Modelling human behaviour for policy decisions

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1 SYNOPSIS

An approach for modelling human behaviour in practice, to be used by energy distribution companies to estimate the results of demand side management activities.

2 ABSTRACT

Knowledge about the human behaviour is essential for successful energy savings policy. Proper monitoring and evaluation of policy measures enables government and distribution companies to promote energy efficiency in a more cost optimal way. ECN has developed a model for customer behaviour as a tool for determining the most cost optimal way of energy savings, both for natural gas and electricity. This tool estimates customer behaviour with a relatively limited amount of data. However, it gives the user possibilities to use market experiences and new data in future model runs. This paper gives an insight to the model structure and shows the thoughts of ECN of how such a model should look like.

The market penetration of energy efficient appliances depends on investment behaviour. The model distinguishes three components;

- the lifetime of appliances to be replaced
- the attitude of the market towards new appliances
- the economic attractiveness of the saving option.

The model identifies the bounding component of these three and thus helps to identify the most effective policy measure.

User behaviour (the way and the frequency appliances are used) is more difficult to influence. Investment behaviour is usually related to one decision (the moment of purchase), but user behaviour determines energy consumption during the entire lifetime of the appliance. Learning from previous campaigns is very important for developing a cost optimal campaign for information and re-information.

Model outcomes for expected results of DSM activities have been compared with expectations of experts from a distribution company. The comparison indicates that with a relatively limited amount of input global results can be produced quickly. Furthermore, this model establishes a basis for a structured and consequent way of calculating DSM results.

3 INTRODUCTION

National energy saving policy in the Netherlands exists at several levels. The national government as well as energy distribution companies perform activities to stimulate energy savings. Examples of activities are environmental action plans and Saving Agreements with Dutch industry. From the government several subsidies are available for energy efficient appliances, although the amount has been decreased substantially. Saving policy is being carried out more and more by distribution companies.

Five years ago these companies started to develop their own Environmental Action Plans (EAP). To cover for the expenses of these activities a levy has been introduced for both electricity and natural gas. In the beginning these plans were strongly technique oriented and mainly consisted of giving subsidy on energy efficient appliances. Until now these plans are reported as a great success, but more and more the awareness is growing that stimulating energy efficiency is more than giving subsidies on energy efficient appliances. Understanding customer behaviour becomes more important. That is why distribution companies are increasing their marketing activities.

In the beginning the main purpose of the market research activities of distribution companies was to account for realized savings. However the gathered information can also be used for estimating future response and impacts of demand side management plans. Therefore ECN is momentarily developing a model to help distribution companies to estimate future results of DSM programmes. By means of this model distribution companies can decide which programmes are most cost effective and how these programmes should be designed. This model is described in Beeldman (1994 and 1995).

An exact decription of human behaviour is difficult and needs a lot of input variables. In practice, and certainly the practice of distribution companies, little is known about the customers. Therefore the model, that ECN is developing, is not meant to give a sound theoretical description of human behaviour, but it is meant as a tool for distribution companies to make estimates of human behaviour with a relatively limited amount of information.

4 HUMAN BEHAVIOUR

There are different kinds of human behaviour. With respect to energy use this behaviour can be divided into two types. The first type is investment behaviour, which is related to the process of buying new appliances, equipment, goods etc. Important questions to be answered are which factors influence the buying of a product and why customers buy specific products.

The second type of behaviour is user behaviour, which is related to the actual use of products after the moment they are bought. It is concerned with questions of how often a product is used and in what way it is used. Both types of behaviour are illustrated by the example of energy efficient lighting.

4.1 Investment behaviour

Investment behaviour concerning energy efficient lighting deals with questions of why people do (or don't) buy energy efficient lamps. Possible answers to the question of why people buy energy efficient lamps are:
- Because it raises cost advantages
- It is good for the environment.
- You get a subsidy, so it must be good.
- Today I get subsidy, maybe next year no more.
- I heard it on TV.
- My neighbour has some.

Reasons why people don't buy energy efficient lamps are:
- It is too expensive.
- People don't like the light.
- It does not fit into the socket.
- People don't know they exist.
- People don't experience the financial advantage.
- People have halogen lamps, and they think it is the same.
- People still have a large stock of normal lamps.

Roughly, all these answers can be grouped in three categories:
- financial reasons;
- informational aspects;
- technical limitations.

Modelling penetration of energy efficient appliances means that you need to take into account these three categories. The model ECN is developing is able to do this. For the various reasons the model often uses the "normal division curve" (Moivre) or derived curves. By defining average and steepness specific behaviour of certain user groups can be simulated. The model first determines the penetration according to the separate categories. Consequently, the most limitative category determines actual penetration in the future.

4.1.1 Financial aspects

The financial aspects are simulated by an S-curve. This curve shows the market penetration of a saving option as a function of the economic attractiveness. This economic attractiveness is measured by the internal rate of return. Figure 1 gives an example of two S-curves.

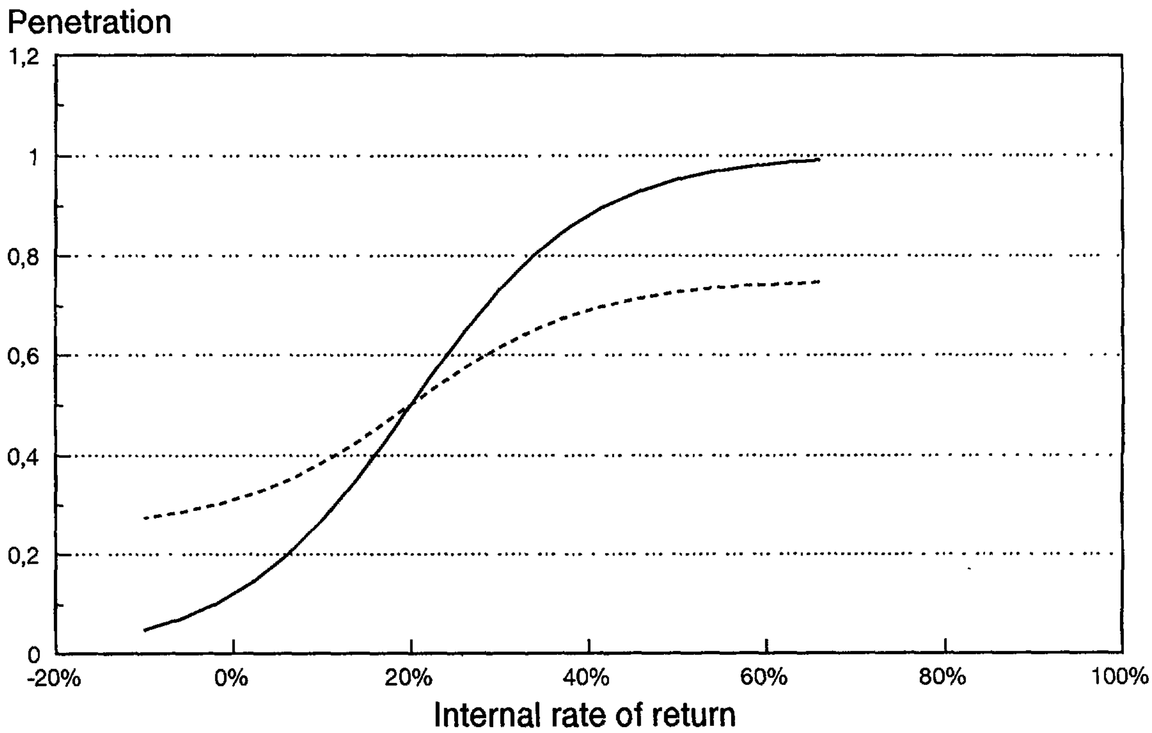


Figure 1 Relation economic attractiveness and market penetration

The ideas behind the S curve are the following. First it is important to realise that the calculated Internal Rate of Return is an average value for a certain customer group. Therefore it would be wrong just to take one value and modelling 100% penetration when IRR is higher than this value and assuming 0% penetration when IRR is below this value. The scale must be sliding. Furthermore different members of a customer group all have their own opinions on how attractive an option must be before buying, but in general an option that is more economically attractive (ceteris paribus) will show higher penetration. The IRR is just meant as a tool for determining economic attractiveness, not to simulate the exact process of investment decision of all customers. To account for all this the S curve is used. Even with low economic attractiveness some penetration will occur due to the fact that certain members of the target group are more eager to invest, because of other reasons (environment, image, curiosity). On the other hand when IRR is above average, some members of the group will still not invest. The shape of the curve (steep or less steep) enables the user of the model to simulate a group with relatively small differences (steep curve, all people invest with almost the same attractiveness) or a group with larger differences (much deviation in user specific IRR demands).

4.1.2 Informational aspects

Informational aspects are often time dependent. It takes time for a new (energy efficient) product to become known and accepted in the market. This experience and acceptance often depends on the market share of a product. Therefore the penetration in the next year based on acceptance is a function of actual penetration. Figure 2 represents this dependency.

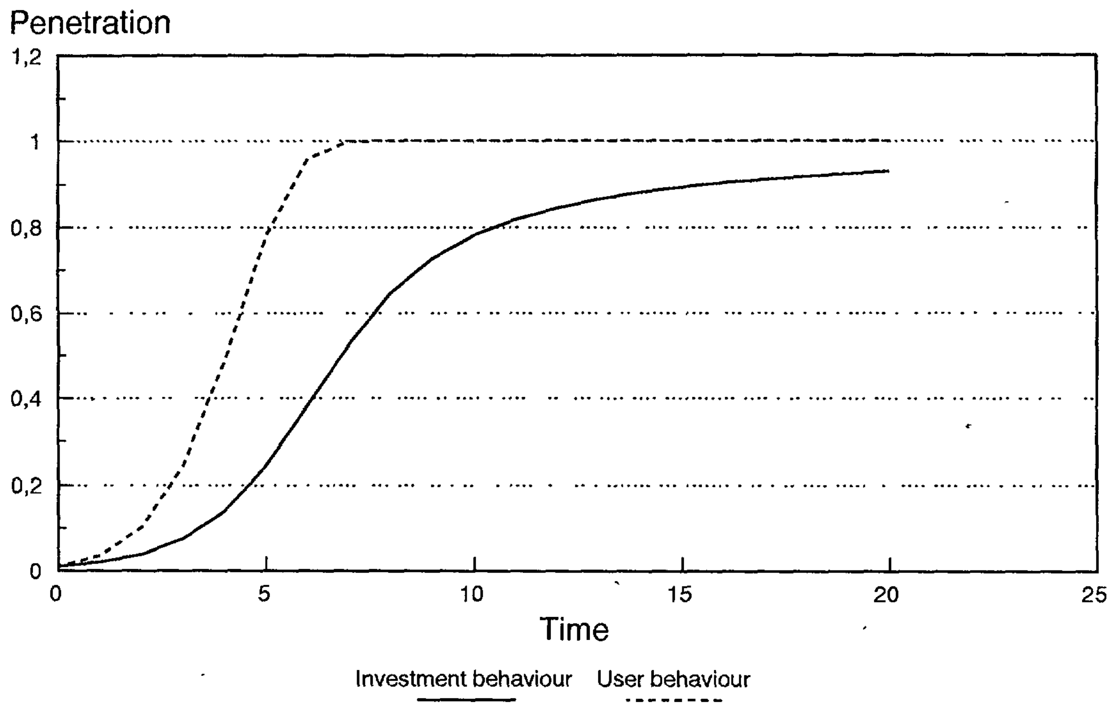


Figure 2 Market penetration as a function of time

The shape of the curve looks the same as figure 1, but in this case the x-axis represents time. The steepness of the curve can differ for different techniques. The time period is a very uncertain factor. Will this be 5, 10 or 20 years? In this case penetration of comparable products can be helpful for determining the time period.

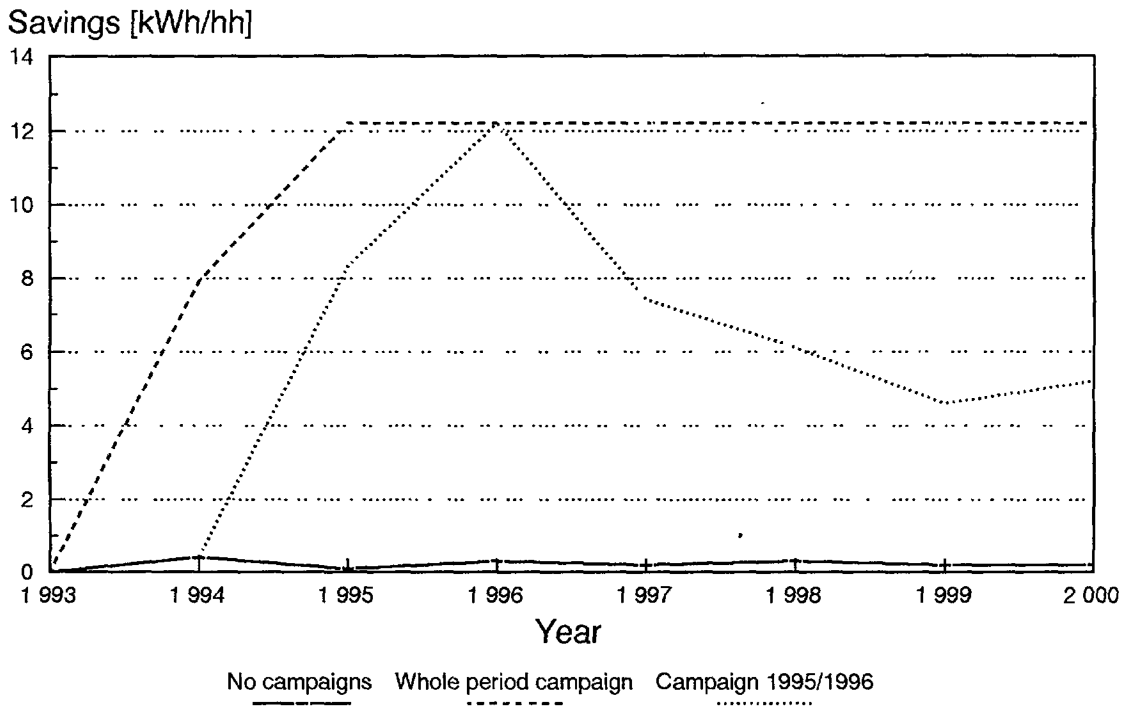
4.1.3 Technical aspects

The technical aspects can be divided in two categories. The first category is purely technical. It determines whether a product is suited for the function. For energy efficient lighting it is known that a part of the sockets is not suited for these lamps. Accounting for these limitations the total potential of energy efficient lamps can be reduced by a certain percentage. The second category is a combination of technique and user aspects. Most important example of this category is the lifetime of appliances. It is very important to understand replacement buying, both for modelling as well for policy. First it gives insight in how fast substantial market penetration can be realised. Second, identifying the moment of replacement makes a good opportunity to influence replacement buying. Modelling lifetime of appliances is done by keeping up annual sales. After the lifetime (fixed or with a certain distribution over time) products need to be replaced, either by energy efficient lighting again, or by standard lighting again. Modelling lifetime of appliances gives also insight in what part of a specific subsidy budget will eventually be spent on replacement buying.

4.2 User behaviour

Investment behaviour can be influenced, monitored and measured but user behaviour is more difficult to influence, monitor and measure. While investment behaviour is usually related to one moment (the moment of purchase), the user behaviour is important for energy consumption during the entire lifetime of the appliance. Proper monitoring and modelling of user behaviour can help to identify the options which are most likely to succeed for influencing user behaviour and will have the largest effects on energy savings. More energy efficient behaviour has financial advantages while no explicit investment is needed. It is difficult for people to maintain a change in behaviour, when they are not permanently confronted with the need or when financial advantages are small. One has to maintain this energy efficient behaviour during the entire lifetime, but the earnings per time are usually less than one Dutch guilder. Therefore energy efficient behaviour has probably more to do with attitude than with financial advantages. That is why it is more important to change people's attitude than to stress financial advantages. Also people tend to forget energy efficient behaviour if they are not re-informed periodically. The ECN model is meant to be implemented by distribution companies to enable them to use experiences from the past for the forecasting of new information campaigns. This also helps to assess the right time period for re-information of customers in order to avoid customers forgetting energy efficient behaviour. The modelling of this customer behaviour is done by making the parameters of the S-curve dependent of the fact whether an information campaign or other energy saving stimulation programme is planned. The values for parameters and how they are expected to change must be deducted from the results of previous campaigns.

The results for actual penetration of an improvement of user behaviour, and more precisely the effects on average electricity consumption, can look like this:



The figure shows that user behaviour is different from investment behaviour. Once an investment has been done, the saving is made each year. However, for user behaviour, the moment the energy efficient behaviour is forgotten, the saving disappears immediately. That is why savings decrease, when an information campaign is only temporary. Gaining insight in the 'curve of forgetting' (Ebbinghaus, 1885) is very important for determining the length and frequency of information campaigns. In principle, it would be ideal if policy makers/ distribution companies could be succesful to make energy efficient behaviour habitual behaviour. This reduces the chance of forgetting. However, changing peoples attitude is one of the most difficult things to do.

5 TRANSLATION OF BEHAVIOUR INTO MODELLING OF ENERGY SAVINGS

The different kinds of behaviour need to be translated into effects on energy savings. The ECN model distinguishes two components in electricity use. The first component is the power demand of an electric appliance and the second component is the time of use during a year. Modelling investment behaviour is usually related to the requested power (and sometimes the time of use); while user behaviour relates to the time of use. Before going into more detail, first some aspects of energy efficient lighting are given.

5.1 Energy efficient lighting

Up to now energy efficient lighting is one of the most successful elements of DSM programmes in the Netherlands. In the period 1991-1993 over 5 million of energy efficient lamps were sold. The overall target for the period 1991-

1995 is 15 million of sold lamps. The number of lamps per household increased from 1 to 1.8. Some figures (EnergieNed, 1994):

Yearly use for lighting per household	:	450 kWh
Number of lamps per household	:	23
Savings energy efficient lighting	:	80%
Costs	:	*f* 35 per lamp
Pay Back Period	:	5-6 years

For energy efficient lighting the savings are not expressed in kWh but just as a percentage of requested power (for instance 80%). The model determines, dependent of the place in the house how many kWh's are saved.

Table 1 Reducing electricity consumption for lighting

		living room	garden
Previous requested power :	75 W		
Time of use (hours):		1000	300
Electricity cons. (kWh) :		75	22,5
Reduction eff. lighting :	80%		
Reduction :		60	18
Reduction good housekeeping :	20%		
Reduction :		15	4,5
Combined effects :		63[1]	18,9

1 = former consumption - (new requested power)*(new time of use) = 75-(.2*750)*(.8*1000)

This example shows that this modelling structure enables calculation of the effects of saving options, dependent of the place in the house, with a relatively limited input. The size of these effects also determines the financial attractiveness and, with this, the penetration. This method of calculation also takes into account that the combined effects of energy efficient lighting and good housekeeping are lower than the sum of the separate effects.

This division of electricity consumption in two components not only separates the effects of investment behaviour and user behaviour, but it also enables modelling the combined effects of influencing investment and user behaviour the same time.

6 COMPARISON OF MODEL OUTPUT AND EXPERTS OPINIONS

Although the model has not been used by a distribution company yet, already some model runs have been made to test the outcomes. These outcomes have not been compared with actual results of demand side mangement programmes but with the expextations of distribution companies for these programmes. Till now, expectations of distribution companies concerning demand side management programmes are mainly based on experts opinions. The table below shows the results for expected sales figures from 1994 to the year 2000. (EnergieNed 1994, Energiebedrijf Amsterdam 1994).

Table 2 Model results and experts opinions

Programme		Number of units sold			CO_2-reduction	
		Dist.Comp	ECN		DC	ECN
Lighting	$1{,}1*10^6$	$1{,}6*10^6$	11,7	13,9		
Refrigerator		74.000	66.000		4,0	4,0
Freezer		12.000	16.000		0,8	1,1
Washing machine		54.000	20.000		1,0	0,3
Dishwasher		8.300	6.400		0,2	0,2
Naturals gas dryer		8.200	12.500		1,1	1,6
Good housekeeping		48.000	25.000		1,1	0,7
Total					*19,9*	*21,7*

The input for these runs (concerning specific characteristics of the customers) has been very limited. The results show that with a relatively limited amount of input the results come close to experts opinions. However, the model is a basis for developing a structured and consequent marketing information system in which evaluation results of actions held can be used for more precise expectations for future results.

6 CONCLUSIONS

Human behaviour is determined by a large number of variables. For distribution companies, the impacts of most of these variables on the energy consumption are usually unknown. ECN has developed a model for determining the cost effectiveness of demand side management programmes, taking into account this limited amount of information and the uncertainties. It leaves the user of the model a relatively large amount of freedom. However, when data about markets become available, they can be used as input for the model. To make a distinction between the buying and the using of apparatus, the behaviour is separated into investment behaviour and user behaviour.
The model has not been used in practice yet. However, results have been compared with opinions of experts of distribution companies. The comparison indicates that with a relatively limited amount of input global results can be produced quickly. Furthermore, this model establishes a basis for a structured and consequent way of calculating DSM results.

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