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New experimental electricity tariff systems for household end Use

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Abstract

A significant tool in Demand Side Management is the structure of tariffs. Price incentives can be directed at different parts of the efficiency-concept: efficiency in capacity planning, efficiency in total electricity consumption, efficiency in total fossil fuel use, efficiency in total energy demand. The tariff system, which is currently used in the Netherlands, does not give proper price incentives for end-user efficiency. In particular total electricity demand is rather stimulated, which is somewhat dampened by the introduction of the eco-tax.

In the Netherlands field experiments with tariff systems directed at influencing household electricity demand were carried out by five utilities. In the experiments differentiated tariff-variants were introduced, replacing the old tariff-system. The experiments included voluntary price differentiation, which introduced a free-rider problem in combination with the chosen price levels. Furthermore remote-monitoring, feedback, special peak-pricing etc. were implemented in the experiments. Some interesting options, in particular those influencing total demand, were not implemented by utilities. The reasons for it should be categorized as 'strategic' and part of the utilities' policy.

1. Reasons for tariff experimentation

In 1989 the electricity sector in the Netherlands was reorganized. Part of it was the separation by law of production companies and distribution utilities. A series of changes in purchase-rates from producers in which flexibility and capacity-cost became more important urged utilities to pay more attention to load patterns.
In a second development, utilities became aware of the significant environmental impact of their activities. In the Netherlands the practise in the field of environmental policy is partly based on voluntary agreements with relevant actors in the field. The utilities signed such agreements (usually referred to as a 'covenants') and they issued Environmental Action Plans (MAPs) for the entire sector as well as for each utility. In these plans targets for carbondioxide-reduction were set and a range of energy management (in particular co-generation) and demand side management activities were formulated (Slingerland, 1997). The instruments used for influencing household energy consumption, which are mainly directed at energy conservation, are financed with the so called 'MAP-levy', a small charge on the energy bill.

1.1. Five experiments

Both developments, the growing interest for avoiding high purchase costs and the introduction of Environmental Action Plans, were good reasons to start thinking about influencing demand and therefore about the customers' tariffs as well. The organization of distributors (EnergieNed) founded a commission that served as a platform group for experiments with tariff systems for household customers. In that group several deputies of utilities willing to experiment with their tariff-systems, exchanged information and discussed their plans. Several ideas for experiments were launched, but many ideas and even concrete project were never realized. The support on the general level remained forthcoming, but finally five experiments were actually conducted.

1.2 DSM by tariffs

In principle all activities conducted by utilities directed at influencing the behaviour of electricity consumers, are Demand Sde Management (DSM). In the past most activities were merely directed at influencing load patterns, not only in the Netherlands but everywhere in Europe. For decades most utilities in the Netherlands applied systems with a differentiated time-of-use (TOU) tariff variant. TOU tariffs existed in many countries and in the US several experiments were held with price incentives at varying times of the day (Faruqui and Malko, 1983; Aigner, 1984). In Europe TOU-tariffs were the major part of DSM activities and nowadays an analysis of all European DSM activities shows that TOU-tariffs and information and persuasion campaigns are the most significant categories: „until recently, most European DSM-programs have been load-management programs rather than energy efficiency programs“ (Vine, 1995). The start of new tariff experiments, combined with the need for improvements in energy efficiency would logically implicate that efforts should be made to include energy saving in the goals of tariff experiments.

1.3 Definitions of tariff-systems

In this paper we will define a tariff-system as a complete set of conditions linked to the settlement of accounts between the utility and the customer. For every category of customers a utility can have only one tariff system, so it is a characteristic of the utility on a specific market. A tariff-system may consist of different tariff-variants, which can be either attributed to a customer on a voluntary or mandatory basis. The tariff-variant is a consumer feature, as each customer can have only one variant. A tariff-variant on its turn may consist of one or more different tariffs, which are the actual price levels or kWh-rates linked to conditions (e.g time-of-use, annual consumption etc.).

1.4. Current tariffs-systems: TOU-reduced rates

Most Dutch utilities apply similar systems for household customers. There are only small price-level differences. Basically there is one system, containing two optional variants for households, which contain the components shown in figure 1.

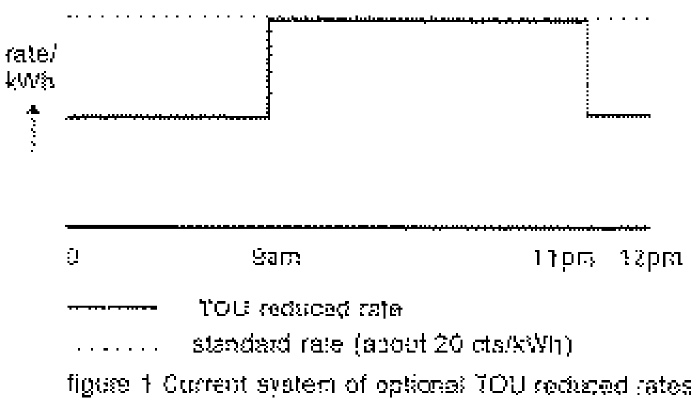

figure 1 Current system of optional TOU reduced rates

The first variant the customer can choose is the simple ‘single’ standard rate variant with only one uniform price level plus an annual standard charge. At first sight the second option looks like a TOU-variant with two price levels and an extra annual standard charge. However, because the low price level is only a reduction (at specified time of day) on the single ‘normal’ uniform price level, it is fundamentally a tariff variant including a price reduction as the higher level is exactly the same as in the single uniform tariff variant.

The main incentive in this current tariff-system appears to be a stimulation of higher consumption levels during nights and weekends. Average household electricity consumption in the Netherlands in 1995 was 3190 kWh. The households with the single uniform tariff-variant (58%) averagely consumed 2780 kWh. The other 42% with the

TOU-reduction variant averagely consumed 3925 kWh (Weegink, 1996 p.21). This 41% higher consumption level is mainly due to the fact that the reduced rate stimulates the possession of specific equipment, in particular electric water heaters. This equipment is also partly used during day time so effectively it even results in an increase of day-time loads as well, so eventual load shifts from day to night are overshadowed by increased loads caused by extra equipment.

As a result in practise the system has hardly incentives for changing load patterns as far as high load reduction (mainly day-time on working days) is concerned. It only contains an incentive for increased consumption during reduced rate periods. The tariff-system is working like a digressive price system (figure 2). Average and marginal kWh-prices are decreasing with higher consumption.

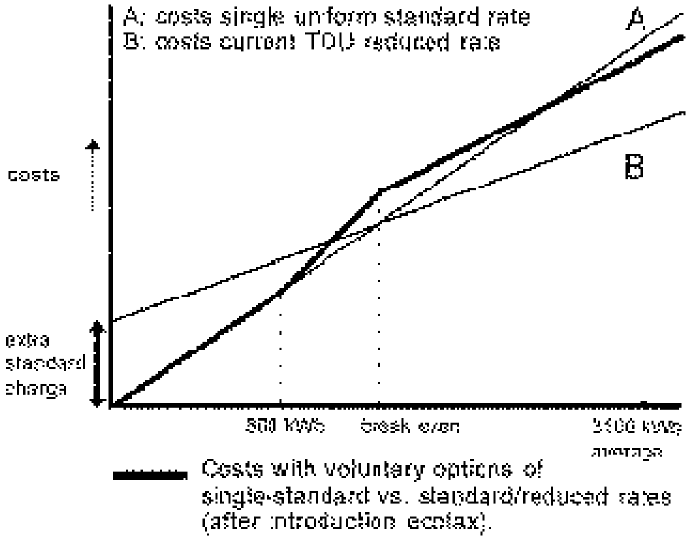

figure 2. Costs depending on annual consumption with current tariff system (optional singe-standard or standard/reduced TOU-rate)

Effectively marginal prices go down when the break-even point between the extra standard charge and the gains of consumption under the low-level regime have been reached. The exact location of that point is dependant of the sum of the extra charge, which is varying between utilities, and the customer's load pattern. Generally that point lies far below the average annual consumption, so the TOU-reduction variant is profitable for most consumers, without any effort of a behavioural change. So either the extra standard charge is far too low, or more likely, the day-time rates are no incentive for a shift of load to off-peak moments.

The current system became even more complex with the energy-tax. In this tax an element of progressive pricing was introduced, as the first 800 kWh per household are not taxed. In figure 2 the result of this simple progressive taxation is added to the scheme.

The current tariff-system is rather ineffective for the reduction of high- and peak-loads which is particularly relevant for the purchase costs of distribution utilities. Utilities were hardly aware of this, but awakening awareness in some of them added to the willingness to experiment with tariff systems.

2. The five field experiments

The cultural change from old public utilities towards new customer oriented organizations is particularly important for all DSM activities. However, this shift is not easily made. On two points the utilities appeared to be hardly able to conduct generally useful experiments, nor useful for themselves. In the first place their culture resulted in a low priority for methodological requirements compared to their internal organizational troubles. As a result the experiments suffered from designs that could not produce the knowledge the were conducted for in the first place (section 2.1). Secondly, in choosing the experimental factors most utilities could not take enough distance from their current policies, resulting in experiments in which only short term options were studied (section 2.2).

2.1 Experimental designs: methodological defects

All organizations that tried to start a field experiment considered it utility-experiments. The conditions were primarily determined by variables within the utilities themselves with consequences for some significant experimental conditions. Methodological requirements for example, were in most experiments not adequate as a result of lack of priority for essential experimental field conditions (table 1).

table 1. Characteristics of the field experiments

experiment (baseline)	pre-test experiment	duration group(s)	N experimental group(s)	N control
Heerlen	no	13 months	52	52
PNEM	yes	6 months	5 *	14 *
Nuon	yes	12 months	357 **	92
ENW A	yes	15 months	100 **	150 **
EDON	no	12 months	400 **	100

* Grid-stations instead of households
** Split up over different experimental conditions

Most experimenting utilities became aware of the fact that they actually were studying consumer behaviour instead of the delivery and tariff conditions too late. They hardly realized the effects they wanted to know could only be expressed in terms of *behavioural change*. Most of them thought group comparisons were sufficient for establishing load shifts and changed consumption. As a result in some cases it was impossible to distinguish effects due to diverging composition of experimental groups, free rider behaviour and actual behavioural change. This was a problem particularly in the Nuon case, because their ‘experimental groups’ were fully a result of the choice of consumers.

From the basic methodological requirements of tariffs experiments (Wolsink and De Jong, 1993) the only one adopted in all experimental designs, was a non-treatment control group. In most cases a pre-test (baseline-measurement) was initiated, but because of technical and organizational problems is was not carried out (particularly EDON) or the measurement was actually limited to a very short period or to only a part of the households. Utilities were hardly aware of the fact an experiment is already started when the base-line measurement is carried out. For reasons of internal tactics towards other divisions in their own organizations, they were more involved with a start of the experiment on the date planned than with adequate baseline data. The time needed for installation and testing of meters was underestimated in most cases. One did not realize that without proper baseline data the establishment of actual behavioural changes is impossible.

There were other large differences in the experimental designs. Particularly the measurement of consumption data varied largely. From simple monthly scores on three TOU-counters to ten minutes averages, opening possibilities for detailed analysis of load patterns. Four experiments were conducted with data of individual households. Only PNEM used aggregate measurements, so they only were able to analyse aggregate patterns of five groups of each about 200 consumers (table 1). Additional data from household surveys could not be linked to individual consumption (table 2). Measurements in the PNEM experiments could be very intensive however, due to this method. They were able to produce exact knowledge about consumption levels and load patterns, but from their design they could not explain the changes they established.

table 2. Measurements of electricity consumption

experiment	measurement	objects	household survey
Heerlen:	scores on 3 counters per month	individuals consumers	afterwards
PNEM	patterns (grid-stations)	groups ind. consumption	not linked to
Nuon	15 min. cons.	individual	yes
EDON	monthly scores on 4 counters	500 participants, individual	yes
ENW A	10 min cons.	individual	yes

In most cases the idea was that behavioural changes were established by comparison of experimental groups and control groups (table 2). Interpretation of groups differences as behavioural change however is tricky, as became apparent in the Heerlen-experiment. Results of the measurements of consumption could not be interpreted. An additional survey, carried out at the end of the experimental period, indicated significant differences in the composition of the experimental and control group. With the survey data these consumption data were 'corrected' for household composition and the possession of important categories of household equipment (de Jong and Wolsink, 1992a). That lesson from the first experiment was learned and the other utilities included surveys in the experiment. In the case of the PNEM the significance was rather limited however, because survey results could not be linked to consumption data, as the latter were only gathered at aggregated level.

2.2 The experimental factors

All tariff systems contain several components which are always (implicitly or explicitly) part of it. The components are:

* voluntary versus mandatory variants, which is referring to the system of selection of variant. These may be mandatory (uniform, but also differentiated rates may be mandatory, as was applied in one of the experiments), or the choice is left to the customer.
* the *standard charge*, an annual amount of money to be paid by all consumers in one category (= all households), regardless of the consumption level.
* *extra standard charge*, linked to particular customers conditions, for example the choice for an optional TOU-reduction variant or any other type of differentiated variant. In the current system this extra standard charge is linked to the TOU-reduction variant.
* *standard kWh-rate*, which is valid for all customers. This rate is charged 24 hours a day for customers which have chosen (or are forced by their utility to accept) the option a single-rate *standard uniform* variant. The notion '-standard' is referring to the price level, which can also be valid at times-of-day only, for example on working days 7 am-11 pm in the current TOU-reduction variant
* *low kWh-rate*, which is referring to a price level below the level of the standard rate. This low rate is mostly linked to time-of-use, it is for example charged to customers which pay the extra standard charge current TOU-reduction on standard the standard rate from 11 pm-7 am and weekends (plus D). However, it may be linked to level of consumption as well. However, low rates could also be linked with consumption levels: in a digressive system for annual consumption above a particular level, stimulating demand that way.
* *high kWh-rate*, which is referring to a price level higher than the standard rate. This rate will also be linked to time of use conditions, in particular to create an incentive against peak loads. However, high rates could also be linked with consumption levels, for example in a progressive system for consumption above particular levels. In the Netherlands the electricity price below the annual consumption level of 800 kWh is 3.9 cents cheaper as there is no eco-tax below that level.
* *characteristics of billing*, which may be either average estimated consumption per month, or actual registered consumption. Mostly monthly averages are used and actual billing is done once a year. Important is also the way

prices are presented to customers. Many utilities in the Netherlands apply systems that do not offer relevant information to customers. Actual kWh-prices are hidden behind figures of fuel costs, capacity costs, VAT, eco-tax, standard charges etc. Billing for many other things is often linked to the electricity bill: gas, television cable, sewerage, waste management. This practise of billing is not clear for customers, which in most cases are hardly aware of their rates and their own consumption.
* *information feedback*, which is systematic information about actual consumption in. The objective is influence consumption by making people aware of their behaviour. This component only exist in some experiments, as actual data about consumption must be available. Billing is the only feedback all customers receive, but that system is totally unfit for influencing consumption.

From all options of potential factors for testing new tariff-systems several were not included in any of the five experiments. Generally the experiments were limited to factors that were primarily considered as variables influencing load patterns. The experimental tariffs were primarily chosen according to short-term utility perspectives. The use of tariffs as an instrument of reducing consumption levels was either not recognised, or deliberately disregarded, which will be discussed in section 5.

2.2.1 Voluntary or mandatory systems

Some factors that were complicating the experiments or that would probably become impediments for results in terms of a change in behaviour, were nevertheless included because they represented existing utility policy and working routines. A good example is the choice for voluntary price-differentiation only by Nuon. As in the Netherlands current practise is a voluntary choice between the uniform standard rate and the differentiated variant, Nuon took a policy of only optional differentiated variants. In a survey previously carried out they tested the popularity of several variants (PGEM, 1993) and in the tested system they reduced the number to one uniform and three differentiated variants.

As in the case of the current system, the utility was creating free-rider problems, all the more because customers had a choice of twice as many options as in the old system. As differentiated tariff-variants actually are meant to influence the behaviour of the customer, the effect will be the opposite. Existing consumption patterns will determine the choice for the variant, as customers can choose for the most profitable variant given their life-style and daily time schedule. In the Nuon-experiment the variants are also voluntary chosen by the participants, so the composition of the groups was already biased by free-rider behaviour. Deviations from the control group or other groups do not indicate behavioural adjustments.

Two experiments contained mandatory conditions. The experiment of EDON had a group with voluntary participants contrasted to a mandatory group. In the ENW-A experiment a mandatory system with differentiated price levels was tested, only contrasted with the control group with standard rates. In all the others the current TOU-reduction variant was replaced by a new variant, leaving the voluntary choice between one single uniform price level and the variant with two price levels as it was.

2.2.2 Different ways of price differentiation

In all projects the tariff differentiation was essentially different from the current TOU-reduced rate variant. The extra annual standard charge for the differentiated variant was abolished, which was financially compensated by raising the kWh-rates. As the old practise of the standard/low price level was substituted by variants of high TOU-rates combined with low TOU-rates (high/low price levels), it is compensated by a small raise of the high-rates.

table 3. Price levels in the experiments.

	per tariff variant (customer choice)	per tariff system
Heerlen	1 or 2 (voluntary)	3 (old: 2)
PNEM	1 or 2 (voluntary)	3 (old: 2)
Nuon	1, 2 or 3 (voluntary)	7 (old: 2)
ENW A	2 (mandatory)	2 (old: 1)
EDON	1 or 4 (voluntary)	4 (old: 2)
4 (mandatory)	4 (old: 2)	

2.2.3 Strength of the price incentive

All tariff-variants with differentiated price levels in the experiments became high/low instead of the current standard/low rates. The size of the price incentive varied. As the extra standard charge was put in the high tariffs as well as the compensation for the time-extension of low rates, the difference between the price levels in the variants with two rates increased. In the experiment of PNEM and particularly of Nuon for some groups the incentive was made even stronger.

In the EDON experiment a peak-rate was introduced. In summer the new differentiated variant had three price levels. However, according to the German experiment in Rheine, as described by Becker and Vosz (1991) EDON wanted customers to avoid particular peak hours. Therefore they introduced a fourth price level, six times as high as the low rate, the same ratio as reported by Becker and Vosz (1991).

2.2.4 Periods of validity

In the current tariff-system the period for low rates is limited to nights and weekends. In all experiments the hours of low rates were extended with hours in the evening (9 pm to 7 am) because of expectations about the possibilities it offers to the households to shift loads effectively (de Jong and Wolsink, 1992b). One variant of Nuon included cheap hours in the morning (7 am - 8.30 am) and another three price-levels with a special peak-rate from 8.30-12 am and 5-9 pm. The special peak-rate in the EDON-experiment was only charged in winter from 9-12 am and from 5-6 pm.

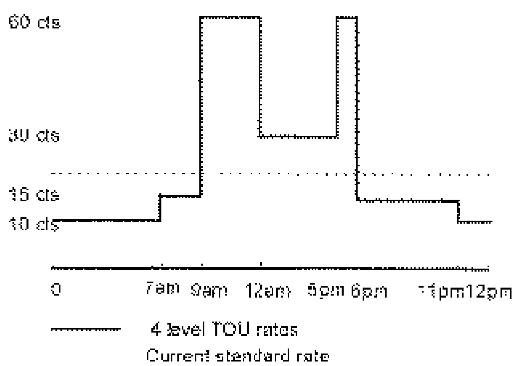

figure 3a. EDON 4-level system (winter)

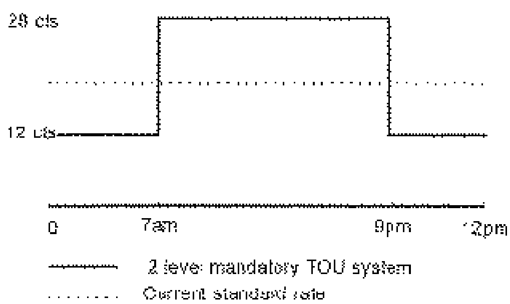

figure 3b. ENW Amsterdam high / low TOU system

The extension of the number of cheap hours had to be neutralized in order to produce a systems that is neutral in terms of costs and benefits. Compensation was found in raising the high rates (see previous section). In figure 3 the differentiated variants of the systems of EDON and ENW Amsterdam (basically the same as Heerlen and

PNEM) and compared with the current tariff system. In the Nuon variant that contained three price levels, a third rate between the high and low rates was introduced for workdays from 12 am-5 pm.

2.2.5 Other characteristics

Because the current voluntary systems were replaced by systems without extra standard charges and differentiated variants with high rates instead of standard rates, the digressive character of the current tariff system was modified. Some experiments, in particular ENW Amsterdam and EDON, introduced new differentiated variants that were not profitable for the customers with an average load pattern, except when they really changed their behaviour. As a matter of fact the goals of direct influence on consumption were still only directed at influencing load patterns, not at influencing total consumption. However, in particular systems that abolished the digressive character of the old system, showed interesting results.

Part of the tariff-system is the way of billing and the information given to the customers. In particular feedback systems might influence customer behaviour. The experiment of ENW Amsterdam was very interesting, as this experiment was not primarily directed at changed tariff systems. It actually was a remote monitoring experiment (measurement of energy consumption from distance) with the addition of some experimental conditions in which the immediately monitored consumer data were used. Mailed and electronic feedback were used to influence the electricity consumption.

3. Results

So far we only discussed the options chosen by the utilities. Now we will discuss general conclusions from the empirical data in the experiments. One overall conclusion in all experiments was drawn: load patterns of participating household actually changed. Some utilities already adjusted their tariff systems according to their experiments (Heerlen and PNEM). It should be stressed that some of these conclusions were based on inadequate experimental designs. Only ENW Amsterdam and PNEM generated adequate baseline data leaving the opportunity to interpret established differences as changes in behaviour.

3.1 Changes in load patterns

In the old system of differentiation low rates ended at 7 am. In the two variants of the Nuon experiment with an extension to 8.30 am significantly higher levels of consumption were measured. However, as these variants were both voluntary options, this effect will be partly due to free riders.

3.1.1 Low rates in the evening

In a survey previous to the experiments the options for several changes in tariffs were tested (De Jong and Wolsink, 1992b). The results indicated that the most promising change would be the extension of the periods with cheap electricity combined with higher prices during the day. Load shift can be formally be expressed in terms of substitution elasticity. Econometric studies and research on differentiated tariff systems with irregular low price levels, suggest that these elasticities are very time-dependant (Gallant and Koenker, 1984; Wolsink, 1987). The variants with an early start of low rates (21 pm instead of 23 or 24 pm) were found to be the most popular and the expected change in behaviour was also the promising.

This change of an early start of low rates was part of all experiments. The experiments of Heerlen and PNEM were particularly directed at it, both with significant positive results. Loads from 9 to 11 pm became significantly higher, and loads during daytime decreased (section 3.1.3). In the Nuon experiment the loads between 9 and 11 pm were significantly higher as well.

In the ENW Amsterdam experiment at first sight there was a curious result of the differentiation. The specific load between 9 and 11 pm was not analysed separately. There was only an analysis of the entire low rate period (9pm-7am). The result was an decrease instead of an increase (Uitzinger et all., 1995, p.64). This decrease however, was part of an overall decrease of electricity consumption, so it was not merely a load shift but rather energy saving (section 3.3).

Intensive load measurements in the PNEM experiment, although at aggregated level (table 2), showed a significant new peak just after 9 pm. This peak might cause local capacity problems in weak parts of the grid.

3.1.2 Avoidance of high rates

Heberlein and Warriner (1982) concluded that price incentives were of limited value compared to other variables. This was confirmed by a large survey with a quasi experimental design, in which the fact that there actually is a price difference appeared to be much more important than the size of the difference (De Jong and Wolsink, 1992b). However, this was only within the range of price differences legally allowed by Dutch law. The EDON experiment was directed at establishing the impact of extremely high peak rates. Particularly in winter the peak price was extremely high (60 cents with a ratio of 6:1 compared with the low rate). The conclusion of the experiment was that the avoidance of the extreme peak rate in winter was substantial: 18-21% of the average kWh-consumption was shifted away from the peak-hour price. The high rate of 30 cents also triggered avoidance, but not that much as the 60 cents price level did: 11-12% of the average kWh-consumption (Hardeman, 1996, p.39). Avoidance probably means shifting electricity consumption to other moments, but it might partly be due to actual conservation (see section 3.3.1).

Nuon reported lower loads during peak rates in the morning, but hardly a decrease in the afternoon. The peak rate of EDON in the afternoon was only valid one hour (5-6 pm) but the design of consumption measurements did not allow an analysis for that hour separately.

The conclusion should (cautiously) be drawn that extreme high price differences actually cause load shifts. Whether or not the size of the incentive is responsible in not clear. At the same time the number of hours the high rates are valid has significantly decreased, so avoidance of high rates has become easier as well.

3.1.2 Decr ease of loads during day time

In the PNEM experiment the most detailed estimate of the decrease in day-time loads could be made. It was established that 3.2% of total electricity consumption was shifted from day-time to evenings, nights and weekends. For the period from 9 am to 6 pm an average cut back of 50 W per household was realized (PNEM, 1993). In the Heerlen experiment a difference of 1.0 to 1.9% of the total consumption between the experimental differentiated tariff-variant and the old differentiated variant (control group) was estimated for the high price level periods of 7 am to 9 pm (de Jong and Wolsink, 1992a). In both experiments the only changes were the extension of low rates from 9 am to 11 am (with accordingly an increase from the standard uniform price level to a 'high' level, see figure 3). So the decrease of day time loads were actually indications of shifts, a real behavioural change. These loads were shifted to the new cheap hours in the evening (section 3.1.1), but strikingly also to the 'old' cheap hours at night. The results from the Heerlen survey suggested that this effect was mainly due to adjusted use of washers and dryers. As washing and drying are carried out in a sequence, 11 pm was too late to start with it. The new time of 9 pm offered opportunities to start this household work in time to finish it the same evening with starting the dryer (De Jong and Wolsink, 1992a).

In the other three experiments a significant decrease in day time loads was established as well. In the ENW Amsterdam experiment this was part of the overall decrease in the electricity consumption. The design in the EDON and Nuon experiments did not make a proper estimation of the decrease possible. In the Nuon experiment lower loads were found for all three new variants, in particular during morning hours. This might suggest a shift, however an explanation in terms of free rider behaviour seems more appropriate. In the Nuon experiment is was very easy for customers just to pick the variant that looks the most profitable one.

3.2 Mandatory differentiated tariff systems

The comparison of the voluntary and mandatory conditions in the EDON experiment revealed only small differences. Peak-priced loads in the voluntary group were a slightly smaller (not statistically significant) than in the mandatory group. Secondary analysis demonstrated that if there was any difference, it was concentrated in October and March (Hardeman, 1996). In winter months there was no difference between the mandatory differentiated tariff-system and the customers who had voluntary chosen the differentiated variant.

This implicates that the impact of a mandatory system on aggregated load-patterns is significantly stronger. This is a confirmation of previous results in the US. Overviews of TOU-studies also lead to the conclusion that optional TOU rates have no significant efficiency implications (Aigner, 1984). The aggregate results of mandatory TOU-systems produce a better contribution to efficient loading (Hausman and Trimble, 1984). All customers participate, as in the voluntary situation only a part is participating with a relatively high number of free riders.

In the only other experiment with a mandatory differentiated system, it was not applied an experimental condition, so there are no possibilities to compare it with an optional system. However, there are some interesting result in the tested mandatory systems of ENW Amsterdam, in particular with respect to total electricity consumption.

3.3 Effects on the total electricity consumption

From environmental point of view the total consumption of energy is the most interesting variable, as more than 98% of the electricity production originates from sources with high impact (fossil fuels and nuclear). As noted, none of the tested tariff-systems was directed at energy conservation, in spite of the officially accepted conservation and carbon-dioxide reduction objective of the electricity sector.

Apart from the goals in terms of changed load patterns, only Nuon and EDON formulated secondary goals. For Nuon it concerned mainly the utility-customer relation, which was a reason to them to experiment with only one system with several voluntary variants. For EDON however, the secondary goal was „Improving the energy awareness of the customers“.

The result of the Nuon experiment appeared to be counterproductive. For all variants in which customers had a voluntary tariff differentiation, the average consumption level increased with 6%. This growth was larger than in the control group (1%) and even larger than the autonomous growth for all Dutch households (3%). Nuon’s only explanation was a growth in possession of ‘white equipment’ (washers, dryers, dish-washers etc.) but they did not have an explanation for such a growth. The most significant difference between the differentiated variants and the control group was the voluntary choice for the differentiation. Probably customers in a situation that they expect to purchase this kind of equipment in the near future, are more interested in choosing voluntary differentiated tariff variants.

3.3.1 Electricity conser vation in the EDON experiment.

Improvement of the „energy awareness“ of customers could mean anything, but in the official report of EDON links it with the environment: „The customer should be aware of the fact that his electricity consumption pattern is partly determining the costs of electricity supply and the burden to the environment. When the customers becomes aware of it, actions directed at influencing behaviour of customers may be carried out more efficiently.“ (EDON, 1995, p.3). According to this description energy awareness may be interpreted as condition for all sorts of successful DSM-activities, not only directed at shifting loads, but at energy conservation as well.

table 4. Annual average electricity consumption (kWh) in the EDON experiment.

year	voluntary differentiation	mandatory differentiation	control
pre-test: 1993/4	3203	3079	3188
experiment: 1994/5	3219	3064	3357
consumption growth	18	-5	169

Although it was not the primary interest to establish energy conservation, this effect actually occurred. In table 4 average consumption levels for the three groups are presented (Hardeman, 1996 p.53). There is no absolute consumption decrease in the two experimental groups. However, compared to the control group there is a statistically significant difference. The autonomous consumption growth of the control group is consistent with the growth in average electricity consumption for all Dutch households, but such a growth is absent in both experimental groups. This relative energy conservation effect has not been noticed in the official utility's report, as the changes were claimed not to be statistically significant (EDON, 1995 p.16). To the false conclusion that „energy conservation as a result of the experimental tariffs could not be demonstrated", the strange remark was added that „eventual effects may be considered result of load shifts", which is obviously a methodologically inadequate remark.

3.3.1 Electricity conservation in the ENW Amsterdam experiment

The most interesting results concerning energy conservation were found in the ENW Amsterdam experiment. The experimental design (pretest-posttest control group) was appropriate to establish real behavioural changes. The changes in electricity consumption within the four experimental groups and the control group are presented in table 5. The four conditions were constructed with the factors price-differentiation, monthly feedback on paper, and weekly feedback on electronic displays.

table 5. Changes in electricity consumption in the ENW Amsterdam remote-monitoring experiment.

experimental conditions	net change (%)
single standard + weekly display feedback	+3% (n.s.)
single standard + monthly written feedback	-6% (sign.)
two price levels + monthly written feedback	-13% (sign.)
two price levels, no feedback	-6% (sign.)

All 95% reliability intervals ±4% (Uitzinger et al., 1995, p.63).

Substantial conservation was found for both groups with the mandatory differentiated tariff system. Statistically significant load shifts could not be established, but there was a net decrease in electricity consumption for all rates. In the groups with a feedback condition only, no significant effect for weekly electronic feedback was found. Monthly feedback on paper, however, resulted in substantial energy conservation. Of course there is a problem with generalization of these result, as they were established in non-representative circumstances. The representativeness of the experimental groups is not the issue here, but the fact that all households were involved in a remote-monitoring experiment. The results of the experiment indicate the possibilities of mandatory price differentiation combined with communication with customers. The potential effect of this combination was also established in Finland by Arvola et al. (1994). It becomes particularly is underlined by the result of the experimental group with differentiated kWh-prices combined with written feedback, which was a particularly strong effect (13% conservation).

4. Conclusions

The general conclusion of the five field experiments is that differentiated tariff-systems may effectively influence household customer behaviour. These effects however are depending on several conditions that are a part of the tariff-system. Simple differentiation with properly chosen validity of TOU-rates may affect daytime loads. Special peak-rates can also be successful for reducing peak loads.

Systems leaving the options for differentiated tariff-variants open for customer choice, are probably less effective, may be even totally ineffective. Creating these options may look customer-friendly, but in the surveys carried out in the experiment no evidence was found that the customers particularly appreciate these voluntary options. Communication with customers is very useful, if not a necessary condition. In all surveys it was concluded that there was a substantial lack of knowledge about the time the rates are changing and about the price levels. The only experiment that introduced feedback as a part of the tested tariff-system had the most substantial and promising results, particularly concerning conservation. Mainly because of the effects on consumption levels (section 3.3.1) and the combination with feedback conditions, but it should be also noted that the most successful differentiated systems were all mandatory.

5. Discussion: utility policy

The obvious goal of all utilities experimenting with the tariff system, was reduction of purchase costs. The fact that utilities accepted new goals in the field of environment and energy conservation, did hardly affect the conditions in the field experiments. The need for improvements in energy efficiency would logically implicate that efforts should be made to include energy saving in the goals of tariff experiments. The fact that they did not, suggests that they actually do not want to use the price instrument for achieving conservation. According to some off-the-record remarks from utilities employers involved in the experiments, the actual will of utilities to achieve real savings might be questioned. The question of conservation goals against the companies interest in turnover is not solved yet, particularly not in the Netherlands (Slingerland, 1997). For example, the price instrument was not included in the Environmental Action Plans either. As a matter of fact the utilities and their umbrella organization EnergieNed resisted against the energy tax that was introduced primarily as an improvement of the incentive for energy conservation.

The environmental goals of were obviously not meant to interfere with the core business of distributing energy and price setting. The primary goal of all experiments was reduction of purchase cost and therefore a reduction of high, and particularly peak loads, an economic rather than an environmental objective. The fact that an overall reduction of electricity consumption during the day effectively implicates a decrease in high and peak loads as well, was not recognized.

It was striking that the divisions taking the initiative for the experiment never were the departments for billing and finance, but divisions of regulation and metering, or employees at internal policy departments, interested in the utility-customer relations. Some of the planned experiments were never carried out, because the divisions within utilities that took the initiative could not convince others or the need for tariff reforms. The general support for tariff-experiments remained at a low level, because at policy level the idea settled that changing tariffs touches on core business. There is more circumstantial evidence for this assumption. In the EDON experiment the results of the differentiated tariff-systems on conservation were not appreciated. There was obviously some fear to draw the conclusion that changes of tariffs can be powerful for achieving electricity conservation. Obviously influencing customer behaviour still is not considered utilities core business. The commission of EnergieNed (section 1.1) that served as a platform for tariff experiments did not exist very long, as at the time the plans became concrete it was disbanded by the management.

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