INTEGRATED SIMULATION FOR (SUSTAINABLE) BUILDING DESIGN: STATE-OF-THE-ART ILLUSTRATION

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The state-of-the-art in integrated building simulation is illustrated by means of a sustainable building design study.

Background

Many buildings are still constructed or remodelled without consideration of energy conserving strategies or other sustainability aspects. To provide substantial improvements in energy consumption and comfort levels, there is a need to treat buildings as complete optimised entities not as the sum of a number of separately optimised components.

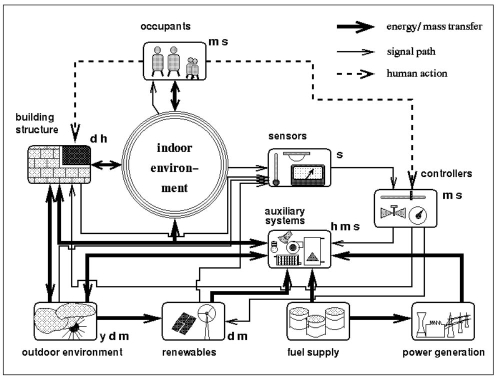

Figure 1 The building as an integration of energy systems.

Simulation is ideal for this because it is not restricted to the building structure itself but can include the indoor environment, while simultaneously taking into account the outdoor environment, mechanical, electrical or structural systems, and traditional and renewable energy supply systems. By assessing equipment and system integration ideas, it can aid building analysis and design in order to achieve a good indoor environment in a sustainable manner, and in that sense to care for people now and in the future.

Although most practitioners will be aware of the emerging building simulation technologies, few as yet are able to claim expertise in its application. This situation is poised to change with the advent of: performance based standards; societies dedicated to the effective deployment of simulation - such as IBPSA[1] ; appropriate training and continuing education; and the growth in small-to-medium sized practices offering simulation-based services.

One thing is clear: as the technology becomes more widely applied, the demands on simulation programs will grow. While this is welcome, in that demand fuels development, it is also problematic because the underlying issues are highly complex. Although contemporary programs are able to deliver an impressive array of performance assessments, there are many barriers to their routine application in practice, mainly, in the areas of quality assurance, program interoperability, and task sharing in program development.

An example state-of-the-art system

The ESP-r system (Clarke 1985) has been the subject of sustained developments since 1974. The aim, now as always, has been to permit an emulation of building performance in a manner that a) corresponds to the reality, b) supports early-through-detailed design stage application and c) enables integrated performance assessments in which no single issue is unduly prominent.

ESP-r comprises a central Project Manager (PM) around which is arranged support databases, a simulator (consisting of specialised concurrent solvers for domains such as heat flow, fluid flow, power flow,

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[1] IBPSA: International Building Performance Simulation Association - http://www.ibpsa.org

control, etc.), performance assessment tools and a variety of third party applications for CAD, visualisation, report generation, etc. (Figure 2). The PM's function is to co-ordinate problem definition and give/receive the data model to/from the support applications. Most importantly, the PM supports an incremental evolution of designs as required by the nature of the design process.

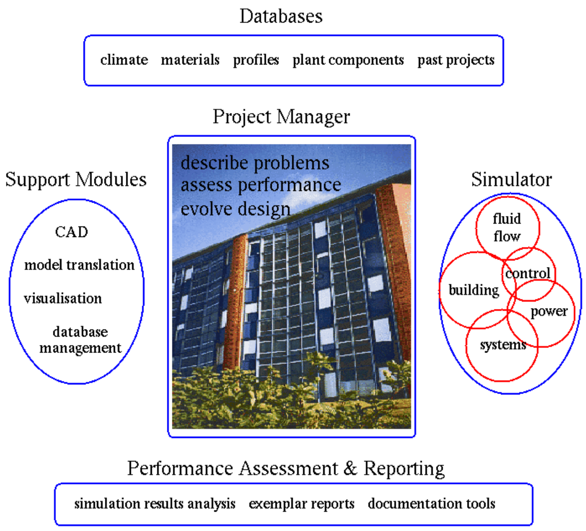


Figure 2 Main architecture of ESP-r.

Case study: embedded energy systems

The Lighthouse Building, designed by Charles Rennie Mackintosh, is the centrepiece of Glasgow's celebrations as UK City of Architecture and Design 1999. This refurbished city centre building is of major architectural significance. A specially configured portion of the building serves as a showcase for state-of-the-art technologies that demonstrate the integration of complementary passive and active renewable energy components at the urban scale.

While a more complete description can be found in (Clarke et al. 1999), the following outlines the design process undertaken.

Implementation of renewable energy systems at the local level can be fraught with technical problems. When undertaking such tasks within an urban environment adds additional problems to a project such as impact on building aesthetics and most importantly, planning requirements which impair system performance. After careful consideration, the renewable energy systems chosen for this demonstration were categorised as: type (i) are those that reduce energy demands and type (ii) are those that generate electricity to meet some of these demands.

The 3 passive (type i) components were:

- advanced glazings, including a triple glazed, double low-e coated, argon filled component, a light redirecting component and a variable transmission component;
- daylight utilisation through illuminance based luminaire control; and
- transparent insulation with integral shading.

The 2 active systems (type ii) consisted of:

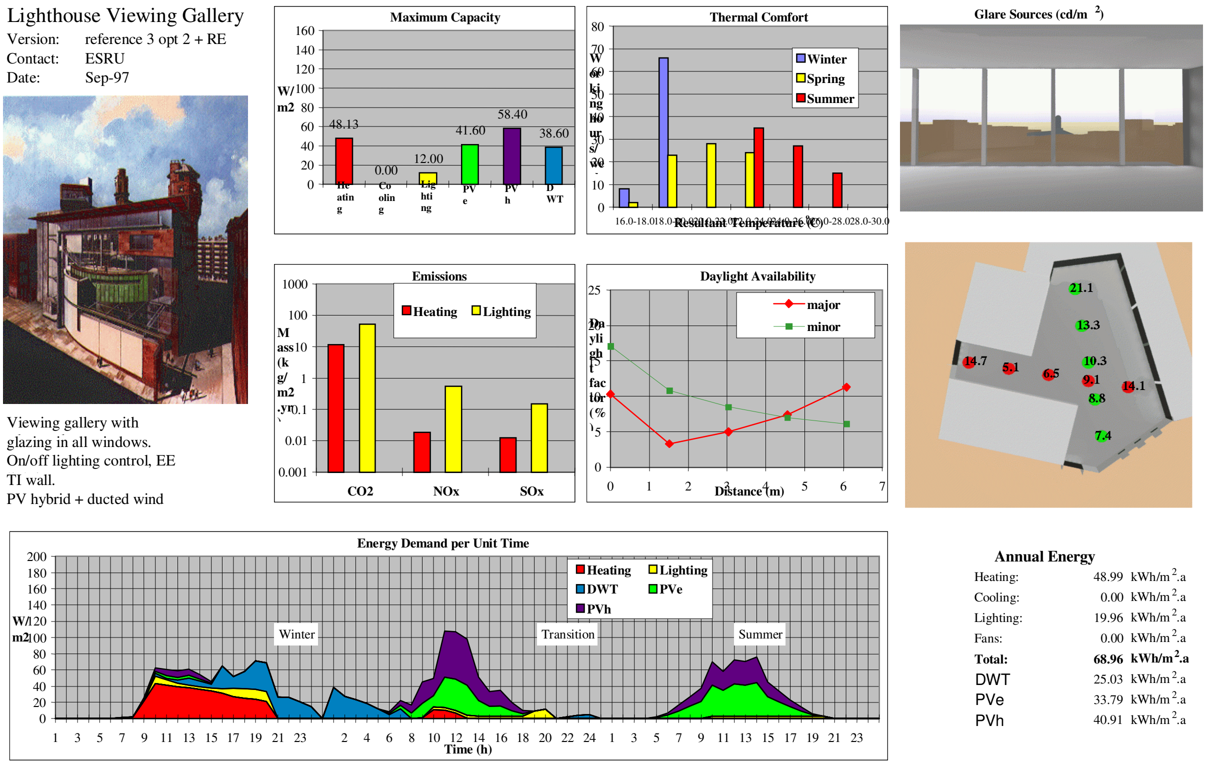
- facade-integrated photovoltaic (PV) cells with heat recovery; and
- roof mounted, ducted wind turbines with integral photovoltaic aerofoils.

Evaluation methodology

The evaluation procedures adopted adheres to a standard performance assessment method whereby computer simulation is used to determine the multivariate performance of an initial model of the building (in this case corresponding to current best practice design). The multivariate performance data are then presented in the form of an integrated performance view such as shown in Figure 3. The model is then modified by incorporating one of the renewable technologies and re-assessed. In this way, the contribution of both passive and active renewable technologies, applied separately or jointly, may be assessed and the different possible permutations compared.

Results

In comparison with the initial design hypothesis, the cumulative effect of advanced glazing, a fast response, critically controlled, convective heating system, high efficacy lamps and luminairs, lighting control and transparent insulation facade resulted in a 58% reduction in annual heating energy demand, a 67% reduction in heating plant capacity, an 80% reduction in lighting energy demand and a 68% reduction in overall energy demand.



Lighthouse Viewing Gallery
Version: reference 3 opt 2 + RE
Contact: ESRU
Date: Sep-97

Viewing gallery with
glazing in all windows.
On/off lighting control, EE
TI wall.
PV hybrid + ducted wind

Annual Energy

Heating:	48.99	kWh/m^2.a
Cooling:	0.00	kWh/m^2.a
Lighting:	19.96	kWh/m^2.a
Fans:	0.00	kWh/m^2.a
Total:	**68.96**	**kWh/m^2.a**
DWT	25.03	kWh/m^2.a
PVe	33.79	kWh/m^2.a
PVh	40.91	kWh/m^2.a

Figure 3: Integrated Performance Appraisal with Passive and Active RE Systems Applied

Figure 3 summarises the final performance results in the form of an “integrated performance view” as produced by ESP-r.

The combination of ducted wind turbines and PV components proved to be a successful matching of renewable energy systems to meet the seasonal energy demands. The wind turbines produce electricity predominately during the winter period when the PV components can contribute little. Conversely, the PV components supply power predominately during the summer period when the winds are light. The combination of the two systems gives rise to an embedded renewable energy approach that is well suited to the climate of Glasgow.

Conclusions

This paper has elaborated and demonstrated the state-of-the-art in integrated building simulation and it’s value when used early in design. This paper has also argued the importance of this technology and how it will benefit in an economical and environmental context. Since many people in the field are not yet aware of this, there is a need for an organisation such as IBPSA. It’s main role is to alleviate the above problem and thus moving the technology in everyday practice of engineers and architects.

Acknowledgements

The ESP-r system has evolved to its present form over 25 years. Throughout this period many individuals have made substantial contributions. In particular, we would like to acknowledge the contributions of some of our ESRU colleagues: Jon Hand, Milan Janak, Cameron Johnstone, Nick Kelly, Iain Macdonald, John McQueen, Abdul Nakhi, Cezar Negrao and Paul Strachan. Our hope is that the many other contributors, too numerous to mention, will be content with collective thanks.

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