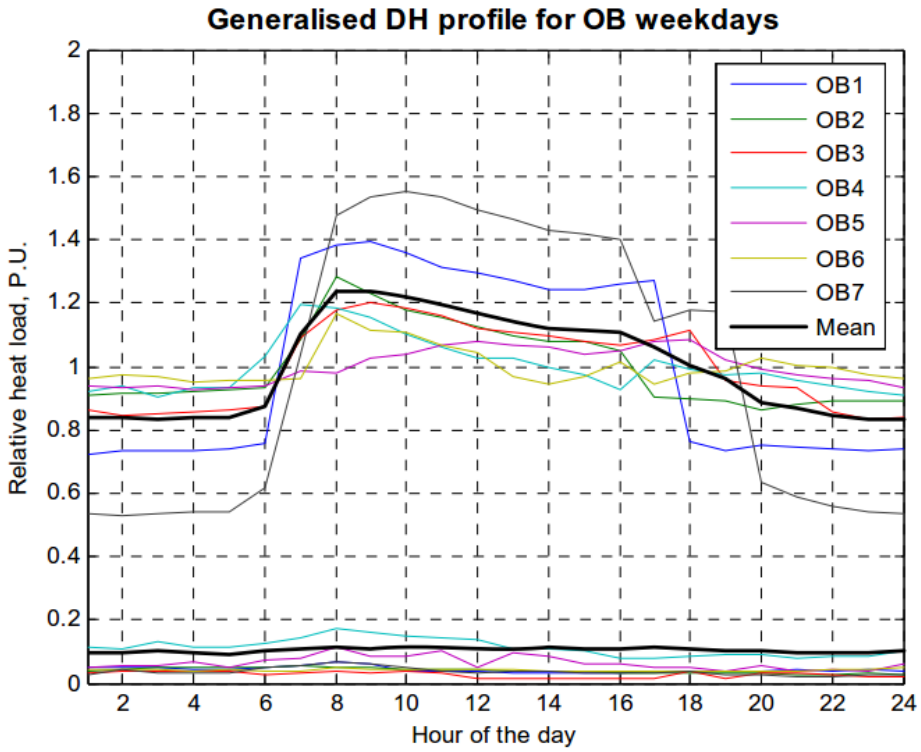
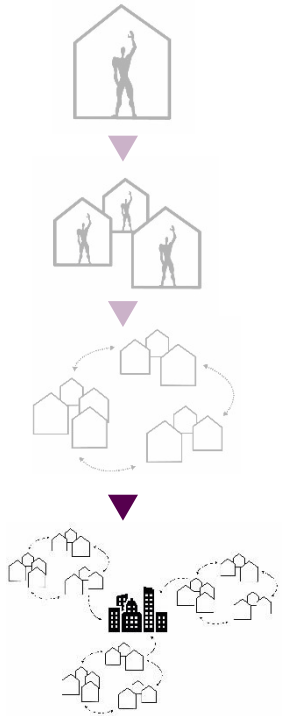
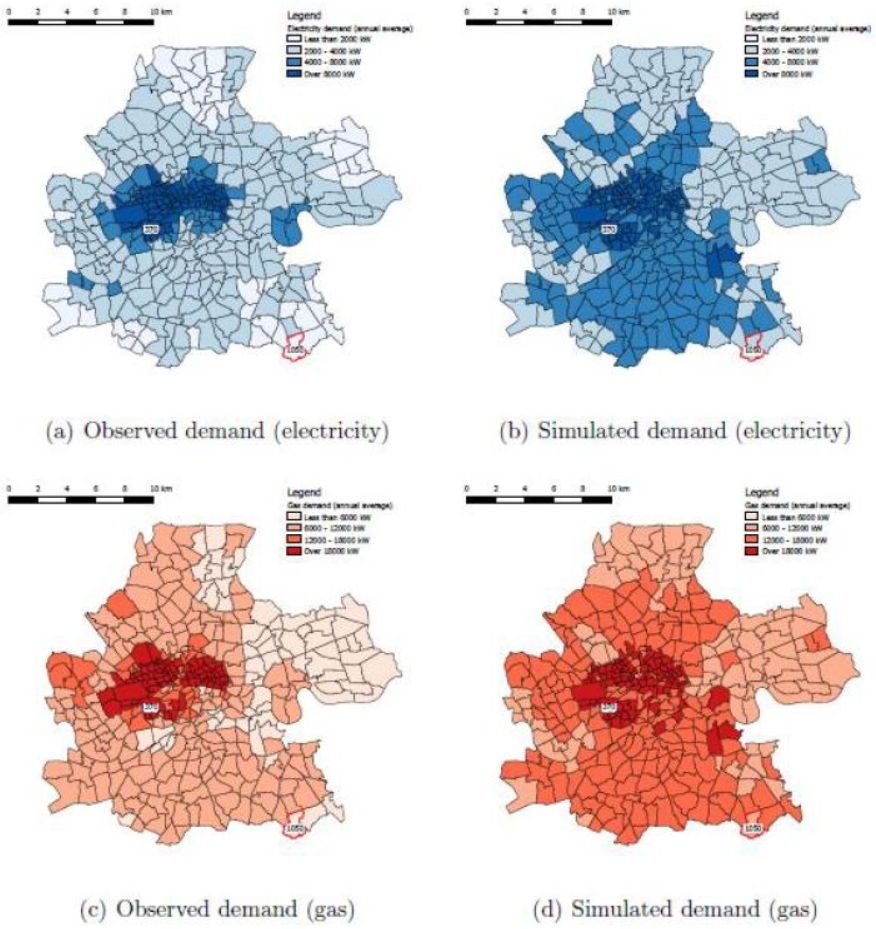


Figure 6.15 Relative design heat load profiles for office buildings, including the generalised heat load profile and relative standard deviation.

Source: Linda Pedersen, PHD Thesis 'Load Modelling of Buildings in Mixed Energy Distribution Systems', Norwegian University of Science & Technology (2007)



District & City Models (incorporating agent-based modelling):



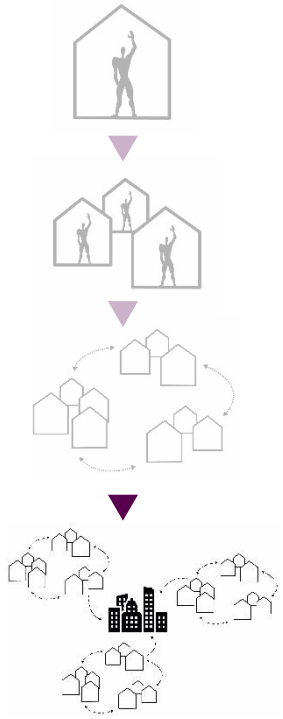
(a) Observed demand (electricity)

(b) Simulated demand (electricity)

(c) Observed demand (gas)

(d) Simulated demand (gas)

Source: Simulating London's electricity and natural gas demands Imperial College, DCEE (2012)



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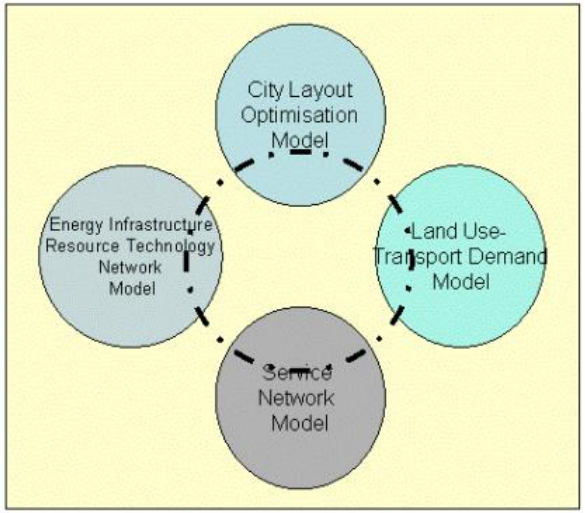
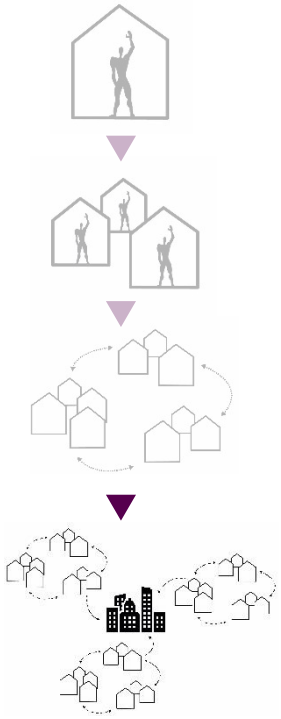


- A hardware or software system that exhibits the following attributes:
  - Autonomous: operates without requiring interventions;
  - Social ability: interacts with others;
  - Reactivity: responds to (changes in) its environment;
  - Pro-active: can exhibit goal-driven behavior.

Source: Imperial College, Urban Energy Systems Project (SynCity Toolkit)



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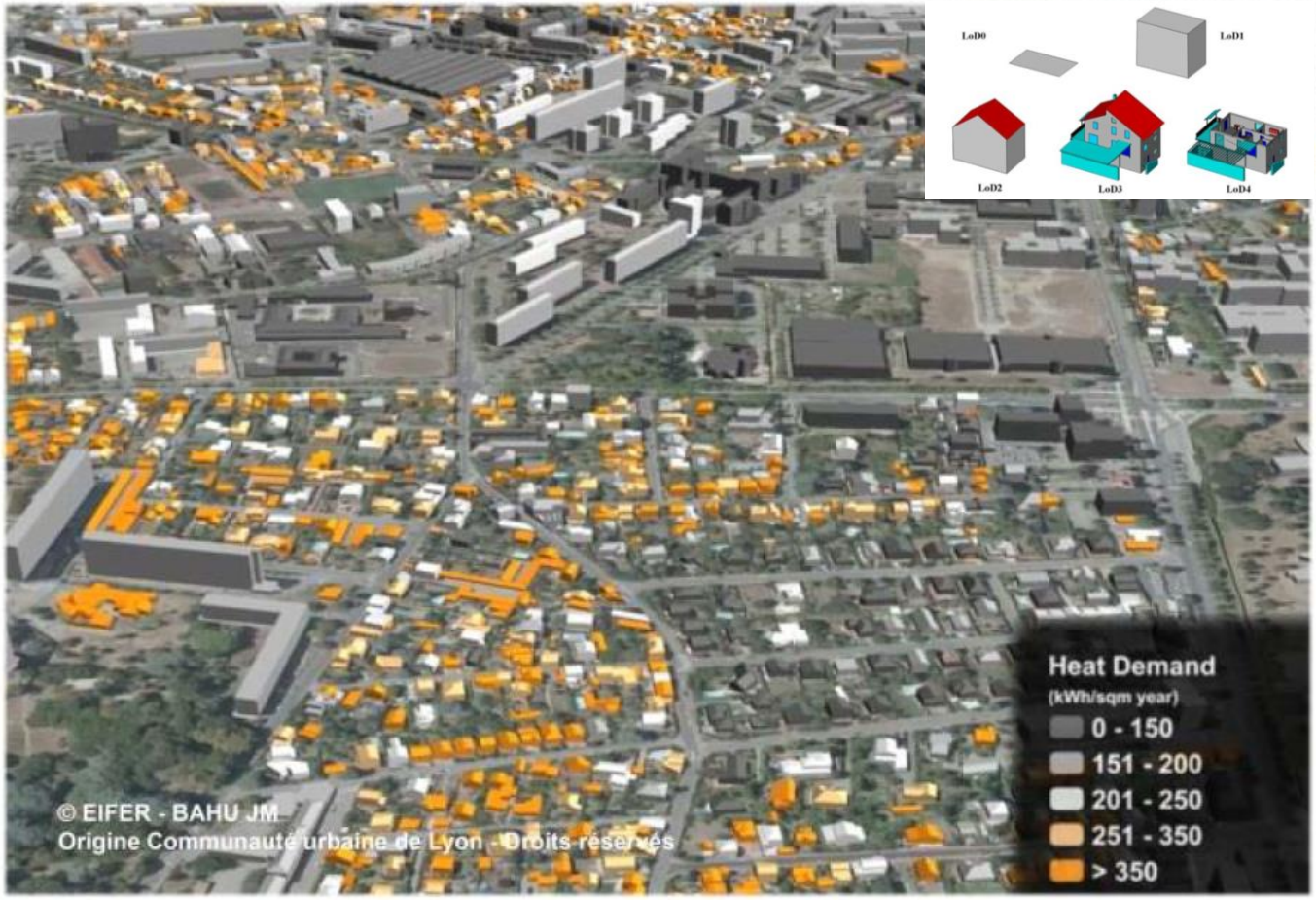
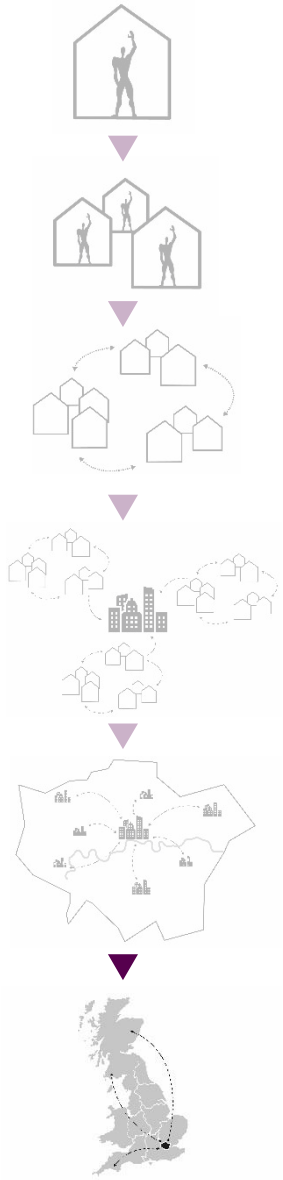
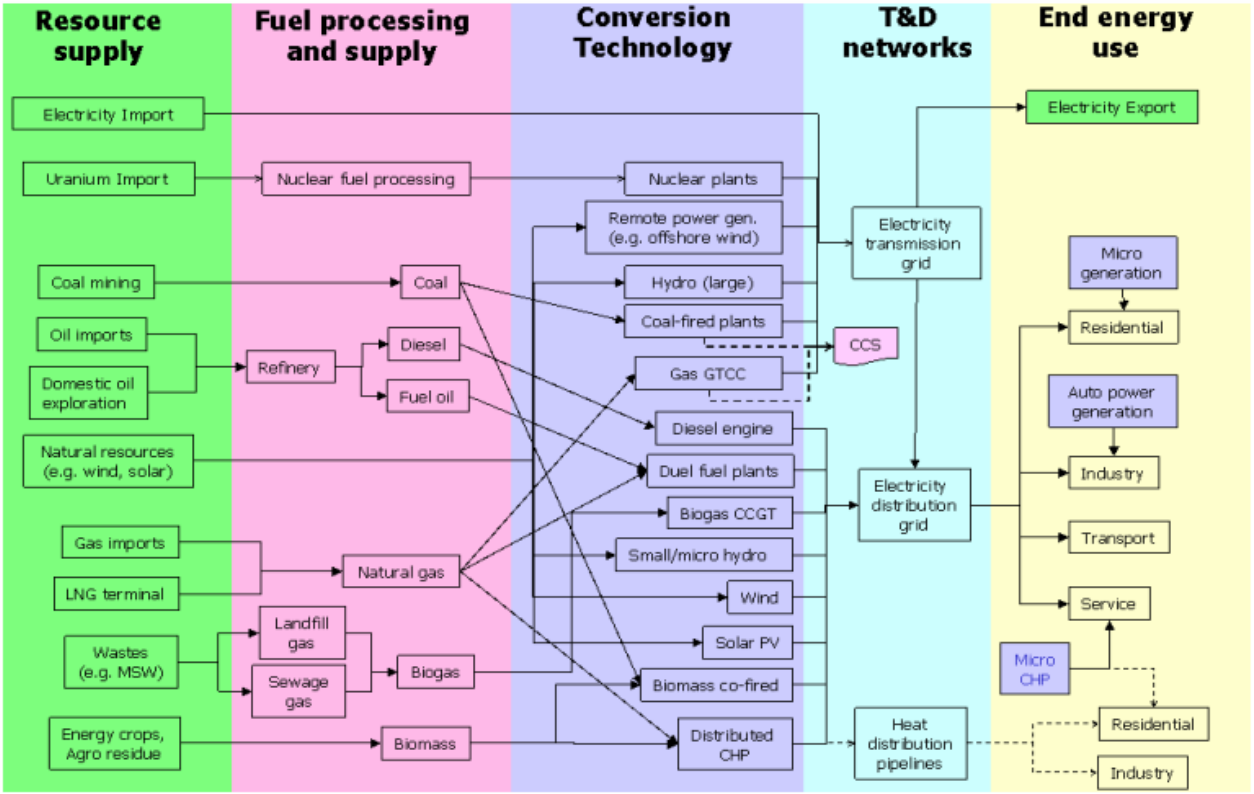


Source: EIFER



NATIONAL/REGIONAL MODELS: UK MARKAL

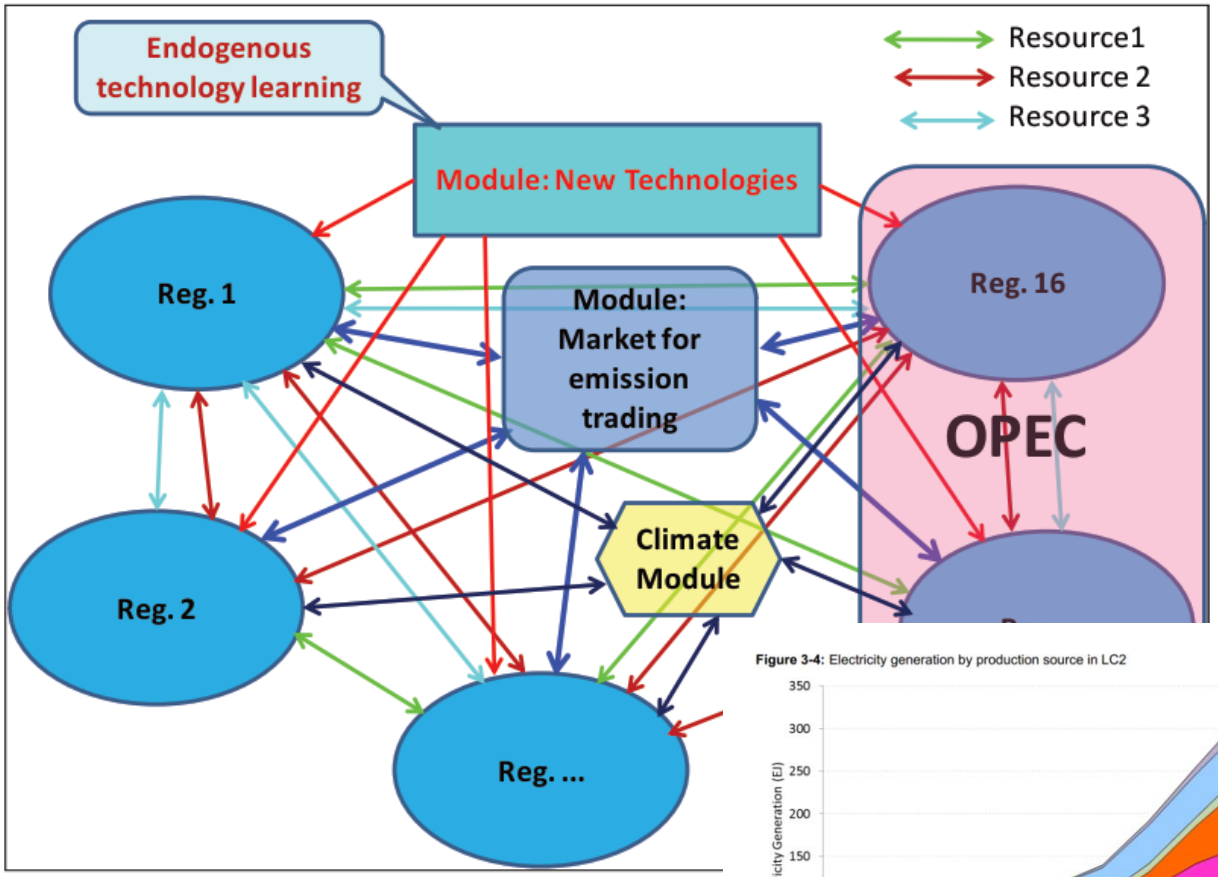
Figure A1.1 Example of Reference Energy System in UK MARKAL model

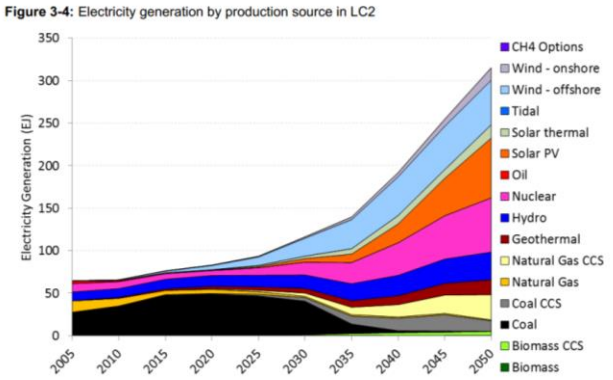


Source: Strachan et al, 2007.

UK MARKAL – multi-time period linear optimization model to help meet energy services demands (based on cost optimization) under a range of physical and policy constraints. Originally developed to help formulate policy for Energy White Paper (2003) and further developed, soon to be superseded by UKTM-UCL.

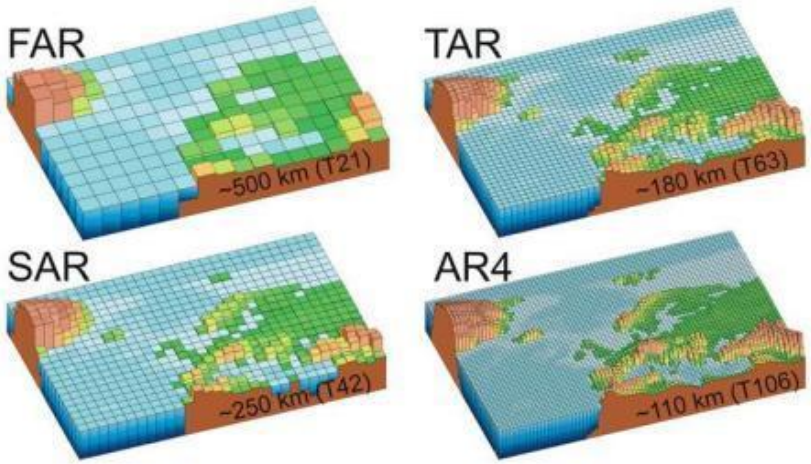
GLOBAL MODELS: TIAM-UCL

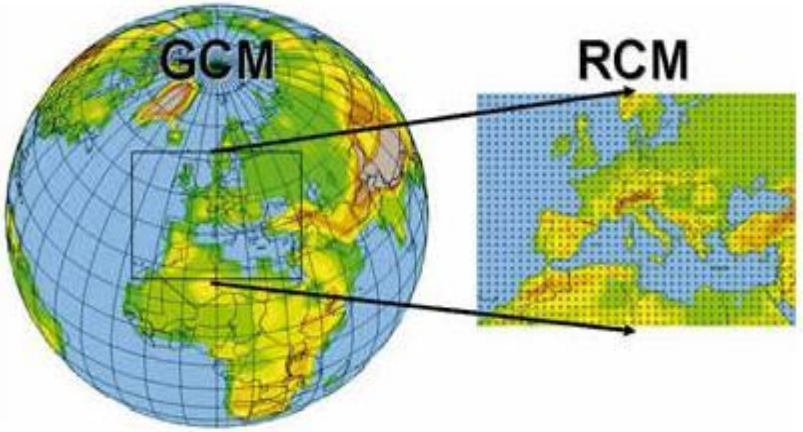




Source: TIAM-CFL, Global Energy Scenarios, UCL Energy Institute (2013)

GLOBAL MODELS: WMO/IPCC

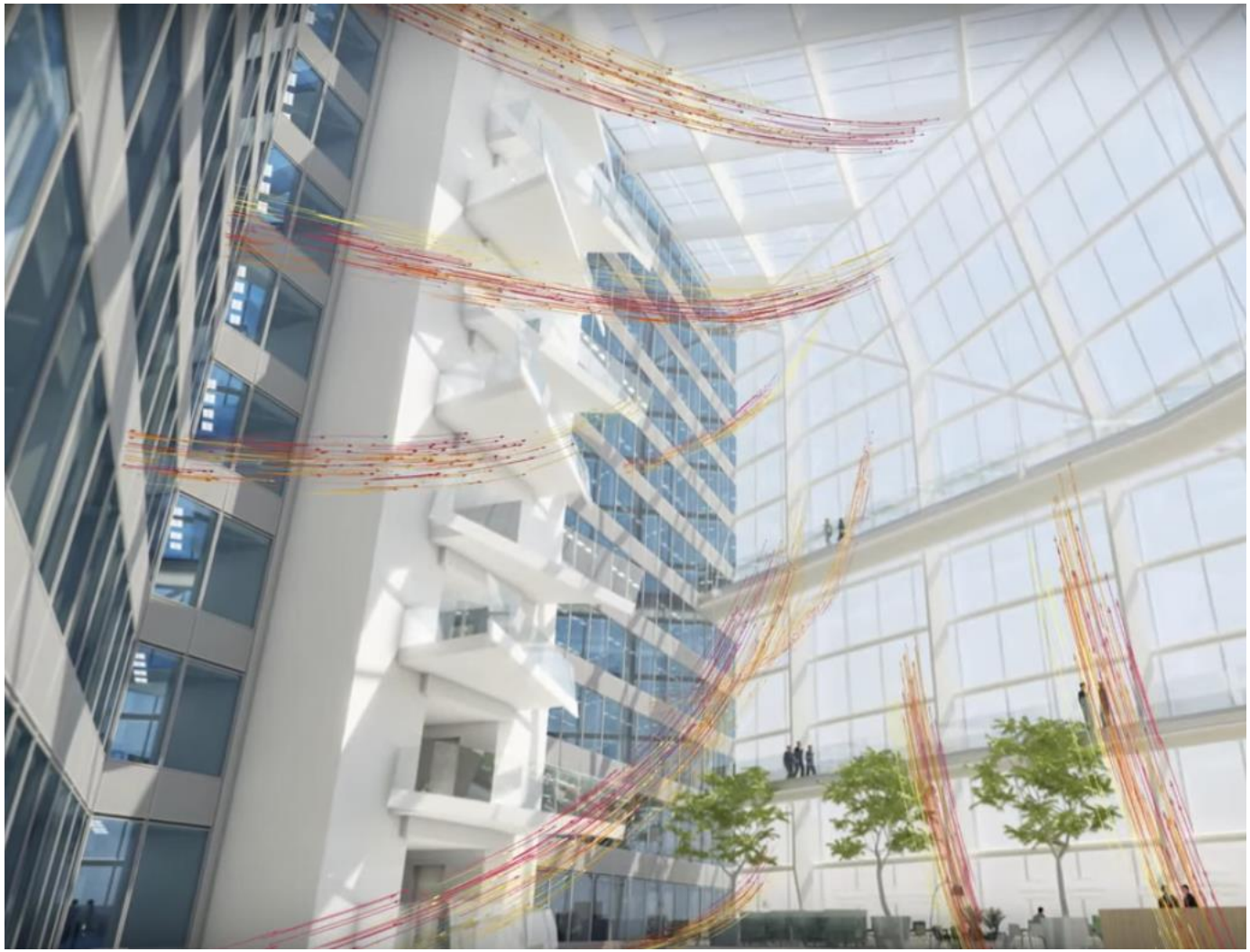




Source: WMO – improvement of resolution in Global Climate Models (CGMs) over the 4 IPCC Reports

Architectural perspectives

NEW APPROACH: The Edge – Amsterdam (NL) – PLP Architects



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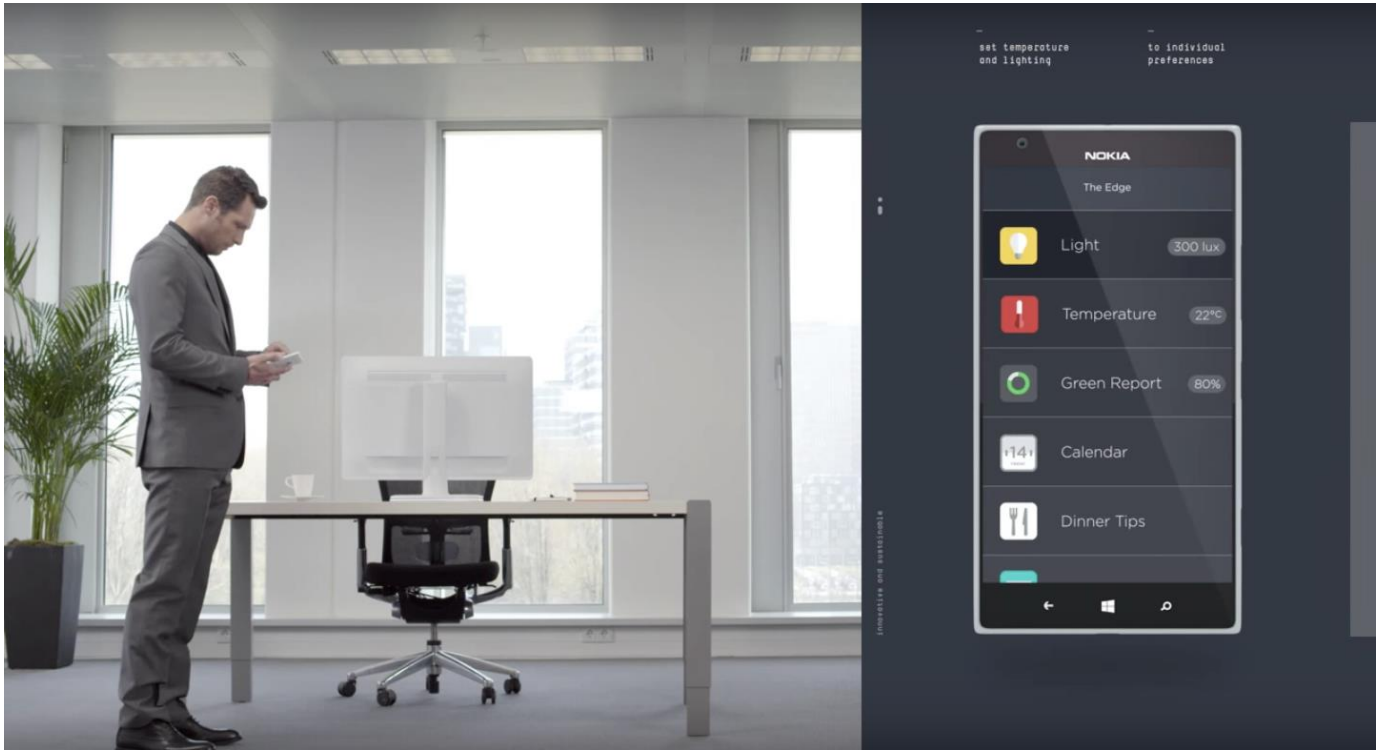
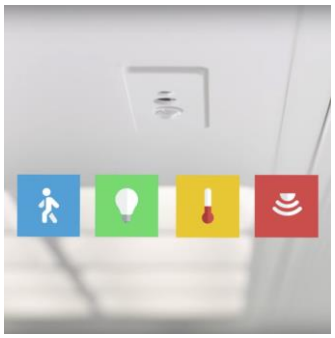
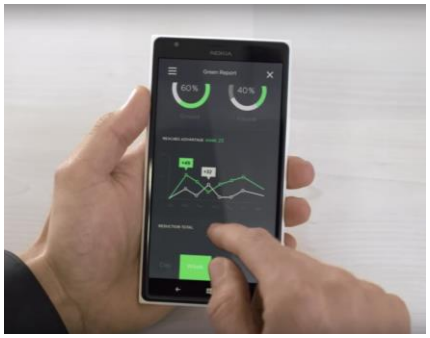
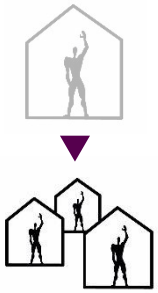
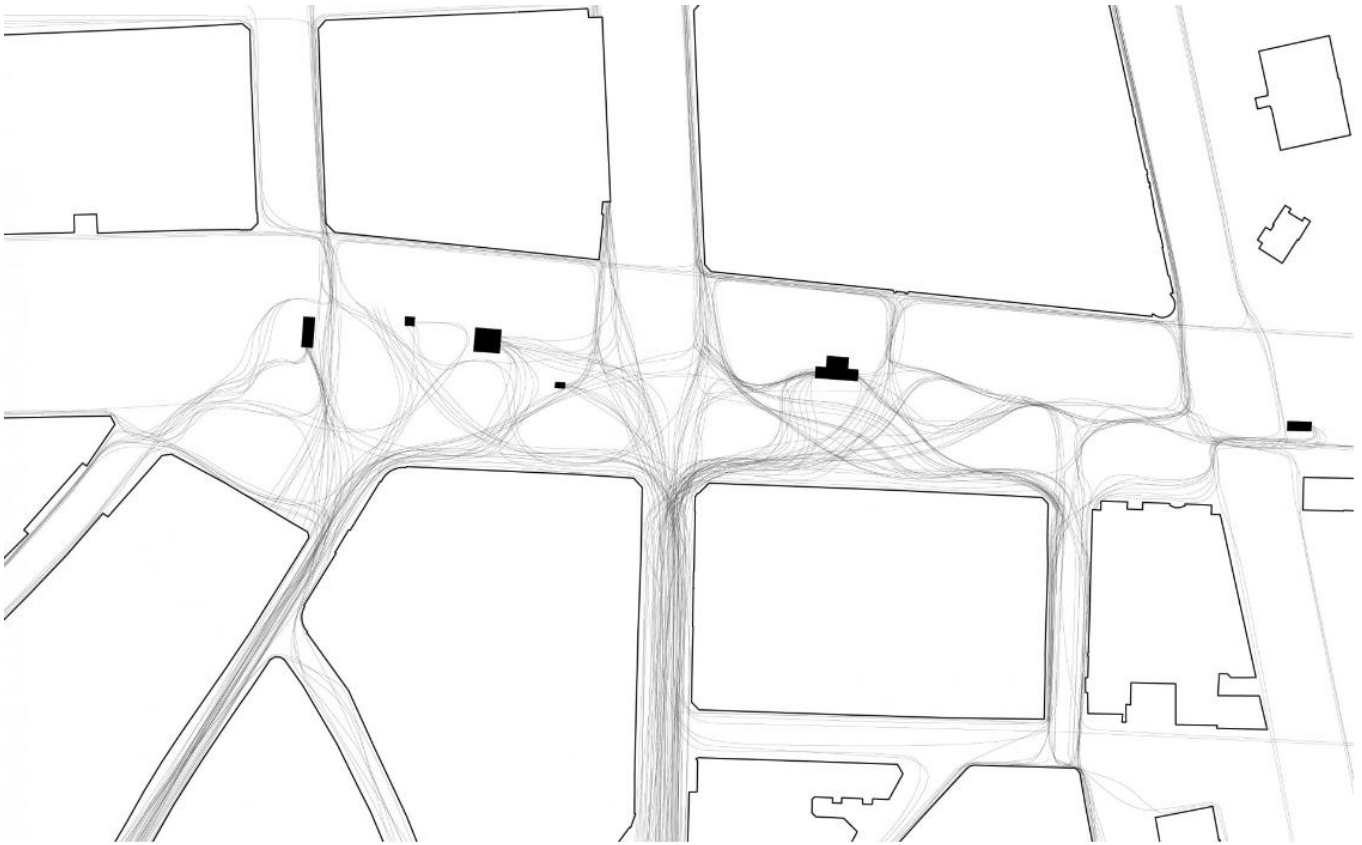








NEW APPROACH: Norreport Station – Copenhagen (DK) – COBE Architects



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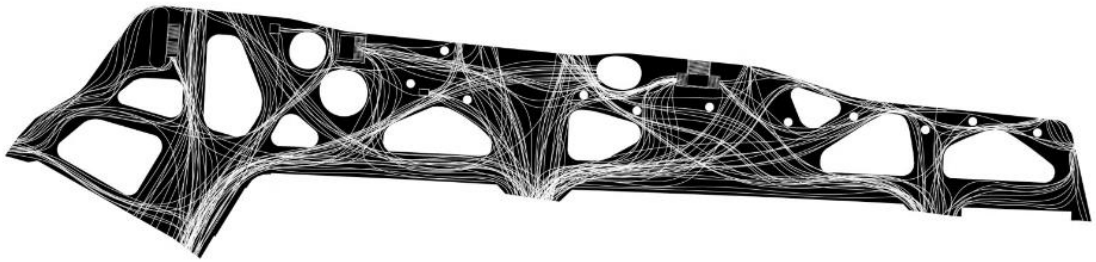
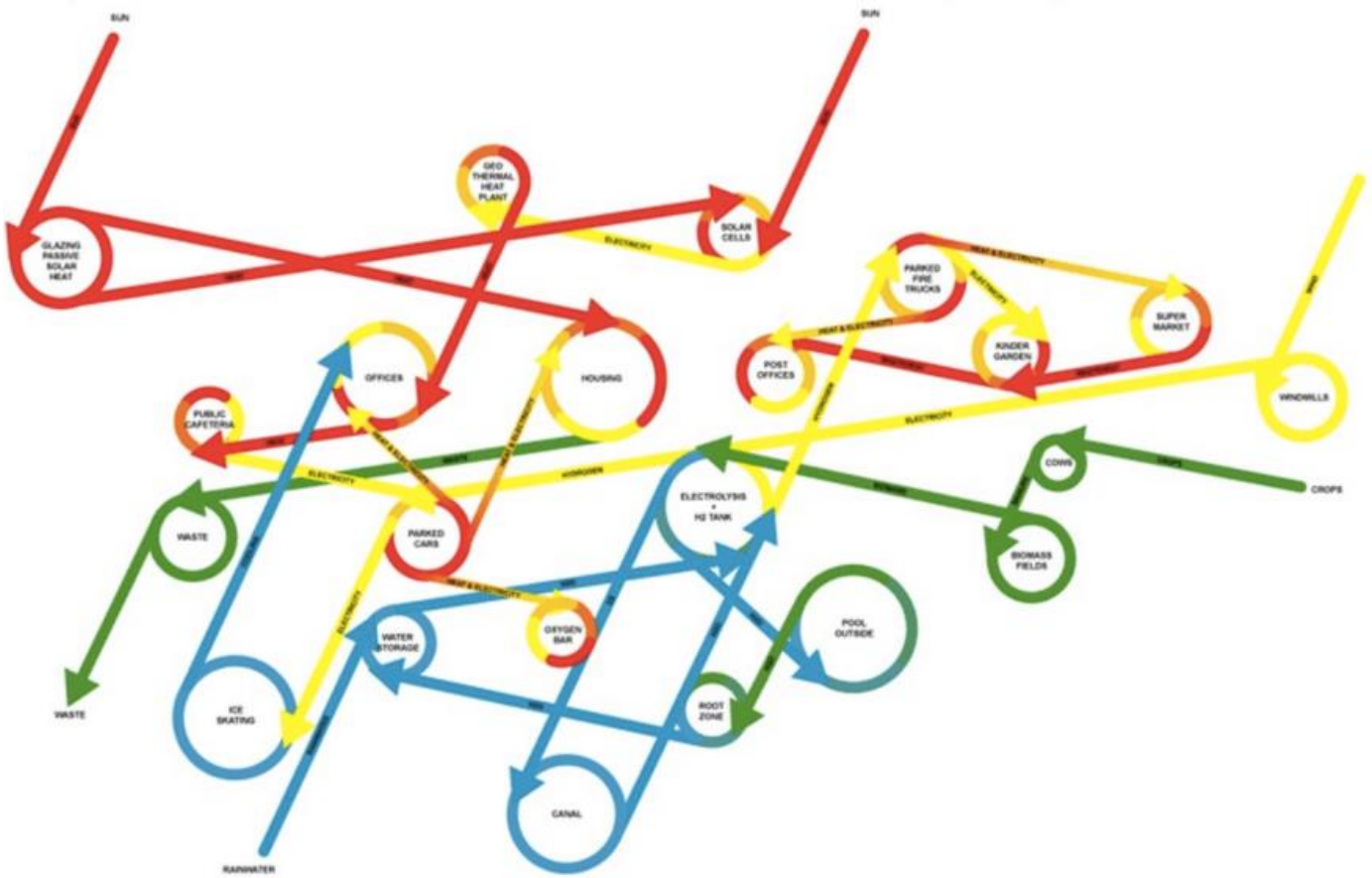


NEW APPROACH: Little Denmark – Copenhagen (DK) – BIG Bjarke Ingels Group



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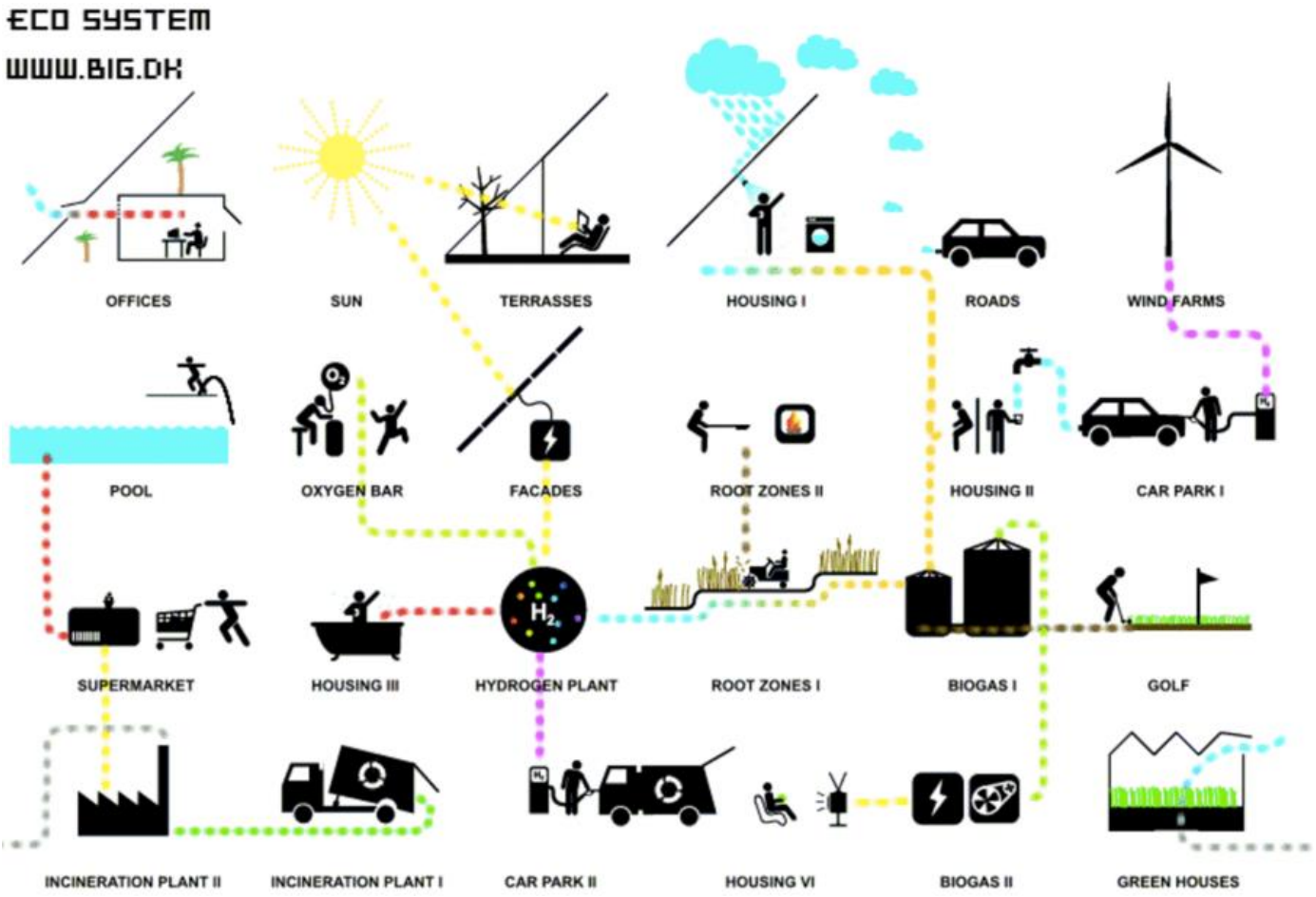
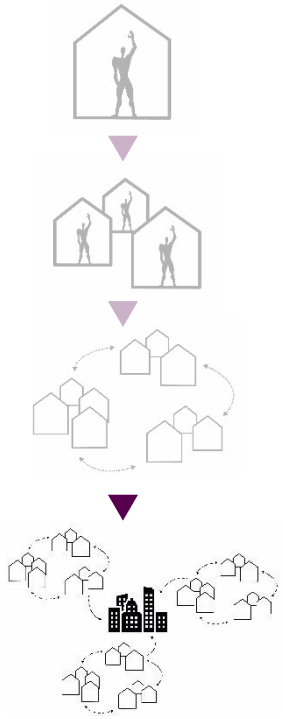
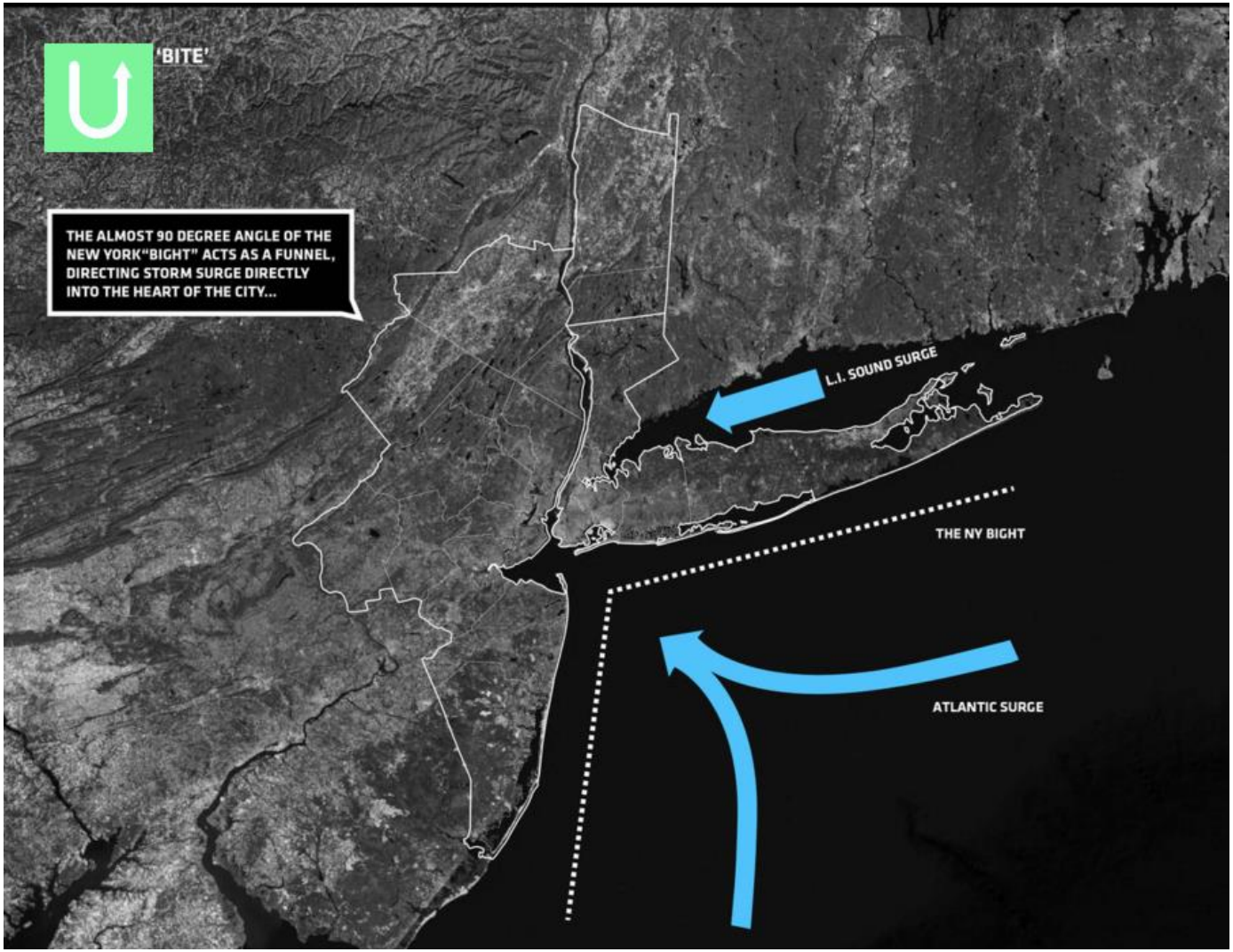
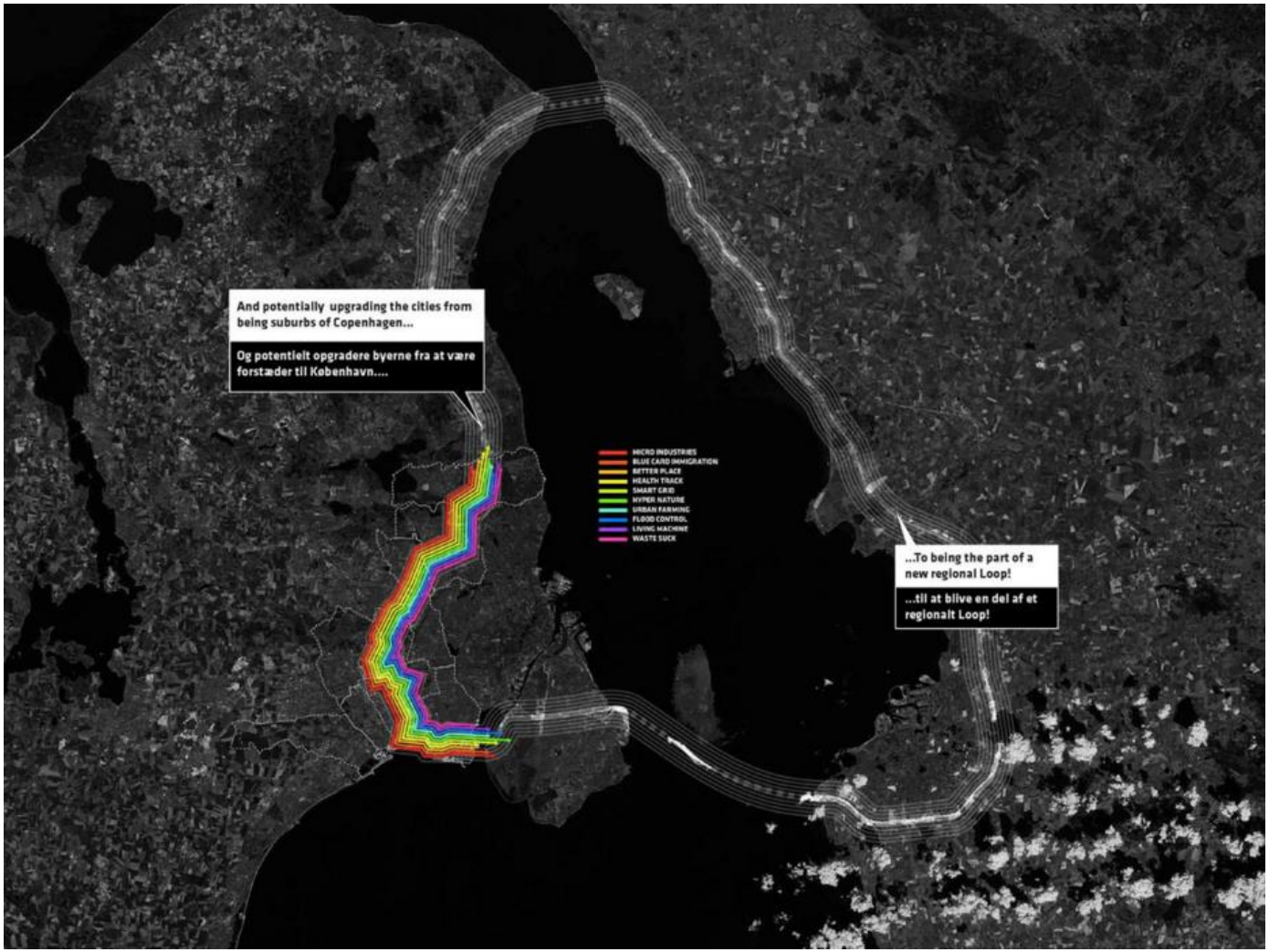




NEW APPROACH: HUD the Dryline – New York (USA) – BIG Bjarke Ingels Group



NEW APPROACH: Loop City – Copenhagen (DK) – BIG Bjarke Ingels Group



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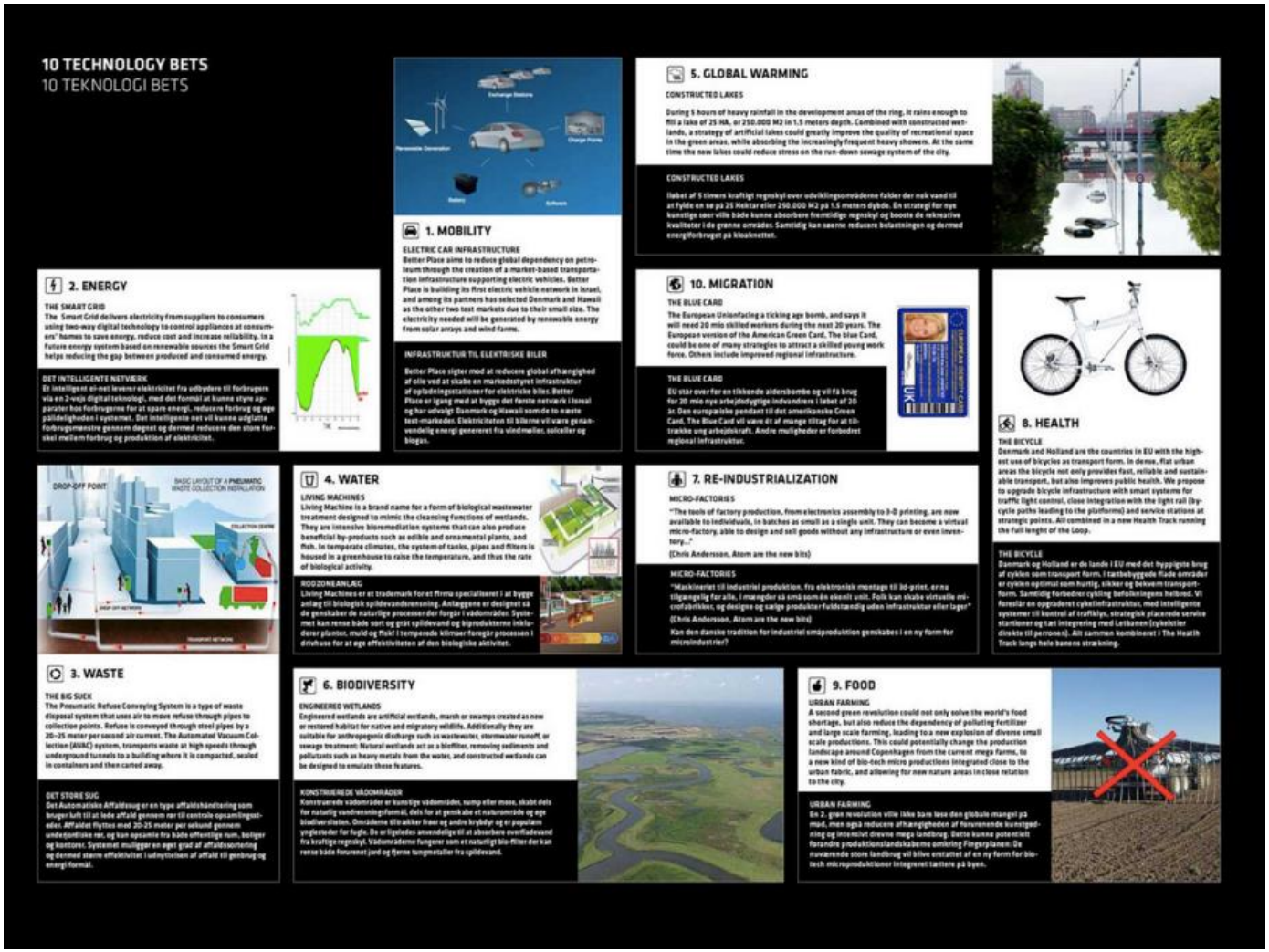
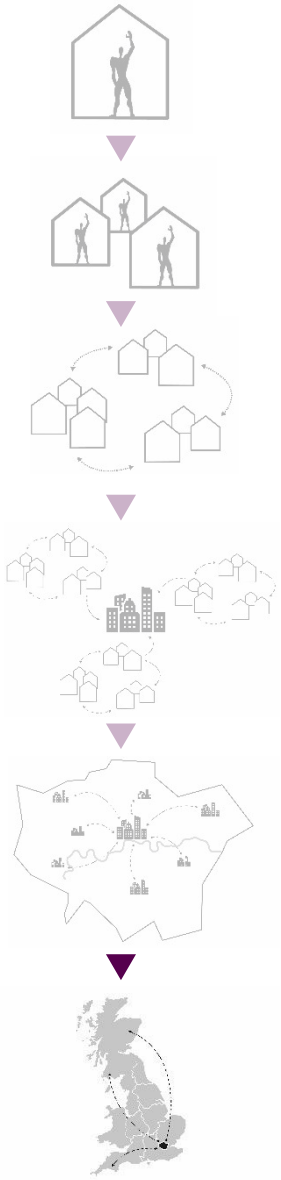


NEW APPROACH: Network&Society – UK – MIT Senseable Citiy LAB

Aggregating all phone calls for an entire country reveals the connections between all places.

We call this the 'human network'.

What if we could draw regional boundaries that minimize disruptions to people's connections



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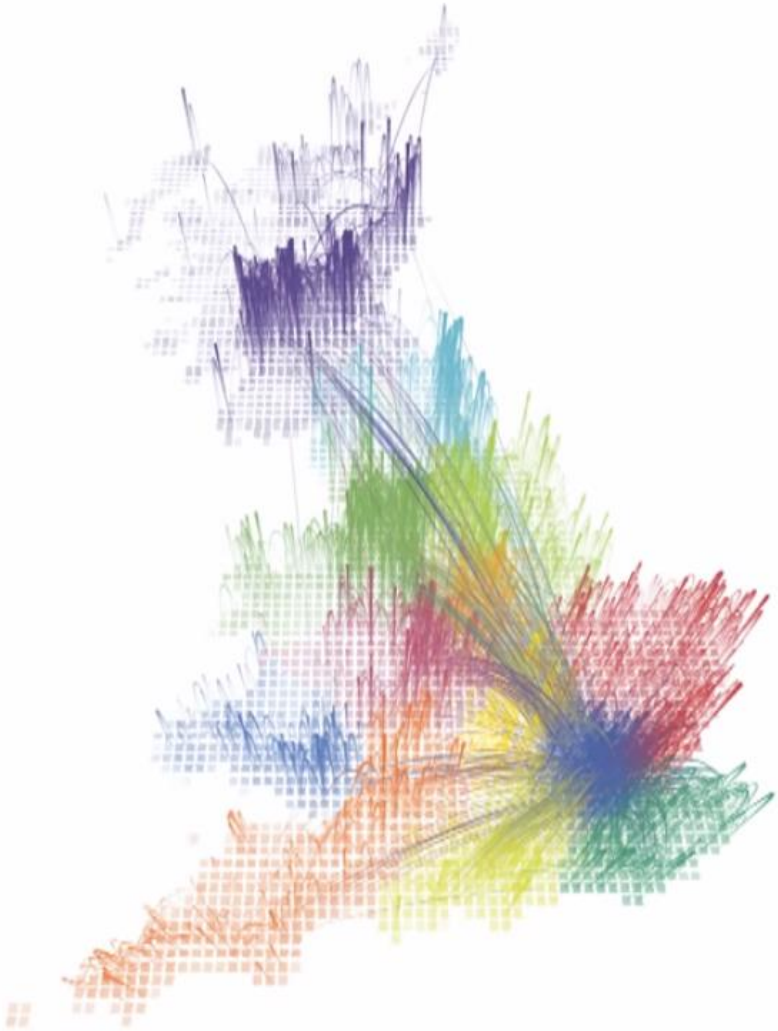
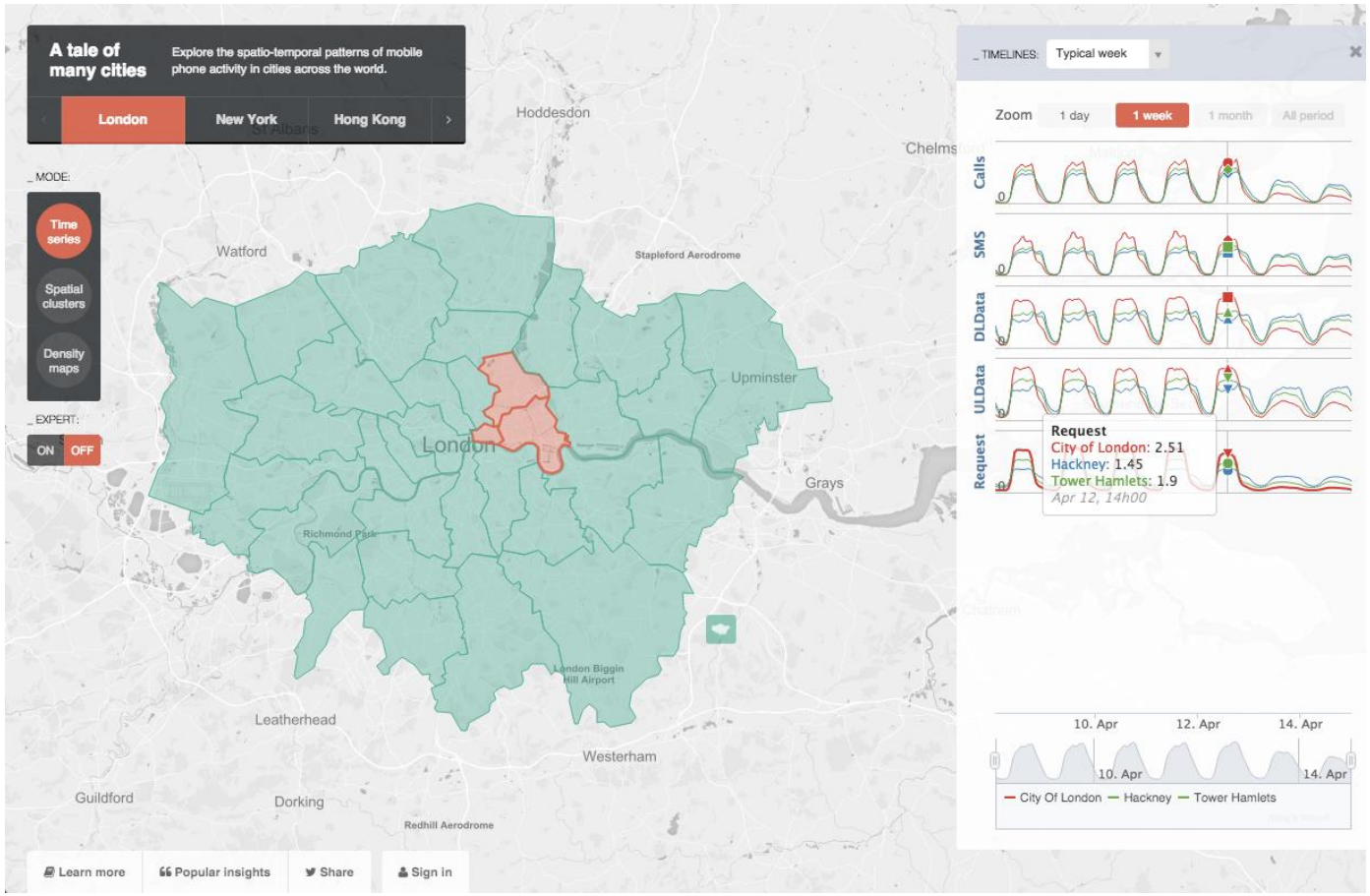


We call this the 'human network'.

What if we could draw regional boundaries that minimize disruptions to people's connections?

An algorithm is able to create the optimal partitioning

NEW APPROACH: A Tale of Many Cities – MIT Senseable Citiy LAB



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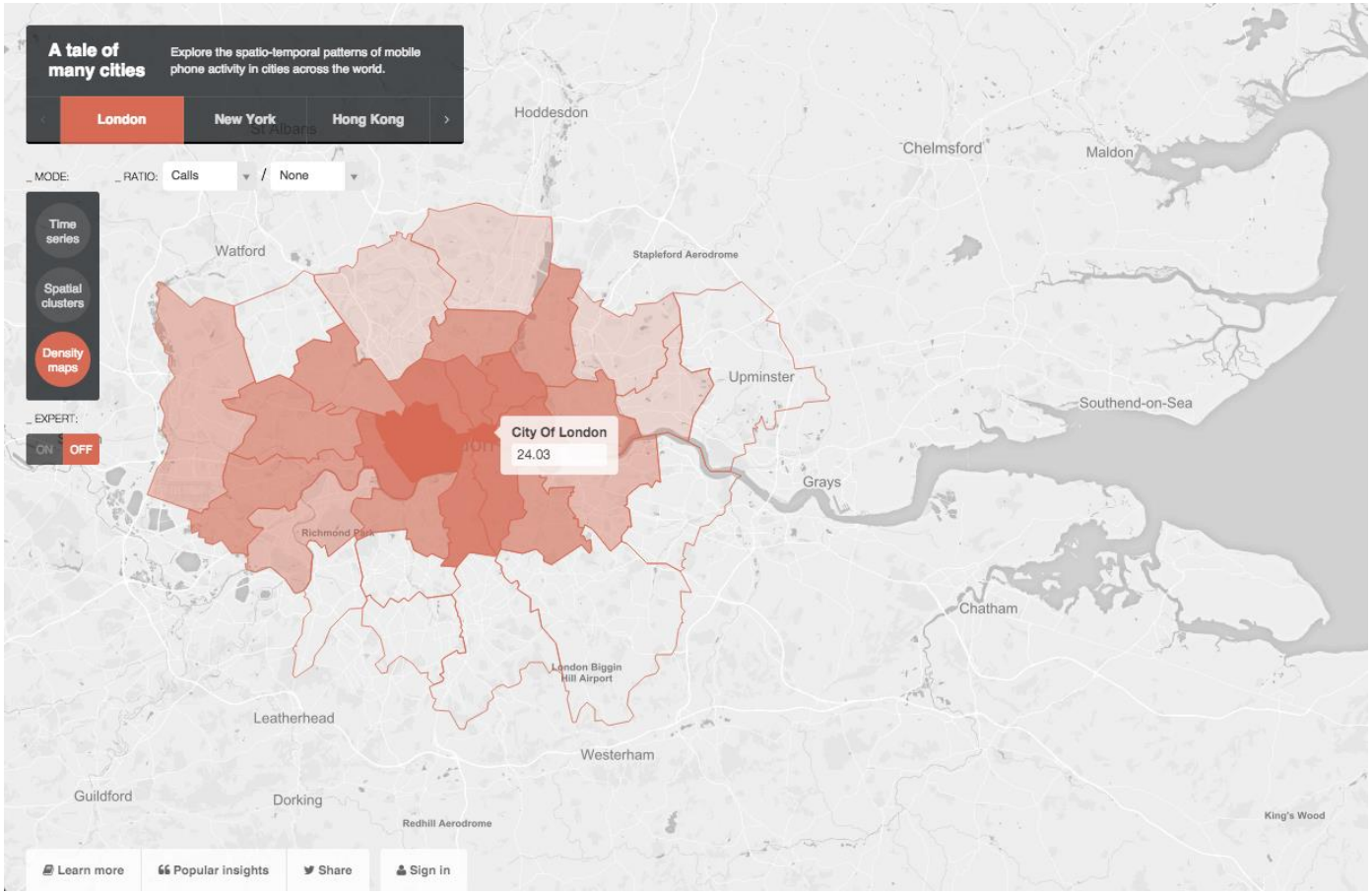

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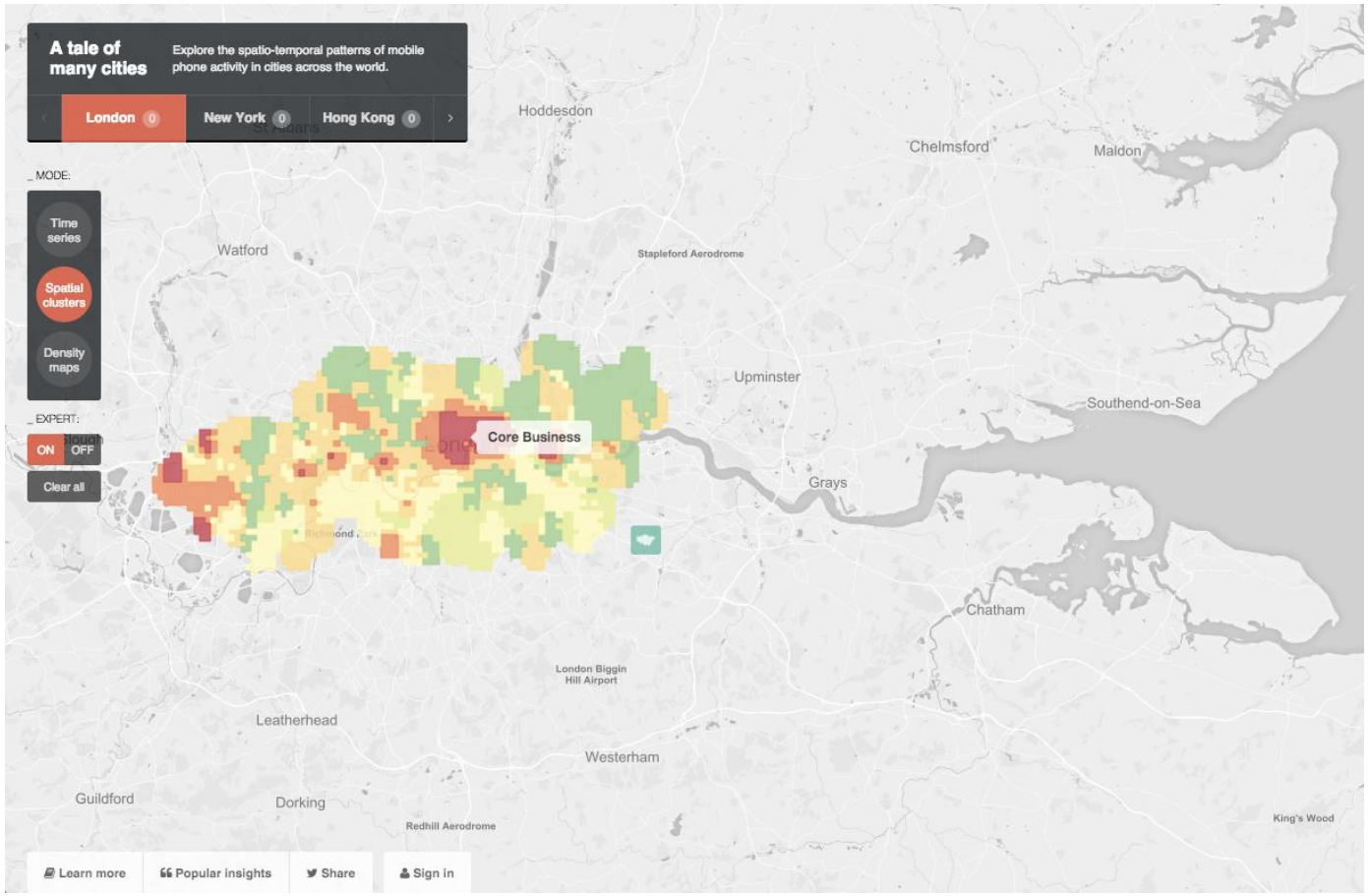
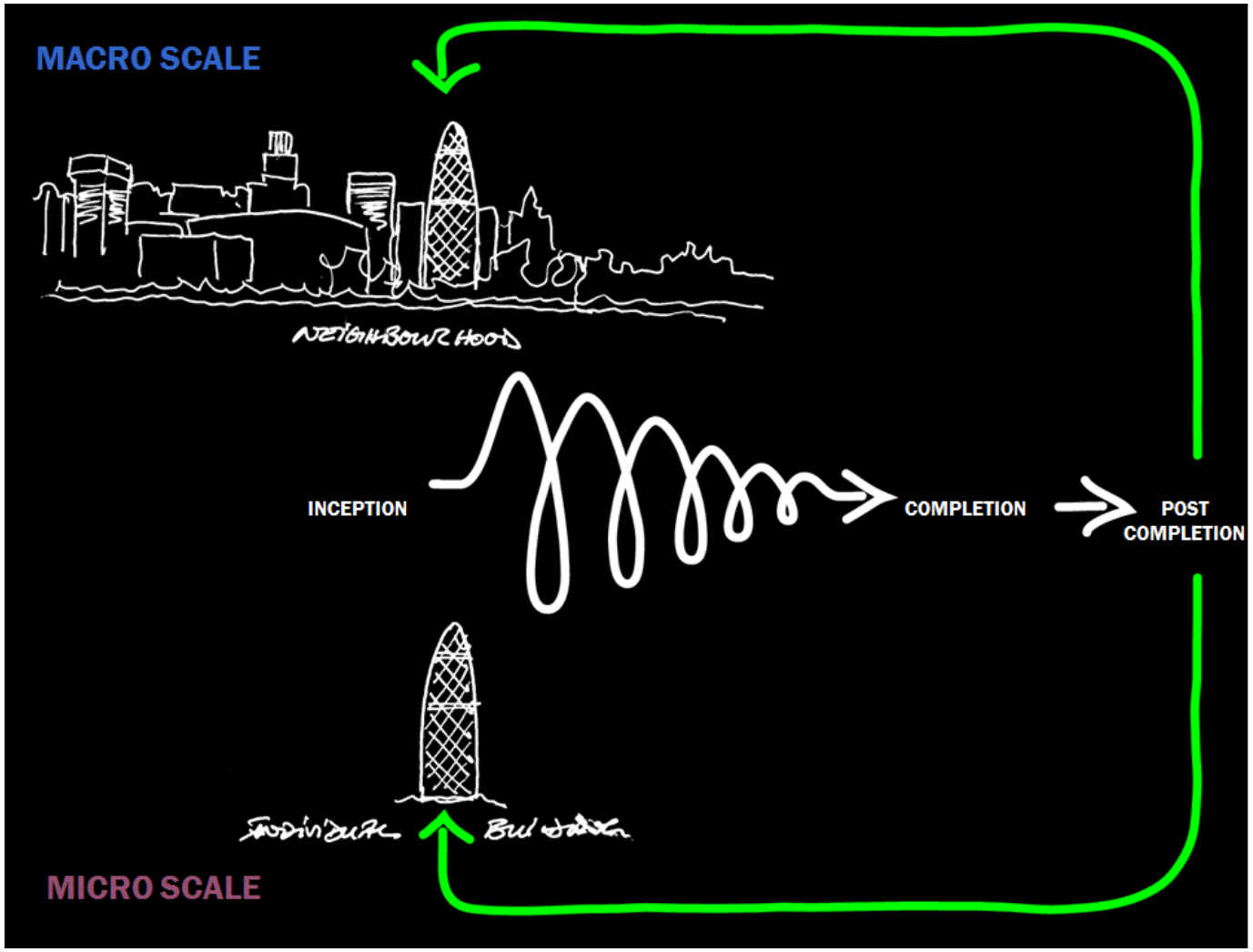


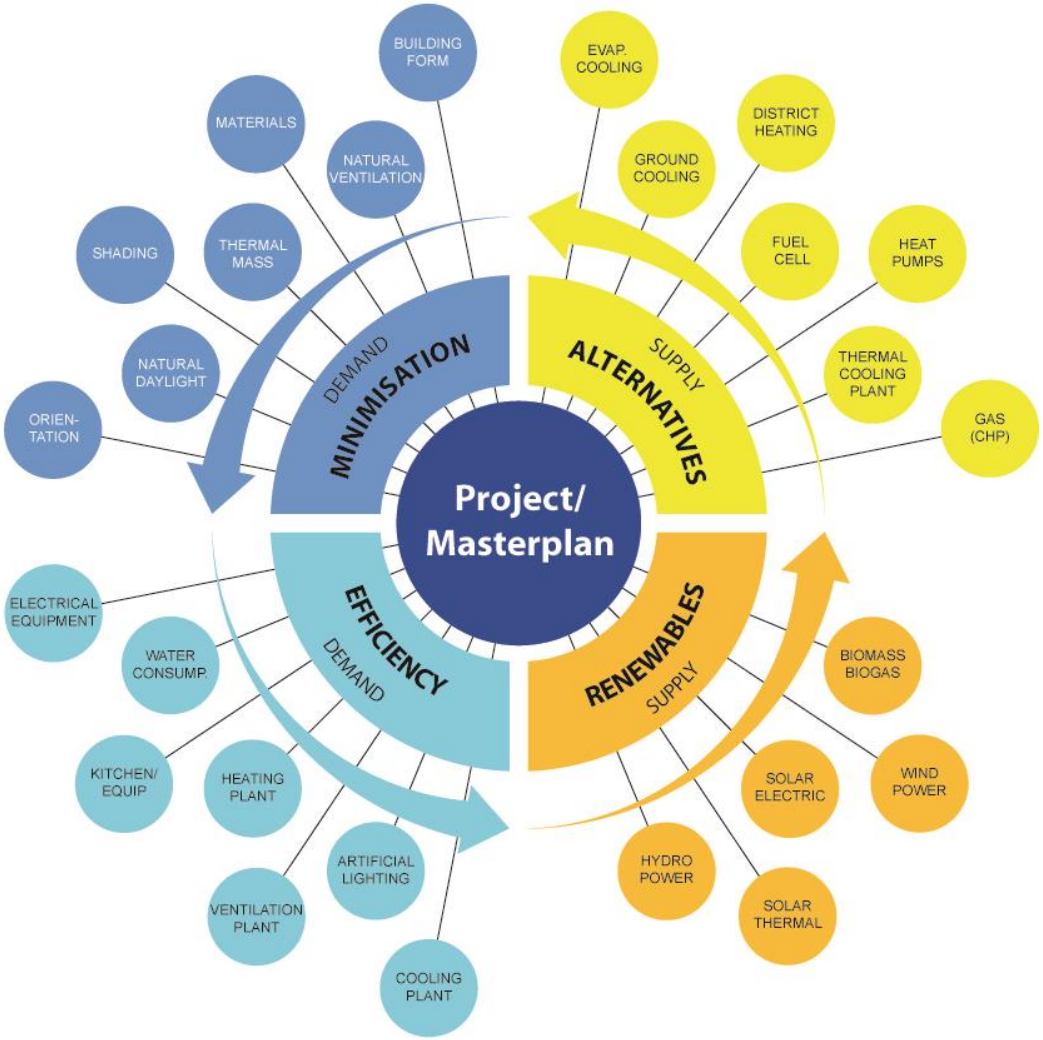
Some experiences ...

The Scale of the Challenge (new city, old city ...)

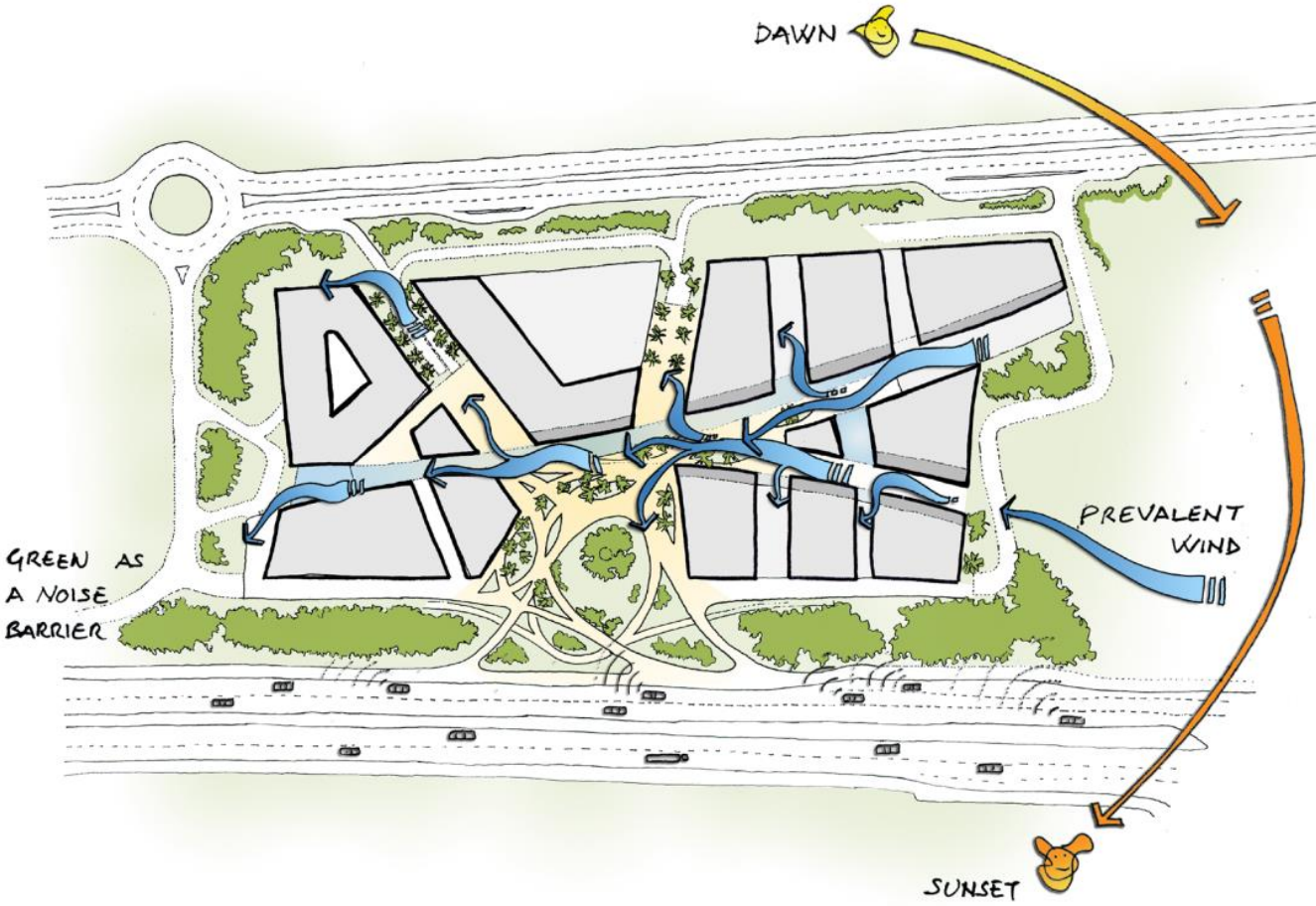
Concepts: Macro - Micro



Concepts: Environmental Design Methodology

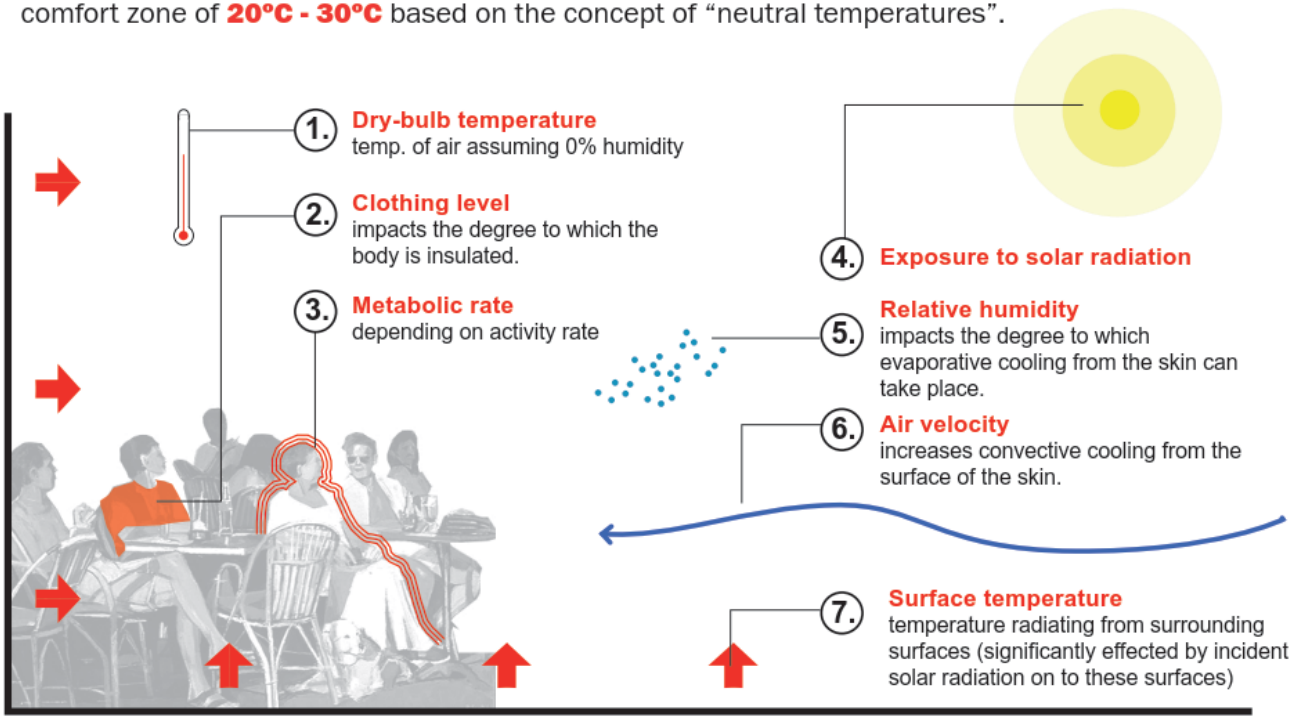


Concepts: Site Analysis

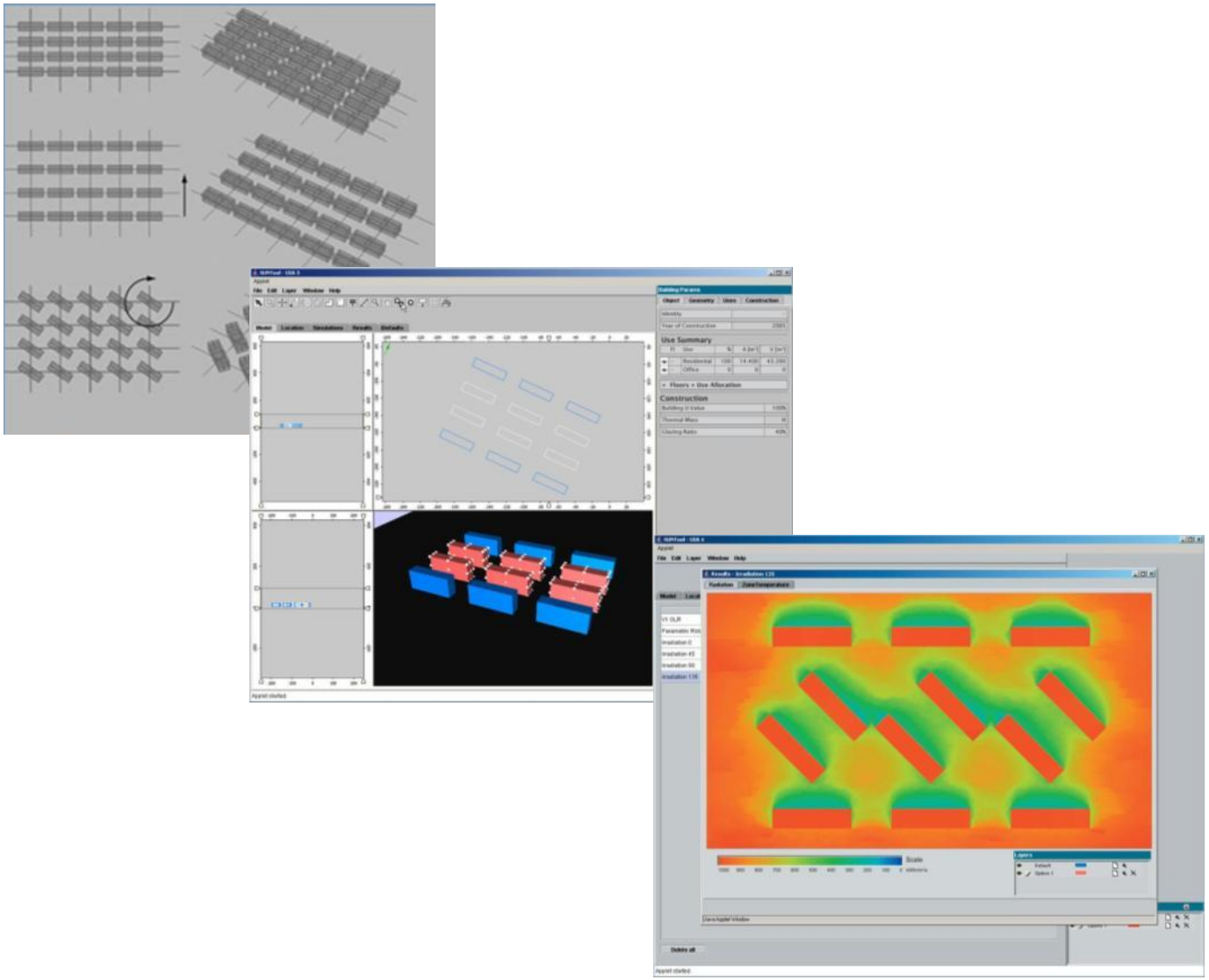


Concepts: Place making

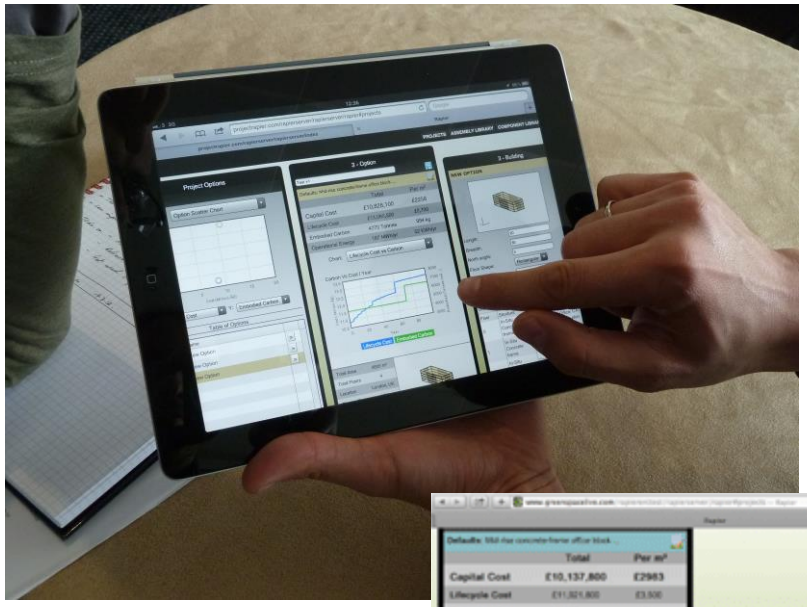
- Comfort, although a subjective sensation, may be nevertheless quantitatively assessed, and manipulated through **passive** (non-energy consuming) and **active** (energy consuming) measures. In this instance, a theoretical adaptive comfort model has been used to define an annual ideal comfort zone of **20°C - 30°C** based on the concept of "neutral temperatures".



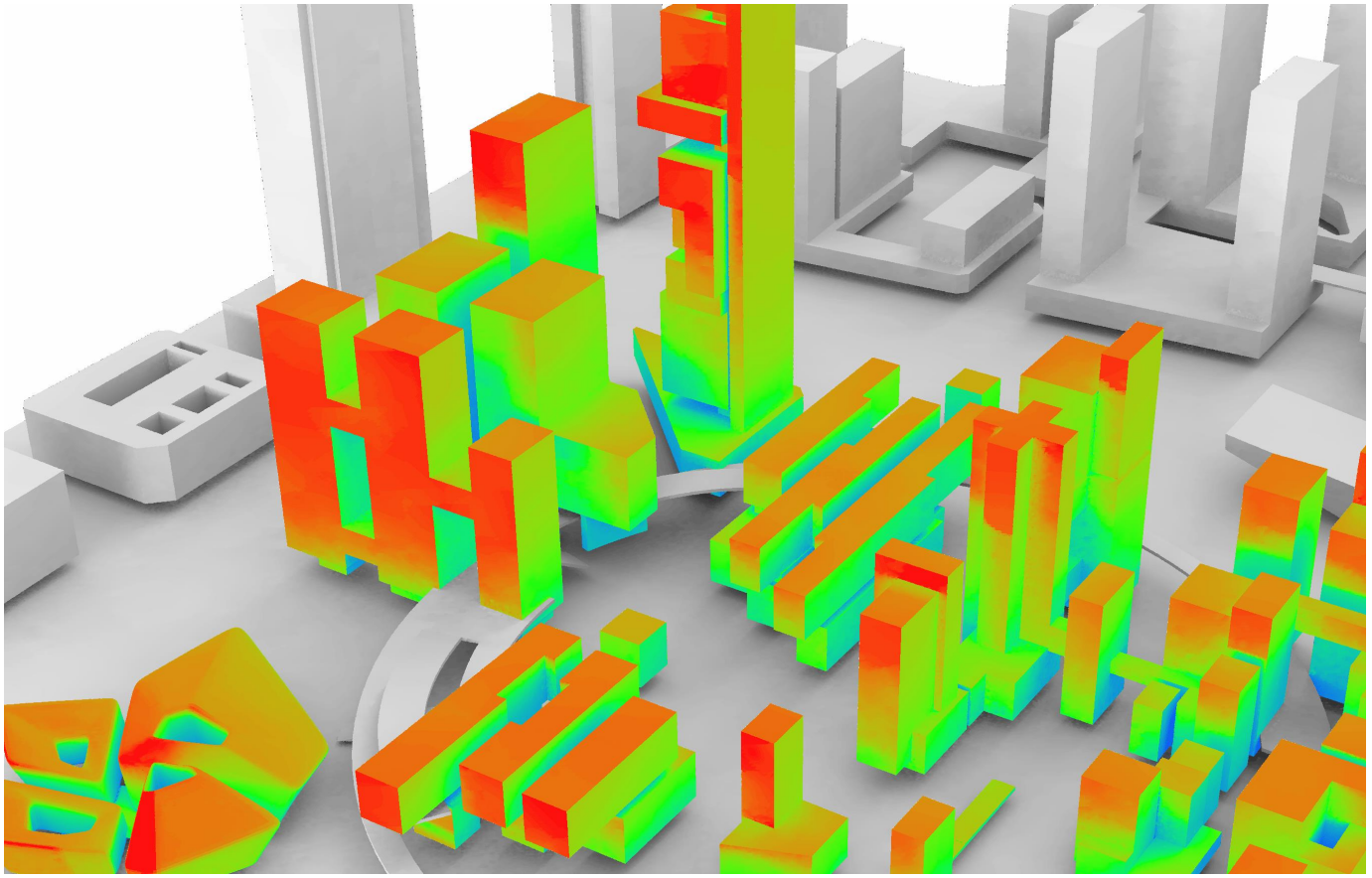
R&D: SUNtool (2003-6)



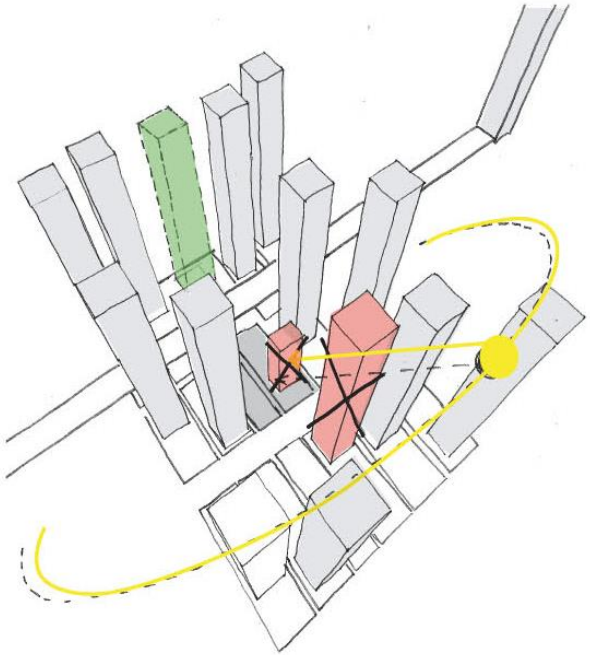
R&D: RAPIERE (2010-)

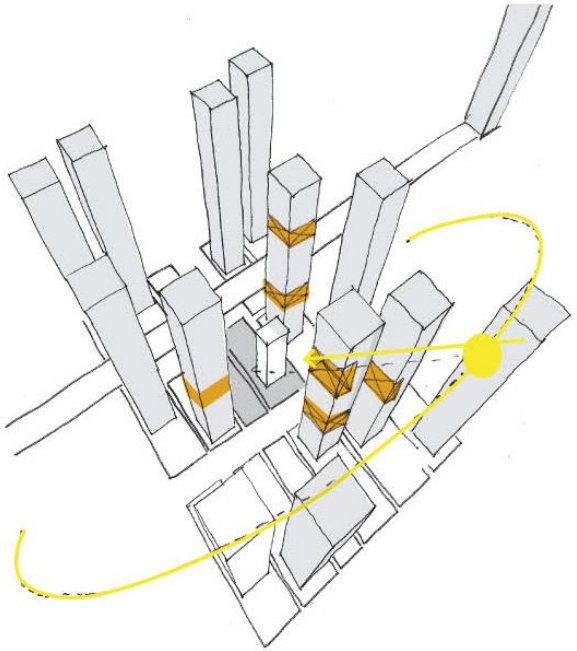


R&D (in-house): Solar Irradiation Mapping

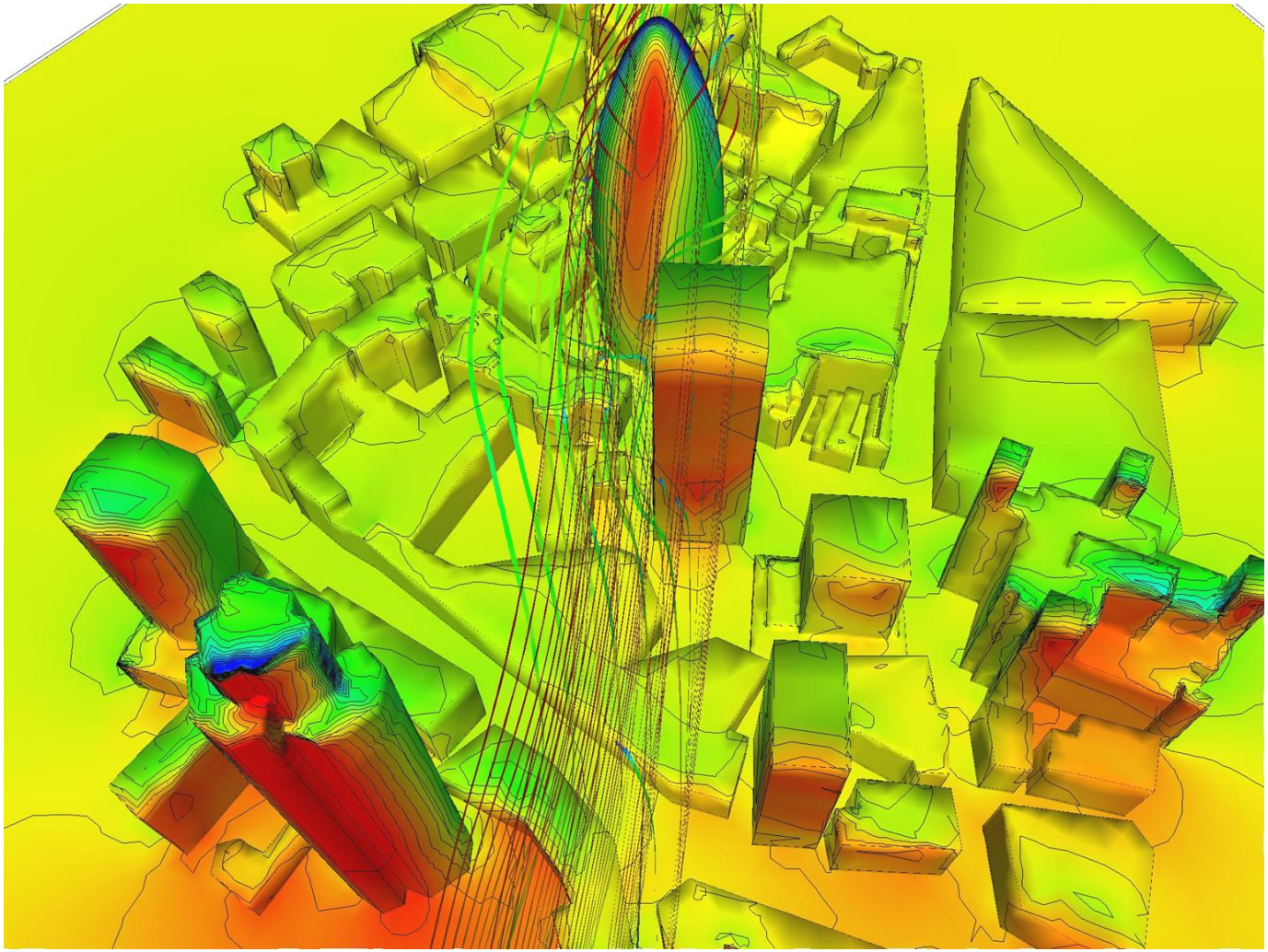


Concepts: Solar Access



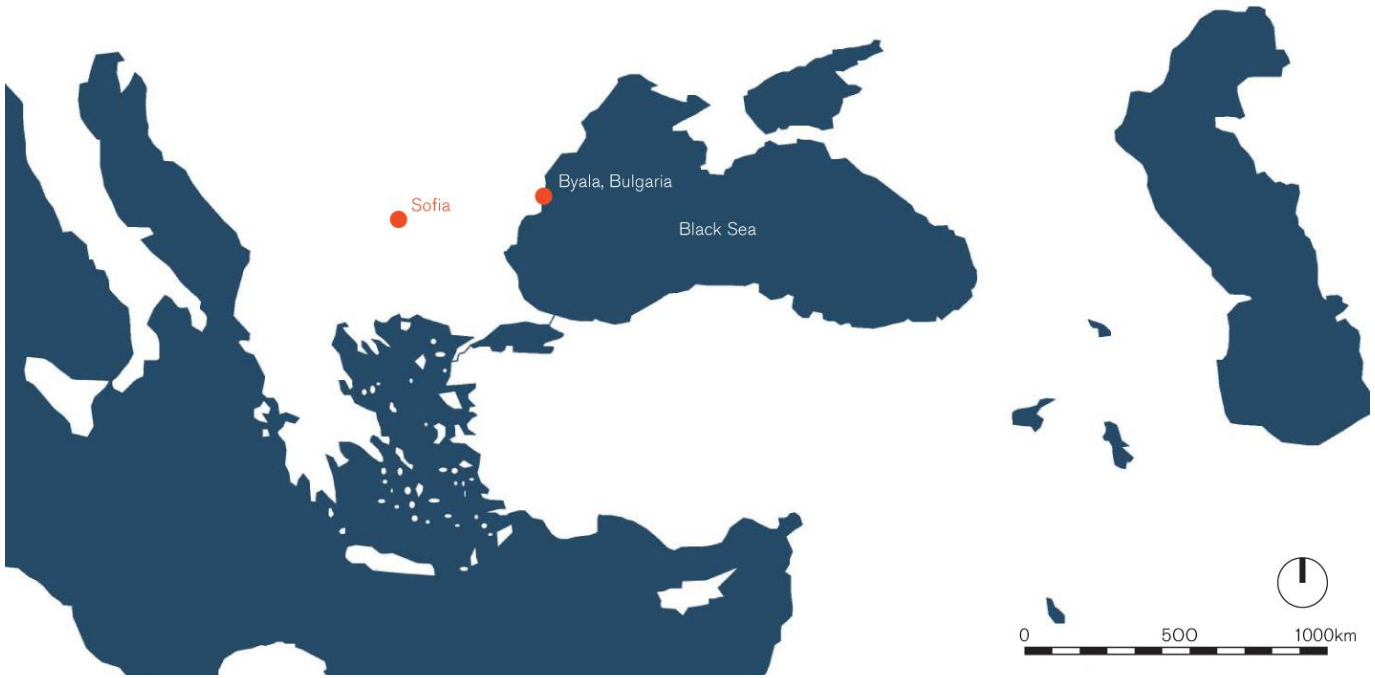


R&D (in-house): Pedestrian Wind Comfort

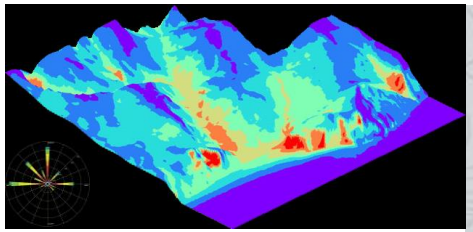


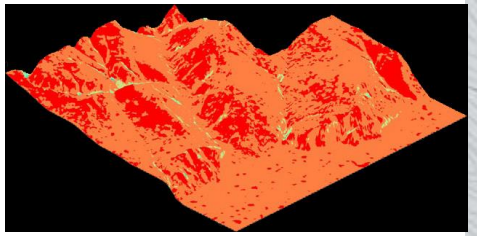
Wind tunnel modelling, use of pressure coefficients in thermal models

Projects: Black Sea Gardens, Bulgaria (Foster & Partners)

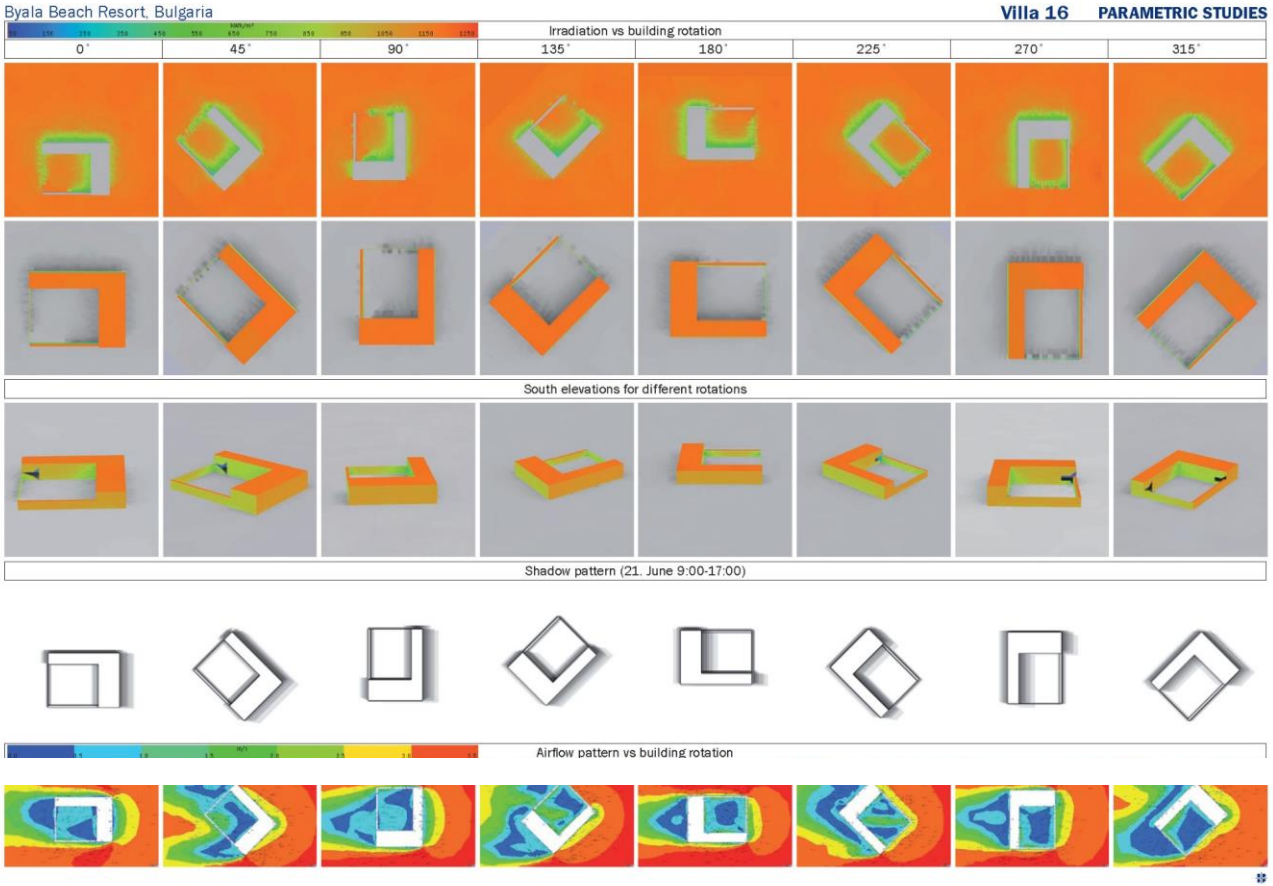


Projects: Black Sea Gardens, Bulgaria – Site Selection



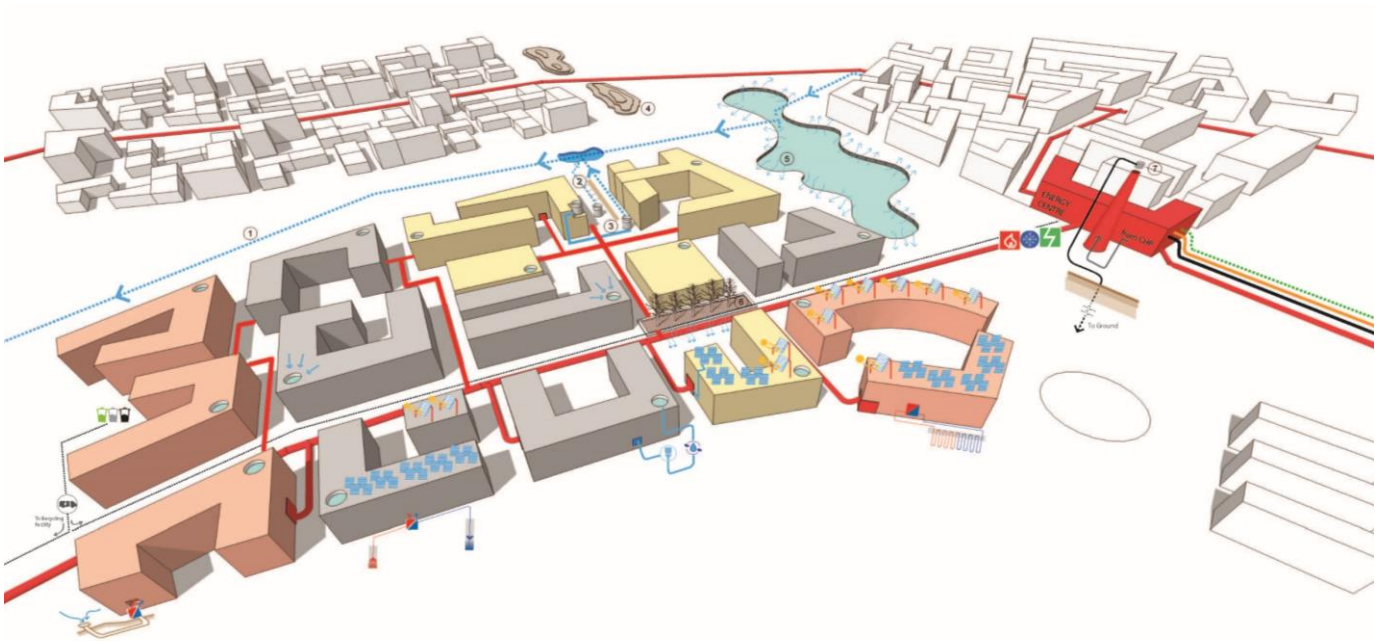


Projects: Black Sea Gardens, Bulgaria – Design of housing



Projects: Black Sea Gardens, Bulgaria – Infrastructure

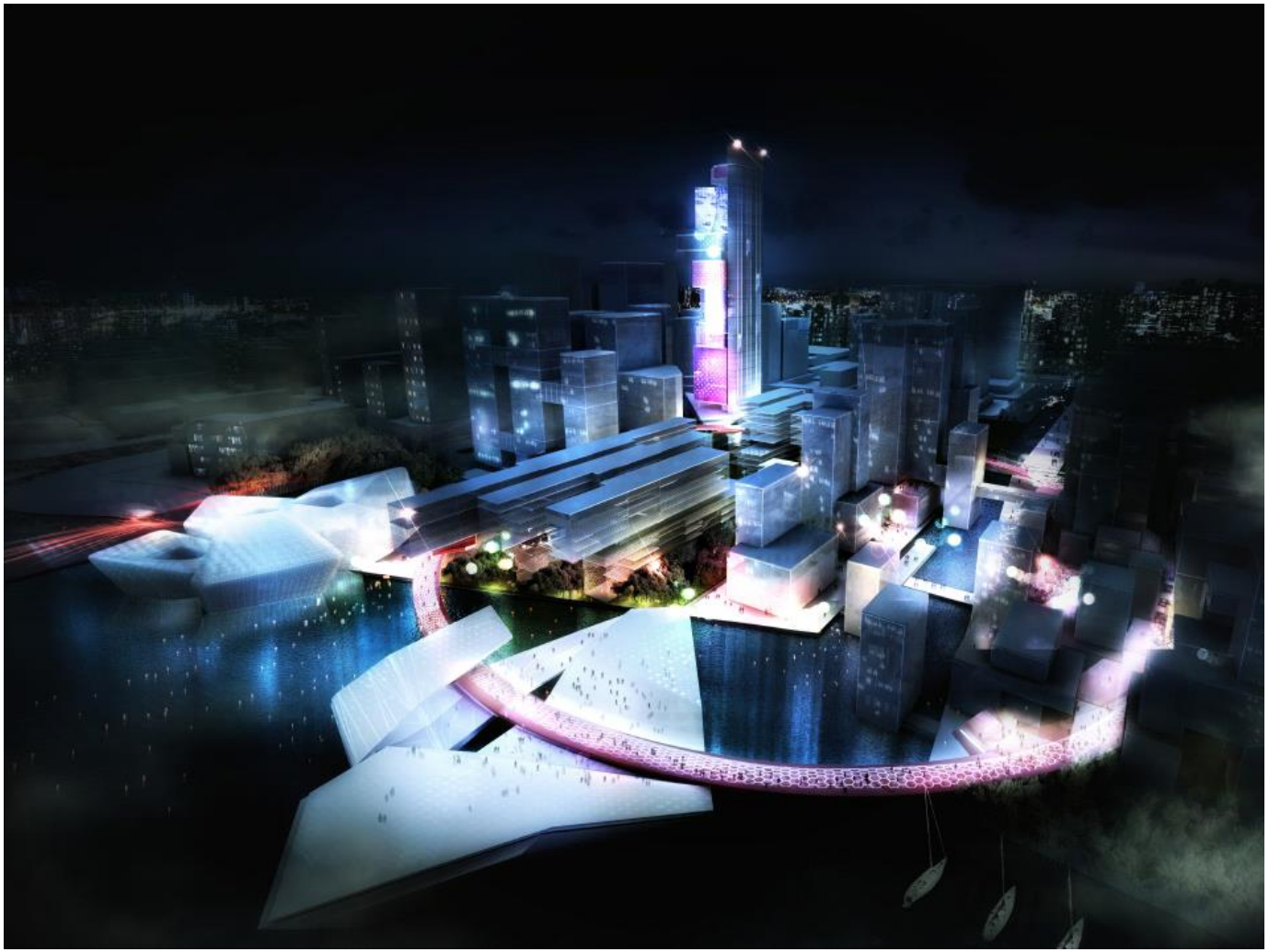
Competitions: Borongaj University Campus, Zagreb, Croatia



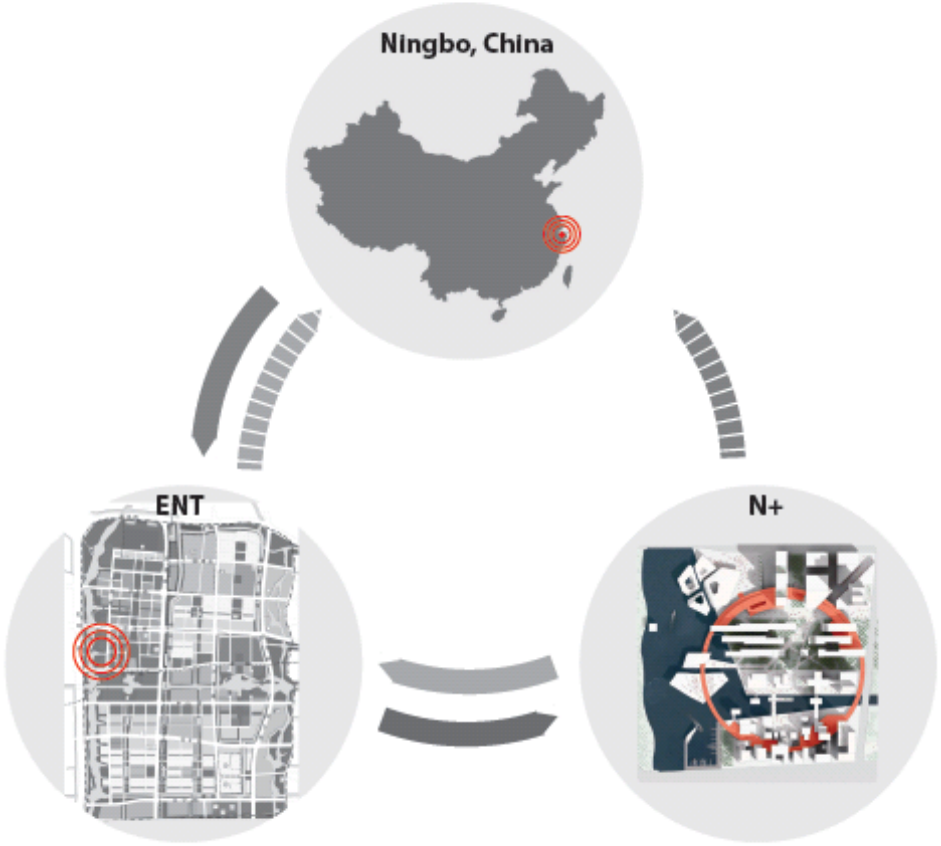
Hybrid Option

- Load Matching & Balancing
- Better Equipment Sizing (Capital Savings)
- Renewables Energy Storage
  (Export Surplus & Import from Grid When Generation Insufficient)
- Network Resilience
- Securily of Supply (Redundancy)
- Minimized Energy & Maintence (operational) Costs

Project: N+, Ningbo, China (PLP Architecture)



Project: N+, Ningbo, China (PLP Architecture)



Project: N+, Ningbo, China – Environmental Themes by District

Environmental Themes Definition

1. Creative Industries

- ☐ Sustainable Design and Production
- ☐ Smart Production / Industry
- ☐ Research & Development
- ☐ Promotion

2. Environmental Education/Information

- ☐ Smart City
- ☐ Smart Homes and Buildings
- ☐ Interactive Information
- ☐ Access to Information

3. Materials

- ☐ Showcase Smart Materials and Systems
- ☐ Development / Marketing of New Green Materials
- ☐ Minimise Embodied Energy / Carbon
- ☐ Smart Design and Use of Green Materials

4. Biodiversity

- ☐ Brand N+
- ☐ Active Community
- ☐ Create New Natural Habitats
- ☐ Enhance Existing Natural Habitats

5. Quality Of Life

- ☐ Active Communities
- ☐ Enhance Environmental Quality
- ☐ Health and Wellbeing
- ☐ Great Public Spaces

6. Waste

- ☐ Smart Management
- ☐ Materials and Energy Recovery
- ☐ Recycle / Reuse
- ☐ Prevention and Minimisation

7. Water

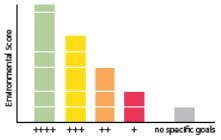
- ☐ Smart Blue Infrastructure
- ☐ Enhanced Recycling / Reuse
- ☐ Basic Recycling / Reuse
- ☐ Demand Minimisation

8. Energy

- ☐ Smart Green Infrastructure
- ☐ Centralised Services and Alternatives
- ☐ Energy Efficiency and Renewables
- ☐ Demand Minimisation

9. Transport

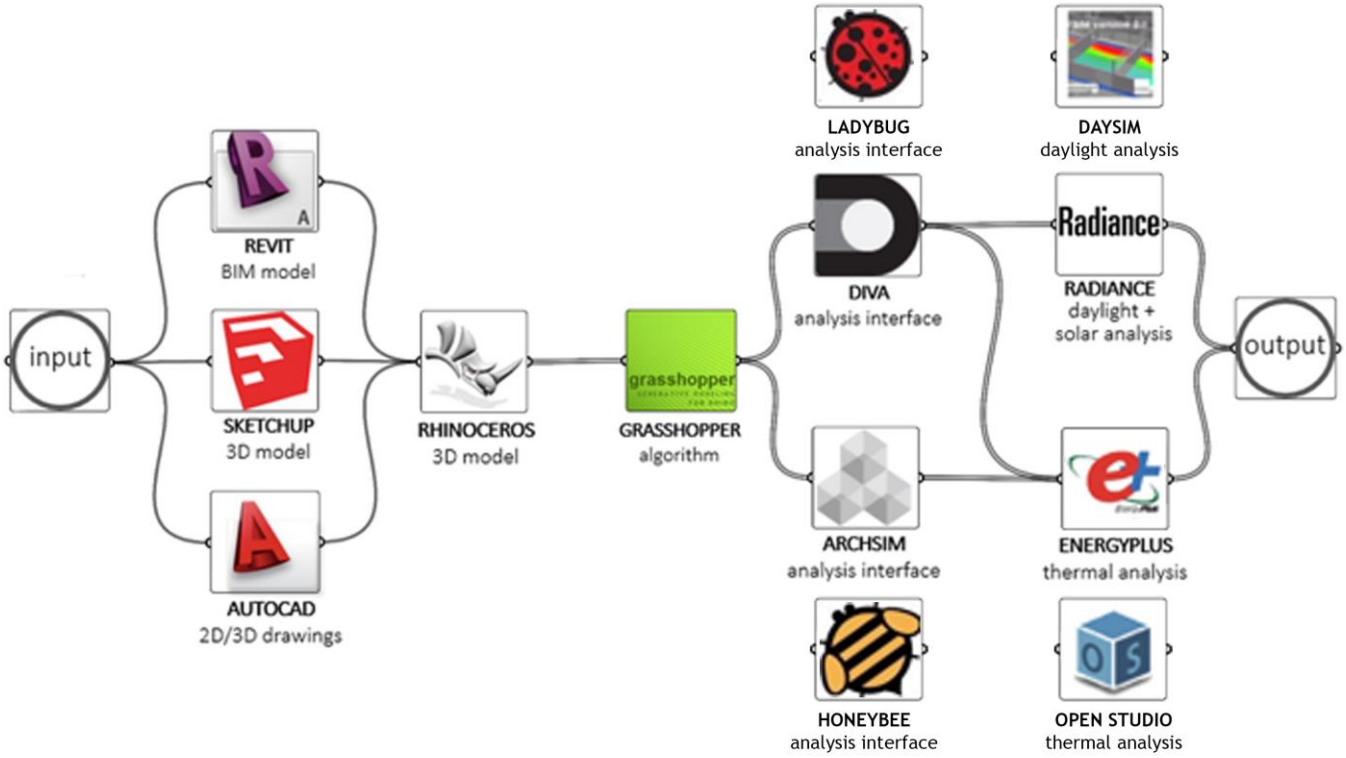
- ☐ Electric or Hydrogen Transport Only
- ☐ Smart Infrastructure
- ☐ Alternative Transport
- ☐ Maximise Pedestrian Mobility



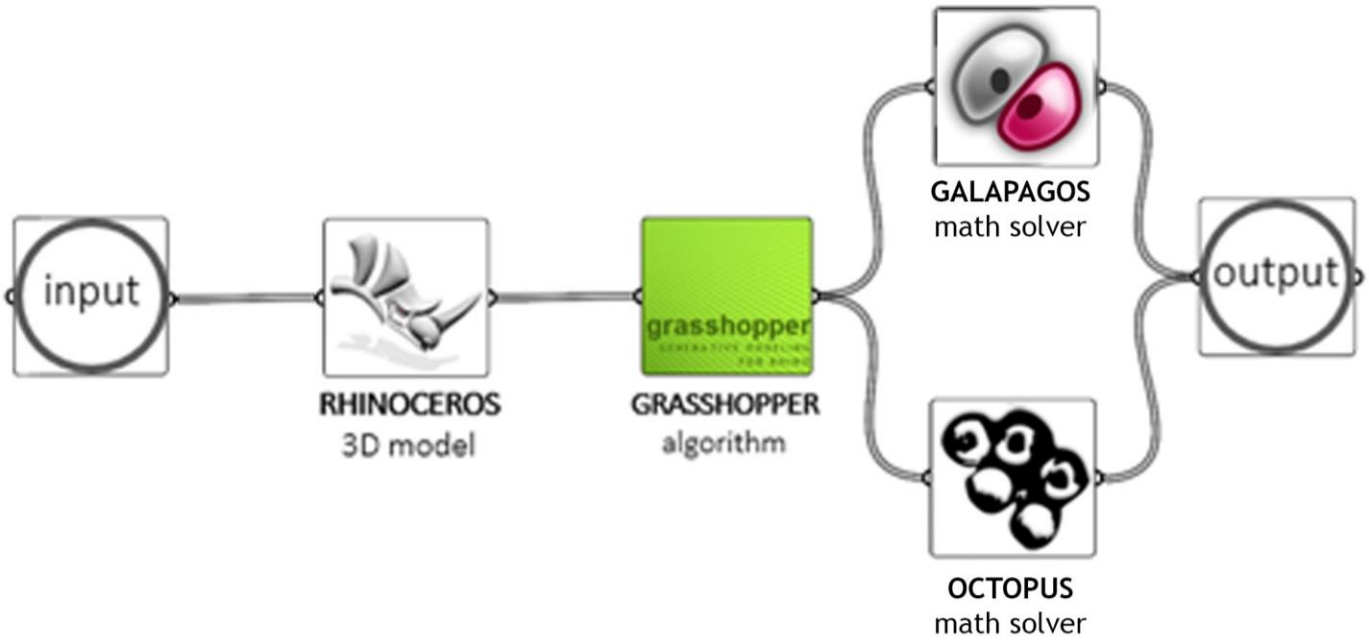
Parametrics

Responding to the urban context

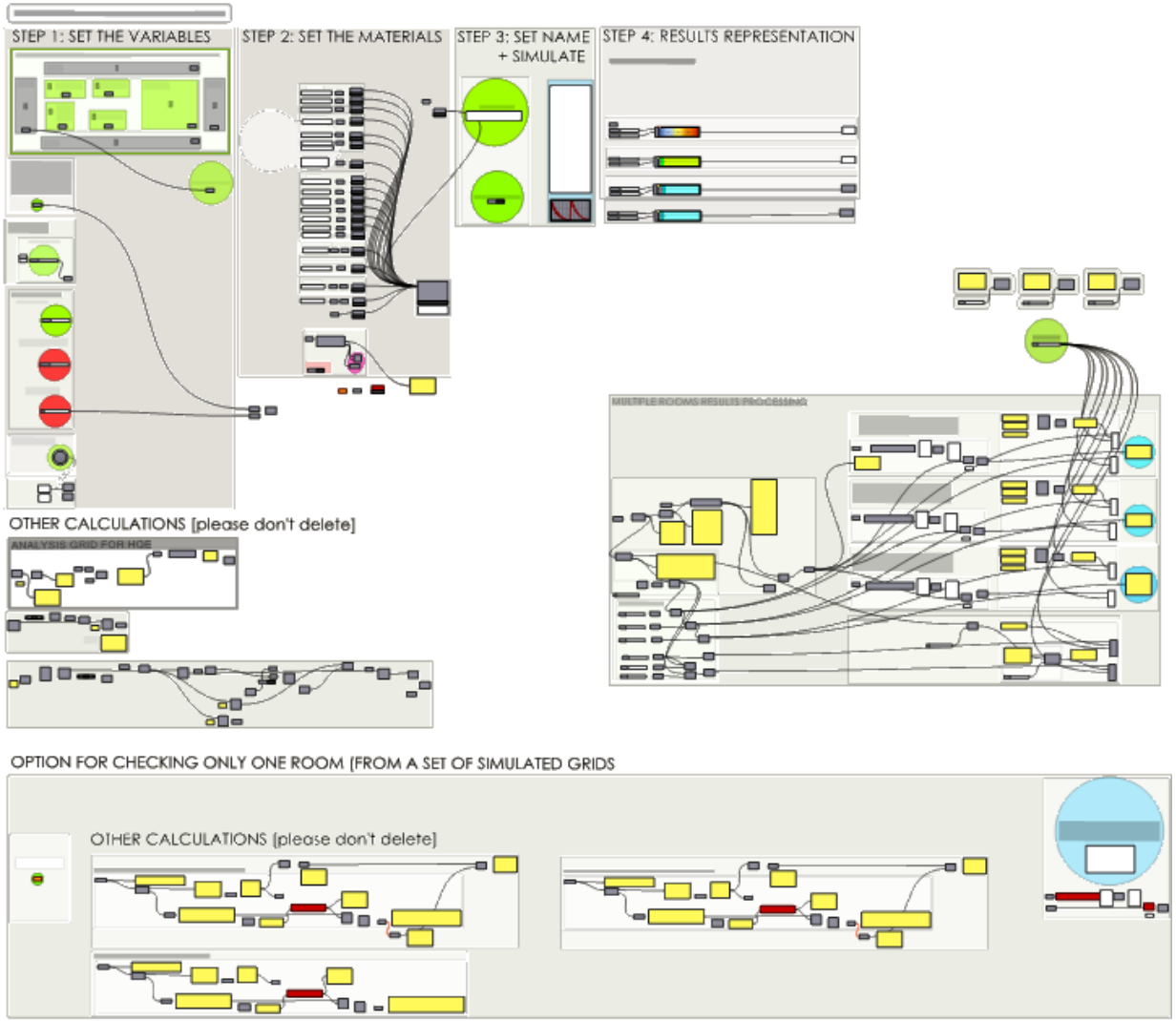
PARAMETRIC: Initial Studies – Workflow & Tools

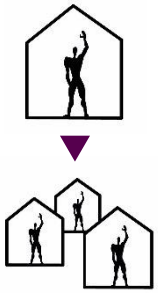


PARAMETRIC: Initial Studies – Optimisation



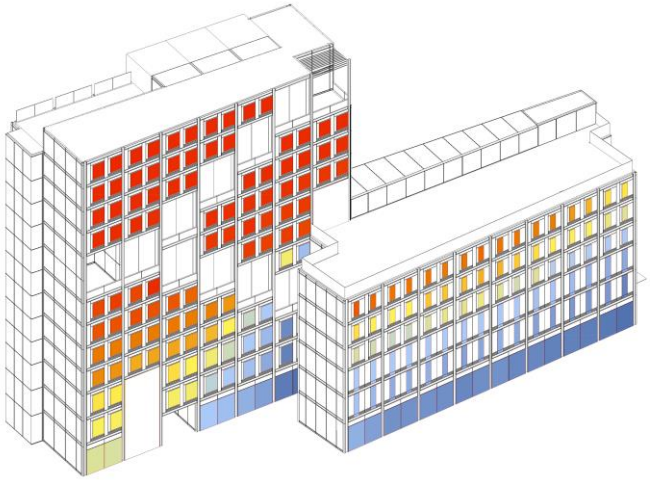
PARAMETRIC: Initial Studies – Script Sample

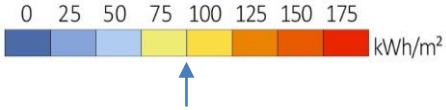




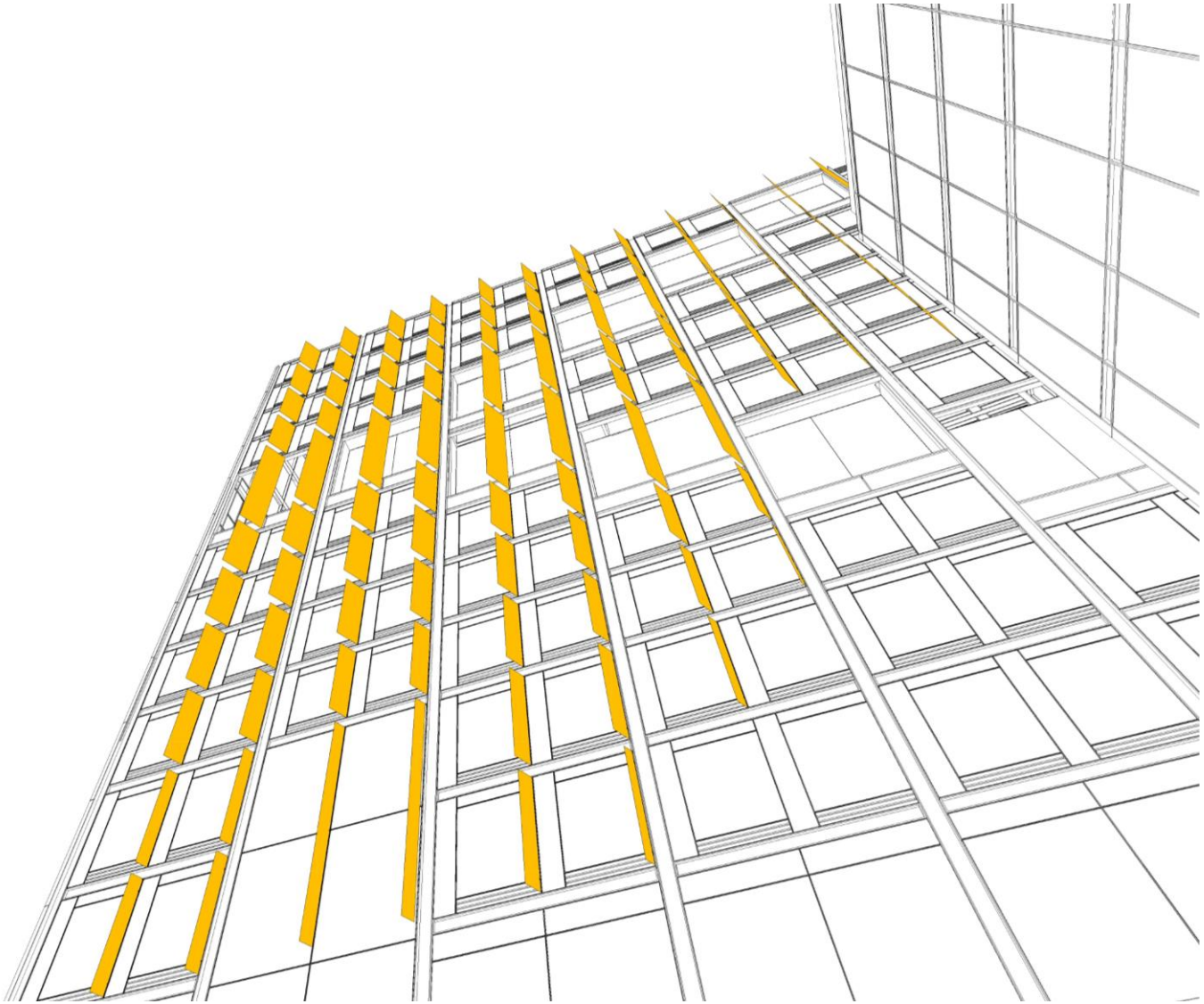
PARAMETRIC: LSE CBR– RSH+P

PARAMETRIC: LSE CBR – External Shading Design

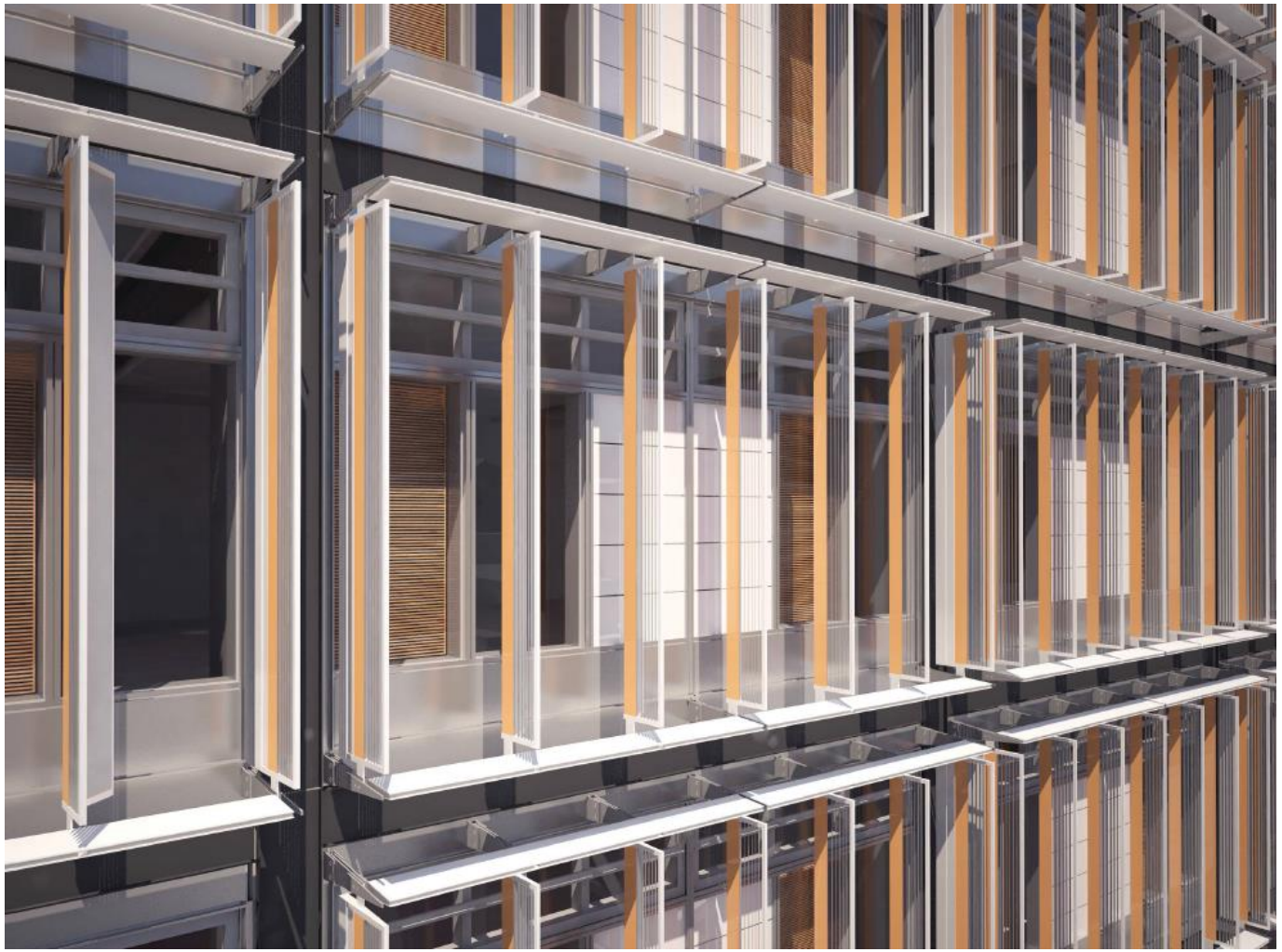




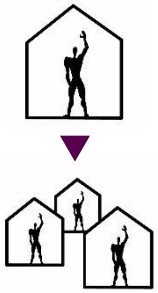
PARAMETRIC: LSE CBR – External Shading



PARAMETRIC: LSE CBR – Façade Visualisation (RSH+P)

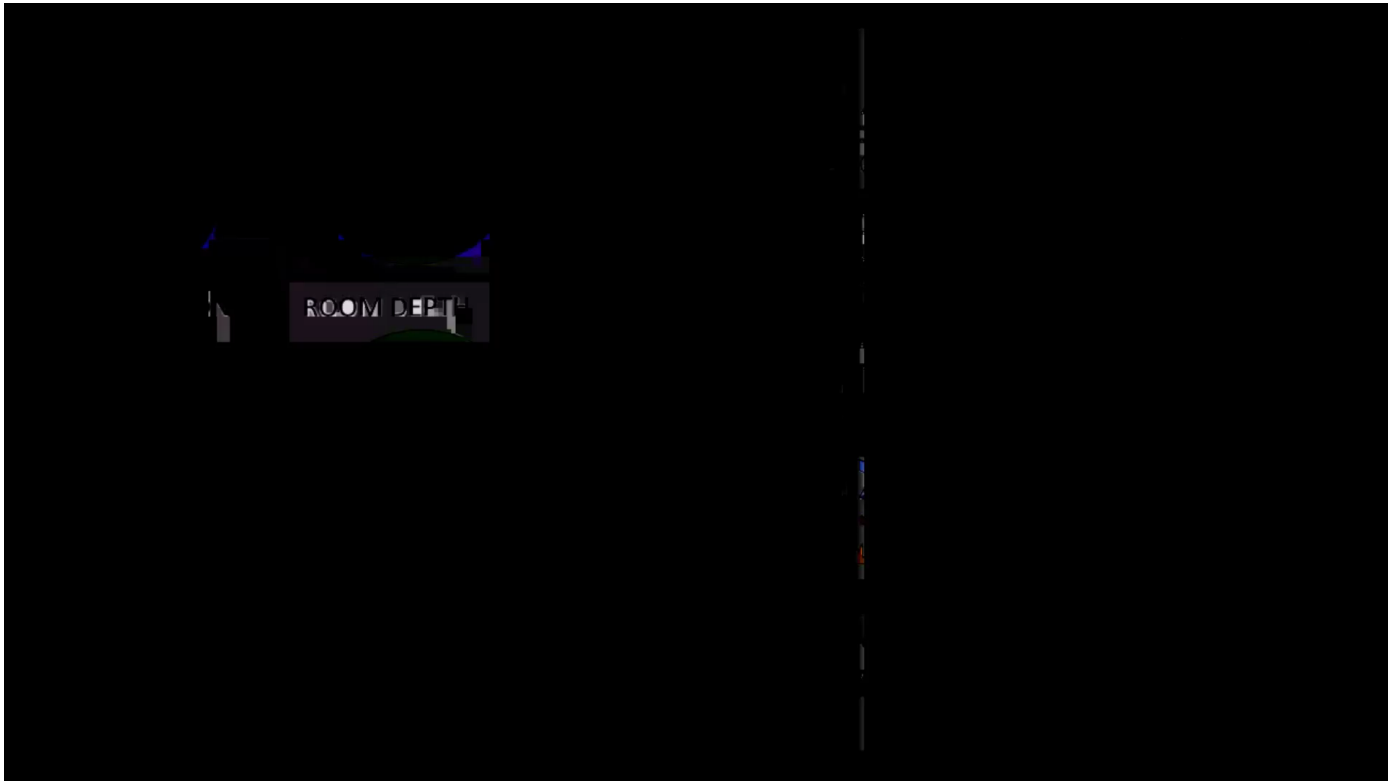


PARAMETRIC: IMT – Paris (FR) – Grafton Architects

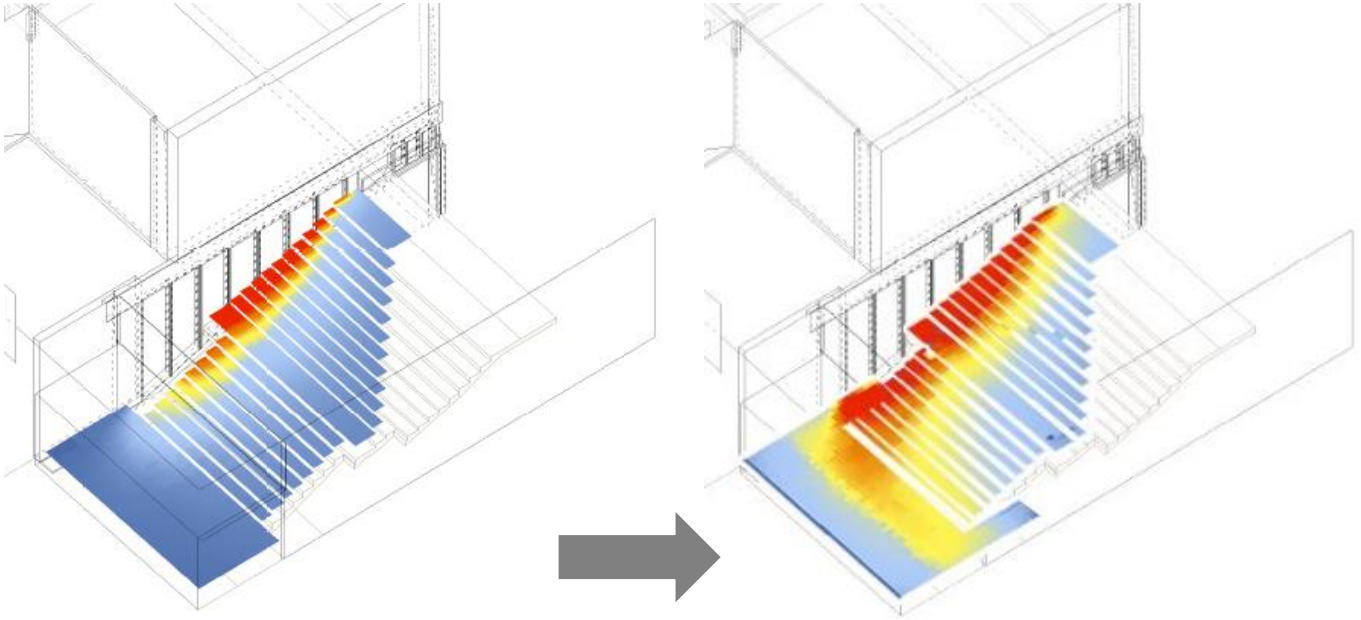


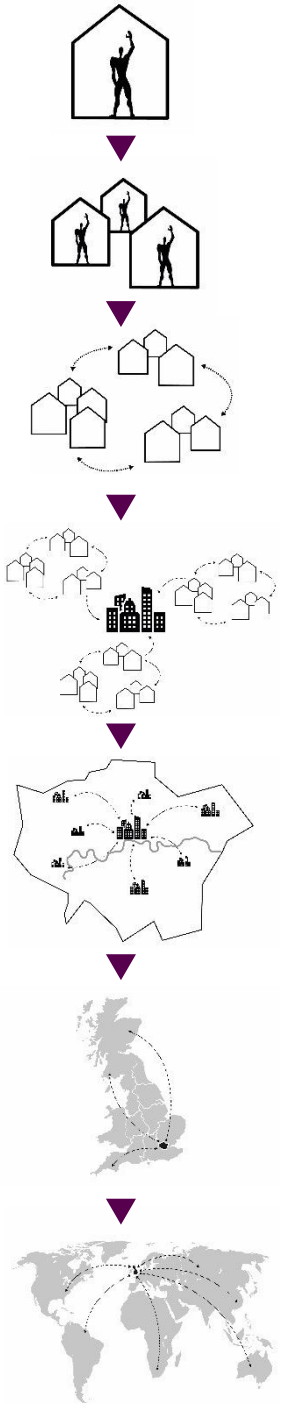
PARAMETRIC: Facade Optimisation – IMT – Paris (FR) – Grafton Architects

PARAMETRIC: DF Analysis – IMT – Paris (FR) – Grafton Architects

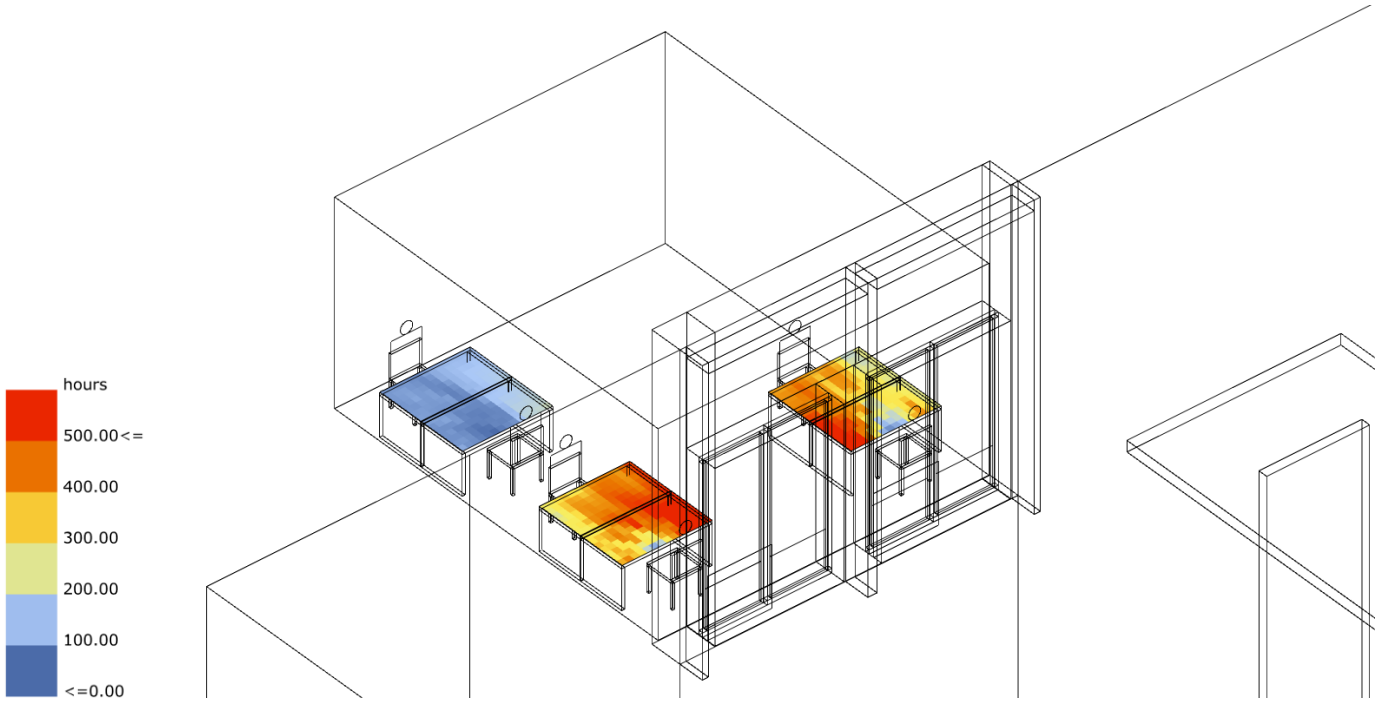


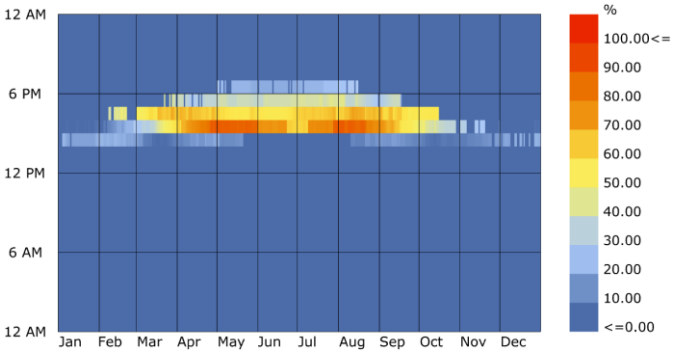
PARAMETRIC: DF Analysis – IMT – Paris (FR) – Grafton Architects



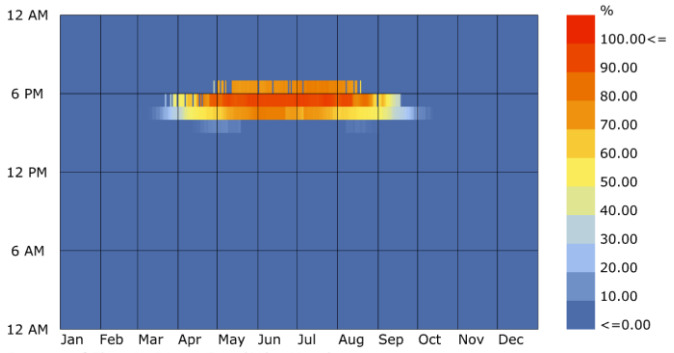


PARAMETRIC: Glare Analysis – IMT – Paris (FR) – Grafton Architects





Percent of Floor in Direct Sun (%) - Hourly
Test Surface
1 JAN 1:00 - 31 DEC 24:00



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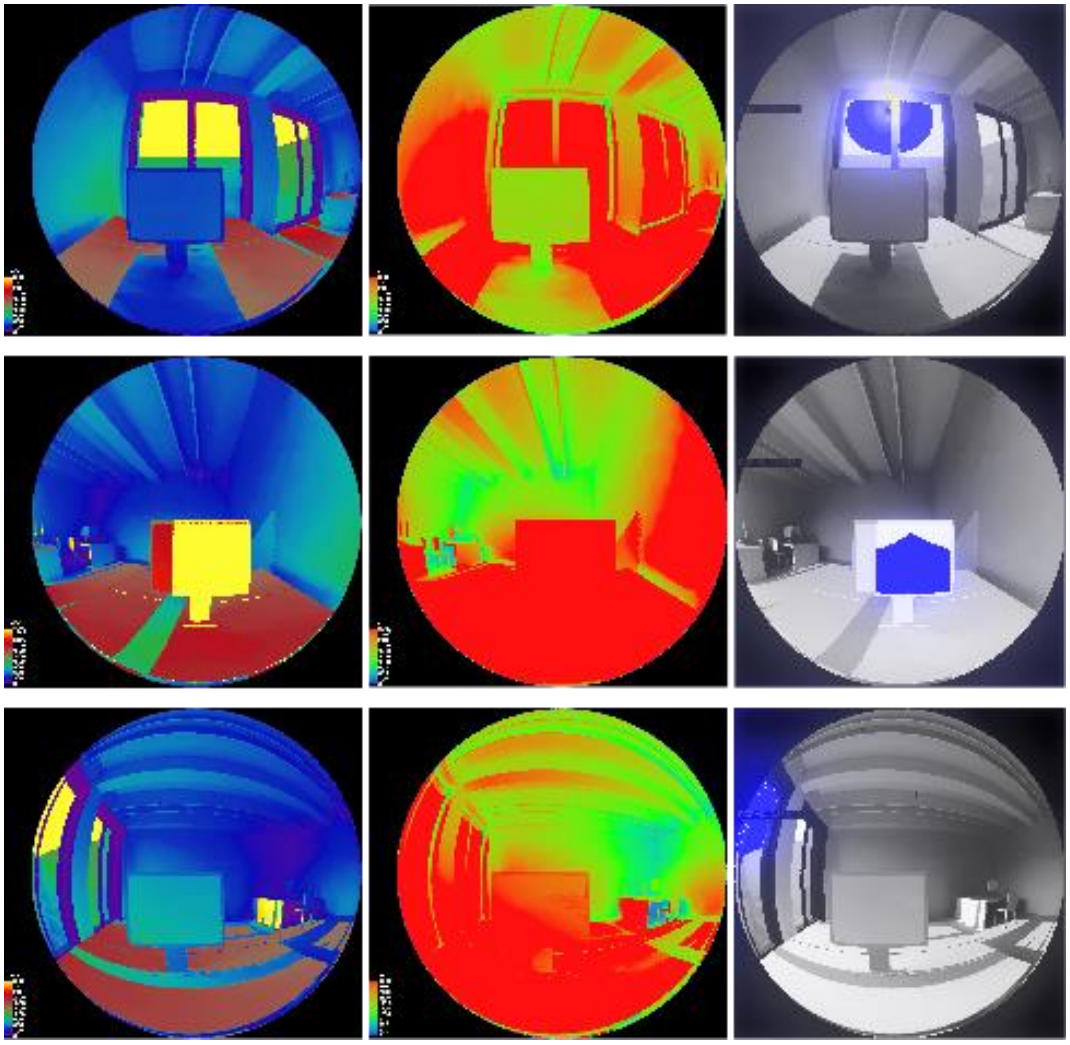
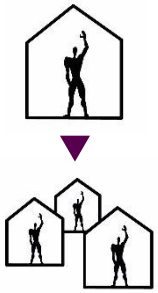


Some thoughts ...

CHALLENGES:

- Increasing complexity (space and time)
- Moving away from building-level tools
  (i.e. from explicit modelling of building, itself imperfect)
- Holistic modelling of energy systems/eco systems required
  (people, transport, water, waste, food, goods and services …)
- Industry – limited capacity (intellectual, computing …), limited time, short-term financial pressures, lack of investment in R&D
- Many models are non-commercial software, e.g. research tools within academia
- Keeping things simple for clients.



CHALLENGES: Just wishful thinking?

- Models we (industry) are using are still very limited, e.g.:
  - Performance Gap – design vs operation;
  - Deterministic – people are 'ghosts in the machine';
  - Behaviours, user interaction with controls etc.
  - Models of thermal comfort (indoor and outdoor);
  - Climatic modelling (Solar Radiation models);
  - Representation of local micro-climates (including street canyons);
  - Convection modelling (inc. infiltration) and mass flow networks;
  - Thermal bridging (2D and 3D Heat Transfer);
  - Modelling of all energy and water end uses (e.g. lifts etc.);
  - Coupled plant and system modelling;
  - Basic systems (e.g. underfloor heating, chilled ceilings);
  - Complex systems (e.g. TABS, ground source etc.);
  - Complex energy networks with seasonal energy storage;
  - Optimisation/parametrics based on metrics/functions;
  - Parallel processing/utilisation of multi-core processors;
  - Integration between different models/tools and with BIM;
  - Emphasis on compliance (Part L, London Plan, BREEAM);
  - Difficult to scale-up to masterplan/district level;

OPPORTUNITIES:

- Improved links between industry and academia

  (not just UK and EU Collaborative R&D)

- Adapting techniques from other industries:
  - Agent-based modelling;
  - Load profiling;
  - Optimisation;
  - …
- Improved information/data exchange protocols (CityXML …)
- Cloud-based computing;
- Impetus from COP21 …