Modelling Buildings; obtaining “accurate” energy data

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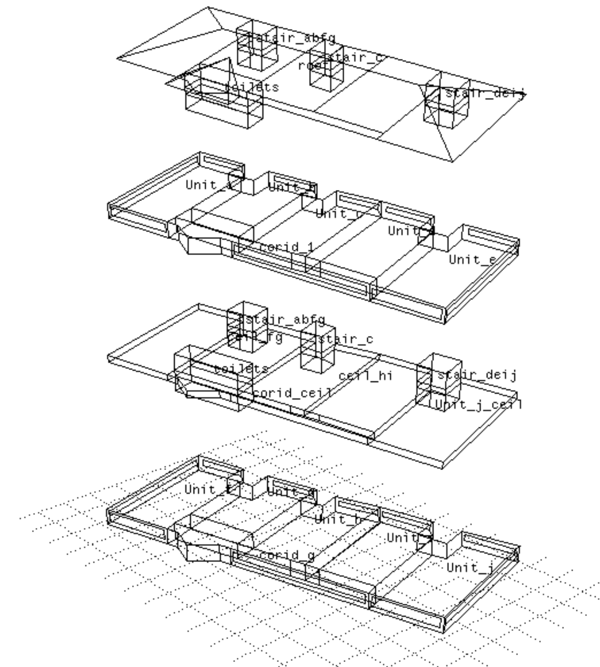
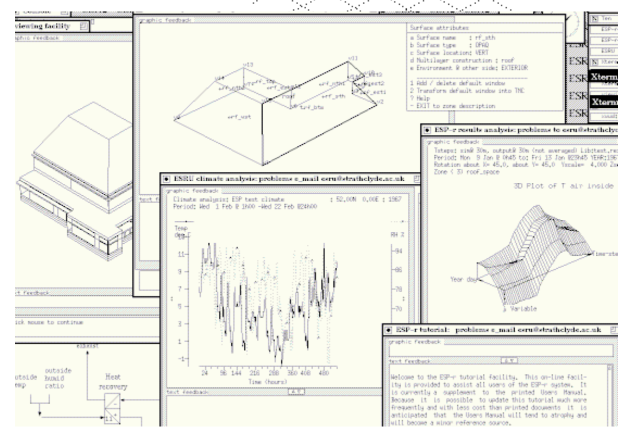
Overview

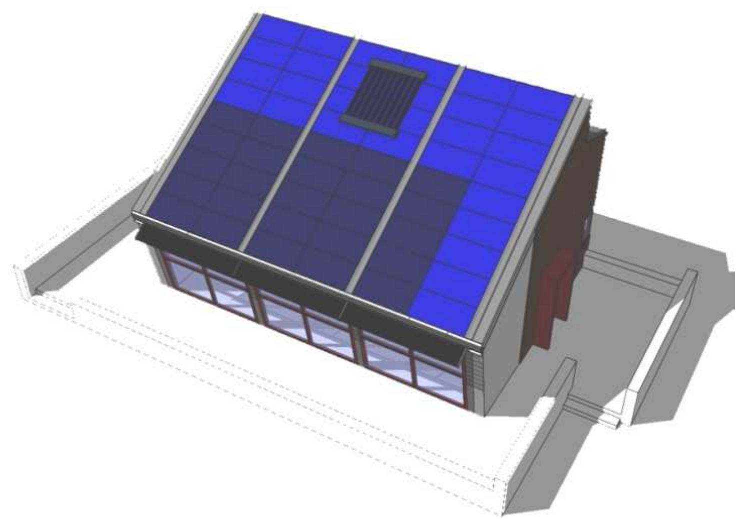
- Approaches obtaining energy data
- Different modelling approaches
- What do we mean by “accurate”?
- Detailed modelling
  - a decoupled demand “profile” approach
  - coupled building/plant modelling
- Example – detailed modelling
- Is this real life? Is this just fantasy?
- Improving realism





Demand Data Sources

- real data:
  - field trials and lab tests are a rich source of data on device and systems performance
  - both are expensive and scope is often limited
- modelling:
  - used appropriately, modelling is useful for answering “what if ?” questions
  - … and to examine performance over a diverse range of situations



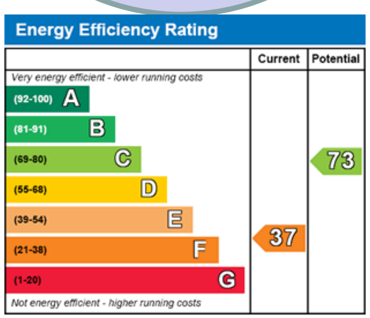
Modelling Approaches

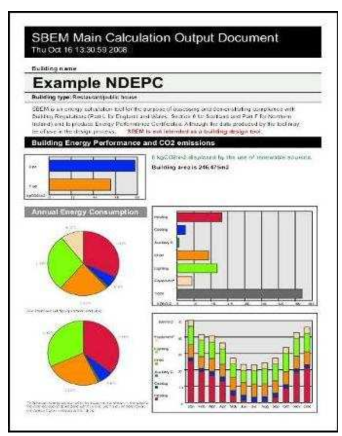
- the type of model dictates the type and 'realism' of the performance data we have available for design

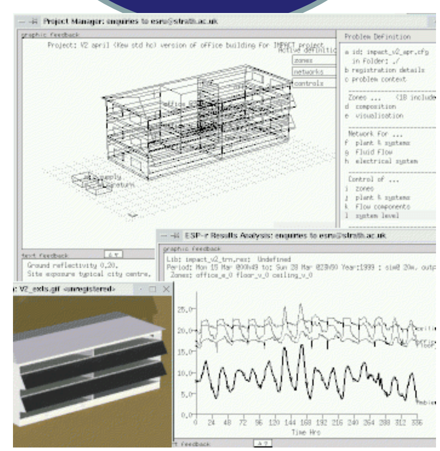
SAP - rating

SBEM – monthly energy consump.

DETAILED MODELLING – time series energy flows, temperatures, etc

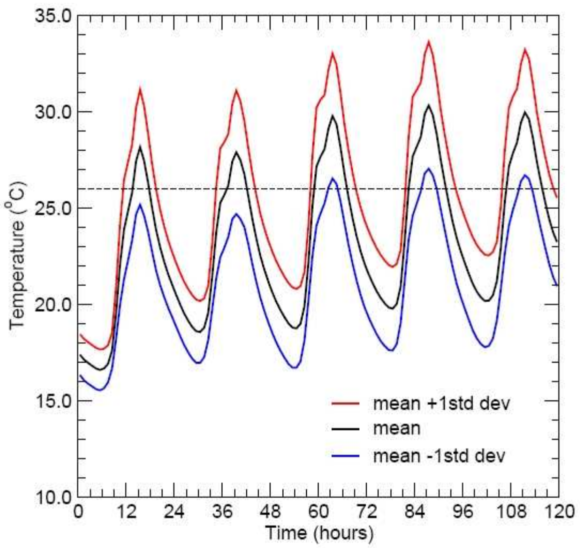


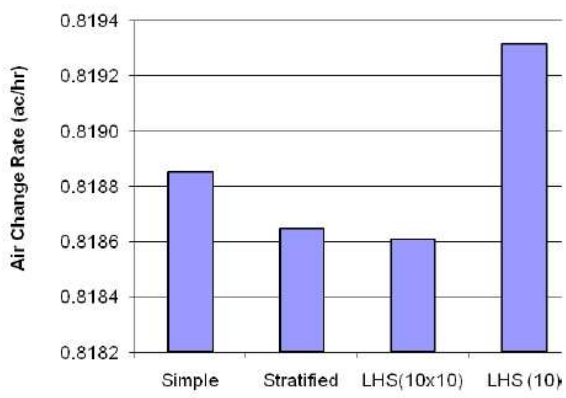




What does *accurate* mean?

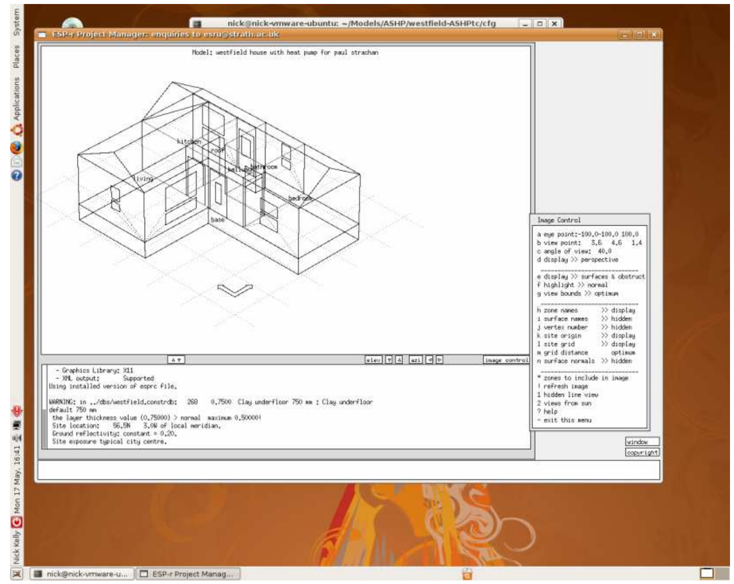
- … simulation will exactly replicate *exactly* how the building will behave once built
- **uncertainty** in modelling
  - the modeller, the software, the physical models, parameters, simulated and actual climate, etc.
- post occupancy factors
  - defects and changes from design
  - behaviour of occupants, etc.
- … simulation gives us a *realistic* indication of likely energy performance … subject to uncertainty and valid assumptions as to how building will be used

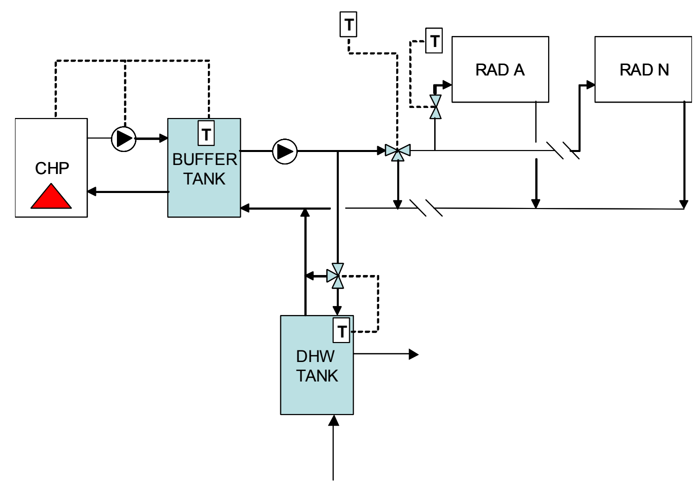




Detailed Modelling

- involves the development of a mathematical building model and its simulation of a building in a “realistic” context
- this is the basis of most building simulation (BS) tools such as IES, ESP-r, Energy Plus
- simulation involves running the model with site-specific climate data and user-defined control constraints
- output includes the effects of time-varying solar gains, infiltration. occupant heat gains, thermal inertia, etc.
- the output is dynamic time series data that can be used to quantify: device efficiency, fuel consumption, energy costs, start-up times. on/off cycling, temperatures, thermal comfort, etc.

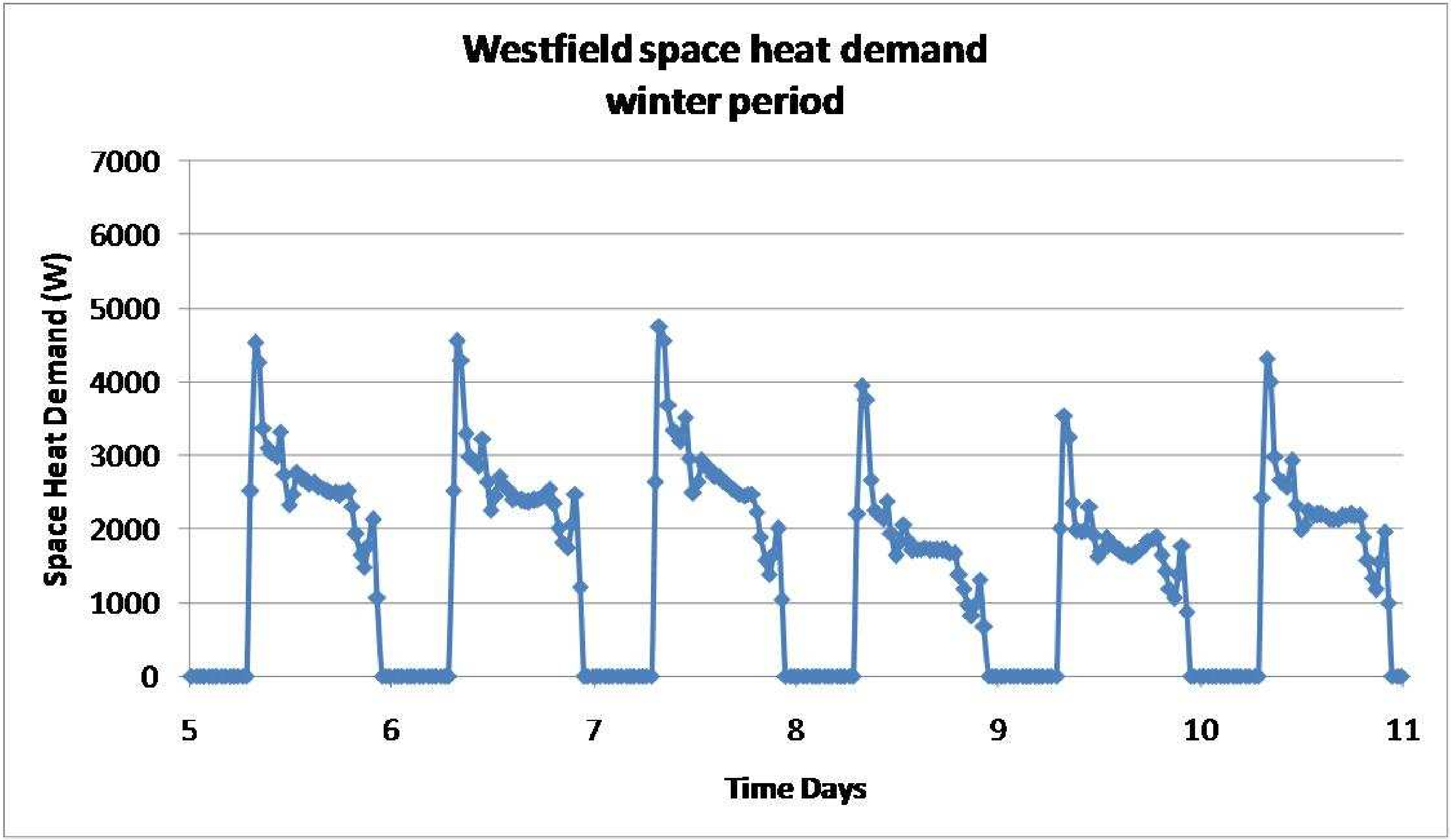




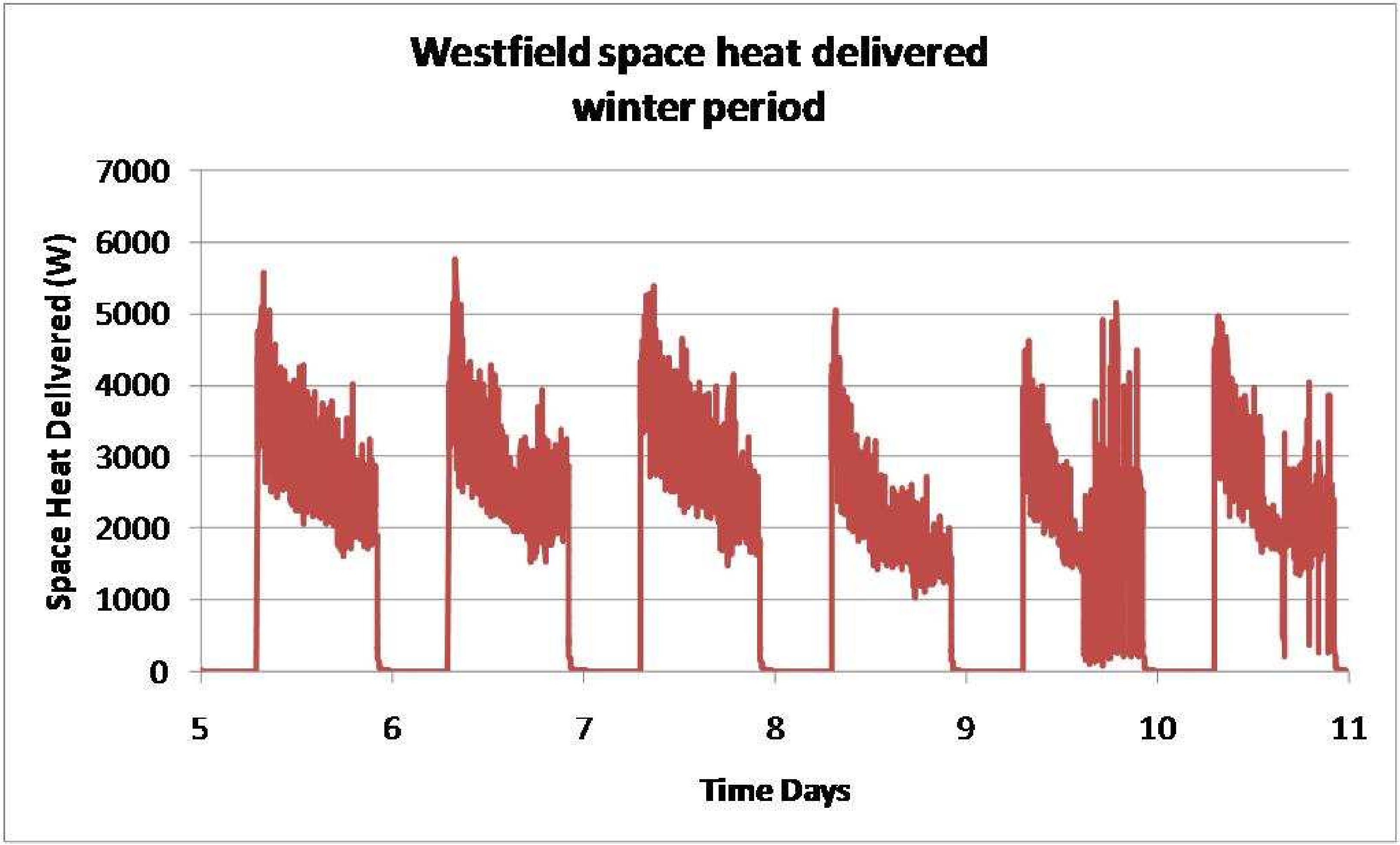
Generating Design Data

- 2 approaches:
- generate time-series heat demand ‘profiles’ for a building – ‘de-coupled modelling’
  - only need to model the building in detail
  - no interaction between load and plant
- model the operation of the heating device (i.e. heat pump) and the building together – ‘coupled modelling’
  - detailed modelling of building *and* system
  - plant/building interactions captured
  - *far* more complex model

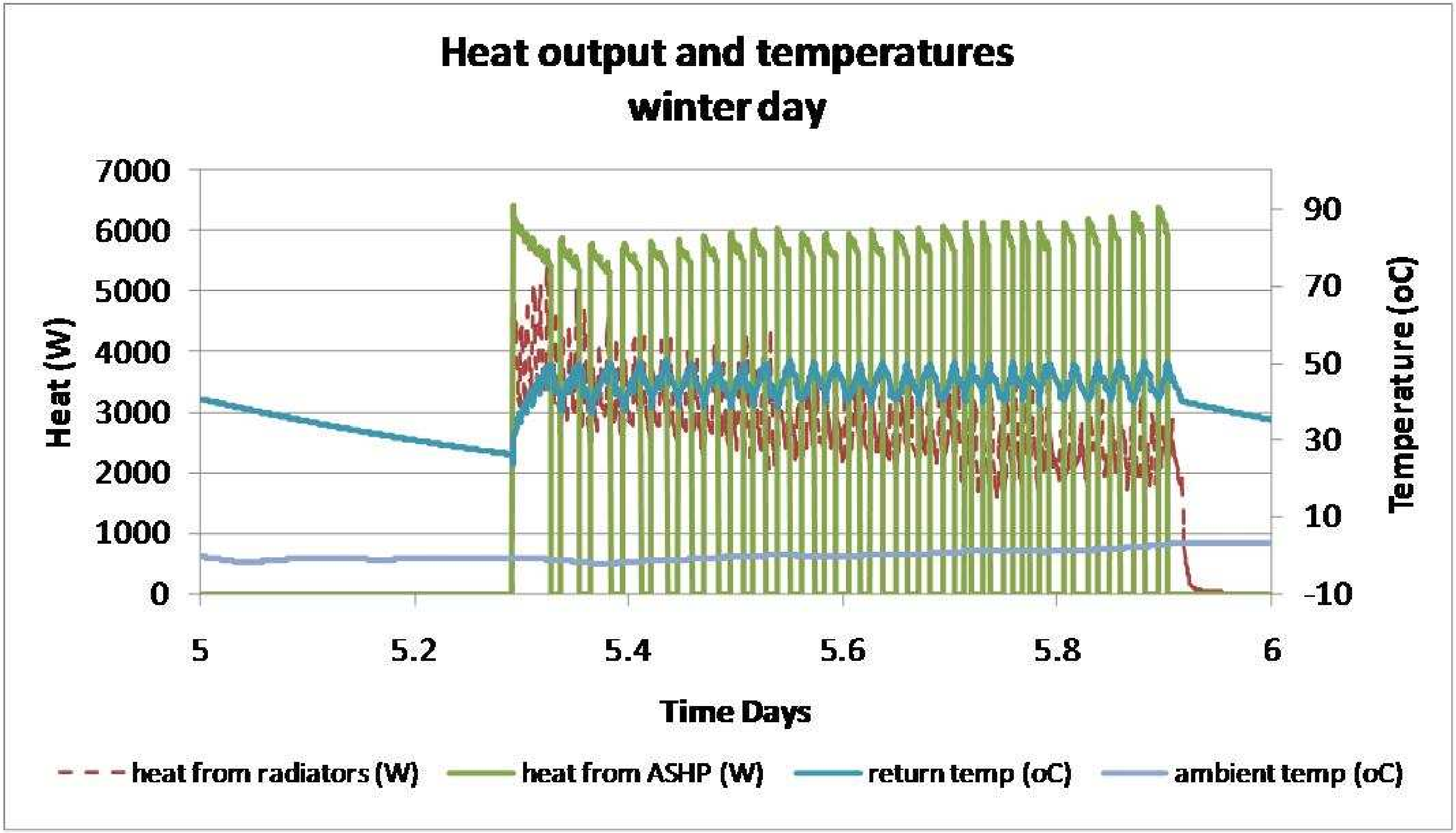
De-coupled Modelling



Coupled Modelling

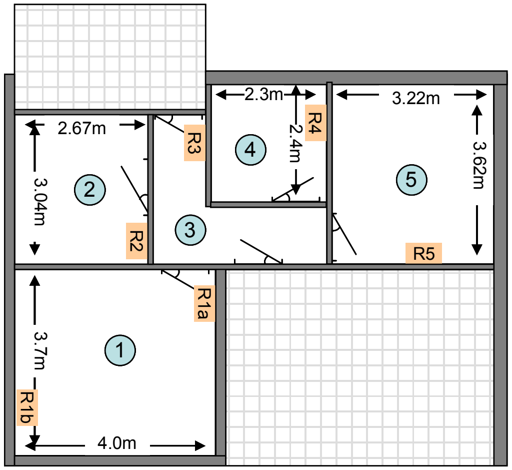


Coupled Modelling



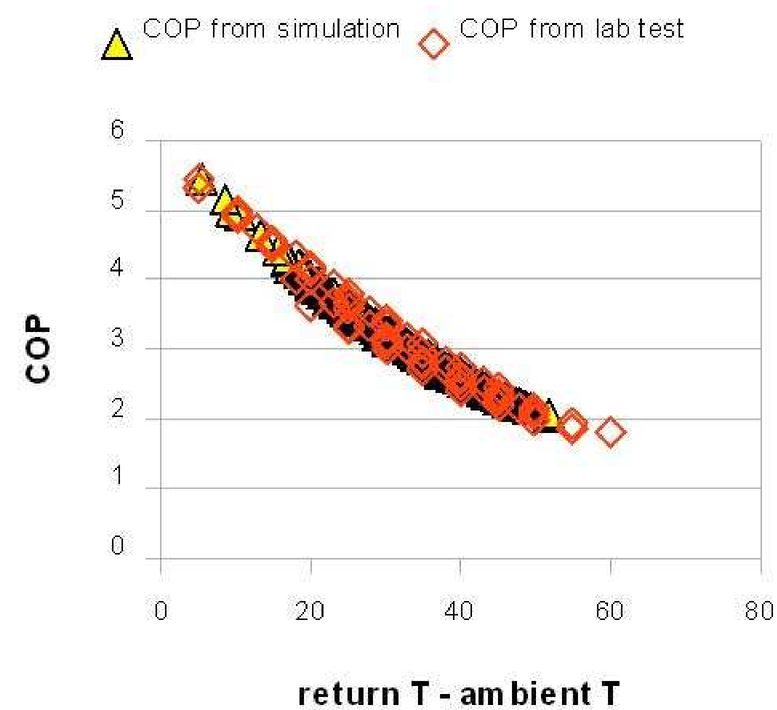
Case Study: Westfield

- Westfield – former mining village in West Lothian
- 8 dwellings were retro-fitted with ASHP systems (space heating only); ASHP feeds hydronic heating system
- all of the buildings were properly insulated and draft stripped prior to the installation of the ASHP
- hot water was provided by a resistance heating coil within the hot water storage tank



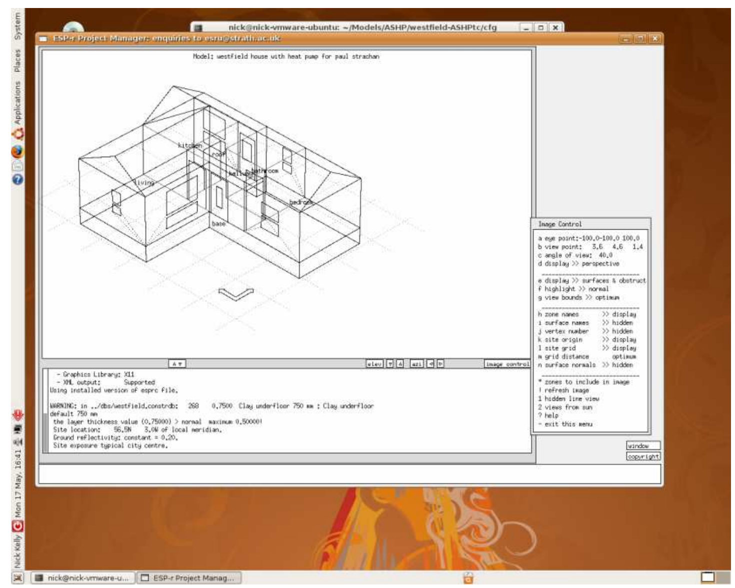
ASHP Model Calibration

- one of the houses modelled in detail using ESP-r
- performance simulated over a year
- the project required the development of an ASHP model for ESP-r
- the model performance map was calibrated using lab test data from BRE
- the dynamics of the model were calibrated using a sub-set of the monitored data and excel
- later the model results were then compared “blind” to aggregate monitored data (90 days data)



Integrated Model

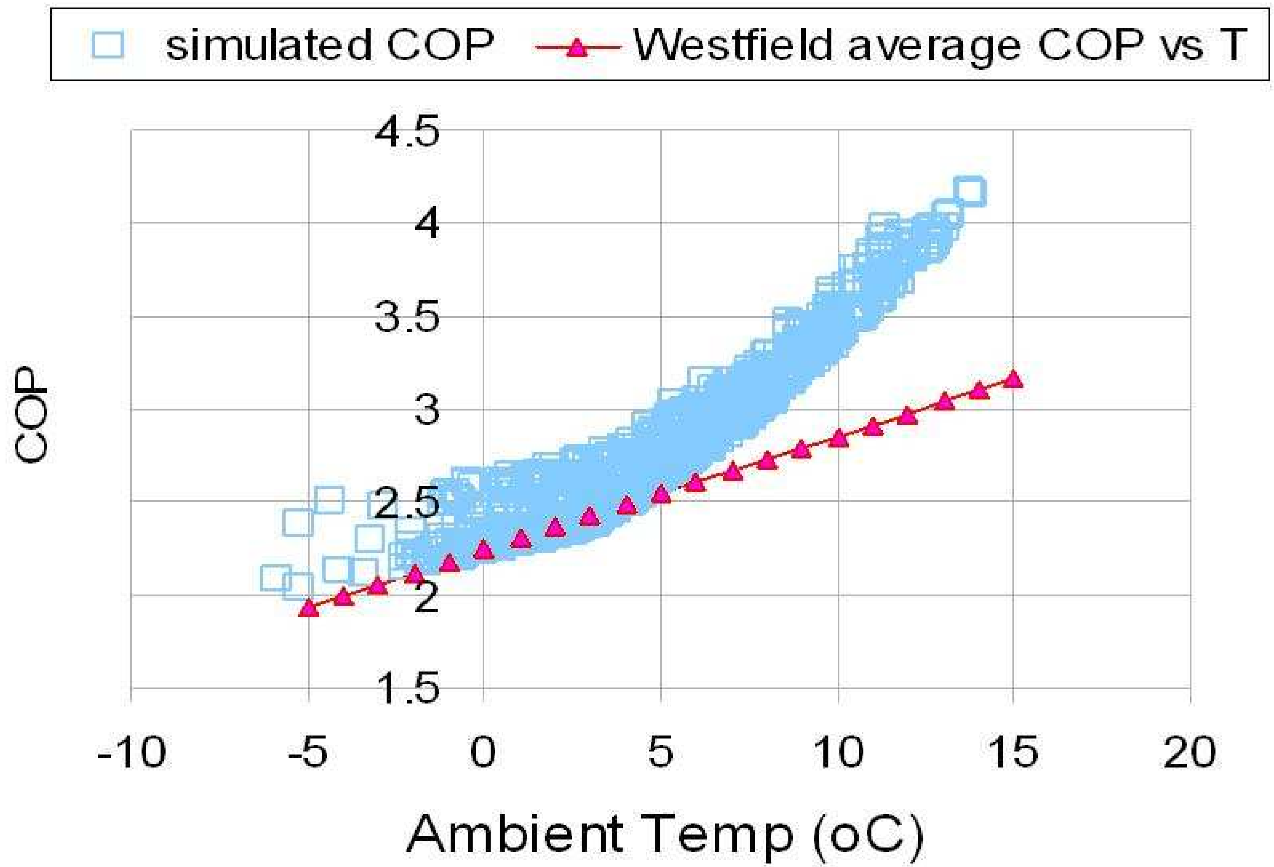
- the ASHP device model was integrated into a larger ESP-r building and systems model featuring:
  - a representation of a typical Westfield dwellings
  - a hot water radiator system
  - a thermostatic control system
  - a calibrated air leakage network
- the model characteristics were determined from a site survey and blower door test of one of the Westfied dwellings.



Simulations

- simulations analysed:
  - the dwelling as-is and then comparing results to field trial data
  - of the dwelling with alternative heating systems
- model was run at 1-min time steps over a full year
- small time step was needed to capture the effects of coil defrost on energy consumption (1-10 mins)
- the simulation produced time series data including ASHP power and thermal output, hot water temps, room temps. etc.
- the results were then used in a basic economic and environmental study of the ASHP

Comparison with Field Trial



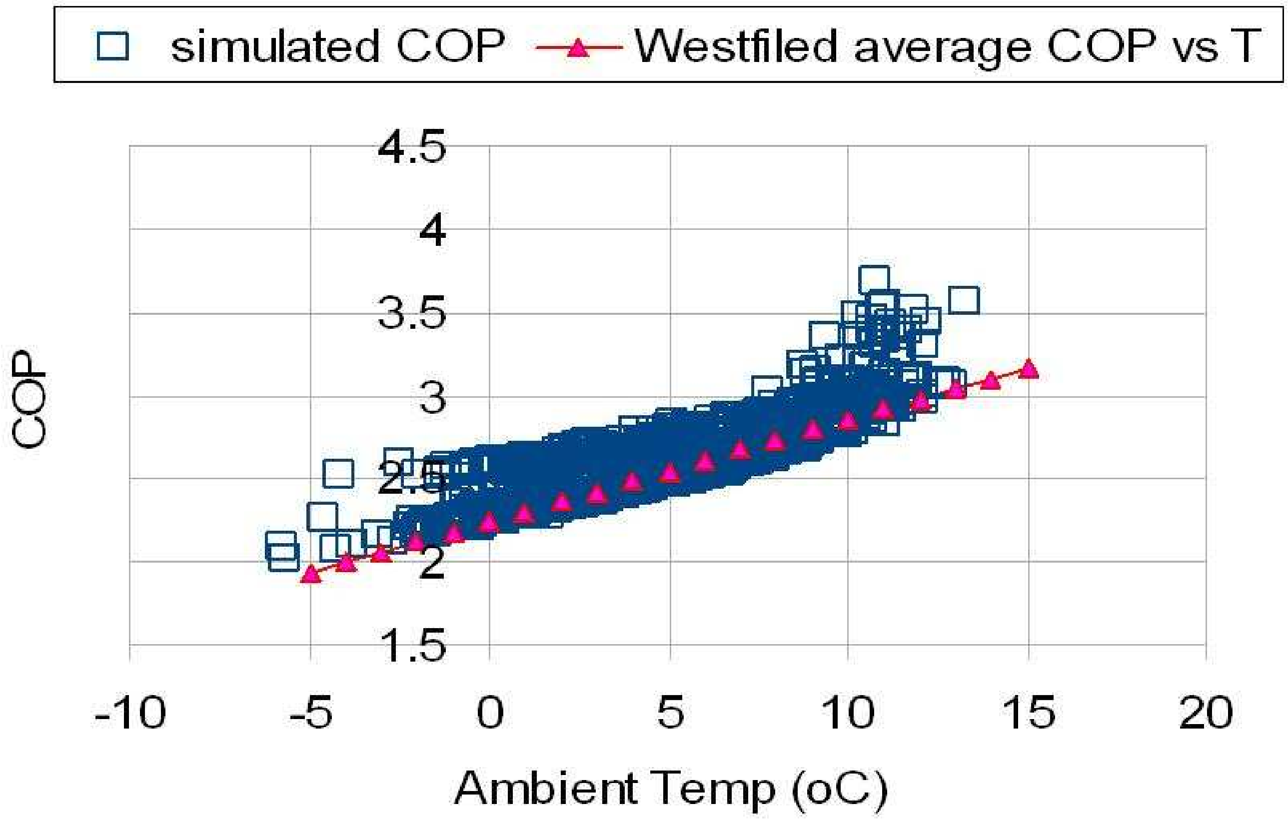
Comparison with Field Trial

- significant divergence between monitored an simulated results above 5^{o}C
- NOT a simulation problem ….

  - ASHP installers forgot to activate outside air temperature compensation on device

  - re-simulated with temperature compensation turned off

Comparison with Field Trial



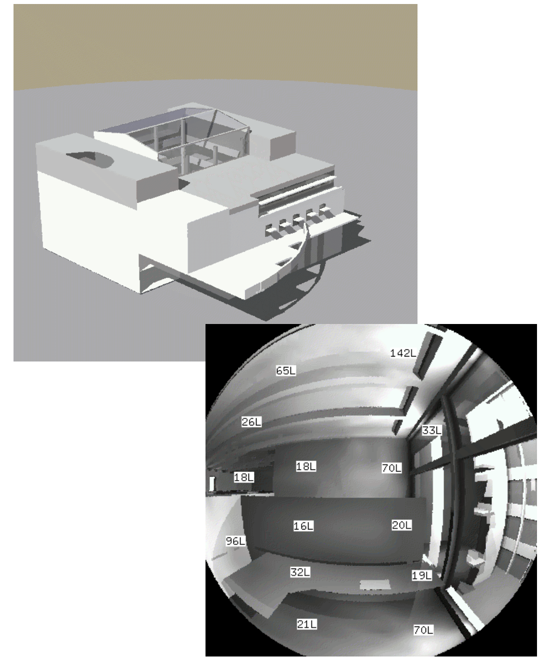
Comparison to Alternatives

- variants of the integrated model were created for a condensing boiler (CGB) and all-electric heating systems

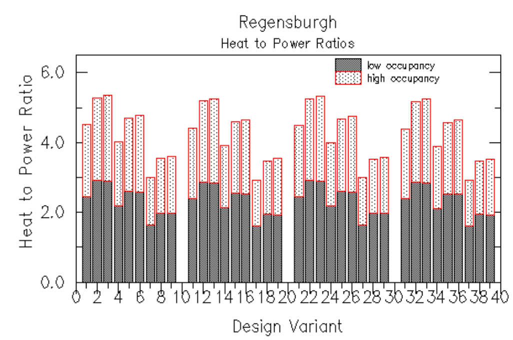
Heating system	Price of fuel		Energy use	Cost	CO_2 emission
	p/kWh	*p/day*	*kWh*	*£*	*kg*
ASHP	12.11	16.47	2,261	334	1,230
Direct electric	12.11	16.47	5,487	725	2,985
Gas condensing boiler	3.41	14.47	7,515	309	1,383

- only *modest* CO_2 savings achieved in comparison to CGB system
- ASHP more expensive to run than CGB

Pros and Cons of Detailed Modelling



- detailed modelling provides a *rich* source of data for a variety of functions:
  - component selection and sizing
  - system configuration
  - control strategy development
- used appropriately it can be used to develop more robust energy system designs



Pros and Cons of Detailed Modelling

- however there are significant overheads in terms of
  - user skill level and background knowledge
  - model development and debug
  - data analysis
- also greater scope for error due to *significantly* increased data requirements

Is this real life? Is this just fantasy?

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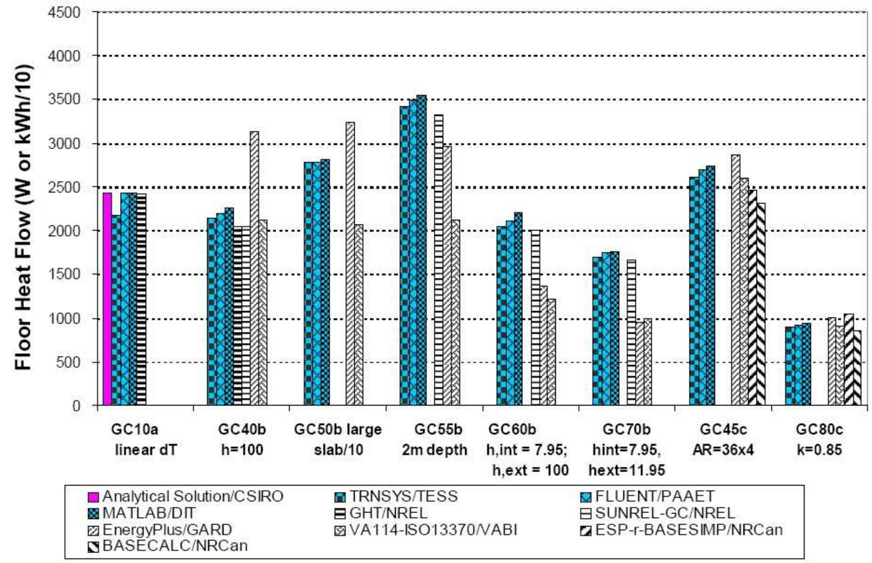
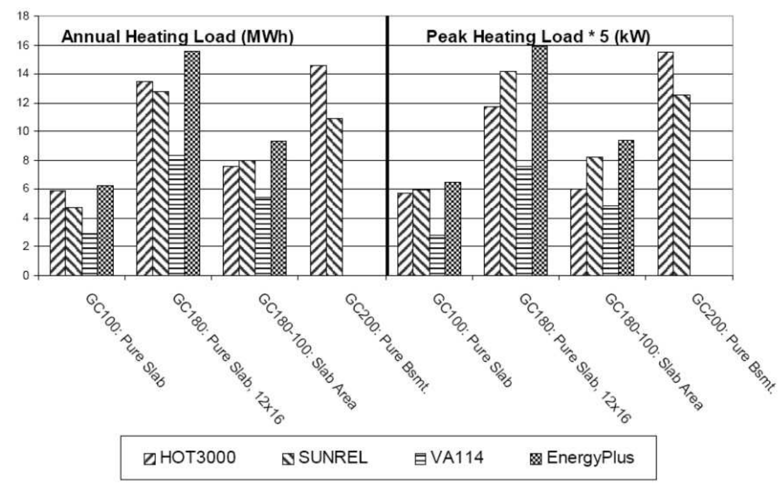
- dynamic simulation tools have been extensively validated over the last 30 years (e.g. BESTEST)
- show good agreement with analytical and closely controlled experimental cases
- … however it is rare that validation is based on an occupied building's energy data
- post-occupancy studies (i.e. PROBE) have shown that all forms of modelling tends to produce over-optimistic results for energy use
- Westfield study compared modelling results to monitored data – rarely the case



IEA BESTEST Ground Coupling Heating Loads



How do we get better?

- clear need for more comparison of original predictions with post occupancy data
- embedding uncertainty in modelling – producing a value *plus* a range
- accounting for “known unknowns”
  - defects in fabric and systems
  - better modelling of people and their interaction with the building and its systems
- better data sources: materials, components, climate
- continued improvement in modelling of physical processes:
  - 3D heat transfer
  - borehole/trench heat transfer
  - interior air movement

Links

- ESP-r (open source) www.esru.strath.ac.uk/software/
- IBPSA www.ibpsa.org
- DoE simulation tools directory http://apps1.eere.energy.gov/buildings/tools_directory/
- Post occupancy evaluation (PROBE) http://www.usablebuildings.co.uk/
- BESTEST www.ecbcs.org/annexes/annex43.htm