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Published in:
Journal of Economic Psychology

Publication date:
1983

Citation for published version (APA):
van Raaij, W. F., & Verhallen, T. M. M. (1983). Patterns of residential energy behavior. *Journal of Economic Psychology*, *4*(1), 85-106.

Journal of Economic Psychology 4 (1983) 85-106
North-Holland

PATTERNS OF RESIDENTIAL ENERGY BEHAVIOR *

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Received July 8, 1982; accepted April 12, 1983

Behavior of the household members and home characteristics are the major determinants of residential energy use. This study is focussed on energy-related behavioral patterns. It is based on self-reported behaviors of 145 households in Vlaardingen, The Netherlands.

Energy-related behavior may not be a separate type of behavior but a contingency for other types of household behaviors, such as recreation, child care, and household chores. Two important aspects of energy contingency are *home temperature* and *ventilation*. Based on these two components, we distinguish five clusters of behavior or behavioral patterns: *conservers, spenders, cool, warm*, and *average*. The energy use of these clusters differs considerably. *Conservers* use less energy, while *spenders* use more energy than the *average* group. The *cool* and the *warm* cluster use less energy than the *average* group.

For energy policy, the differences between these behavioral patterns (clusters) are relevant, whereas each cluster is different on sociodemographic and attitudinal variables. This requires different strategies for changing and maintaining energy-related behaviors.

Introduction

Energy use in the home is determined by the technical and architectural characteristics of the house and its heating system, on one hand, and the behavior of the residents, on the other hand. The technical-archi-

* The questionnaire design and the data collection was done by Lagendijk Opinion Research in Apeldoorn, The Netherlands. Financial support for this study was provided by DSM, Gasunie, and Bouwfonds Nederlandse Gemeenten. We thank Ton van Osch for parts of the data analysis, Dennis Anderson and George Gaskell for their critical comments on an earlier version of this article.

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tectural characteristics pertain to (1) the insulation of the *shell* (walls, windows-doors, roof, and floor), and (2) the efficiency of the *kernel* (heating system). A well-insulated shell prevents heat leakage and uncomfortable draughts, but may create too low levels of air change without a special ventilation system with heat recovery. An efficient heating system and energy source is another way of saving energy. Other relevant house characteristics are the number of rooms in use, the orientation towards the sun and the wind, the ratio of house volume and surface, and attachment of neighboring houses. Verhallen and Van Raaij (1981) concluded that the following technical home characteristics are relevant for energy use: home insulation, home attachment, energy use of neighbors in attached homes, and wind orientation of the home.

The *behavior* of the residents is the other determinant of energy use in the home. Van Raaij and Verhallen (1983) distinguish purchase-, maintenance-, and usage-related energy behavior. *Purchase-related* behavior refers to the consideration of the energy attribute in the purchase of durables (heating system, airconditioning, refrigerator) or home improvement (wall insulation, double glazing). Energy-efficient equipment and home improvement may be considered as household investments. A higher purchase price will be offset by lower operating costs. Cunningham and Joseph (1978) and Hanna (1978) investigate the acceptable payback periods and the information disclosure methods for energy-efficient equipment. *Maintenance and operating behavior* forms a second category of energy-related behavior, which is almost completely neglected in behavioral energy research. *Usage-related* behavior involved the day-to-day energy-conscious behavior of setting thermostats, using ventilation systems, opening windows and doors.

Usage-related behavior consists of behavioral patterns and habits, and is, in general, hard to change. In most households, energy behavior does not constitute a separate type of behavior but is a contingency of, or condition for, behaviors such as household work (cleaning, cooking, doing the laundry), child care, in-home entertainment (TV, visits of friends), hobbies, sleeping, and resting. This study deals with usage-related energy behavior, as a separate type of behavior for some households (the *conservers*) and for others, as a contingency of other types of behavior and life-style of the household members.

Verhallen and Van Raaij (1981) identified eight factors in energy-related household behavior, related to temperature and ventilation. Temperature and ventilation create conditions for behaviors and are self-controlled contingencies, to be traded off for other contingencies, such as comfort, hospitality for friends, and optimal working conditions.

Technical house characteristics and household behavior have their separate effects on energy use. Verhallen and Van Raaij (1981) find that these factors explain 24 and 26 percent of energy use variance, respectively. Special circumstances (absence during the day, illness, and shift work by the husband) explain another 11 percent. However, house characteristics and household behavior also have interactive effects. In the same study it is found that residents of homes with superior insulation have lower thermostat settings (conserving energy) but air their dwellings more often (spending energy). Home characteristics have both positive and negative effects on energy use. Home insulation increases the comfort perceived by the residents, leading to lower thermostat settings. On the other hand, better insulated homes have a low level of air change; a ventilation system is needed for refreshing the air, thus, wasting energy.

Hamrin (1979) obtained another interaction of house characteristics and household behavior. Residents with a high level of energy consciousness tend to conserve more energy in a home with passive energy conservation equipment. Passive equipment requires the active involvement of the residents to open and close shutters, set thermostats, etc. Residents with a low level of energy consciousness tend to conserve more in a home with active energy conservation equipment. Active equipment does not require the active involvement of the residents, because the system operates automatically. This means that one should "match" the type of home (active or passive energy conservation) with the energy involvement of the occupants. Energy-conscious or price-conscious persons are more willing to be actively involved in day-to-day energy conservation (usage-related behavior), while less energy-conscious or less price-conscious persons may feel they have invested in energy conservation (purchase-related behavior) and are less willing to be daily involved. Darley (1977–78) finds a similar interaction between a technical product, clock thermostat, and household behavior.

Attitude and behavior

Energy-related attitudes consist of the (cognitive) beliefs about energy conservation and the (affective) evaluation of these beliefs. Attitudes may be an important determinant of behavior. If people do what they say and act according to their attitudes, an attractive change strategy may be to influence the attitudes in an energy-conserving direction and to wait for the actual energy conserving behavior to occur.

Seligman et al. (1978) obtain a relatively high predictive value of attitudes predicting electricity use for summer air conditioning (55 percent explained variance). The important attitude factors in their study are: (1) attitude toward personal comfort and health, (2) high effort *vs.* low pay-off, (3) individual contribution to alleviate the energy crisis, and (4) concern with the legitimacy of the energy crisis. In a second study, Seligman et al. (1979) obtained the same factors with an additional factor "belief in science and technology". Again, these attitude factors explain the use of electricity very well (59 percent explained variance).

Verhallen and Van Raaij (1981) obtain a much lower percentage of explained variance, only five percent, for attitudes explaining energy use for home heating in winter. The attitude factors are: (1) energy consciousness, (2) home comfort, and (3) price consciousness. The low proportion of explained variance questions the usefulness of changing attitudes in order to change behavior. Geller et al. (1978) conclude that educational efforts to change attitudes are less effective than action-oriented efforts to change behaviors.

Van Raaij and Verhallen (1983) argue that the attitude–behavior relationship may be strengthened by introducing intervening constructs between attitude and behavior: (1) acceptance of responsibility, (2) perceived effectiveness of one's contribution, (3) cost-benefit trade-offs, and (4) knowledge of energy consequences of behavior. If these intervening constructs are included, positive attitudes may be linked to energy conservation behavior. Assuming a positive attitude, acceptance of one's own responsibility for energy conservation, perception of effectiveness of one's own contribution, and higher economic and behavioral benefits as compared with costs, households will perform energy conservation behavior in accordance with their attitudes. Many conditions have to be fulfilled before the positive attitudes lead to the desired conservation behavior. It might be better to change behavior directly than to start with changing attitudes at first.

This study is focussed on household behavior and even more on the *energy contingencies* that people create for their activities. Households do not make explicit decisions to use energy at some level or up to some amount of money. Households engage in activities and consume energy in the process (Morrison and Gladhard 1976). Energy is a contingency for the activities or a part of the activities. These contingencies are mainly temperature (thermostat setting) and ventilation (air refreshment). This corresponds with the house characteristics *kernel* and *shell*. In some advanced heating systems these two aspects are integrated: climate conditioning and air heating.

An important but yet unanswered question is who handles the energy contingencies in the household: the household energy officer. Is it one person, the housewife, who controls the thermostat and ventilation? Or, do all family members handle these contingencies with or without coordination? Do rules and norms exist in the household about thermostat settings during the day (when at home or not at home), during the evening (when most household members are at home), and during the night (when sleeping)? Are thermostats turned down one hour before leaving the home or going to bed? Do people check that doors and windows are not open longer than necessary? When airing rooms, do people turn down the thermostat or radiators in the rooms concerned?

Research questions

In this study, we look for patterns of energy behavior with regard to home temperature and ventilation. Temperature and ventilation are the major energy contingencies of household activities. Degree of humidity may be the third contingency. In this study three research questions are addressed:

(1) Do patterns of energy behavior exist with regard to temperature and ventilation?
(2) Do different behavioral patterns lead to significant differences in the energy use?
(3) Do households with different behavioral energy patterns differ in their socio-economic characteristics and energy-related attitudes? And, do households with different energy patterns live in different

type of homes in terms of insulation, wind orientation, and home attachment?

If meaningful patterns of energy behavior can be distinguished corresponding with differences in energy use, and if the households with different behavioral patterns have different socioeconomic characteristics, a backward segmentation approach is feasible.

For some segments, energy conservation behavior may be a voluntary behavior, and, if so, could be changed and maintained through attitude change and information. For other segments, however, energy behavior may be less voluntary and more dependent on household characteristics (e.g. family life-cycle) and, if so, would be more difficult to change by information and attitudinal intervention.

Study design

The same data set is used as in Verhallen and van Raaij (1981). From November 1976 through November 1977, the energy use and energy behavior of 145 households in Vlaardingen, Holy-North, The Netherlands, has been recorded. In the suburb of Holy-North 157 similar houses have been built by the Bouwfonds, 79 houses with standard thermal insulation of walls and windows, and 78 houses with superior insulation. All 157 Bouwfonds houses are similar in design, except for insulation, wind orientation, and position of the houses with regard to neighboring houses. The houses have been built in rows, attached to each other. About one-third of the houses have only one attached neighboring house (semi-detached); the other houses have two attached neighboring houses (fully attached). Fully attached houses have a lower degree of heat loss than semidetached houses. All homes have a similar central heating system using natural gas as fuel for heating water pumped through radiators in the rooms.

In retrospective and simultaneous self-report, the 145 respondents, mainly housewives, who participated in this study, reported seventeen types of energy-reated *behaviors*: Thermostat settings while at home, when not at home, in the evening, at night, during absence, with freezing temperatures outside; use of ventilation openings; use of bedrooms other than for sleeping hours; use of radiators in bedrooms; open windows of bedrooms during the night; length of curtains; closing of curtains; use of hall-door; opening windows in living room and bedrooms; airing bedrooms; and use of power ventilation system.

The following *socio-economic* characteristics of the households were obtained: educational level of the husband and wife, family composition and age of children, household income, and occupational level of the husband.

Special circumstances relevant for this study are the number of bedrooms used regularly, absence during weekends and during working hours, presence of guests during the investigation period, stays at home because of illness, changing work hours due to a shift system, vacation during the investigation period, and changes in family composition, such as a new-born baby or older child leaving home.

In the first wave, in November 1976, the respondents answered eight questions on their energy concern, price concern, attitudes toward home temperature and draughts, and ecological concern. Three components were obtained in a principal component analysis of these questions, explaining 0.62 of the variance. These components are: (1) *energy concern*, concern about energy shortages (0.29), (2) *home comfort*, home temperature and draughts (0.17), and (3) *price concern*, conserving for financial reasons (0.16). In the remainder of this study, component scores on these three components are used, computed for each of the 145 respondents. For a more elaborate description see Verhallen and Van Raaij (1981).

Patterns of energy behavior

The 17 types of household behaviors were subjected to a principal component analysis and six components emerged after varimax rotation, explaining 0.58 of the total variance in behavior. The components with their proportions of explained variance are

(1) *Bedroom conditions while sleeping*, use of radiators in bedrooms and opening bedroom windows during the night (0.14)
(2) *Home temperature during absence from home*, temperature during the day while absent from home, temperature at night, temperature during absence from home (0.12).
(3) *Home temperature while at home*, temperature during the day while at home, temperature in the evening while at home (0.09).
(4) *Use of curtains*, length of curtains to the window sill or to the floor, closing curtains in the evening and at night (0.08).

(5) *Airing rooms*, use of ventilation openings, opening windows in living room and bedrooms, use of power ventilation system (0.08).
(6) *Use of bedrooms*, use of bedrooms expect for sleeping hours, airing bedrooms, opening windows of bedrooms (0.06).

The *use of hall door* proved to be a relevant specific component to be added to subsequent analyses.

In the remainder of this study, component scores on these six components are used, along with the scores on the variable "use of hall door".

Clustering procedures were employed in order to obtain distinct behavioral patterns for subgroups of respondents. Three different clustering algorithms (Johnson 1967; McRae 1971; Wisehart 1978) were used on both the original variables and the component scores (six components and one variable). In all of these six cluster analyses, the 4 through 10 cluster solutions were neither distinct nor meaningful and interpretable. Some reasons for not finding natural groupings are: (1) the relatively small sample size ($n = 145$); outliers may influence the formation of clusters which may lead to groupings that are not easily interpretable; (2) the scattered behaviors, that is, no natural density points in the behavioral space can be found; and (3) the fact that energy behavior is only one aspect of different household behaviors. The latter explanation is consistent with our assumption that energy, temperature and ventilation, is a contingency for household and leisure behavior.

In order to test whether a natural grouping exists in the behavioral space, a pattern analysis was performed. The pattern analysis contained the following steps:

(1) Component scores were dichotomized into above/equal vs. below the mean score for the six components and the hall door variable.
(2) In this way $2^7 = 128$ binary strings were distinguished for the 145 respondents.
(3) The expected number of respondents for each binary string was computed based on the proportion of respondents with scores above or below the mean score of the seven variables.
(4) The observed number of respondents with a certain binary string was compared with the expected number of respondents based on its probability (binomial test).

No significant deviations from a distinction based on chance level were obtained. As no clear natural density points could be found, the respondents were classified in five predefined behavioral patterns based on four variables:

(1) Home temperature while at home (Component 3).
(2) Home temperature during absence from home (Component 2).
(3) Airing rooms (Combined components 1 and 5).
(4) Use of hall door (Added variable).

Several reasons exist for selecting these four variables. First, they explain about 50 percent of the variance explained by all of the original 17 variables. Second, the first two variables apply to home temperature (*kernel*), while the latter two variables refer to ventilation (*shell*). And it will be recalled that temperature and ventilation are the two important aspects of the energy contingency in the home. A third reason for selecting these four variables is that they proved to be significantly

Table 1
Five behavioral patterns (clusters) based on sixteen binary strings of dichotomized variables.

Behavioral pattern (n = 145)	Temperature		Ventilation	
	Temperature presence	Temperature absence	Airing rooms	Hall door
I. Conservers (n = 18)	0	0	0	0
II. Spenders (n = 22)	1	1	1	1
	1	0	1	1
	0	1	1	1
	1	1	0	1
	1	1	1	0
III. Cool (n = 23)	0	0	1	1
	0	0	0	1
	0	0	1	0
IV. Warm (n = 45)	1	1	0	0
	1	0	0	0
	0	1	0	0
V. Average (n = 37)	1	0	0	1
	0	1	0	1
	1	0	1	0
	0	1	1	0

Note: 0: more energy conserving behavior.
1: more energy spending behavior.

related to the energy use in the investigation period (Verhallen and Van Raaij 1981: table 1). A fifth variable, the use of the pilot-flame of the central heating system, explained a significant part of the energy use but was not included because switching the pilot-flame on and off is not part of the daily energy behavior in the home. At most, the pilot-flame is switched on and off two to four times a year.

Keeping the four above-mentioned variables (home temperature during presence and during absence, airing rooms, and use of the hall door), we obtain $2^4 = 16$ binary strings after dichotomization. These sixteen binary strings (patterns) can be grouped in five major behavioral clusters according to the distinctions made in table 1.

We may describe the 18 respondents of cluster I by a low temperature as well as a low ventilation level: the *conservers*. The 22 respondents of cluster II have a high score on at least three of the four variables: the *spenders*. The 23 respondents of cluster III have a low temperature but are average or high on ventilation: the *cool*. The largest cluster is cluster IV with 45 respondents: they have average or high temperatures and low ventilation: the *warm*. The 37 respondents of cluster V have average scores on both temperature and ventilation: the *average*.

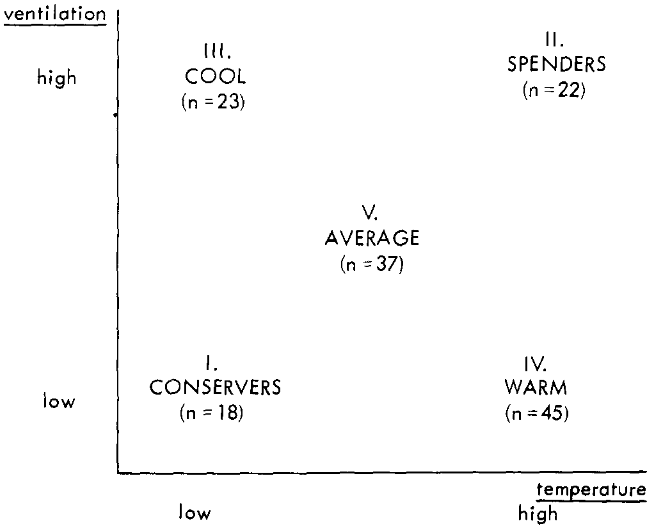

Fig. 1. The five behavioral patterns (clusters) based on temperature and ventilation (see also table 1).

We now turn to an investigation of energy use and socioeconomic and attitudinal characteristics of these five clusters.

Behavioral patterns and energy use

To evaluate the behavioral patterns distinguished in the above section (table 1 and fig. 1), we consider the amount of natural gas used in the five behavioral patterns (clusters). Energy use was measured for three periods during the investigation:
Period 1: October 29, 1976 – January 14, 1977.
Period 2: January 14, 1977 – March 29, 1977.
Period 3: March 29, 1977 – November 1, 1977.

As can be observed from table 2, the average use of energy of the five clusters differs considerably. Using an analysis of variance, the differences are highly significant in all three periods. The proportions of explained variance by the five clusters range between 0.12 and 0.17.

We observe in table 2 that the *conservers* (I) have lowest energy use levels, while the *spenders* (II) have highest use levels in all periods. The *cool* and the *warm* (III and IV) have similar energy use levels, below the

Table 2
The average use of natural gas of the five clusters (in m^3).

Cluster	Period 1	Period 2	Period 3	Total
I. Conservers ($n = 18$)	864	696	437	1998
	(174)	(165)	(212)	(484)
II. Spenders ($n = 22$)	1151	934	670	2755
	(191)	(146)	(170)	(436)
III. Cool ($n = 23$)	931	803	506	2238
	(172)	(180)	(166)	(468)
IV. Warm ($n = 45$)	927	768	512	2207
	(167)	(205)	(160)	(423)
V. Average ($n = 37$)	979	820	605	2404
	(186)	(189)	(298)	(630)
Total ($n = 145$)	963	804	555	2314
Explained variance (in percentages)	15.5	11.8	12.9	17.0
$F(4, 140)$	6.43	4.67	5.17	7.19
$p <$	0.000	0.001	0.001	0.000

Note: The numbers within brackets are the standard deviations of the means.

average level (V). Note that the standard deviations in Period 3 (summer period) are relatively high for the *conservers, spenders*, and *average*. This means that individual differences are higher in the summer periods.

The differences between the *conservers* (I) and *spenders* (II) are largest. In table 3 these differences are shown, along with the proportions of the energy use of *conservers / spenders*. The absolute differences between *conservers* and *spenders* are similar in the three periods, except that in Period 1 the difference is somewhat larger. Relating these differences to the energy use of both clusters, we observe an increasing relative difference. In Period 3, the difference constitutes 53.3 percent of the energy use of the *conservers* and 34.8 percent of the use of the *spenders*. The average difference between both clusters over the year is 31.5 percent of the average energy use. From table 3, we may conclude that on average the *spender's* household uses 33.2 to 53.3 percent more energy than the average *conserver's* household. In other words, changing from an average *spender* to an average *conserver* behavioral pattern means a decrease of natural gas use of 27.5 percent over the total year, and of 34.8 percent in Period 3 (April–November). The variance in energy use if quite large, in fact, as large as 2166 m^3, a difference between 1297 and 3463 m^3 of annual gas use.

The question arises whether these differences in use can be completely attributed to the differences in the behavioral patterns. The possibility still exists that the differences in use can be attributed to home characteristics and special circumstances. The behavioral patterns (clusters) in that case are not voluntary behaviors but depend on home characteristics and special circumstances.

Table 3
The average differences in the use of natural gas between *conservers* and *spenders* (in m^3).

	Period 1	Period 2	Period 3	Total
Difference between I and II	287	238	233	757
As a percentage of *conservers'* use	33.2	34.2	53.3	37.9
As a percentage of *spenders'* use	24.9	25.5	34.8	27.5

Behavioral patterns and home characteristics

It is necessary to check the home characteristics of the five clusters (behavioral patterns). If significant differences in the home characteristics between the clusters are obtained, a rival hypothesis for explaining the energy use differences is provided. If the home characteristics explain the differences in energy use, we should reject an explanation by behavioral patterns.

In our sample, 68 percent of the houses are fully attached (two neighbors), while 32 percent are semi-detached. The largest difference is between the clusters III and IV; 79 percent of the *warm* and 57 percent of the *cool* live in fully attached houses. This difference is, however, not significant but only indicative. It may partly explain the difference in temperature. A higher temperature of the *warm* may more easily be maintained in a fully attached house.

No significant differences between the clusters are obtained for wind orientation of the home and energy use of the neighbors. A significant difference ($p < 0.05$) between the clusters II and III is obtained for home insulation: only 36 percent of the *spenders* live in a home with superior insulation, while 65 percent of the *cool* live in such a house. The problems of the *cool* are obviously not poor home insulation but probably too much ventilation.

In a more sophisticated way, the partial effect of the behavioral patterns on energy use can be studied. Using multiple regression analyses, both home characteristics and behavioral patterns were used to explain energy use for the three periods and for the total year. The unstandardized regression weights of the dummied behavioral patterns were computed and are, in fact, the differences in absolute quantities (in m^3) between the behavioral patterns and the pattern of the average cluster.

The differences in column 1 of table 4 are the differences with cluster V (*average*) computed from the last column of table 2. In column 2, the differences are given as derived from multiple regression after partialling out home characteristics and special circumstances. In column 4, the differences with cluster V are given after partialling out home characteristics special circumstances, and attitudes.

Partialling out the effects of home characteristics and special circumstances does not lead to any substantial changes in the energy usage differences between the clusters and the *average* cluster, except for the

Table 4
Differences of energy use between the clusters in the total period as compared with the *average* cluster.

Cluster	(1)	(2)	(3)	(4)
I. Conservers	−407	−347	−365	−296
II. Spenders	350	336	381	377
III. Cool	−167	−171	−179	−181
IV. Warm	−197	−194	−181	−232

Note: (1) Differences computed from the original data; see table 2.
(2) Differences computed from multiple regression partialling out home characteristics.
(3) Differences computed from multiple regression partialling out home characteristics and special circumstances.
(4) Differences computed from multiple regression partialling out home characteristics, special circumstances, and attitudes.

conservers. Partialling out home characteristics in column 2 reduces the difference between *conservers* and *average*, while addition of special circumstances in column 3 increases the difference slightly. Partialling out attitudes in column 4 has no effects on the *spenders* and *cool* but a strong effect on the *conservers* and *warm*. Partialling out attitudes reduces the energy saving of the *conservers* but increases the energy saving of the *warm*. This means that attitudes are relevant for the *conservers* and *warm*, but irrelevant for the *spenders* and *cool* (table 4). The energy use of the *conservers* is largely governed by their price and energy concern, while the comfort attitude of the *warm* has a contrary effect on their energy use. Partialling out attitudes means that the *conservers* and *warm* become similar.

Going from column 4 to column 3 for *conservers* and *warm*, we observe that the difference increases substantially. It may be concluded that a large proportion of the difference between both may be attributed to sociodemographics and attitudes. Campaigns for changing attitudes will probably have effects on these segments, but not on the *spenders* and the *cool*. Changing the attitudes of the *warm* in the desired direction will have an energy conserving effect. *Conservers* already possess the desired attitudes. Changing their attitudes in an undesired direction will have negative effects on energy conservation.

The differences in energy use, reported in table 4, show the same pattern as in table 2. The energy use of the *conservers* is as much below average as the *spenders* are above. The *cool* and the *warm* clusters have about the same level below the *average* level.

The *cool* deviate in some ways from the other clusters. A greater proportion of the *cool* cluster live in superior insulated houses, although this is only indicatively significant ($p < 0.15$) for the fully attached houses. This finding relates to the significant difference between the *spenders* and *cool*. In a superior insulated, fully attached house, a *cool* behavioral pattern dominates (low temperature, high ventilation).

Do the *cool* use less energy than the other clusters? The answer is yes *and* no. In a standard insulated house, the *cool* use less energy than the other clusters: 2003 as compared with 2397 m^3 for the fully attached houses, and 2433 as compared with 2712 m^3 for the semi-detached houses, in the total period (table 5). In a superior insulated house, however, the *cool* use more or the same amount of energy than the other clusters: 2057 as compared with 1987 m^3 for the fully attached houses, and 2535 as compared with 2439 m^3 for the semi-detached houses in the total period. The differences in the summer period (Period 3) are even more striking. We may conclude that home insulation has no effect on the energy use of the *cool*, while it has a significant effect ($p < 0.001$) on the other segments (behavioral patterns). The *cool* have a somewhat lower energy use in standard insulated homes. A very interesting question for further research is why the *cool* are different in this respect and do not benefit from home insulation. The *cool* maintain a low temperature, while home insulation is more effective for residents with a high home temperature. The *cool* have a high level of ventilation, and by opening windows and doors, they may counteract the insulation effects in such a way that they even use more energy in a superior insulated home. Their need for fresh air offsets the energy conservation

Table 5
Average use of energy in the total period and Period 3 of the *cool* vs. other clusters, for the house characteristics attachment and insulation (in m^3).

Cluster	Fully attached		Semi-detached		Total
	Standard insulation	Superior insulation	Standard insulation	Superior insulation	
Total period					
Cool (III)	2003	2057	2433	2535	2237
Other	2397	1987	2712	2439	2329
Period 3					
Cool (III)	419	472	544	590	506
Other	572	463	706	600	564

effects of home insulation. In Verhallen and Van Raaij (1981: fig. B), is shown that ventilation offsets part of the energy-saving effects of home insulation.

If 18 percent of energy saving is technically possible in the superior insulated homes as compared with the standard insulated homes, the actual energy saving is only 11.5 percent, due to increased ventilation. For the *cool*, the offsetting effects of increased ventilation is even stronger than the energy-saving effect of home insulation.

Socio-demographic and attitudinal differences between the clusters (behavioral patterns)

Having characterized five behavioral patterns (clusters or segments) with regard to energy use and house characteristics, one has to check the sociodemographic and attitudinal differences between the clusters. No significant differences are obtained for income and occupational level of the husband. The age of the *warm* residents is somewhat higher than the age of the members of the other clusters. The educational level of the *conservers* is higher than the spenders ($\chi^2 = 7.2$; $df = 2$, $p < 0.05$). The family size of the *conservers* (2.8) is smaller than that of the other groups. This means that the *conservers* have fewer children and are probably more absent from home.

In table 6, family size and the attitudinal differences between the clusters are shown. The *conservers* have a somewhat higher degree of energy concern. The *warm* emphasize comfort significantly more than the *conservers* ($p < 0.01$). The differences in price concern are not significant.

Table 6
Behavioral patterns (five clusters) and family size, attitudinal components.

	I Conservers	II Spenders	III Cool	IV Warm	V Average
Family size	2.82	3.41	3.13	3.39	3.05
	(1.07)	(1.14)	(0.97)	(1.04)	(1.00)
Energy concern	0.21	0.09	−0.21	−0.04	0.02
	(1.00)	(1.07)	(0.73)	(0.90)	(0.78)
Comfort	−0.34	−0.06	−0.23	0.20	0.09
	(0.60)	(0.77)	(0.51)	(0.72)	(0.85)
Price concern	−0.11	−0.04	0.04	−0.02	0.07
	(0.98)	(0.90)	(0.71)	(0.63)	(0.73)

Note: The numbers in parentheses are the standard deviations of the means.

We may conclude that comfort is the most important attitudinal component. The *conservers* and the *cool* do not stress comfort but for the *warm* comfort should be de-emphasized in an energy-conservation campaign in order to reduce their energy use.

Prediction of cluster membership

With a five-group discriminant analysis an effort is made to predict cluster membership based on socio-demographic, attitudinal variables, and special circumstances. With help of these variables, 64 percent of the 145 respondents can be correctly classified. Based on chance, this would be about 20 percent. In table 7 the classification results are shown. Fifteen of the 18 *conservers* (0.83) and 17 of the 23 *cool* (0.74) can be correctly predicted, better than the total sample: 93 of the 145 households of the total sample are correctly predicted, i.e. 64 percent. The prediction results of the *warm* (0.56) and the *average* (0.60) are below the prediction results of the total sample. Most misclassifications occur between the *warm* and the *average*; the *warm* and the *average* are the most similar groups and also the largest groups. No misclassifications occur between the *conservers* and the *spenders*. These groups are obviously the most dissimilar.

One discriminant dimension proved to be significant in discriminating between the five groups (canonical correlation is 0.67; $p < 0.05$). The graphic results are shown in fig. 2. The *spenders* and the *conservers*

Table 7
Classification of the respondents in five clusters, 5-group discriminant analysis.

Actual (n = 145)	Predicted				
	I Conservers	II Spenders	III Cool	IV Warm	V Average
I. (n = 18)	*15* (0.83)	0 (0.00)	1 (0.06)	1 (0.06)	1 (0.06)
II. (n = 22)	0 (0.00)	*14* (0.64)	4 (0.18)	2 (0.09)	2 (0.09)
III. (n = 23)	1 (0.04)	1 (0.04)	*17* (0.74)	1 (0.04)	3 (0.13)
IV. (n = 45)	3 (0.07)	6 (0.13)	3 (0.07)	*25* (0.56)	8 (0.18)
V. (n = 37)	4 (0.11)	4 (0.11)	1 (0.03)	6 (0.16)	*22* (0.60)

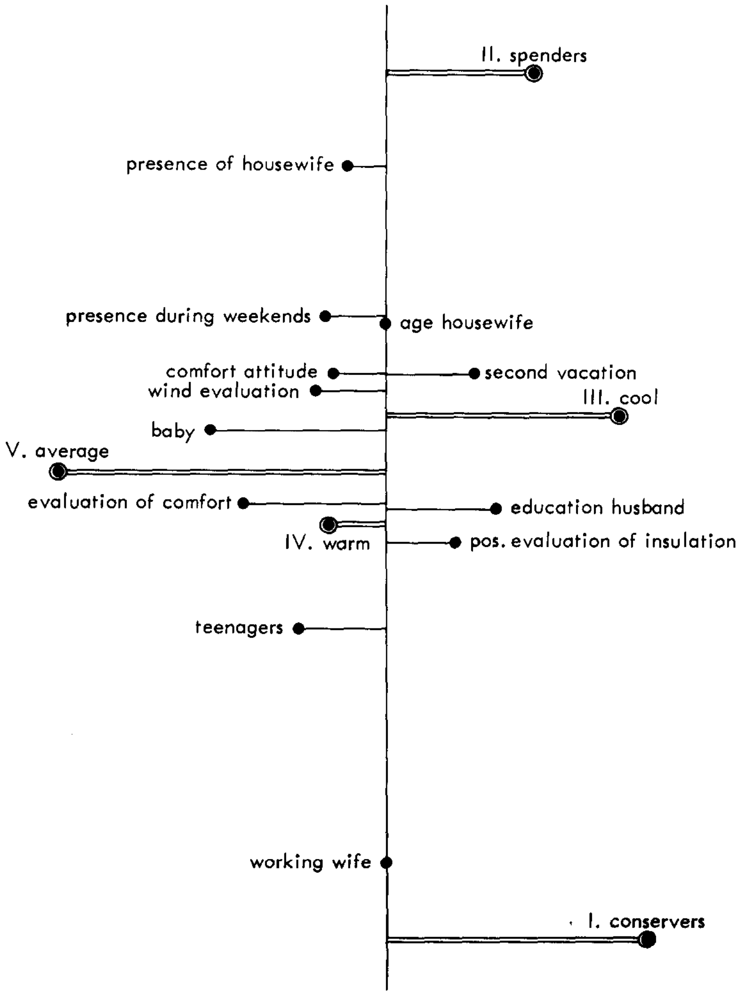

Fig. 2. Graphic display of discriminant analysis results (5 groups).

occupy extreme positions on this dimension, while the other clusters are close together in the middle. This dimension leads to a number of interpretations and research hypotheses. First, the *conservers* are characterized by more working wives and the presence of teenagers, while the *spenders* are older and more at home. Second, the *warm* segment has a positive evaluation of home insulation and comfort. Third, the *cool* segment more often has a second vacation in the winter (which saves energy) and a higher educated husband.

A general finding is that high levels of energy use are a characteristic of some stages in the family life-cycle. The presence of a baby and young children requires a higher temperature, and this is also the case for older people. Low levels of energy use are characteristic for households with a working wife and/or teenagers.

Energy use seems to fluctuate with the stages of the family life-cycle. When both partners work, energy use is relatively low. With the arrival of the first child energy use tends to rise. With older children and the wife probably working again, a lower energy use results. Older couples are more often at home and have, consequently, a higher use of energy; their physiological need for higher temperatures also contributes to a higher usage level. Fritsche (1981) obtained a similar pattern. Specifically he found that energy usage increases with each stage in the life-cycle through the child-rearing years, thereafter declining (but at a slower rate than it grew) as family members leave home.

Discussion and recommendations for energy conservation programs

In this analysis, energy behavior is the focal point. Two contingencies of energy use in the home are heat production (*kernel*) and the heat preservation (*shell*). This relates to two types of behavior: "Thermostat and temperature behavior" and "ventilation behavior". Five distinct behavioral patterns of energy use are obtained, the *conservers, spenders, cool, warm*, and *average* (fig. 1).

The energy use of these five groups differs considerably. The average difference between *conservers* and *spenders* is 31 percent, while the other groups are between these extreme usage levels (tables 2 and 3). The five groups do not differ with regard to their home characteristics. Partialling out home characteristics and special circumstances does not lead to substantial usage differences, however partialling out attitudes reduces the energy use differences between the *conservers* and the *warm*. Comfort is the most important attitudinal dimension. Price concern is less relevant in this study, although price will probably become more relevant with rising energy prices.

The five clusters of behavioral patterns obtained constitute a base for segmenting the population. Different energy conservation strategies/programs may be appropriate for each of the distinct segments.

The *conservers* (I) maintain a low temperature and a low level of ventilation in their homes. They are characterized by a higher level of education, a smaller family size, and more often the wife is also working outside the home, as compared with the other segments. Their energy use is lower than all other segments; and large individual differences are observed in the summer period. Although there are some effects of their house characteristics (Table 4), a major explaining factor is their positive attitude toward energy conservation: a high level of energy concern and a low level of comfort concern. In this sample, the *conserver* segment is rather small. This segment shows the desired behavior and energy use. In an energy conservation campaign the goal should be to reinforce this type of energy behavior.

The *spenders* (II) maintain a high temperature and a high level of ventilation in their homes. They have a lower educational level and are more often at home. Their energy use is higher than all other segments and we observe large individual differences in the summer period. The proportion of superior insulated homes is rather low for this segment (36 percent). Attitudes do not explain their high levels of energy use. Attitudinal campaigns will probably not be very successful for this segment. Behavioral recommendations to lower their thermostat settings, to ventilate less, and to insulate their homes may be the best campaign strategy. Changing the energy behavior of the *spenders* will remain a difficult task. Home insulation might be more feasible.

The *cool* segment (III) maintains a low temperature but a high level of ventilation. Their energy use is intermediate. The proportion of superior insulated homes is high for this segment (65 percent). Attitudes do not explain their energy use. The *cool* segment uses less energy in a standard-insulated home than in a superior insulated home (table 5), as compared between the two types of home insulation and as compared with the other segments. Home insulation has either no effect or an adverse effect on this segment. The high level of ventilation of the *cool* counteracts the positive effects of home insulation. In an energy-conservation campaign the adverse effects of high ventilation levels should be stressed. Reduction of the level of ventilation or heat recovery in their ventilation systems may help this segment.

The *warm* segment (IV) maintains a high temperature and a low level of ventilation. Their energy use is intermediate. This segment is generally older and they emphasize comfort more than the other segments. It is well-known (Newman and Day 1975) that older people prefer a higher temperature. Energy conservation campaigns should de-emphasize comfort or should advocate that good clothing instead of high temperature may not reduce comfort. In this sample, the *warm* segment is larger than all other segments.

The *average* segment (V) is by definition not deviating in its characteristics. Again we observe large individual differences in the summer period. In energy-conservation campaigns, an attempt should be made to move this segment in the direction of the *conservers*. The *average* segment requires no specific treatment but could benefit from information about lower temperatures and less ventilation.

This study shows that a segmentation approach based on behavioral patterns provides better insights in the interaction of energy behavior, attitudes, house characteristics, and sociodemographics. An attitudinal campaign should be directed to the *conservers* to reinforce their behavior, to the *warm* to de-emphasize comfort, and to the *average*. Home improvement and retrofitting is beneficial for the *spenders* but, in some ways, detrimental for the *cool*.

In general, information campaigns should not only recommend lower thermostat settings and alert turning down of the thermostat, but should mention that closing doors and windows and a clever use of ventilation systems also saves energy.

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