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EVALUATION OF PASSIVE SOLAR RETROFIT OPTIONS

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ABSTRACT

If passive solar energy is to make a significant contribution to the reduction of residential energy consumption by the close of the century, passive retrofit designs must be incorporated into a sizeable proportion of the existing housing stock. By the year 2000 70 percent of the housing stock will be of pre-1980 construction. Moreover, these homes will account for over 80 percent of the total residential space heating demand. Displacement of conventional fuels by passive solar design techniques will depend upon their acceptance as a retrofit option. An evaluation framework has been developed which allows for the assessment of the role of passive solar retrofit in the nationwide reduction of conventional fuel use.

Three types of analysis are proposed within this framework: the physical/technical capability of the present housing stock to incorporate passive solar retrofit; the economic feasibility of the application of retrofit designs; and the actual market potential or acceptance of these alternative retrofit options. Each type of analysis has specific data requirements and a series of evaluation procedures to help establish estimates of the potential for passive solar retrofit in the present housing stock. The data requirements with their respective sources and evaluation procedures for the first two types of analysis --physical/technical setting and economic feasibility--are examined in this paper. A distinction is drawn between community specific case studies and more generalized national assessments.

Information derived from these three types of analysis, whether case specific or national in scope, can then be used in an evaluation of potential economic impacts. The establishment of regional economic benefits and costs serves as a measure of the merit or attractiveness of the implementation of a passive solar retrofit program.

1. INTRODUCTION

The physical/technical characteristics of the existing housing stock must be assessed before evaluating the economic competitiveness and market potential of passive solar retrofit options. Two alternative approaches can be used in such an assessment procedure. The case study approach utilizes neighborhood specific survey results to arrive at a detailed characterization of physical attributes of the housing stock. An alternative approach is to use readily accessible data bases which allows for the physical description of housing stocks across a broad geographic spectrum. A nationwide appraisal generally requires the use of the second approach, although the two approaches can be combined to allow a more complete description of national housing stock characteristics. The nonhomogenous nature of construction practices and consumer preferences necessitates fairly detailed geographical resolution of the housing stock inventory.

In characterizing the physical/technical attributes a number of parameters must be established. The first group is comprised of information about the actual structural characteristics of homes. These parameters include dwelling type (e.g., single-family detached or multi-family high-rise), age, style and model, type of construction and thermal integrity. Thermal integrity is in turn defined by more specific building characteristics such as insulation R-values, type, size and orientation of windows and so forth. The second group of parameters includes information about dwelling site characteristics. The two most important for passive solar retrofit consideration are residence orientation and shading.

There are a number of public and private sources that can be used to help define the parameter values. Some of these have included: Bureau of Census Housing Survey data bases [1,2]; satellite reconnaissance photos from various divisions of NASA; low level aerial photographs from local, state and federal agencies; and construction practices governed by state and federal building codes. In addition a number of institutions (utilities, state and local energy offices for example) have developed descriptions of existing housing stock which can be used for community specific analyses.

One example of such an analysis is the Philadelphia Solar Planning Project. The city tax files were used to evaluate the predominance of different housing types. The two-story row house was found to be the predominant type. The tax files were then used in conjunction with a geographic atlas and a computer program to evaluate the orientation of all two-story row houses. 184,000 were found to be properly oriented to accept retrofit designs. A voluntary Class B audit was conducted to gather information concerning the thermal integrity of the homes. The audit consisted of a questionnaire relating to solar retrofit and conservation characteristics of the homes. It was distributed by the Philadelphia Gas Works. A field check on 100 homes included in the audit revealed that home owner responses about orientation were generally inaccurate. The results of the Class B audit were then used in conjunction with a methodology suggested by Balcomb and McFarland of Los Alamos Scientific Laboratory (LASL) [3] to estimate heat loss for the homes in the sample. The experience of the Philadelphia retrofit assessment program can be used to guide other city case studies (such as the Albuquerque, New Mexico study described below) in certain areas of physical/technical assessment.

Once the physical/technical setting has been identified, the economic considerations can be addressed. The physical performance of the passive solar retrofit options determine, in part, the potential benefits (i.e., reduced conventional fuel use) to the consumer and to the nation. Additional economic information is required in order to more accurately assess the extent of these benefits. Two types of information are needed. The first deals with the conventional (backup) fuel type and heat delivery systems used in existing homes. The second includes the financial climate faced by consumers. Examples of economic parameters include present and projected fuel cost, future conventional fuel/furnace alternatives, home value and ownership patterns, retrofit costs (both material and labor) and the cost of financing (e.g., interest rates and loan period). Some of the previously mentioned sources have been used to identify fuel use, fuel cost and delivery system specifics. Typical solar costs have been derived from actual construction projects. Consumer costs have been obtained from various financial institutions.

Sets of procedures for the physical/technical and economic analyses are outlined below for use in a case study of Albuquerque, New Mexico being conducted by the Modeling and Economic Analysis Group at LASL and the University of New Mexico Resource Economics Department. As stated earlier, the third type of analysis--market potential or acceptance--is not examined in this paper. Procedures which will be used to assess the potential impact of a retrofit program on the "local" economy are presented next. The details of the Albuquerque study are discussed and used to draw conclusions as to other case studies and the eventual assessment of national retrofit potential.

2. ALBUQUERQUE CASE STUDY

One purpose of the Albuquerque case study is to arrive at an estimate of the number of homes which can physically accept a retrofit passive solar design. This estimate can then be combined with an economic feasibility assessment to project possible levels of retrofit adoption Albuquerque would experience should a vigorous passive solar retrofit program be implemented. The potential impact of the retrofit program on the "local" economy can then be assessed using an input-output (I/O) framework. This would result in estimates of increases in production, income, and employment for all sectors of the "local" economy. The procedures for assessment of the technical and economic feasibility of retrofit designs in Albuquerque are presented below. The subject of market penetration will not be dealt with at this time. The use of an I/O framework to assess maximum potential community impacts will be briefly presented.

2.1 Physical/Technical Assessment

The physical/technical assessment is basically a three step elimination procedure applied to a sample of homes in the Albuquerque area. The homes contained in the sample are those included in a Home Energy Analysis (HEA) conducted by the New Mexico Energy Institute [4]. Three types of information must be identified before a home's ability to accept a retrofit design can be evaluated: 1) age and construction type, 2) orientation and 3) shading characteristics. Information concerning these elements can be found in the HEA. This information can be evaluated to determine whether or not a home should be eliminated from the sample.

The age and construction type is used to partition the homes in the sample into two groups --those which can accept either a trombe wall or a greenhouse and those which can only be retrofitted with a greenhouse. It is assumed that block wall construction can be appropriately retrofitted with either design, whereas frame construction would only accept a greenhouse. These two groups can be subdivided further by screening out very old structures which, in many cases, will not be good economic candidates for a retrofit due to their short remaining useful life.

The orientation information contained in the HEA tells which side of the house faces to the south (front, back,etc.). The survey also contains more specific information about the characteristics of the south wall; included are details such as the presence or absence of awnings, whether there is another structure within 100 feet, the number of glazings and square footage of window area, and length of the side of the house. This information can be used to further assess the appropriateness of the home for retrofit. Identification of the living area adjacent to the south wall may restrict the type of design which can realistically be retrofitted. For example, if the garage is adjacent to the south wall a more complex design might be necessary to deliver heat to the living area than if the den or living room were on the southern exposure. The orientation information can be correlated with low level black and white aerial photos, zoning maps and field checks to ascertain the reliability of the survey data and provide experience in the use of these other data bases.

Two of these other data bases--aerial photos [5] and field checks--will be used to assess the degree of shading for homes, which at this point, are still included in the retrofit sample. The HEA asked respondents if much of their house was shaded in the summer. Responses were categorized by three types: (1) little or none, (2) about half, and (3) most or all. There are three problems with adapting this information to the needs of retrofit assessment. First, it is necessary to distinguish deciduous shading from evergreen, and second, it is necessary to distinguish between vegetive and nonvegetive shading. The third problem is to evaluate the meaning of the presence of summer shading for the winter season. An object which shades a home in the winter may not shade it in the summer. This relationship will be determined by the height and setback of the shading object. Use of aerial photos and field checks will be necessary to properly assess the true nature of the shading. Once the nature of the shading is known, the appropriateness of the home for retrofit can be assessed. Homes with evergreen, nonvegetive or excess winter shading will, in most cases, be eliminated from the sample.

The result of this three step elimination process will be a sub-set of homes which can physically accomodate a retrofit design. Information on the thermal integrity of this subset of homes will be used in the next step --economic feasibility analysis. Thermal characteristics are not directly addressed in the HEA. The respondents were asked about the R-value of walls, floors and ceilings; the type of windows and doors; the number of stories; floor, window and door areas and the number of glazings. This information can be used to estimate the heat loss factor which might be appropriately used to evaluate the home heating load (part of economic feasibility assessment). As a last step, the size and composition of the sample will be used to estimate the total number of homes in Albuquerque which are physically/technically capable of accepting a retrofit greenhouse or trombe wall.

2.2 Economic Feasibility Assessment

The economic feasibility assessment procedure is used to identify the cost components of the retrofit designs and incorporate them into an estimate of the potential benefits (to the resident) which might result from the installation of a retrofit trombe wall or greenhouse. These cost components can be divided into three groups: (1) construction costs, (2) foregone costs (benefits) in the form of displaced conventional fuels, and (3) general economic conditions facing the consumer. These cost components are discussed and a brief description of the economic assessment procedure is given below. [6]

The New Mexico Solar Energy Association (NMSEA) has established the cost of several retrofit trombe wall and greenhouse designs. Their workshop projects have provided them the opportunity to estimate these costs based on the construction of retrofit units by do-it-yourselfers as well as contracted professionals with the use of materials readily available in the Albuquerque area. The NMSEA designs and costs will be used to detail the labor and materials components of the program.

The foregone costs are defined as the fuel savings over the projected life of the unit or the appropriately defined homeowner use period. These fuel savings are tied to the performance of the retrofit design and the cost of the conventional fuel. The performance of the design is, in turn, determined by the thermal integrity of the home and performance estimates supplied by the Los Alamos Scientific Laboratory Solar Load Ratio methods. [7] The HEA will supply the type of conventional fuel used. This allows for the specification, through the price of the conventional fuel, of the value of the fuel displaced by the design. This value when summed over the relevant number of years provides the benefits that will accrue to the homeowner.

The third group of components is defined by the cost to the homeowner of building and maintaining the retrofit design over and above the actual construction cost. If it is assumed that the construction is financed through a conventional home improvement loan, part of these costs can be quantified through the loan terms available to the typical homeowner (e.g., interest rates and financing period), the values of which can be provided by local lending institutions. Recurring costs (operating and maintenance costs, insurance expenditures, and property taxes) are another type of expenditure included in this group. These are usually specified as some proportion of the initial construction costs. NMSEA, insurance brokers and the New Mexico State Bureau of Revenue are sources for specifying values for these types of recurring costs. The Bureau of Revenue can also supply information pertaining to the calculation of the solar energy tax credit. All of these general economic parameters will be specific to Albuquerque.

The economic feasibility procedure uses all three groups of information to estimate the present value characteristics of the design. This is done by calculating a present value for the design cost components, a present value for the design benefits, and by comparing the two. A design is feasible if the benefits exceed the costs to the home resident. The homes physically capable of accepting a retrofit design will be classified by conventional fuel type and thermal integrity category (from information contained in the HEA) for this purpose. Homes which use a less expensive conventional fuel, for example, may not experience positive benefits if a retrofit design were constructed. The end result of the economic feasibility analysis is the further elimination of homes from the subset established by the physical/technical analysis.

2.3 Potential Impact Assessment

The final estimate of the number of homes which can both physically and economically be included in a retrofit program for Albuquerque will be used in conjunction with the labor and materials estimate for the designs in an input/output [8] framework to assess the maximum potential impact levels on the Albuquerque economy.

[As stated earlier, one essential step in the assessment of economic impact has been excluded from discussion in this paper. Market penetration estimates are necessary to establish the level and timing of retrofit adoption. Information from the physical/technical and economic analyses are combined in a market penetration algorithm to help establish the number of homes adopting solar retrofit design by year. The total number of homes by year, however, can be bypassed in determining the maximum potential impact on Albuquerque's economy. (Thus, the thorny problem of actual adoption and its timing--a formal market penetration analysis--can be excluded.) This is done by examining varying levels of adoption in a single year. Economic impact (change) associated with these varying levels of adoption (transformed into number of homes) can then be interpreted as the maximum potential effect on Albuquerque.]

The dollar value of increased demand by various economic sectors (industries) can best be computed by using the material and labor category cost estimates derived for each specific passive solar design. When multiplied by number of homes adopting the passive solar retrofit option, these material and labor cost categories result in a total dollar increase in final demand or purchases for each economic sector. This information can then be used directly in an I/O framework to estimate changes in Albuquerque's total production, income, and employment levels.

An I/O framework describes the relationships among economic industries (sectors) in a given geographic region. Further, through careful transformation and interpretation of the I/O structure one is provided with reasonable estimates of multipliers: that is numbers that when multiplied by the change in final demand (from material and labor costs for a set number of homes) result in estimates of the total impact on a region's economy. For example, construction work expense for a greenhouse retrofit will result in further expenditures for items such as food and clothing by the workers or material suppliers themselves. The multipliers derived from the I/O structure allows one to easily transform these direct passive solar retrofit dollar outlays into the total effect on a region's economy.

In the Albuquerque case study an I/O model developed in 1975 for the county [9] will serve as the tool for assessing the maximum potential impact on Albuquerque's economy. Multipliers for total production, income, and employment will be developed from this model and subsequently used in conjunction with alternative levels of passive solar retrofit adoption and direct costs to provide estimates of the maximum expected economic effects. In addition to providing a general picture of the total maximum potential impacts (additional costs and benefits of passive solar retrofit) on Albuquerque's economy, use of this I/O structure and multiplier analysis will provide information on possible material/labor bottlenecks and shortages that could occur under a vigorous retrofit program.

3. CONCLUSIONS

The retrofit assessment procedure presented here has been directed to a case study of Albuquerque, New Mexico. By judicious application of this assessment procedure to other communities some measure of regional potential and impact could be constructed. If a sufficient number of communities were chosen and these communities covered a large geographic area, a national assessment would result.

The transition from a community specific physical/technical assessment to a regional or national assessment can be accomplished with the aid of neighborhood profiles drawn from the limited number of case studies which are available. A neighborhood profile can be used to represent a broadly defined housing type which, for the purpose of a national assessment, can be assumed to typify the shading and orientation characteristics of neighborhoods of like types. Building type and age are housing characteristics which are readily available from national level data bases. These two characteristics can be coupled with the climatic type to classify a community or portions of a community into one of several profile categories. This categorization can then be matched with the neighborhood profiles from case studies (augmented with available neighborhood profile data bases) to infer specific physical/technical capabilities for locations which lack specific case studies. This type of evaluation procedure can be applied to a regional or national assessment effort. The economic assessment procedures can be conducted in a fairly straight forward manner for these additional communities.

The potential impact assessment can serve as a measure of the attractiveness of the implementation of a vigorous retrofit program. Costs and benefits are measured in several ways when this type of analysis is used. Changes in production, income and employment are three such measures. Assessment of the impact on the tax base can also serve as a benefit measure. The amount of conventional energy which could be displaced by a retrofit program is another measure of the benefit to a community or region of implementation of a retrofit program. The costs and benefits to a group of communities can serve as the basis for a regional or national potential impact assessment.

4. ACKNOWLEDGEMENTS

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