

# 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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# ABOUT CHAPMANBDSP



# 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’?**



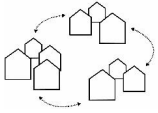
## DIFFERENT SCALES:



**Building**



**Masterplan/Neighbourhood**



**District**



**City**



**Region**



**Country**



**Global**

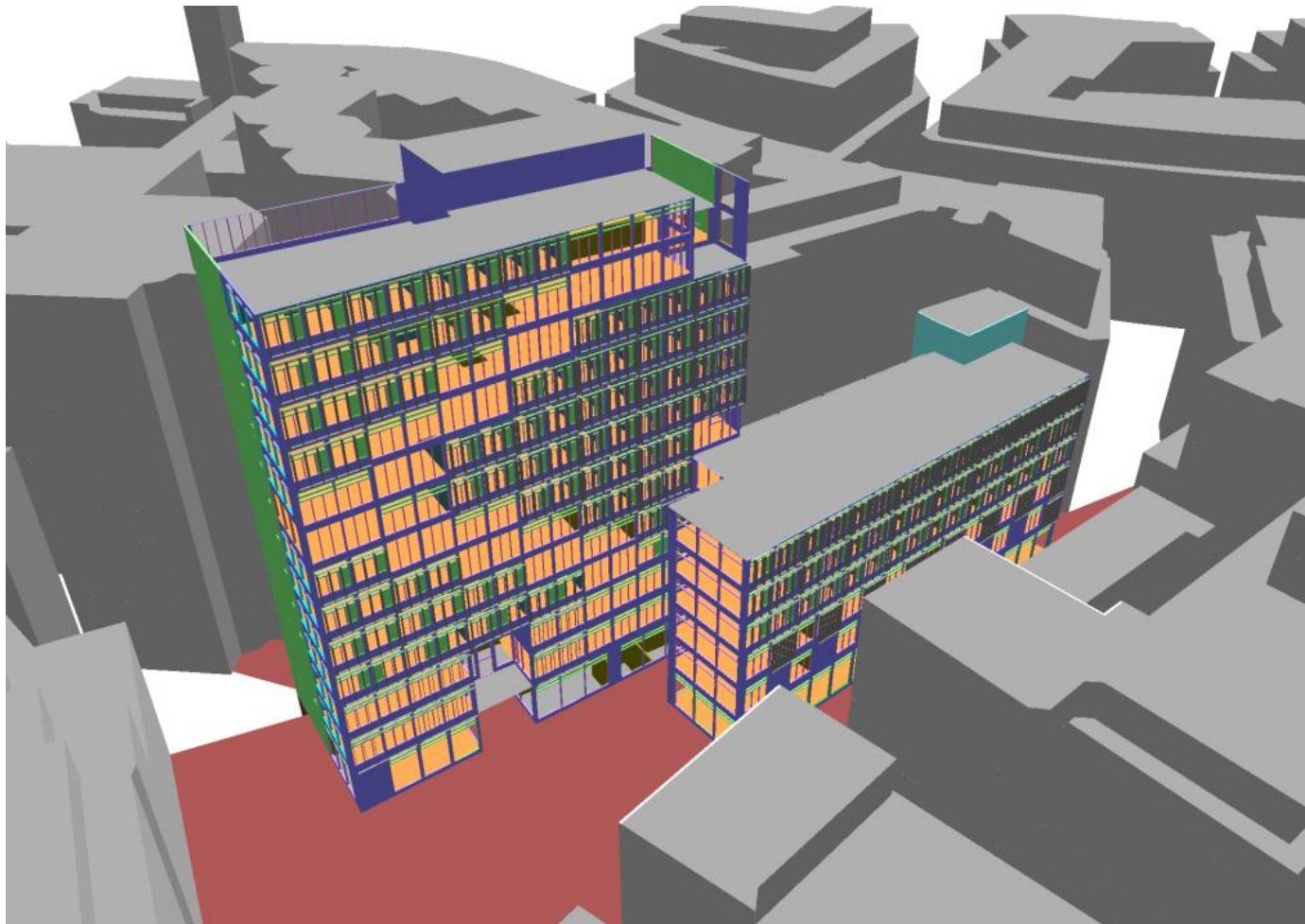


**Engineering perspectives**





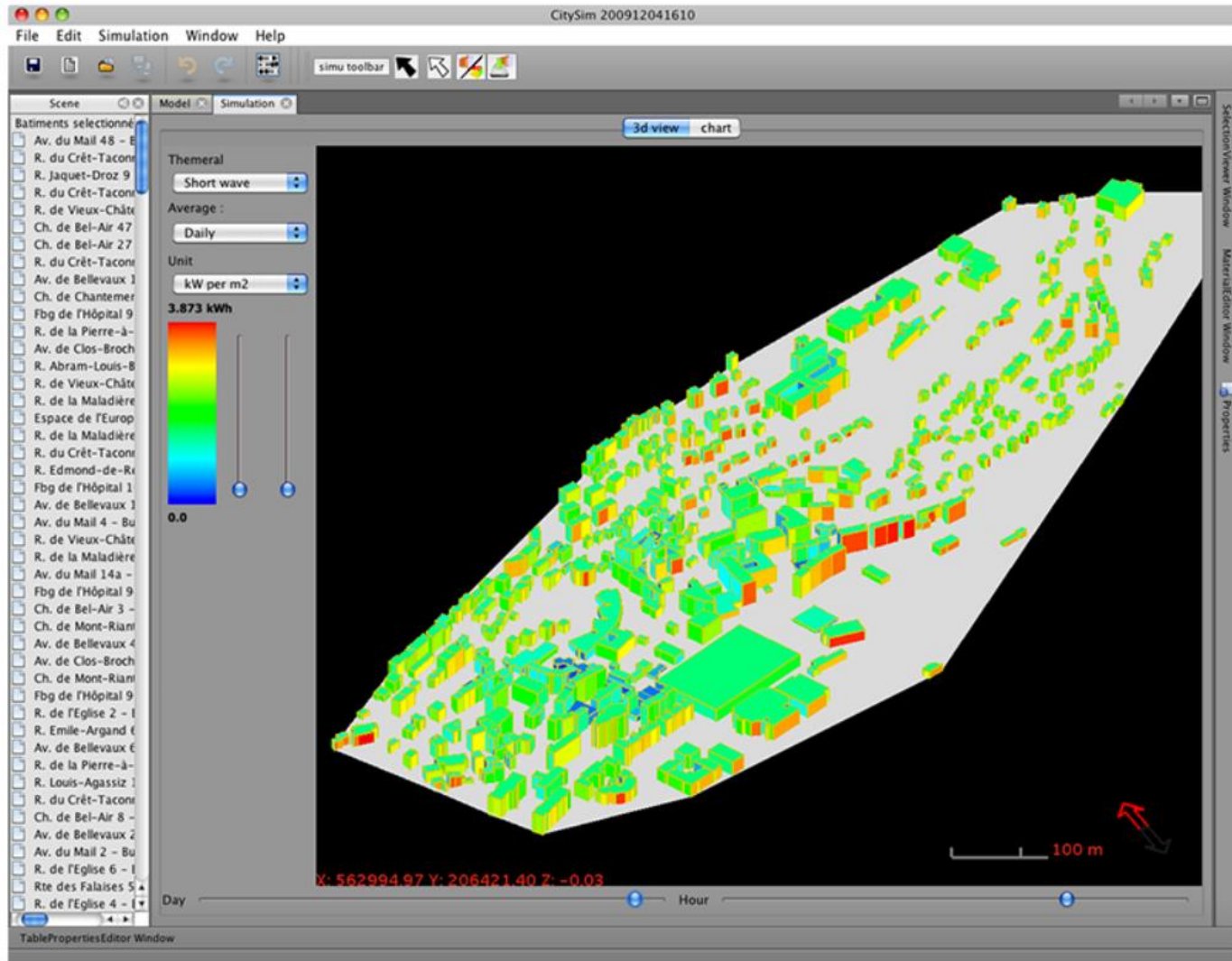
**BUILDING LEVEL:** Dynamic Thermal Modelling; Daylighting; CFD ...



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):

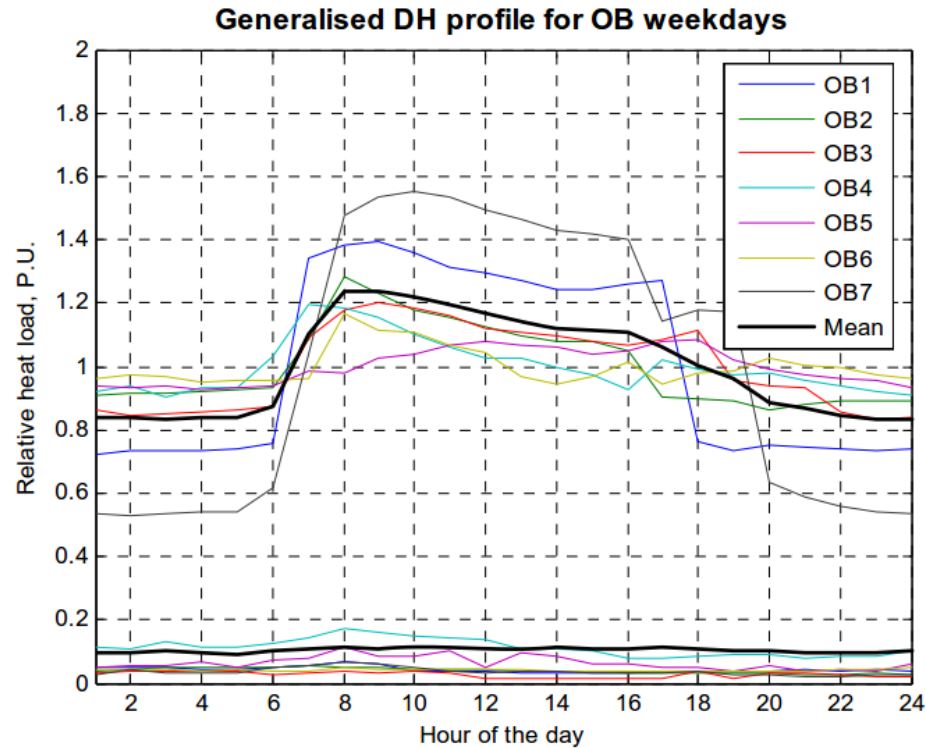
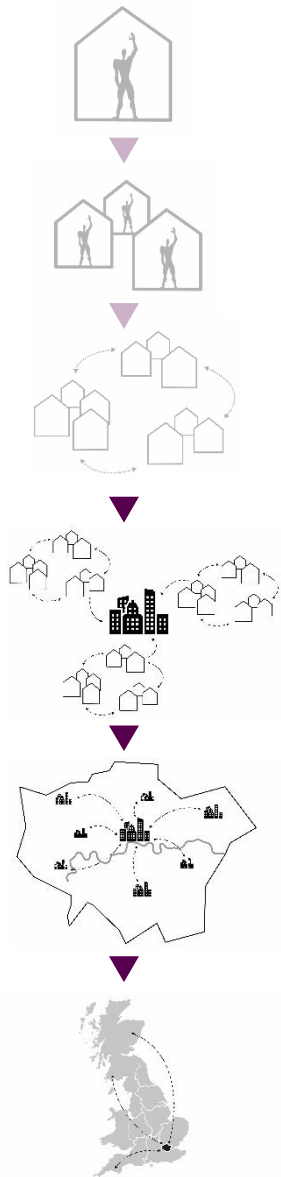


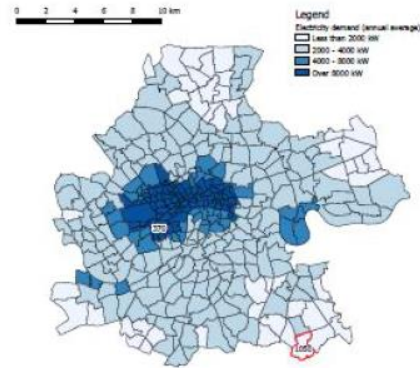
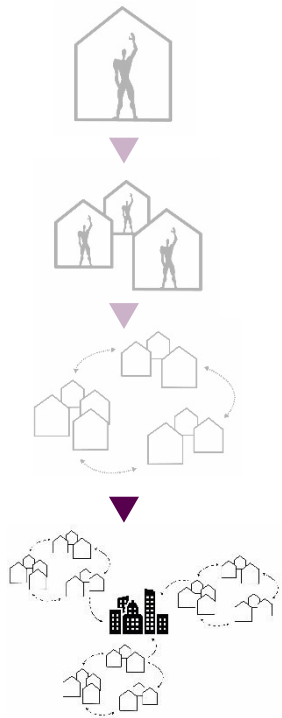
Figure 6.15 Relative design heat load profiles for office buildings, including the generalised heat load profile and relative standard deviation.

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

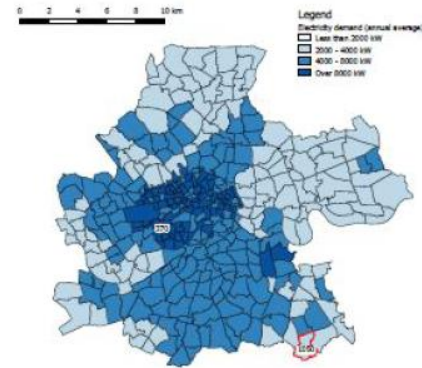




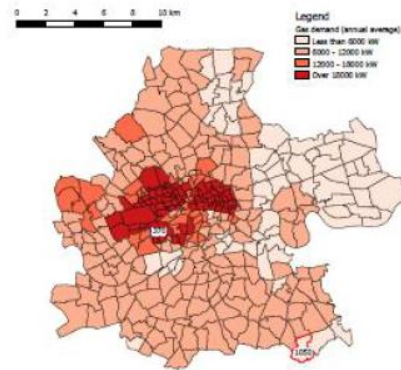
## District & City Models (incorporating agent-based modelling):



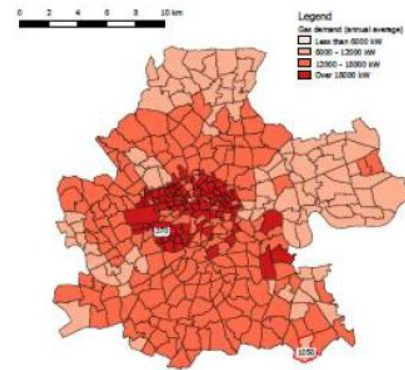
(a) Observed demand (electricity)



(b) Simulated demand (electricity)



(c) Observed demand (gas)



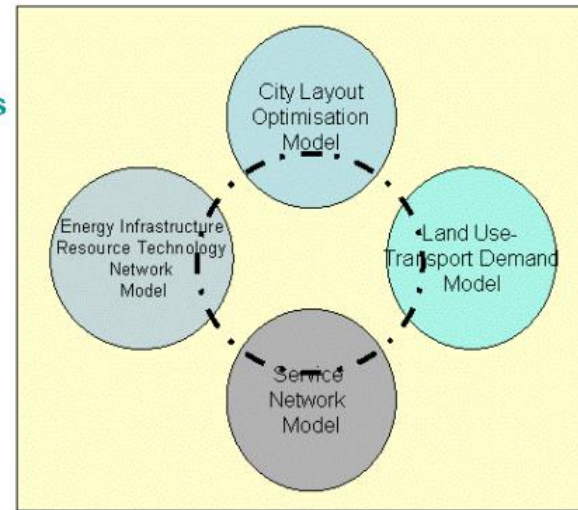
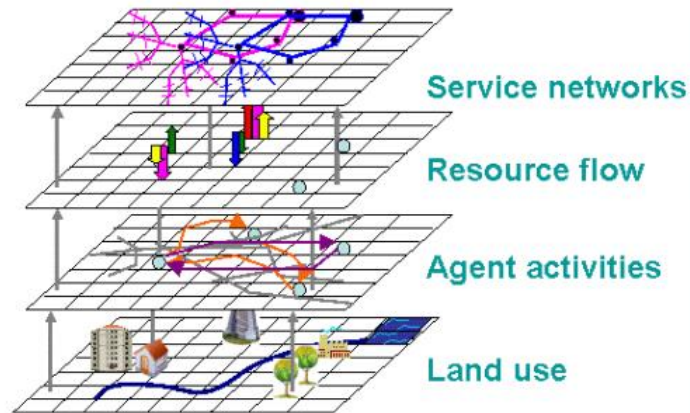
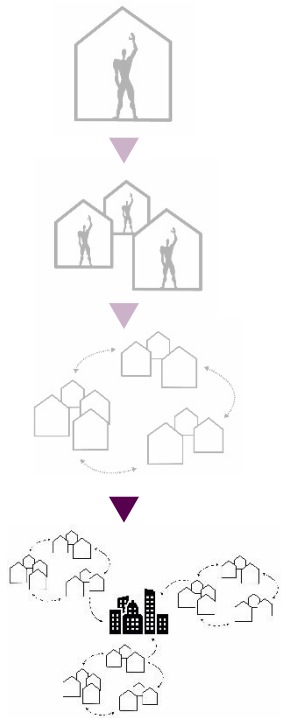
(d) Simulated demand (gas)

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





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

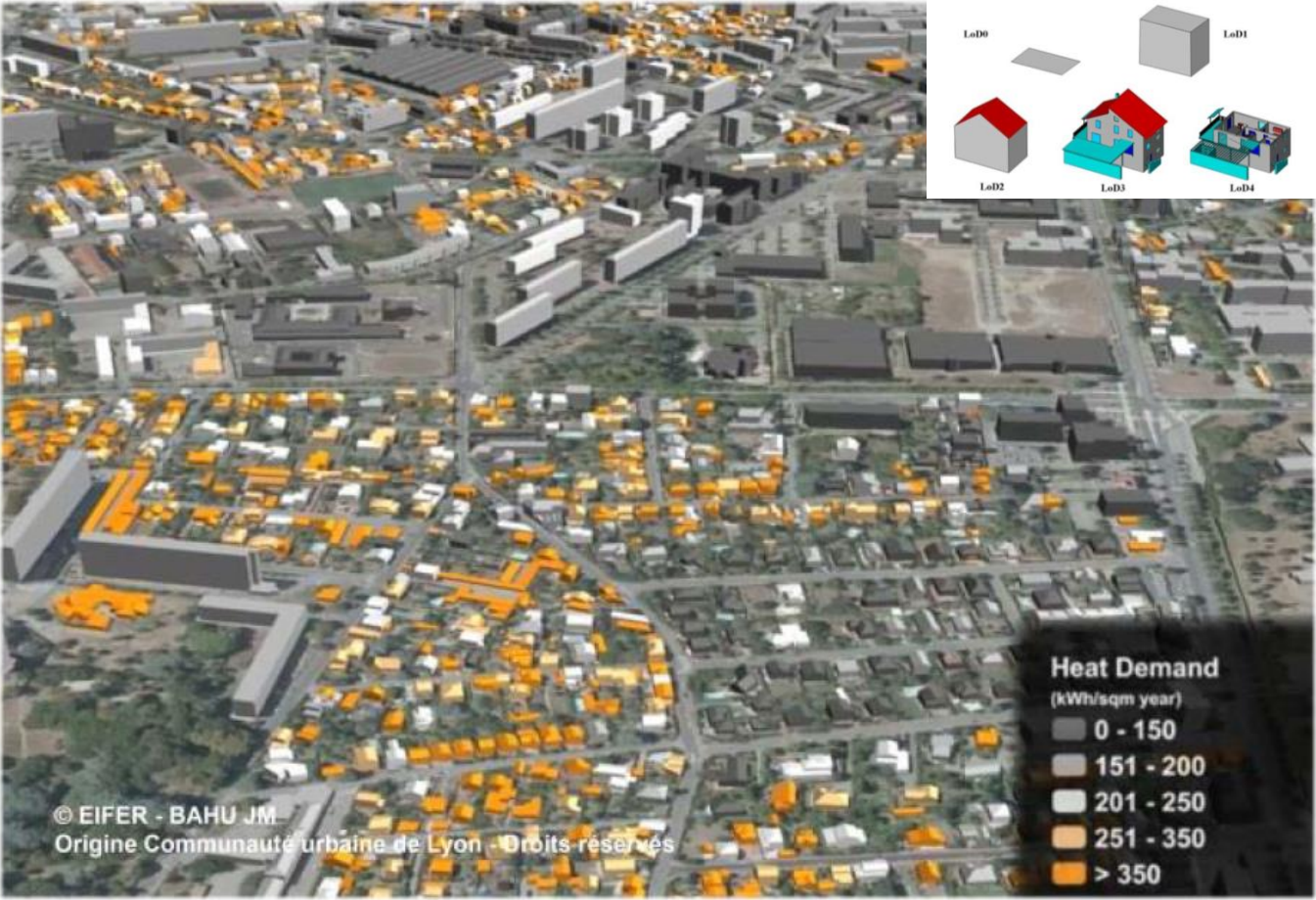
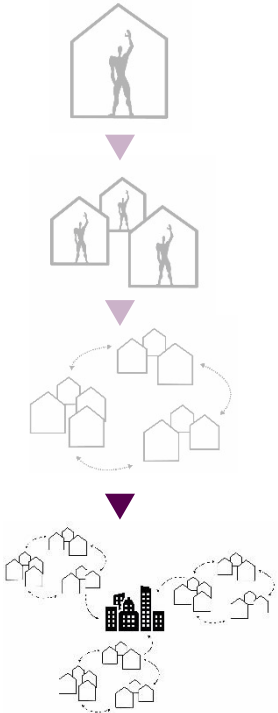


- **A hardware or software system that exhibits the following attributes:**
  - **Autonomous:** operates without requiring interventions;
  - **Social ability:** interacts with others;
  - **Reactivity:** responds to (changes in) its environment;
  - **Pro-active:** can exhibit goal-driven behavior.

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



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

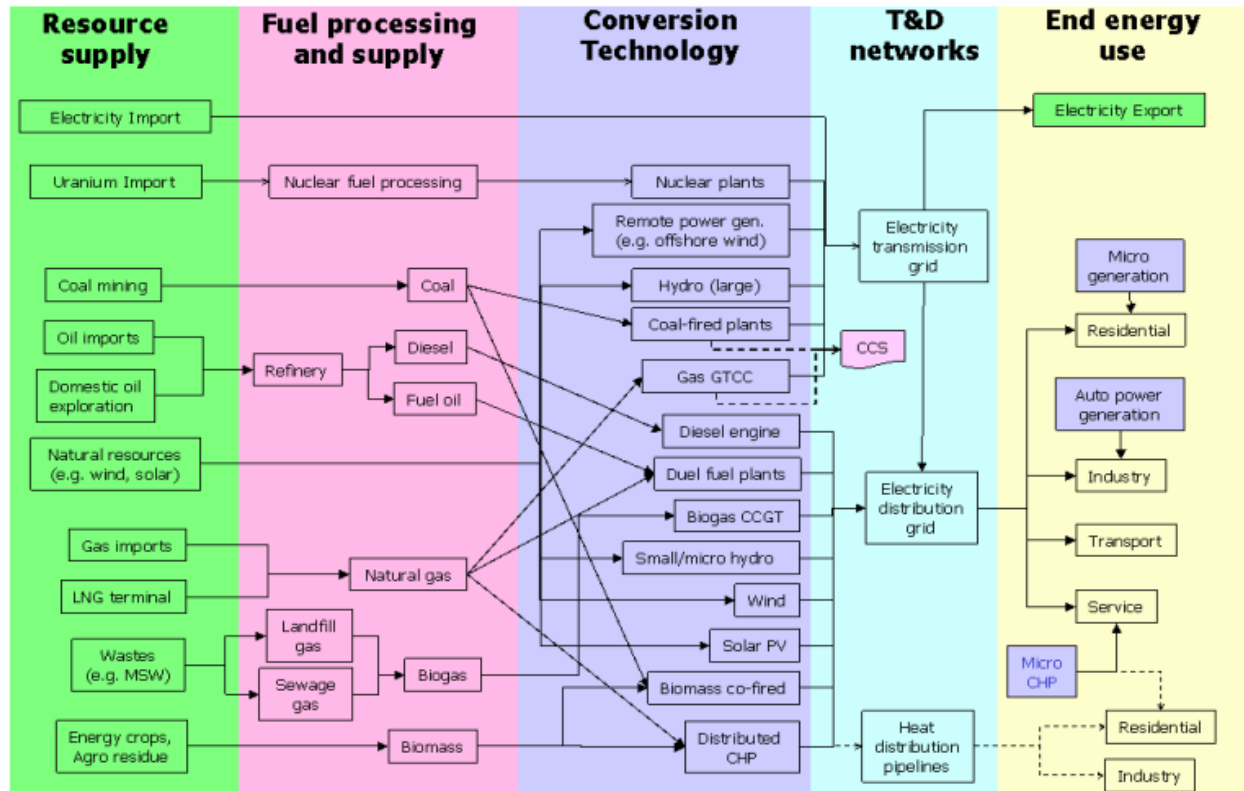


Source: EIFER



## 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

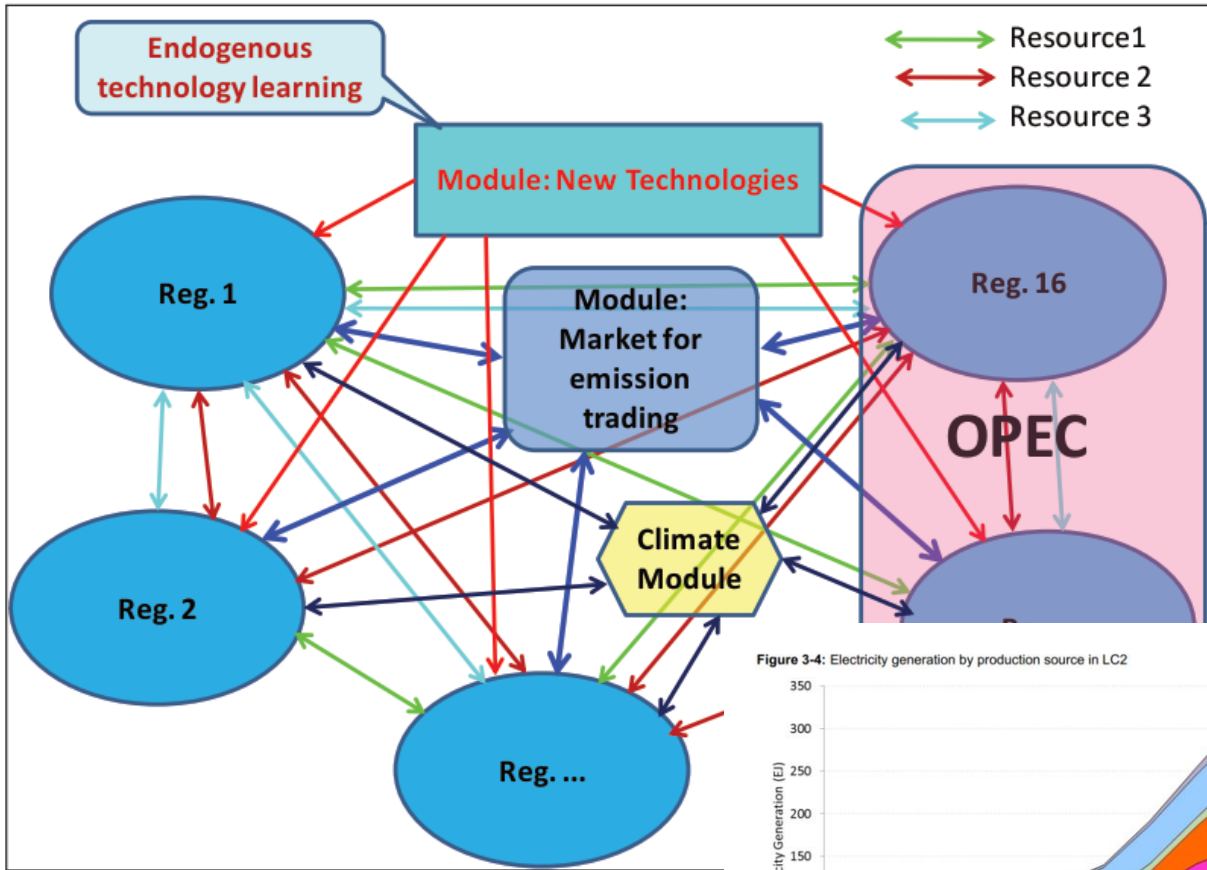
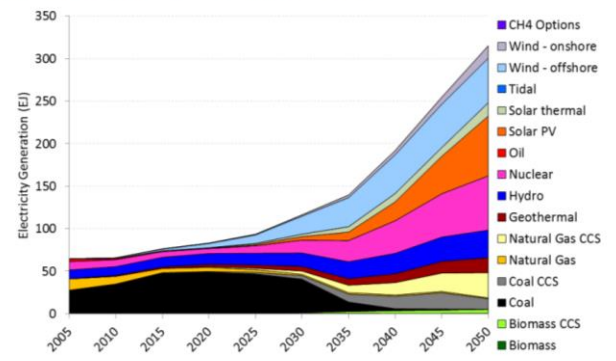


Figure 3-4: Electricity generation by production source in LC2

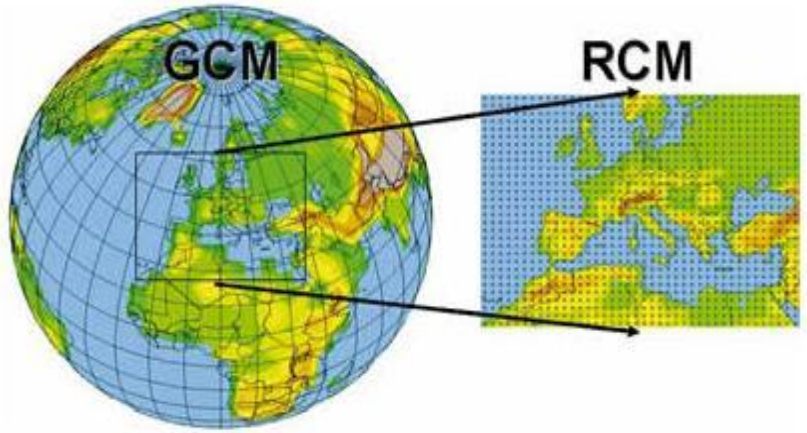
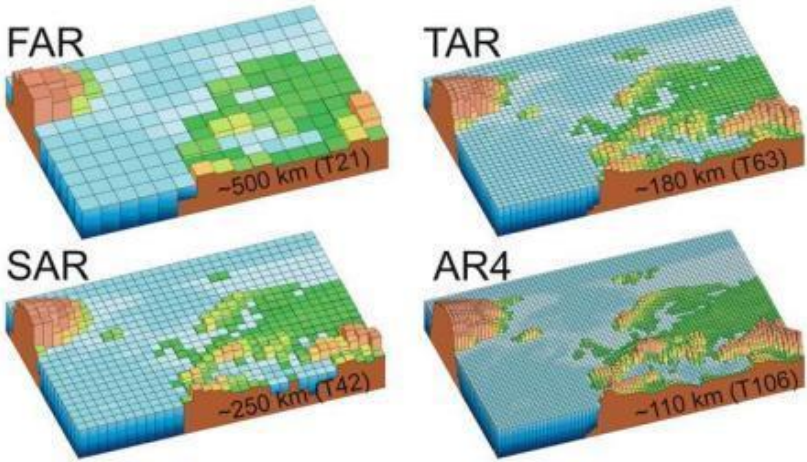


Source: TIAM-CFL, Global Energy Scenarios, UCL Energy Institute (2013)





# GLOBAL MODELS: WMO/IPCC



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



**Architectural perspectives**



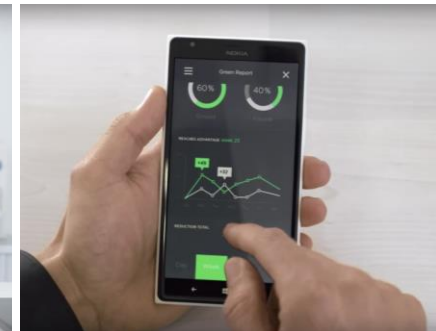
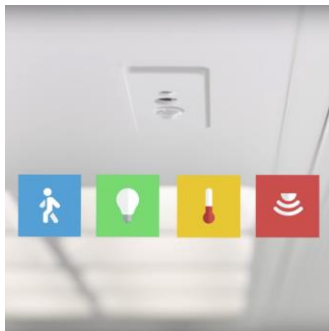
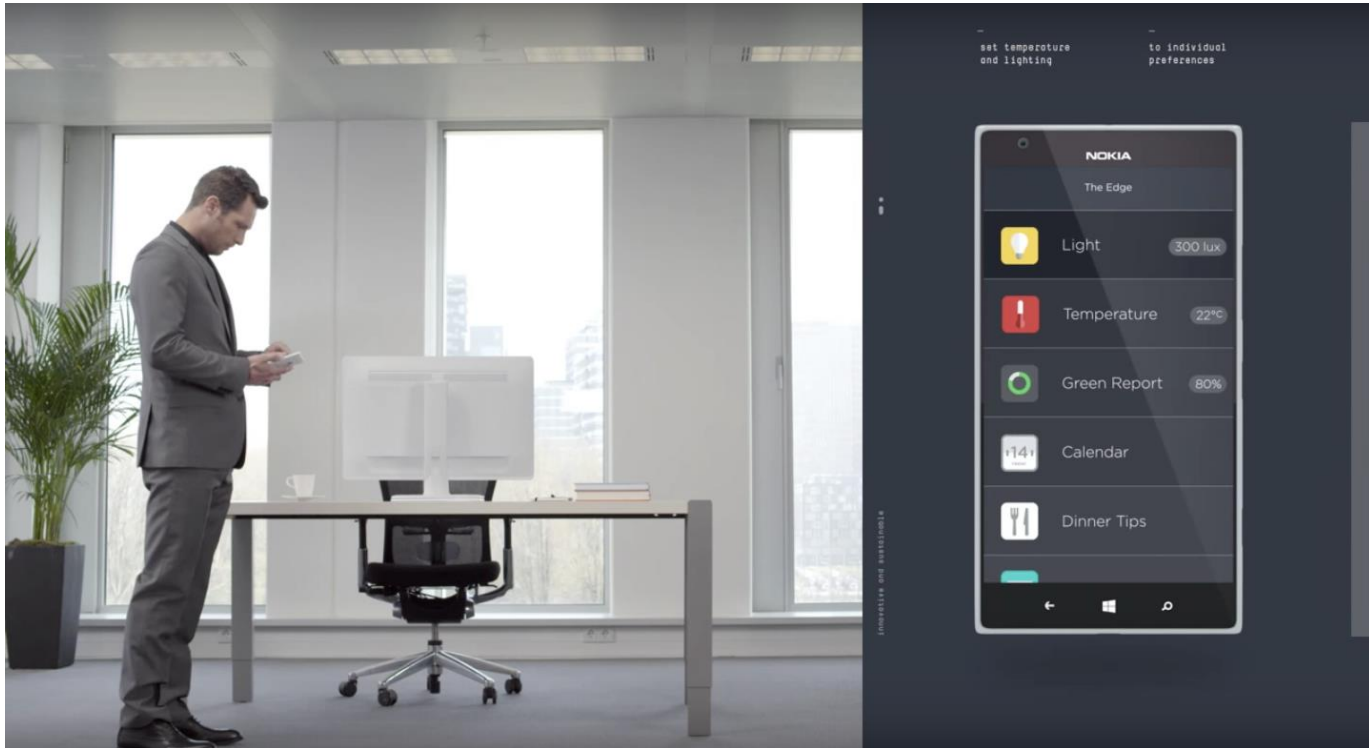


**NEW APPROACH: The Edge – Amsterdam (NL) – PLP Architects**



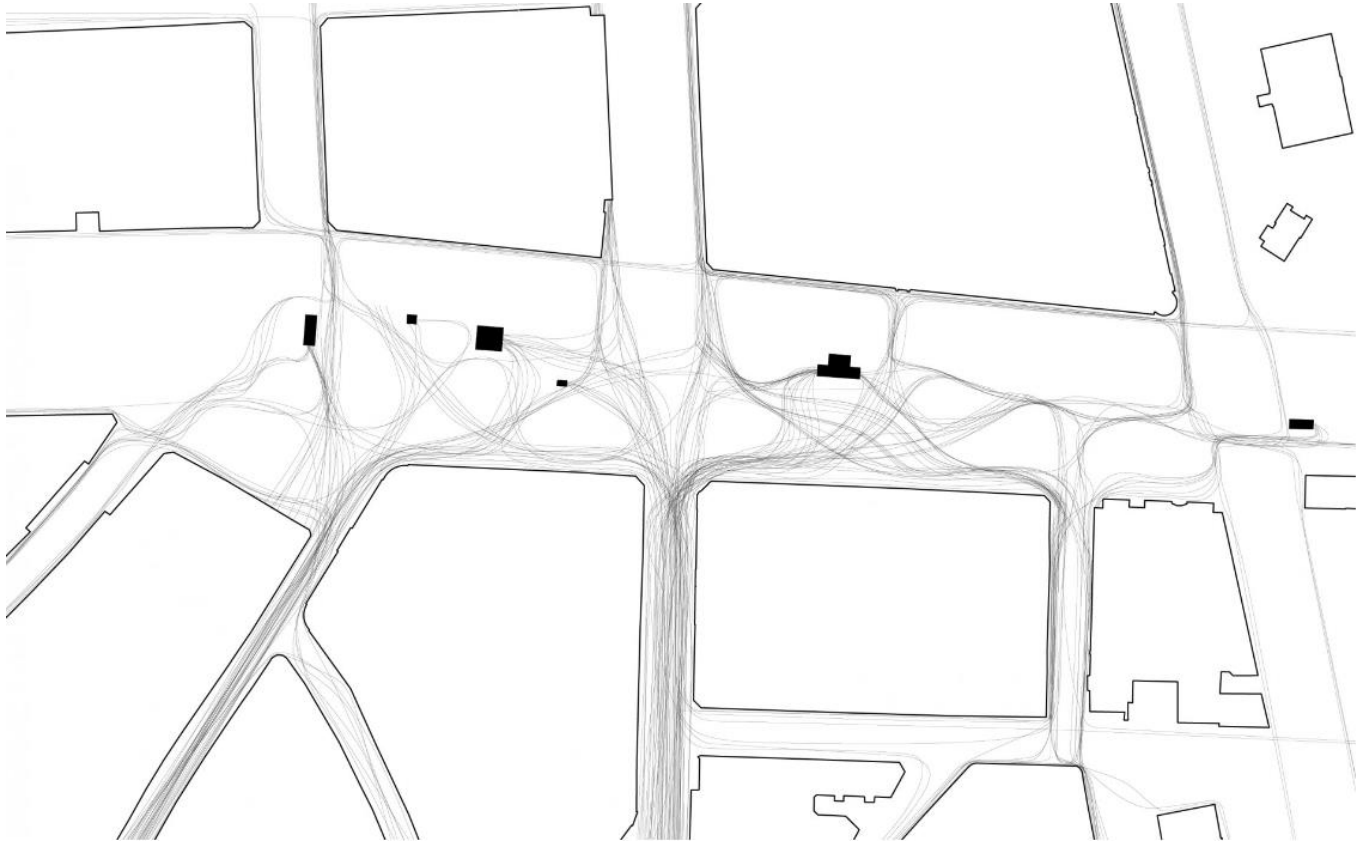
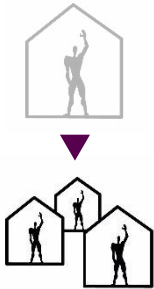


## NEW APPROACH: The Edge – Amsterdam (NL) – PLP Architects

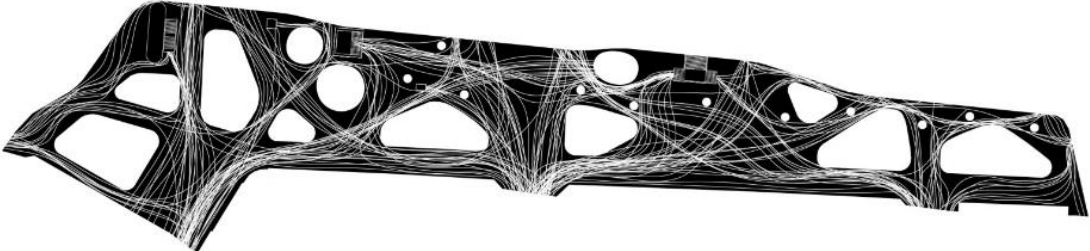
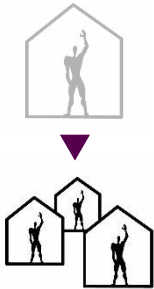




**NEW APPROACH: Norreport Station – Copenhagen (DK) – COBE Architects**



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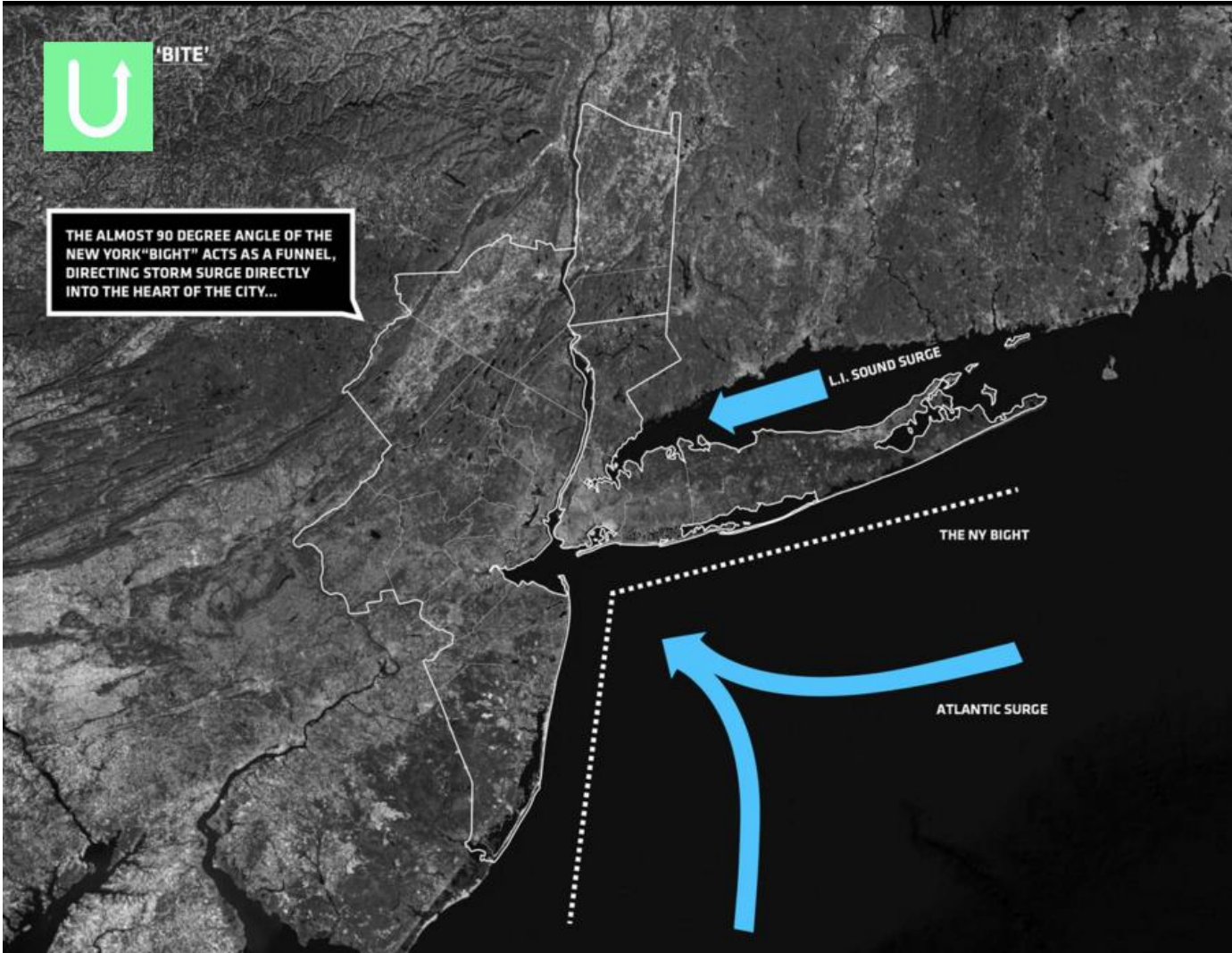
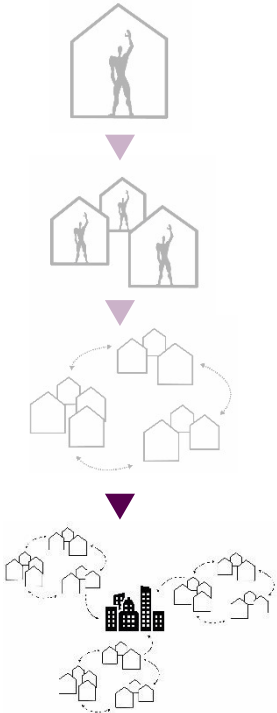


# NEW APPROACH: Little Denmark – Copenhagen (DK) – BIG Bjarke Ingels Group



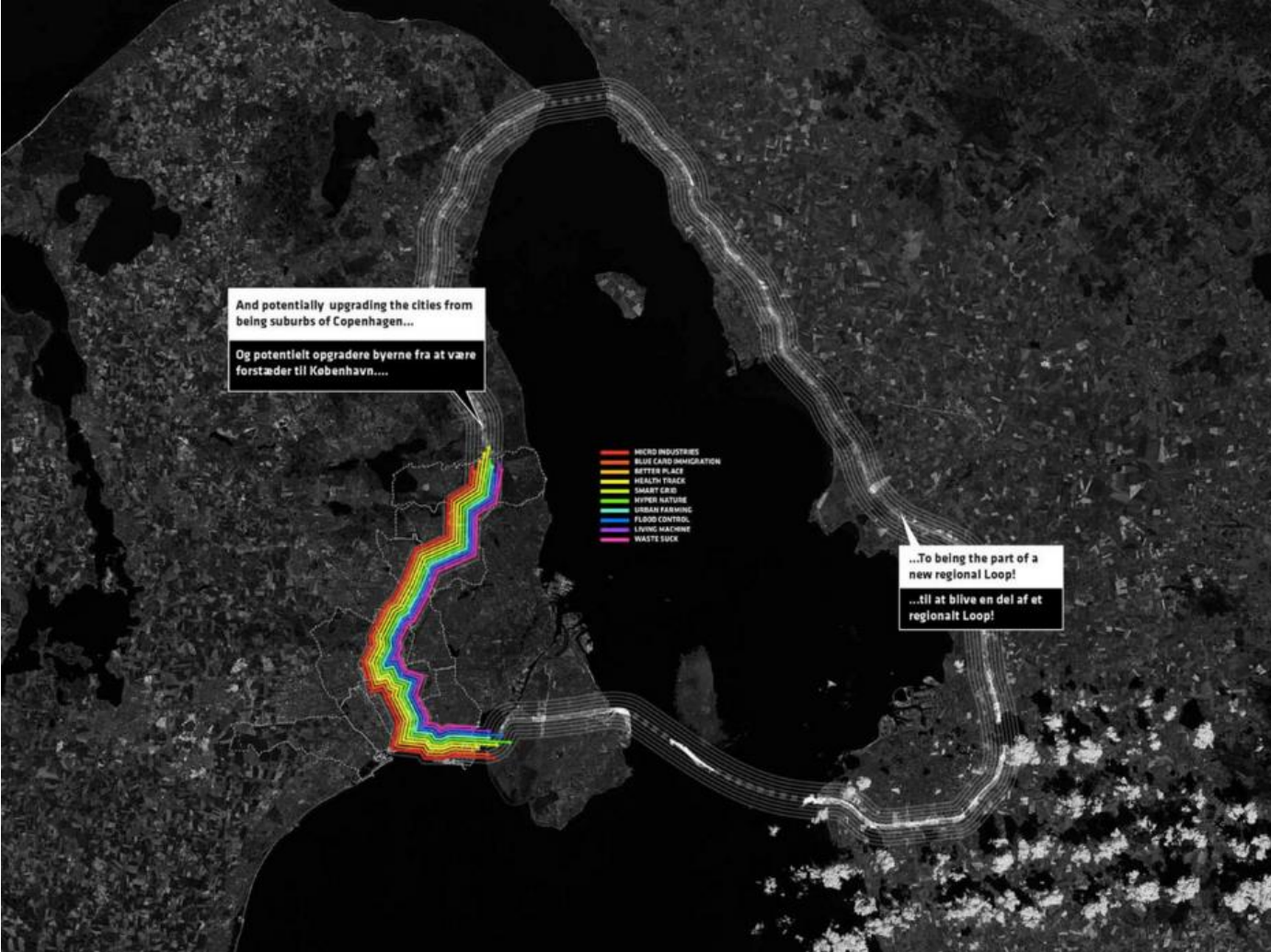


# NEW APPROACH: HUD the Dryline – New York (USA) – BIG Bjarke Ingels Group





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



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



## 10 TECHNOLOGY BETS 10 TEKNOLOGI BETS



### 2. ENERGY

**THE SMART GRID**  
The Smart Grid delivers electricity from suppliers to consumers using two-way digital technology to control appliances at consumers' homes to save energy, reduce cost and increase reliability. In a future energy system based on renewables the Smart Grid helps reducing the gap between produced and consumed energy.

**DET INTELLIGENTE NETVÆRK**  
Et smartnet leverer elektricitet fra leverandør til forbrugeren via en 2-vejs digital teknologi, med det formål at kunne styre apparater hos forbrugeren for at spare energi, reducere forbrug og øge pålideligheden i systemet. Det smartnet gør det muligt at reducere forbrugsmønstre gennem dagligt og dermed reducere den store forskel mellem forbrug og produktion af elektricitet.

### 1. MOBILITY

**ELECTRIC CAR INFRASTRUCTURE**  
Better Place aims to reduce global dependency on petroleum through the creation of a market-based transportation infrastructure supporting electric vehicles. Better Place is building its first electric vehicle network in Israel, and among its partners has selected Denmark and Hawaii as the other two test markets due to their similar size. The electricity needed will be generated by renewable energy from solar arrays and wind farms.

**INFRASTRUKTUR TIL ELEKTRISKE BILER**  
Better Place sigter med at reducere global afhængighed af olie ved at skabe en markedsstyret infrastruktur af opladingsstationer for elektriske biler. Better Place er i gang med at bygge det første netværk i Israel og har udvalgt Danmark og Hawaii som de to næste test-markeder. Elektriciteten til bilerne vil være grøn, nemlig energi genereret fra vindmøller, solceller og biogas.



### 3. WASTE

**THE BIG SUCK**  
The Pneumatic Refuse Conveying System is a type of waste disposal system that uses air to move refuse through pipes to collection points. Refuse is conveyed through steel pipes by a 20-25 meter per second air current. The Automated Vacuum Collection (AVC) system, transports waste at high speeds through underground tunnels to a building where it is compacted, sealed in containers and then carted away.

**DET STORE SUK**  
Det Automatiske Affaldsug er en type affaldshåndtering som bruger luft til at løfte affald gennem rør til centrale opsamlingssteder. Affaldet flyttes med 20-25 meter per sekund gennem underjordiske rør, og kan opsamlere fra både offentlige rum, butikker og huse. Systemet muliggør en øget grad af affaldsortering og dermed større effektivitet i udryddelsen af affald til genbrug og korrekt forvaltning.

### 4. WATER

**LIVING MACHINES**  
Living Machine is a brand name for a form of biological wastewater treatment designed to mimic the cleaning functions of wetlands. They are intensive bioremediation systems that can also produce beneficial by-products such as edible and ornamental plants, and fish. In temperate climates, the system of tanks, pipes and filters is housed in a greenhouse to raise the temperature, and thus the rate of biological activity.

**BOODZONANLÆG**  
Living Machines er et behandlings- og et firma specialiseret i at bygge anlæg til biologisk spildevandsrensning. Anlæggene er designet til de genskaber de naturlige processer der foregår i vådområder. Systemet kan være både stort og småt og anvendes til huse og virksomheder. Systemet består af tankene, rør og filtre som er placeret i et drivhus for at øge effektiviteten af den biologiske aktivitet.

### 6. BIODIVERSITY

**ENGINEERED WETLANDS**  
Engineered wetlands are artificial wetlands, marsh or swamps created as new or restored habitat for native and migratory wildlife. Additionally they are suitable for anthropogenic discharge such as wastewater, stormwater runoff, or sewage treatment. Natural wetlands act as a biofilter, removing sediments and pollutants such as heavy metals from the water, and constructed wetlands can be designed to emulate these functions.

**KONSTRUERTE VÅDOMRÅDER**  
Konstruerede vådområder er kunstige vådområder, søer eller mose, skabt dels for naturlige vandrensningseffekter, dels for at give stedspecifik og økologisk biodiversitet. Områdene tiltrækker frugt og søde frugter og er populære ynglesteder for fugle. De er ligeledes anvendelige til at absorbere overskydende fra kloak og regnvand. Vådområder fungerer som et naturligt bio-filtre der kan fjerne både fosfor og jern og fjerne tungmetaller fra spildevand.

### 5. GLOBAL WARMING

**CONSTRUCTED LAKES**  
During 8 hours of heavy rainfall in the development areas of the ring, it rains enough to fill a lake of 25 HA, or 250.000 M3 in 1.5 meters depth. Combined with constructed wetlands, a strategy of artificial lakes could greatly improve the quality of recreational space in the green areas, while absorbing the increasingly frequent heavy showers. At the same time the new lakes could reduce stress on the run-down sewage system of the city.

**CONSTRUCTED LAKES**  
I løbet af 8 timers kraftigt regnvejr over udviklingsområderne falder der nok vand til at fylde en sø på 25 hektar eller 250.000 M3 på 1,5 meters dybde. En strategi for nye kunstige søer ville både kunne absorbere fremtidige regnsky og booste de rekreative kvaliteter i de grønne områder. Samtidig kan søerne reducere belastningen og dermed energiforbruget på kloaknettet.



### 10. MIGRATION

**THE BLUE CARD**  
The European Union facing a ticking age bomb, says it will need 20 mio skilled workers during the next 20 years. The European version of the American Green Card. The blue Card, could be one of many strategies to attract a skilled young work force. Others include improved regional infrastructure.

**THE BLUE CARD**  
EU står over for en tilvækst alderenskrise og vil få brug for 20 mio nye uddannede inden for de næste 20 år. Den europæiske pendant til det amerikanske Green Card. The Blue Card vil være et af mange tiltag for at tiltrække ung arbejdskraft. Andre muligheder er forbedret regional infrastruktur.

### 8. HEALTH

**THE BICYCLE**  
Denmark and Holland are the countries in EU with the highest use of bicycles as transport form. In dense, flat urban areas the bicycle not only provides fast, reliable and sustainable transport, but also improves public health. We propose to upgrade bicycle infrastructure with smart systems for traffic light control, close integration with the light rail bicycle paths leading to the platforms) and service stations at strategic points. All combined in a new Health Track raising the full height of the Loop.

**THE BICYCLE**  
Danmark og Holland er de to lande i EU med det højeste brug af cyklen som transport form. I tætbefolkede byer anvendes cyklen optimalt som hurtig, sikker og bælværdig transportform. Samtidig forbedrer cyring befolkningens helbred. Vi foreslår at opgradere cykelinfrastrukturen med intelligente systemer til kontrol af trafiklys, strategisk placerede service stationer og tæt integrering med letbaner i byens trafiknet. Alt sammen kombineret i en ny form for mikroadfarter.

### 7. RE-INDUSTRIALIZATION

**MICRO-FACTORIES**  
"The tools of factory production, from electronics assembly to 3-D printing, are now available to individuals, in batches as small as a single unit. They can become a virtual micro-factory, able to design and add goods without any infrastructure or even inventory..."  
(Chris Anderson, Atom are the new bits)

**MICRO-FACTORIES**  
"Mikrofabrikker til industriel produktion, fra elektroniske montage til 3-D print, er nu tilgængelige for alle, i mængder så små som én enkelt enhed. Føle kan skabe virtuelle mikro-fabrikker, og designe og tilføje produkter uden infrastruktur eller lager..."  
(Chris Anderson, Atom are the new bits)

Can den danske tradition for industriel småproduktion genopstå i en ny form for mikroindustri?



### 9. FOOD

**URBAN FARMING**  
A second green revolution could not only solve the world's food shortage, but also reduce the dependency of polluting fertilizer and large scale farming, leading to a new explosion of diverse small scale productions. This could potentially change the production landscape around Copenhagen from the current mega farms, to a new kind of bio-tech micro productions integrated close to the urban fabric, and allowing for new nature areas in close relation to the city.

**URBAN FARMING**  
En 2. grøn revolution ville ikke bare løse den globale madmangel på mad, men også reducere afhængigheden af forurenende kunstgødning og intensivt drivhus mads landbrug. Dette kunne potentielt forandre produktionslandskabet omkring forogtjænen. De nævnte områder kunne landbrugs vil blive erstattet af en ny form for bio-tech småproduktioner integreret tættere på byen.



**NEW APPROACH: Network&Society – UK – MIT Senseable City LAB**



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

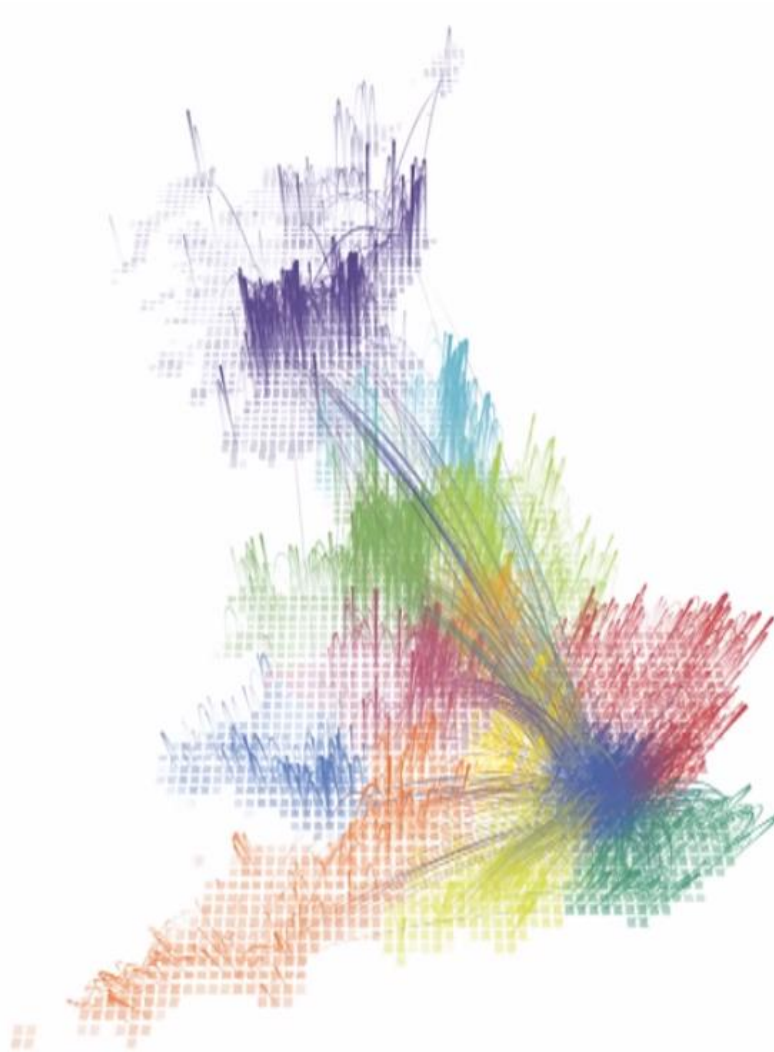
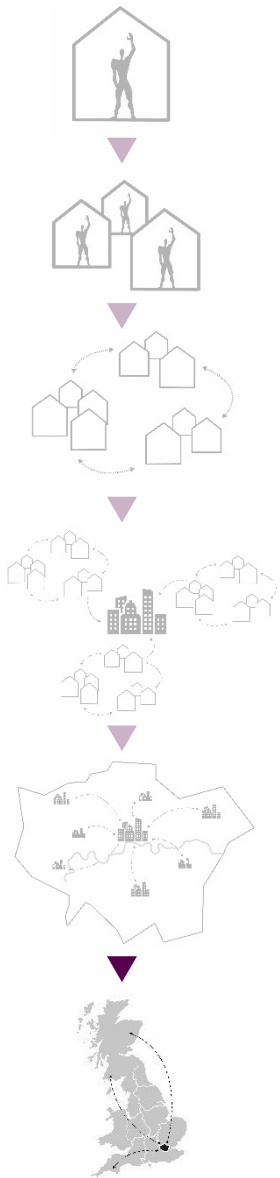
We call this the 'human network'.

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





# NEW APPROACH: Network&Society – UK – MIT Senseable City LAB



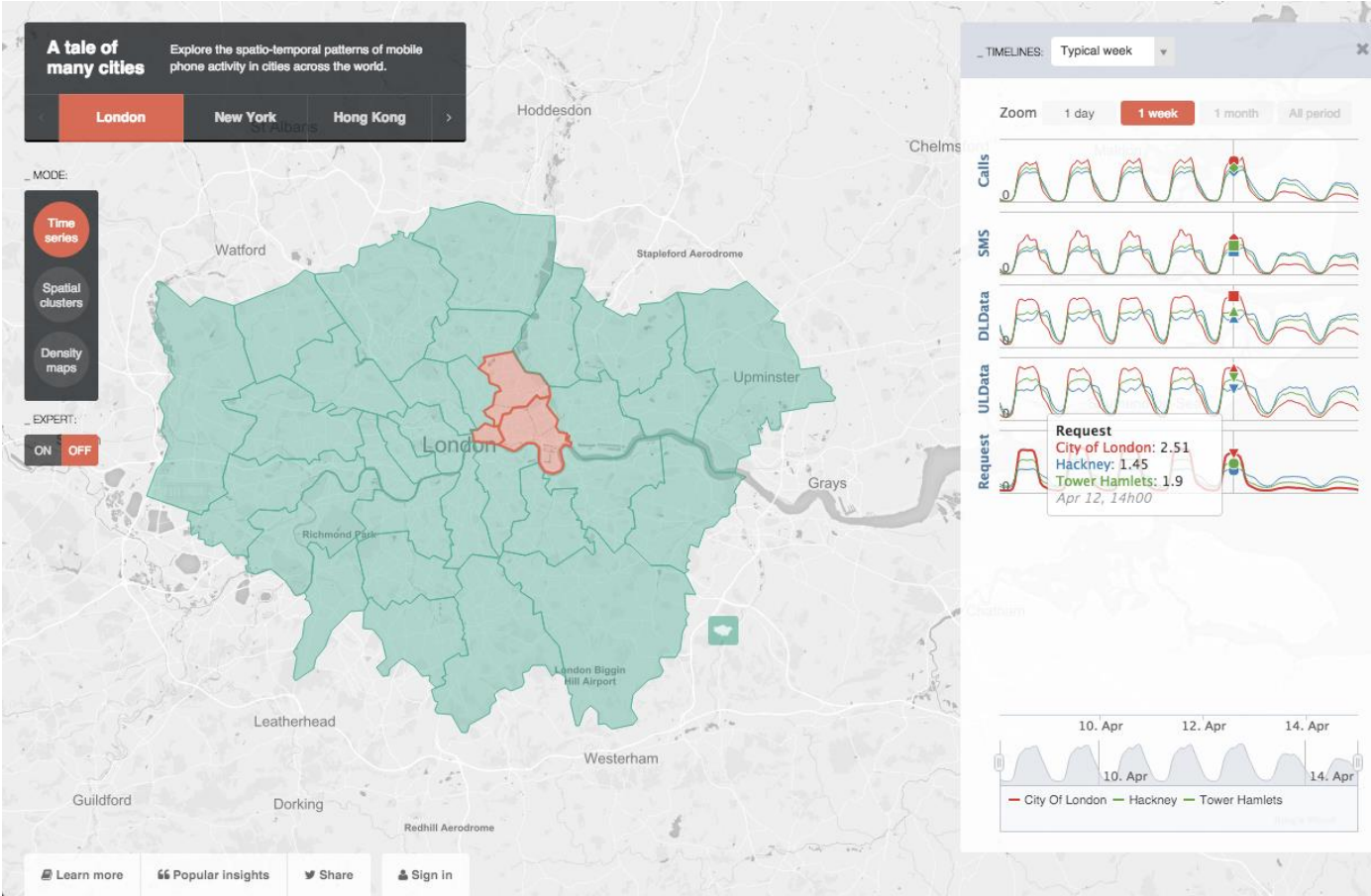
We call this the 'human network'.

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

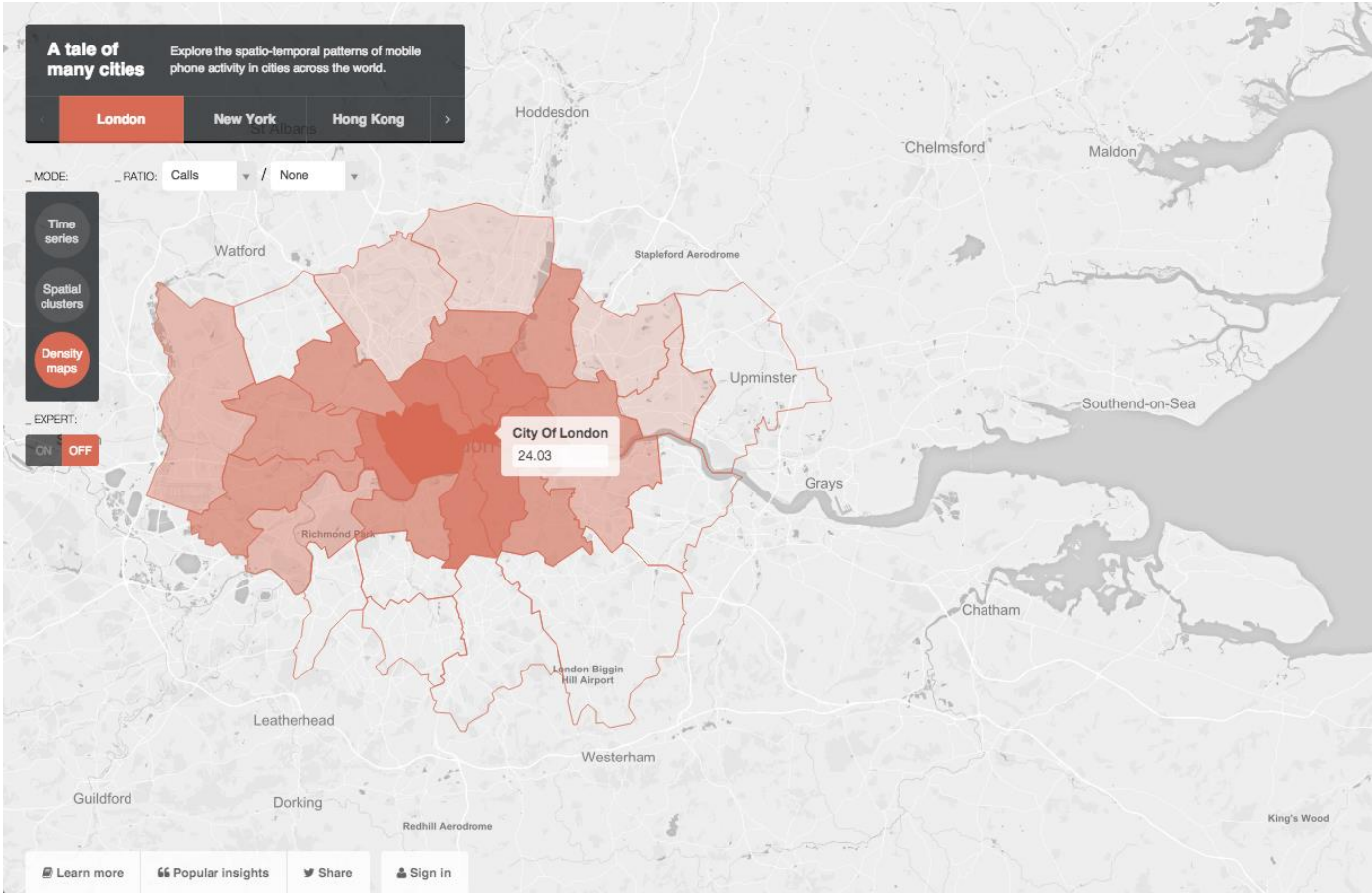
An algorithm is able to create the optimal partitioning



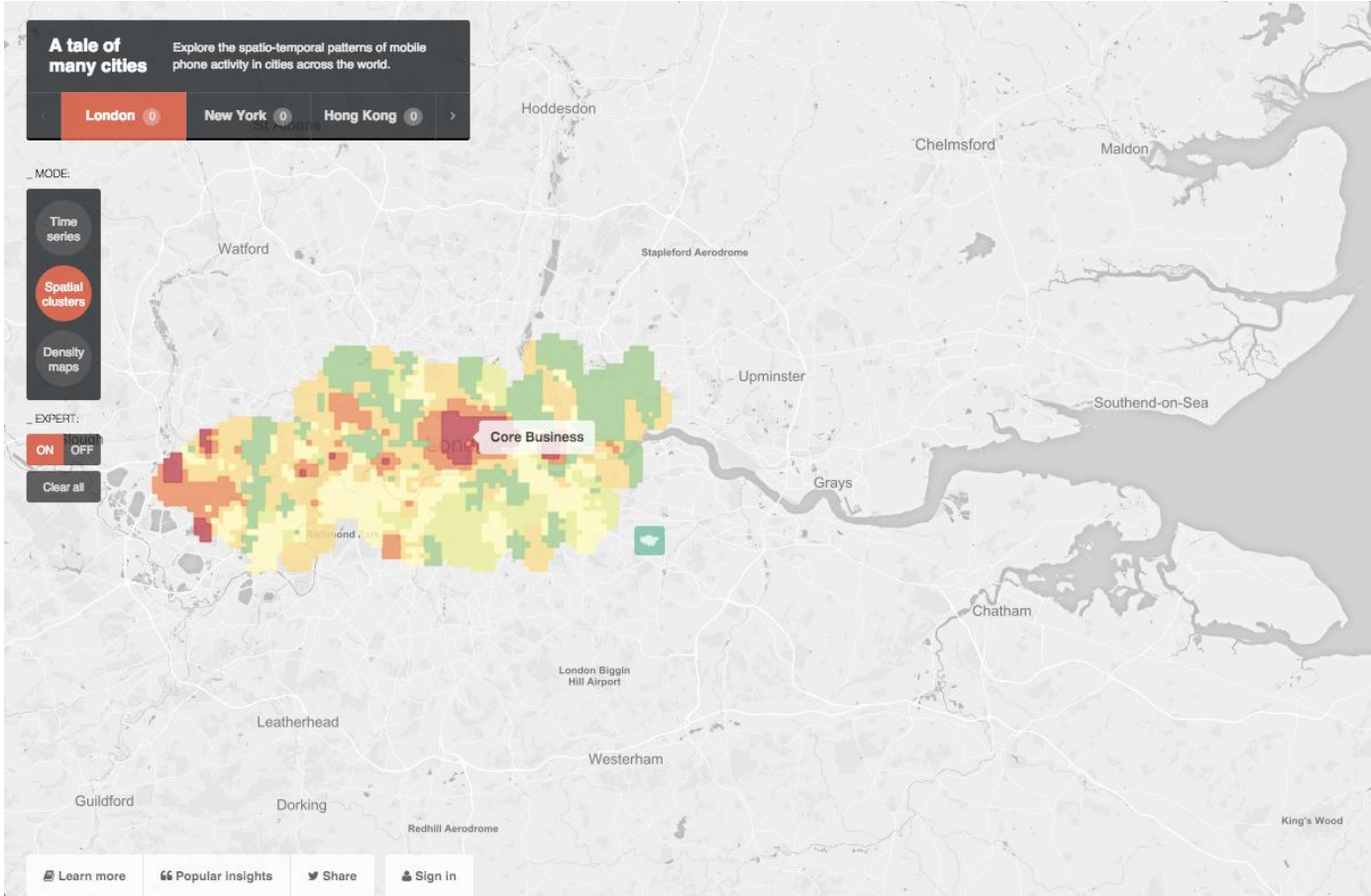
# NEW APPROACH: A Tale of Many Cities – MIT Senseable City LAB



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**Some experiences ...**

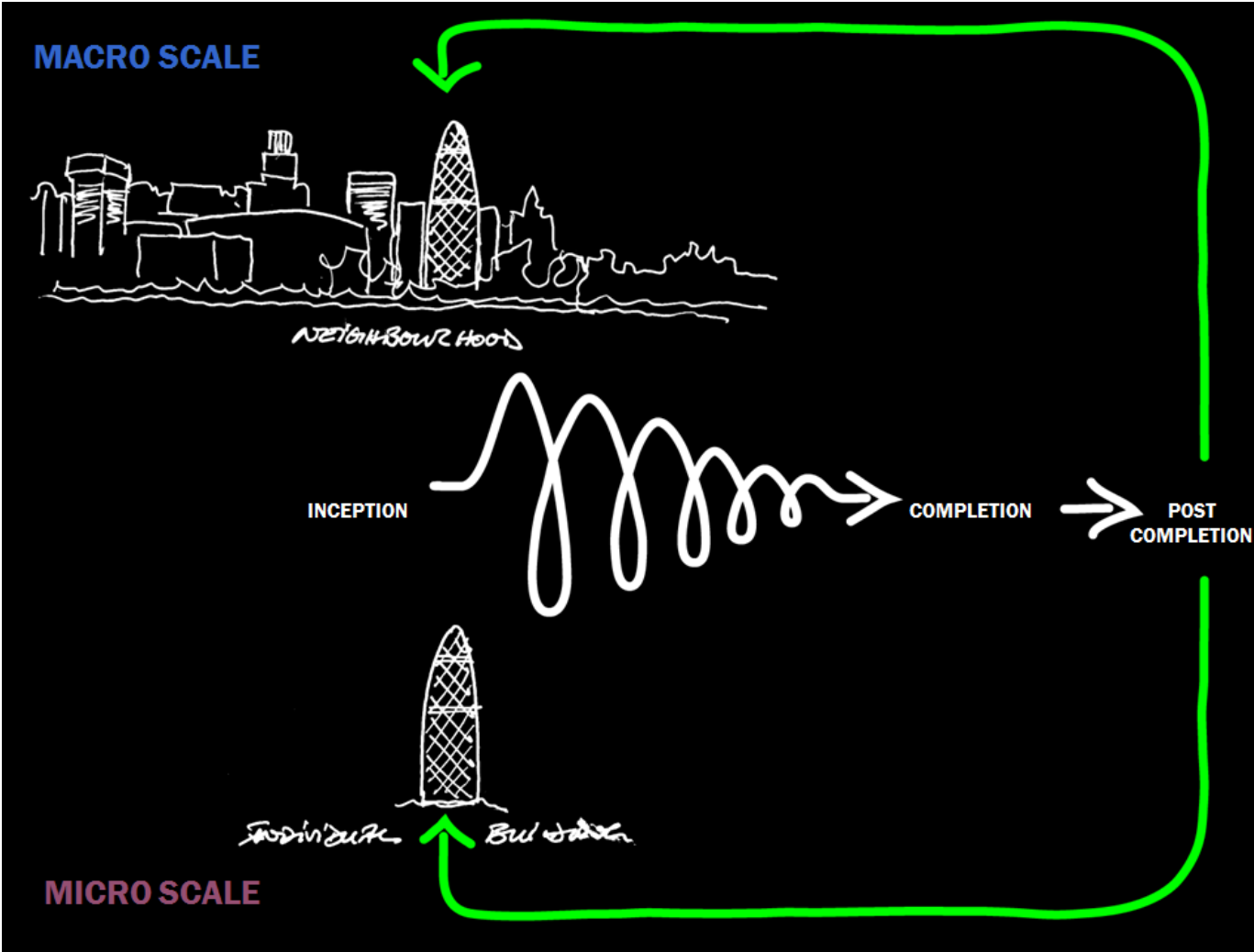




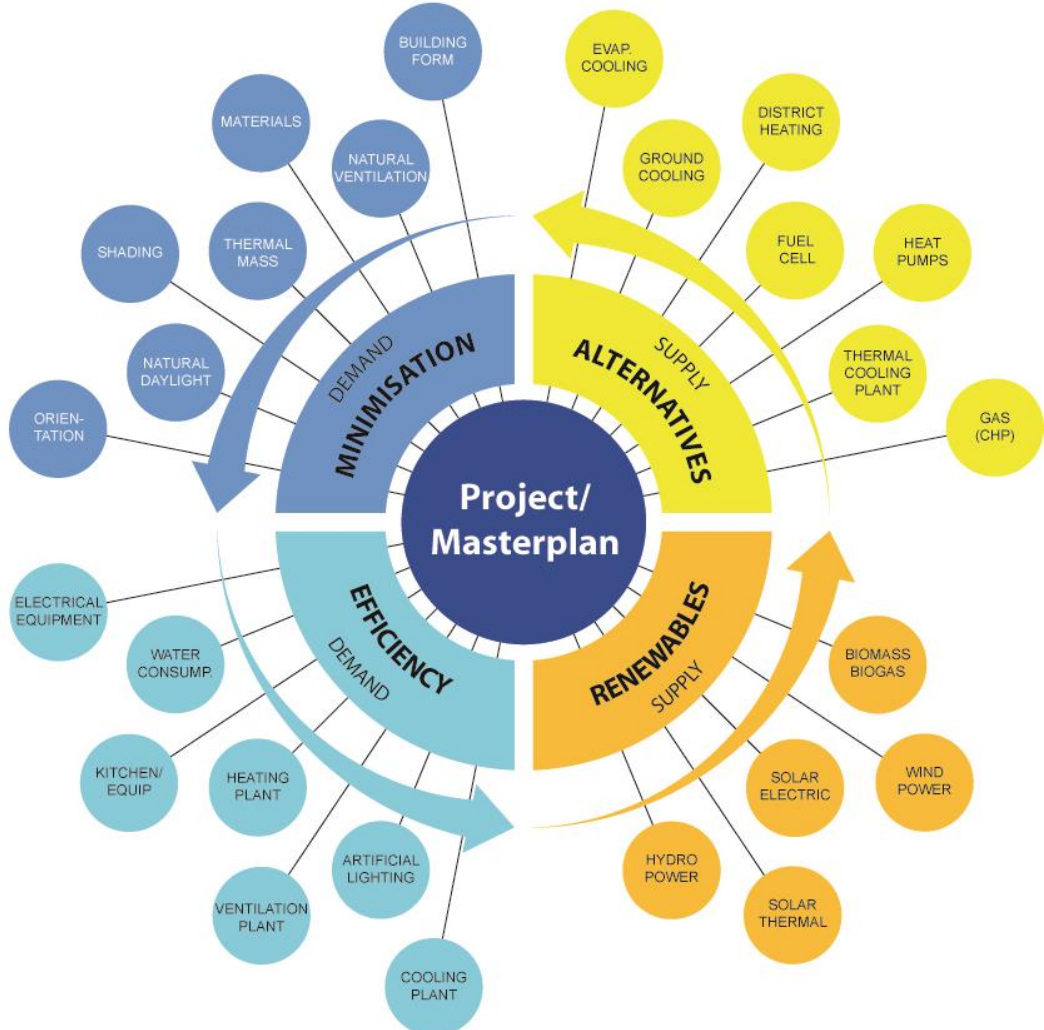
## The Scale of the Challenge (new city, old city ...)



**Concepts: Macro - Micro**

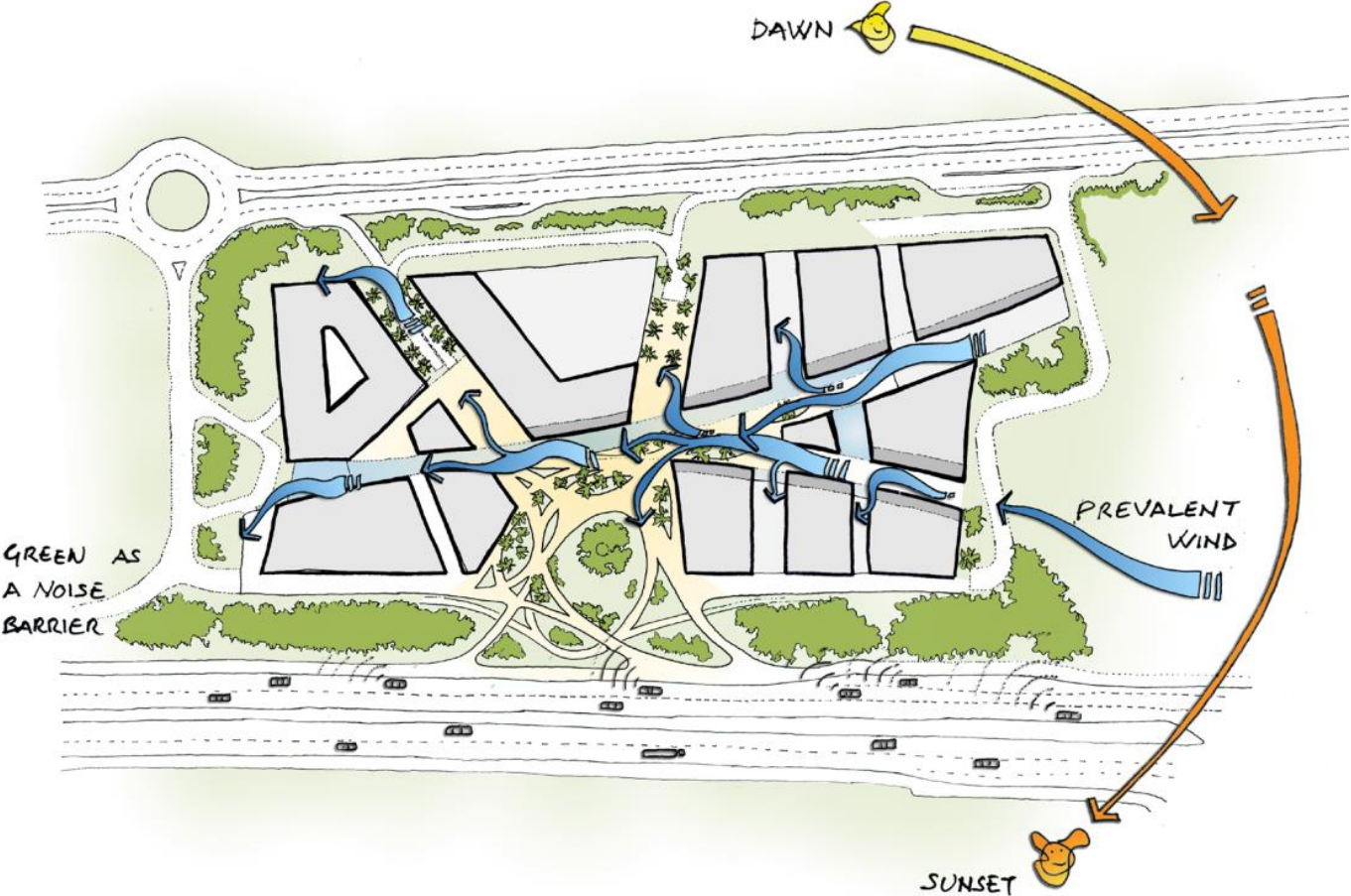


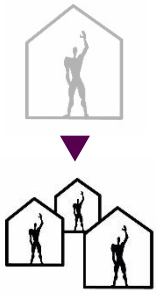
# Concepts: Environmental Design Methodology





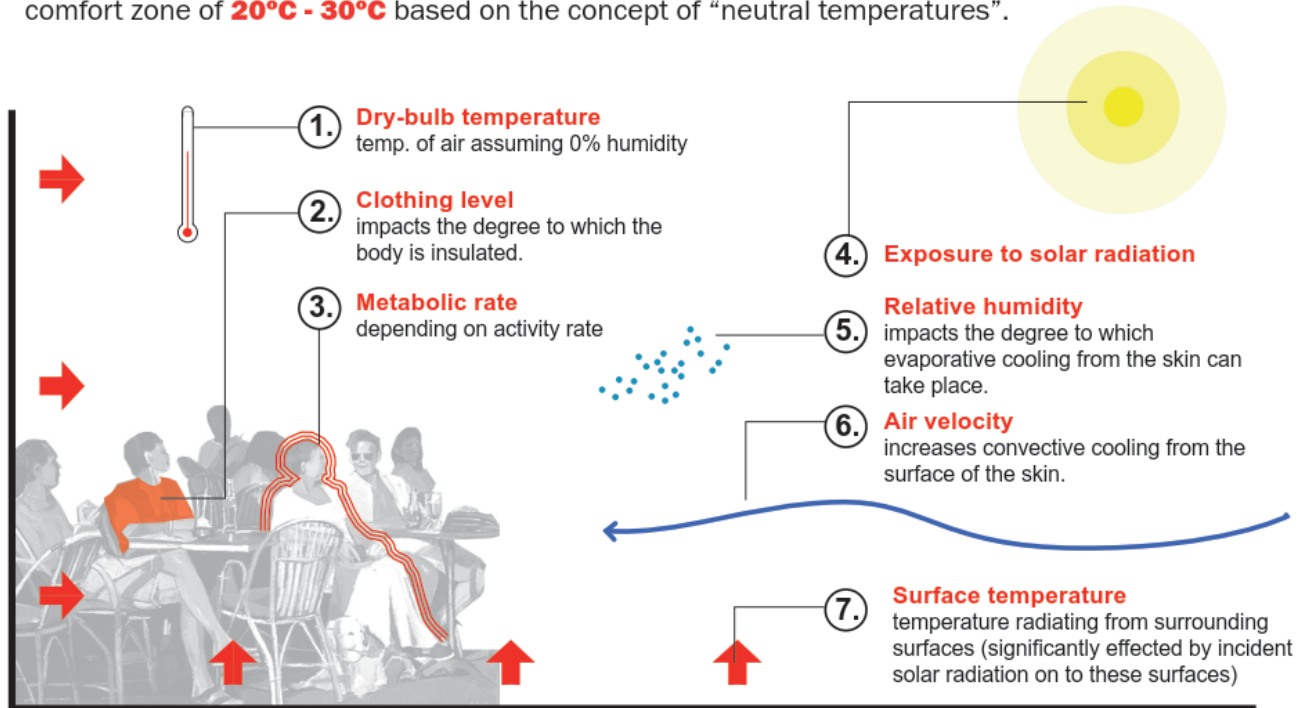
# Concepts: Site Analysis



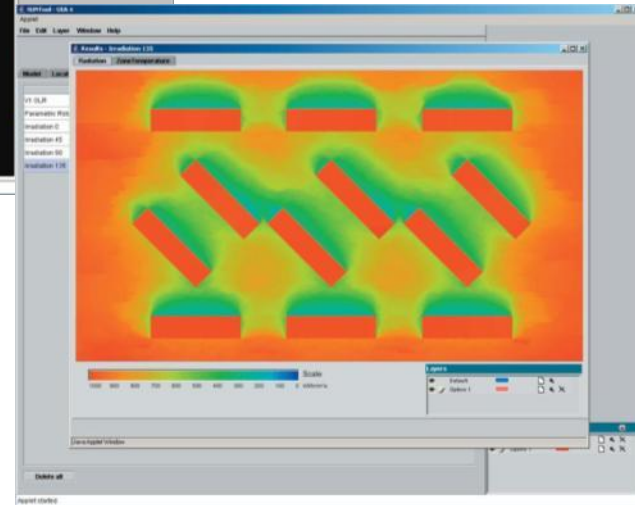
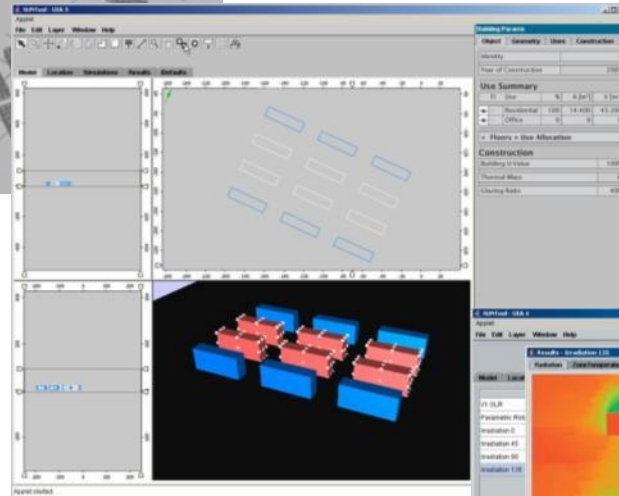
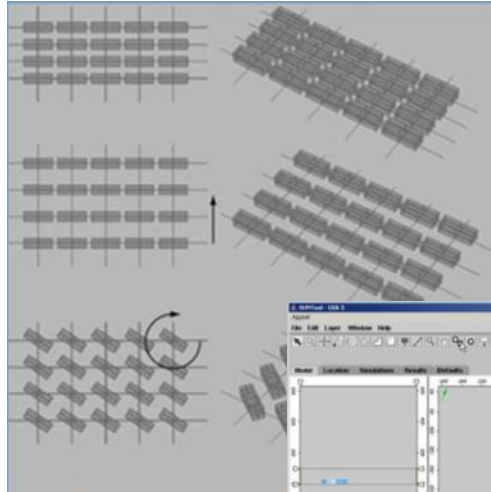


## Concepts: Place making

- 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)

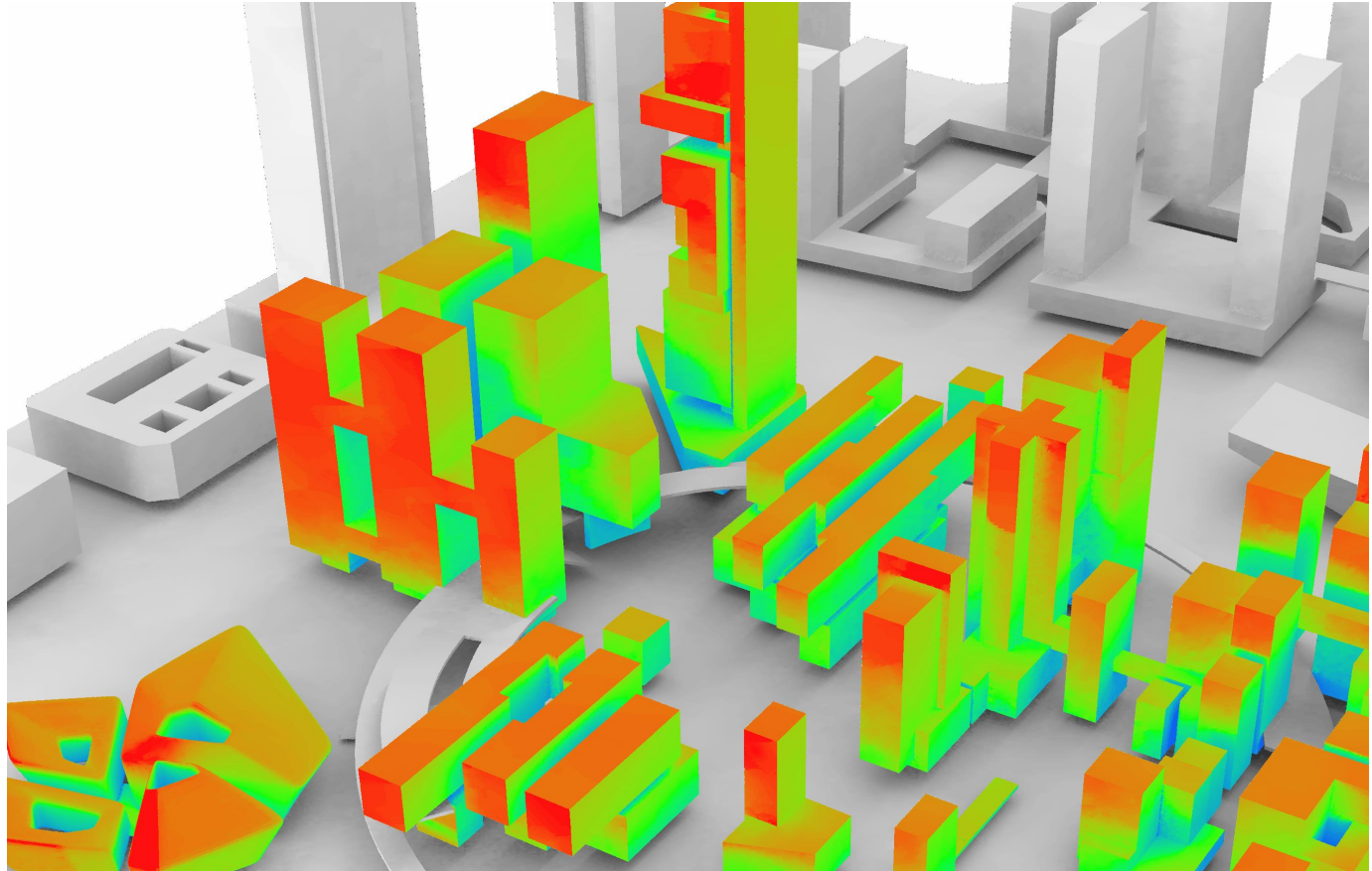
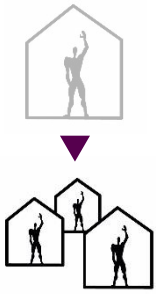




## R&D: RAPIERE (2010-)

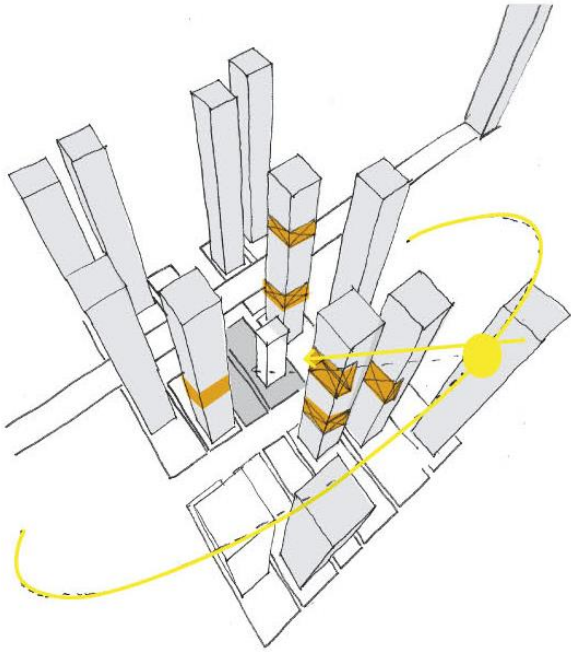
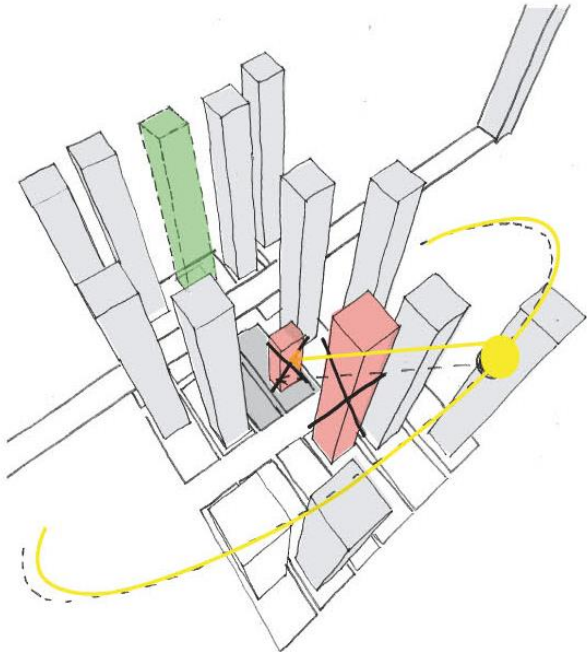
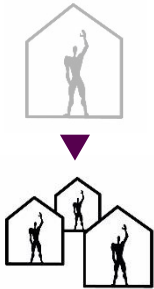


## R&D (in-house): Solar Irradiation Mapping



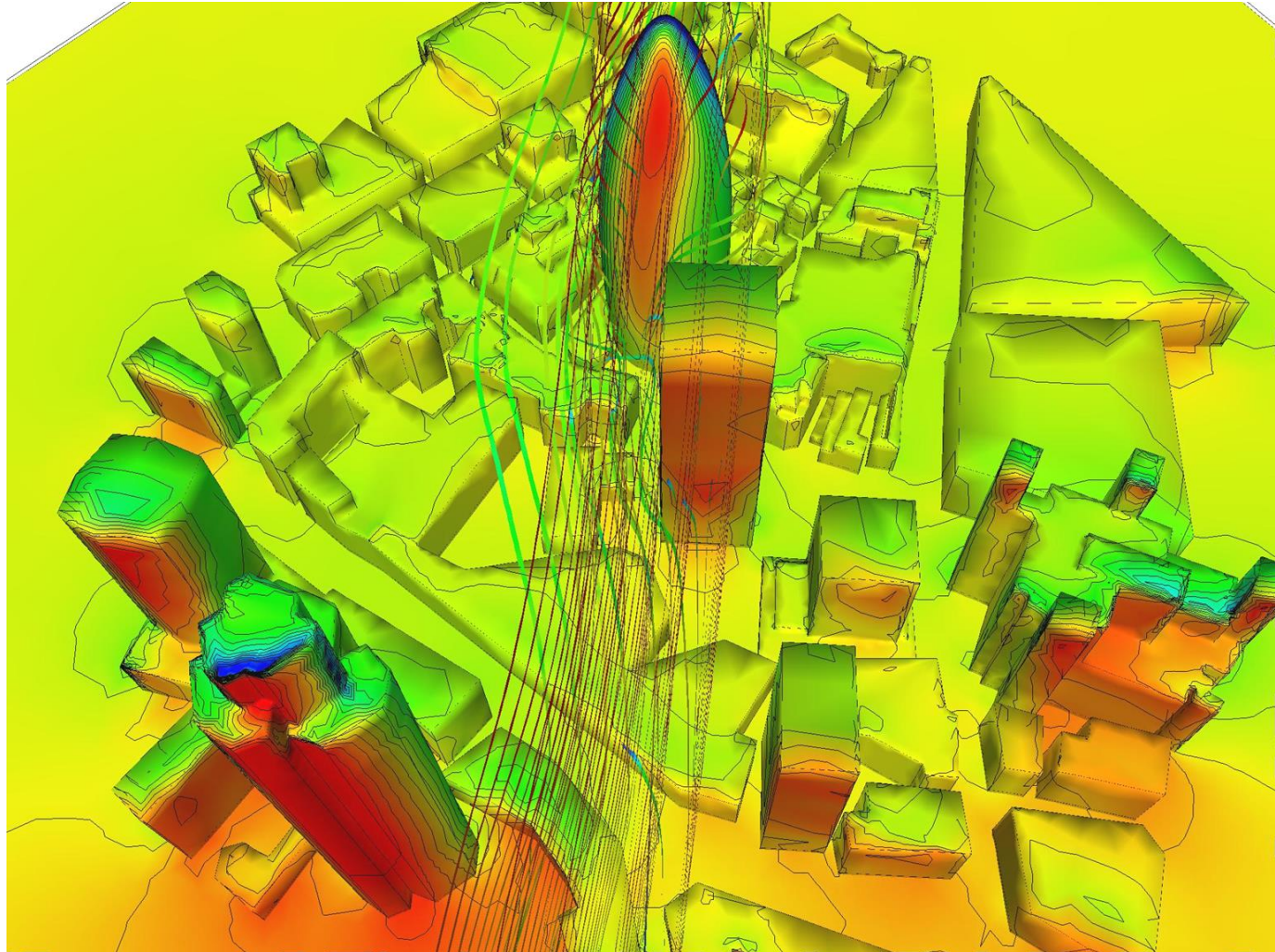


**Concepts: Solar Access**





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



Wind tunnel modelling, use of pressure coefficients in thermal models

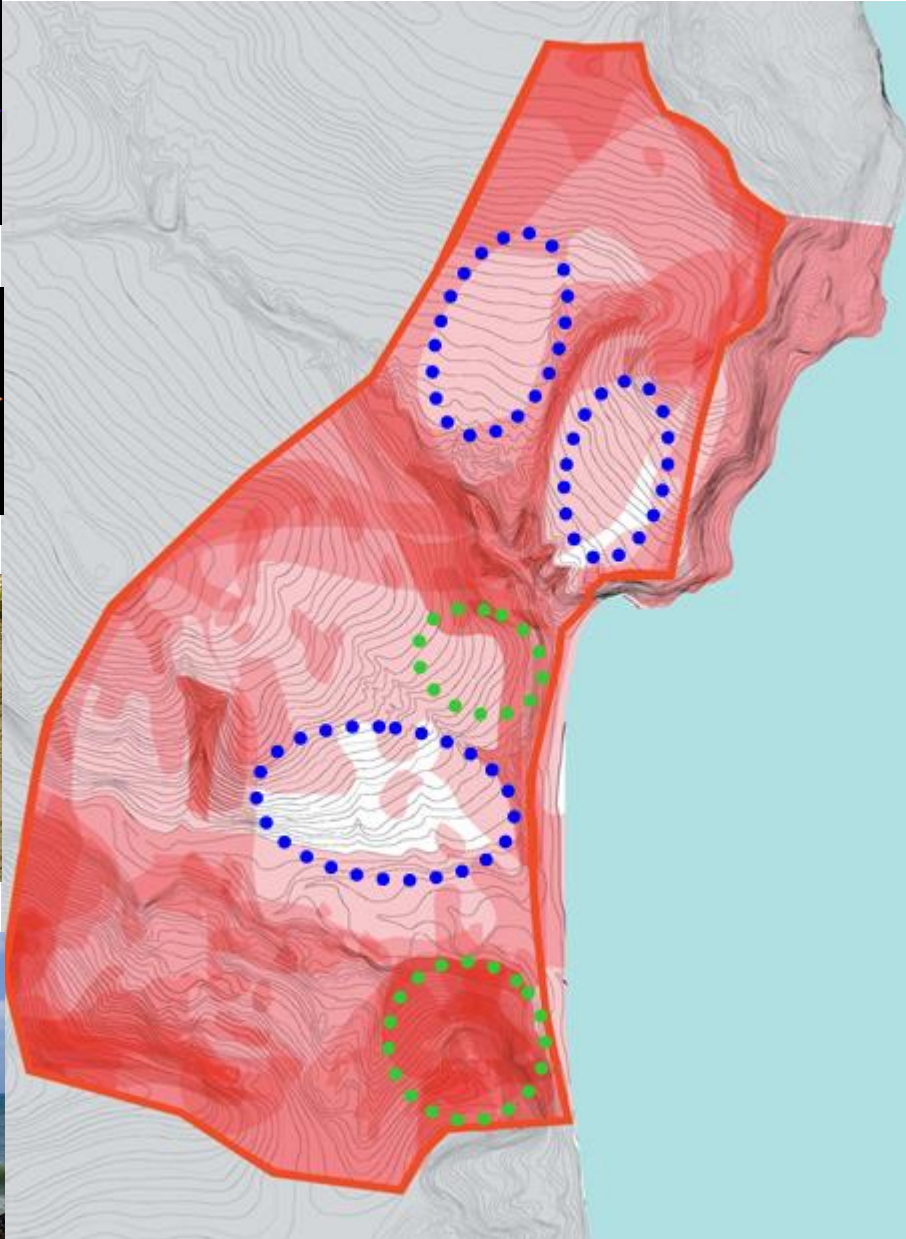
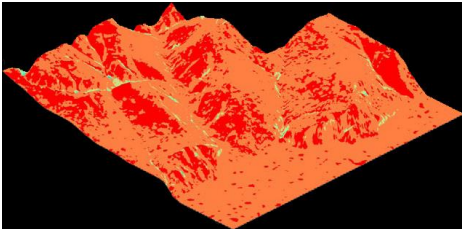
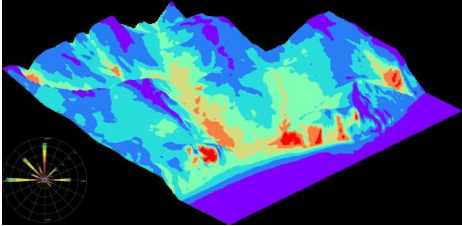


# Projects: Black Sea Gardens, Bulgaria (Foster & Partners)

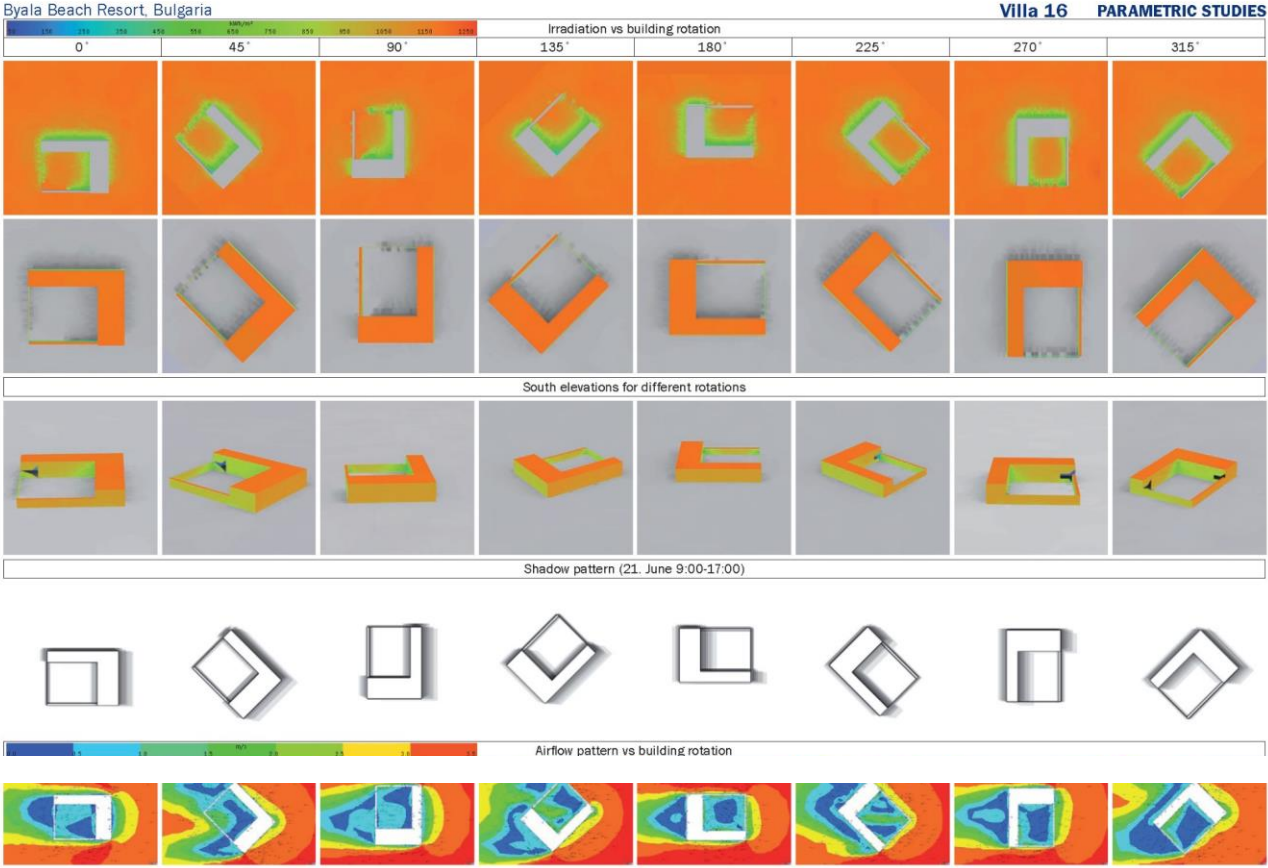




# Projects: Black Sea Gardens, Bulgaria – Site Selection



# Projects: Black Sea Gardens, Bulgaria – Design of housing





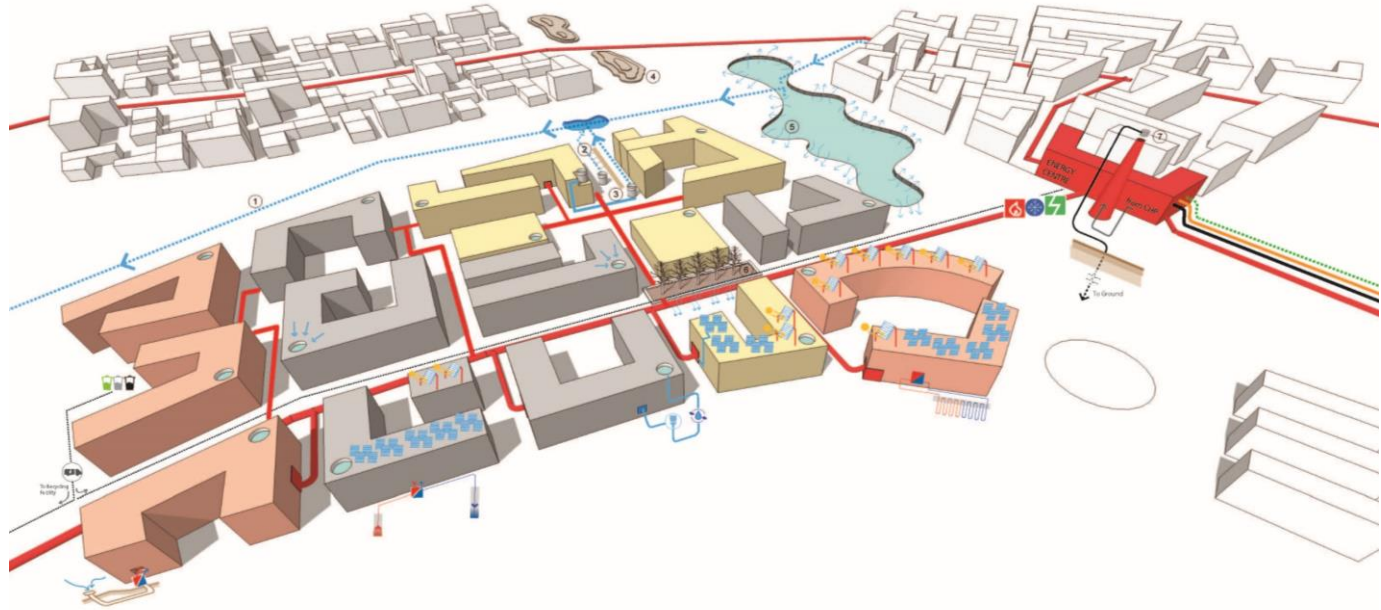
# Projects: Black Sea Gardens, Bulgaria – Infrastructure



- Roads
- Hot Water Supply
- Hot Water Substation
- Chilled Water Supply
- Chilled Water Substation
- Power Grid
- Power Substation
- - External Grid Connection

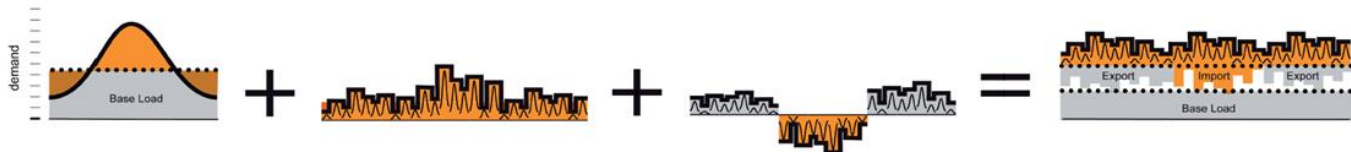


# Competitions: Borongaj University Campus, Zagreb, Croatia

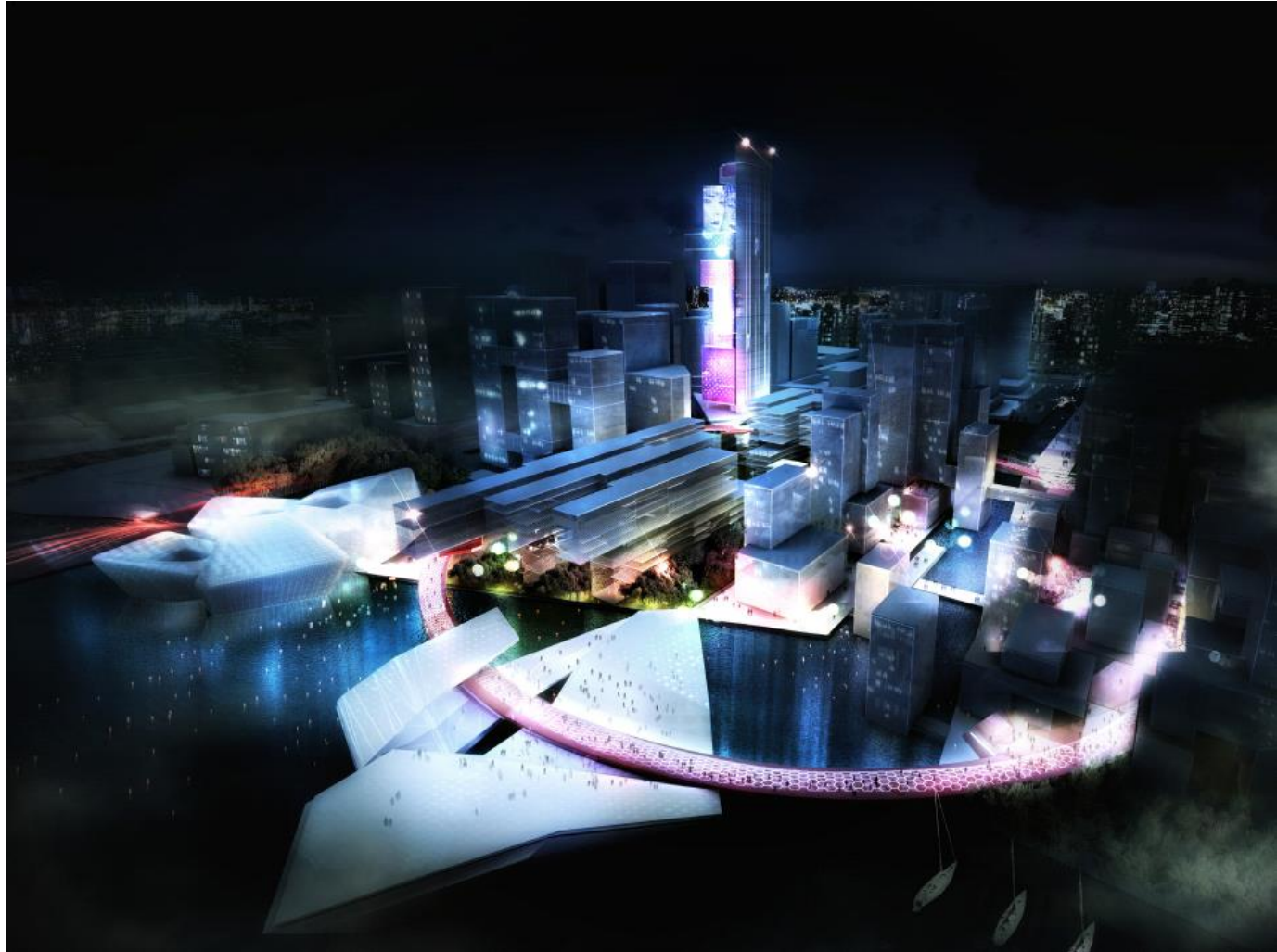


## Hybrid Option

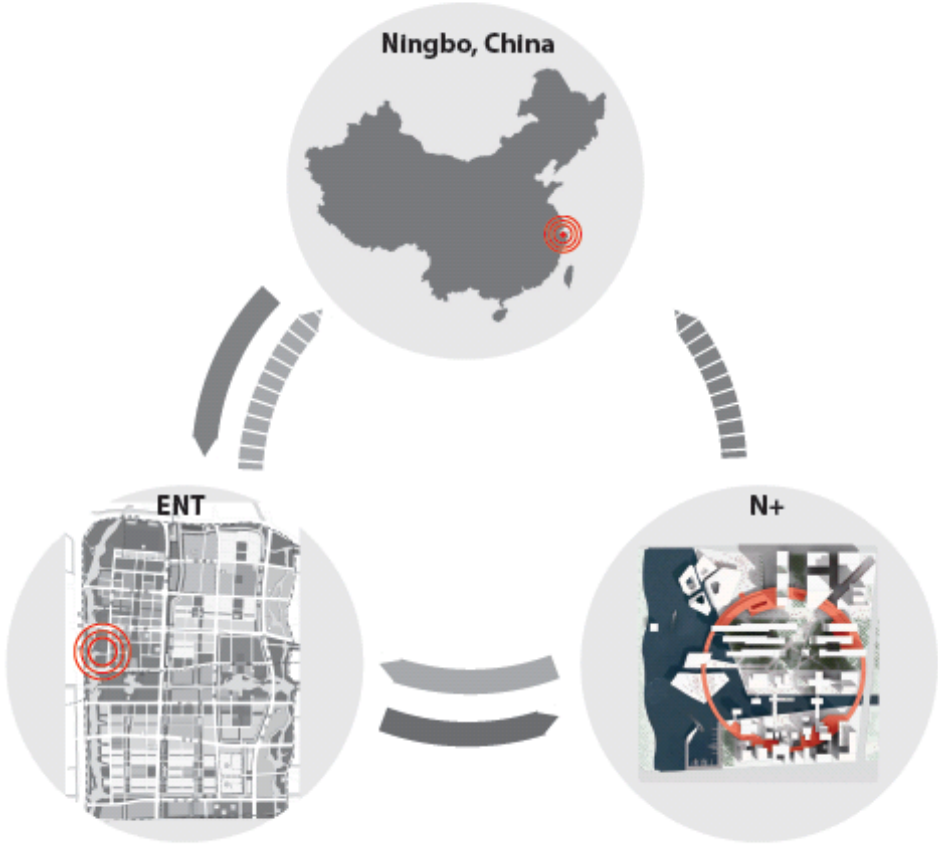
- ✓ Load Matching & Balancing
- ✓ Better Equipment Sizing (Capital Savings)
- ✓ Renewables Energy Storage  
(Export Surplus & Import from Grid When Generation Insufficient)
- ✓ Network Resilience
- ✓ Security of Supply (Redundancy)
- ✓ Minimized Energy & Maintenance (operational) Costs



**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

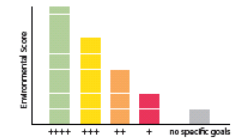
- Smart Blue Infrastructure
- Enhanced Recycling / Reuse
- Basic Recycling / Reuse
- Demand Minimisation

### 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

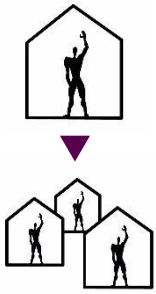




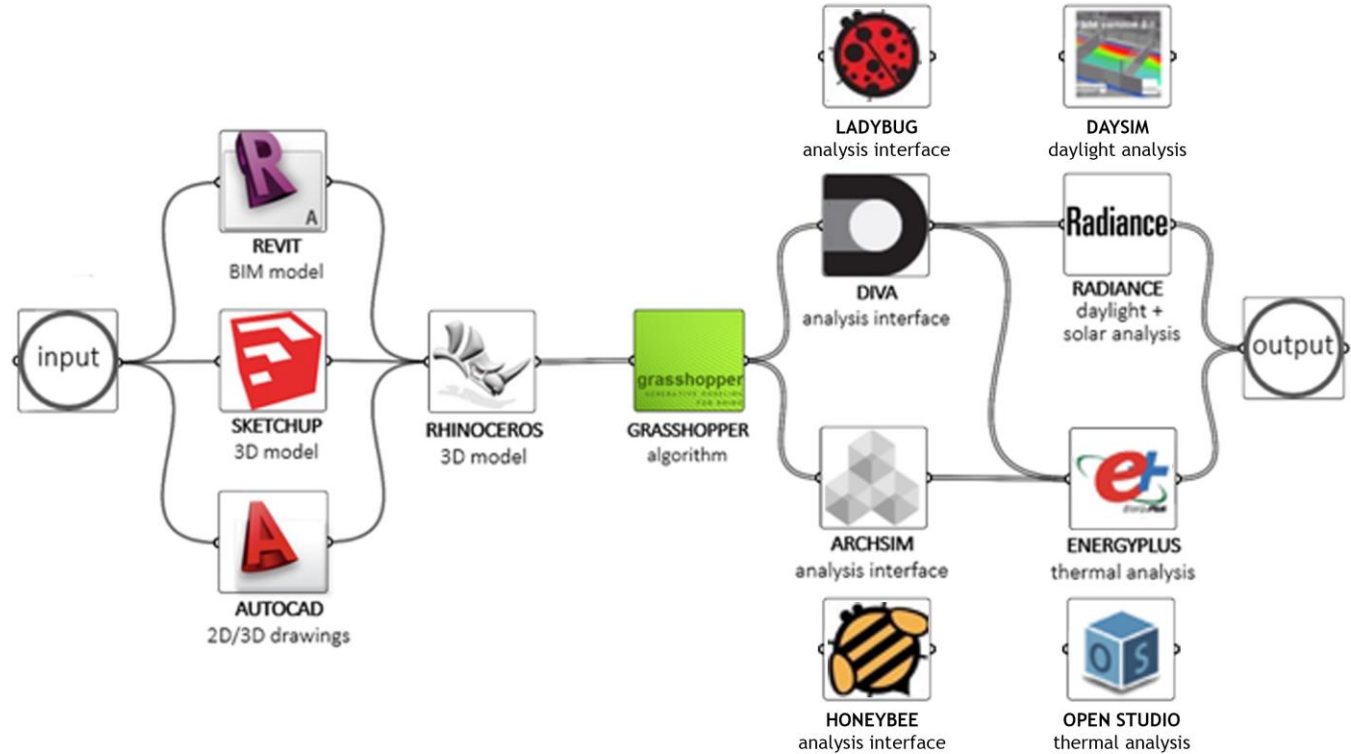
# Parametrics

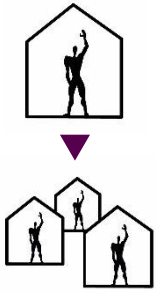
Responding to the urban context



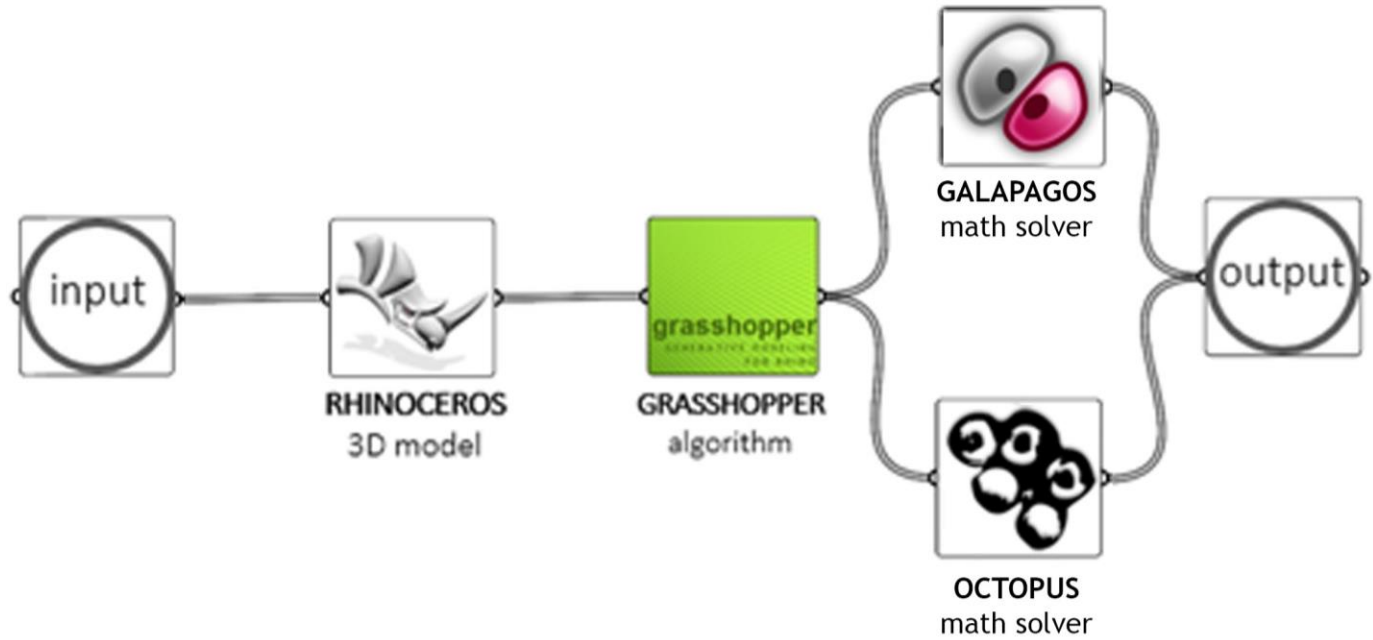


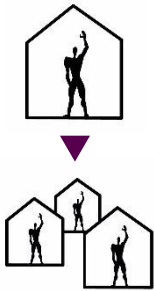
## PARAMETRIC: Initial Studies – Workflow & Tools



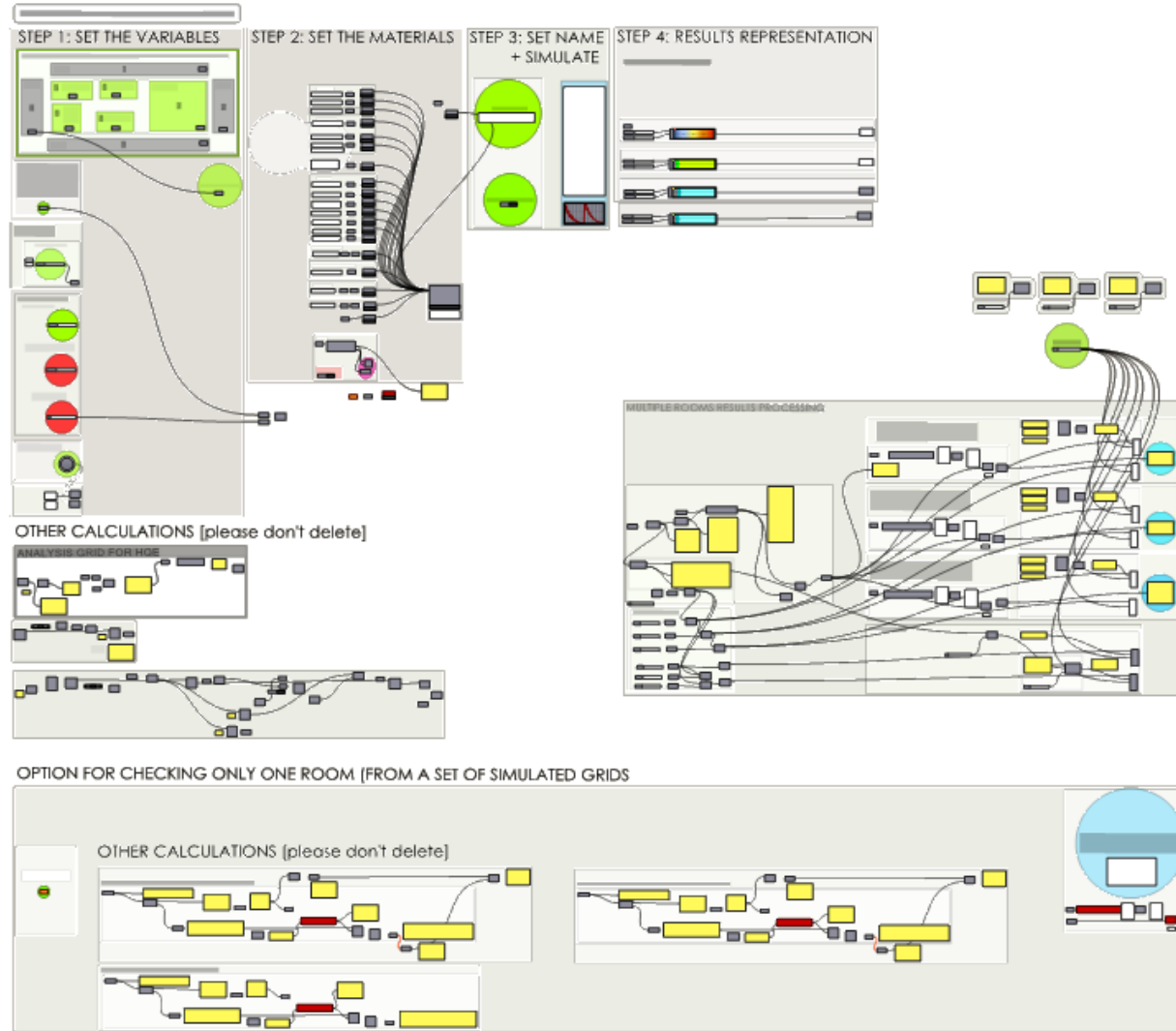


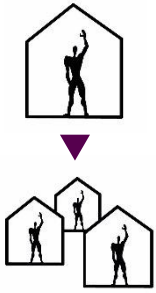
## PARAMETRIC: Initial Studies – Optimisation





# PARAMETRIC: Initial Studies – Script Sample





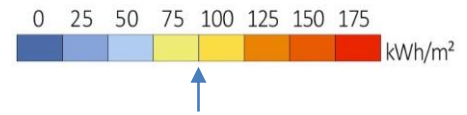
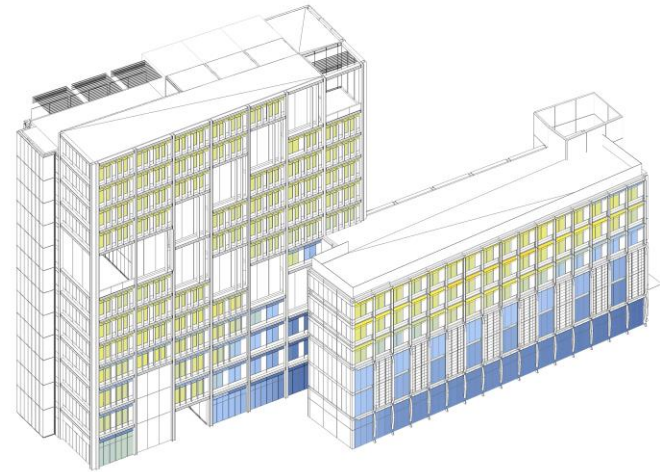
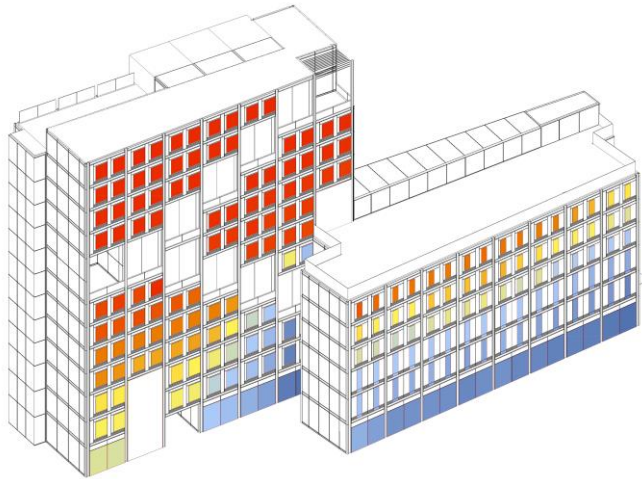
## PARAMETRIC: LSE CBR- RSH+P





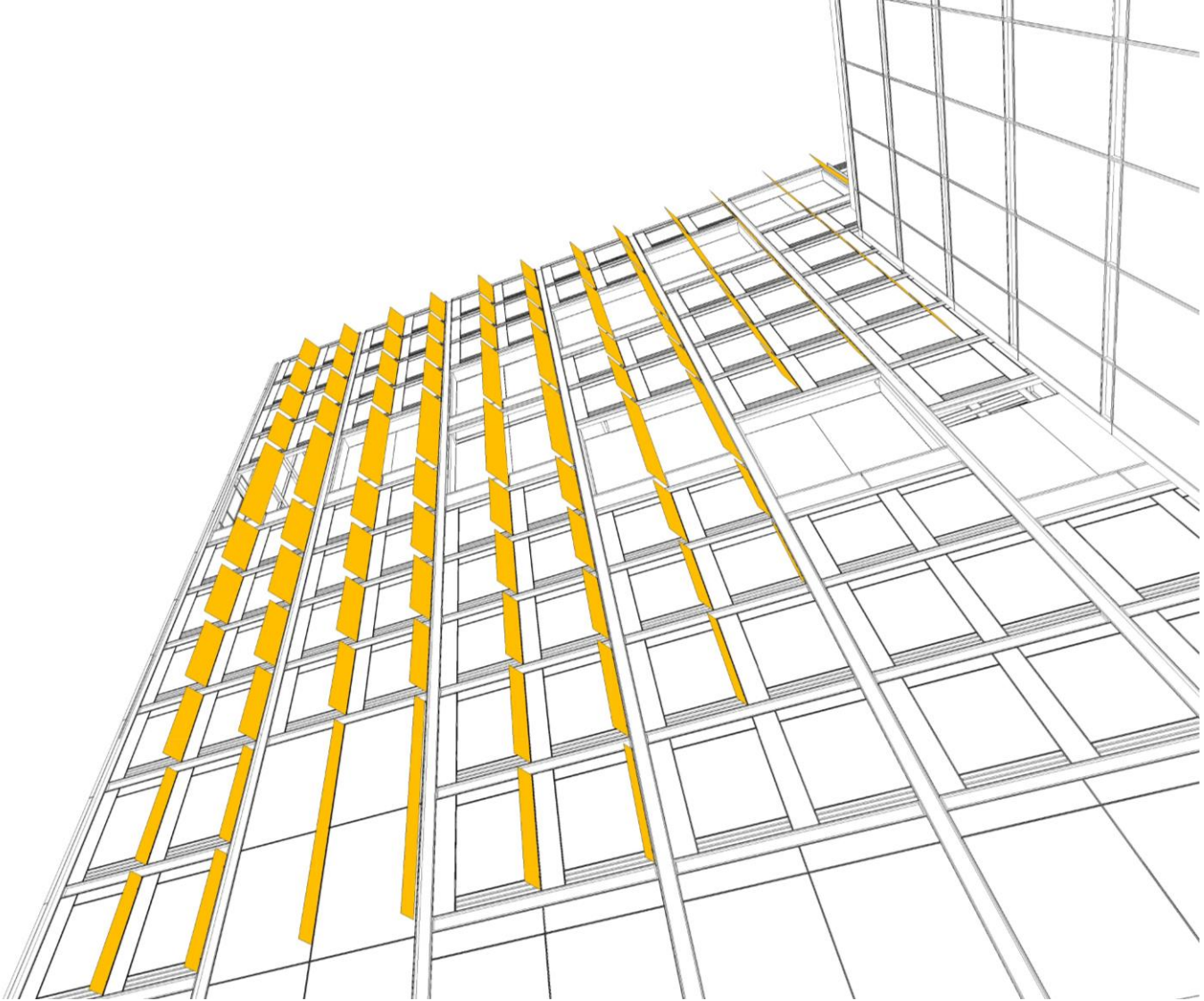


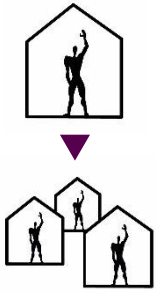
# PARAMETRIC: LSE CBR – External Shading Design



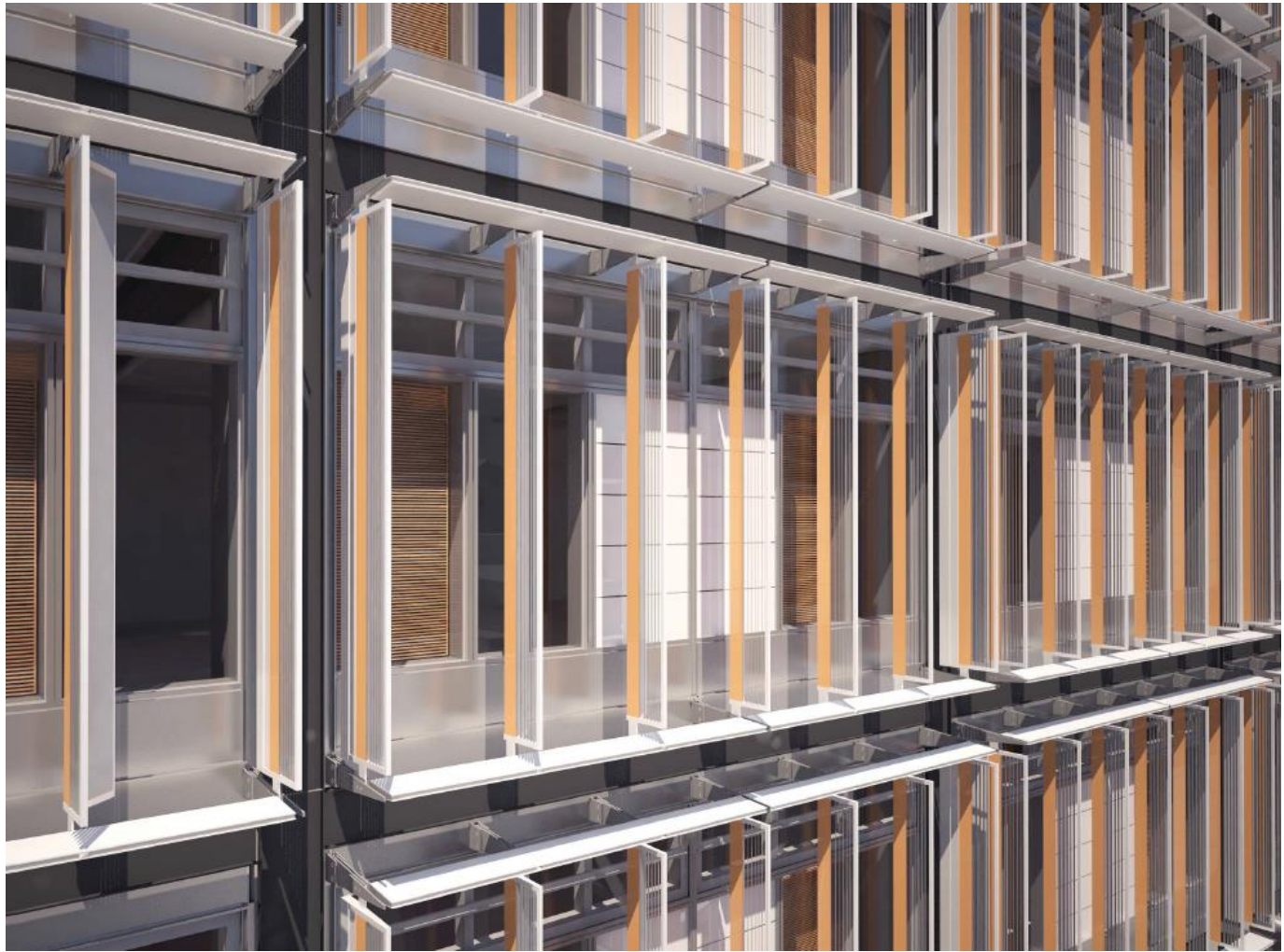


**PARAMETRIC: LSE CBR - External Shading**

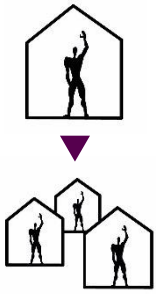




## PARAMETRIC: LSE CBR – Façade Visualisation (RSH+P)



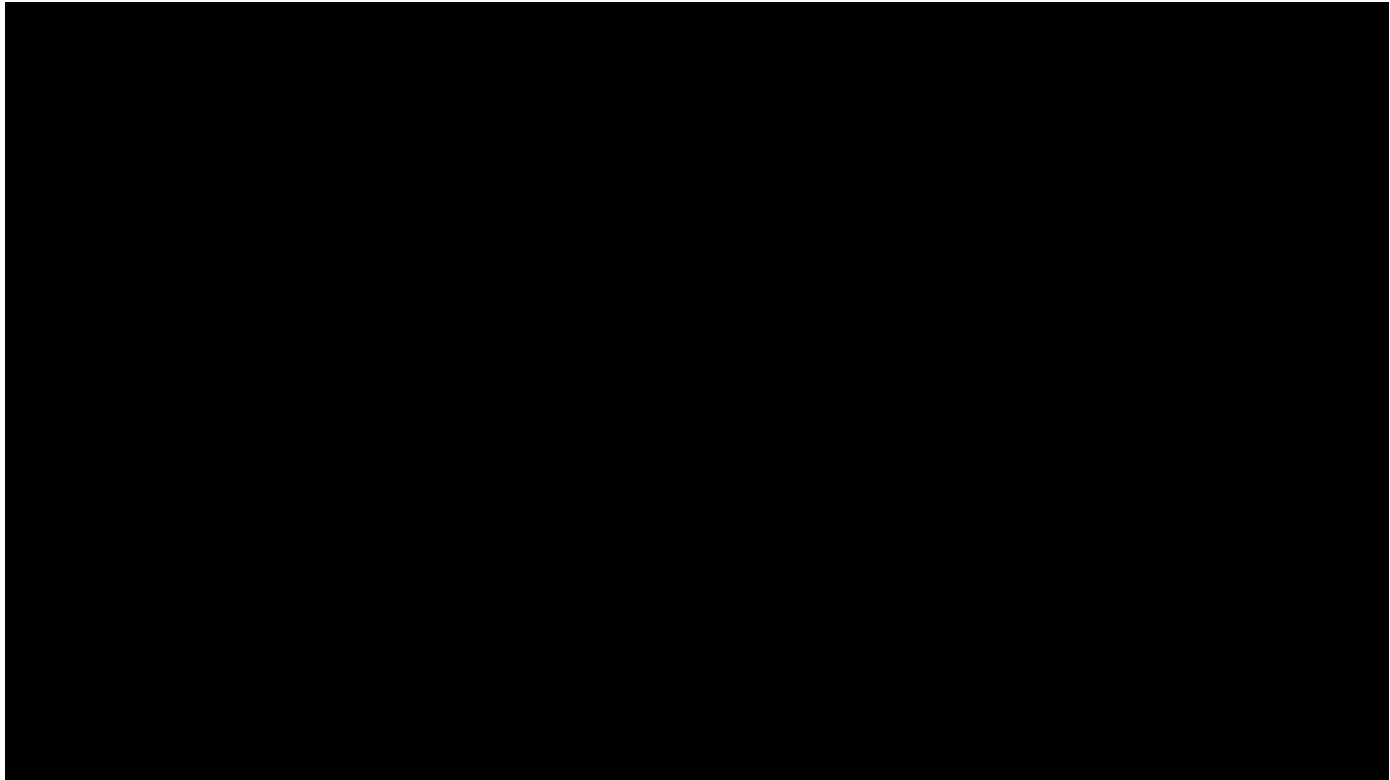
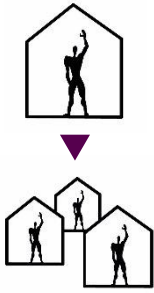




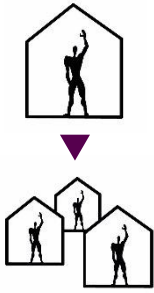
## PARAMETRIC: IMT – Paris (FR) – Grafton Architects



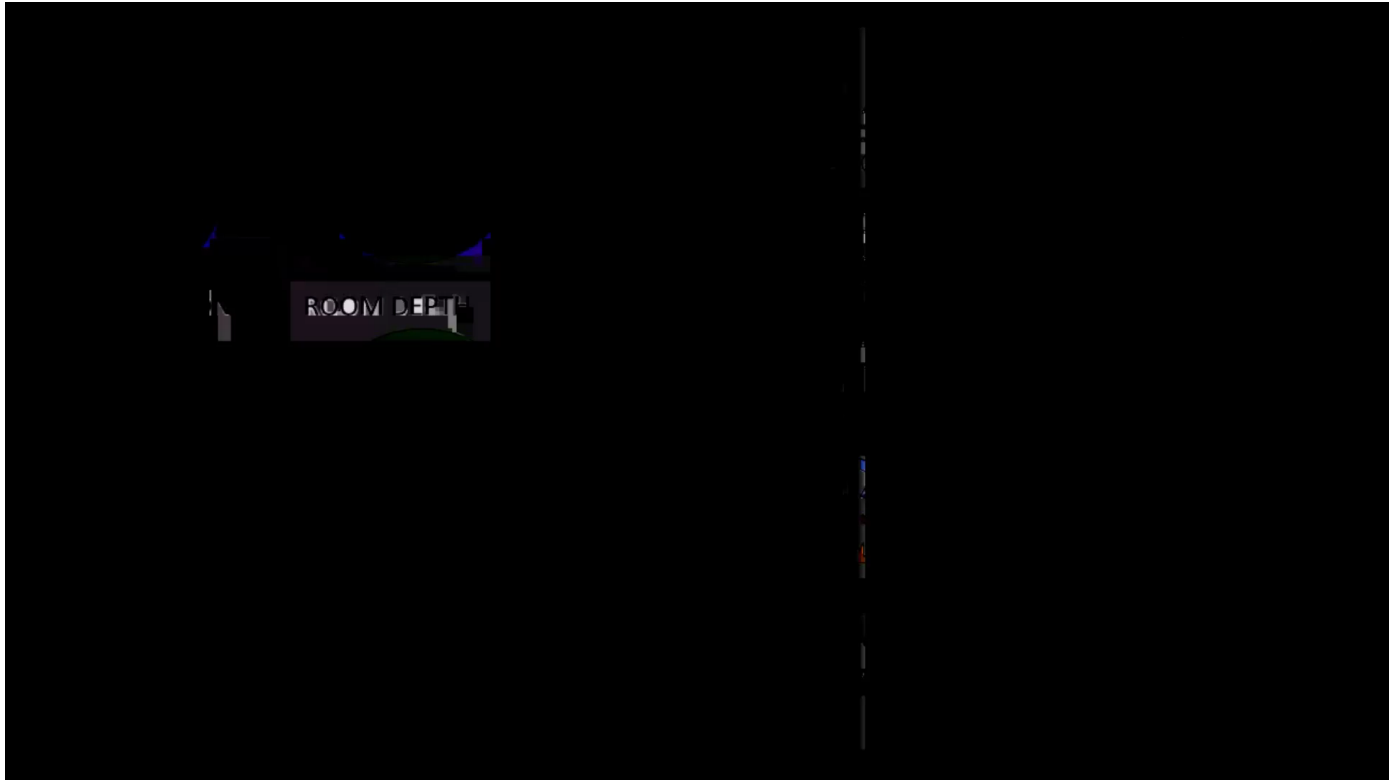
**PARAMETRIC: Facade Optimisation – IMT – Paris (FR) – Grafton Architects**

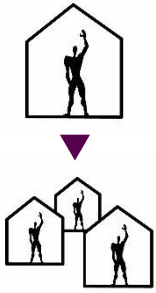




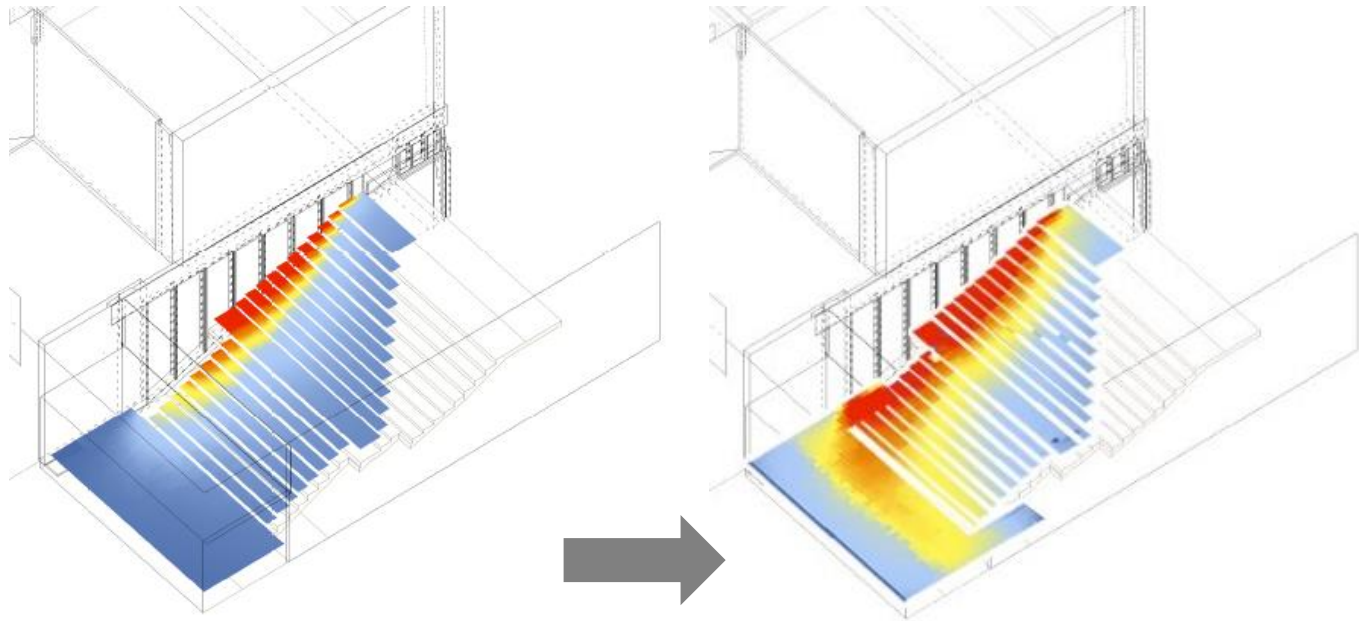


# PARAMETRIC: DF Analysis – IMT – Paris (FR) – Grafton Architects

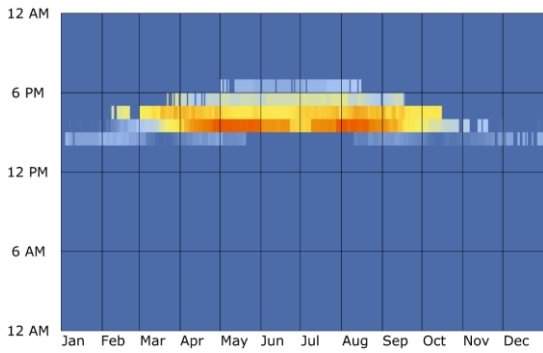
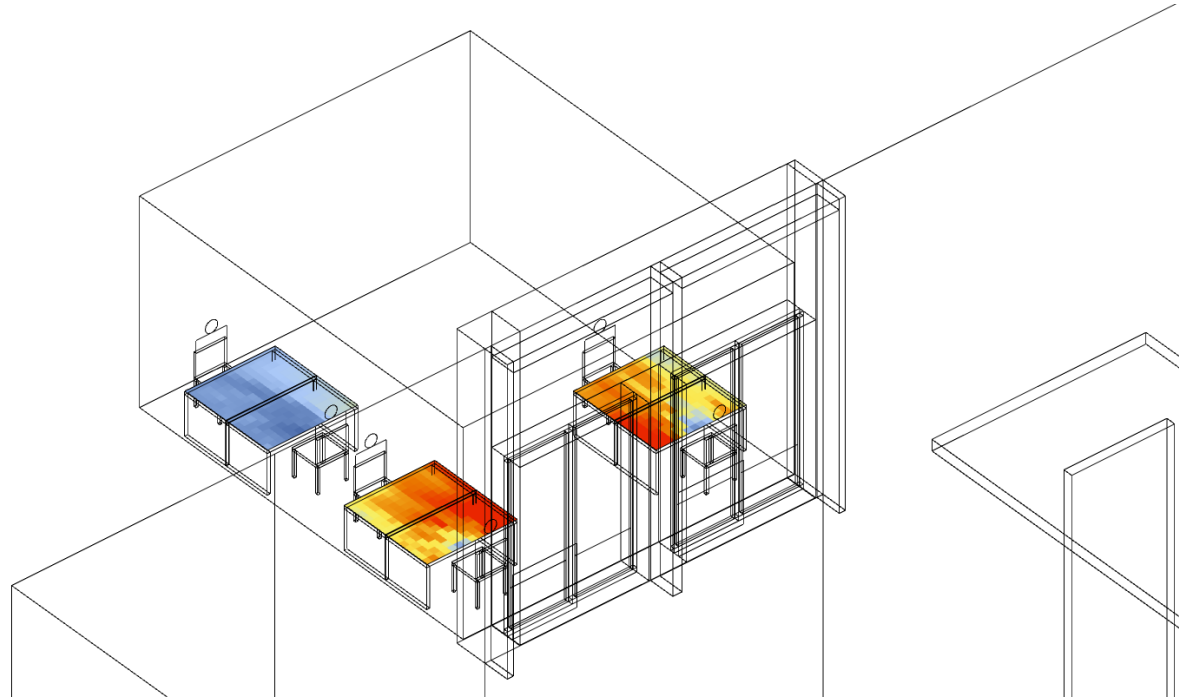
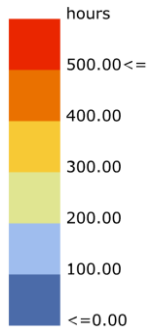
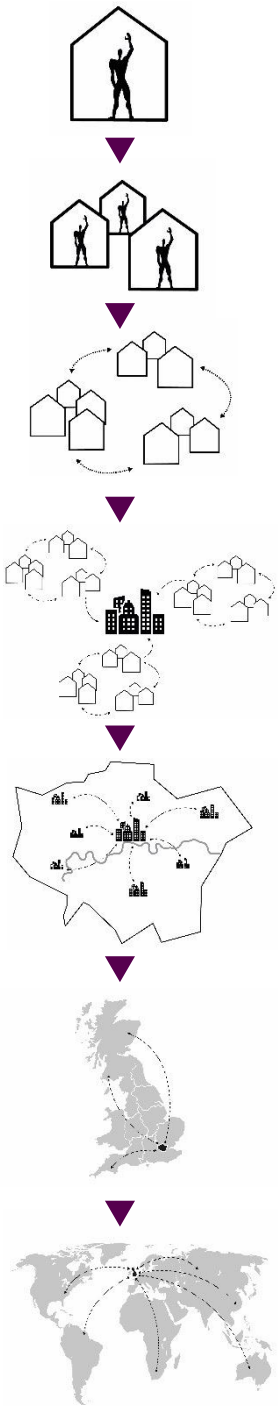




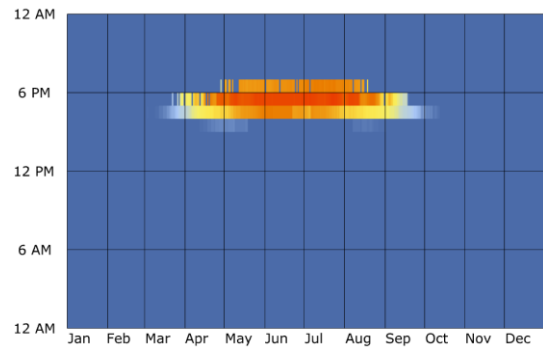
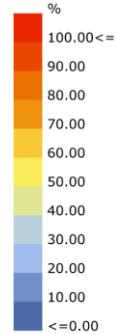
# PARAMETRIC: DF Analysis – IMT – Paris (FR) – Grafton Architects



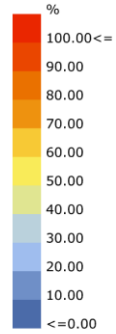
# PARAMETRIC: Glare Analysis – IMT – Paris (FR) – Grafton Architects



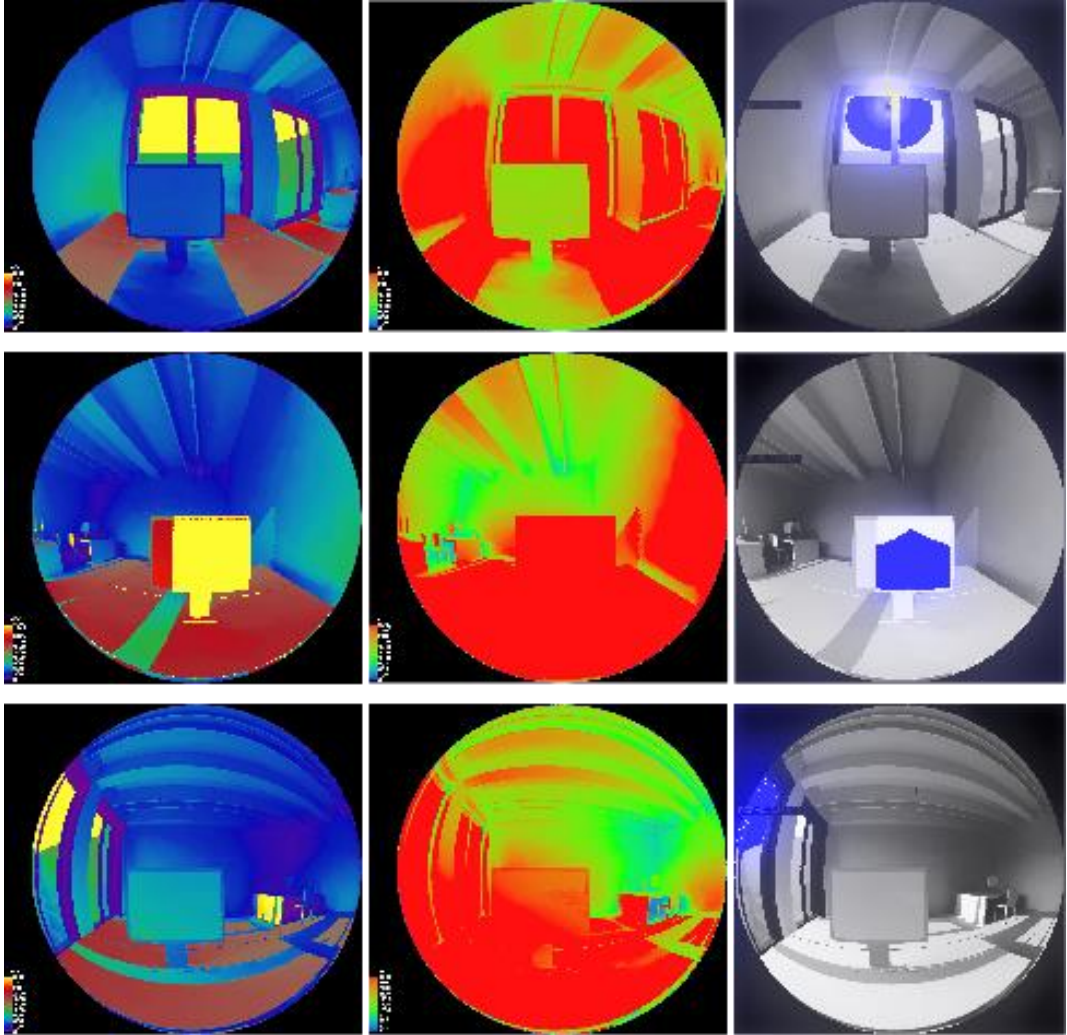
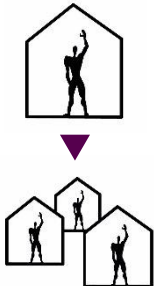
Percent of Floor in Direct Sun (%) - Hourly  
Test Surface  
1 JAN 1:00 - 31 DEC 24:00



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



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



Some thoughts ...



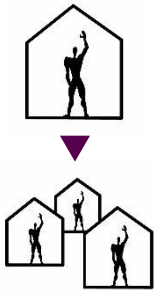


## CHALLENGES:



- 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 ...



