DEMONSTRATION OF ENERGY EFFICIENT HOUSES AS INTEGRATED SYSTEMS

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ABSTRACT

This paper first deals with the concept of Energy Efficient Houses as Integrated Systems. Quantitative Analysis is used to show that evenly distributed insulation is more effective than excessive insulation applied to only one element of a house and that ventilation rates are a critical factor in determining the magnitude of energy loss. For a new approach to be adopted on a large scale, it is suggested that a means to implement Planned Change is required. Various models to bring about this change are discussed with an indication of the final recipe used for a Demonstration Project.

KEYWORDS

Energy Efficiency; Low Energy; Integrated Design; Thermal Comfort; Demonstration; Planned Change; CLER Model.

INTEGRATED DESIGN OF ENERGY EFFICIENT HOUSES

This first part of the paper argues the case for, and demonstrates the advantages of, the Integrated Approach to Energy Efficient Design. The basic concept is explored by way of worked examples, attention being given to insulation & ventilation levels, solar gain, thermal comfort and the control of condensation.

The Concept

Energy Conservation by applying insulation to the fabric of the building is now a fairly common practice. However, the net effect of applying more than one measure on the thermal dynamics of the building, due to interaction of the elements, is not adequately understood by the designers (Makkar, 1979). Nor is the contribution of radiant temperature toward thermal comfort or the relationship between the thermostatic setting of temperature and draughts and other factors (Fanger, 1970).

As the following analysis will show, the reduction in energy demands of a house goes hand in hand with the improvement of thermal comfort. In other words, any insulation measure to reduce energy consumption will inevitably result in an improvement in thermal comfort; (with the exception of the trivial case where underheating is chosen as the way to reduce consumption).

Quantitative analysis of energy loss, carried out to include the various insulation measures, ventilation rates, incidental gains (due to inhabitants and energy uses in houses such as TV, lighting and cooking), solar gains and balancing of radiant and ambient temperatures illustrates the need and the procedure for the integrated approach.

No Insulation

An end of terrace house on a site in London is chosen as an example. Taking into account the site, the clients brief etc. the resultant design as envisaged by the architect is the starting point for this analysis. The integrated approach as developed in this paper does not require any architectural compromises, instead, it deals with the possibilities for energy reduction and thermal comfort for a given basic design.

This design is shown in Diagram 1 and includes 100mm insulation in the loft but no other insulation measures; orientation is East-West. The energy consumption to maintain 20^{o}C ambient temperature is 14,004 kWh. (Note: Adjusted Degree Day method of energy loss calculation is used throughout this paper. It includes 22kWh/day as incidental gains due to 4 persons (Siviour, 1976). It also includes useful heat provided by solar gain according the orientation and size of glazed areas). This case is common practice in London and establishes the base point. Table 1 gives the areas and 'U' values of each of the elements of the building. The ventilation rate of 2 ac/h assumes that no special measures are taken to reduce ventilation. This figure is the average of air change rates for similar houses for varying wind conditions around London.

Element	Area m^2	'U' Value $W/m^{2o}C$
Roof	48.77	0.35
Ground Floor	48.77	0.62
Glazing - East	5.15	3.6
Glazing - West	7.92	3.6
Glazing - North	0.9	3.6
Walls	73.31	1.0
Ventilation Volume 218m^3	2 air changes/hour	
Total Energy Consumption: 14,004kWh		

Table 1

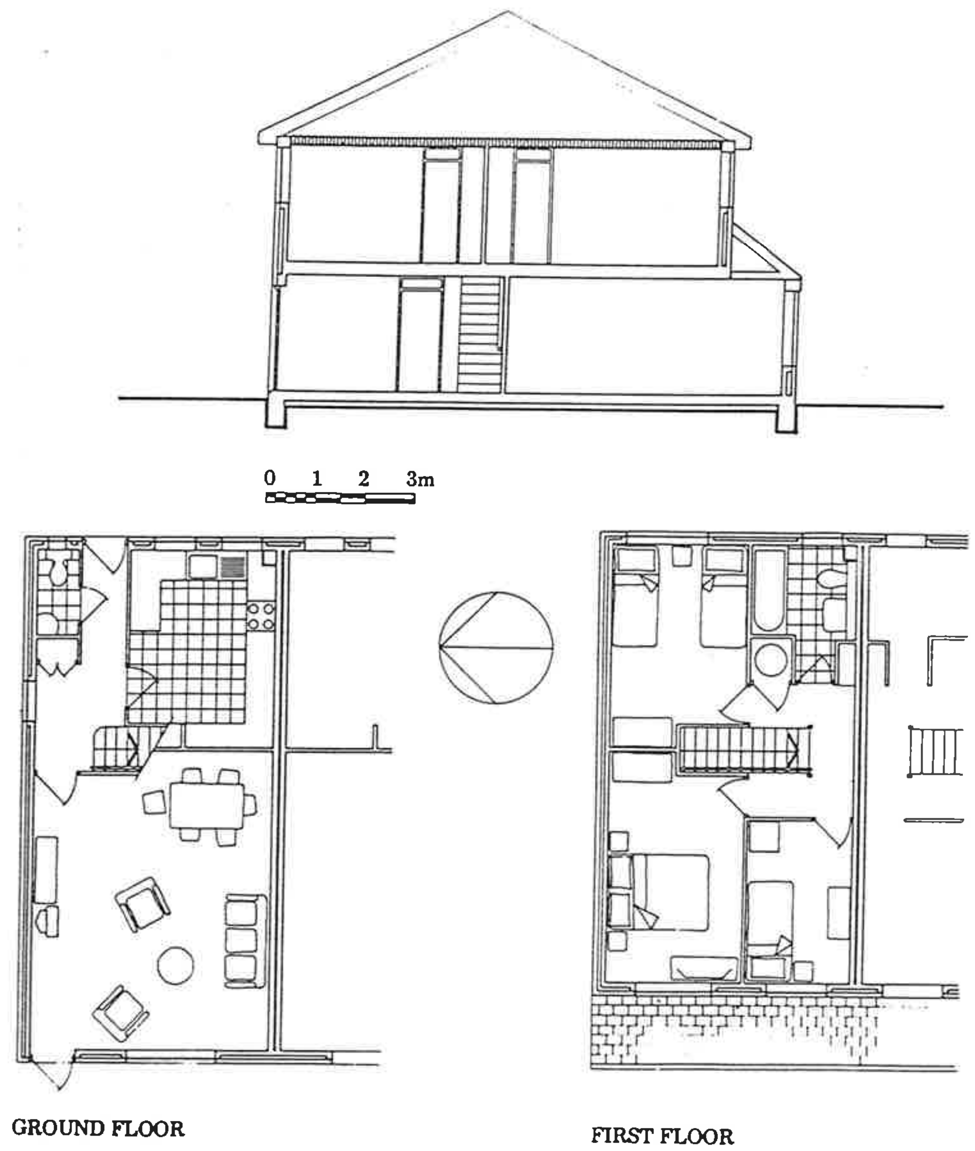


Diagram 1: Basic House Plan

High Insulation of Roof -v- Moderate Insulation Throughout.

Two alternative modes of insulation are applied to this house:

(1) Insulation in the loft is increased to 400mm without dealing with any other element.

(2) Insulation is provided moderately to various elements thus 140mm in the loft, 50mm in the walls and 50mm under the floor. Ventilation rate remains 2ac/h for both options.

Table 2 gives the resultant energy consumptions for these two options:

Element	Option 1 Insulation & 'U' Value (Thick insulation to one element)		Option 2 Insulation & 'U' Value (Moderate Insulation to all elements)	
Roof	400mm	0.1	140mm	0.26
Ground Floor	NIL	0.62	50mm	0.31
Glazing - East (with curtains)	NIL	3.6	NIL	3.6
Glazing - West (with curtains)	NIL	3.6	NIL	3.6
Glazing - North (with curtains)	NIL	3.6	NIL	3.6
Walls	NIL	1.0	50mm	0.31
Ventilation	2ac/h		2ac/h	
Energy Consumption	*13,393 kWh/pa*		*9,642 kWh/pa*	
Energy Reduction from base of 14,004 kWh	*611 kWh/pa* *4%*		*4,362 kWh/pa* *31%*	

Table 2

It can be seen that when the very thick insulation to one element is redistributed evenly to all the elements (of the fabric) this results in considerably greater savings.

Effect of Reduction in Ventilation Rates

If measures are then taken to reduce the ventilation rate from 2 ac/h to 1 ac/h, which can be achieved by draught-stripping and providing draught lobbies (as shown in Diagram 2), the energy consumption for this option (3) reduces to 5,121 kWh/pa = 63% reduction from the base consumption.

An interesting point to note here is that the reduction of 4,521 kWh in energy requirement due to halving of ventilation rate suggests that it is one of the most effective measures for energy conservation.

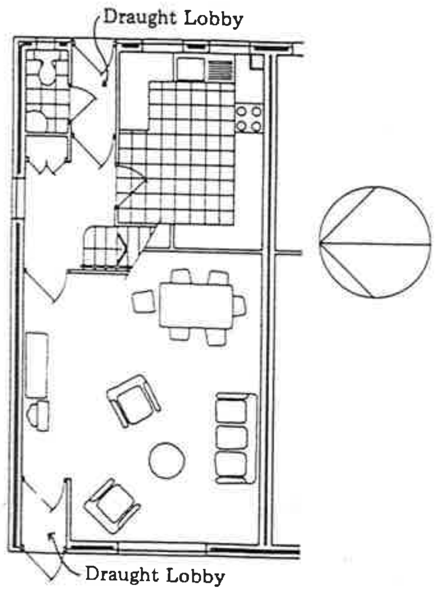


Diagram 2

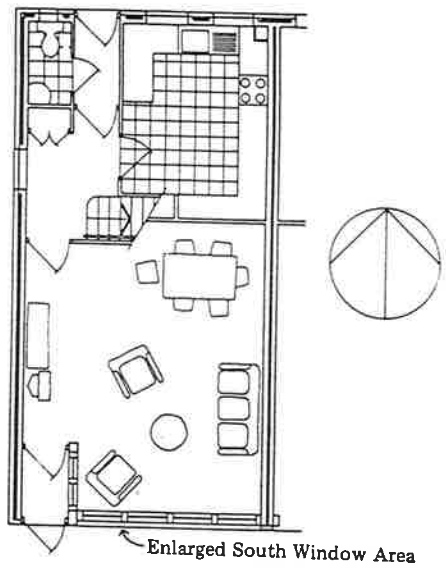


Diagram 3

Solar Gains

Having taken these measures it is now possible to consider the effect of orientation on energy consumption. So far it was assumed that the orientation was E-W, with the living room facing West. If now the house is orientated North-South, with the living room facing South, the calculated energy consumption is reduced marginally by 66 kWh to 5,055 kWh per annum. This means that orientation, by itself, for this type of house, is comparatively insignificant. If the window area is enlarged to the total width of the living room (Diagram 3) and curtained at night the calculated energy consumption is *increased* to 5,281 kWh/pa.

At this stage it is important to note that it is not being suggested that solar gains -v- energy loss through glazing *always* result in increased energy consumption, merely that a simple approach does not always achieve the desired results. For example in situations where openings on the South side are increased with an equivalent decrease in glazed area on the North side this *will* lead to a net saving of energy (Turrent & colleagues, 1980). This case is not discussed quantitatively here.

A glazed wall is now added, internally, to the living room and it is assumed that a means exists to distribute the solar gains to the rest of the house. (Diagram 4).

The Atrium thus created is unheated by the heating system. The calculated energy loss now is 3,954 kWh/pa. a further reduction of 1,167 kWh/pa from the previous option when part of the South wall was simply glazed. In the house in the example, redistribution of solar gains was achieved by drawing the air from the atrium into the house by a warm air heating system.

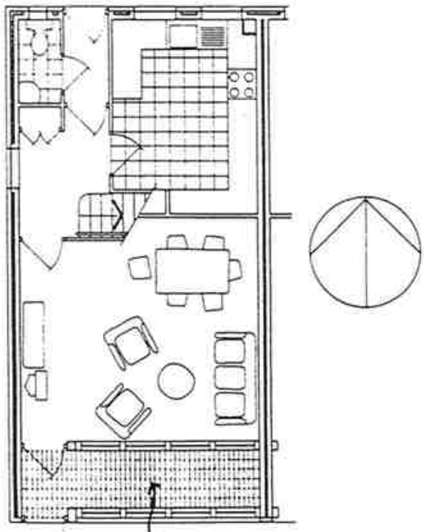
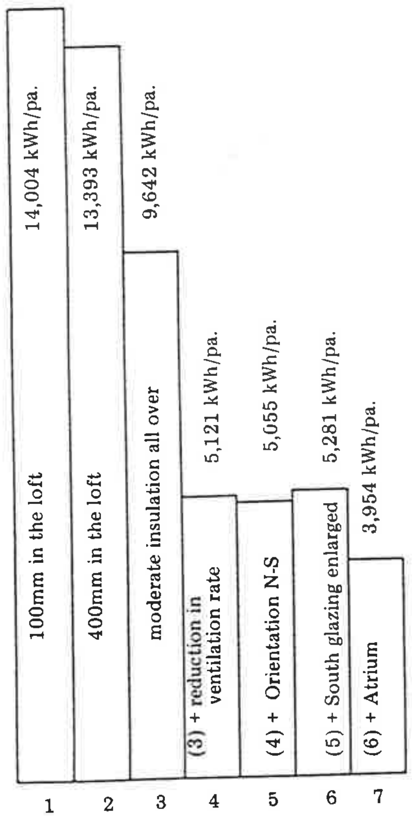


Diagram 4



Graph 1

1st Integration

Graph 1 gives a summary of energy reduction as a result of integrating more and more energy saving measures.

It may be noted that deliberate attempts at increasing solar gains resulted in comparatively little saving in energy. It is however worth noting that 1,167 kWh/pa solar gain is still equal to 23% of 5,121 kWh - being the residual energy requirement of the house after the initial energy conservation measures have been applied (represented by column 4 in Graph 1).

Ambient -v- Radiant Temperatures

The perception of thermal comfort depends upon the ambient temperature, the mean radiant temperature inside the house and air movement, assuming fixed clothing and activity levels according to the habits of the people and the humidity level in the house.

Assuming low levels of air movement, the (simple) relationship between perceived temperature - called resultant temperature, t(res), the ambient temperature, t(ai), and the radiant temperature, t(r) (CIBS, 1978) is given by

$$t(res) = \frac{t(ai) + t(r)}{2}$$

Thus it can be seen that the mean radiant temperature makes about the same contribution to the resultant (perceived) temperature as the ambient temperature. The importance of the radiant temperature can therefore be assessed.

Balancing the ambient and radiant temperatures to achieve the resultant temperature of 20°C while 0°C exists outside, the following relationship for the options considered previously is obtained:

	Radiant Temperature °C	Ambient Temperature °C
100mm in the loft	18.3	21.7
400mm in the loft	18.9	21.1
moderate insulation all over	19.3	20.7
enlarged south glazing	19.2	20.8
south facing atrium	19.3	20.7

Table 3

2nd Integration

The 2nd stage of integration deals with improving the surface (radiant) temperatures in order to reduce the ambient (hence paid) temperature. In the cases considered the radiant temperature has been found to improve consistently with increased distribution of insulation. If the mean radiant temperatures were found to be too low, then special measures would have been required to improve them. As the radiant temperatures have turned out high, this exercise is unnecessary. But the principle remains sound. A small mathmatical exercise will show that it is not possible to reach a radiant temperature of 20°C so long as the resultant temperature remains at 20°C. (With external temperature at 0°C).

Assuming the final ambient temperatures as given in Table 3, calculations were carried out for net energy losses. Results for energy losses taking radiant temperature into account and without taking these into account are given in Table 4 for all the specifications discussed earlier.

Specification	Orientation	Annual Energy Consumption kWh	
		Radiant temperature NOT taken into account	Radiant temperature TAKEN into account
(1) 100 mm in the loft	E-W	14,004	14,394
(2) 400 mm in the loft	E-W	13,393	13,783
(3) 140 mm in the loft 50 mm in the floor 50 mm in the walls	E-W	9,642	10,140
(4) As (3) + ventilation rate halved	E-W	5,121	5,439
(5) As (4) Orientation N-S	N-S	5,055	5,374
(6) As (5) South glazing enlarged	N-S	5,281	5,695
(7) As (6) Atrium created	N-S	3,954	4,273

Table 4

The Integrated Approach was developed and successfully used for a number of developments. Currently there is a project at 31, Lawrie Park Road, London S.E.26. where a Demonstration Suite has been set up. This project is funded by UK. Dept. of Energy and the E.E.C. However, the concept of demonstration, to achieve replication, required special research effort. The rest of the paper deals with the Concept of Demonstration as a Strategy for Planned Change.

DEMONSTRATION OF THE INTEGRATED APPROACH TO ENERGY EFFICIENT BUILDING

Introduction

The development of the concept of Demonstration resulted from the juxtaposition of two main factors:

Firstly, a growing awareness in the minds of the authors that for the widespread adoption of energy saving techniques in buildings, it is not sufficient simply to provide rational proof of the existence and efficacy of the measures and

Secondly, the introduction (by both the UK Department of Energy and the EEC Directorate - General for Energy) of "Demonstration" programmes afforded the opportunity/funding to explore the problem in depth and propose, implement and evaluate a method of overcoming it.

The Problem

The designs of the *majority* of buildings currently under construction, or undergoing major refurbishment, pay scant regard to energy conservation. (At least this is the case in the UK). There are now certain requirements regarding thermal standards incorporated in the Building Regulations and these are, of course, complied with (except they are not always adhered to in London - which has a different type of Building control with no specific thermal requirements). However, the Building Regulations standard is fairly low - lagging a long way behind what can be achieved at a reasonable/acceptable cost - in time, effort and money - particularly through use of the Integrated Approach. The materials and techniques are available and cost-effective but are not being utilised, except by a small minority of individuals and groups.

In order for energy conservation to be more widely implemented in buildings it is obviously necessary for a change to take place - a change in the behaviour of those responsible for commissioning, designing and constructing the buildings and their services. There are two ways in which change occurs - one is a gradual process whereby new ideas/knowledge/technology are slowly absorbed into society, the other is by "Planned Change". The first, 'natural' process *is* occuring - society in general is becoming more aware of the need and value of energy conservation but this is an extremely (some would say 'painfully'?) slow process and our aim is to speed it up. We therefore turn to the concept of *Planned Change.*

Planned Change

Planned Change is defined as,

"a method which self-conciously and experimentally employs social knowledge to help solve the problems of men and societies"' (Bennis and colleagues, 1976)

and

"where a change agent deliberately intervenes in a situation and manipulates social processes to obtain a preferred subsequent situation". (Bhola, 1982).

There are three groups of strategies for planned change:

Empirical - rational
Normative - re-educative
Power - coercive.

The first group is rather simplistic, whereas use of the third group is not generally socially acceptable. The 'normative-re-educative' group is a much broader category - embracing the numerous interactions between individuals, groups, institutions, societies and the natural environment and including overt behaviour, value and belief systems, cultural norms, roles and relationships and perceptual and cognitive orientations. One particular theory/model for planned change which falls within this group - Bhola's "Configurational Theory for Innovation Diffusion and Planned Change: The CLER model" (1982) - will be used later in this paper to explicate the principles of Demonstration.

First it is necessary to look at which individuals or groups should be the 'target' of the planned change or the potential "change adopters". Ideally, it would be desirable to influence all parts of society at one time so that the change would be wrought throughout society and thus operate more effectively. However, it is generally impractical, as in this case, for the change agent (the authors) to intervene in all groups and at all levels. Therefore, attention must be focused on the individuals/groups/institutions which are: (a) most influential in terms of solving the given problem and (b) most accessible (or can be made so) to the change-agent.

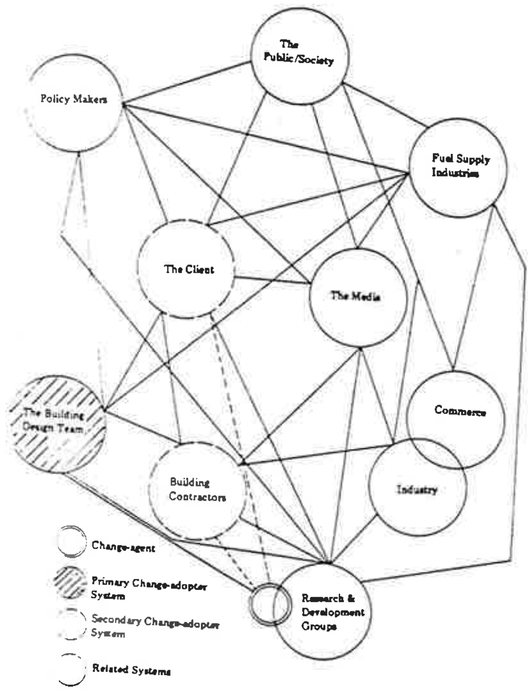


Fig. 2.1 Interrelationships between Involved Groups

In the area of energy conservation in buildings there are 5 broad categories within society who may have an influence on its implementation:

(i) Policy/decision makers.
(ii) Society as a whole including the building users and clients.
(iii) The media.
(iv) Industry including the fuel industries.
(v) Designers and constructors of buildings, their services and their environment.

Some of the interrelationships between these groups are indicated in Fig. 2.1.

Of these, the last group - the professionals involved with the building process - was seen to be the one which could most *directly* affect the energy-efficiency of the buildings and, was also the group in which the change agent could most directly intervene. The behaviour of the other groups with regard to this subject - and indeed, other aspects of societal life - will affect the likehood of the desired change taking place. For instance, should the government and the fuel industries drastically increase or reduce fuel prices, this would affect others' perception of the need and value of energy (fuel) conservation. Therefore, the change agent, whilst concentrating on bringing about change within the building professions, will also attempt to influence these other groups in the same direction, to whatever extent is possible, so as to strengthen the effect of the change strategy.

Demonstration and the CLER Model for Planned Change

Demonstration has been defined as,

"a means whereby, in a non-formal situation, an awareness of the practicality of the subject may be imparted and uncertainties reduced by presenting appropriate information in a suitable format - taking into account the needs, attitudes, previous experience and perception of those to whom it is directed so that they consequently change their existing practices and adopt the desired practices". (Ince, 1981).

In this specific case the desired change is that building practitioners (architects, surveyors, services engineers, quantity surveyors and builders) should incorporate energy conservation measures in their buildings so as to reduce the fuel consumption whilst maintaining or improving comfort conditions.

This definition is closely comparable to the work of Havelock and Benne (1966) who identified two phases in imparting knowledge - preparation of the message and transmission of the message. They saw message preparation as consisting of four steps - assembly of all the relevant facts/data/information; recording the information so it is understandable and acceptable to the receiver; screening (reviewing/evaluating) and 'packaging'. They considered the most effective vehicle for the transmission of knowledge as being, "opportunity to experience it firsthand or through observing a demonstration". It is, of course, widely accepted that first-hand experience is the most effective strategy for learning/changing, but in the case of energy conservation in buildings there are two barriers to utilising this - firstly, some impetus is required to encourage people to provide themselves with the experience - it cannot easily be given to them, secondly, the time-scale of building (anything from 9 months to 5 years or more) mitigates against the immediacy of experience. The aim then, is to provide a Demonstration which as closely as possible imitates direct experience.

Bhola's CLER model (1982) is a useful tool for identifying the various elements of the situation within which the change agent must operate and consequentially indicating the strategies and tactics which can be utilised to bring about the desired change.

The model is represented as: Change = f (C, L, E, R) where

C stands for the network of *c*onfigurational relationships, which include the change-agent and the (potential) change-adopter;

L stands for *l*inkages within and between change-agent and change-adopter systems;

E stands for the *e*nvironment surrounding the change-agent and change-adopter systems;

R stands for the *r*esources available to the change-agent for promoting change and to the change-adopter for adopting/incorporating the change being offered.

The network of configurational relationships (C) is the network of relationships between any two social configurations of individuals - the change-agent may belong to any configuration and so may the change-adopter. In this specific case, the change agent is a small group and the potential change-adopters are groups of professionals (architects, surveyors, etc.) some of whom are also linked together in various institutional configurations as indicated in the network in Fig. 2.2 below:

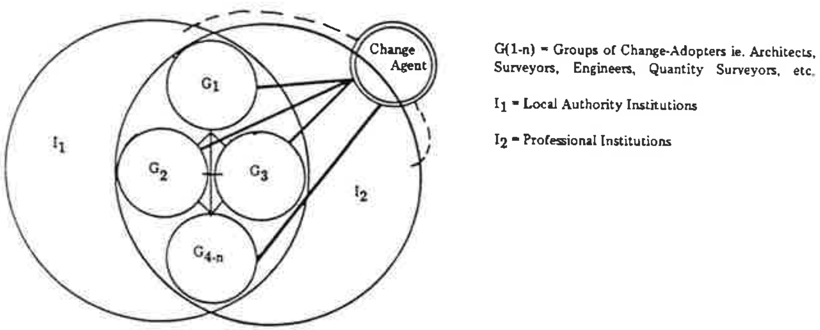


Fig 2.2. Groups of Change Adopters

Linkage (L) is the potential for communication - in either personal or impersonal mode - between the change-agent and the change-adopter and also within the change-adopter systems. In the case of the specific demonstration under consideration there are some existing linkages between the change-agent and some of the change-adopters - these linkages need to be re-inforced and others need to be created - these will have been formed once the change-adopters have been persuaded to visit the Demonstration - at that point the potential for communication will have been created. Encouragement to visit the demonstration will be via notices in relevant professional journals, invitation by mail and word of mouth. There are some linkages - specifically between potential change-adopters and others within the change-adopter system who are strongly opposed to the desired change, which it would be *desirable* to sever. It is unlikely, however, that the change agent will be in a position to achieve this severance and must therefore allow for the counteractive effect of these individuals/groups.

Environment (E) comprises the physical, socio-cultural and intellectual conditions and forces which impinge on the change-adopters and may have a supportive, neutral or inhibiting effect. Some of the

environmental factors influencing the demonstration of energy conservation at the present time are:

Supportive	Neutral	Inhibiting
Increasing awareness of need for conservation	High levels of unemployment (will encourage some to embrace additional skills; others will be too 'careful' of their job to be adventurous)	*Apparent* surplus of fossil fuels
Fuel pricing policies		Few incentives - e.g. tax or rates reduction.
Conservation is gradually emerging from being a subject only for 'cranks' to being 'respectable'		Relatively low level of Government support.
		Modest requirements of Building Regulations.

The Resources (R) available for the demonstration of energy conservation (looked at under Bhola's groupings) are:

Conceptual: The professions concerned already have, to a great extent, the necessary cognitive and technical skills to embrace the concepts and techniques of energy conservation, providing that they can be brought to a state of readiness/willingness to do so. Skills will be enhanced through the exhibits and through literature to take away. Attention will also be drawn to sources of assistance, consultancy services for specific projects and the availability of a computer program for analysing heat losses and the comparative effectiveness of measures in specific cases. Data from the continuous monitoring of the energy-efficient buildings, round which the project is centred, will be displayed, together with costs of the measures and the techniques of implementation - including a film of the actual building in progress. Visitors to the Demonstration during the first 6-9 months will also be able to visit the new houses in course of construction. One example of the new houses will subsequently be open to visitors - the demonstration suite itself serving as the example of the energy-efficient rehabilitation. There is also a facility to hold seminars within the Demonstration Suite.

Influence: influence resource is really a use of power - directly or indirectly - and is related to work on attitude change which has indicated that a change is more likely to take place if the proposal comes from a 'respected' source. In relation to the demonstration project the change agents are developing lines of indirect influence by:

(a) convincing local politicians, heads of design departments/practices and others in similar 'elite' positions, of the need/benefits of energy conservation. (This has to be achieved outside the demonstration project itself, but by similar means). These individuals/groups may then influence those over whom they have any kind or degree of power to adopt the change, or at least to visit the Demonstration (with a pre-disposition towards adoption).

(b) through use of the media to create a pre-disposition towards the change - there will be an 'official opening' of the Demonstration Suite by a public figure - to stimulate media interest (among other reasons) and reports about the project will be circulated to relevant technical/professional journals and to the National Press.

All four elements of the CLER model act co-operatively and must be considered as a combined force although it may, in some circumstances, be possible, or preferable, for the change-agent to manipulate only a selection of the four variables. Where it is *desirable but not possible* to manipulate all four variables, the desired change may not be achieved, or only partially achieved. In this Demonstration project it is possible that the desired level of change *may* not be achieved for various reasons, e.g. personnel not being granted time off work to visit the Demonstration or, not being given additional time, or manpower, to design energy efficient buildings or, perhaps, the 'rewards' for adopting the change are not 'visible' or high enough compared to perceived cost.

Demonstration of the Integrated Approach to Energy Efficient Design: A Strategy for Planned Change in a Specific Situation.

'Demonstration' in this instance is used to describe a particular strategy/mode of presenting knowledge with the intention of bringing about a behavioural change. The desired change is that building professionals will take steps to ensure that their buildings are 'energy-efficient' i.e. use the minimum amount of fuel whilst preserving (or improving) the quality of life of the building users. There are various strategies which could, theoretically, be employed to bring about this change - such as, for example, making more stringent regulations, creating social/moral pressure or doubling the salaries of those who comply! Such strategies, even if seen as desirable, could not be implemented by the particular change-agent in this particular case. The use of Demonstration as the change strategy was indicated both by its characteristics (of being a close substitute for direct experience) and by a particular set of (externally supplied) conditions.

The 'external' conditions which acted in favour of the Demonstration strategy were that the change agent was able to obtain funding for a 'Demonstration project' (from the UK Dept. of Energy and the

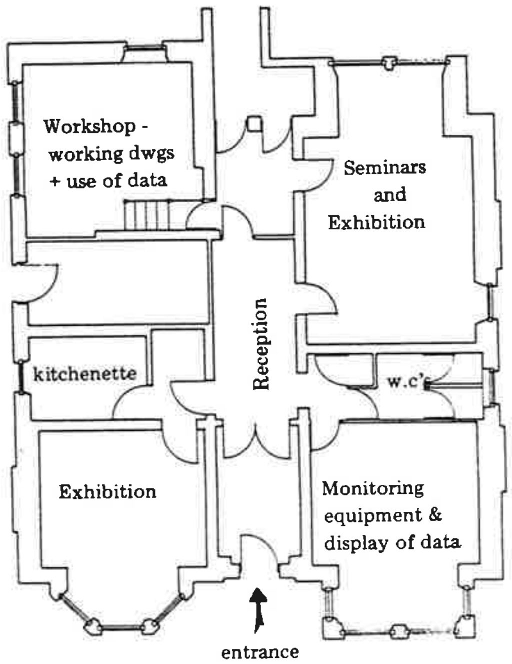


Fig. 2.3 Layout of Demonstration Suite

EEC) and a local authority (London Borough of Lewisham) was prepared to provide the sites for the new building and the rehabilitation of old houses to energy efficient standards. The authority was also prepared to allow the use of part of one old house for the Demonstration for a period of at least 2 years. The Demonstration project is located in a "Demonstration Suite" comprising four large rooms (and ancillary services) being the ground floor of one of the old houses which has been rehabilitated to energy-efficient standards. (see Fig. 2.3).

Certain restraints were imposed as a result of the location (e.g. from outside the Suite should appear as an integral part of the house) and by the funding bodies. Within this framework it has been possible to devise a Demonstration made up of a number of elements which together make up this strategy for Planned Change.

The Demonstration will include the following elements, all of which will be oriented to take into account the needs, attitudes, previous experience and perception of the potential change-adopters (building professionals):

1. A permanent exhibition presenting:

   (a) The principles of the Integrated Approach to Energy Efficient Building;
   (b) The techniques, materials and equipment used in the new and rehabilitated houses to achieve energy conservation;
   (c) Some of the advantages and disadvantages of various techniques;
   (d) Indications of relative costs and savings of different measures;
   (e) Examples of other energy-efficient buildings;
   (f) Indications of how various measures could be applied in different situations.

2. A film recording the actual implementation of the energy conservation measures during the building process.

3. A full monitoring system - recording internal and external temperatures and fuel consumption - to indicate the effectiveness of the designs in achieving comfort in the dwellings *and* saving fuel. The monitoring system will provide daily summaries of this information so that visitors can relate the previous day's figures with their own recollection of that day's climatic conditions. There will also be a computer-generated graphic display where the thermal behaviour of any of the 33 monitored dwellings over any given day can be viewed in a condensed mode - to give a 'feel' for how the buildings respond to climatic conditions over a period of time.

4. A variety of literature for visitors to take away - including reproduction of the information contained in the exhibition; design details ('hints and tips'); lists of relevant trade associations, manufacturers/suppliers of energy saving equipment/materials; bibliography of publications and an indication of individuals and groups with experience in this field who could be approached for design assistance.

5. Facilities for small (up to 25 persons) seminars are available within the Demonstration Suite, with members of the change-agent system available, if desired, to participate in seminars, or to accompany visitors to the suite and discuss the subject with them - this interpersonal activity is not intended to be 'forced' on the visitors, but can be a very effective change tactic when it is found acceptable by the change-adopter.

Outline of Evaluation Methods to be Employed

Evaluation of the Demonstration will be carried out firstly during the first 6 months or so of the operation of the project with a view to modifying the elements according to the evaluation results. Further evaluation will be carried out following these modifications. At both these stages it will be possible only to evaluate the *immediate* effects of exposure to the Demonstration and may not indicate whether any change will endure for a length of time. Therefore, some of the visitors will be contacted some 6-12 months after their visit - to discover whether the change has endured.

A questionnaire has been devised which all visitors will be asked to complete. It is in two parts - one to be completed before exposure to the Demonstration and the second part immediately after exposure. It is also intended to interview some visitors *during* their exposure to the Demonstration and to *observe* others - these techniques being used to evaluate which elements of the Demonstration have most impact or are confusing or insufficient.

The evaluation of the longer term effects of this change strategy will probably need to be carried out by a postal questionnaire, though it may be possible, and would be desirable, to interview some of the change-adopters after a period of time has elapsed.

Acknowledgements: Computer Software: Dan Hamm. Calculations: Andrew Burke.
Architectural Graphics: Nicholas Borowiecki. Typescript: Glenda Hill.

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