Energy Efficient Houses - An Integrated Approach

J. Owen Lewis, Architect and Consultant, Dublin, Ireland
M. J. Shine, Commercial Dept., Electricity Supply Board, Dublin, Ireland

ABSTRACT

This paper outlines the design of 6 energy efficient houses at Kilcock, Co. Kildare by the Electricity Supply Board, Ireland. The aim of the project is to collect and disseminate information on the costs and benefits of energy efficient houses. The houses will be monitored both occupied and unoccupied over a number of years. Energy efficiency has been the determining factor in all stages of the project within the constraints of owner requirements and overall commercial viability. The various stages of house orientation, architectural thermal and construction design, choice of heating and other services, present a fully integrated approach to the total design of energy efficient houses.

RESUME

Ce rapport donne un aperçu des 6 maisons efficientes du point de vue de l'énergie à Kilcock, Comté de Kildare par la Electricity Supply Board, Irlande. Le but du projet est de recueillir et disséminer des informations sur le coût et les avantages des maisons à efficience énergétique. Les maisons seront contrôlées pendant plusieurs années, inoccupées et occupées. L'efficience énergétique a été le facteur déterminant dans tous les stades de ce projet respectant les exigences du propriétaire et la viabilité commerciale totale. Les différents stades d'orientation des maisons, de plan architectural thermique et plan de construction, de choix de système de chauffage et d'autres installations, présentent une approche tout à fait intégrée dans la conception globale de maisons efficientes du point de vue de l'énergie.

INTRODUCTION

The Electricity Supply Board is currently engaged in the construction of six energy efficient single family houses in Kilcock, Co. Kildare. The project forms part of a programme of energy conservation demonstration projects being co-ordinated by the Commission of the European Communities Directorate General for Energy. Its principal objective is to collect and disseminate information on the costs and benefits of energy efficient measures in housing. The project has three distinct phases - design, construction and performance monitoring. This paper is primarily concerned with the first, outlining the overall design process within the context of the project aims and presenting the final design decisions reached.

THE PROJECT

The project is essentially a demonstration one, intended to have relevance for house designers, builders and owners. To ensure a suitable balance and interaction between the various facets of design an integrated approach was adopted, with energy efficiency embracing all aspects - architectural, thermal, and services.

After initial calibration and performance tests the major thrust of project results will come from measurements with the houses occupied. To facilitate their sale on the open market the houses are related to contemporary private sector speculatively-built houses which now represent about one third of Irish house building.

This emphasis on both the building trade and the house buyer played a substantial role in setting the form and scope of the project.

Design Team

The team set up to implement the design process included the project architect, engineering personnel in the E.S.B. and a builder engaged in private sector house construction. A quantity surveyor also participated to provide cost estimates of various proposals. He will also ultimately ascertain the cost of the various energy-related design decisions which when combined with monitored results will provide the basis for cost benefit analysis.

Project Aims

Within these broad parameters it is intended that the project will yield information on the following:-

- The practicability of building highly insulated houses using available materials and techniques.
- The contribution of improved building fabric design and conservatories to savings in space heating costs.
- The energy profiles of space heating and domestic hot water services in energy efficient houses.
- The performance capabilities of a variety of space and water heating systems for low energy housing applications.
- The appropriate ventilation requirements and systems for well sealed low heat loss buildings.

THE SITE

The houses are being constructed on the outskirts of the small town of Kilcock in County Kildare, some 28 km west of Dublin. The site is less than a kilometre from the centre of Kilcock. It forms part of a housing estate which is in the early stages of development. The type of house already built (two-storey, pitched roofed with 'neo-Georgian' facade) could be described as fairly typical of many contemporary private-sector housing developments in Ireland, and the estate layout is also representative of this type of housing. The site is comparatively flat and without trees or other features. The subsoil is of firm clay, well drained and with good bearing capacity.

Climatically Ireland enjoys temperate conditions. There is a relatively narrow range between Summer and Winter values of the main meteorological parameters, largely as a result of the moderating influence of the Atlantic Ocean and the Gulf Stream. Fig. 1 shows the mean monthly degree-day distribution (1964-77) to a base of 15.5°C for the nearest available meteorological station, the mean annual total being 2374.

BUILDING FORM

Irish planning legislation regulates physical development through local planning authorities. The estate developer from whom the ESB purchased the site had previously obtained planning permission for six semi-detached houses. Because of the decision to relate the houses to contemporary

speculatively-built housing, the starting point in the design process was the existing permitted designs and the earlier developments on neighbouring sites. The aim was to provide similar accommodation, including three bedrooms, kitchen/dining and living spaces within the same floor area in a semi-detached house.

The general street arrangement was set by the estate's road layout and minimum set-back distances. The earlier houses bear an angled relationship with the road, and this relationship has been maintained. Individual houses are further stepped to reduce the scale of the facade and create opportunities for southern orientation. The houses have been completely replanned to achieve a more efficient use of space and make better rooms, to provide for increased services and to create lobbies at both entry points. The fenestration has been redesigned to meet architectural and thermal criteria and small conservatories are provided in three houses. Garages have been added to the houses in such a way that ground floor wall heat losses are minimised.

The houses are illustrated in figs. 2, 3 and 4.

MATERIALS

The construction systems adopted utilise indigenous materials and conventional building techniques as far as possible to maximise relevance to contemporary Irish private housing. In the context of the building fabric, improved energy efficiency is sought by means of better design, integration of thermal insulation and draught-stripping and exploitation of passive solar gains.

The external walls will be concrete blocks in cavity construction and rendered externally. The roofs will be pitched timber trussed rafters finished with concrete tiles. There will be concrete ground floors and timber first floors and timber framed windows. Three different standards of thermal performance will be achieved by varying levels of thermal insulation and the introduction of controlled ventilation and heat recovery. One house is designed as a 'control' house to proposed national standards, three are intended to meet projected medium-term standards, and two are to meet levels of conservation anticipated in the longer term. Table 1 sets out the outline constructional specification and design heat losses for the

	House A	Houses B, C, D	Houses E, F
External Walls	300mm Cavity Wall; 100mm Cavity insulated with 40mm expanded polystyrene	As for House A with cavity completely insulated	As for Houses B, C and D
Party Wall	215mm solid block, plastered both sides	As for house A	As for House A
Floor	Solid concrete, with 25mm polystyrene under final screed + edge insulation	As for house A with additional 25mm of insulation	As for house A with additional 25mm of insulation
Roof	Tiles on batons; Roofing felt and rafters; 10mm plasterboard ceiling on under joists with vapour check; 100mm mineral fibre between joists	As for house A with additional 50mm insulation in attic	As for house A with additional 100mm
Glazing	Single glazing, hardwood frame	Double glazing with hardwood frames	Triple glazing (or equivalent)

Table 1 Constructional Specification

three house types.

THERMAL PERFORMANCE

Design Heat Losses

Table 2 shows the design heat losses for the 6 houses. The heat loss values are based on an average internal temperature of 19.5°C and an external design temperature of -1°C. The internal temperature value is a floor area weighted average for the houses based on standard room design temperatures (1). An average house air-change rate of 1.4 per hour is derived in a similar manner to determine the ventilation losses.

House	A	B	C	D	E	F
Fabric Loss (KW)	3.1	2.0	1.9	2.0	1.6	1.6
Total Heat Loss (KW)	5.3	4.2	4.2	4.2	2.6	2.6

Table 2 Design Heat Losses

In the last two houses where mechanical ventilation with heat recovery is to be used, a ventilation heat loss of 1 KW has been assumed.

Dynamic Performance

A set of computer simulation programmes from Trinity College, Dublin (2) are being used to study the dynamic thermal performance of the houses. Solar radiation and other weather parameters, fabric thermal characteristics, ventilation, occupancy, and incidental heat gains are used as inputs to the programmes.

These combined with thermostat settings and heating system ratings enable environmental conditions within the houses to be ascertained and daily or seasonal space heating energy consumptions to be predicted.

As an example, for house type C the simulation predicts a space heating energy consumption of 9,500 kWh using weather data from Dublin Airport meteorological station for the 79/80 heating season (1 Sept. '79 to 31 May, '80). This is based on an internal temperature of 19°C from 07.00 to 23.00 hours with 5°C setback outside these hours. Fig. 5 shows the heating sys-

tem output profile and internal temperatures achieved in the house using the weather data of the 20-22 Jan. 1980 inclusive.

It is intended to carry out further studies using this simulation package. Particular attention will be paid to the treatment of the conservatories. It is also hoped that experimental results from the houses will contribute to validation of some aspects of the programmes.

SERVICES

The houses will be used to evaluate a variety of space and water heating systems in the context of thermally well designed environments. The evaluation will include an analysis of capital and running costs, environmental comfort levels achieved, operating characteristics, and where relevant, demand implications for the Electricity Supply Board. The various systems scheduled for test are outlined below and summarised in Table 3.

Space Heating

All houses will have direct electric systems installed for thermal calibration and comparison tests that will take place during the unoccupied stage of the project.

A water based electrically-heated central storage system will be installed in three of the houses - the control house and one of each of the other thermal design types. The system, Centralec, has been designed and patented by the ESB for use in domestic and small commercial premises. It uses mainly off-peak electricity and has advanced energy input and output controls. The water store is accommodated in a services compartment on the first floor of the houses. The Centralec distribution system normally uses steel radiators but in one of the houses an arrangement of polypropylene pipes buried in the floor screed will be used.

The remaining houses will have air source heat pumps for space heating. The systems will be tested using a variety of controls and operating regimes. The heat distribution systems will be similar to that of Centralec. The ability of the heat pumps to meet domestic-hot-water requirements will also be examined. This is particularly relevant in low heat-loss houses where heat pump capacity is not a problem but capital cost may be.

	HOUSE					
SERVICES	A	B	C	D	E	F
SPACE HEATING SYSTEM	WATER STORE OFF-PEAK ELECTRIC	AIR SOURCE HEAT PUMP	WATER STORAGE OFF-PEAK ELECTRIC	SOLID FUEL	AIR SOURCE HEAT PUMP	WATER STORAGE OFF-PEAK ELECTRIC
HEAT DISTRIBUTION SYSTEM (LOW PRESSURE HOT WATER)	RADIATORS	RADIATORS	RADIATORS	RADIATORS	UNDER FLOOR	UNDER FLOOR
DOMESTIC HOT WATER	ELECTRIC IMMERSION	ELECTRIC IMMERSION & SOLAR	E. IMMERSION & AIR SOURCE HEAT PUMP	E. IMMERSION SOLID FUEL	E. IMMERSION AND HEAT PUMP (ABOVE)	IMMERSION & SOLAR
VENTILATION	NATURAL (WITH KITCHEN EXTRACT	NATURAL WITH KITCHEN + BATHROOM EXTRACT	NATURAL (AS FOR B)	NATURAL (AS FOR B)	MECHANICAL AND HEAT RECOVERY	MECHANICAL AND HEAT RECOVERY

Table 3 Summary of Services Proposals for Energy Efficient Houses

In recent years solid fuel back-boiler type central heating systems have become increasingly popular in Ireland. It is intended that one such enclosed system will be evaluated during the project. All houses will have provision for the later fitting of a solid fuel burning appliance if required by the occupant, including interlinking arrangements with the space heating and domestic hot water systems.

Domestic Hot Water Systems

All houses will be fitted with electric immersion elements in well insulated 270 l. storage cylinders. Provision will be made for time switch control to optimize operation for minimum electricity cost. In 4 of the houses the immersion elements will act as back up and auxiliary to other systems. Two of the houses will use air source heat pumps to provide the domestic hot water requirements (as already indicated one of these will also be meeting the space heating duty). Two others will have solar panels installed - direct type systems with separate solar storage cylinders.

Ventilation Systems

Construction supervision, improved window joinery, entry point lobbies and appropriate draught sealing will ensure that natural ventilation losses are kept to a minimum. Suitable location and sizing of vents and moisture removal at source in bathrooms and kitchens will help to minimise the risk of condensation. In the lowest heat loss houses mechanical ventilation systems with heat recovery will be installed.

MONITORING AND FEEDBACK

One of the major components of the project will be an effective monitoring system to assess the performance of the considerable number of energy related features and systems included in the houses. In excess of 200 parameters will be monitored, ranging from ambient temperatures to heat pump compressor energy consumptions.

Data Acquisition System

An intelligent acquisition system will be located on site to collect data from the various transducers. A VDU/keyboard unit will be used to set up logging routines and other operational characteristics. Collected data will be conditioned in both hardware and software to enable display of data in suitable engineering format. Following appropriate data reduction

the required parameter values will be stored on a magnetic cartridge for processing on a Mainframe Computer.

A modem communications link will be used to enable remote interrogation of the system. This is particularly important since the houses are located some 30 km from the ESB central office and regular inspection of the operating conditions of systems under test in the houses will be necessary.

Feedback

It is intended that the results acquired during an extended period of monitoring will provide useful information on the performance of energy efficient housing and their related systems in Irish and other north European Maritime climatic conditions.

The project is designed to ensure that these results are disseminated to interested audiences. The ESB's Commercial arm, publicity media and the University School of Architecture are being used to communicate the results of this study to the most relevant sectors - the house buyer, the building trade and future house designers - since it is on their response that the ultimate effectiveness of the project depends.

REFERENCES

(1) CIBS Guide. Section A3, A5. 1979.

(2) James A. McGovern, Computer Simulation of Building Thermal Response to Irish Weather Patterns, this conference.

(3) D. F. Cooney, S. McGrath, Development of an Off-Peak Heating System, this conference.

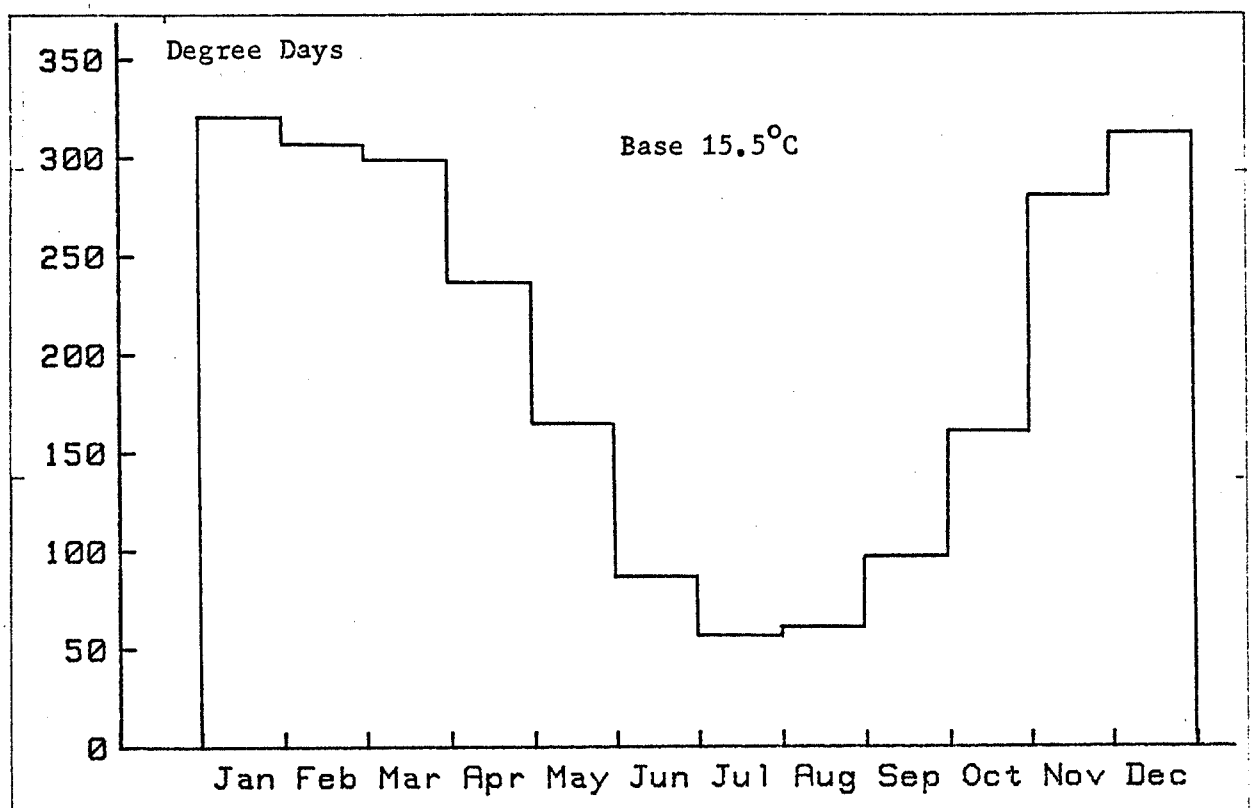

Fig. 1 Mean Monthly Degree Days - Baldonnel 1964-77 (Total 2,374)

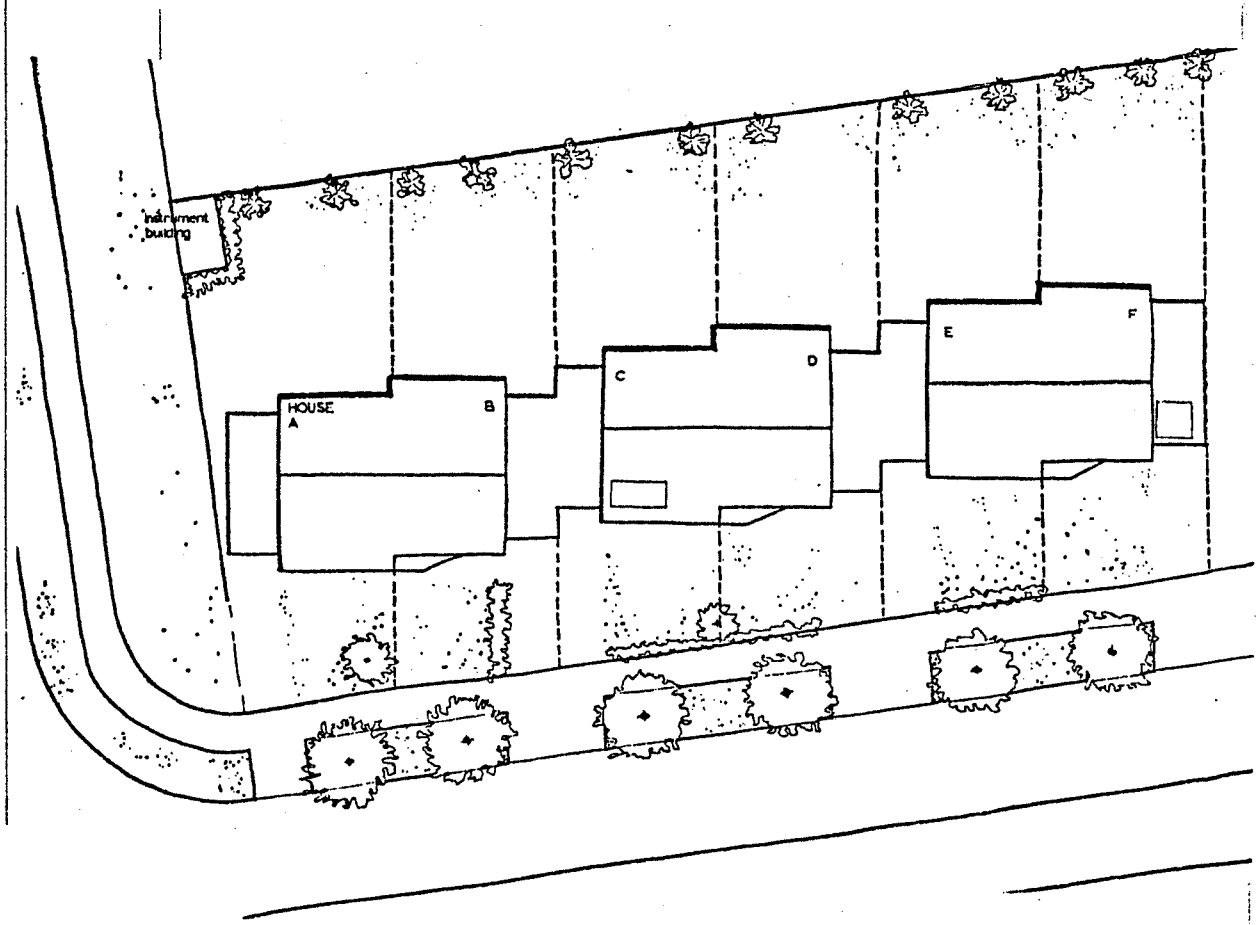

Fig. 2 Energy Efficient Houses - Site Plan

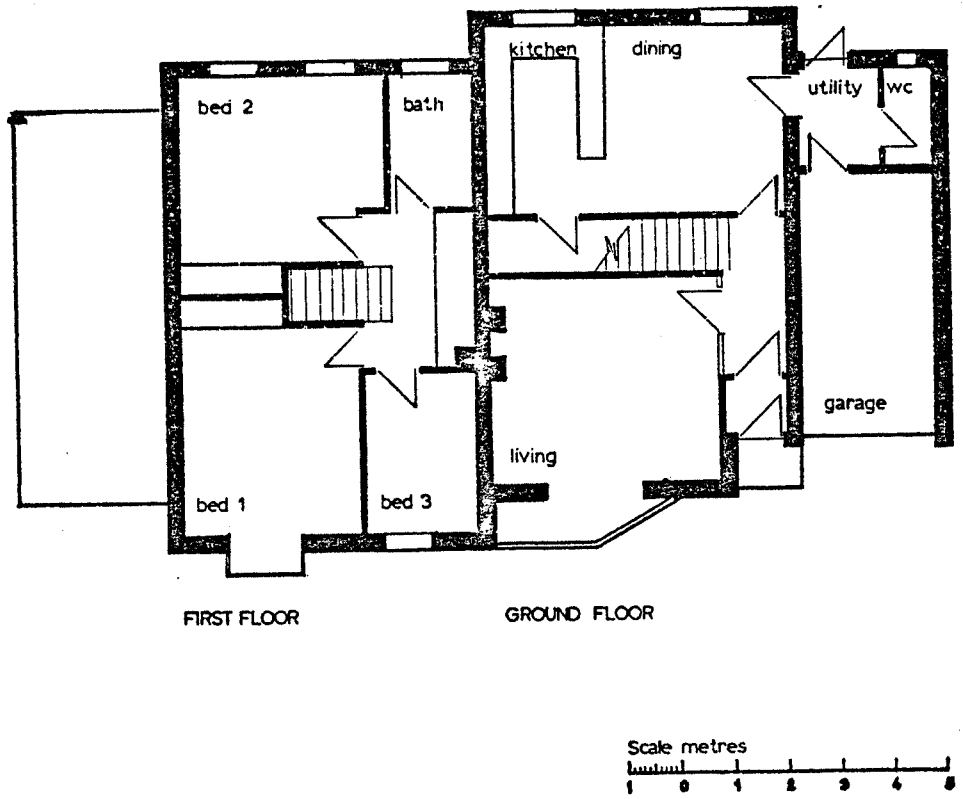

Fig. 3 Energy Efficient Houses - Plan

Fig. 4 Energy Efficient Houses - Front Elevation

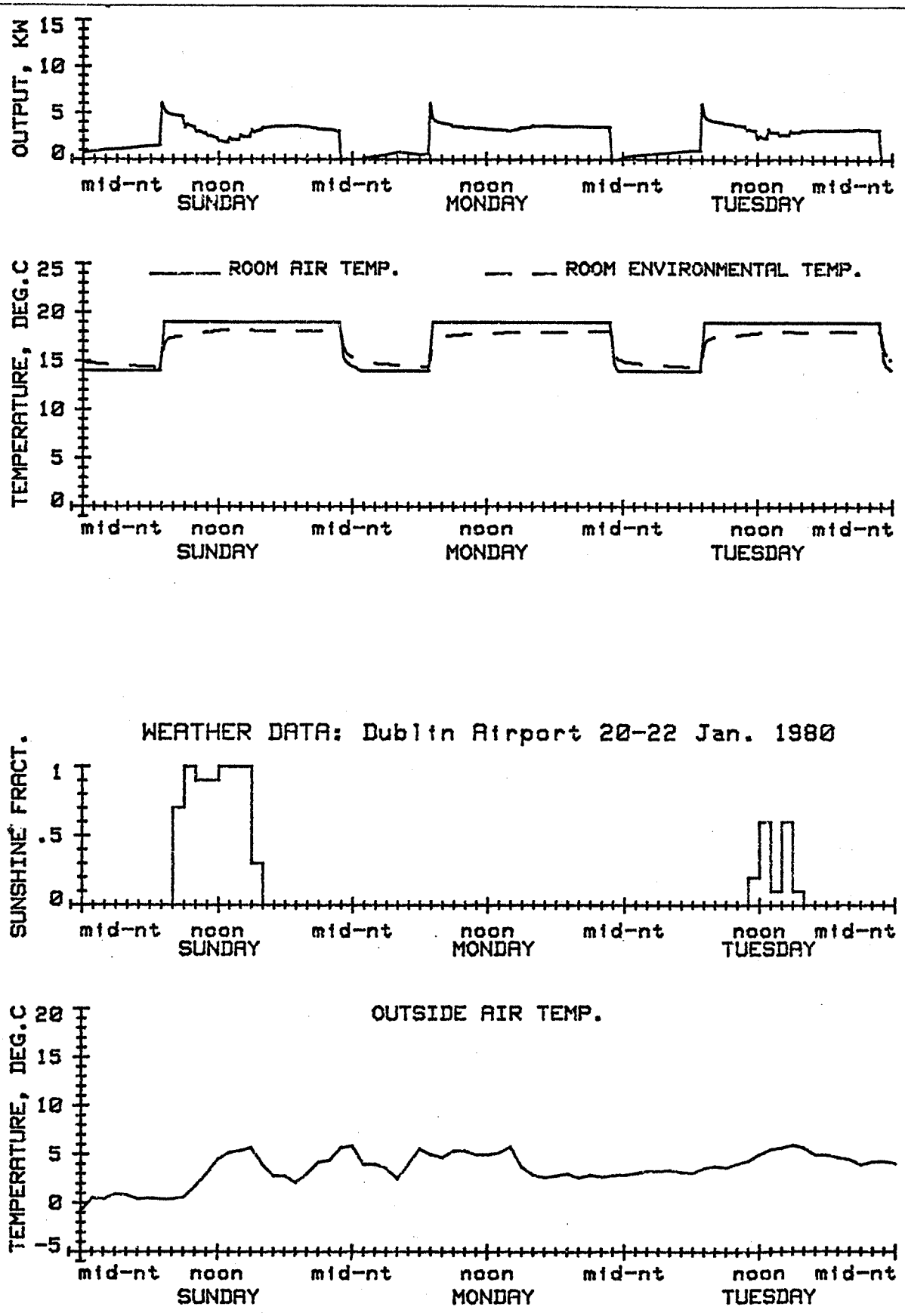

Fig. 5 Simulation Results for House C