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A BEHAVIORAL MODEL OF RESIDENTIAL ENERGY USE *

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The energy use in the residential sector is an important area for campaigns to conserve energy. In the first section of this article, a model is proposed that relates personal, environmental (e.g. home) and behavioral factors to energy use. This model is instrumental in relating variables that determine energy use in the home.

In the following these determinants of household energy use: socio-demographic factors, family life-style, energy prices, energy-related behavior, cost-benefit trade offs, effectiveness and responsibility, feedback, information, home characteristics are discussed.

In the third section several options for energy-saving campaigns and related research are discussed.

Introduction

About 30 percent of the total energy demand in The Netherlands comes from the residential sector. Home heating constitutes three-quarters of residential energy use, water heating about 15 percent, and the use of electricity for equipment and lighting about 10 percent. It is clear that most energy saving can be attained in home heating. If household members accept lower thermostat settings and avoid heat losses through windows and doors as much as possible, considerable savings will be attained.

Energy saving in the home creates benefits for the household itself in

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the form of lower energy bills, and for the community at large in the form of lower imports of oil from the OPEC countries. Why do not all consumers behave in a more energy-conscious way? First, energy conservation is not seen as a problem that concerns them. Many consumers hold others (e.g. the government) to be responsible for the supply of energy. Second, consumers do not behave in an energy-conscious way due to their social environment. Third, consumers do not always know the energy costs of many household behaviors. They do not consider a behavioral change to be effective to conserve energy. Fourth, the feedback information of the energy bills comes too late to make people aware of energy wasting types of behavior. Fifth, some homes and heating systems are energy wasting and cannot be managed in an energy-conscious way by the household members. Sixth, many consumers are unwilling to give up the comfort of high home temperatures. And finally, energy-conscious behavior asks for some involvement with thermostat settings, closing curtains, turning off radiators. This means that you have to put effort and concern in the energy area, additional to your other concerns and efforts.

In the first section of this paper, we propose a model of energy behavior and in-home energy use. This model is an extension of the model proposed in Verhallen and Van Raaij (1981). Several groups of variables are considered as they influence energy use. These groups are the energy-related household behavior, energy-related attitudes, home characteristics, sociodemographic and personality variables, energy prices and feedback information about energy use.

In the second section of this paper, the groups of factors influencing residential energy use are elaborated, and the relevant literature is discussed.

In the third section, recommendations are made derived from the proposed model for energy conservation policy and research. This research may ascertain the relationships in the model and is directed to find effective ways of influencing household members to conserve energy in the home.

The behavioral model: an overview

In the model we propose relationships between groups of variables (fig. 1). The core groups are *energy use* and *energy-related behavior*. The

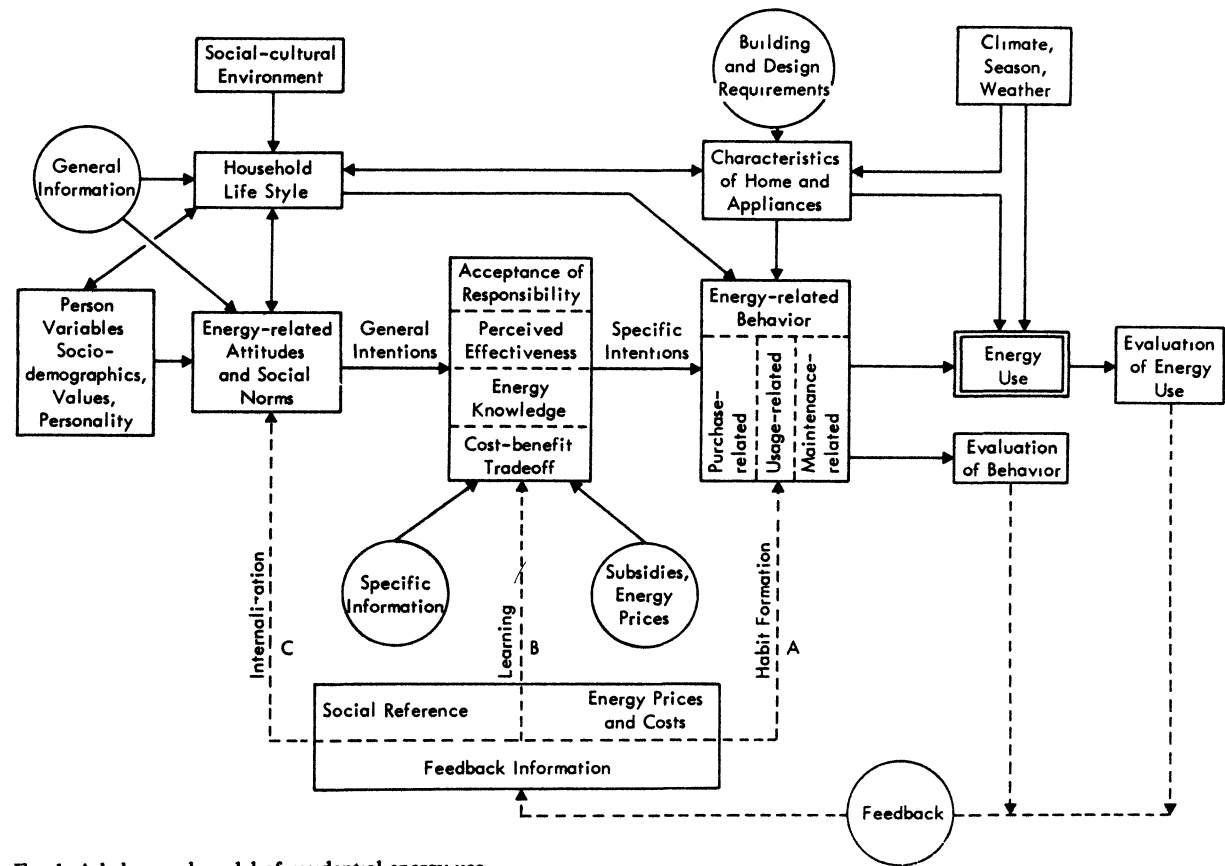


Fig. 1 A behavioral model of residential energy use

energy use of a household is influenced by energy-related behaviors. We distinguish between purchase, usage, and maintenance-related behaviors.

Purchase-related behavior has to do with the purchase of household appliances, heating equipment, and ventilators, and the relative importance and usage of the energy attribute of the products in the choice process.

Usage-related behavior refers to the day-to-day usage of appliances in the home and the home itself. It is the frequency, duration, and intensity of the use.

Maintenance-related behavior refers to the behavior to maintain the in-home heating system and appliances. This includes servicing, small repairs and small home improvements.

- To take the familiar example of the automobile, purchase-related behavior pertains to the consideration of the energy efficiency of the car in the purchase process; usage-related behavior pertains to the driving style, intensity, duration, and frequency of use; while maintenance-related behavior pertains to servicing of the car and regular engine inspections.

Home characteristics have a direct influence on energy use because homes differ in their number of rooms, degree of insulation, wind exposure, and other characteristics. Home characteristics may also influence household behavior and, thus, energy use. We postulate that interactions exist between home characteristics and household behavior (matching of persons and homes related to energy use), or that household behaviors reduce or increase the effects of home characteristics.

Energy-related *attitudes* are price concern, environmental concern, energy concern, health concern, and attitudes toward personal comfort. Attitudes are related to behavior but do not necessarily cause behavior. We assume that persons try to maintain consistency in their attitudes and behaviors. If we change behaviors in a more energy-conserving direction, we may expect that persons develop energy-conscious attitudes. The reverse is not always true. Energy-conscious attitudes do not always lead to energy-conserving behavior. Attitudes may lead to good intentions but social norms, lack of knowledge on the energy use of certain behaviors and on the energy-conservation effects of behavioral change, and situational factors may block the intention to be realized in actual behavior. In the model we state four intervening factors between attitudes and behavior: acceptance of responsibility, energy knowledge,

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perceived effectiveness of one's contribution, and (expected) cost-benefit trade-offs.

A number of *person variables* may influence energy-related attitudes and behaviors. Personality values are related to interests and opinions, which generate activities that may require more or less energy. Household life-style is determined by these person variables and social-cultural factors. Household life-style consists of enduring overall patterns of activities, e.g. leisure, hobbies. The combination of age, marital status and family size is the family life-cycle. Family size and composition, presence or absence from home have a direct effect on energy behavior and energy use. Household income, educational level and employment are also related to energy use.

Energy *prices* are an important factor. Price increases tend to reduce demand by the price elasticity of energy may be small for some segments of the population. Large price increases tend to reduce demand at least temporarily, while consumers adapt more easily to small price increases.

General information refers to information on the energy problem in our society at large: the supply of energy, the energy-inefficiency of cars and appliances, political questions on the OPEC countries. *Specific information* refers to the information on energy costs, the energy usage of certain behaviors, and the effects of energy-conserving behavioral change.

The model contains *feedback* loops from the evaluation of energy use and behavior to the intervening factors between attitudes and behavior, and to energy-related attitudes. Feedback information is information about energy use in a particular period, for a particular activity, or momentary energy use. The shorter the feedback period or the better related to a specific activity, the more effective the feedback information will be.

The factors that can be influenced in an energy-conservation campaign, are given in circles: (1) general information, (2) specific information and behavioral advice, (3) subsidies and energy prices, (4) building and design requirements, and (5) feedback information. The model shows how these five factors are related to energy use. General information has the longest path to energy use and will probably be the least effective as compared with the other influencable factors.

Factors influencing residential energy use

In this section we review the research on the groups of variables that influence energy use in the home. It is impossible to cover all literature in the area of residential energy use. For a more complete coverage we refer to the bibliographies by Joerges (1979b) and McDougall and Anderson (1982).

Energy use

Energy use and the evaluation of energy use are the dependent variables in the proposed model. The best measures of energy use are the differences of meter readings for natural gas and electricity at two or more occasions. Other energy sources, such as heating oil, coal, wood, and bottle gas create some measurement problems, because of the lack of continuous measurements. In these cases, especially for coal and wood, we have to estimate volumes. In most studies (Verhallen and Van Raaij 1981; Midden et al. 1983), the investigators/field workers read the meters. Self-reports of meter settings by household members might be an alternative way of measuring energy use.

Most reliable and easy estimates can be attained with one energy source for home heating (natural gas, oil) but one should exclude the use of natural gas for cooking and include the use of electric stoves and wood burned in fireplaces. The energy source for summer air conditioning is mainly electricity. Here, one should subtract the electricity used for lighting and household equipment. The energy contributions of household appliances and human bodies are relatively small and are not considered in most studies.

Energy behavior

We distinguish three types of energy-related behaviors: purchase-, usage- and maintenance-related behavior.

Purchase-related behavior refers to the consideration of the energy attribute in the purchase of consumer durables (stove, refrigerator, air conditioning or heating system, car). Energy-efficient equipment may be more expensive at the point of purchase but less expensive in use. Box and Hermans (1977) conclude that the energy attribute is relatively unimportant in the purchase decision process. The more the appliance

is deemed necessary, the less important seems to be the energy attribute. Anderson and Claxton (1982), and Redinger and Staelin (1981) study the effect of the energy label for major household appliances. The labels have a low impact on the choice process, unless salespersons emphasize and explain the energy label to their customers. Hutton and McNeill (1980) provide an overview of current energy labeling research.

Hanna (1978) compared a number of disclosure methods for energy saving investments. The rate of return method (initial investment and annual benefits) is both easy to understand and valid, and corrects for the expected future energy prices.

While purchase-related behavior pertains to a one-time investment in energy saving, *usage-related behavior* involves the day-to-day energy conscious behavior of setting thermostats, using ventilation systems. Usage-related behavior is very much interrelated with behavioral patterns and habits, and, in general, harder to change.

One of the few studies investigating household behavior is Verhallen and Van Raaij (1981). They find six factors in energy-related household behavior, plus two specific factors:

- (1) Bedroom temperature while sleeping (**).
- (2) Thermostat setting during absence (**).
- (3) Thermostat setting while at home (**, except in summer).
- (4) Use of window curtains.
- (5) Airing of rooms.
- (6) Use of bedrooms for studying/playing.
- (7) Use of hall-door (**, except in summer).
- (8) Use of pilot flame (**).

These behavioral factors explain 26% of the energy use for home heating. The factors marked with '**' contribute significantly at $p < 0.01$. Factors 3 and 7 do not contribute in the summer period. Household behavior proved to be a better determinant of energy use than personal attitudes.

Household behavior and home characteristics do not only separately determine energy use in the home but also interactively. Residents of well-insulated homes have lower thermostat settings (saving energy) but air out their dwellings more often (wasting energy), especially if they prefer to have a low bedroom temperature (Van Raaij and Verhallen 1983). Home characteristics, thus, have both positive and negative effects on energy conservation. Similarly, home insulation increases the

personal comfort perceived by the household members and this leads to lower thermostat settings. Home improvement and retrofitting not only save energy by improved insulation but also by changed behavior of household members. However, Edelson and Olsen (1980) find that after a better home insulation has been installed, some residents increase their consumption of heating fuel by 40 to 50 percent, presumably on the assumption that now their home is well-insulated, they can keep it as warm as they want. Van Raaij and Verhallen (1983) find a similar increase of energy use in the "cool" segment in their study. The "cool" segment of residents are characterized by low thermostat settings and a high level of ventilation. Additional insulation has no effect on their energy use for home heating. For the other four segments in their study, a better insulation leads to a lower energy use. Hamrin (1979) compared the energy use of the residents of homes in two Californian suburbs "Blue Skies Radiant Homes" and "Village Homes". The first type of homes have active solar energy systems and conservation facilities. The second type of homes have passive solar energy and conservation systems, requiring the residents' active involvement by closing shutters and setting thermostats. Contrary to expectations, in the Village Homes less energy was used than the Blue Skies Radiant Homes. The Blue Skies Radiant Homes residents perceive their homes as a way to conserve energy without changing their life-style (purchase-related behavior) and are less involved in energy-conservation behavior. The Village Home people were much more active day-to-day energy conservers (usage-related behavior) and actually used less energy. This means that active involvement in energy conservation leads to a lower energy use, and also that one should "match" the type of home with the life-style of the residents.

Energy-conscious persons conserve more effectively with a solar energy and conservation system requiring their active involvement, while less energy-conscious persons conserve more effectively in home with solar energy and conservation system not requiring their involvement.

Maintenance and operating behavior is added as a third category of energy-related behavior, drawing a parallel with other man-machine systems (Clemens 1983). Research on this category of behavior is almost non-existent but relevant for future research on residential energy conservation.

Stern and Gardner (1981) conclude that more energy can be saved

with increased efficiency (purchase- and maintenance-related behavior) than with curtailment (usage-related behavior). They state that psychologists are generally unaware of the technical aspects of energy use and potential conservation.

Life-style

The concepts of life-style and behavioral routines are crucial to energy conservation. In a process of socialization and in reference with other persons (friends, neighbors, relatives, colleagues) households develop their life-style and habits, partly as a consequence of housing, family composition, and income conditions, and partly as a way of self-expression and self-realization. Life-style is connected with a number of products (e.g. hobbies, sports), membership of clubs, and subscription to magazines. This means that life-style and behavioral routines are hard to alter or change only gradually over time. Attitudinal changes are in general easier to accomplish than behavioral changes. Many persons claim energy-conscious attitudes, but have not yet changed their behavior accordingly.

Characteristics of the home and appliances

Home characteristics such as wall-cavity insulation, double glazing, energy efficient heating and ventilation systems, are important contributions to energy conservation. The attributes of energy-using equipment, the number and kind of household appliances, from freezer to dishwasher and hot-water boiler, are important for the energy use of the household. A detailed discussion of the purchase, usage, and maintenance of these appliances goes beyond the scope of this article. Here we focus on the technical qualities of the home in relation to the behavioral patterns and life-style of the residents.

As already shown, a "matching" of homes and residents (Hamrin 1979) or a matching of appliances and residents (Darley 1977-78) provides the possibility of energy conservation.

Rosson and Sweitzer (1981) emphasize the following physical housing factors determining energy consumption in the home:

- (1) temperature difference between inside and outside of the house,
- (2) heat losses through wall, glass, ceiling, and roof transmission,

- (3) air infiltration (one-half air change per house for houses without weather strips or storm windows),
- (4) efficiency of the furnace, depending on its age and maintenance/service.

While wall, glass, ceiling, and roof insulation are purchase-related consumer investments, the furnace requires periodical attention and care (maintenance-related behavior).

Verhallen and Van Raaij (1981) and Van Raaij and Verhallen (1983) find as important technical home characteristics:

- (1) home-insulation,
- (2) home attachment (apartment vs bungalow),
- (3) energy use of neighbors in attached homes,
- (4) wind orientation,
- (5) temperature difference between living room and bedrooms on the second floor.

Sociodemographic factors

A number of sociodemographic factors influence energy use and conservation. *Household income* is one of the most important factors. Newman and Day (1975) already concluded that the poor use less energy and that their energy use is non-discretionary (for essentials only). The better-off spend 40 percent more on natural gas for home heating, because their dwellings are larger and the energy price constitutes a relatively small proportion of their budget. The poor in the U.S.A. are generally older, have small families (children have left home), have a lower educational level, are more often black; their families are more often incomplete (husband or wife absent) and they do not own but rent their homes. Their homes are generally of a poor quality, with a poor insulation and a less efficient heating system. They conserve energy as much as they can, but their poorly insulated home is energy-wasting. Low-income earners cannot easily reduce their energy use any further.

Cunningham and Joseph (1978) conclude that low-income consumers cannot reduce their energy use, while high-income consumers are unwilling to reduce their energy use. Middle-income consumers are the most likely conservers. Verhage (1980) finds that early adopters of

energy conservation measures are relatively higher represented in the middle-income category (between Dfl. 25,000.00 and Dfl. 50,000.00), while late adopters are relatively higher represented in the high-income category (over Dfl. 50,000.00). This might mean that the first to start energy conservation in the home are the middle-income consumers, while the high-income consumers will follow. The low-income consumers do not adopt energy-conservation measures, because they are unable to reduce their energy use any further.

Household income strongly affects investment behavior of households with regard to home insulation and solar energy. Low-income consumers accept only short payback periods, while high-income consumers are willing and able to accept longer payback periods (Cunningham and Joseph 1978).

Low-income consumers are more often renters rather than owners of a house. For renters the financial cost-benefit ratio is different. After home insulation the house-owner may increase the rent, reducing the benefits for the renter. Expected future energy prices have a specific effect on the situation of low-income consumers. In The Netherlands, it has been calculated that in 1980 both low- and high-income consumers spend about 4 percent of their income on energy. It is expected that in 1985 these percentages will be 10 and 7 percent for the low- and high-income consumers, respectively. Joerges (1979a) also concluded that the poor pay more, at least for energy.

Other socio-economic factors have some influence on energy use and conservation, although research is not very conclusive here. Verhage (1980) finds that early adopters of energy conservation are not significantly different from other respondents with respect to *age* and *educational level*. Fritzsche (1981) and Verhallen and Van Raaij (1981) find that *household composition* (number of persons in household) is a determinant of energy use. A construct that combines age and household composition is *family life-cycle*. Energy use tends to fluctuate over the family life-cycle. Young households without children and both partners working outside the home tend to have a low level of energy use. Households with children at home have a higher use of energy. After the children have left home, the energy use decreases, but gradually increases with age, because older persons need a higher temperature.

Regional differences are another determinant of energy use. Northern countries and even northern parts of a country have a higher energy use

per household. Rural areas have a higher energy use than urban areas. Hemrica (1981) find that Dutch households in the rural areas use an average of 3200 m³ natural gas for home heating, while households in large cities need an average of 1550 m³ per year. These regional differences reflect the different types of houses (bungalows *vs.* apartments), differences in life-style, and differences of the exposure of the houses to the wind.

Energy-related attitudes

Energy-related attitudes include the (cognitive) beliefs about an object and the (affective) evaluations of those beliefs. Fishbein and Ajzen (1975) employ the expectancy-value formulation of attitudes. A person has a number of salient beliefs about an object, knowledge about the characteristics or attributes of that object. These beliefs are evaluated on a favorableness dimension. The summation of evaluations \times beliefs constitutes the personal attitude toward the object. Similarly, social norms multiplied by the motivation to comply with the norms constitute the second component influencing behavioral intention (subjective probability of performing a behavior). Behavioral intention determines behavior, along with unanticipated situational constraints. For instance, a person may have a favorable attitude toward energy conservation (the attitude object); subjective norms also support energy conservation. Both components create a strong behavioral intention to conserve energy, and, if no situational constraints occur, actual energy conservation behavior. In this model, personal attitudes and/or subjective norms trigger the behavior. Changing a person's attitude or changing subjective norms will finally lead to the desired behavior.

Fishbein and Ajzen (1975) are not opposed to the reverse order that behavioral changes may create attitude change. This possibility is stronger represented in the model of Bentler and Speckart (1979). In this model, not only attitudes and subjective norms, but also prior behavior determine behavioral intentions.

Behavior is partly habit formation. Prior behavior leads to repetition (habit formation) and to complementary behavior. In a test of the Bentler-Speckart model more relationships between the concepts proved to be significant. This means that not only changes in attitude or subjective norm but also changes in earlier behavior may trigger the desired behavioral changes. The Bentler-Speckart model also shows that

relationships exist between prior behavior, attitude, and subjective norm. Persons tend to be consistent and avoid large divergence between these factors.

Seligman et al. (1978) find a relatively high predictive value of attitudes predicting electricity consumption for summer air conditioning (55 percent). The important attitude factors in their research are:

- (1) Attitude toward personal comfort and health.
- (2) High effort, low pay-off: "Conserving energy in the home requires a great deal of effort for too little dollar savings".
- (3) Individual contribution to alleviate the energy crisis.
- (4) Concern with the legitimacy of the energy crisis.

In a second study by Seligman et al. (1979) the same factors emerged with an additional factor "belief in science and technology". Attitudes in the studies of Seligman et al. predict the use of electricity very well (59 percent variance explained). For many American households, more energy is used for home air conditioning in summer than for home heating in winter.

Verhallen and Van Raaij (1981) obtain a lower predictive value for attitudes predicting home heating in winter. The attitude factors are:

- (1) Energy concern;
- (2) Home comfort;
- (3) Price concern.

These three factors explain less than 5 percent of the respondents energy behavior. Verhallen and Van Raaij (1981) conclude that household behavior and home characteristics are more important determinants of energy use than attitudes.

Rosson and Sweitzer (1981) find that the excessive energy users have fairly traditional consumption attitudes and try to pass on the responsibility to others to avert an energy crisis. The conserving group can be described as "socially conscious" and "ecologically minded" in the same way as Webster (1975). These consumers are more sensitive and worried about the energy situation. They are younger, with larger families, better educated and more family-centered.

Geller et al. (1979) conclude that educational efforts to change

attitudes in an energy conserving direction are less effective than action-oriented efforts to change behaviors.

Leonard-Barton and Rogers (1979) also find specific attitudes and beliefs about the consequences of energy conserving actions to have more influence on conservation behavior than general beliefs, e.g. with regard to the energy crisis. In recent discussions on the attitude-behavior relationship in energy conservation (Ellis and Gaskell 1978; Olsen 1981; Ritchie et al. 1981) it is argued that specific attitudes will be better predictors of energy conservation than general attitudes. In our model both general and specific attitudes are represented, for three reasons:

- (1) The distinction between general and specific attitudes is not only a matter of degree but also of difference in content. General attitudes are operationalized as energy-concern, price-concern, ecological-concern, and attitudes on comfort and health. Specific attitudes are defined as e.g. beliefs about the consequences of energy-conservation actions (Leonard-Barton and Rogers 1979) or claimed knowledge, and the importance of individual efforts (Ritchie et al. 1981).
- (2) General attitudes may provide a general context shaping more specific and critical factors. General energy concern may lead to a higher sensitivity for specific behavioral recommendations.
- (3) Specific intervening constructs are perhaps non-attitudinal. Olsen (1981) argues for a separate concept of behavioral intention in recognition of the fact that such an intervening construct may arise from non-attitudinal factors. In the model, these external factors are "specific information and behavioral advice" and "subsidies and prices".

Responsibility, effectiveness, and knowledge

Modifying Schwartz' (1970, 1975) theory of the activation of moral norms, we postulate two intervening constructs between attitude and behavior: acceptance of responsibility and perceived effectiveness of one's contribution.

Acceptance of responsibility is the attribution of responsibility for energy conservation to oneself as a consumer and not away from oneself to the government, industry, or ecology groups. Denying one's own responsibility means that there is no need to change one's behavior

or life-style. Hummel et al. (1978) study the "perceived blame" of the energy crisis. They find that self-blame of consumers coincides with a higher willingness to conserve energy. Blaming the environmentalists for the energy crisis concurs with less willingness to conserve.

Perceived effectiveness of one's contribution refers to the personal efficacy one perceives. Does your own energy conservation contribute to alleviate the energy crisis? Does a lower thermostat setting really contribute to energy saving? While each consumer's contribution may be marginal, the total energy conservation of all consumers is enormous. Consumers who perceive that their marginal contribution is ineffective, are less inclined to save energy. Through feedback mechanisms persons learn about the effectiveness of their contribution.

Energy knowledge is the knowledge of energy costs, energy conservation behaviors, and the energy consequences of these behaviors. Perhaps the most striking gap in consumer information on the energy problem is which behaviors have which effect on the use of energy. Although this cannot be answered in a general sense, because prior behavior and home characteristics will influence the size of this effect, this knowledge will affect not only the perceived effectiveness of one's contribution, but also the cost-benefit tradeoffs.

Cost-benefit tradeoff

Not only economic *costs* and *benefits* are involved in energy conservation but also behavioral costs and benefits. The behavioral costs are a decrease in personal comfort, the efforts of lowering thermostats and closing shutters, the lower status of the non-carowner, and the unattractiveness of change. The behavioral benefits are only minor compared with the behavioral costs; we may mention the pride of having visible energy-saving equipment and being a "socially conscious" person. In the economic and behavioral cost-benefit tradeoff, the behavioral costs may be too high for many consumers. In the model, the cost-benefit tradeoff has been placed between attitudes and behavior, because this economic and behavioral cost-benefit tradeoff is an important intervening construct between favorable attitudes and good intentions at one hand and the behavioral realization at the other hand.

For purchase-related behavior the financial cost-benefit tradeoff, e.g. the rate of return on a certain investment, is relevant. For usage-related and maintenance-related behavior the behavioral costs may dominate the cost-benefit tradeoff.

The intervening constructs between attitude and behavior lead to the following hypothetical conditional roles:

- (1) Assuming a positive personal attitude and subjective norm toward energy conservation:
- (2) If consumers have the (physical, financial) possibility to perform energy-conscious behavior (no constraints),
- (3) If consumers accept their responsibility for energy conservation,
- (4) If consumers have sufficient knowledge on the energy consequences of behaviors,
- (5) If consumers perceive their contribution to energy conservation to be effective,
- (6) If the economic and behavioral costs–benefits for energy conservation are positive,
- (7) Then consumers will perform energy conservation behavior in accordance with their attitudes.

Energy prices

The price of natural gas, fuel oil, or electricity plays an important role in the energy use of consumers. We distinguish three aspects of the energy price.

- (1) *Knowledge* of energy prices is generally poor. Most consumers do not exactly know the price of one m³ natural gas or 1 liter fuel oil. Van Helden and Van Broekhuizen (1977) summarize the problems. The unit price of electricity, for instance, varies with usage. Large users pay a lower unit price than small users. Many utility companies have day and (cheaper) night rates. Consumers in many countries pay one bill for their natural gas, electricity and water. They pay monthly advance bills for an estimated standard amount and an annual settlement to correct for their actual use. These factors lead to obscure the direct relationship between energy use and energy costs, and, thus, price knowledge.
- (2) *Price elasticity* is related to price knowledge. We may distinguish discretionary and non-discretionary energy use. Discretionary energy use is the energy use that may be postponed, reduced, or curtailed, for instance, by not heating all rooms of the home or not using electrical equipment.

Non-discretionary energy use is the energy used for essentials such as cooking or heating at least the living room at 16°C. Non-discretionary energy use is very much price insensitive, even for low-income consumers. Discretionary energy use is more price sensitive, because the consumer has more alternatives in this case. Van Helden and Van Broekhuizen (1977) obtain an overall short term price elasticity of 0.15 for electricity. A price increase of 10% leads to a short term reduction of 1.5 percent.

Middle-income households have a higher price elasticity (0.18) compared with low- and high-income households, 0.12 and 0.14, respectively. This confirms that middle-income consumers are most willing and able to conserve energy.

- (3) Price, thirdly, constituted a *feedback mechanism*. Paying the energy bill may increase one's energy consciousness, price knowledge or sensitivity. The shorter the time interval between energy use and payment, the more effective the feedback mechanism will be. Annual settlement bills for energy are a very poor feedback mechanism for consumers: the relationship between usage and payment is almost lost.

Price rates. Progressive rates with a lower unit energy price for the heavy user do not stimulate energy conservation. Proportional rates or even degressive rates tend to reduce energy use, especially the discretionary energy use. However, with a degressive rate we discriminate against large families, rural areas and poorly insulated houses. We should correct the basis non-discretionary energy quota for these factors, if we should follow this policy of energy conservation.

The price mechanism may not only reduce discretionary energy use but may also spread out peak loads, especially for electricity. A (lower) night rate for hot water heating in electrical boilers will stimulate a better distribution of electricity consumption over the day. Consumers may change the timing of their household work (e.g. washing at night) to avoid peak loads. Kohlenberg et al. (1976) experimented with a peak load signal as feedback information for household members. A combination of feedback plus incentives was most effective and reduced peaking about 50 percent, but removal of experimental treatments resulted in a return to pre-treatment consumption patterns. Obviously, it takes time and effort to change established behavioral patterns in an energy-conscious way. Degressive and peak load rates may stimulate

these behavioral changes. Heberlein and Warriner (1983) conclude that attitude, knowledge and commitment have stronger effects on behavior than price and ability. The behavior is the shift of residential electricity use from on- to off-peak periods.

Feedback information

Feedback is the information persons obtain about the consequences of their behavior. Feedback about energy-related behavior involves monetary information about energy costs of the expired periods (energy bill), numerical information about kWh's electricity or cubic meters natural gas, and social information from referent persons about one's behavior. In general, the shorter the feedback period the more effective the feedback will be. In that case one can easily relate the costs to a certain behavior of wasting or conserving energy.

Feedback information on energy costs is more effective to reduce energy consumption than general information on energy conservation and information prompts. Additional financial rewards increase the effectiveness (Kohlenberg et al. 1976; Hayes and Cone 1977; Winett and Neale 1979; Battalio et al. 1979). Seaver and Patterson (1976) recommend to add social commendation to the feedback information to increase effectiveness. Most experiments on feedback have used small and biased (volunteer) samples, which makes a generalization of the results dubious. In many experiments, the energy use returned to the pre-experimental baseline level after finishing the experiment and removing the feedback information, rebates, or rewards.

This may be attributed to three different feedback functions (see the model):

- (A) The feedback information may not have been specific enough for the household to learn which behaviors have energy relevance and no learning has occurred on the energy effects of these behaviors.
- (B) The feedback period was not long enough for the households to establish new patterns of energy-conservation behavior and no habit formation took place.
- (C) No internalization of the behavior in terms of personal attitude and subjective norm.

The latter condition may be explained by Bem's (1967) theory of *self-perception*. Through feedback information, rewards, or rebates new

energy-conserving behaviors are elicited. After a while, the persons adapt their attitudes in a way to become consonant with their behavior. The new energy-conserving attitudes remain after the experimental conditions have been removed. The energy-conserving behavior has been triggered externally through a reward system. The energy-conserving attitude has been formed through an internalization or self-perception process. In the model, the external feedbacks (A and B) and the internal feedback (C) are given with a dotted line. Social feedback information pertains to the information about the energy use of social referent persons (neighbors living in the same type of house; colleagues with the same occupational status; people of the same social class). Crucial is that the referent persons are perceived as true referents, with which one wants to compare oneself. Otherwise, differences in energy use are easily discounted as uncomparable cases.

Russo (1977) investigated the effect of feedback information about the energy use in the same period the year before, corrected for weather differences. This type of information has a small but stable effect. Note that the energy prices have increased and that it is not unlikely that consumers pay more now for less energy use compared with a year ago.

Feedback information provides the consumer with knowledge about the quantity and costs of the energy used. If the consumers are able to relate this information with their usage behavior, a learning process and behavioral adaptations toward an energy saving life-style may be stimulated. Internalization toward energy conscious attitudes and knowledge about energy-efficient *vs.* energy-wasting ways of behaving should be stimulated. Rewards and rebates may stimulate conservation behavior during the experimental period. Attribution of one's behavior to the rewards and rebates may inhibit internalization and, thus, a long-lasting effect.

Social reference and community approach

The network of social contacts with friends, neighbors and colleagues is important for the dissemination of information about energy conservation, and for social comparisons.

Communication occurs in social networks of cliques (homogeneous subgroups) and liaisons (persons connecting cliques). The strength of the liaisons is crucial for the dissemination of new information through personal contacts. While communication through the mass media is

important to provide facts and figures, personal communication is more convincing to change attitudes and behaviors (Nan Lin 1973).

Warren and Clifford (1975) found that energy saving innovations and behavioral changes have a stronger diffusion in "integrated" neighborhoods, i.e. neighborhoods with many social contacts, memberships of organizations, and outside contacts (liaisons). Diffusion is slower in neighborhoods without social contacts. The social structure reinforces the diffusion of energy-saving innovations. This reinforcement may be positive or negative. In the case of negative reinforcement, the social contacts derogate the innovation or the source of the information.

We may expect that the visible forms of energy conservation will have a stronger social-reference effect. Double-glass windows are more popular than wall-cavity insulation (Meyer and Vlieg 1979), because of the visibility of double glass. Many consumers feel the need to show others their energy-conscious behavior.

The supportive function of the social reference and community to stimulate the adoption of energy-conserving home improvement and energy-conserving behaviors and life-style, is much neglected in research.

Discussion

The main purpose of the model is to collect and to structure the determinants of residential energy use. This provides researchers and policy makers with a comprehensive review of factors relevant for the explanation of energy use and a means for evaluating the effects of different policy options. In the model, it is shown that some options, e.g. general information campaigns, will have very general and indirect effects. The path from general information to energy-related behavior is too long. Other policy actions, e.g. behavioral advice, have a shorter path to energy-related behavior and will probably be more effective.

Two other characteristics of the model should be mentioned. First, the model is not a process model. Processes mediating the effects on energy use, e.g. socialization, attitude change, and learning, are not described in full detail. Second, the model may be applicable for other energy-related behaviors. With minor modifications it may be used for the explanation of automobile use. "Characteristics of home and appli-

ances" becomes "characteristics of the car". "Building and designs requirements" also pertain to automobiles. The "structure of roads and public transit" should be added. The model may also be used for environmental behavior, e.g. recycling behavior and garbage separation.

Recommendations for energy conservation

Although the number of behavioral energy conservation studies is rapidly growing, several factors and relations within the model have not yet received much attention.

Behavioral evaluation. Studies have mainly focussed on energy use as the dependent variable. Other evaluation standards have received relatively less attention. Rohles (1981) mentions seven aspects of thermal comfort: air temperature, relative humidity, radiant temperature, air velocity, clothing, physical activity, and time. He discusses how these factors may be modified to conserve energy. Psycho-physiological research will be needed to create further insights. Other possible evaluation standards are perceived health, effort, convenience. In many instances, these evaluation standards are traded off against energy use.

Maintenance and operating related energy behavior. Research on this type of behavior is scarce. Especially for new types of energy producing or conserving equipment (solar and wind energy, energy-efficient furnaces), we need to know more about how consumers handle and service these appliances.

Energy knowledge. It has been found oftentimes that although consumers hold energy-conscious attitudes, they do not behave in an energy-conserving way. Specific knowledge of the effects of different energy-related behaviors or behavioral patterns is needed in order to behave according to one's general attitudes.

Cost-benefit tradeoff. Research on the willingness to change specific behaviors and the factors relevant for costs and benefits of behavioral change may lead to better insights into the effects of behavioral recommendations.

More general options for energy conservation programs and research are discussed in the following paragraphs.

Attitudinal change. Many traditional energy conservation campaigns have educational, informational or attitude-change purposes. It is assumed that attitude change leads to behavioral changes in the direction

of energy-conserving behavior. We assume that positive attitudes toward energy conservation are only materialized in energy-conservation behavior under the conditions that the economic and behavioral trade-offs are favorable for energy conservation, and/or that persons accept their responsibility for energy conservation and judge their contribution to be effective. Positive attitudes plus the mentioned conditions may lead to energy-conserving behavior. Research is needed to ascertain whether all conditions are necessary or only a subset, because some conditions may be substitutes for each other.

Behavioral change. Through recommendations, information, prompts, and information about the energy costs of certain behaviors we may change behavior directly without changing attitudes first. Feedback methods are promising for behavioral change. Most persons do not want to give up their preferred life-style, habits, and behavioral routines. More research is needed to study the interrelationships of behaviors: sequential patterns, co-occurrence of behaviors, traditional ways of doing household work, and preferred hours of the day for household work. Research is needed to relate household behavior patterns and life-style to socio-demographic characteristics (age, income, family composition, occupation, education), and to study the effect of changing one type of behavior on the other behaviors (substitution, complementarity).

Home improvement. Energy-efficient equipment, and home retrofitting have their impact on household behavior. Residents may reinforce or counteract the energy-conserving technical facilities. Research is needed, how to introduce energy-conserving innovations (Van Raaij 1981), how to adapt the innovations to household behavior, and how to match technical innovations and home characteristics to the life-style of the household.

Continuous innovations ask no or little change of household behavior and are easier to introduce than discontinuous innovations that require considerable changes in household behavior, and are, consequently, more difficult to introduce. Examples of research on the interaction of technical equipment, home characteristics, and household behavior are Darley (1977-78), Hamrin (1979), Verhallen and Van Raaij (1981).

Feedback. Feedback information is effective in teaching consumers the energetical consequences of their behavior. Several types of feedback are already mentioned in this article. The shorter the feedback

period, the more effective the feedback will be. Momentous feedback is possible with the (Canadian) Energy Use Display Meter (Mauser et al. 1979). The content of feedback information may be (1) the quantities used, (2) the financial costs of used energy, (3) a comparison with earlier and comparable periods, and (4) a comparison with the energy use of referent households. Rebates and rewards reinforce the effects of personal feedback, but are difficult to realize outside experimental settings.

Self-monitoring is a type of feedback, in which the residents record their own energy use by reading the meter regularly. Self-monitoring requires the active involvement of the residents and is only successful if this involvement has been realized.

A final criterion for the evaluation of feedback procedures is the degree of energy conservation realized during or after a feedback period. In order to assess the stability and nature of these results, the criteria mentioned in the model should be taken into account. This means that the degree of internalization (attitude change), learning (increased energy knowledge), or habit formation (behavioral change) determine the success of the feedback treatment. This corresponds with C, B, and A types of feedback, respectively. The distinction of these different types of feedback criteria will strongly improve our understanding of the feedback process and effects.

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