BSG Seminar
24/02/2015

Building Simulation:
Are Graduates Ready?

Building Performance Simulation: Teaching &Learning Requirements

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and
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Are graduates ready?

- Modelling is the representation of a system, while simulation is the processing of the model in a manner that emulates reality.
- Most BPS tools are not truly simulation-based but mix simplified calculations with some aspects of simulation.
- This inappropriate mix, along with limitations with simulation itself, is the reason for the gap between virtual appraisals and real world observations.
- BPS users cannot simulate something if they do not understand the component parts or the rationale of the systems that may be created by mixing these parts.
- Simulations do not generate solutions but aid understanding of overall systems performance as the prerequisite of solutions generation.
- Effective simulation application requires 3 user attributes: understanding of fundamentals, modelling & simulation skills, and raised scholarship.
- Graduates may not appreciate these distinctions or have the knowledge to apply effectively simulation in practice.
- Present T&L provisions do not have the required depth and width, treat BPS as a bolt-on activity and do not place learning in the context of agreed application practices.

Understanding fundamental

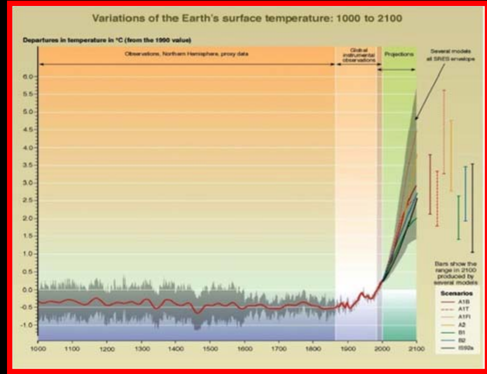
If you don't understand something, don't propose it.

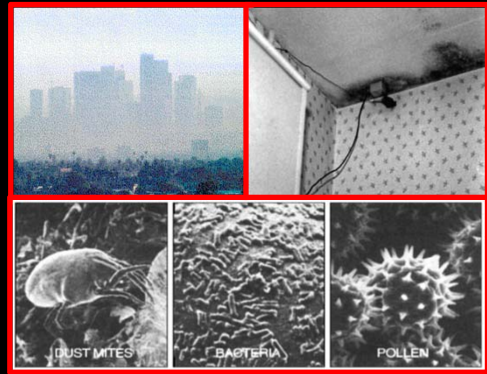
Myriad technologies and drivers

Demand-side:
- daylight utilisation
- smart control
- smart zoning
- passive solar devices
- heat recovery
- solar ventilation pre-heat
- switchable glazings
- selective films
- transparent insulation
- moveable devices
- breathable walls
- phase change material
- demand management
- smart meters & grids
- electric vehicles

Supply-side:
- condensing boiler
- heat pump
- combined heat and power
- tri-generation
- photovoltaics
- desiccant cooling
- evaporative cooling
- electricity to heat
- smart space/water heating
- urban wind power
- biomass/biofuel heating
- culvert heating/cooling
- district heating/cooling
- energy storage
- fuel cells

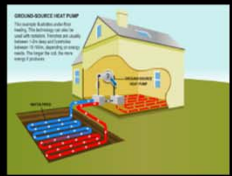
How to ensure appropriate deployments:
- technical feasibility;
- social acceptability;
- economic impact;
- life cycle economics;
- energy/ carbon economics;
- environmental impact assessment;
- controllability assurance;
- hybrid schemes for resilience

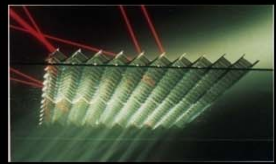


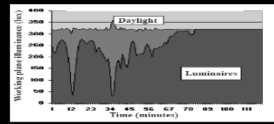


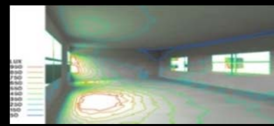
Fundamentals:
- building physics
- thermo-fluids
- heat and mass transfer
- radiation exchange
- systems and plant processes
- micro-climate
- electrical systems
- renewable energy systems
- air quality
- human comfort
- computational approaches
- control systems

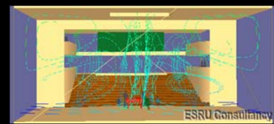
An expanding problem domain

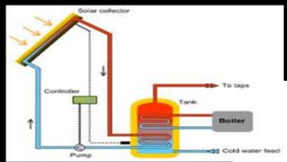


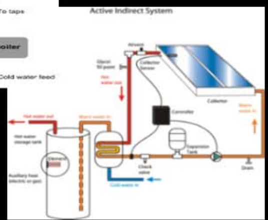


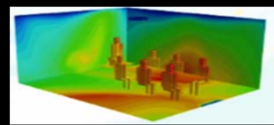


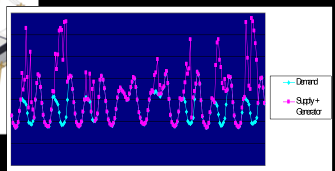


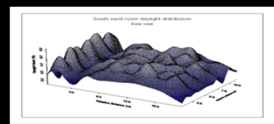












Emergence of the 'smart' city

monitored
data

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

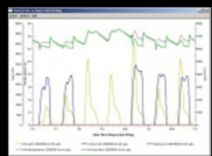
database of
actual & future
consumption etc.

e-Services:
- ❑ alarms & alerts;
- ❑ conditions monitoring;
- ❑ local & aggregate control;
- ❑ health services;
- ❑ information;
- ❑ equipment control;
- ❑ trend analysis.

remote
monitoring

theoretical
benchmarking

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



Simulation

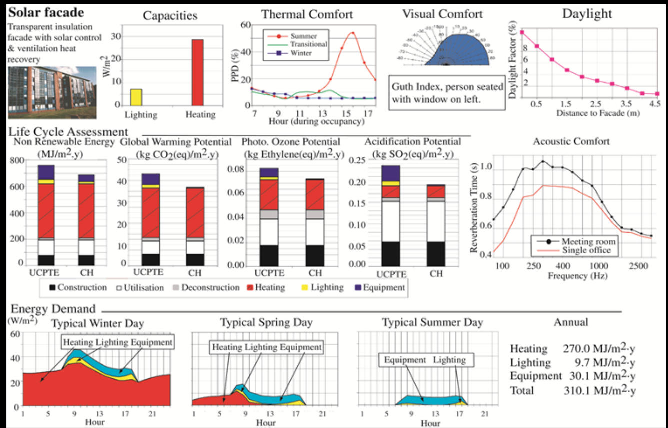
scenario
appraisal

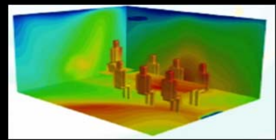
Modelling & simulation skills

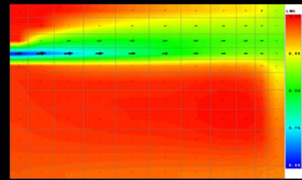
If you can’t simulate it, don’t build it.

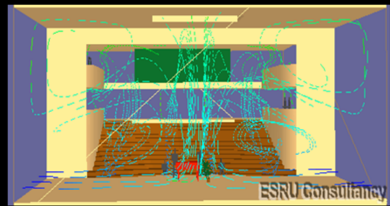
Modelling and simulation

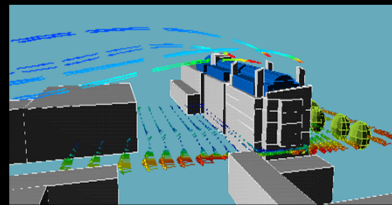
- Simulation's role is to support multi-variate assessment and deliver experiential outputs to aid understanding.

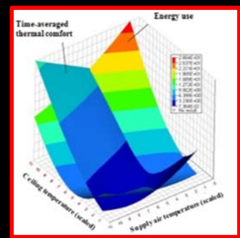


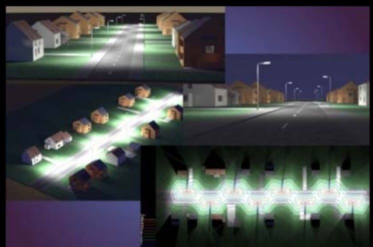


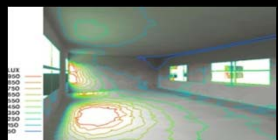


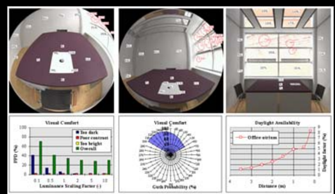


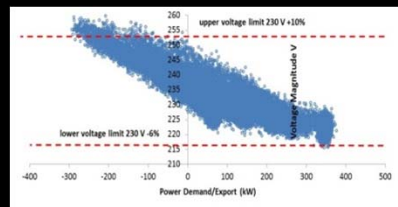








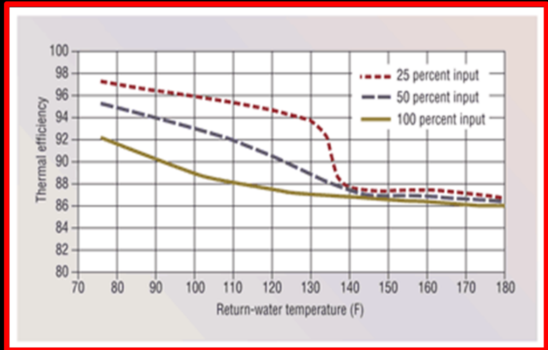




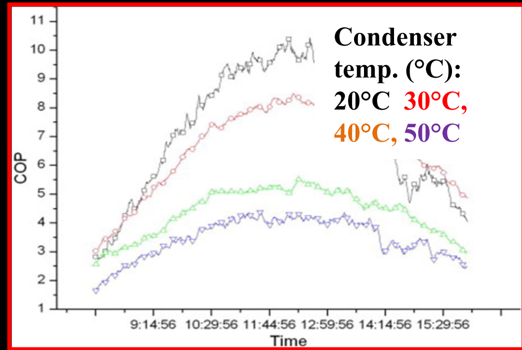
- All energy systems are: dynamic, non-linear, systemic and stochastic.

System dynamics

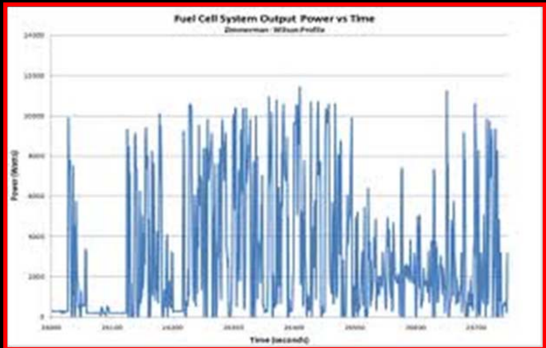
boiler

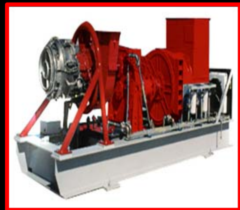


heat pump

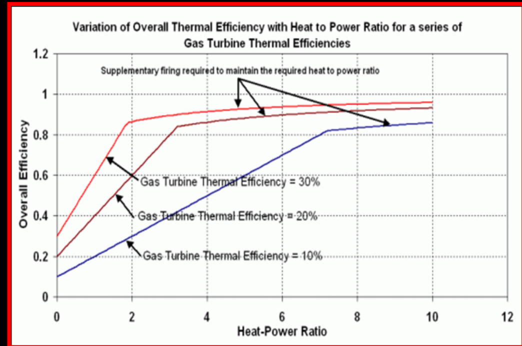


fuel cell

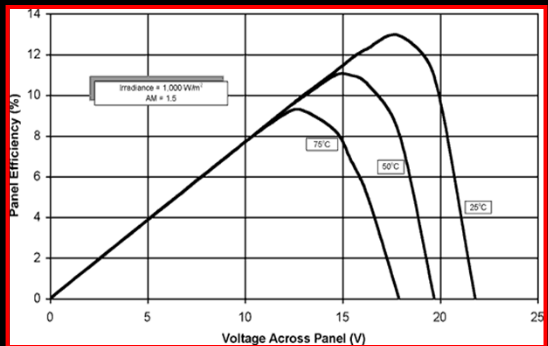




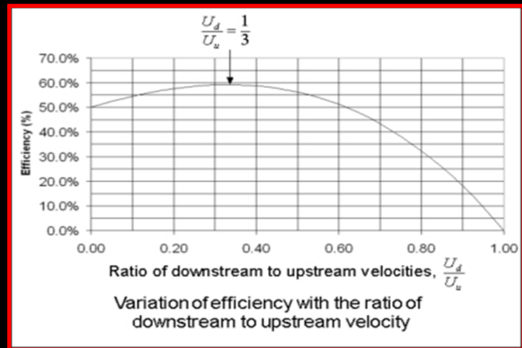
gas turbine



photovoltaics

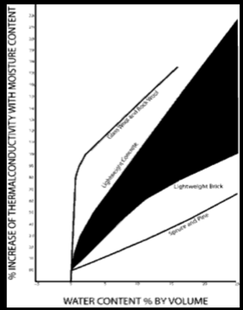


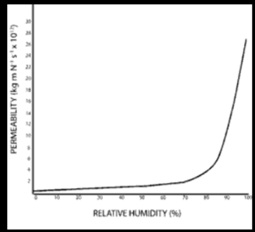
wind turbine

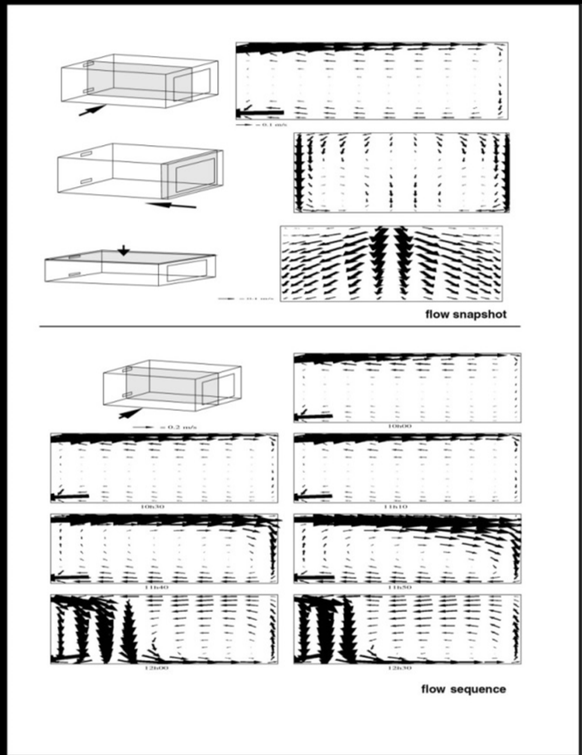


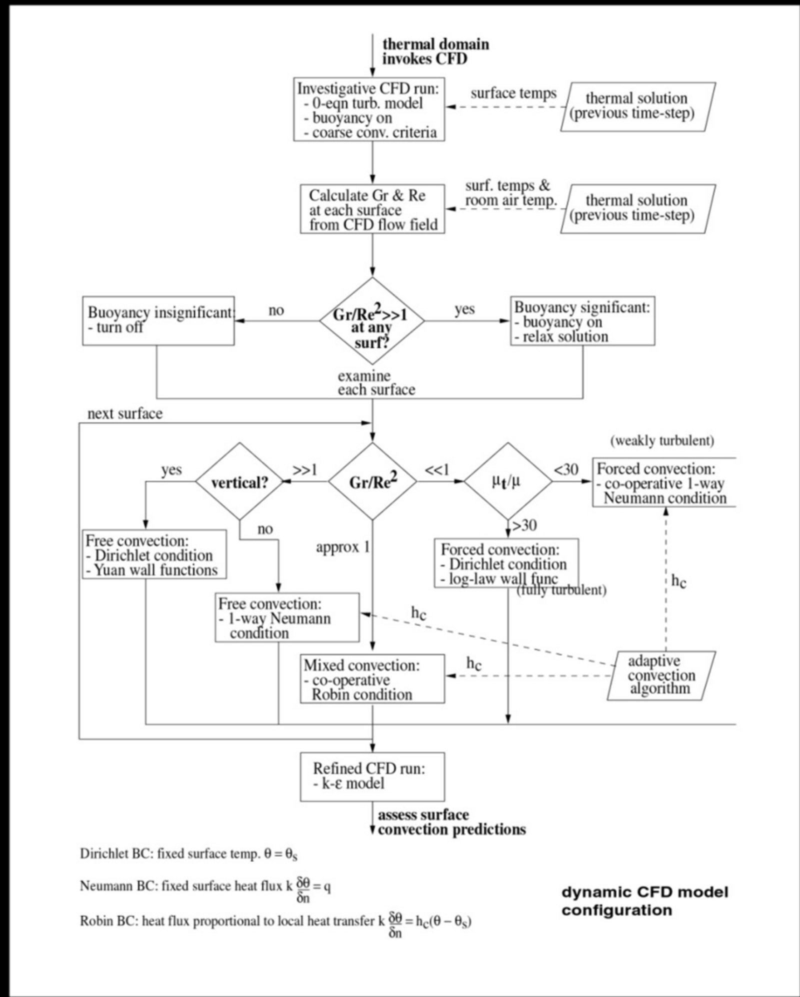
System non-linearity

Gr – how buoyant; Re – how forced
$Gr/Re^2 \ll 1$ - forced convection dominates
$Gr/Re^2 \gg 1$ - free convection dominates
$Gr = Re^2$ - forced and free convection significant
μ_t - eddy viscosity; μ - molecular viscosity
$\mu_t/\mu < 30$ - flow is weakly turbulent

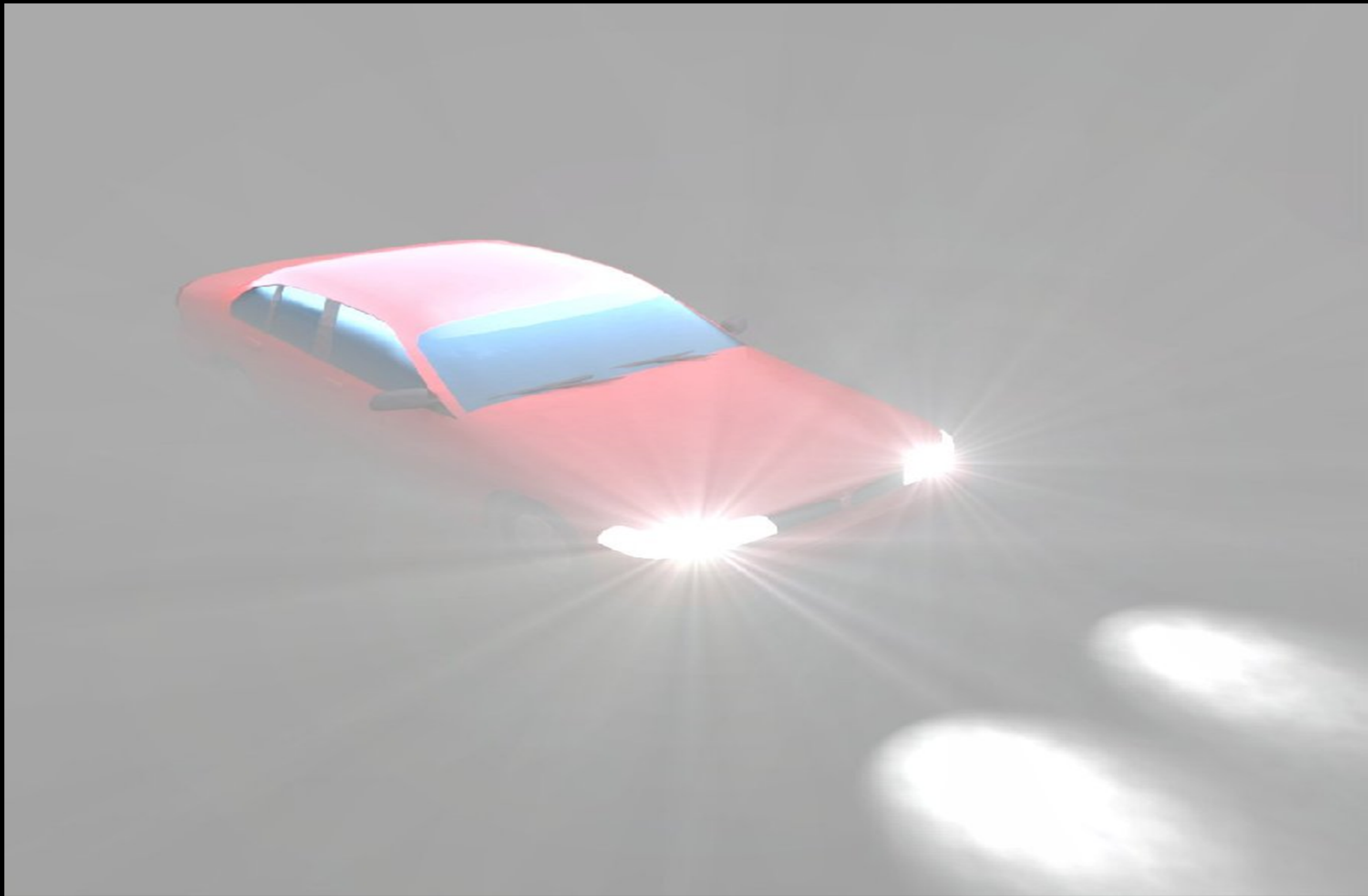






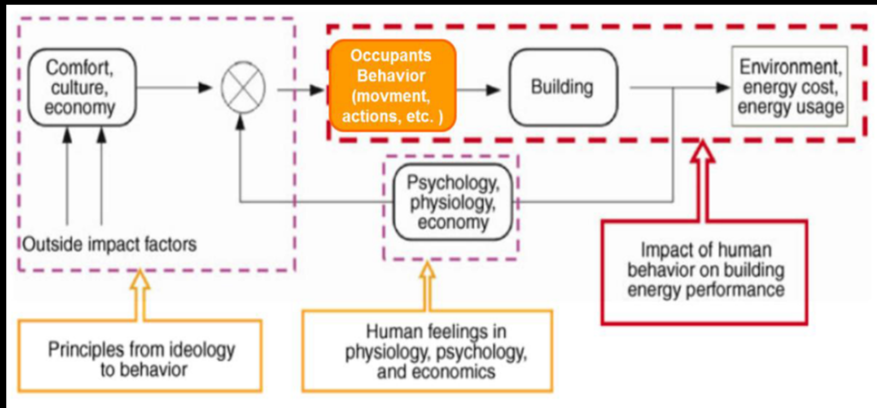


Systemic nature



Stochastic processes

- ❑ Occupant impacts:
  - heat and pollutant emissions;
  - door and window opening;
  - blind positioning;
  - light switching;
  - small power usage;
  - movement;
  - control system adjustments; and
  - response to external factors.



IEA Annex 66: Simulation of occupant behaviour.

- ❑ Stochastic due to personal preferences, individual behaviours and response adaptation.

- ❑ Ultimate aim is the insertion of 'agents' within simulations to:
  - model above impacts; and
  - embed the means of judging performance acceptability within the simulation process itself (i.e. performance acceptability is decided by a model of real occupants and not by tool users).

Raised scholarship

Effective design requires an appreciation of what has and has not worked in the past and the rationale of new options.

So many options

- Need to understand reasons for past failures.
- Place fundamentals teaching in the context of overall systems design.
- Adopt a computational approach to group and individual project work.
- Share case study materials between organisations.
- Develop practice-led activities through Graduate Academies.
- Develop on-line CPD courses.

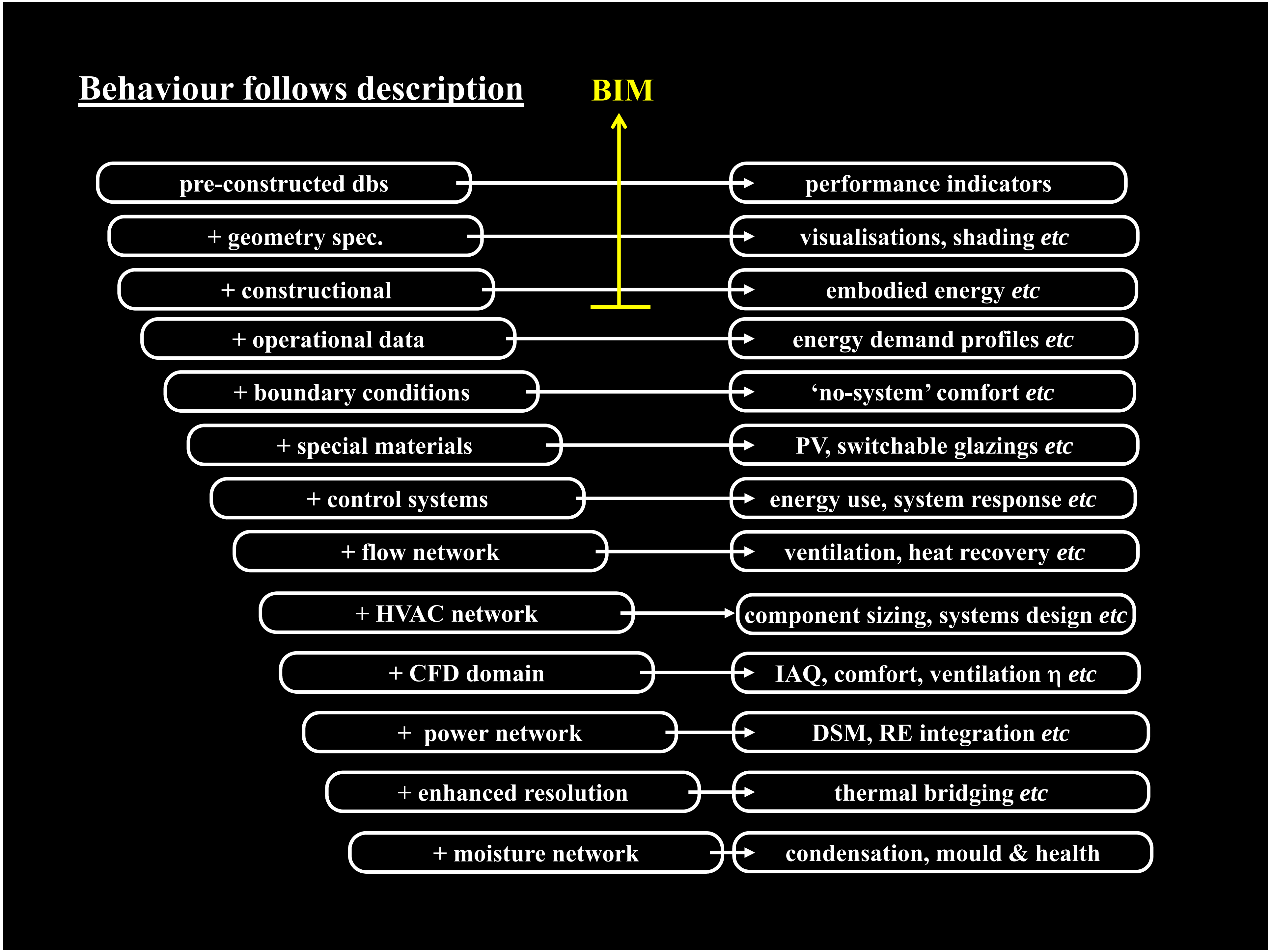
District heating
Micro-grids
Smart grids
Energy Centres
Zero carbon communities
Smart Cities
Urban renewable energy
Electric vehicle integration
Biomass heating systems
Heat pumps
Schools of the future
Combined heat and power
Refurbishment
Resilience
Post occupancy evaluation
Simulation-assisted control
Zero carbon homes
Demand response
Demand side management
Internet energy services
Building-integrated PV

Options appraisal

Requires changes to work practices and adherence to standard performance assessment methods (PAMs – action in **red**, knowledge in yellow):

1. establish initial model for an unconstrained base case design;
2. calibrate model using reliable techniques;
3. assign boundary conditions of appropriate severity;
4. undertake integrated simulations using suitable applications;
5. express multi-domain performance in terms of suitable criteria;
6. identify problem areas as a function of criteria acceptability;
7. analyse results to identify cause of problems;
8. postulate remedies by relating parameters to problem causes;
9. establish revised model to required resolution for each postulate;
10. iterate from step 4 until overall performance is satisfactory;
11. repeat from step 3 to establish design replicability.

Issues: PAMs required for all aspects: comfort, health & productivity; operational & embodied energy, emissions & environmental impact, technology options appraisal, demand management, embedded generation, regulations compliance, hybrid systems control, economics, *etc*.


Behaviour follows description
BIM
pre-constructed dbs
performance indicators
+ geometry spec.
visualisations, shading etc
+ constructional
embodied energy etc
+ operational data
energy demand profiles etc
+ boundary conditions
'no-system' comfort etc
+ special materials
PV, switchable glazings etc
+ control systems
energy use, system response etc
+ flow network
ventilation, heat recovery etc
+ HVAC network
component sizing, systems design etc
+ CFD domain
IAQ, comfort, ventilation η etc
+ power network
DSM, RE integration etc
+ enhanced resolution
thermal bridging etc
+ moisture network
condensation, mould & health

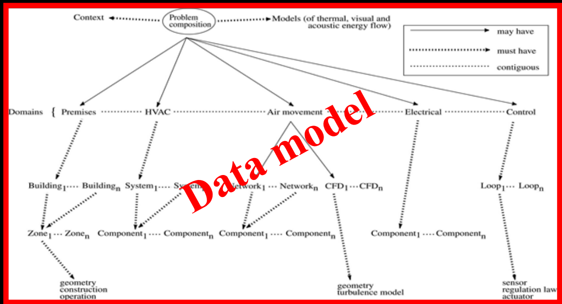
Behaviour follows description (i.e. reward follows effort)

increasing effort

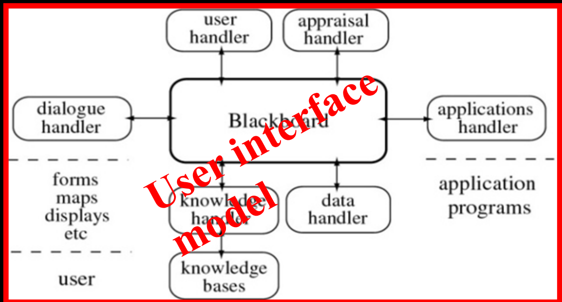
Design process integration

A computational approach to design will require changes to present work practices

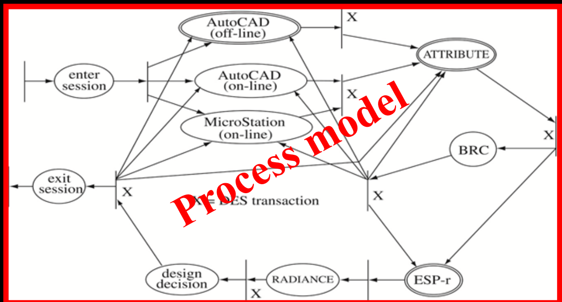
Design process integration



Issues: extension of BIM to cover all performance domains & criteria; agreed semantics; tool interoperability; parameterised model prototypes.



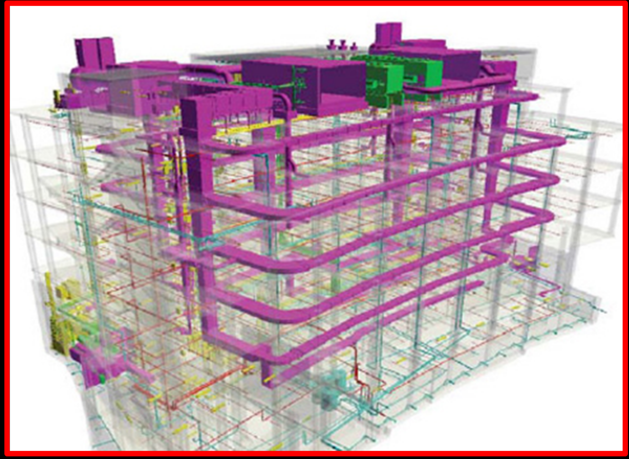
Issues: interface standardisation; applications harmonisation, standard PAMs; standard databases; co-simulation support; pre-formed entities.



Issues: work flow management; standard model making procedures; standard & exceptional assessment procedures; action planning procedures.

Business integration

- BIM extension to cover all BPS domains.
- Scant support for:
  - problem decomposition/abstraction;
  - model calibration and quality assurance;
  - tool application coordination and interoperability;
  - conceptual outlook and skill level of users;
  - temporal aspects of design;
  - semantic diversity in the industry;
  - scenario-based design appraisal;
  - standard performance data presentation;
  - judging designs in terms of diverse considerations; and
  - mapping of simulation outcomes to design intervention.
- Industry needs:
  - user and tool accreditation procedures;
  - tool selection support;
  - model making guidance;
  - automated model calibration and quality assurance;
  - standard performance assessment methods;
  - agreed performance assessment criteria;
  - impartial program validation.



Source: www.viatechnik.com/bentley-triforma-modeling/

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Context
Geometry
Construction
Operation
Flow
HVAC
Renewables
Lighting
Electrical
Moisture
Control