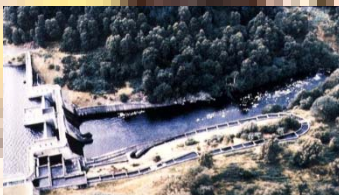
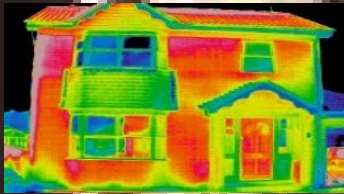


Energy systems modelling & monitoring



1/5/19

Modelling challenges

Energy processes are **dynamic**

Continuity: $\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$

X - Momentum: $\frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho u^2)}{\partial x} + \frac{\partial(\rho uv)}{\partial y} + \frac{\partial(\rho uw)}{\partial z} = -\frac{\partial p}{\partial x} + \frac{1}{Re_x} \left[\frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z} \right]$

Y - Momentum: $\frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho uv)}{\partial x} + \frac{\partial(\rho v^2)}{\partial y} + \frac{\partial(\rho vw)}{\partial z} = -\frac{\partial p}{\partial y} + \frac{1}{Re_y} \left[\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} \right]$

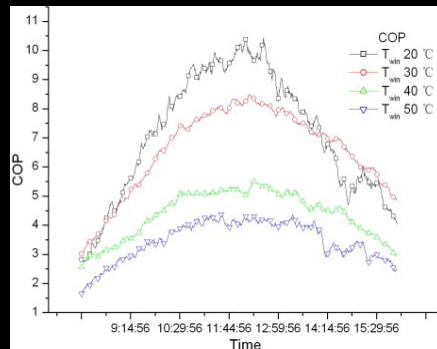
Z - Momentum: $\frac{\partial(\rho w)}{\partial t} + \frac{\partial(\rho uw)}{\partial x} + \frac{\partial(\rho vw)}{\partial y} + \frac{\partial(\rho w^2)}{\partial z} = -\frac{\partial p}{\partial z} + \frac{1}{Re_z} \left[\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} \right]$

Energy: $\frac{\partial(E_T)}{\partial t} + \frac{\partial(uE_T)}{\partial x} + \frac{\partial(vE_T)}{\partial y} + \frac{\partial(wE_T)}{\partial z} = \frac{\partial(uq_x)}{\partial x} + \frac{\partial(vq_y)}{\partial y} + \frac{\partial(wq_z)}{\partial z} - \frac{1}{Re_x Pr_x} \left[\frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} + \frac{\partial q_z}{\partial z} \right] + \frac{1}{Re_x} \left[\frac{\partial}{\partial x} (u \tau_{xx} + v \tau_{xy} + w \tau_{xz}) + \frac{\partial}{\partial y} (u \tau_{xy} + v \tau_{yy} + w \tau_{yz}) + \frac{\partial}{\partial z} (u \tau_{xz} + v \tau_{yz} + w \tau_{zz}) \right]$

Overall problem is **systemic**

- Capital/running/maintenance cost
- Thermal/ visual comfort
- Emissions & air quality
- Network interaction/ power quality
- Demand/ supply matching
- Adaptability/ resilience

Defining data are **non-linear**

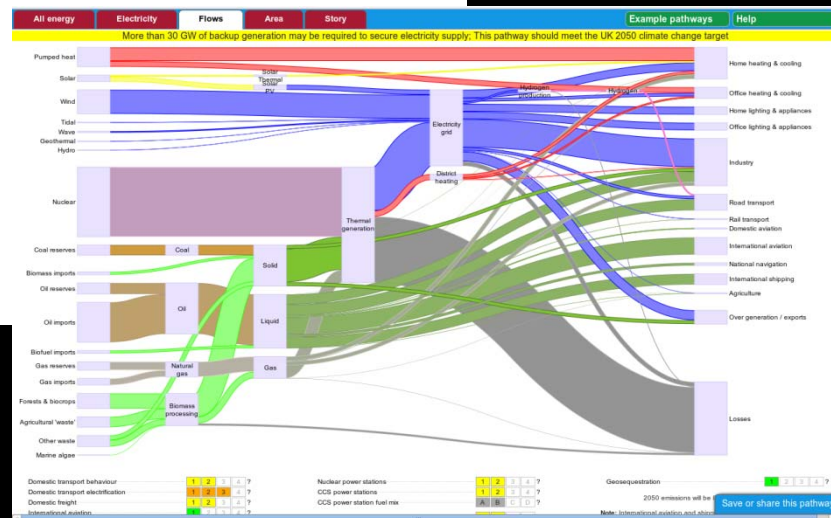
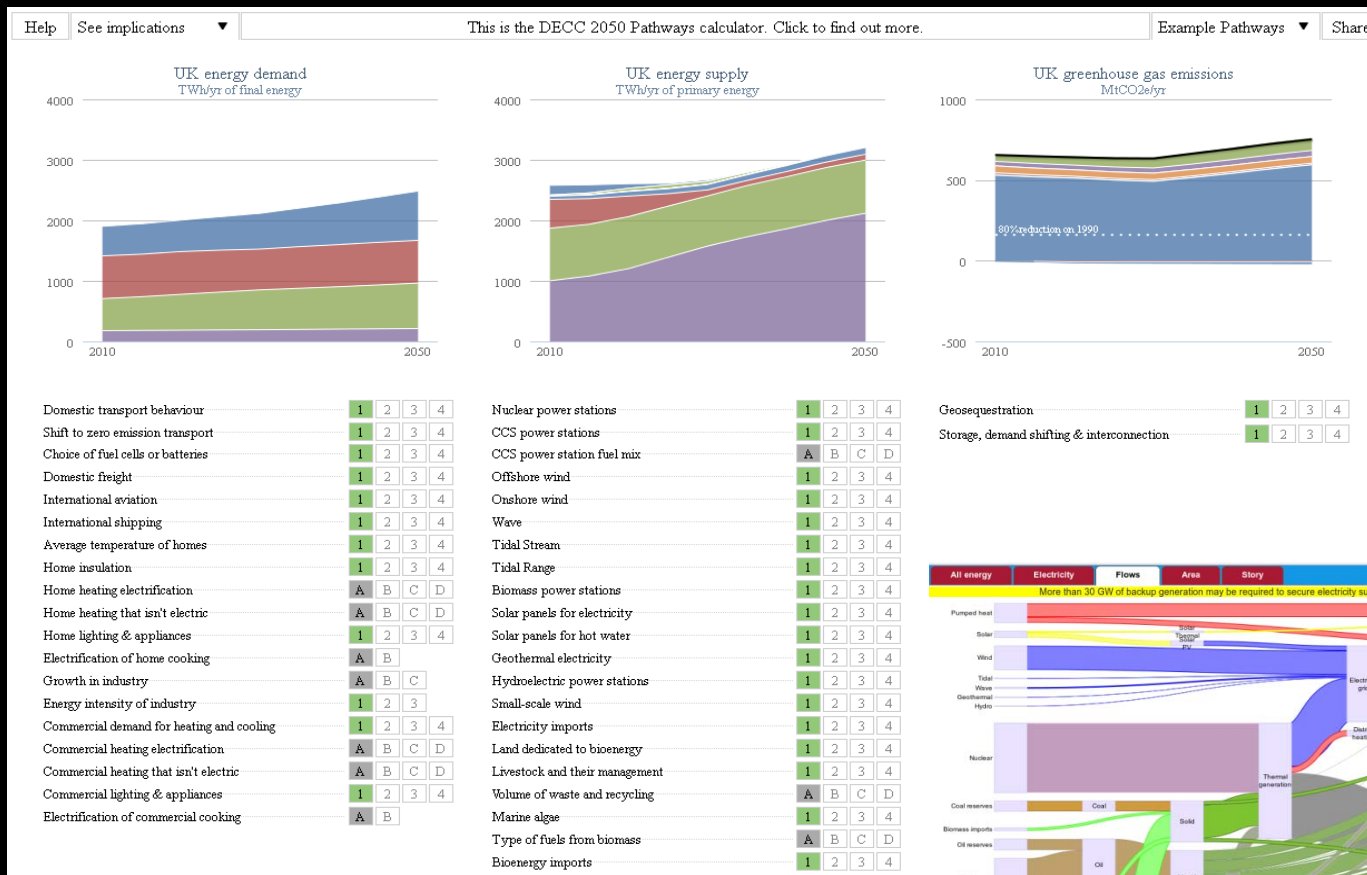


Influences are **stochastic**



Violation of these predicates leads to a calculation tool, not simulation for reality emulation.

DECC: 2050 calculator (<http://2050-calculator-tool.decc.gov.uk/#/home>)

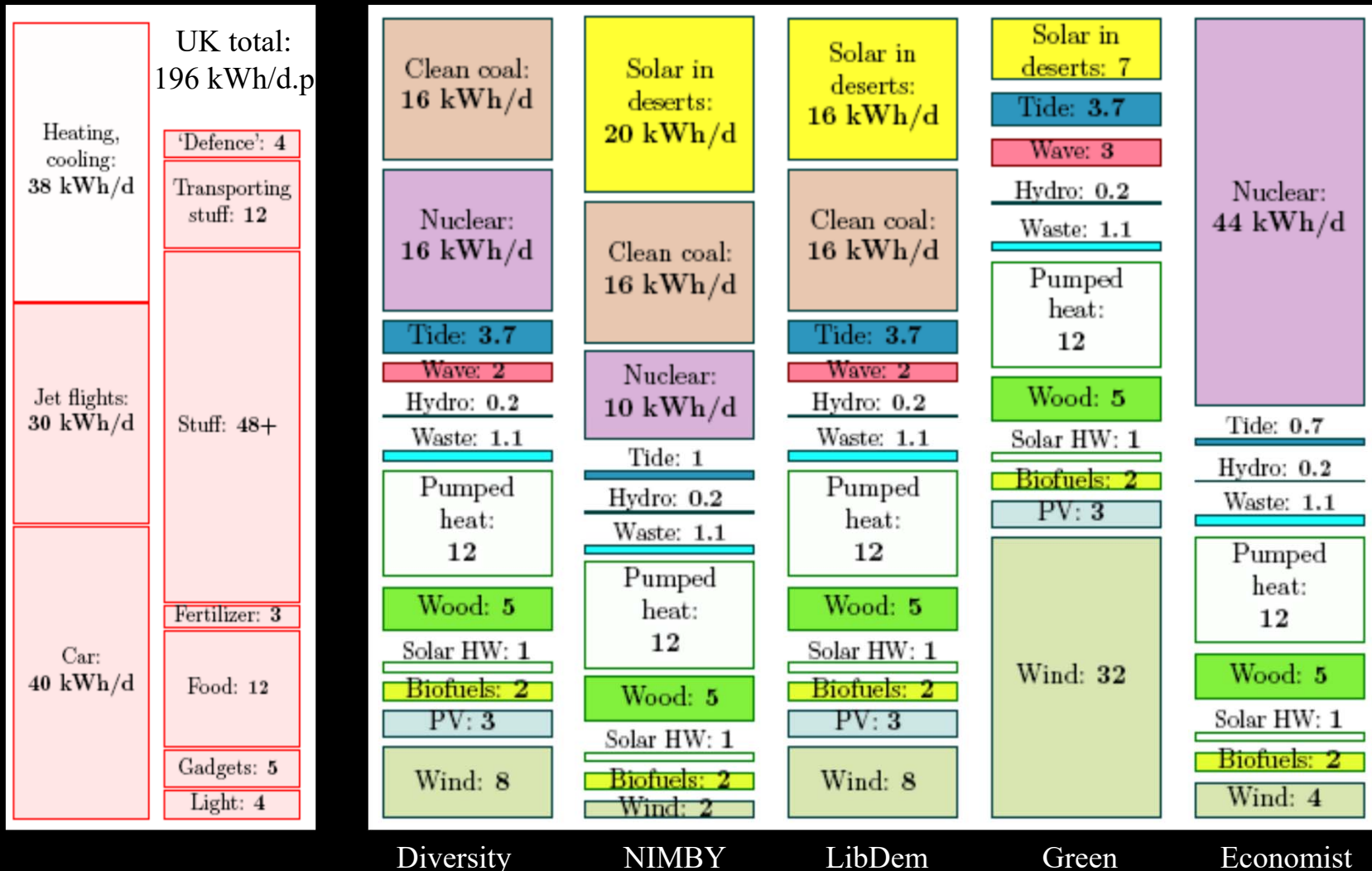


<http://withoutotair.blogspot.com/2010/07/2050-calculator-tool-at-decc.html>

International versions:
<https://www.gov.uk/guidance/international-outreach-work-of-the-2050-calculator>

Sustainable energy options

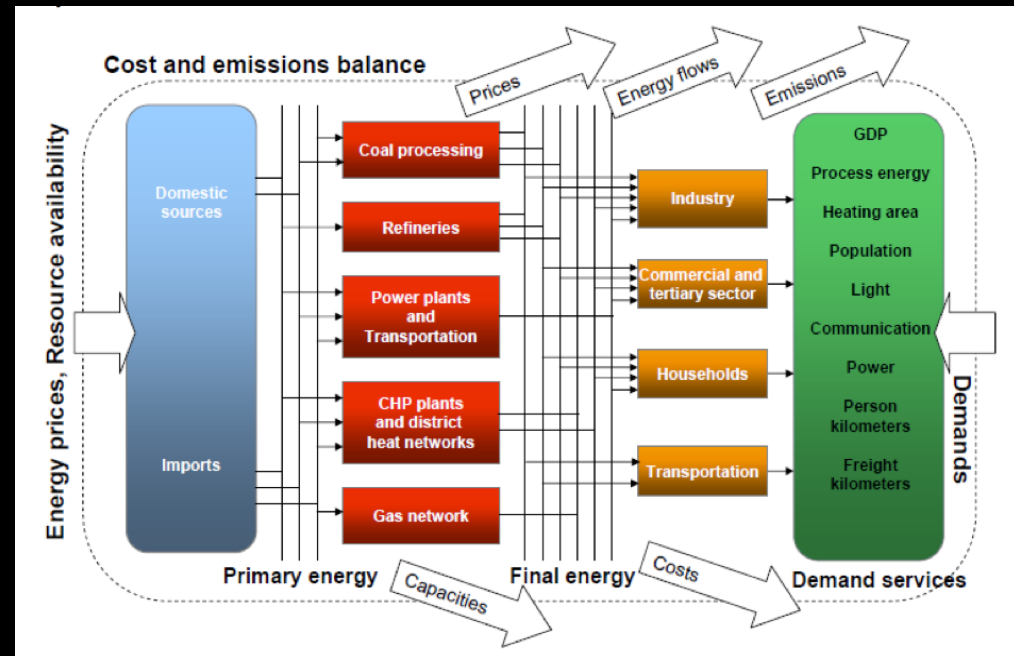
Source: MacKay, www.withouthotair.com



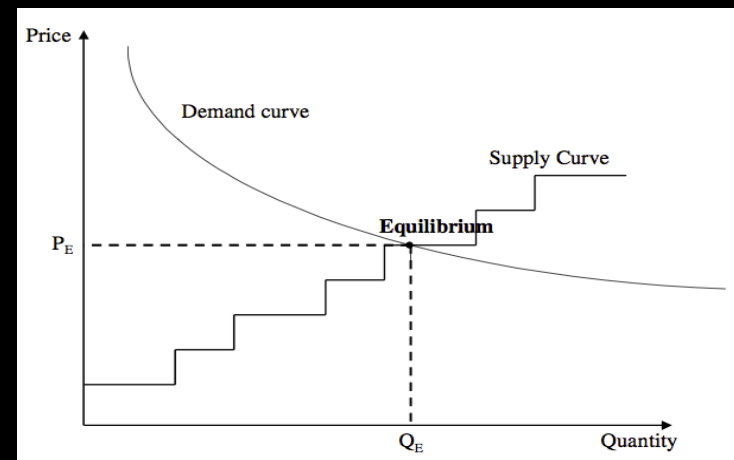
Issues: new technology vs. lifestyle change; political imperative; balance of options; supportive legislation.

The Integrated MARKAL-EFOM System) TIMES

- ❑ Determines the energy system that meets the energy service demands over discrete time periods at least cost.
- ❑ Makes equipment investment decisions and operating, primary energy supply, and energy trade decisions, by region.
- ❑ Outputs the optimal mix of technologies and fuels at each period, together with the associated emissions to meet the demand.
- ❑ Outputs are energy system configurations, which meet the end-use energy service demands at least cost while also adhering to various constraints (e.g. 80% emissions reduction, 40% renewable electricity penetration *etc.*).



TIMES inputs and outputs (Remme et al., 2001)



Market equilibrium (Loulou et al., 2005)

'Big data' analytics for e-services



Queries:

- energy use profiling;
- heat-to-power ratios;
- district heating feasibility;
- daylight/solar/wind access;
- fuel poverty distribution;
- carbon maps.

metered data

database of actual & future consumption

remote monitoring

scenario simulation

e-service delivery:

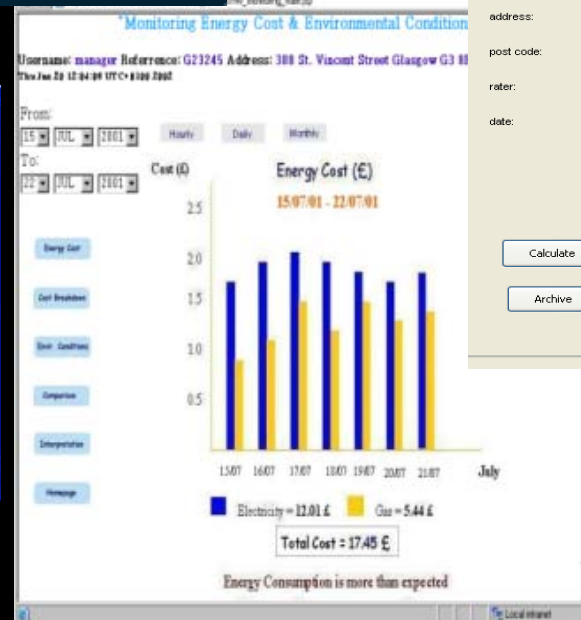
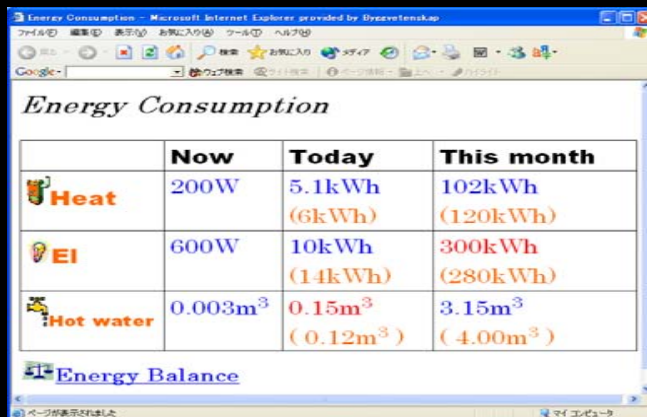
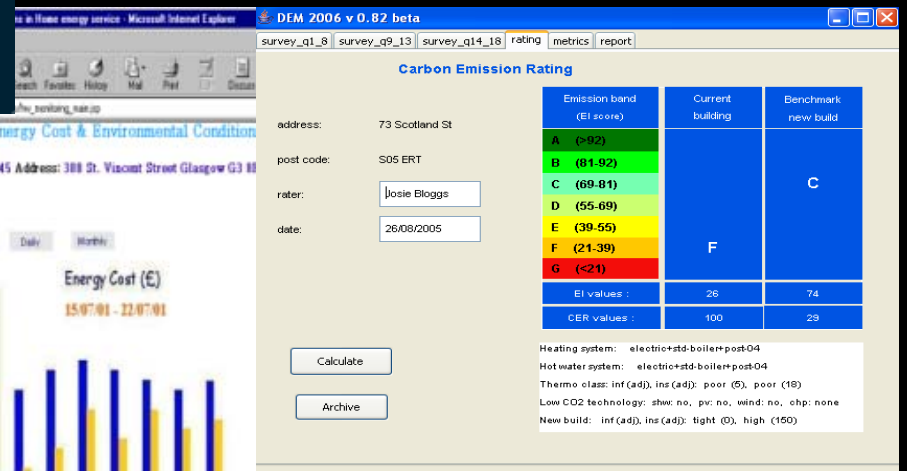
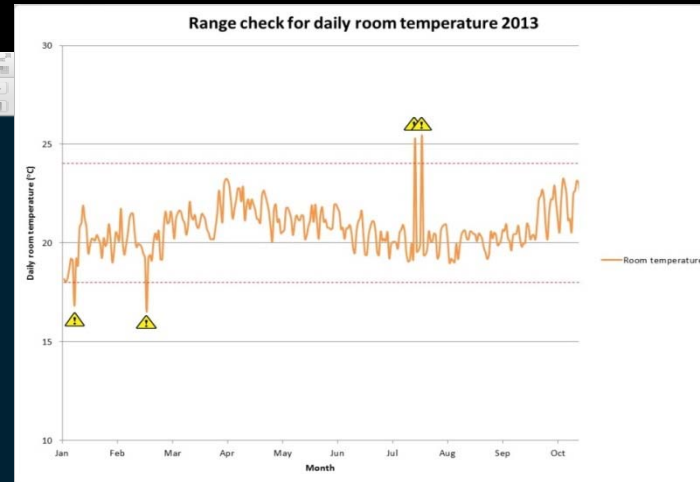
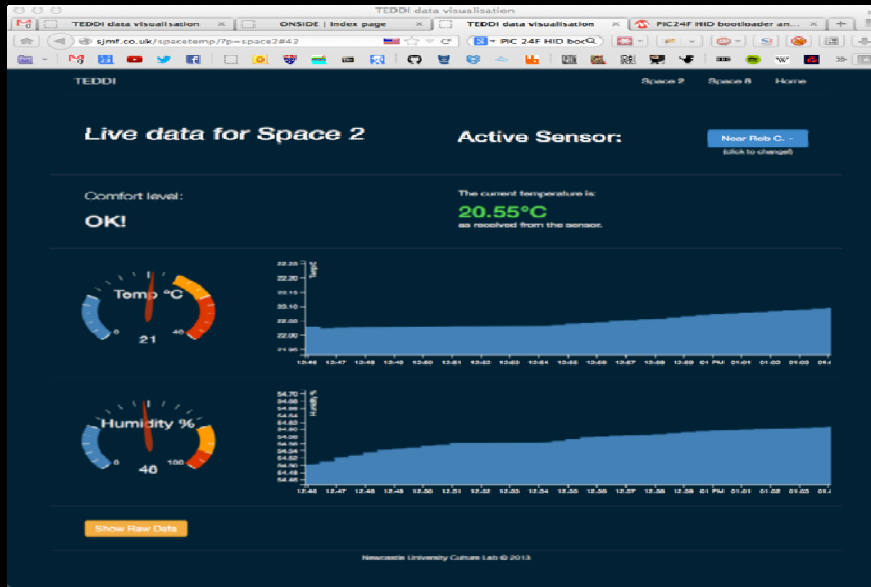
- alarms & alerts;
- conditions monitoring;
- local & aggregate control;
- health services;
- information.

information for government, local authorities, institutions, industry, utilities, citizens and others

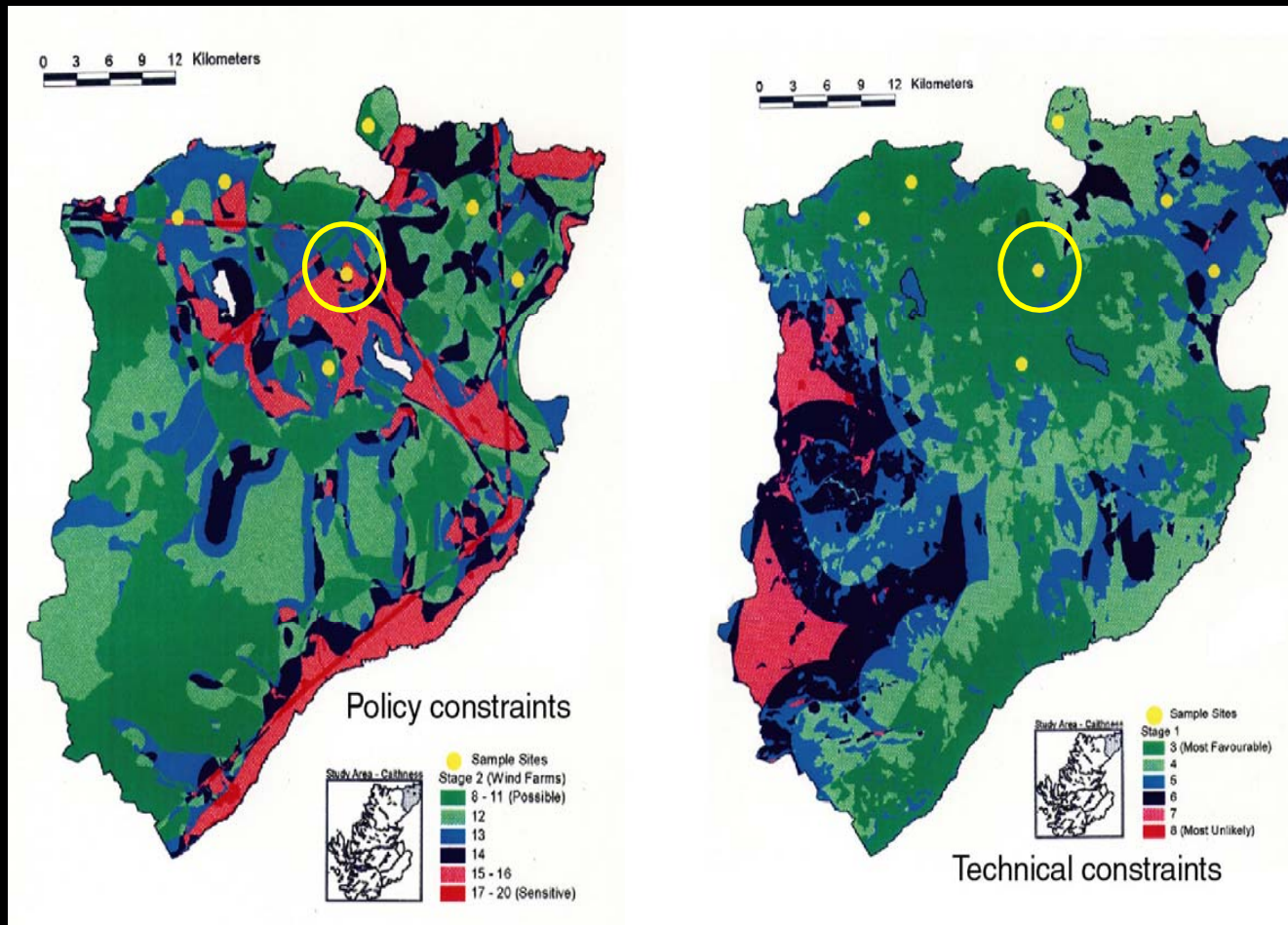
consumption/emissions monitoring; city profiling; property classification; trend analysis; action planning; equipment monitoring/control; post-occupancy impact assessment; target attainment

Issues: resilient comms; cybersecurity; consumer participation; ESCo growth; service quality assurance.

E-service outcomes

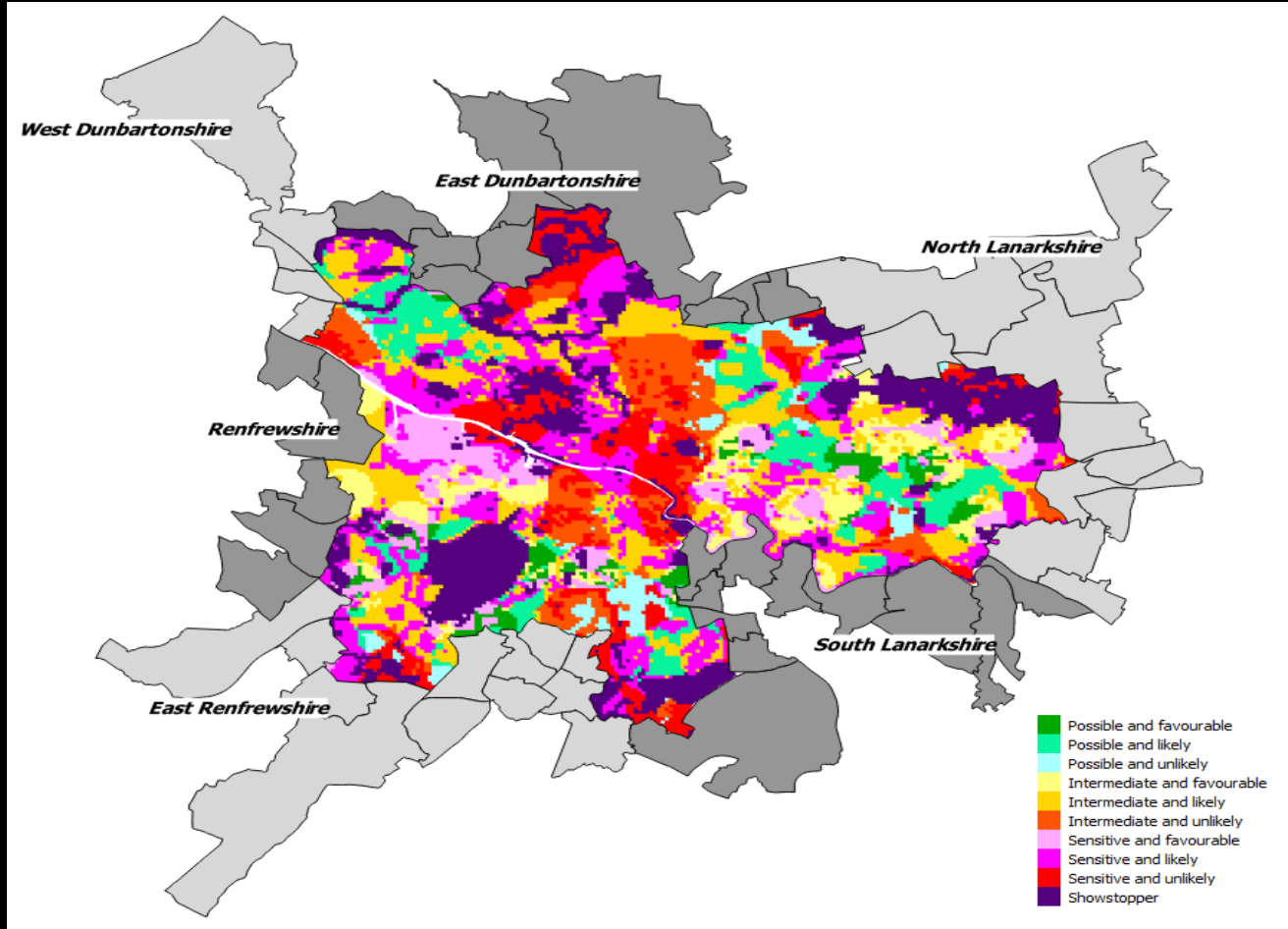


Energy opportunity map – national scale



Issues: technical and policy conflicts; evaluation approaches site and technology dependent; often used as a supportive strategy for development.

Opportunity mapping – urban scale



Issues: derelict and vacant land use, LV network access, technical/policy constraints rating/weighting.

Matching supply to demand

The screenshot displays the 'Match and Dispatch' software interface. At the top, a blue title bar reads 'Match and Dispatch' with menu options 'File', 'Tools', and 'Help'. Below the title bar, the interface is divided into several sections:

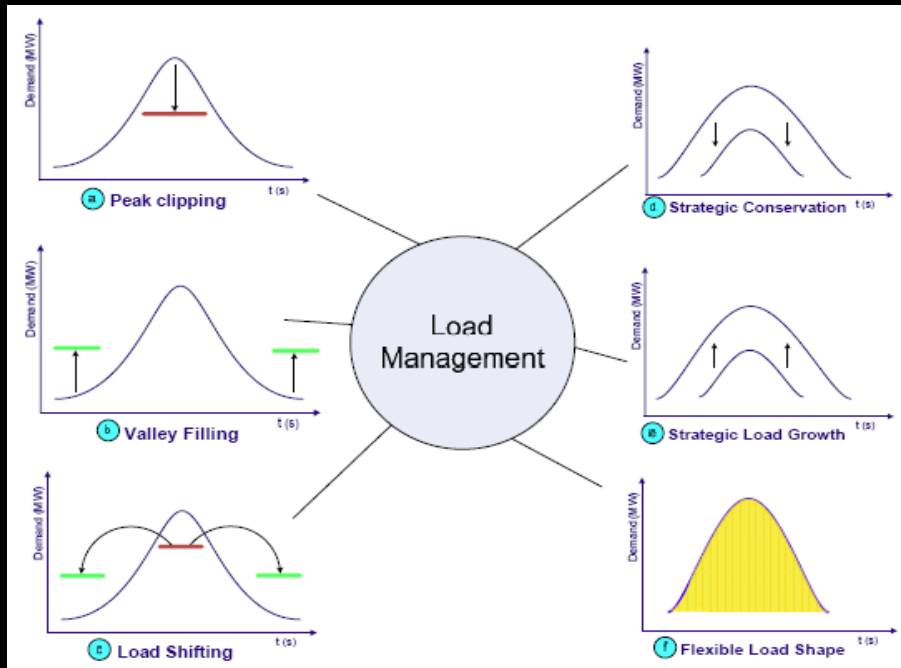
- Left Panel:** Contains input fields for 'Selected Demand' (230.724), 'test2', 'Selected Supply' (161.619), '1,2,3,4,7', 'Selected Auxilliary' (-2.7452), and '215Ah @ 12V (US-185HC)'. It also features an 'Auto Search' button with a dropdown set to '1' and a 'Size Supply' button. A status indicator shows '1 result found'.
- Central Diagram:** A flow diagram showing 'Demand 1' (highlighted in a red box) connected to 'Supply 1' through 'Supply 7' (collectively in a red box labeled 'supply scenarios'). These are then connected to 'Auxiliary 1' (highlighted in a red box). A red box labeled 'combinatorial search' is positioned between the supply and auxiliary boxes. A red box labeled 'load management' is positioned below the demand box.
- Right Panel:** Contains 'Match Results' with a table:

Correlation	Inequality	Excess	Deficit
0.76	0.26	3.10255	74.9524

 Below this are 'Current Match Rating' (Good Match 7/10) and 'Potential Match Rating with Improved Storage' (With increased storage 10/10). A red box labeled 'goodness of fit' is placed to the right of these ratings.
- Bottom Section:** Three graphs are displayed:
 - Supply and Demand:** A line graph of Power (KW) vs Days (0.0 to 9.0). It shows Demand (blue line) and Supply (green line). A red box labeled 'supply v. demand' is overlaid on the graph.
 - Residual Power:** A bar chart of Power (KW) vs Days (0.0 to 9.0). It shows the difference between supply and demand. A red box labeled 'surplus or deficit' is overlaid on the graph.
 - Auxiliary Performance:** A line graph of State of Charge (%) vs Days (0.0 to 9.0). It shows the charge level of the 215Ah @ 12V battery. A red box labeled 'auxiliary duty cycle' is overlaid on the graph.

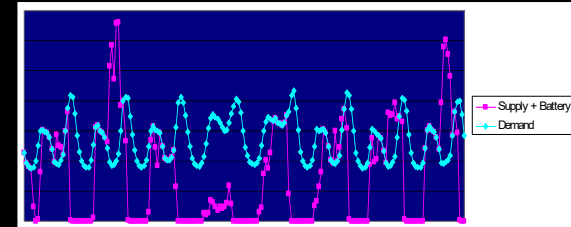
The Windows taskbar at the bottom shows the Start button and several open applications: 'Exploring - My Doc...', 'Microsoft Excel - Io...', 'Microsoft Word - Lo...', 'MERIT: Projec...', and 'untitled - Paint'. The system clock shows '10:37'.

Demand management/response

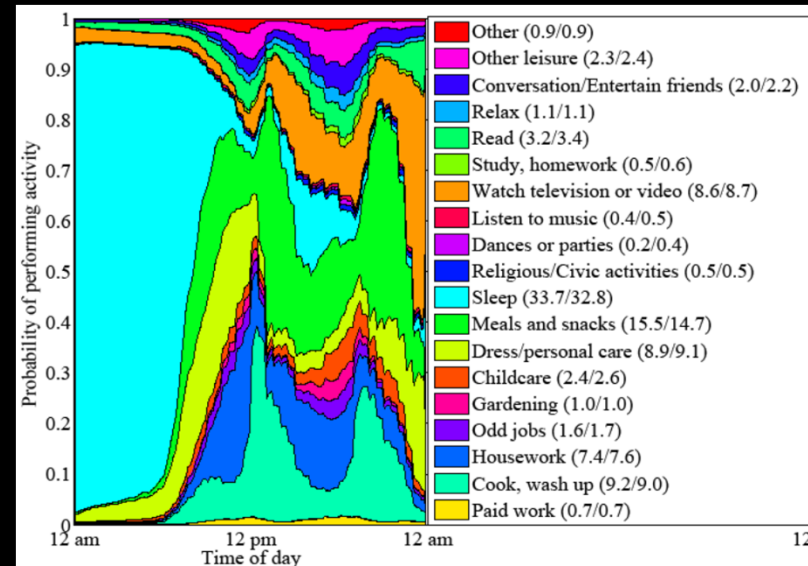
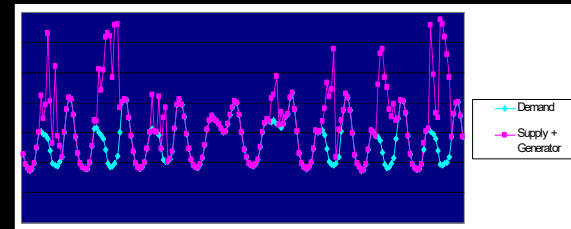


Issues: active network control; user needs and expectations; who benefits; unintentional impacts; tariff complexity; understanding building physics.

62%



81%

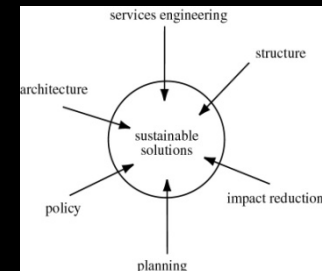
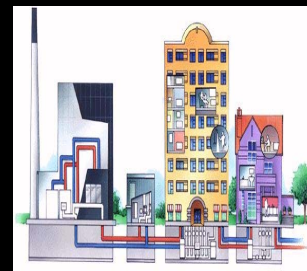
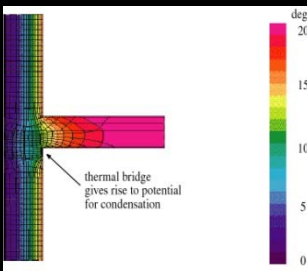
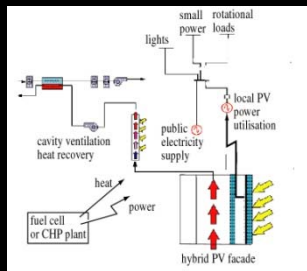
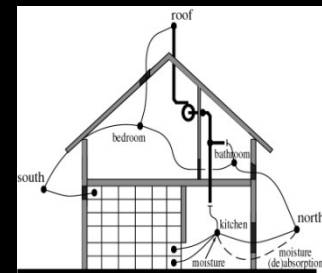
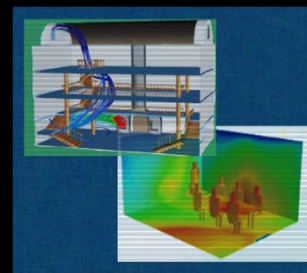
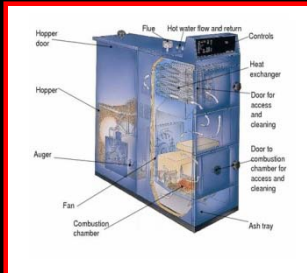
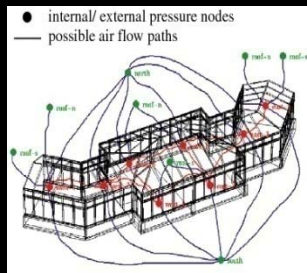
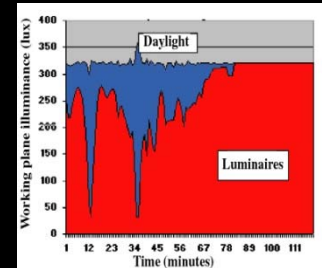
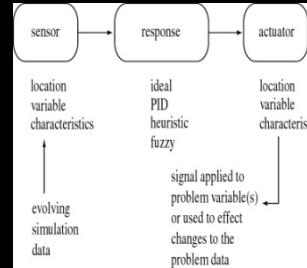
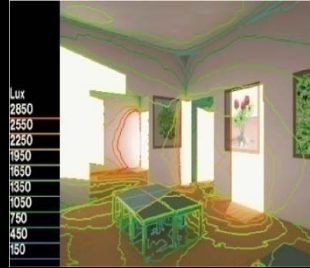
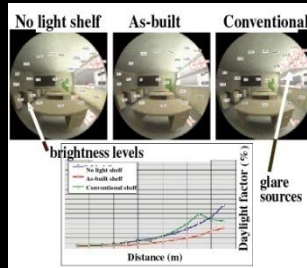
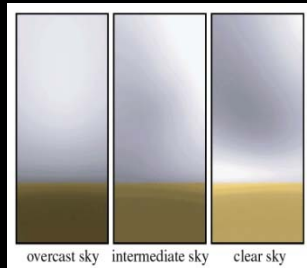
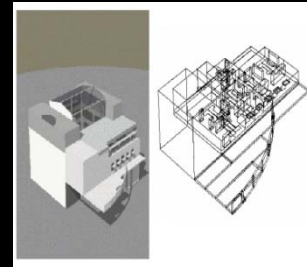
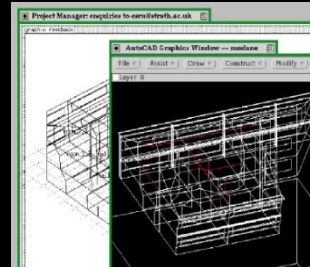
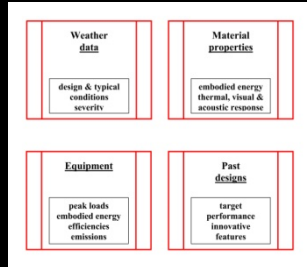
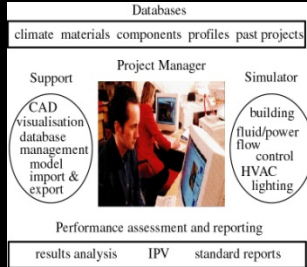


Source: Darren Robinson, 2012

Integrated performance simulation

Behaviour follows description.

increasing effort

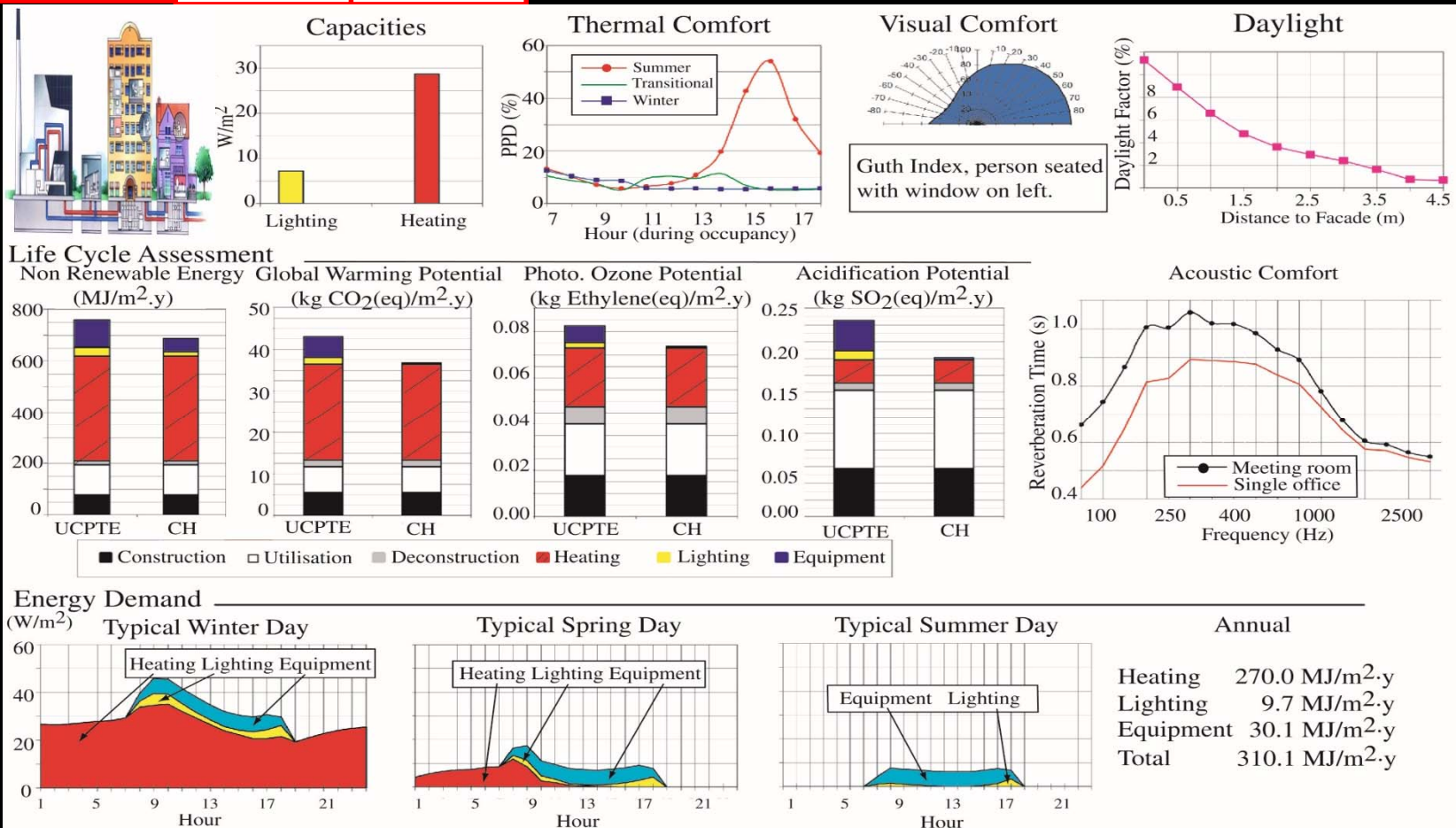


Simulation-assisted building design

Version 1

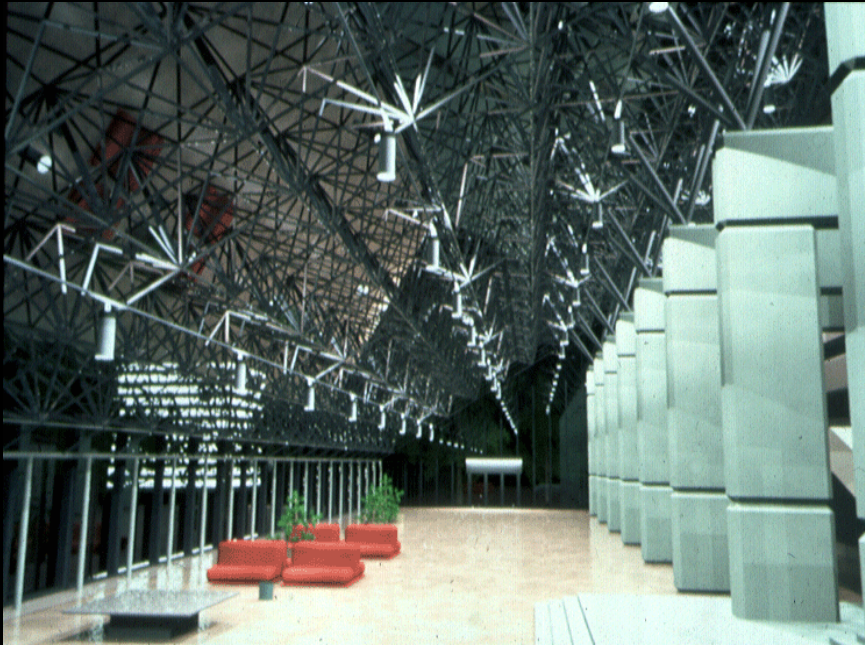
Version 2

Version 3

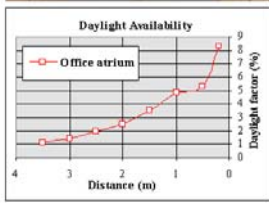
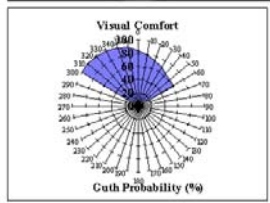
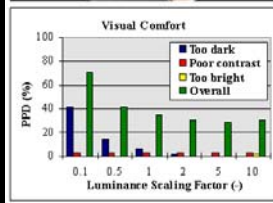
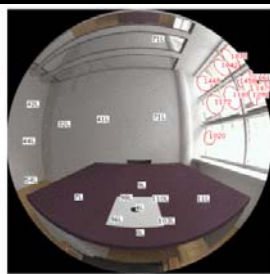
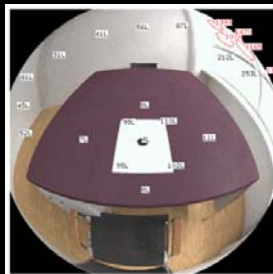
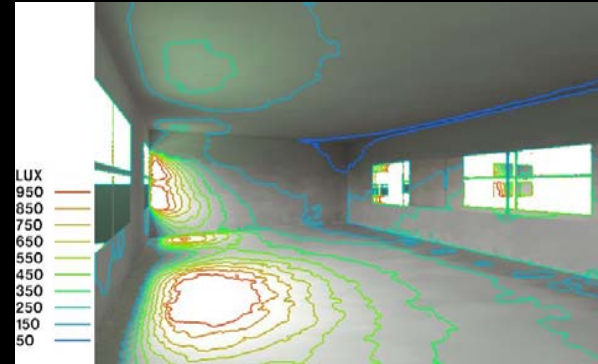


Issues: validation; accreditation; standard performance assessment methods; education & training.

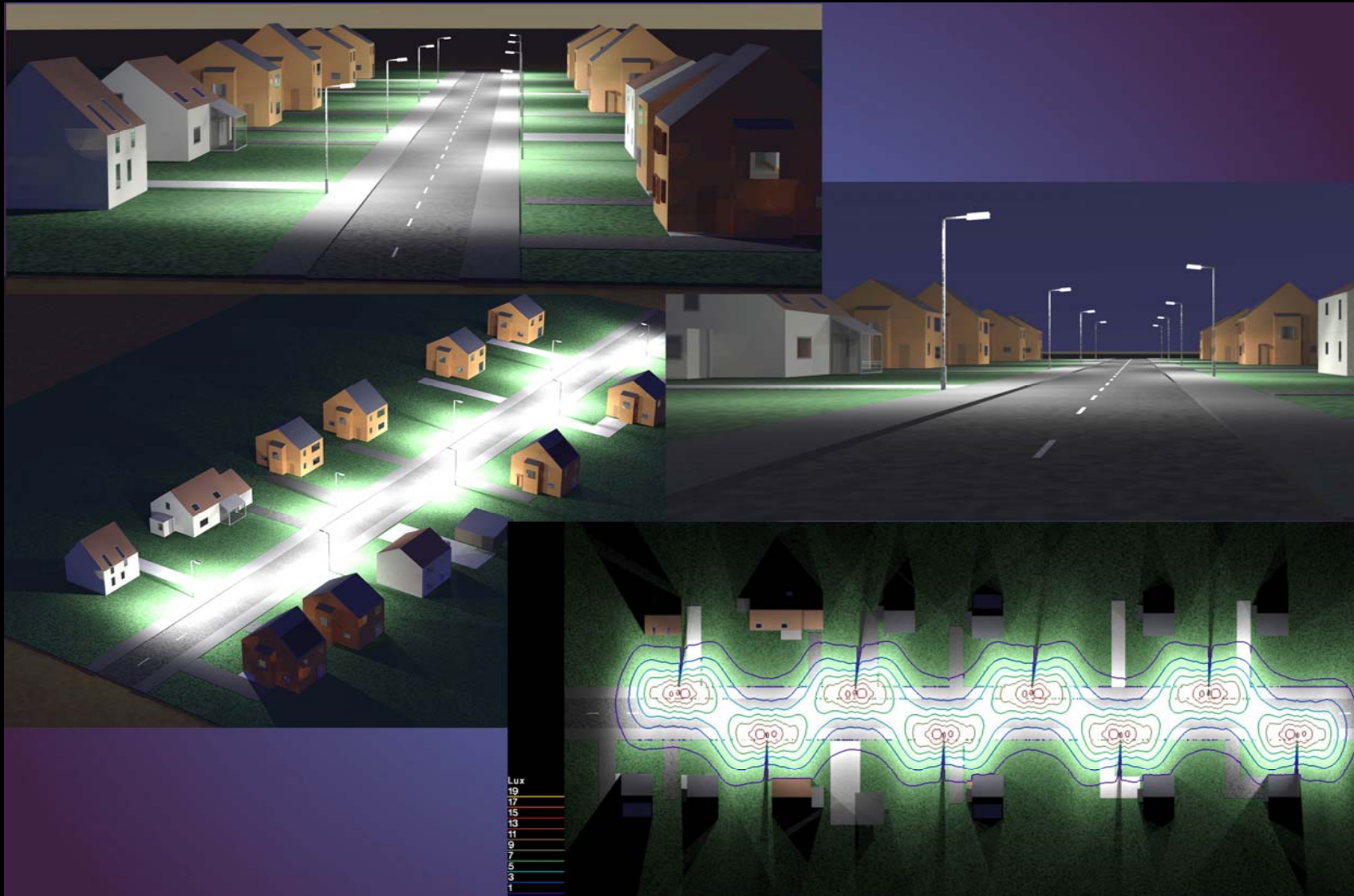
Visualisations



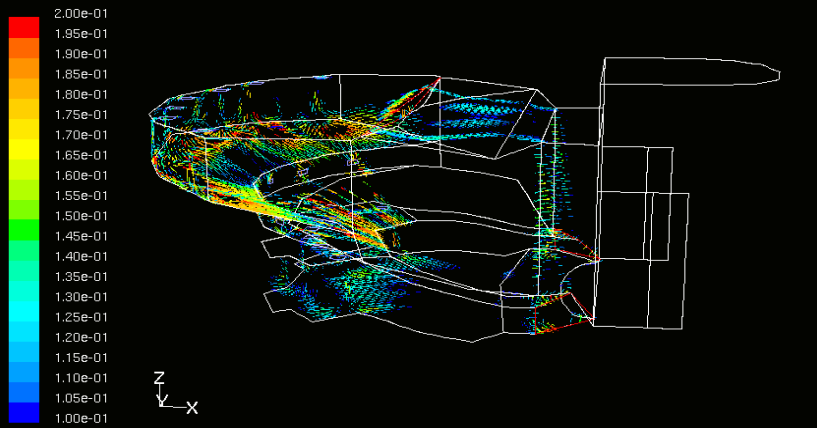
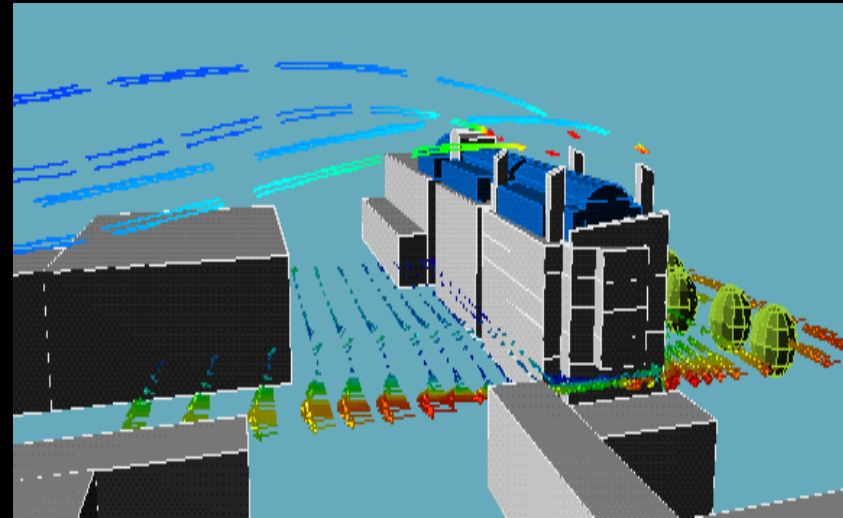
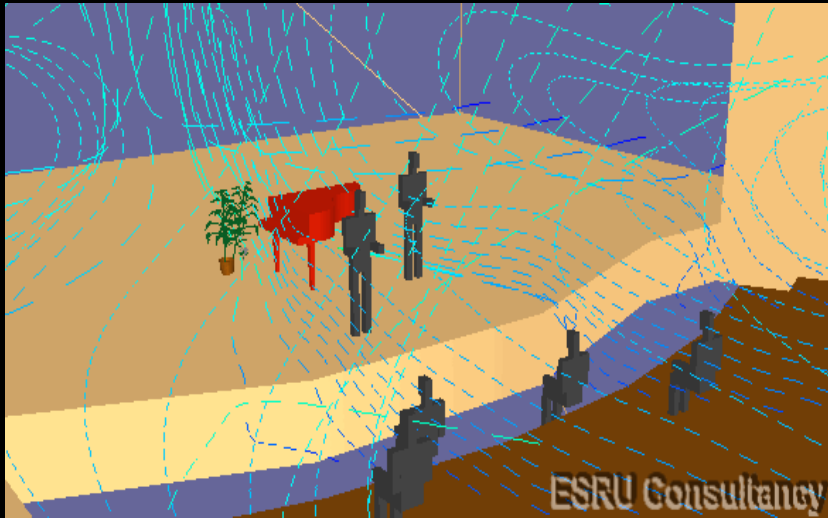
Internal lighting



External lighting

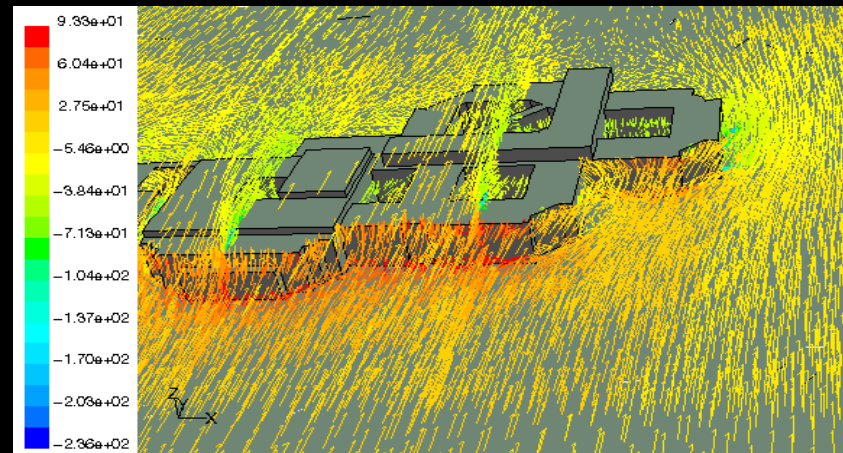


Air flow and emissions



Velocity Vectors Colored By Velocity Magnitude (m/s)

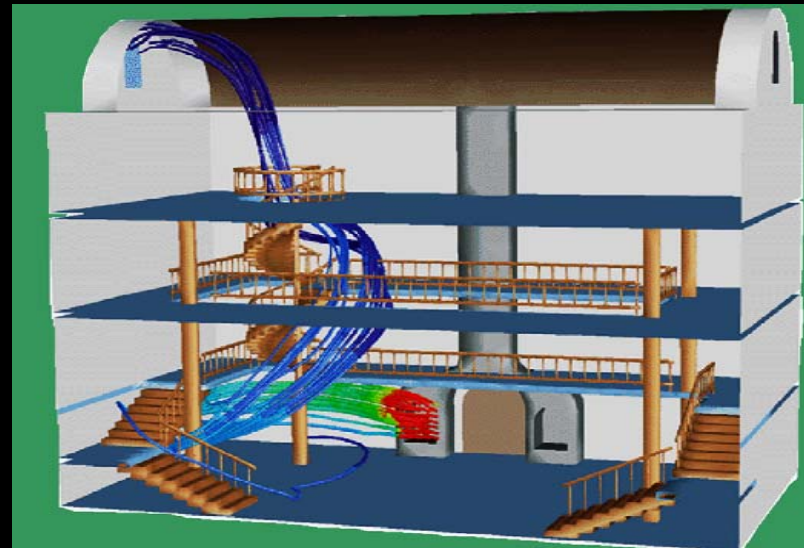
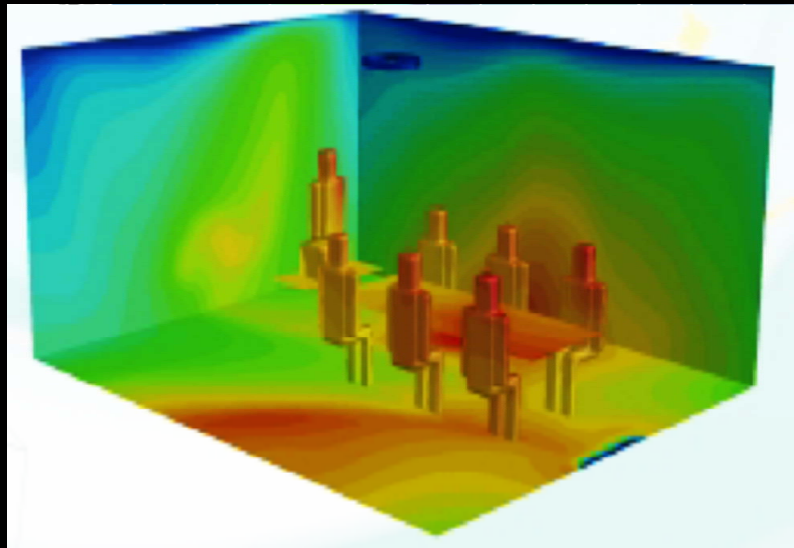
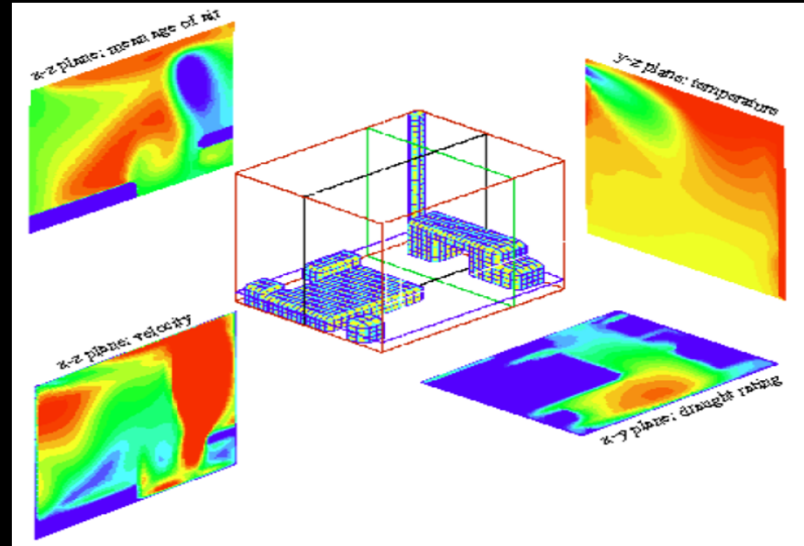
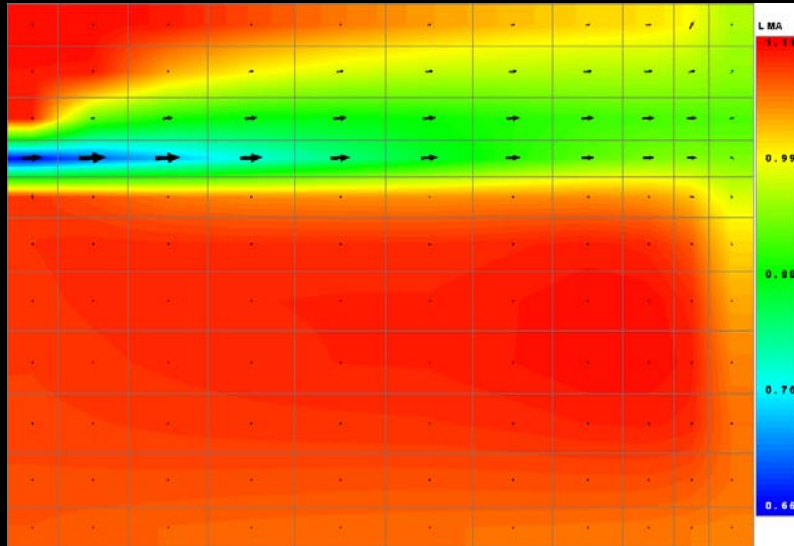
Dec 14, 2004
FLUENT 6.1 (3d, segregated, ske)



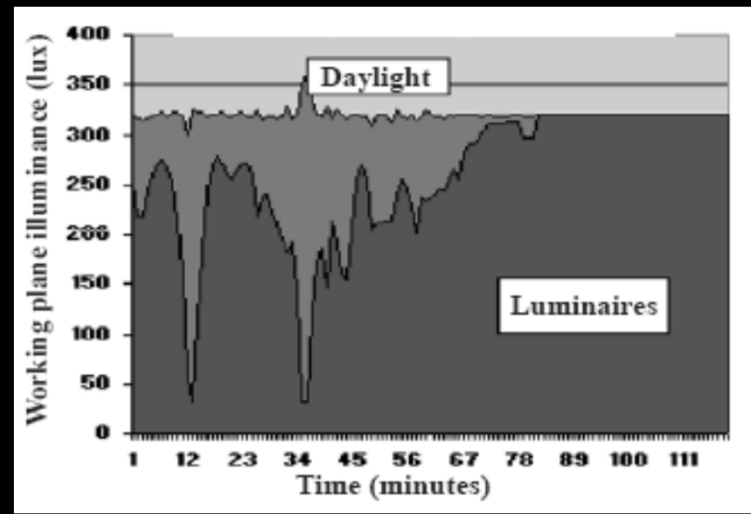
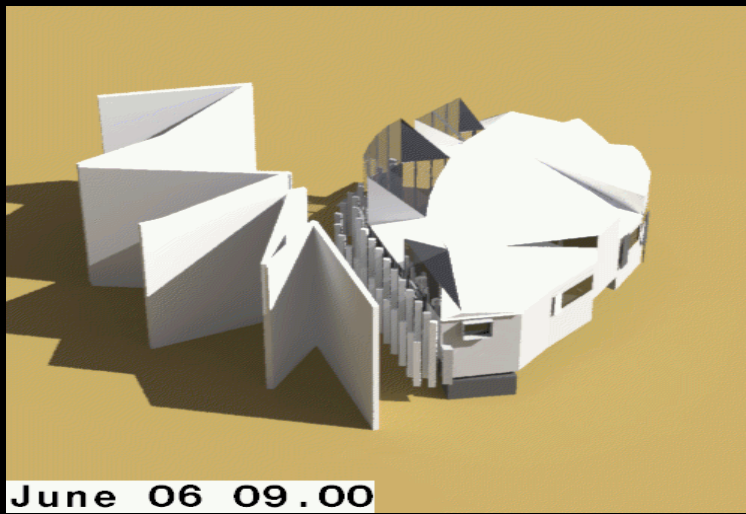
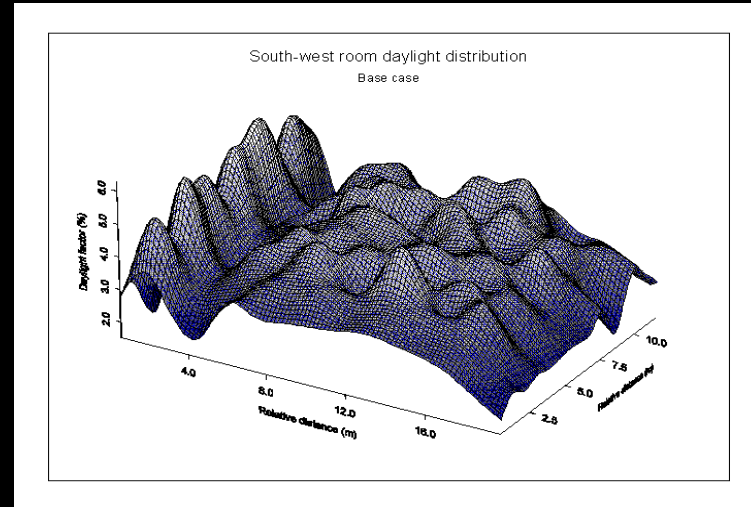
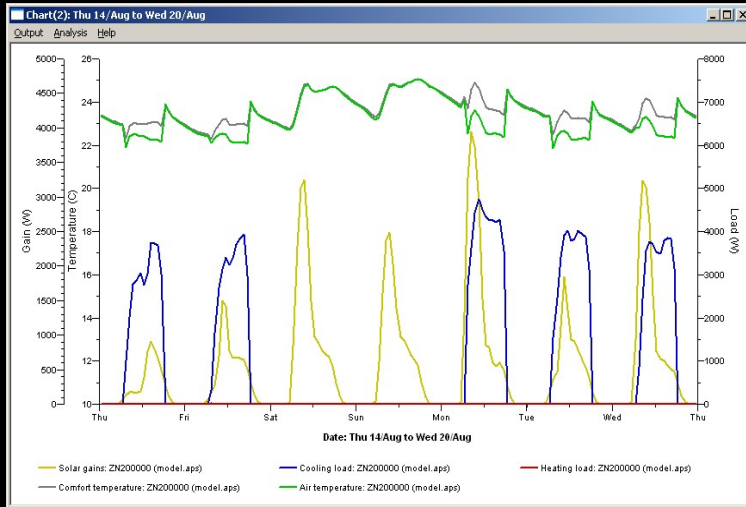
Velocity Vectors Colored By Static Pressure (pascal)

Jun 28, 2001
FLUENT 5.5 (3d, segregated, ke)

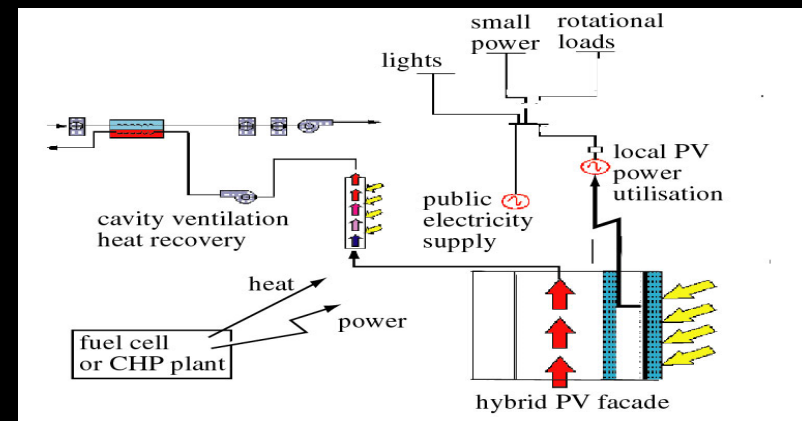
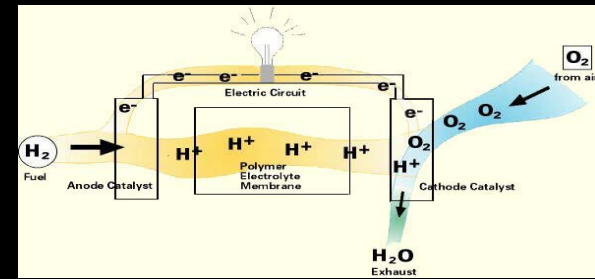
IAQ & comfort



Appropriate data presentation



Integrating renewables



Non-building applications

