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The end-users as starting point for designing dynamic pricing approaches to change household energy consumption behaviours.

Report for Netbeheer Nederland, Projectgroep Smart Grids (Pg SG).

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Executive summary

Introduction

The increasing deployment of intermittent resources, decentralised generation, and the expectation of further electrification pose a number of challenges to DSOs and TSOs in relation to the balance of supply and demand. The increasing interest in demand reduction and demand shifting has resulted in discussions about how dynamic pricing can be used to best encourage household end-users to change their energy behaviours - more specifically to shift (and reduce) energy consumption. If end-users can be incentivised to decrease their energy consumption during peak hours, this may prevent the need to extend the grid and thus save considerable costs. As for end-users, dynamic price incentives may provide them with insight in their own energy consumption patterns and related costs. It may help them in gaining or maintaining control over their energy consumption, saving costs, getting reassurance that behavioural changes have worked, getting support in motivating other household members to reduce energy consumption, accomplishing other benefits like increased comfort, indoor climate, health impacts, and social aspects. In addition, becoming more aware of the varying price of electricity may encourage the uptake of a more pro-active role as energy users and producers. For society at large, reduction and shifting may serve environmental goals (e.g. when it allows for more decentralised renewable energy generation) and the societal goal of maintaining the stability of the energy system.

Research aim and focus

Having a strong interest in demand shifting, and a (less strong) interest in demand reduction, Dutch DSOs have questions on how to best design a dynamic pricing approach in such a manner that it encourages household end-users to change their energy behaviours. The initial research question therefore has been formulated as follows:

Which dynamic pricing approaches (being a combination of a dynamic price incentive, technology and feedback) work best for which end-users and under what circumstances in the Netherlands?

This study focuses on electricity, demand shifting and reductions. This report is based on a review of existing studies, reviews and pilots that report on the impact of price incentives to shift and/or reduce energy consumption at the household residential level. This review aims at learning what type of approaches work best, for whom, in which context and under what conditions. Regarding the conditions, we focus on what would work in the Dutch context and what role DSOs could and/or should take. In addition to this report we have also developed a step-wise approach for designing a demand-management approach that consists of several building blocks which can be combined in various ways, depending on the end-user characteristics. Rather than designing the invention around a chosen price incentive or technology, we turn the process around and take the end-users as a starting point in the process of designing a dynamic pricing approach. This step-wise end-user centred approach and an accompanying background document have been published in Dutch as separate documents next to this report.

Dynamic pricing approaches

Dynamic pricing is a means to an end - or to several ends - like for instance to balance supply and demand; to prevent the need for grid extension; to achieve end-user energy saving; to raise awareness; to more actively engage end-users and decentralized producers. A dynamic approach consists of the following three elements: the pricing mechanism (e.g. ToU, CPP, CPR, RTP described briefly below); supportive technology and feedback.

In this study we reviewed several forms of dynamic pricing:

- **Time of Use (ToU)** tariffs are recurring daily and aim at encouraging people to use energy during periods of the day when overall energy consumption is lower. In principle, ToU is not aimed at reducing overall energy demand, merely at shifting the demand from one period to another. The peak hours are invariable and known a long time in advance by the end-users. A day can have one or more peak periods during which the prices are set higher in comparison to the prices for the rest of the day. Two to four levels of prices may be distinguished (peak, partial peak, off-peak, and weekend tariff) and in addition, prices may also vary according to the season.
- **Critical Peak Pricing (CPP)** schemes offer lower year-round tariffs during non-peak hours in exchange for substantially higher tariffs during critical peak hours. Critical peak periods or event days occur at times of increased wholesale prices due to heightened consumption (e.g. very hot or cold days) or when the stability of the system is jeopardized (e.g. risk of black-outs). The maximum number and length of critical peak periods is agreed upon with the end-user in advance. However, the exact moments when critical peaks occur cannot be set in advance as these depend on market and weather conditions.
- With **Critical Peak Rebate (CPR)** schemes the end-user is refunded at a predetermined tariff for any reduction in consumption relative to what the utility expected the household to consume during a few critical peak hours a year (usually during very hot summer afternoons, or very cold winter evenings).
- **Real-time pricing (RTP)** means that the end-user pays a price that is tied to the electricity price on the wholesale market. To encourage consumption reduction during high price periods and reduce risk of high bills, end-users can be informed when wholesale prices reach a certain threshold.
- **Inclining Block Rates (IBR)** currently is the least common scheme. As the name indicates, Inclining Block Rates offer block-wise increasing rates. Prices increase step-wise as consumption increases - so the more one uses, the higher the price per unit. This pricing mechanism has been proposed as a complement to e.g. ToU or CPP and serves mainly conservation goals.

Technology, the second element, covers a wide range of supportive and feedback devices, of which smart meters and In-House-Displays can be considered as 'must-haves' in combination with dynamic pricing. An important technology is the In House Display (IHD) which provides feedback in a variety of forms and has been shown to significantly improve the response from end-users. Other useful technologies include ambient displays like energy orbs, smart apps, websites, email services, but also very simple devices like paper mailings, fridge magnets or stickers and water saving showerheads. In addition, more complex technologies can support behavioural changes in response to pricing, including all sorts of smart appliances that can be programmed to respond to (changes in) information and/or remote-controlled.

The third element of a pricing approach is feedback, which is part of any approach that aims at encouraging end-users to change their energy consumption behaviour. In this study we distinguish between feedback intended to communicate changes in the price and feedback to communicate consumption patterns and volumes.

Letting go of a one-size-fits-all approach

In this study we explicitly diverge from studies that state that the combination of ToU, CPP, CPR, with multiple enabling technologies and feedback technologies generate the highest peak clipping and load shifting. Such 'full court' approach basically is a *one-size-fits-all* approach that uses as many technologies and feedback options as available in order to reach as many different people as possible. This is unlikely to deliver the cost-efficient approach and since the brunt of the costs eventually comes down on society, it is undesirable from a societal perspective.

There are several more reasons why a 'one-size-fits-all' approach is not advisable when aiming at energy consumption reduction or shifting.

- 'one-size-fits-all' approaches usually focus on providing financial incentives, assuming that people are mainly economically motivated to participate. However, there is plenty of evidence that people are not predominantly motivated by financial gains, but can also have other motivations that relate to environmental goals, health, comfort, etc.
- Research on energy DSM aimed at energy consumption reduction has shown that approaches that target individual behaviour only - without addressing the social and physical environment in which behaviours are embedded - have not been very successful in achieving *lasting* behavioural changes. In the case of dynamic pricing, attention for the characteristics of the house, the appliances, as well as the social processes within a household are relevant to take account of.
- The risk of rebound during or after the pilot is larger if individuals are targeted with financial incentives only. No social norms are addressed; no pro-social behaviour is likely to occur (which is needed if the longer-term goal is to facilitate the transition to a more sustainable energy system).
- Studies show that often a small percentage of the participants is responsible for the response, while it remains unclear why and how they responded and why the rest did not. On average 30% of households were responsible for 80% of the load shifting.

Top 10 lessons

Based on our review of pricing mechanisms, technology, feedback, behaviour and segmentation the following top 10 lessons could be drawn:

1. For the near future Time of Use with several pricing variations a day, combined with Critical Peak Pricing for several additional days annually is the most promising dynamic pricing intervention for the Netherlands.

2. Focusing on load shifting only creates the risk of overall load increase. If e.g. the off-peak price is too low compared to the peak price this can create an increase in consumption.
3. The *theoretical* load shifting and reduction potentials tell us little about the actual occurrence of the shifting and reduction. That depends on the end-user. Lifestyle had a strong influence on the actual occurrence of shifting or reduction behaviours.
4. People are not motivated by pricing incentives only. Environmental motives, "the desire to contribute", control, comfort, ease and wellbeing are important motivators as well.
5. A one-size-fits-all approach reaches a maximum of 30% of end-users, with very different responses within this 30%. If the aim is to also reach the remaining 70%, a differentiated approach is needed.
6. Time of Use interventions target habitual behaviours. Critical Peak Pricing and Critical Peak Rebate focus on conscious and less frequent behaviours.
7. Load shifting can be achieved without technology (using only fridge magnets and calendars). Additional technology such as e.g. an In House Display however increases the response rate.
8. End-users highly value easy aids such as calendars, magnetic stickers and detailed frequent energy bills.
9. Different end-user segments need different tailored interventions consisting of a specific combination of dynamic pricing mechanism, technology and feedback.
10. A tailored approach and voluntary participation are very important to avoid discrimination (and sabotage).

Designing a comprehensive and tailored dynamic pricing approach

Understanding what motivates behavioural changes (both intentional and routine behaviours) and consequently the responsiveness of households to pricing signals, the potential flexibility of certain loads in households, and how such changes can be made durable is important when designing an effective dynamic pricing approach. Different end-users are likely to have different attitudes, motivations, behaviours, capabilities, knowledge and other resources - which will affect how they respond to and participate in dynamic pricing interventions. Ideally, these different end-users should be targeted in ways that fit their needs, preferences, knowledge, capabilities etc. This would entail that real needs and real behaviours of real households are included in a segmentation, to understand how their attitudes, motivations, awareness, capabilities, sociodemographic variables, home and appliances play a role in maintain a certain way of life. To understand how a particular lifestyle brings with it certain patterns and volumes of energy consumption it is important to know how people wash, eat, clean, care, relax, move, sleep etcetera. Segmentation offers a first step towards tailoring a pricing approach to the motivations, behaviours and needs of a group of end-users that share relevant characteristics - thereby increasing the chances that these end-users will respond. Such a comprehensive segmentation includes several crucial elements:

- Attitude, motivation, awareness, capabilities, behaviours
- Sociodemographic variables
- House-related characteristics

- Appliances
- Presence patterns
- Household dynamics: timing and negotiable (read flexible) use

Segmentations that address all these elements do not exist to our knowledge. Nevertheless, first steps to segment lifestyles have been undertaken. A Swiss segmentation study addressed attitudes, motivations, awareness, reported actual behaviours and a number of sociodemographic variables. The resulting segments, although not translatable one-to-one to the Dutch context, do offer end-user profiles that we can expect to occur in the Netherlands in different percentages and possibly with nuance differences. This resulted in different dynamic pricing approaches for each of the following six segments:

- **Segment 1: Idealistic savers**
- **Segment 2: Selfless inconsistent energy savers**
- **Segment 3: Thrifty energy savers**
- **Segment 4: Materialistic energy consumers**
- **Segment 5: Comfort-oriented indifferent energy consumers**
- **Segment 6: Problem Conscious welfare oriented energy consumers**

To design tailored dynamic pricing interventions that consist of a combination of segments, pricing mechanism, technology and feedback we designed a toolbox, see figure 1 below. Each element in the toolbox is a building block that can be chosen or not. Each column represents the building blocks that can be chosen within the categories: pricing mechanism, technology and feedback. The combination of selected building blocks create a basic design for a tailored dynamic pricing intervention aimed at a specific segment.

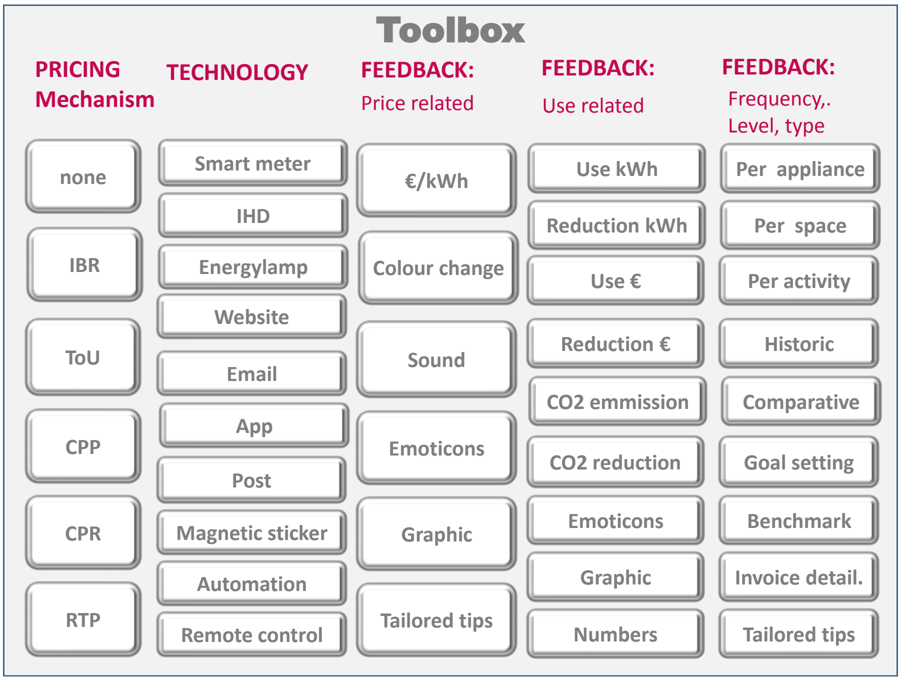

Figure 1: toolbox to design tailored interventions

As an example of how a dynamic pricing approach can be designed, we used six segments from a Swiss study by Sütterlin et al (2011) to design 6 tailored dynamic pricing interventions. Table 1 and figure 2 demonstrate how choices for building blocks from the toolbox are made for one segment ('Idealistic savers').

Segment 1	Idealistic savers
General Considerations	This group shows most efforts to save energy, and already does a lot in terms of reduction. Driven by idealism, these people are willing to make financial sacrifices and impose restrictions to themselves even if it means loss of comfort. This customer is knowledgeable and consists largely of highly educated women.
Preferred behaviour	Both routine behaviour and efficiency measures
Main motivation	This group could be motivated to shift their consumption but from an environmental motivation.
Choices related to Pricing Mechanism	Saving and shifting will not be financially motivated (no emphasis should be put on money) and a price incentive may not be the best incentive. If a price incentive is used, a combination of ToU, possibly with CPP, is a good option to visualise energy shifting options. Because this segment is not financially motivated, RTP is probably not suitable (because you still need to respond strongly to price). You could also simply CPP (and focus on shifting only).
Choices related to technology	Since this group is highly educated and well informed, different technologies can be used to support further behavioural change. The use of technology should be functional for this group. Almost all options are ticked in the toolbox because these people want information to be provided both at home and at work on PC, smart phone, IHD. This group does not like ceding control (especially to a party that is less environmentally conscious and idealistic than themselves). Remote control by third parties is not an option; automation is possible if this group can control it themselves.
Choices related to Feedback	Detailed and differentiated information is desired. Because this group is well informed, it is well able to interpret the information. Text, graphics, and / or lamp signals when price changes are options. Tailored advice needs to be focused on shift options. Important for this target group: who gives feedback and how reliable they find this party.

Table 1: Considerations made in choice for dynamic pricing approach (price incentive, technology and feedback) for Segment 1.

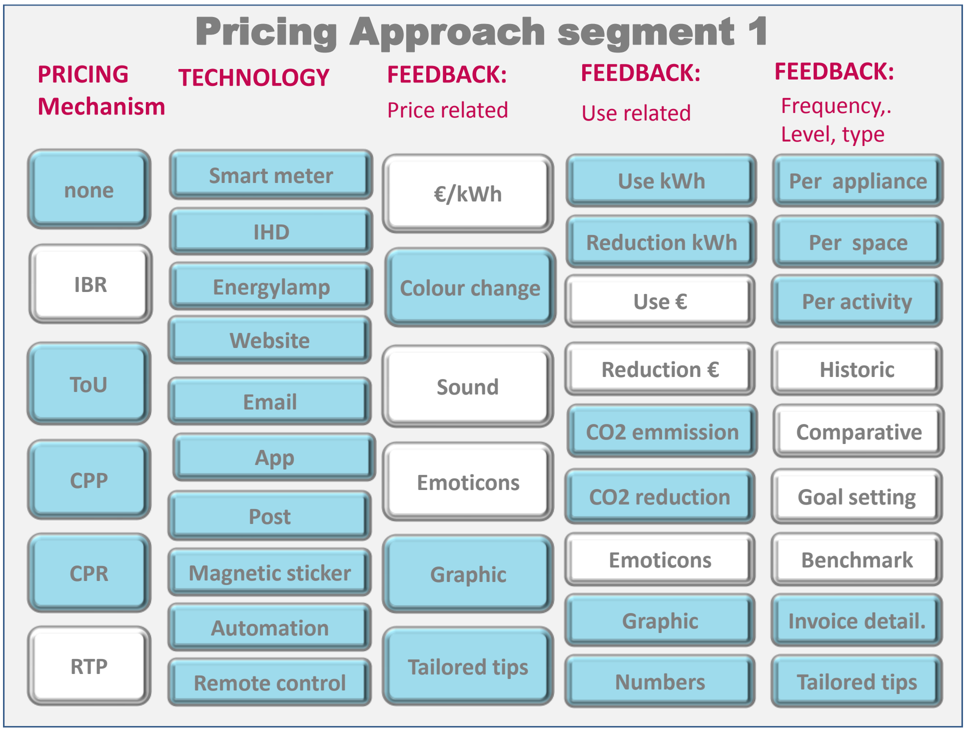

Figure 2: Dynamic pricing approach for segment 1 (the blue blocks)

The role of the Dutch DSOs: towards a DSO-led decentralised approach?

The role of DSOs in the Netherlands differs from the role of DSOs in most other EU countries. Because of the separation between transport and supply, the DSOs have been created as public organizations responsible for balancing demand and supply.

A tailored pricing intervention requires a lot of detailed personal data from individual households and a comprehensive segmentation asks for a lot of private and sensitive information from households. It is unlikely that end-users provide such information easily - for several reasons, one being the perception that the privacy and security of their data cannot be safeguarded.

Rather than trying to create an elaborate and costly centralised data system that 'guarantees' the safety and protection of privacy and other end-user interests, it may be a better idea to keep end-user data and information decentralised. That would also better fit with a future situation in which end-users become more actively engaged in smart grid technologies. And it would make it easier for DSOs not to compromise their task of furthering of the public interest as a priority when working closely with parties that have very different priorities (e.g. the enormous interest in selling as much smart and intelligent devices as possible collide with cost-efficiency for end-users as a priority). In a decentralised data en information management system, the end-users' active role would become key. Such a system ensures that personal information needed for the segmentation as well as household metering data remain with the end-user and with no one else. This also resonates with other studies that discuss the options of full end-user control and ownership over (metering) data.

The role of the DSO could be to design a tool that provides to the end-users several segment-descriptions with accompanying price-technology-feedback combinations with an explanation of critical issues and potential risks and benefits. Or the toolbox could allow for a household to fill in their personal data and the tool would subsequently advise the best fit in terms of combination of pricing mechanism, technology and feedback. This would allow households to choose the segment that fits their situation best. Next, the households could ask the DSO or retailer for this dynamic pricing intervention combination (perhaps with options to adapt elements further to be in line with one's personal situation). The toolbox would enable this interaction between households and DSO and/or retailer. In addition, it would do so in such a manner that personal data and information stay with the end-user. The end-user keeps control over his/her data, the choice of segment and the choice for a price intervention.

The role of a DSO in rolling out well-tailored dynamic pricing interventions could thus lie in facilitating the development of such toolboxes and the segmentation (that serves as a starting point). However, the DSO should not undertake this without strategic alliances. For credibility and trustworthiness, it would be good to collaborate with an independent organisation that intermediates between DSO, energy suppliers, other relevant stakeholders and end-users, whereby it is clear that this intermediary serves the societal interest and ensures fair play.

1. Introduction: background, scope and focus

1.1. Background

In the face of increasing intermittent resources, decentralised generation, the expectation of further electrification creates an unprecedented pace of change within the electricity supply industry worldwide (IEA DSM (www.ieadsm.org)). These changes pose a number of challenges to in particular DSOs and TSOs in relation to the balance of supply and demand. Many studies investigate options to change the current system where electricity is provided 'on demand' in response to the energy needs of end-users. To secure grid balance, energy production and demand need to become more integrated and the concept of smart grids is being deployed worldwide. At the same time, smart meters find their way to an increasing number of households which gives rise to questions as to why we have smart meters when the rates are still dumb (Faruqui and Palmer, 2011). The increasing interest in demand reduction and demand shifting has resulted in discussions about how to best encourage household end-users to change their energy behaviours and more specifically how to motivate households to shift (and reduce) energy consumption. If end-users can be incentivised to decrease their energy consumption during peak hours, this may prevent the need to extend the grid and thus save considerable costs. Therefore, DSOs and TSOs regard dynamic pricing primarily as a useful tool for peak shifting (peak clipping) rather than overall consumption reduction (conservation). In view of the current centralised supply system and their wish to use the distribution infrastructure cost-effectively, DSOs and suppliers regard peak shifting as more important on the short term than average load reduction or conservation (Landis+Gyr, 2009).

For end-users at the household level, dynamic or time-dependent price incentives offer a way to save money and to gain more insight in their own energy consumption patterns and related costs. Cost savings can result not only from reduced energy consumption, but also from shifting consumption. Dynamic pricing may also help end-users becoming more aware of the varying price of electricity and taking a more pro-active role as energy users and producers (e.g. in case of decentralised applications like rooftop PV panels; or when they offer electricity storage capacity in the future - Electric Vehicles). For society at large, shifting may serve environmental goals (e.g. when it allows for more decentralised energy generation) and the common societal goal of maintaining the stability of the energy system. A mass roll-out of dynamic pricing would involve a paradigm shift in thinking about the use and production of electricity among many household end-users and supply side stakeholders. We are used to set electricity prices that change on a yearly basis. Electricity prices at the APX index are currently not reflected at all in consumer prices, nor are the varying costs of transport. Suppliers could offer dynamic tariffs for delivered electricity and DSOs can vary the transport-tariffs. A cost-reflective approach can bring about awareness of the fact that a reliable electricity supply brings along costs; or that, if supply and demand are well balanced real-time, this

could potentially also result in lower electricity costs. The focus of this study is on electricity and options for behavioural change by means of Demand Response through the use of dynamic pricing.
Having a strong interest in demand shifting, and a (less strong) interest in demand reduction, Dutch DSOs have questions how to best design a dynamic pricing approach so that it encourages household end-users to change their energy behaviours. The Dutch DSO branch organisation Netbeheer Nederland and the authors have formulated the initial research question as follows:

Which dynamic pricing approaches (being a combination of a dynamic price incentive, technology and feedback) work best for which end-users and under what circumstances in the Netherlands?

Price-incentives are a central element in this study. Other approaches that do not include a price incentive (e.g. complementary currencies) therefore receive less attention because they fall outside the scope of the initial questions - not because they a priori considered less useful.

1.2 Scope and focus

First of all, this report is based on a review of existing studies, reviews and pilots that report on the impact of price incentives to shift and/or reduce energy consumption at the household residential level. This review aims at learning more about what type of approaches work best, for whom, in which context and under what conditions. Regarding the conditions, we focus on what would work in the Dutch context and what role DSOs could and/or should take. Second, on the basis of this learning, and on the basis of discussions with the Dutch DSO branch representatives and practitioners active in starting dynamic price pilots, we have developed a step-wise approach towards designing a demand-management approach that consists of several building blocks which can be designed and combined in various ways. These building blocks include dynamic price-incentives, supportive technologies, and feedback. Third, in addition to this, we also pay brief attention to the process of designing such an approach, and the role(s) that Dutch DSOs can take and what considerations appear important. The second and third parts result in a toolbox for practitioners and will be made available in Dutch language.
This report reviews relevant literature, thereby trying to focus on those elements around behaviour and behavioural change in relation to dynamic pricing that so far have not been addressed in a satisfactory way. In addition, we will also address the building blocks of the toolbox, and conclude with lessons, a recommended direction for DSOs (to further explore) and remaining dilemma's and unsolved issues that need further research and/or piloting.

1.3 Method and considerations

We started with a review of empirical evidence and conclusions from existing studies, cases, pilots, experiences, and assesses these outcomes in order to arrive at conclusions and recommendations that are grounded in sound empirical evaluation.

The following questions served as a basic guideline while conducting the research:

- What possibilities exist to use dynamic pricing (in combination with smart meters) to effectively change energy behaviours at the household level?
- Incentives and interventions can aim at demand reduction and/or demand shifting: do these two present a trade-off or a win-win?
- What are effective combinations of incentives, technologies and feedback?
- What role(s) can/should the DSO play in the design and implementation of interventions that aim at changed behaviours to achieve demand reduction and shifting?
- What issues around trust and privacy need to be addressed?
- What specific Dutch context factors make some approaches more appropriate for the Dutch context than others?

Relevant findings were first collected in a large overview (summarised in Annex 4). However, while doing so, we became aware that several studies (and reviews of studies and pilots) present conclusions that give rise to questions. Several reviews gather and summarize outcomes of studies, pilots etc. (see Annex 4) without giving due attention to the manner in which these outcomes have been arrived at. Several studies can be suspected for presenting overly optimistic interpretations of pilot results, which easily happens due to a number of reasons (Klopfert and Wallenborn 2011):

- Studies and reviews that extensively report on failure and on disappointing results of pricing pilots are less widely available than the positive ones. One could argue that this relates to the overall positive outcomes of pricing pilots. However, a more realistic explanation would be that pilot initiators are more interested in sharing successes than in sharing project ‘failures’.
- Self-selection of participants results in distortions. If only very motivated participants participate (instead of using a representative sample) then the pilot results lead to over-optimistic conclusions
- Many studies do not even report what the response rate was to their pilot; this makes it difficult to place outcomes in perspective (e.g. impact of intervention on saving and/or shifting).
- Most studies do not account for the Hawthorne effect, which involves that people behave differently when they know that they are being studied; it increases their motivation to achieve the task that is being investigated compared to situations where participants do not feel being observed. A way around this is e.g. first only installing a smart meter to observe any changes in behaviour before actually implementing other interventions. The Hawthorne effect is likely to play an increasingly diminishing role as the duration of pilots increases.
- Most studies do not account for drawback effects: when an intervention is new, people respond, but as the newness wears off over time, the response of people diminishes. So in the short term an intervention may appear very successful, but in the longer term people are likely to fall back to their old behaviours. (Important is to evaluate the persistence of behavioural change after a period longer than one year; in addition ways must be found to make the new behaviours into

routines - so that it doesn't matter that the newness wears off).

- Surveys held before or afterwards may invite socially acceptable answers from respondents (a way around this can be to address the same item with very different questions).
- Many pilots have been done in the US and transferability of those conclusions to European contexts is problematic because of differences in climatic circumstances.
- An important limitation of most pilots and studies is that they focus on whether price incentives have had an impact in terms of saving or shifting, not addressing the question *how* end-users decrease their energy use if they do so.

These are not just issues of interest to researchers, they have a crucial impact on how the outcomes of studies are being valued and translated into recommendations. In our view, many pilots and projects start with a focus on economic incentives in combination with technology, intended to bring about changes in end-user behaviour. By taking a techno-economic starting point, and assuming that a part of the end-users will and a part of the end-users will not respond to financial incentives (the dynamic prices), these studies seem to ignore the fact that end-users can have various motivations to change their behaviour - a financial motivation being one of these. Most studies conclude with recommendations to design a one size fits all dynamic price approach which then in practice may turn out to be not effective nor cost-efficient.

In our review, we explicitly search for a better understanding of why and how end-users change their behaviour. Rather than starting an intervention with selecting instruments (price incentive, technology, and feedback), we propose to turn the process around and take the end-users as a starting point in the process of designing a dynamic pricing approach. When we know more about the end-users, their needs, motivations and behaviours, we are better able to design a dynamic pricing approach that also fits their interests and needs (Breukers et al, 2009).

We will however start with an introduction to dynamic pricing mechanisms, load shifting, then continue with essential components of a dynamic pricing approach (technology and feedback), and then discuss behavioural change and how to put the end-user centre stage to any pricing intervention. We continue with a reflection on the Dutch context and the role of the Dutch DSOs and conclude with recommendations, lessons learnt, and remaining dilemma's.

2. Dynamic pricing

Price incentives aim to achieve a shift and/or a decrease in overall energy consumption. When these incentives vary according to time (e.g. hour of the day, season, critical peak periods), it is called time-dependent or dynamic pricing. Dynamic pricing became first relevant in areas with summer and winter peaks in demand combined with supply constraints where the demand during critical hours needed to be reduced and shifted to off-peak hours (California, Ontario, North-eastern parts of the USA and parts of Australia) (Darby 2006). For other countries, increasing issues with balancing demand and supply and expected expansion of micro generation inform the recent heightened interest in dynamic pricing.

Generally, DSOs and energy suppliers regard dynamic pricing first and foremost as a potentially effective means to achieve a better balancing between demand and supply and realising security of supply. Next, for DSOs that have a clear public task (like the state-owned DSOs in the Netherlands) the overall societal aims in terms of increasing energy efficiency, energy conservation and facilitating the deployment of renewable energy that ask for strategic load shifting to high supply hours are also aims that can be supported by dynamic pricing. Several studies and reviews conclude that these pricing schemes all have the potential to result in a shift in demand and in a reduction in demand (Faruqui and Palmer, 2011; 2012; Stromback et al, 2011). Dynamic pricing can be coupled to automatic and remote control of appliances (e.g. washing machine, dishwasher, thermostat). The dynamic tariff can apply to both the energy-price of suppliers and/or the price of transporting the energy by the DSO or TSO. The most common forms of dynamic prices are briefly presented below.

2.1 Time of Use (ToU) pricing

Time of Use (ToU) tariffs are recurring daily and aim at encouraging people to use energy during periods of the day when overall energy consumption is lower. In principle, ToU is not aimed at reducing overall energy demand, merely at shifting the demand from one period to another. The peak hours are invariable and known a long time in advance by the end-users. A day can have one or more peak periods during which the prices are set higher in comparison to the prices for the rest of the day. Two to four levels of prices may be distinguished (peak, partial peak, off-peak, and weekend tariff) and in addition, prices may also vary according to the season (Stromback et al, 2011:83,84).

Annex 1 lists several trials conducted in Europe with ToU pricing - in Northern Ireland, UK, France, Germany and Norway. The realised peak reductions in these pilots vary from 0 to 12%.

Many studies only focus on the achieved peak reduction, but some also metered the increase during partial peak or off-peak periods. For example in a large roll-out of ToU in the region of Trento in Italy, the morning peak moved from 7-8 o'clock to the partial peak period of 6.45-7.15 but this peak was less high than the previous peak, which means that the remaining demand was shifted to off-peak periods. In this case there was no overall reduction of consumption (Torriti 2012).

2.2 Critical Peak Pricing (CPP)

Critical Peak Pricing (CPP) schemes offer lower year-round tariffs during non-peak hours in exchange for substantially higher tariffs during critical peak hours. Critical peak periods or event days occur at times of increased wholesale prices due to heightened consumption (e.g. very hot or cold days) or when the stability of the system is jeopardized (e.g. risk of black-outs). The maximum number and length of critical peak periods is agreed upon with the end-user in advance. However, the exact moments when critical peaks occur cannot be set in advance as these depend on market and weather conditions. Usually, households are informed a day in advance of an expected critical day (Stromback et al, 2011:83). The number of critical peak days vary from 1 to 18 a year (San Diego Gas & Electric Company 2010).

Often CPP is the winner over other pricing mechanisms in terms of reduction and shifting potential, but this should be placed in perspective since CPP only is accomplishing this during the peak days while ToU schemes are at work seven days a week (Stromback et al, 2011). CPP also raises questions about fairness, e.g. for those who are less well able to shift during critical peaks (e.g. people who need to stay at home and cannot not use during CPP event days) - which is why it is usually voluntary. One European example of the use of CPP is the TEMPO Tariffs pilot that EDF started as an experiment in France in 1989- 1996 and which recruited some 400,000 end-users. The programme combines ToU with CPP and has been quite successful with an overall national peak reduction of 4%. ToU in combination with CPP can achieve a load shifting up to 30% (for a limited number of days and hours a year) and supplemented with load control this percentage has in cases (outside of Europe) risen to 50%. In Sweden this percentage of 50% has also been reached - thanks to electric heating and water heaters that provided significant flexible loads and thus good opportunities for shifting.

2.3 Critical Peak Rebate (CPR)

With Critical Peak Rebate (CPR) schemes the end-user is refunded at a predetermined tariff for any reduction in consumption relative to what the utility expected the household to consume during a few critical peak hours a year (usually during very hot summer afternoons, or very cold winter evenings). Like with CPP, the maximum number and length of critical peak periods is often agreed upon in advance. And like with CPP, the exact timing cannot be predicted as it depends on market dynamics but usually end-users are notified a day in advance of a critical day. (Stromback et al, 2011:83). Because with CPR participants benefit from participation, unlike with CPP where participants can be financially 'punished', this scheme may be more appealing to end-users. It is also a relatively new form of pricing which has not yet been used in a large number of pilots.

In Europe the need for load shifting during a limited set of hours in a year is less felt than in countries with great climatic differences and either extremely hot or cold days and therefore CPP and CPR have not seen a wide roll-out in Europe. One exception being France where the TEMPO project combined CPP with ToU tariffs. scheme. In addition CPP and CPR are particularly useful when there is a significant flexible load (e.g. air conditioning (AC) and electric heating that can be turned off during peak hours, and in Europe these technologies are less widely used then in countries such as the US, Australia and New Zealand. Consequently, most findings of CPP and CPR pilots are from outside of Europe - with peak shifts of up to 38%. Effects have been shown to be lasting during long-term pilots (Stromback et al, 2011).

2.4 Real-time pricing (RTP)

Real-time pricing (RTP) means that the end-user pays a price that is tied to the electricity price on the wholesale market. To encourage consumption reduction during high price periods and reduce risk of high bills, end-users can be informed when wholesale prices reach a certain threshold (e.g. by an text message alert) so that they need not check the prices continuously (Stromback et al, 2011:83). RTP has also been trialled as day-ahead real time pricing which poses fewer technical challenges. to be truly effective RTP schemes need to be connected to smart appliances (price to device) that automatically respond.

RTP means that the end-user pays a price of electricity on the wholesale market reflects. He/she pays a price linked to the price of electricity on the APX. It is especially useful if the end-user can receive a signal (e.g. an SMS alert) when prices exceed a certain threshold - so that the end-user need not keep their eyes on the prices all day. RTP has also been tested as a day-ahead RTP which is technically less challenging. A limited number of pilots that have not produced robust results show the following percentages (Frontier Economics and Sustainability First, 2012; Stromback et al, 2011):

- 13% reduction on the basis of peak 3 European pilots
- 10% peak reduction on the basis of 12 American pilots

In a US pilot where one group participated in ToU and CPP pricing, and the other group in RTP, the latter showed a weaker response (the peak reduction in the RTP pilot was 17% versus 20% peak shift in the ToU and CPP pilot). RTP is experienced as complex by end-users which may have influenced the lower results with the RTP pilot (Frontier Economics and Sustainability First, 2012). A pilot study in Norway with 81 participants gave non-significant results (Frontier Economics and Sustainability First, 2012). Like with CPP/CPR, automation of remote controllable appliances is likely to enhance the response - particularly in case of flexible loads like AC or electric heating. (Frontier Economics and Sustainability First, 2012).

2.5 Inclining Block Rate (IBR) pricing

This scheme is the least common scheme. Prices increase in steps as consumption increases. This pricing mechanism has been proposed as a complement to e.g. ToU or CPP and serves mainly conservation goals. As the name indicates, Inclining Block Rates offer block-wise increasing rates.

As a household consumes more, the rates increase. The first block is the cheapest, sometimes even free, and subsequent blocks are increasingly expensive. IBR is mainly seen as an incentive to encourage reduction. The few pilots, for example in California and Japan showed that a small group of end-users with a very high consumption showed most response. In Belgium, and IBR system is in place since 2001, with the aim to help low-income consumers to keep their spending on energy within limits. However, it has had little effect on the consumption of the poorer households, because they appeared not to be aware of the existence of this mechanism (CREG, 2010).

2.6 Dynamic pricing and Conservation

Most dynamic pricing schemes mainly focus on realising a displacement of the demand to off-peak periods, but some such as the inclining block rate also aim for overall reduction. A review of 5 large studies conducted mainly in the North-West of Europe concludes that: *"(…) in best cases a consumption reduction of 2-4% can be expected in the short term. This corresponds to around 15 to 30 Euros saved per year for an average European household (3,500 kWh at 0,20€ per kWh). The best cases include a smart meter that is linked to an IHD (direct feedback) or to accurate billing, with energy efficiency advice."* (Wallenborn & Klopfert 2010:21). In US pilots, we see similar savings percentages (EPRI 2008). ToU schemes in general will not explicitly aim at reduction, although consumers can become more energy-literate and reduce their energy consumption in the process. With CPP and CPR there is a larger reduction to be expected because often the energy which is not consumed during these critical hours or days is unlikely to be fully compensated for with consumption at other times. E.g. if the air-conditioning or electric heating is turned off for a few hours, this will not be compensated for at other times. There is also a potential danger of increased consumption as a result of dynamic pricing, as the Italian Trento ToU project demonstrated. The off-peak tariff was so low that even with increased consumption the energy bill of households still showed cost-savings, whilst their comfort level had increased. An increase of 13% had been witnessed (Torriti 2012).

2.7 Responsiveness to dynamic pricing

The responsiveness of end-users depends, first of all, on the characteristics and resources of the end-users themselves (more about that in the following sections below), the shift able loads in their households (e.g. electric heating and AC offer good opportunities with minimal loss of comfort), and it depends on the duration of the periods of high pricing as well as the ratio between peak and off-peak prices (Faruqui and Palmer 2011; Stromback et al, 2011). Faruqui and Palmer (2012) have indicated that the response on increasing tariffs follows an 'arc of price responsiveness' which means that the amount of demand response rises with the price ratio but at a decreasing rate. A New Zealand study among 400 households showed that end-users who decreased electricity consumption did increase their response to inclining lower tariffs during off-peak periods but that their response did not differ when faced to pay 8 or 18 cent per KWh in peak period (Thorsnes et al, 2012). The optimal ratio between peak and off-peak tariff for different segments is a topic for further piloting and research.

In addition, for both CPR and CPP, the responsiveness of participants increases when the change in tariff is announced timely (e.g. a day rather than an hour in advance) and when the duration of the price change is not too long (4-6 hours rather than 6-10 hours) (EPRI 2008). In combination with remote control of appliances the responsiveness can double.

2.8 Shifting demand, shifting loads

Figure 3 and table 2 below look at 'load management' options from a supplier or DSO point of view, summarizing the ways in which load may be managed and with different purposes (from matching renewable production to reducing peak demand). These load management options can be realised using dynamic pricing, sometimes in combination with automated, utility- or household remote control. We will not discuss forms of load management that have not been piloted in Europe or that are technologically extremely challenging, nor will we discuss load management forms that predominantly need the involvement of large energy-users (e.g. industries). Our focus lies on strategies aimed at changing household demand patterns, that can in principle be readily implemented - and then our specific focus is on better understanding behavioural aspects related to those demand patterns. This means that the use of pricing mechanisms in this study is mostly focused on peak clipping or load shifting.

The six load management options fall into three main categories (http://bee-dsm.in/DSMTheory_1.aspx):

- Load management programmes that aim at redistributing energy demand to spread it more evenly throughout the day.
- Conservation programmes aimed at reducing energy use.
- Strategic load growth programmes aimed at increasing energy use during some periods, e.g. to encourage the use cost-effective electrical technologies or the direct use of intermittent sources.

Peak clipping (figure 3) is an option that can be used to meet extreme demand on critical peak hours or days, in combination with CPP and CPR. Often the avoided electricity consumption realised with CPP and CPR is not consumed at other moments, because it often involves the turning off of high flexible loads such as air-conditioning or electric heating. An overall reduction of consumption can of course also contribute to peak clipping. Strategic conservation is focused on the permanent reduction of consumption in both peak and off-peak periods and can be realised by a combination of ToU and inclining block rates. Valley filling is an option that has the purpose of flattening out the load, in principle industry with a base load that runs continuously already demonstrate a flat load. In the future valley filling will be an option to maximise the use of intermittent renewable sources that produce during those valley hours, e.g. solar. Real Time Pricing will be a logical pricing mechanism for this option.

Flexible load shape is the most complex option and will be an option for the future where many intermittent renewable sources, storage options such as EV and heat pumps, micro-CHP, and smart appliances interact with an household demand and ask for a on a need basis direct response from the household. Real Time Pricing will then most likely be used as dynamic pricing mechanism in combination with utility control of storage and demand technologies. Strategic load growth occurs only when specific technologies are added to the household mix such as EV or automation, and these can then be used to also allow for flexible load management.

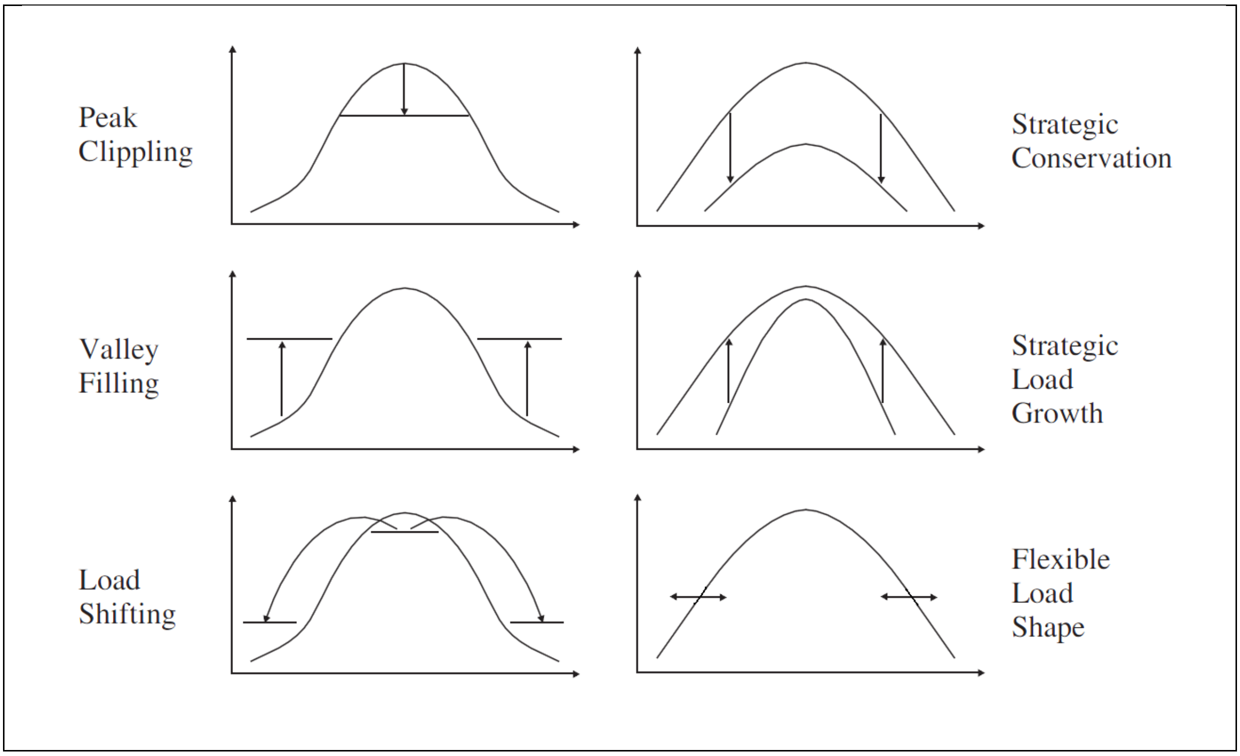

Figure 3: overview of load shifting options

Type of shift	Definition & relevance for households?	Which price mechanism & why	Implications for technology, feedback and remote control?
Peak clipping:	Peak shaving and clipping both aim at a non-shiftable reduced electricity consumption in critical peak periods (when overall demand is high). Relevant for households.	CPP, CPR potentially with ToU	This option is traditionally accompanied by remote utility control and needs remotely accessible appliances (e.g. thermal and cooling)
Valley Filling:	Encouraging an increase of energy use during off-peak periods (in order to make the production and supply system more efficient, e.g. to use intermittent renewable generation or to increase cost-effectiveness of certain energy intensive technologies). Currently more relevant for large energy users but in the future with micro grids and decentralised generation on household level households will also benefit from valley filling.	ToU, RTP, and to a lesser extent CPP, CPR	This option requires a relatively dynamic price information to allow for cost-effective use, or a link to renewable generation information. Automation can facilitate the effective response of appliances. But households can also manually shift demand, e.g. tumble dryers, washing machines and charging of EV.
Load Shifting:	Regular moving of demand from times of high to times of low demand (resulting in demand increase during off-peak hours and demand decrease during peak hours) Relevant for households.	ToU most effective, in combination with CPP, CPR	This option allows for most influence of household members to respond through changes in behaviour, and not necessarily with assistance of automation.
Strategic Conservation:	Overall and constant reduction in consumption	In principle dynamic pricing is not the first option to achieve strategic conservation. tailored tips, tricks, installation of energy efficient appliances and changing of routine behaviour is more suited.	Automation can help to achieve strategic reduction by controlling thermal devices such as the fridge, AC, thermostat and regularly turning devices off (without compromising comfort or hygiene)
Strategic Load Growth:	Strategic load growth allows for an overall increase of load level because of the installation of automation or additional technologies such as EV that will also allow for a more flexible load shape to develop. The load growth can, just as is the case with valley filling, also take place strategically during specific moments of the day or certain days to match generation by intermittent and renewable sources such as windy or sunny days or moments. For large users and in future with increased integration of EV and renewable also for households.	RTP or a new version of CPP is the best option to encourage temporary load growth	functions most effectively with automated remote control unless the predictability of the need for increased demand is increased.
Flexible Load Shape:	This entails the ability of the demand side to respond to sudden generation changes in real time by providing reserve - e.g. when wind produced electricity is lower due to forecast errors. For households and companies that have reserve capacity (e.g. electric vehicles; decentralized energy generation)	RTP, CPP, CPR	In combination with EV, decentralized energy generation.

Table 2: different forms of load management

2.9 Load shifting and/or reducing?

From the perspective of DSOs there is the tendency to focus on shifting only, because net stability is the priority concern that DSOs need to address for the short, medium and longer term. However, a single focus on shifting only can have severe perverse effects, as two examples show. First, the top-down mandatory enrolment of a ToU in Trento, Italy, aimed at shifting only. This shifting was achieved, but the end-users increased their overall energy consumption while lowering their bill. While overall costs decreased, an overall increase in consumption of 13% (!) and new peaks and large shoulders resulted (Torriti 2012). An OECD study among 10,000 households in different EU countries also showed how incentives that solely aimed at shifting resulted in cases in overall increases in energy consumption, for instance because people decided to run half-filled washing machines during times of low tariffs. While for energy suppliers, this inefficient behaviours may not be a crucial issue, for Dutch DSOs that also aim at furthering the common interest of attaining a more sustainable (hence more efficient) energy system, such outcomes should of course be prevented.

3. Essential components of a dynamic pricing approach:, technology and feedback

Dynamic pricing is a means to an end - or to several ends - like for instance to balance supply and demand; to prevent the need for grid extension; to achieve end-user energy saving; to raise awareness; to more actively engage end-users and decentralized producers. A dynamic approach consists of the following three elements: the pricing mechanism, supportive technology and feedback. Pricing mechanisms (e.g. ToU, CPP, CPR, RTP) have been discussed above. Below we turn to the elements technology and feedback.

3.1 Technology

As for technology, this covers a wide range of supportive and feedback devices, of which smart meters and In-House-Displays can be considered as absolute 'must-haves' in combination with dynamic pricing. An important technology is the In House Display (IHD) which provides feedback in a variety of forms and has been shown to significantly improve the response from end-users (Stromback et al, 2011). Other useful technologies include ambient displays like energy orbs, smart apps, websites, email services, but also very simple devices like paper mailings, fridge magnets or stickers (figure 4) and water saving showerheads.

Figure 4: Example of a sticker indicating the time bands (CER 2011: 56)

A crucial precondition to work with dynamic pricing is the presence of smart meters. Both national and EU energy policy aim for a widespread roll-out of smart meters. In fact the latest EU directives stipulates that a European roll-out of 80% of the smart meters by 2020 is mandated (Directive 2012/27/EU). The smart meter is a needed for actual and real-time metering of the energy consumption patterns. This allows for the design of a tailored feedback that takes account of the particularities of the household. The smart meter makes a two-way communication possible between households and utilities or suppliers, depending on which party is responsible for the roll-out of the smart meter. In the Netherlands the DSOs are responsible for the roll-out. However, households have the opt-out option whereby they the smart meter is installed in their homes but administratively disconnected, which entails that the smart meter is not sending data out of the home to any third party. The household itself can still make use of the data by means of technologies such as e.g. usb energy sticks or wireless plug systems.

Smart meters are promoted by policies that aim at achieving energy efficient behaviours and encouraging end-users to become more active participants in the energy market. While information feedback is considered useful to inform end-users on their current and past energy consumption and associated costs, the addition of dynamic pricing is considered potentially useful to encourage a shift in demand. Some ask rhetorically what the use would be of having smart meters with dumb rates (Faruqui and Palmer, 2011). Others however, point out that meters nor rates in themselves will cause changes in consumer behaviour. Based on their review of 6 large Northern European studies, Klopfert and Wallenborn indicated that a 2-4% reduction in electricity consumption can be achieved through combinations of smart meters and feedback (including dynamic prices), *but only when consumers have opted for its use*. No such effect is observed when smart meters are installed without the explicit agreement of consumers (Klopfert & Wallenborn; 2011). Frontier Economics has investigated the costs and benefits of smart meter roll-out in Germany and concluded that full-scale mandatory rollout of smart meters in Germany is not cost-efficient. Instead it is suggested to install the meters only in those households where the saving potential is highest and where the residents themselves think installation is worthwhile. In addition, a variety of factors may play a role depending on the particular housing characteristics, appliances and equipment, size of the house and consumption patterns. The benefits of any given technology option will differ for different households (Frontier Economics, 2011). This conclusion highlights the need for a segmentation approach to the roll-out of the smart meter and the accompanying dynamic pricing. Even if there is a large *theoretical* potential for energy saving and shifting in households, the extent to which this potential can be realized depends on which households are willing to participate actively and respond to information and incentives by reducing and/or shifting their consumption. Working with estimations on how 'average' households will respond are of no use, because the actual saving potential can vary from household to household. We will discuss segmentation in detail in section 4.

3.2 Automation and remote control

More complex technologies that support behavioural changes in response to pricing include all sorts of smart appliances that can be programmed to respond to (changes in) information and/or remote-controlled. The following two types of automation can be distinguished:

1. remote-controlled end-user appliances, not involving any further agreement of the end-user other apart from his/her agreement to participate
2. through the use of interfaces (smart thermostats or websites), which allow end-users to

choose the extent to which they want their appliances to respond to price signals.

In principle, the advantages of automation and remote control is that it allows for very quick responses and controllable levels of reduction, that it is available when system emergencies occur unplanned and when households are unable to take action (e.g. when away or asleep). At the same time, there is no evidence showing that with this second type of automation, the extent of participation to critical events is any lower than when appliances were remote-controlled (Stromback et al 2011).

Well-known examples of automation in combination with pricing come from countries were AC or electric heating is widespread (e.g. the state-wide California pricing pilot and the SMUD pilot in the US (SPP 2004) which then are programmed to respond to peak periods. Most cases on which figure 5 below is based, stem from such countries.

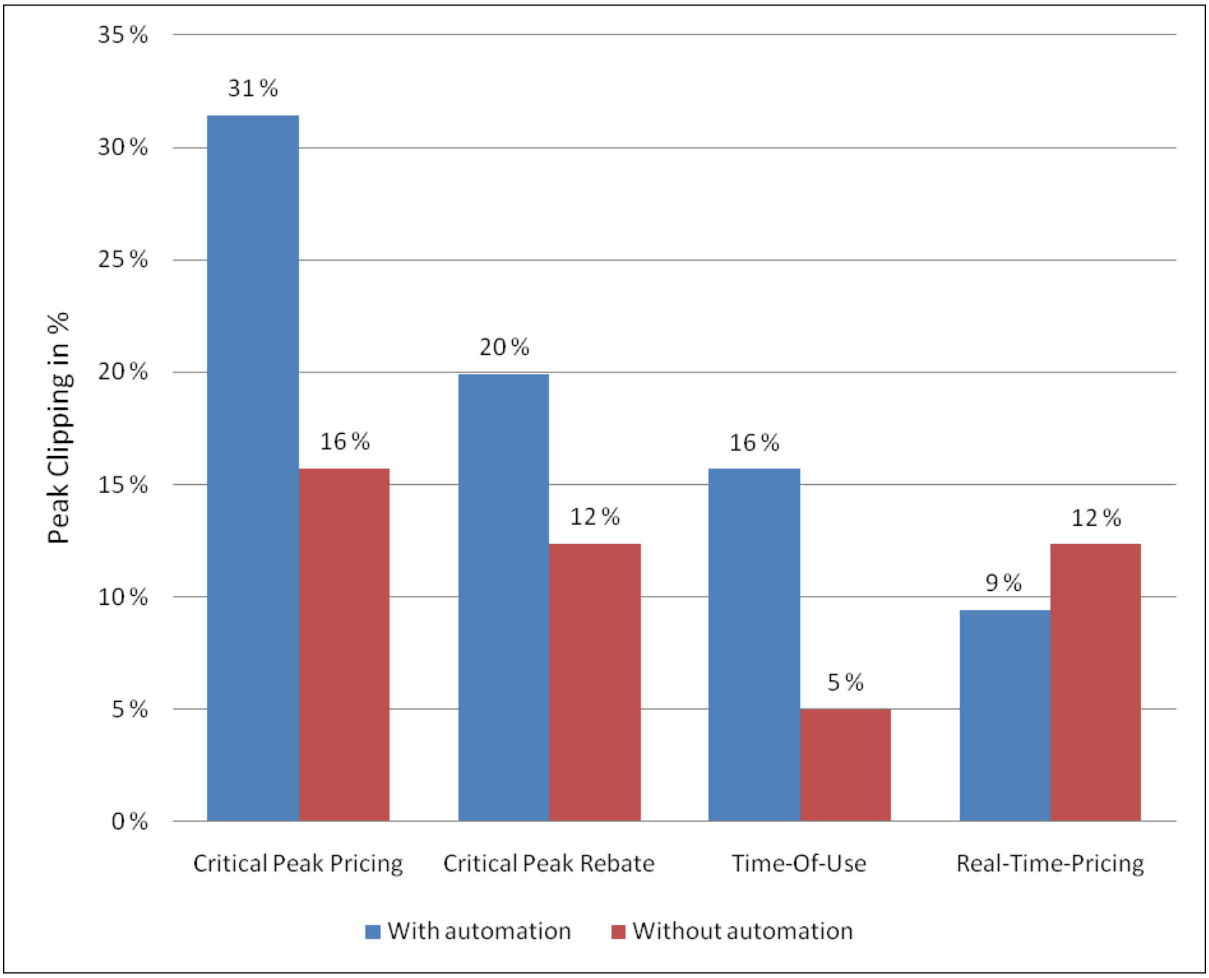

Figure 5: Impact of automation on peak clippings (Stromback et al 2011: 58)

(nr of trials without automation: CPP: 69; CPR 16; ToU 215; RTP 15; nr of trials with automation: CPP 29; CPR 11; ToU 35; RTP 10)

These levels of response to CPP and CPR will most likely not be reached in Europe, since the climatic circumstances and the availability of flexible loads with great potential are different. Automation systems can also include lighting, white goods and entertainment equipment, which is most likely the automation form that would fit the European countries with moderate climates without temperature extremes and without electric heating. Automation can include very low-cost options like for instance using a time-clock that makes sure that the fridge turns of 15 minutes at set intervals. However, it can also include high-cost options when smarter appliances have to be purchased and/or made suitable for remote-control, and become part of full Home Energy Management systems, security systems, with couplings to personal computers (PCs), smart phones or pads.

A crucial precondition for effective use of automation is that the end-user understands the technology and appreciates it. In addition several studies highlight the concerns consumers have to hand over control over their energy demand to third parties. In fact on average throughout European countries, the majority of consumers do not wish to hand over control to a utility. In the Netherlands, this amounts to 53 percent of the respondents that said no to utility control (Accenture, 2010 a, 2010b; Ryan & Blackmore, 2008).

Since automation and other technologies are intended largely to interact with the end-users and are intended to be integrated in their homes, this interaction should fit the needs, wishes and capabilities of the end-users. Different (segments of) people are likely to appreciate technologies differently. In addition, people may change their appreciation - changing from an initial hesitant attitude to a more enthusiastic one or changing from enthusiasm to weariness with a particular technology. An important question in this light is for instance how to keep the IHD interesting for users over time (Van Dam et al, 2010). Hence, the choice of technology needs to be tailored to the changing needs of end-users to achieve optimal effectiveness. And to achieve this tailoring, segmentation is key.

3.3 Feedback

Feedback intended to support reductions in energy consumption has gained a lot of attention in research (Darby, 2006; 2010; Mourik, 2011; Stromback et al 2011). Feedback is part of any approach that aims at encouraging end-users to change their energy consumption behaviour. Traditionally, we can distinguish between direct, indirect and associative feedback (Darby, 2006). Direct feedback consists of information that is readily available on request (that is to say that this instantaneous responds to changes in the energy metabolism, and as the results of shows). Learning from this feedback takes place through the process of reading this feedback or by having to pay for energy. The advantage of this form of feedback is that it directly shows the impact of behavioural changes. Indirect feedback is characterised by a time delay - it is suitable to show the effects of changes in the heating consumption. Unintended feedback results from (associative) learning, for example when the bill increases after buying a new device or when the installation of own generation / micro generation encourages people to read their meter (more often). In addition, we distinguish between feedback intended to communicate price changes and feedback to communicate (changes in) consumption patterns and volumes.

A study on effective feedback to encourage behavioural change towards energy consumption reduction (Mourik 2001) concludes with recommendations that are relevant as well when designing a dynamic pricing intervention - whereby the relevance will however depend on the characteristics of each segment. The lessons are summarised as follows (Mourik 2011):

1. Need for a smart meter and user interface, which can be an In-House-Display, a smart phone App or an ambient technology (e.g. changing light colours)
2. Feedback lasts at least 3 months but preferably is permanent: for any programme to be able to change routine behaviours, a minimum of 3 months is necessary to have the potential to make the 'new' behaviour lasting. The longer the intervention, the better the chances that the new behaviour lasts
3. The feedback is direct, without time-delay. Direct feedback allows people to walk around in the house and experience how turning devices on or off as well as other behavioural changes affect energy usage. This helps to make energy visible and to set priorities with regard to behaviours that can be changed and how that will affect energy usage.
4. The feedback is detailed, providing Information about devices, spaces, people and functions (e.g. cooking, heating, entertainment). Pilots showed that the more detail is provided, the more effective the feedback is in changing energy behaviours. Detail helps end-users to estimate how devices, actions, and people contribute to the overall energy usages, which allows them to start discussing this and set priorities.
5. The feedback is historical, normative and involves goal setting. Historical feedback shows usage in the course of time, preferably in months. This can be compared with the other months in the same year or with the same months in previous years. If a normative element is added - showing usage of similar users in the same period - effectiveness is further enhanced. It should be up to the end-user to define who count as similar users. Feedback can become even more effective if end-users set a goal and get feedback about the extent to which they are successful in achieving this goal.
6. The feedback is positive, graphical and symbolic: the most appreciated display of feedback is a combination of graphical and textual information. *Graphs* are preferred to show historical feedback. Feedback is best positive, not providing too much Information of what has not been achieved but rather emphasising remaining saving potentials. Symbols like smiley or polar bears that look happy or not depending on energy consumption have shown to be effective.
7. There is a combination of user-interfaces (device media/locations) at different spots in a household displaying different Information in combination with particular media. Direct simple feedback where householders can respond directly is particularly effective when show non home displays (fixed or mobile). Background information, information on patterns and changes in these is best provided on a website or via the bill. Certain spaces/rooms may also affect the acceptance of feedback - e.g. a display near the front door that shows the thermostat temperature and that tells which lights are still on, is considered helpful as the hallway is a spot where people consider what is working, what is on/off in the house. The couch in the living room however is more a place to relax and there people do not want to be incentivized by a display that encourages them to take action.

8. The feedback system is being continuously improved and updated: a danger of feedback systems is that they disappear into the background because they no longer provide new information, are not considered aesthetic, are not inviting much interaction with the end-users. Feedback systems should be developed as very interactive systems that deliver information that is constantly renewed and updated (like with a computer or smart phone) and that is of increasing complexity.
9. There is maximum interaction possible with the meter and/or display which results in new routines around the feedback system. Keeping the end-users engaged is a huge challenge for a decrease in engagement will make the feedback less effective. However, if checking and using the system is so easy then it can become a new routine. Coupling the system to other systems that ask for regular interaction can help (e.g. security system or smart Phone with daily briefs).
10. A supportive social environment ensures that there is no constant negotiation on underlying norms : The social environment needs to be supportive in order to make the changed behaviour last. This starts with the household itself: if some members do not participate in the initiative, the feedback will be less effective overall because this de-motivates the participating members of the Household. The display and the feedback are tailored to the situation and wishes of each household (member) : A household is not a homogenous group. Men and women often differ in their attitude towards energy, their responsibilities within the household. In addition, there are generational differences in attitudes and motivation. It is important that diverse user can get feedback that meets their needs and wishes. Communicating consumption patterns can in general be done in Euro's, not only when end-users are financially motivated but also when this is the most tangible unit for people - easier to understand than CO_2 or kWh.
11. The feedback also gives personal advice and is coupled to other interventions: the most successful feedback gives personal advice to each household member. In addition, the feedback is supported by other interventions like financial incentives, audits, campaigns.
12. There is no negative impact on (perceived) comfort and ease-of-use. When end-users have the idea that behavioural change negatively affects comfort and ease, they will be less motivated to change their behaviours. The most successful feedback and communication will show that changes will result in an increase rather than a decrease in comfort and ease.

3.4 Pricing and feedback

Different pricing incentives will ask for different types of feedback (feedback related to price changes and feedback related to consumption changes) during the times the price is applicable to, and feedback on. RTP needs real time feedback on consumption and on price changes. This can be provided by means of ambient technologies such as light bulbs that start to flicker or change colour when prices increase and consumption is 'too' high. In addition, users must be enabled to study their historical usage as well to see what the impact of their changed behaviour has been on consumption and price. For ToU, the feedback should at least show the attained reduction or shifting in response to the peak and off-peak tariffs. Some people may want to check this on a daily basis, for others find a monthly overview sufficient. In addition simple technologies such as stickers or magnets with an overview of the ToU periods are very valuable to remind people. For ToU the feedback will need to be provided long enough for new routines to rise. When new routines have become embedded, the frequency of feedback can be decreased. Providing feedback whenever consumption is increasing again during peak hours, can be useful as well. Feedback that informs individual household members of their achievements can be useful, so that they are all enabled to make a well-informed decision about the best options for reduction and/or shifting.

The more stable the price incentive over time, the more simple the feedback can be. When pricing incentives are not frequent, and even not fixed in advance (e.g. CPP, CPR), text message alerts, or other reminders and prompts via email or facebook will work well. The more frequent the feedback on consumption is needed, the more complex the necessary technology will be: e.g. smart appliances, real-time feedback, remote control, energy orbs etc.

3.5 Effective load shifting and combination of pricing, technologies and feedback

In some studies results demonstrate that the more combinations are made between pricing mechanisms, technologies en feedback the higher the response of people (in terms of the achieved shift and the number of people that respond). Faruqui et al (2010) for example demonstrated after analysis of multiple large pricing pilots in the US that the combination of ToU, CPP, CPR, with multiple enabling technologies and feedback technologies generated the highest peak clipping and load shifting. See figure 6 below. However, this is easily explainable since with such a 'full court' approach a large section of different segments can be reached. As such the rule ‘more is better’ may apply when all segments are targeted with a one-size-fits-all approach - using as many technologies and feedback options as available in order to reach as many different people as possible. However, this will not deliver the most cost-efficient approach and since the brunt of the costs eventually comes down on society, it is undesirable from a societal perspective. A New Zealand's pilot that targeted a particular segment (high incomes, high age, new houses) found that ToU worked fine in combination with only energy saving tips and a monthly bill that showed the realised shifts during peak-periods per day (Thornes et al. 2012).

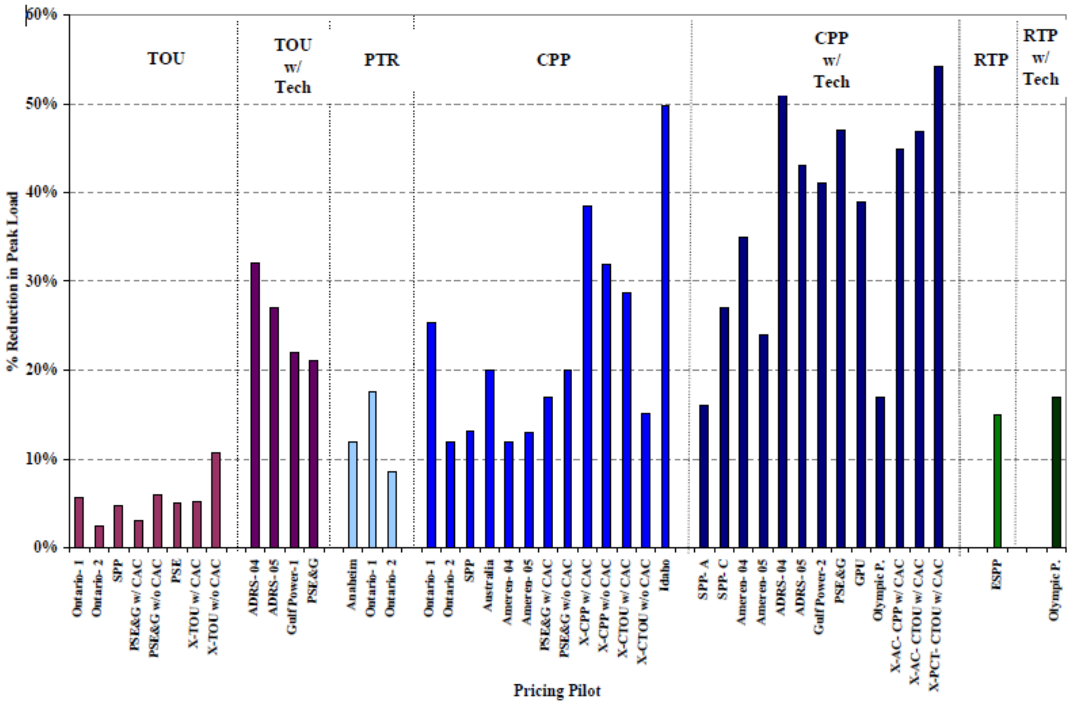

Figure 6: effective combinations of pricing mechanism and technology (source: Faruqui & Sergici, 2009)

With these lessons in mind, a next step is to consider what elements are relevant when designing the feedback components in a dynamic pricing approach. When addressing messaging and channels (IHD, billing, website, smart phones, email), different technologies come up which will appeal more or less to particular end-users. This will also be discussed in the section on segmentation.

3.6 Pre or post-paid energy

Next to price incentive, technology and feedback, the type of payment can be useful to consider. Here we can distinguish between post-paid and pre-paid systems. In the Netherlands post-payment is most common. This can also involve long-term contracts whereby end-users sign-up for receiving electricity for a set price for the duration of a couple of years. Prepayment systems have gained popularity in Northern Ireland recently. These keypads or pay-as-you-go meters (Darby 2006) allow households to pay for electricity as they use it - instead of paying quarterly bills. Credit can be topped up when needed and apps have been launched to make this more user-friendly. In 2006, savings due to the use of key-pad meters were estimated at 3%. In 2009, 30% (230,000) of all electricity customers in Northern Ireland were using the keypad prepayment meters1. Of these, 58% are low-

[1] with new connections continuing at a rate of 2000 per month

income, 32% middle or higher incomes, including 17% more wealthy consumers. Other countries that have prepayment systems adopted include the UK, Australia, Argentina, South Africa and Belgium. In the UK, prepayment meters are popular among *very* low income households, because it gives them budgeting control and avoids worries about bills and becoming indebted - which outweighs disadvantages such as the risk of self-disconnection and self-rationing. A large scale survey (Electricity Association 2001) showed that 85% preferred this method of payment, even when the respondents were aware of it being more expensive than alternatives (which is the case in the UK). In Flanders, Belgium, each household receives a free amount of electricity; senior and disabled citizens get an additional amount as part of a social tariff provision. While electricity suppliers have no obligation to deliver to households that do not pay their bills, the DSOs have the social obligation to serve end-users in their area that are unable to stay with their existing supplier or find a new one. EANDIS is such a 'social supplier' and installs prepayment meters that operates with a budget meter card, for each new end-user it takes on in this manner. The social electricity provision is such that households cannot completely self-disconnect (Owen and Ward 2010: 23).

Currently, two prepayment meters are in use. The first type, non-smart token meters (e.g. UK) work as follows: customers buy a token from a Pay point for a fixed amount (say £5). When the token is inserted into the meter, the meter operates with the energy credit/debt value on the token but does not gain any other information. These meters have to be manually re-set (requiring a supplier visit) when tariffs change (e.g. in the UK). The second type are the semi-smart keypad meters (e.g. Northern Ireland), where customer buys credit from a Pay point for a fixed amount (say £5) which is added to the key or card or embedded in a vend code (keypad meters). When the card or key is inserted into the meter, (or the code is typed into the keypad) the meter operates with the monetary credit/debt values and also receives any updates needed to tariff rates. It is these semi-smart meters that allow for offering a wide range of ToU tariffs.

In the Netherlands, both Eneco and Essent have done trials with prepaid electricity.[2] Both companies have however decided to discontinue their trials. A keypad meter like the one in Northern Ireland is very user-friendly with displays that can provide feedback in several ways and formats, depending on the end-user preferences. In addition, credit can be topped up in various ways - by phone, at pay points, or online. In Northern Ireland the prepayment scheme, originally intended for fuel-poor households, has become a commonly chosen payment scheme.

[2] Newspaper TROUW 19.11.2007

4 Behavioural change

4.1 From routines to intentional behaviours (and back)

To effectively target household and to design pricing mechanisms and load management that meet high response from households we need to understand the behaviour change asked from households, and therefore we first briefly discuss the types of behaviour people perform and what types of behaviour are asked of households when they are targeted with ToU, CPP, CPR or RTP. We can make a distinction between conscious/intentional behaviours and routine behaviours, but it makes more sense to talk about a behaviour spectrum as displayed in figure 7 below.

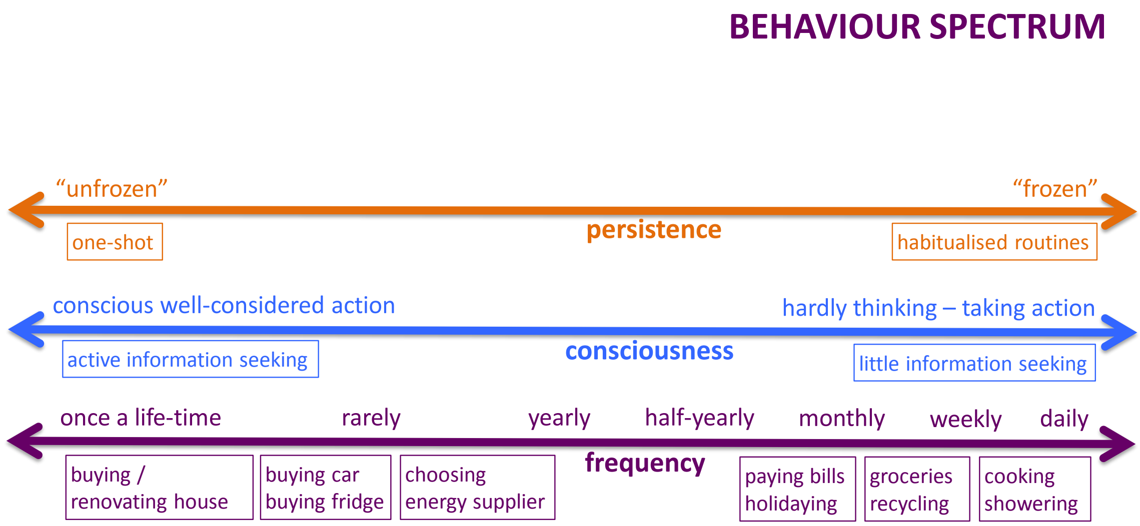

Figure 7: Behavioural Spectrum[3]

Intentional behaviours can include one-shot behaviours that are performed rarely and very consciously like for instance buying a house or investing in improvements of the energy efficiency of the house (e.g. insulation, double-glazed windows). But we can also think of more frequent intentional behaviours, e.g. the purchase of smart appliances and changing the settings of the thermostat. Dynamic pricing in the form of CPP, CPR and RTP encourage intentional behaviours - e.g. the critical peaks only occur a limited number of days a year in which energy consumption needs to be reduced or shifted. With RTP however, if the response is automated (e.g. automated response when the prices reach a certain threshold, the intentional behaviour only pertains to the moment of

[3] The authors thank Julia Backhaus for contributing to this figure

deciding to automate the response).

Routine behaviours are the recurring, habitual behaviours that affect how we do our daily things (cooking, washing, caring, working, etc). We can change unconscious routines by making them conscious first. Then an intentional behavioural change is possible which subsequently needs time become a new habit. Examples are changing the moment of dishwashing to other set times of the day or evening; or changing routines in showering - showering less long, less frequent or using less hot water. ToU asks for changes in routine behaviours as end-users are encouraged to permanently perform (different) behavioural patterns at different times of the day/night. People need at least 3 months to get used to new (dishwasher, washing machine, cleaning, entertainment, eating) routines during which (and preferably longer than that) reminders and prompts are crucial (Abrahamse et al, 2007; Darby, 2006; Fischer & Duscha, 2008; Janssen et al, 2007;Martiskainen, 2007). In addition since it involves the changing and settling of new routines, the effectiveness of ToU increases over time: people unfreeze their old ways of doing, adopt new ways of doing which over time become established routines. They may even purchase necessary appliances like for instance timers to help them control the energy usage of certain appliances (Filippini 2011; Thornes et al 2011; Torriti 2012).

Generally speaking, investment and intentional behaviours are easier to perform compared to changing routines (Breukers et al., 2009; Mourik et al., 2009; PwC2009). When changing routines, people find turning off the lights easier than using dishwasher and washing machine more efficiently. Turning appliances off is an even more difficult routine to adopt. Decreasing temperatures or decreasing level of coolness (in summer) is done less easily as this is perceived as directly impacting on the need for comfort. And turning off the stand-by mode is done even less frequently as it affects the perceived need for convenience and control (people often worry that that programmed settings are lost when turning the appliance really off) (DEFRA, 2007). Hence, there appears to be a negative relation between changing routine energy behaviour and the need for comfort and convenience. This also has consequences for the effectiveness of price incentives that target demand shifting through routine behavioural changes.

4.2 Behaviours and potential load shifting

Table 3 summarises the theoretical potential for load shifting and the reduction for different types of loads (appliances and practices) of households. Annex 2 provides for each appliance a more detailed argumentation.

Appliance	"Household Practice or need"	Flexibility in terms of potential load shifting	Options for reduction	Flexibility in terms of Willingness to shift and reduce	Automation/ remote control?
tumble dryer	Washing & cleaning	+	+	-	=/-
washing machine	Washing & cleaning	+	+	+/-	++
dish-washer	Washing & cleaning	+	-	+	+/-
cooking (if electric)	Eating & drinking	+/-	-	-	-
water cooker, microwave, espresso machine, coffee grinder, blender, oven	Eating & drinking	+	-	-	-
fridge and freezer	Eating & drinking	+	++	++	++
lights inside the house	Comfort	-	++	-	++
outside lighting	Safety	+	-	+	++
TV's	Leisure	+	-	-	-
music installations	Leisure	+/-	-		-
games	Leisure	+/-	-	-	-
PC's, tablets,	Leisure/ administration	+/-	-	-	-
hair-dryer; el toothbrushes, el razors, etc.	Care	+/-	-		-
stand-by	Ease	+	-		+
Vacuum cleaner; do-it-yourself and garden-related machines (e.g. lawn-mower, drilling machine, terrace heater)	Cleaning and maintenance of the house, balcony and/or garden. Hobby	+	-	+	-

Table 3: options for load shifting and reduction for different types of household demand.

Understanding what motivates behavioural changes (both intentional and routine behaviours) and consequently the responsiveness of households to pricing signals and the potential flexibility of certain loads in a household and how such changes can be made durable is important when designing a dynamic pricing approach. Segmentation offers a first steps towards designing and tailoring a pricing approach to the motivations, behaviours and needs of the end-users. A segmentation approach ideally addresses the following components:

- housing characteristics and appliances available
- patterns of presence and absence of the residents
- attitudes, motivations and actual behaviours of the residents
- socio-demographic factors such as age, income, education, gender

This is further discussed in the section below.

5. The end-user as a starting point

There are several reasons why a 'one-size-fits-all' approach is not advisable when aiming at energy consumption reduction or shifting.

- 'one-size-fits-all' approaches usually focus on providing financial incentives, assuming that people are mainly economically motivated to participate. However, there is plenty of evidence that people are not predominantly motivated by financial gains, but can also have other motivations that relate to environmental goals, health, comfort, etc. Two pilots in Sweden (Lindskoug,2006) showed that the majority of participants had other than economic motivations; they were environmentally motivated, wanted 'to contribute', or were interested in the challenge presented to them.
- Research on energy DSM aimed at energy consumption reduction has shown that approaches that target individual behaviour only - without addressing the social and physical environment in which behaviours are embedded - have not been very successful in achieving *lasting* behavioural changes (Breukers et al, 2009). In the case of dynamic pricing, attention for the characteristics of the house, the appliances, as well as the differences between social processes within a household are relevant to take account of. The introduction of dynamic prices in combination with an IHD that provides information on energy consumption, can trigger very different reactions in a household and can even cause conflicts to occur (e.g. Hargreaves et al 2010).
- The risk of rebound is larger if individuals are targeted with financial incentives only. No social norms are addressed, no pro-social behaviour is likely to occur (which is needed if the longer-term goal is to facilitate the transition to a more sustainable energy system). The likely result is that when the incentive is withdrawn, the individuals that responded will fall back into their 'old' behaviours - because their motivation was related only to their direct self-interest. If the incentive stays in place (which is the case with dynamic pricing), there is the risk of rebound: money saved will be invested in other energy-consuming activities - because the motivation is not based on pro-social values, nor on any broader consideration of societal interest related to energy- and environmental issues.
- Studies show that often only a small percentage of the participants is responsible for the response, while it remains unclear why they did and the rest did not respond. On average 30% of households were responsible for 80% of the load shifting (Faruqui et al., 2010). Using segmentation can help to gain more insight in this and design interventions that also reach the remaining 70%.

In line with an acknowledgment of multiple motivations and diverse (options for) behaviours, a dynamic pricing intervention may focus on facilitating one or more of the following end-user tasks (Foster and Mazur-Stommen, 2012):

- becoming aware and learning about one's energy consumption
- gaining or maintaining control over one's energy consumption
- saving costs
- being reassured that previous actions or investments have worked

- getting support in motivating other household members to reduce energy consumption.
- accomplishing other benefits like increased comfort, indoor climate, health impacts, social aspects

5.1 Segmentation: as the second-best option

Different end-users are likely to have different attitudes, motivations, behaviours, capabilities, knowledge and other resources - which will affect how they respond to and participate in dynamic pricing interventions. Ideally, these different end-users should be targeted in ways that fit what their needs, preferences, knowledge, capabilities etc. How to do that? Approaching individual end-users would enable us to find out what sort of intervention fits best with the needs of these end-users. However, interventions are often of a scale that does not allow for this individual approach in practice. In such situations, segmentation can offer a 'second-best' solution, as it allows for tailoring an approach to the needs of a group of end-users that share relevant characteristics. Then a dynamic pricing approach can be tailored to the particular characteristics of such a segment (targeting diverse motivations, norms, knowledge and capabilities, resources and behaviours/practices).

5.1.1. Segmentation: load profiles and socio-demographics

Segmentation is not totally new to dynamic pricing pilots. For instance, segmentations preceding the launch of dynamic pricing pilots addressed the characteristics of the house, the appliances and technologies present in this house. However, such segmentation have not paid attention to the people who actually live in this house (Stromback et al, 2001). Often, segments are constructed around particular 'load profiles' in order to match the envisaged pricing approach and technologies with the appliances and technologies in the household. While this is useful to estimate the theoretical technical potential of saving and shifting, this is not giving us any information on whether the people targeted will perform the behavioural changes needed to realize these potentials in full, and in practice the actual response is lower than the theoretical potential.

Apart from segmentation beforehand to distinguish diverse 'load profiles, segmentation on socio-demographic factors has also been used. Segmentations have been performed in order to explain pilot results - trying to correlate end-user responses to their socio-demographic characteristics. The Irish CER trial (see annex 1) made use of segmentation, investigating whether particular societal groups had responded in different ways to the ToU tariffs. They did so by using an existing and widely used demographic classification (http://www.mrs.org.uk) and performing surveys before and after the trial. It was found that the level of energy usage reduction declines as the socio-economic class declines. This is however also related to the level of overall household consumption which tends to be larger in high-income households. For peak reduction these relations could not be established with equal clarity. Factors such as employment status and home ownership also impacted overall and peak reductions (CER 2011:83). The CER trial addresses segments, but does not pay attention to actual motivations and behaviours of the people targeted. In another European trial, the EDRP study (see annex 1), there was limited evidence of how different population segments (e.g. based on geographic location or on an existing UK demographic classification called *Mosaic*) were affected by the interventions. The effects found were e.g. that smaller households were more likely to reduce overall energy consumption and to shift consumption from the evening peak period (EDRP, 2011).

Using a database with registered data of 50,000 households including socio-economic information of the householders, building-specific information (building type, year, size etc.) and meter readings on heat consumption (space and water) and electricity consumption (lighting and appliances) revealed the following correlations between users, buildings and energy consumption (Gram-Hanssen, 2011).:

- The number of household members is the strongest predictor of electricity consumption; income is the second most important and the size of the home the third.
- Variables like age and education of the inhabitants explain consumption only to a small degree
- Living together with more people is more energy efficient (the trend towards more single person households drives increases in energy consumption).
- Even when comparing households in detached houses of the same size and with the same income, huge variations in the electricity consumption appear. Income and household size together only explain one third of the variation in electricity consumption.

So while household size and income are the strongest predictors for electricity consumption, they still only account for one third of differences in consumption. Furthermore, heat consumption is much more dependent on the energy efficiency of the building (house-related characteristics), while electricity consumption is more dependent on end-user practices (including number, size and use of appliances) (Gram-Hanssen, 2011).

A recent study among more than 4,000 US households concluded that lifestyle factors reflecting social and behavioural patterns associated with air conditioning, laundry usage, personal computer usage, climate zone of residence and TV use explained 40% of the variation in electricity consumption (Sanquist et al, 2012). Sanquist et al define lifestyle as : "...patterns of consumption influenced by decisions at various points across the lifespan, such as what profession to engage in, where to live, when (or whether) to marry and have children, and more proximal choices regarding what to purchase and how and when to operate energy consuming equipment. This conceptualization suggests that analysis of life-style and energy consumption needs to encompass not only the traditional demographic segmentation elements, but also information about what people own and how they use it" (2012:1). In a Swedish study, large differences in electricity consumption were found between households that had very similar profiles with respect to electric space heating systems and number of household members and perceptions and experience with ToU mechanism (Bartusch et al, 2012). A study amongst more than 1000 respondents found that the use and duration of appliances related to cleaning and entertainment accounted for a large part of the variance in electricity consumption between otherwise similar households (income, age, dwelling) (Bedir et al, 2013).

What can be concluded from the above is that differences in end-user practices and energy consumption of households can only to a limited degree be explained by the socio-demographic factors that the usual segmentation studies use. These include factors such as age, education, income, environmental attitude, household size etc. While such segmentations can help to find out how to tailor a *communication* strategy to different segments (e.g. the sort of information, level of detail, media used to communicate) these segmentations do not predict actual behaviour.

5.1.2 Attitude, motivation, behaviours

A desk-research on energy saving showed that for the majority of households, a main reason to start with energy consumption reduction is financial, the second is environmental (Mourik, 2011). The primarily environmentally motivated segments have shown to be the ones that also realised indirect energy saving - in their consumption behaviours regarding food, mobility and waste (Hargreaves et al., 2010). As such these segments are less prone to performing the rebound behaviour discussed above. Pilots aimed at shifting demand that inquired into motivations, showed that not only costs but contributing to security of supply and contributing to societal/environmental problem solving were also important motivations for the targeted segments, e.g. richer and older segments (Thornes et al. 2012). In addition, the motivation to contribute to security of supply is probably not a motivator that will resonate with the average European citizen, since in Europe black outs and brown outs are less common. A Swiss study showed that environmentally aware segments were put off when they were encouraged to save money by saving energy. Similar situations occur for some well-to-do households (Sütterlin et al, 2011). In addition, a segment that is environmentally motivated to shift consumption is likely to have difficulties if the organisation that offers the pricing intervention is doing this from a commercial point of view only (Curtius et al, 2012). This would mean that the Dutch DSOs will be well positioned to target this segment, as long as the DSOs societal aim and non for profit character is well highlighted.

A consumer survey in Austria, Germany, Liechtenstein and Switzerland showed that 77% of the 837 respondents indicated a willingness to contribute with demand shifting - e.g. by having the washing machine work on other times of the day (Curtius et al. 2012). These respondent were not fully representative for the average population in these countries, with a bias towards males and middle aged people. Perceived or experienced decreases in comfort and well-being are a huge barrier to behavioural change (Peters et al, 2010). The following groups of needs appear to be an important consideration for people when encouraged to save energy (in order of appearance): control (over costs and energy saving), comfort, wellbeing (health, safety, social relations/contacts), desire to behave environmentally responsible; and ease (Caird & Roy, 2007; ON World, 2010b; PikeResearch, 2009; Zwiers, 2010). Of course this is a generic picture: the extent to which and ways in which these needs are relevant differs for different (segments of) people. Likely these groups of needs play an important role when people consider to shift their energy consumption.

A pilot among a couple of thousands of Dutch end-users showed that the perception of energy saving behaviour is an important predictor of the actual performance of that behaviour - next to the attitude one has towards energy saving. If people have a positive attitude towards energy saving this is more likely to result in actual saving behaviour compared to a situation where this positive attitude is absent (Van der Sluis et al., 2011). However, this does not mean that a pro-environmental or pro-energy saving attitude will always translate in energy saving behaviours. For example, while generally, people with a higher education tend to be more concerned about the environment and understand the need to save energy, this does not translate into energy saving behaviours (Axel-Nilssen 2003). This is the (in)famous attitude-behaviour gap: pro-environmental attitudes do not necessarily translate into pro-environmental behaviours. Saving energy in many cases goes against the energy intensive lifestyles that people are locked into. For instance, environmentally aware parents may still choose to pick up their kids from school by car because of time pressure (due to their busy urban working lives) or safety considerations. Energy consumption at the household level is not so much driven by environmental attitudes and awareness, but rather by 'actual and perceived' needs (Anker-Nilssen, 2003; Mourik, 2011). The meaning people give to energy consumption or saving is connected with how they live: often the search for time, comfort and convenience has a larger impact on household energy consumption - independent of economic or environmental attitudes (Anker-Nilssen 2003; Klopfert and Wallenborn, 2011). Facilitating behavioural changes is not just about creating awareness, changing attitudes and intentions towards more sustainable behaviour. It is also about changing the social, institutional, physical and technological contexts in which these behaviours are embedded. Social norms around comfort and convenience for instance can change over time (e.g. car use and car ownership in cities).

5.2 Improving segmentation

	Extravagant consumption	**Average Consumption**	**Thrifty consumption**
Motivated & capable	+++	++	+
Motivated	++	+	+/-
Capable	+	+/-	0
Neither motivated, nor capable	+/-	0	0

Table 4: Potential savings in different households (Klopfert and Wallenborn, 2011)

Table 4 by Klopfert and Wallenborn (2011) shows potential savings as the result of a combination of consumption patterns and motivation. According to this table, the highest potential lies with end-users that are 1) extravagant and motivated, and 2) average, motivated and capable. The authors argue that a third dimension needs to be taken into account. This is the dimension of lifestyle. However, they see no way of including that since no clear classification or segmentation of lifestyles is available. So if any type of intervention aims at changing consumption patterns, it needs to address lifestyles (in all their diversity) as well.

This would entail that that real needs and real behaviours of real households are included in a segmentation, to understand how attitudes, motivations, awareness, capabilities, sociodemographic variables, home and appliances play a role in supporting a certain way of living. To understand how a particular lifestyle brings with it a certain patterns and volumes of energy consumption it is important to know how people wash, eat, clean, relax, move, sleep etcetera. First steps have been

taken to understand and segment lifestyles, in a Swiss segmentation study addressed attitudes, motivations, awareness, reported actual behaviours and a number of sociodemographic variables (Sütterlin et all, 2011). The segmentation is based on an inquiry that is representative for the Swiss population, whereby respondents were asked about their attitudes, behaviours, preferences.
The segmentation study by Sütterlin et all (2011) aims at identifying the saving potential - it does not focus on shifting. The resulting segments, although not translatable one-to-one to the Dutch context, do offer end-user profiles that we can expect to occur in the Netherlands in different percentages and possibly with nuance differences. They include motivation, capabilities, consumption patterns as well as lifestyle elements (e.g. attitudes in combination with actual behaviours). In fact, they match rather well with some other segmentation exercises performed in the Netherlands (van Dam, 2013). Therefore, these segments offer the best possible starting point available for designing a dynamic pricing intervention (including technology, feedback) aimed at shifting and reducing household electricity consumption in the Netherlands. We briefly summarise the six segments that were identified, the percentages are relevant only for the Swiss situation, but Dutch research has found strong similarities with segments found in Dutch pilots (Van Dam, 2013; Mourik, 2011b):

Segment 1: Idealistic savers (15.6%)

This group shows most efforts to save energy, both through routine behaviour and efficiency measures. Driven by idealism, these people are willing to make financial sacrifices and impose restrictions to themselves even if it means loss of comfort. They support policies that put a price on the energy intensity of products within a product category. They believe that they can make a difference, in a positive sense.

Segment 2: Selfless inconsistent energy savers (26.4%)

This group also shows significant energy-saving activities. At the same time, they are not very consistent: although they do believe that they can make a difference, they are quite inconsistent in terms of energy efficiency measures at home - because at that level they do very little.

Segment 3: Thrifty energy savers (14%)

The thrifty savers are into energy-saving as long as this does not bring them any negative financial consequences. This also applies to their acceptance of policies: these should not ask for any additional financial efforts from end-users. Their motivation is not primarily intrinsic- but relates to financial necessity and social pressure.

Segment 4: Materialistic energy consumers (25.1%)

The materialists do little to save energy, but are open to energy efficiency measures for the house. They are not very positive about policies if these have financial implications for them. The main motivation for energy saving behaviour is financial.

Segment 5: Comfort-oriented indifferent energy consumers (5.3%)

The comfort oriented are the least likely to energy saving behaviour. They do not care about the potential societal problems that the increasing energy consumption entails. They do not feel responsible and energy consciousness is nil. Their behaviour is driven by the search for personal comfort. This group of people is opposed to restrictive policies and interventions that discourage this behaviour.

Segment 6: Problem conscious welfare-oriented energy consumers (13.6%)

This segment is not enthusiastic about saving energy. Although they are aware of the consequences of their behaviour and also believe that energy-saving behaviour can make a difference, do not they feel called to action. This is possibly because they think that their ability to save energy is very limited. Although oriented towards comfort, they also feel a certain social pressure to do something about the energy situation.

For each of these 6 segments we can ask questions like the following ones:

- what are important motivations for a specific segment (e.g. financial, environmental, social)
- what do we know about their behaviour and where can we see opportunities for change (and should the focus be on reduction and/or shifting). This could mean that pricing is not the first motivator and a pricing mechanism can even have adverse effects.
- what is this segment willing to shift in terms of activity, and what not?
- what does this imply for the choice of a dynamic pricing mechanism?
- what does this imply for the choice of technologies?
- what does this imply for the choice of feedback messages and media?

Answers to these questions can help to design tailored dynamic pricing interventions that consist of a combination pricing mechanism, technology and feedback. Figure 8 below shows a toolbox (to be read horizontally) offering building blocks. Each element in the toolbox is a building block that can be chosen or not. Each column represents the building blocks that can be chosen within the categories: pricing mechanism, technology and feedback. The combination of selected building blocks create a basic design for a tailored dynamic pricing intervention aimed at a specific segment. Figure 9 shows how such a basic design could look like for segment 1, based on considerations as elaborated in box 1.

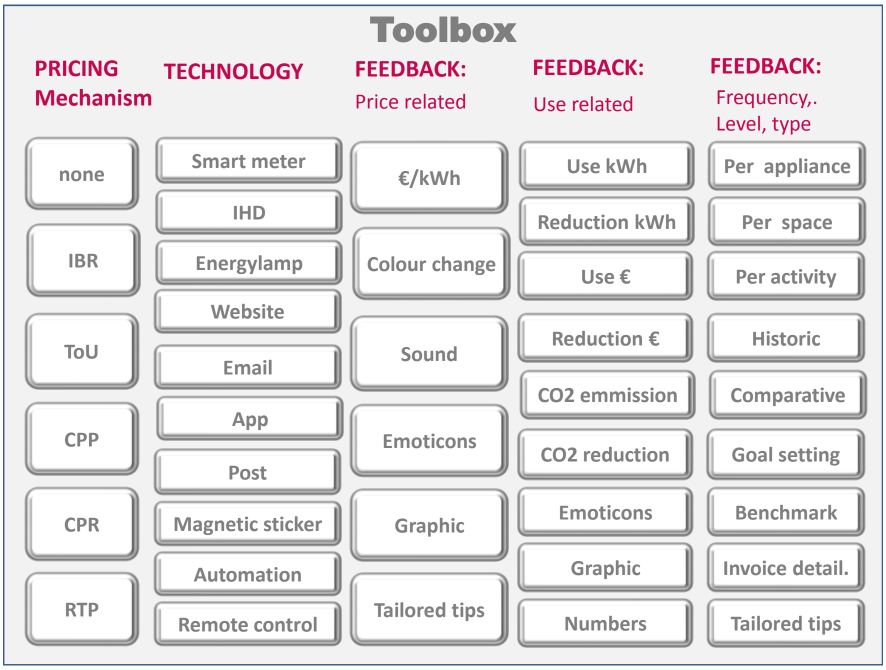

Figure 8: toolbox to design tailored interventions

Segment 1: "Idealistic Savers"

General Considerations

This group shows most efforts to save energy, and already does a lot in terms of reduction. Driven by idealism, these people are willing to make financial sacrifices and impose restrictions to themselves even if it means loss of comfort. This customer is knowledgeable and consists largely of highly educated women.

Preferred behaviour

Both routine behaviour and efficiency measures

Main motivation

This group could be motivated to shift their consumption but from an environmental motivation.

Choices related to Pricing Mechanism

Saving and shifting will not be financially motivated (no emphasis should be put on money) and a price incentive may not be the best incentive. If a price incentive is used, a combination of ToU, possibly with CPP, is a good option to visualise energy shifting options. Because this segment is not financially motivated, RTP is probably not suitable (because you still need to respond strongly to price). You could also simply CPP (and focus on shifting only).

Choices related to technology

Since this group is highly educated and well informed, different technologies can be used to support further behavioural change. The use of technology should be functional for this group. Almost all options are ticked in the toolbox because these people want information to be provided both at home and at work on PC, smart phone, IHD. This group does not like ceding control (especially to a party that is less environmentally conscious and idealistic than themselves). Remote control by third parties is not an option, automation is possible if this group can control it themselves.

Choices related to Feedback
Detailed and differentiated information is desired. Because this group is well informed, it is well able to interpret the information. Text, graphics, and / or lamp signals when price changes are options. Tailored advice needs to be focused on shift options. What is important for this target group: who gives feedback and how reliable do they think this party is?

Box 1: Consideration that underlie the choices of building block for segment 1

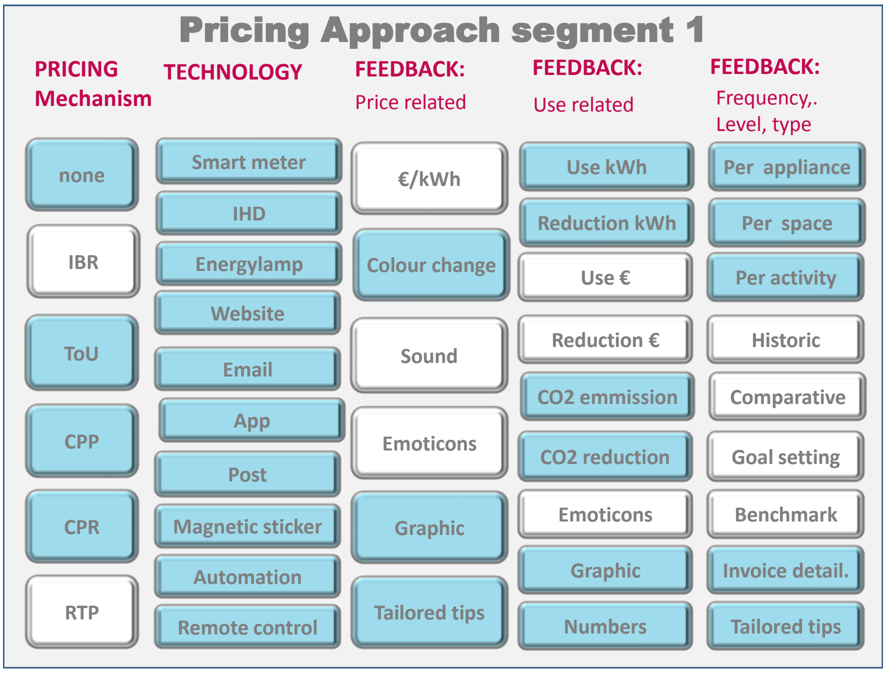

Figure 9: Dynamic pricing approach for segment 1 (the blue blocks)

Annex 3 elaborates the tailored dynamic pricing interventions for all six segments, demonstrating how this toolbox can be used.

Of course, for any particular project in the Netherlands, further tailoring can and needs to be done based on issues like house characteristics, appliances, presence-patterns and particular other local characteristics. Next, further tailoring and fine-tuning is possible in the choice of dynamic prices, technologies and feedback. Below we briefly elaborate on these issues that need to be addressed as well.

House characteristics

The influence of the house, it's energy quality and the appliances in the house is significant.

A survey showed that in general, people are more willing to invest in more energy-efficient appliances than investing in measures like insulation and double glazing (Logica CMG, 2009). Such preferences are however likely to differ for different segments.

There is a positive correlation between home-ownership, age and type of house: the older the residents, and the larger the home is, the more appliances a household owns (OECD, 2010). The type

of appliances differ with the level of education, the higher the education the more PCs a household owns. Research shows that the influence of behaviour on energy consumption is larger than the influence of the house-characteristics. Identical energy-efficient houses can show a consumption that differs with a factor 2 - caused by differences in behaviours (Darby, 2006).
Tenants often have less options to install appliances that can support reduction or shifting. Remote controlled HR-E boilers are the responsibility of Dutch housing corporations, and the same goes for generation.

Appliances

In recent years many appliances have become much more energy efficient, and high consuming appliances have been replaced. However, the savings acquired by using more efficient appliances is nullified by the tendency to purchase ever more appliances (Nationale Denktank, 2009; TNO, 2008).
Appliances' potential to realise demand shifting lies in the shifting of their usage to off-peak periods, or the turning off during peak periods. In addition, smart appliances or appliances with a timer/thermostat can be programmed such that they temporarily use less electricity (e.g. the fridge during peak hours). 'Thermostatic demand' is regarded as a demand that is potentially highly flexible: the demand of an average fridge can be shifted during peak hours with some 30% (Zehir, 2012) - which is significant if we consider that almost all households have a fridge that is on every day. Other opportunities for shifting are offered by appliances' batteries that can be loaded during off-peak periods - and used during peak hours.
An additional value of shifting loads through different appliance-use is that it can also contribute to a better integration of decentralized renewables - by adjusting the energy use period of the appliances to moments of high generation by wind, solar, either remote controlled or with a timer.
The potential flexibility of many appliances is already accounted for in several studies. What these studies fail to address sufficiently is the use and timing of use of appliances - e.g. the example of watching TV in the evening which is non-negotiable for many. Timing of usage is strongly affected by timing of activities (presence) and lifestyles. Some use-moments are non-shiftable because it entails too much of a disruption for a households' routine or because the use at that specific moment is considered necessary.

Presence patterns

This refers to the presence at home of household members during the day and evening. In as far as this increases their (theoretical) flexibility to reduce or shift consumption during these periods, it will affect the effectiveness of price incentives. Some researchers claim that electricity demand loads are determined predominantly by the timing of daily practices of such people travel to work and children to school, cooking and eating (Devine-Wright et al, 2009; Torriti, 2012). Average presence profiles differ across segments, but also from country to country. In Italy, the presence of people during the day for example is higher than the European average (Torriti, 2012). This makes their flexibility to respond to price incentives (without automated control) larger than in other countries. The French cook and eat around eight o'clock in the evening, the Dutch usually cook and eat earlier. All these activities, including sleep, work, housework, eat, relax, watch TV affect the flexibility and thus response to price incentives. Very little research has been done on how people change the usage of particular appliances in response to DSM incentives. A UK survey showed that less than 20% of those individuals who cook or watch TV between 7 and 9 PM, would be willing to postpone these activities till after 9 PM (Platchkov et al, 2011). A qualitative inquiry in the UK confirmed this, where respondents indicated that changes to these kind of lifestyle practices that relate to a particular 'natural rhythm' of a household are non-negotiable - referring exactly to cooking and watching TV after work (Hargreaves et al, 2010).

Across Europe, eight o'clock PM is television time for a large part of the population. That time is sacred and often responsible for up 3GWh. A huge potential but only theoretical because many people need their comfort and relaxation at that time, not earlier or later. Activities in the morning peak periods differ from evening peak period activities, both in content and in the way they are valued. In the morning activities can be started after which the absence of the residents is not an issue (washing, dishwasher). An Italian study of a ToU pilot in Trento (Torriti, 2012) showed a greater willingness to shift the activities in the morning than in the evening. This has been confirmed by findings in a RTP US study on the willingness to pay for electricity related to the willingness to experience higher temperature (because allowing the temperature setting of the AC to be changed by remote control (a higher temperature rise was considered acceptable in the morning in comparison to the evening. This RTP pilot concluded that there are probably 6 tot 10 relevant timing slots in which people are more or less willing the shift or reduce their energy use (Violette et al., 2010).

Household dynamics

Each household has its own dynamic or moral economy: the history and social practices from which norms and values, habits and routines, thoughts, motivations and wishes and needs in relation to comfort, cleaning, caring, leisure practices have developed. The household members very often grows into this more economy without noticing, with each member having a specific role and opinion. The household dynamics usually are not under discussion, expect when a disruptive event such as a new baby, a move, a high energy bill happens. Each household views the energy consumption through their personal moral economy lens. Therefore, when a tailored dynamic pricing intervention is developed it is crucial to pay attention to this household dynamics because different household members can respond differently.

Main elements of a comprehensive segmentation

Recapitulating the discussion above, we can now summarise the crucial elements of a comprehensive segmentation (which intends to design tailored dynamic pricing interventions).

- Attitude, motivation, awareness, capabilities, behaviours
- Sociodemographic variables

- House-related characteristics
- Appliances
- Presence patterns
- Household dynamics: timing and negotiable (read flexible) use

6. The Dutch context & role of DSOs

Consumers in the Netherlands (and elsewhere) are familiar with some dynamic pricing mechanisms, e.g. Time of Use is common when booking holidays, hotels and airline tickets that differ in price according to day of the week, season. When it comes to critical peaks and pricing around such peaks, this is a less familiar thing for the Dutch. Also unusual are calls from national government to reduce or shift energy consumption to prevent power black-outs - as has been done in countries with more extreme climatic conditions. Dutch households are likely to be less aware of the possibility of interruptions in energy supply. A need to *shift* energy consumption in order to maintain a proper balance between supply and demand is something most Dutch people are not likely to be familiar with at all.

Due to large differences in climate conditions, results of dynamic pricing programmes in the US and Canada (Faruqui and Palmer, 2011) are not easily translated to the Dutch context. Nor can the results from Italy, which has seen a massive uptake of household Air Conditioning systems and an accordingly rise in electricity consumption (Battle and Rodilla 2008). In the Netherlands there is no widespread use of AC nor a widespread use of electrical heating (like in Scandinavian countries), so these potentials for shifting and reduction are absent. Dutch households typically use gas for cooking and heating which limits options to shift and reduce electricity usage in comparison to households in countries where electrical heating and cooking is more commonplace.

As for the gas-defined usage, the options for shifting and reduction lie to large extent in one-off behaviours like changing the thermostat settings, investment behaviours to reduce the leakage of warmth, and to a small extent to changing routine behaviours (showering, baths, and cooking in the Dutch situation). Like in Ireland, the majority of Dutch households do not use electricity for heating nor AC for cooling, the main options for electricity reduction and shifting therefore relate to routine behavioural changes in the areas of lighting, TV, PC-use, gaming, use of the oven, dishwasher, fridge, freezer, washing machine, all other electrical appliances. Investment/intentional behaviours involve the purchase of new appliances, software or games that affect the time spent behind the computer, and the setting of timers on e.g. the fridge (programming devices to turn off at certain moments during the day or night). In the Netherlands, many people come home from work at around 18.00. They cook and eat dinner, and enjoy some leisure time in the following hours. The loads that related to these activities between 18.00-21.00 are difficult to shift.

The Dutch are quite active on social media (including) Twitter. Many people are also used to touch on a service like SMS alerts. This offers opportunities for providing feedback to support behavioural changes and feedback to communicate (changes in) tariffs. Like elsewhere in Europe, the ageing of the Dutch population is a trend that will affect presence patterns and peak demand patterns and changes in/proliferation of new appliances in and around the house in the Netherlands. Other relevant trends are developments like teleworking (working from home) and increasing unemployment as a result of the crisis which affect presence patterns and hence future options for reduction and shifting.

The initial mandatory roll-out of the smart meter was not pushed through due to strong resistance from consumer organisations and privacy watchdogs (Elburg, 2009). This has raised issues around who is entitled to read and process user data, who owns these and how access is granted. Several changes followed, e.g. at present the smart meter can only be read 6 times a year and people have the right to administratively opt-out in which case the meter readings do not leave the house. Currently, the smart meter is being rolled-out in pilots to learn about the best strategies and end-user acceptance. In 2015 a more massive roll-out is planned which is to incorporatie the lessons learnt in the pilots. In addition many smart grid pilots are initiated to learn about end-users response and technical aspects. The lessons learnt are however not widely shared or disseminated. Cooperation and knowledge sharing between DSOs, retailers and other stakeholders is taking place on a rather limited scale and offers room for improvement.

6.1 Role of DSOs in the Netherlands

Faruqui et all (2012) mention the following benefits of dynamic pricing and smart meters:

- avoided or deferred resource costs (including generation capacity and, to a lesser extent, transmission and distribution capacity)
- reduced wholesale market prices,
- improved fairness in retail pricing (i.e., providing a better match between the costs that customers impose on the system and the amount they are billed)
- customer bill reductions, facilitating the deployment of both distributed resources (such as solar electric systems) and end-use technologies (such as plug-in electric vehicles)
- environmental benefits (through possible emissions reductions)

The question is who benefits from these effects, on what terms and to what extent? And how transparent is the envisaged distribution of costs and benefits? And what role Dutch DSOs are to play in this area? DSOs can introduce dynamic tariffs on the electricity transport-cost parts of the energy bill. Energy suppliers can do this for the delivered electricity.

Because of the separation between transport and supply in the Netherlands, Dutch DSOs have a different position compared to their colleagues in most other EU countries. The Dutch DSOs have been created as public organizations responsible for balancing demand and supply.

It is questionable whether most Dutch end-users are aware of the separation between transport and supply and of the public role that DSOs are now supposed to fulfil. The fact that Dutch DSOs are public organizations, does not necessarily mean that they are regarded as a more trustworthy. The Dutch government does not have a good record when it comes to safeguarding citizens' privacy. However, trust in DSOs affects the credibility to end-users of information provided and it likely also affects the extent to which end-users are willing to participate in dynamic pricing interventios. It is important for DSOs to learn how they are being viewed by end-users.

Several relevant questions that can be asked from an end-user-point of view include:

- What are risks of being disconnected (related to the smart meter)?
- Does "administratively off" ensures that metering information can indeed not be exchanged?
- Are measures taken sufficient to guarantee security and privacy protection of end-users?
- To what extent do end-users have opt-out options from dynamic pricing schemes?
- What sort of access do they have to their own data?
- How is the public interest that DSOs claim to represent, defined?
- What other interests do DSOs, energy suppliers and others have and how does this affect how DSO engage and communicate with end-users?
- Is there a more 'neutral' organization or an organization that represents consumers that endorses the information provided by DSOs?
- How transparent is the market that is arising around the marketing of smart metering technology (a billion-euro-market), feedback technologies and ICT, related consultancy, and energy-sector parties interested in customer retention, network balancing, etc.?

Dutch DSOs need to consider these type of questions that can arise. If there is a lack of clarity on roles, responsibilities this can thwart end-user acceptance and commitment.

7. Conclusions: lessons, recommendations and remaining dilemma's

7.1 Top 10 Lessons

Based on our review of pricing mechanisms, technology, feedback, behaviour and segmentation the following top 10 lessons could be drawn:

1. For the near future Time of Use with several pricing variations a day, combined with Critical Peak Pricing for several additional days annually is the most promising dynamic pricing intervention for the Netherlands.
2. Focusing on load shifting only creates the risk of overall load increase. If e.g. the off-peak price is too low compared to the peak price this can create an increase in consumption.
3. The *theoretical* load shifting and reduction potentials tell us little about the actual occurrence of the shifting and reduction. That depends on the end-user. Lifestyle had a strong influence on the actual occurrence of shifting or reduction behaviours.
4. People are not motivated by pricing incentives only. Environmental motives, "the desire to contribute", control, comfort, ease and wellbeing are important motivators as well.
5. A one-size-fits-all approach reaches a maximum of 30% of end-users, with very different responses within this 30%. If the aim is to also reach the remaining 70%, a differentiated approach is needed.
6. Time of Use interventions target habitual behaviours. Critical Peak Pricing and Critical Peak Rebate focus on conscious and less frequent behaviours.
7. Load shifting can be achieved without technology (using only fridge magnets and calendars). Additional technology such as e.g. an In House Display however increases the response rate.
8. End-users highly value easy aids such as calendars, magnetic stickers and detailed frequent energy bills.
9. Different end-user segments need different tailored interventions consisting of a specific combination of dynamic pricing mechanism, technology and feedback.
10. A tailored approach and voluntary participation are very important to avoid discrimination (and sabotage).

7.2 Towards a DSO-led decentralised approach?

The research question that we have addressed in this report was as follows: *Which dynamic pricing approaches (being a combination of a dynamic price incentive, technology and feedback) work best for which end-users and under what circumstances in the Netherlands?*

The preceding sections have discussed how to design a tailored pricing intervention (combining price incentive, technology and feedback) that takes the end-user seriously. In addition, we addressed the situation in the Netherlands and the role that the Dutch DSO can take. However, section 6 also raised some end-user issues regarding privacy, acces to and ownership of data. A tailored pricing intervention requires a lot of detailed personal data from individual households and a comprehensive segmentation asks for a lot of private and sensitive information from households. It is unlikely that end-users provide such information easily - for several reasons, one being the perception that the privacy and security of their data cannot be safeguarded.

Rather than trying to create an elaborate and costly centralised data system (Curtius et al. 2012) that 'guarantees' the safety and protection of privacy and other end-user interests, it may be a better idea to keep end-user data and information decentralised. That would also better fit with a future situation in which end-users become more actively engaged in smart grid technologies. And it would make it easier for DSOs not to compromise their task of furthering of the public interest as a priority when working closely with parties that have very different priorities (e.g. the enormous interest in selling as much smart and intelligent devices as possible collide with cost-efficiency for end-users as a priority). In a decentralised data en information management system, the end-users' active role would become key. Such a system ensures that personal information needed for the segmentation as well as household metering data remain with the end-user and with no one else. This also resonates with other studies that discuss the options of full end-user control and ownership over (metering) data (e.g. Wallenborn and Klopfert, 2011).

The DSO could take up a role in designing a tool that provides to the end-users several segment-descriptions with accompanying price-technology-feedback combinations with an explanation of critical issues and potential risks and benefits. Or the toolbox could allow for a household to fill in their personal data and the tool would subsequently advise the best fit in terms of combination of pricing mechanism, technology and feedback. This would allow households to choose the segment that fits their situation best. Next, the households could ask the DSO or retailer for this dynamic pricing intervention combination (perhaps with options to adapt elements further to be in line with one's personal situation). The toolbox would enable this interaction between households and DSO and/or retailer. In addition, it would do so in such a manner that personal data and information stay with the end-user. The end-user keeps control over his/her data, the choice of segment and the choice for a price intervention. This approach of actively including end-users entails an institutionalisation of end-user involvement and commitment.

The role of a DSO in rolling out well-tailored dynamic pricing interventions could thus lie in facilitating the development of such toolboxes and the segmentation (that serves as a starting point). However, the DSO should not undertake this without strategic alliances. People consider information more credible when the source of information is considered impartial. While people might consult and even trust their energy supplier or a company that provides energy efficiency products and services, endorsement from scientists, consumer - or environmental organisations might be important when positioning energy saving products and services (Logica 2007). For credibility and trustworthiness, it would be good to collaborate with an independent organisation that intermediates between DSO, energy suppliers, other relevant stakeholders and end-users, whereby it is clear that this intermediary serves the societal interest and ensures fair play.

7.3 Remaining dilemma's and suggestions for further research:

Several of the dilemma's and other issues that need further research have been touched upon in the main text. For some issues - e.g. related to consumer access and ownership of data and information - we have suggested solutions. However, additional research or pilots are needed to further elaborate these ideas for solutions.

We still understand too little about how and why people reduce or shift

Surveys that accompany trials and pilots give little insight into *how* households change their behaviours, which household members take on what roles, how changes are negotiated or not, etc. Qualitative research that provides insights is still limited (e.g. Hargreaves et al, 2010)

Lifestyles and social practices

Households that are comparable demographically and technically, show very different behavioural responses which reflects different lifestyles, histories and social practices. Feedback or incentives are being interpreted and negotiated through the particular lifestyle-lens and acted upon accordingly (feedback is more than 'just information' and "there is no guarantee (…) that the meanings intended by the communicator are those understood by the recipients" (Hargreaves et al, 2010:6112). In addition segmentation assumes a world of individuals while it also makes sense to look at historically developed social practices and norms (e.g. with respect to hygiene and washing/showering; regarding dress standards and heating/AC, on comfort and heating) and how this can be an entry point for change. Lastly segmentation is based on the assumption of coherent individual attitudes and beliefs. It does not allow for internal inconsistencies or multiple identities (e.g. the same person can be man, father, researcher, tennis-player, party-crasher and each of these identities might bring along slight differences that also result in different behavioural choices).

Rebound

When people are only incentivized on their motivation to save money, then a rebound effect is more likely to take place compared to a situation where environmentally motivation (pro-social values) plays a role. However, unintended or indirect rebounds pose a more complex challenge that is not easily solved.

Engagement with the IHD

Since engagement with the IHD is important for end-users to remain committed to decrease and shift energy usage, it is important to learn more about how this engagement can be maintained.

Persistence

Many studies have something to say about persistence and point out that savings persist in cases over the course of a two-year pilot (Faruqui and Palmer, 2012; Stromback et al 2011; Foster and Mazur-Stommen 2012). However, post-pilot inquiries or ongoing inquiries after full-scale roll-out, into the persistence of behavioural changes have been done, which leaves questions unanswered as to whether seemingly persistent behavioural changes really last.

Equity issues

To what extent are particular segments affected disproportionately by a particular dynamic pricing approach? We can think of low-income households, who may have fewer, older and less efficient appliances and therefore less room to shift or reduce. But also households were most people are away during day-time in comparison to households with people at home all day.

Some shifting activities, e.g. programming the fridge thermostat in such a manner that less electricity is used during peak hours, need to be performed before the peaks occur (Zehir 2012). The only way for people who are not at home (or are otherwise unable to perform several manual actions during off-peak periods) is to work with remote control. However, this asks for additional technology and costs. Some segments may be financially disadvantaged over others because of this. These and other socio-demographic factors are important to consider. While some studies argue that poor households are not disproportionately affected by dynamic pricing (Faruqui and Palmer, 2011) others state that pilots show mixed results. High income families often have two working parents -with more absence unless one of them works at home. This affects their ability to shift. Low income segments often already cut down on their energy cost to save money and have fewer options to change routines to reduce electricity (fewer and less efficient/older appliances) and energy (low quality social housing) and they have fewer scope to invest in more efficient appliances or efficiency improvements of the house (and split incentives) (Brandon & Lewis 1999). Even if this segment would respond to and profit from price incentives that target shifting , the question rises if they might end up using less energy than is needed to maintain a very basic level of well-being and health. Housing corporations have an important role to play in improving the quality of social housing and decreasing consumption while at the same time ensuring no increases in bill.

Future of gas in the Netherlands?

In case of a future spread of household heat-pumps, this may raise the flexibility of load. Like with air conditioners, the demand is flexible to the degree that end-users are willing to accept small decreases in comfort during peak periods (Frontier Economics and Sustainability First, 2012).

Who has access, to what sort and form of data, to what extent? Privacy issues

Do end-users have access to their data? In what form, to what extent? Who else has access? How can privacy of the end-user be protected and by whom? What can be learn from mistakes made in the past?

Correlation between motivations and effectiveness of pricing mechanisms

Research into concrete motivations for concrete Dutch segments is lacking. Especially the impact of motivations around comfort and their influence of the effectiveness of certain dynamic pricing mechanisms needs further research. E.g. a load shifting that demands a permanent behavioural change can be experienced as diminishing comfort and therefore not accepted.

Theoretical and real load flexibility

The real flexibility of promising loads such as e.g. television watching or dishwashing need to be investigated in real life for different segments. Are people actually willing to shift their television time or dishwasher cycles? What do these people need to make this shift? In practice much of the theoretical load flexibility is not existing because people feel they cannot shift their activities due to needs, norms and capacity.

The role of social media and feedback?

The role of social media in delivering feedback and the role of tablets and smart phones is not sufficiently understood.

Moral economies and negotiating household practices

Feedback could play a role in the discussions within households about the household's energy consumption practices and could mediate between different members 'needs and wishes.

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Annex 1: European examples of dynamic pricing

	pricing mechanism	Number of participants	Overall consumption reduction	Peak reduction	Peak-to-off-peak differential (approx)
1.Electricity Smart Metering Customer Behaviour Trials (CBT (2009-2010)	ToU	2,920	2.5%	8.8- 11.3 %	143-271%
2a EDRP EDF project	ToU	194	2.3-4%[1]	Varied, between 4% (weekdays) to 8% (weekends)	165%
2b EDRP SSE project	ToU	1,352	2.5-3.6 %[2]	up to 0,5%[3]	180-210%
3 TEMPO EDF	ToU and CPP	From 800 in 1989 to 20,000 in 1995 to >300,000 after 2004		cuts in total national peak consumption by 4%; the total peak load reduction that has reportedly been achieved through the Tempo program is 450 MW - due to an average peak load reduction of 45 percent from participants on red days (and 15 percent on white days).	126-286 %
7. PowerShift 2003-2004	ToU	100	None 2% increase compared to control group	Very little (1-2 % compared to the control group)	267%
4. Norway DSR	ToU	40	-	Participants with standard electric water heaters: average reduction during morning peak load of 1kW per hour. Participants with hot water space heating systems: average reduction during morning peak load of 2.5 kW per hour.	-
5. Elforsk pilot Sweden	CPP	93	-	The load was cut back to an average of at least 50% during high price instances.	-
6. Intelliekon	ToU	(of 2000, part was provided a ToU tariff)	9.7%	2%	250%
7. Norway effloccom			-	Varied	-

1. This percentage of saving counts for all 1,979 participants of the whole trial (Wallenborn & Klopfert 2011); no percentage is available for the ToU sample that consisted of 194 participants
2. This percentage counts for the total of 2,7887 participants of the whole trial (Wallenborn & Klopfert 2011); no percentage is available for the ToU sample that consisted of 1,352 participants
3 Foster and Mazur-Stommen 2012

1.Electricity Smart Metering Customer Behaviour Trials (CBT), Northern Ireland (CER 2011)

Duration
18 months (July 2009- December 2010).
Month 1-6: collection of energy consumption benchmark date
Month 7-18 (Jan 1st 2010-Dec 2010): actual trial

Scope: National-wide pilot of TOU rates and informational interventions.

Aims:
"ascertain the potential for smart metering technology, when combined with time of use tariffs and different DSM stimuli, to effect measurable change in consumer behaviour in terms of reductions in peak demand and overall electricity use" and to identify a "Tipping Point" that is a point at which the price of electricity will significantly change usage. (CER 2011:4)

Recruitment, response, segmentation used, control group, representativeness
Test and Control Groups: participants divided into trial and control groups. Trial groups were asked to trial different ToU tariffs and DSM stimuli. The control group kept their normal electricity supplier tariff, did not receive DSM stimuli and were asked to continue consuming electricity as normal.
Pre-and post-surveys were held among trial-participants.
To the trial 5,375 were initially recruited and of this number, 5,028 were still in when allocation started in November 2009.
Participant recruitment followed an 'opt-in' approach, with an average response rate of 30%.
The trial group was representative of the national sample.

Interventions (pricing mechanism; technology; feedback)
ToU rates: 4 tariffs offering different unit prices for night time, day time and peak times; and a weekend tariff.
Aims of cost neutrality and cost reflectivity in the design of the ToU:
- The ToU tariff would be neutral in comparison with the standard tariff to ensure that 'average' end-users who did not change their consumption patterns were not penalised financially .
- The trial-participants were guaranteed that they would not pay more than if they had been on the normal tariff.
- The base ToU tariff was to reflect the underlying cost of energy transmission, distribution, generation and supply as per standard tariffs.
- The ToU structure (time bands) would be based on system demand peaks.
- Tariffs would be based on the cost inputs used in the 2009/10 regulated tariffs

Feedback and technology:
- Smart meters were installed prior to the benchmark period.
- IHD showing near-real-time information on electricity consumption and costs and historical consumption information
- Budgeting feature with default and self-entry options;
- Bi-monthly enhanced electricity bill and a monthly enhanced bill (enhance parts of the bill: information on estimated costs of running select appliances, energy saving tips, weekly average costs of electricity, an explanation of changes in consumption, a list of online resources for further information)
- a fridge magnet outlining the time bands and the tariffs per band, customized for each tariff group; a sticker providing details of the time bands
- Overall Load Reduction (OLR) incentive: a financial incentive to reduce use 10% below actual historical consumption

Achievements:
Response to tariffs and DSM stimuli
- The deployment of ToU tariffs and DSM stimuli reduced overall electricity use by 2.5% and peak consumption by 8.8%;
- The combination of bi-monthly bill, energy usage statement and IHD was more effective than other DSM stimuli. It resulted in a peak shift of 11.3%;
- Households with higher consumption levels tend to deliver greater reductions.
- Shifting mostly takes place from peak to post-peak; and in general from peak to night usage.
- Of the tariff groups that were trialled, no single one in combination with DSM stimuli stands out as more effective than the others.
- The peak and overall load reductions detected for all the stimuli tested proved to be statistically significant. An exception is the overall load reduction detected for the bi-monthly bill and detailed energy statement

stimulus, although the peak load reduction for this stimulus was statistically significant; - No evidence was found for a tipping point (demand for peak usage is estimated as being highly inelastic relative to price) **Demographic, behavioural and experiential conclusions** - 82% of the participants change their electricity use in response to the trial, with 74% indicating major changes in their households - 75% thought the magnet was useful and 63% found the sticker useful; - the IHD was found effective in supporting peak reduction (91% indicated the IHD as an important support) and supporting shifts to night rates (87% found it an important support). - Barriers to peak reduction relate to the difficulty participants had with connecting behavioural changes to bill reduction. Their perceptions may have involved exaggerated expectations of savings and exaggerated expectations of consequences if reduction is not achieved; - Barriers to shifting to night usage relate to safety and convenience. - The OLR incentive was recalled by 58%. The communications, reasonableness of the target and effectiveness of the OLR incentive in motivating change were rated as very good. - No secondary benefits were identified in increased awareness of general energy - efficiency or in relation to efficiency investments for the home; - The trial has made participants more aware of energy usage (54% agreed) which is in line with the recorded reduction in usage. 18% stated that there had been no impact on the way their household uses electricity; - Households headed by individuals with higher education or social grade achieved higher levels of reduction compared to those with lower levels. This was partly related to the typically higher consumption levels of these households. Therefore, the impact of education or social grade on the ability to gain benefit from the tariffs is limited - The impact of the tariffs on households that are entitled to receive Free Electricity Allowance – e.g. elderly, people that get invalidity or disablement benefits - showed that these exhibited the same levels of changes as other households (they do not appear to be disadvantaged) - Fuel poor households (that lack financial means to adequately heat their homes) also benefit from the deployment of time of use tariffs. -
Remarks: • Savings were *not* distributed equally across demographic groups. Households with higher initial consumption and more formal education, higher incomes or more children under 15 had higher savings. • Not clear *how* savings were achieved • Interesting: comparability to Netherlands: no use of electricity for heating, no AC penetration • This is one of the largest and statistically most robust trials to date.

2. The Energy Demand Research Project (EDRP) was a large project in the UK to test consumers' responses to different forms of information about their energy use. The primary purpose was to investigate consumer behaviour. Four energy suppliers conducted trials in the period from 2007 to 2010; two of these interventions made use of dynamic pricing and focused on shifting, in addition to reduction. These two trials (conducted by suppliers EDF and SSE) tested time-of-use (TOU) tariffs for electricity in combination with smart meters and other interventions (advice, historic and real-time feedback, and incentives to reduce overall consumption). These trials showed effects on shifting load from the peak period, with bigger shifts at weekends than on weekdays. Estimates of the magnitude of shifting effect vary with trial but were up to 10%.

2 a. EDRP EDF trial ToU tariffs for electricity (EDRP, 2011; Foster and Mazur-Stommen 2012)
Duration: between 2007 and 2010
Scope: 194 participants (of a total of 1,979 participants, 194 were offered ToU Tariffs (the rest did not receive any dynamic pricing incentive)).

Aims: Aim of the ToU as part of this intervention was to shift peak consumption

Recruitment, response, segmentation used, control group, representativeness

With one exception, all trial groups had smart meters and received more accurate billing, including the control group. There were 7 trial groups could with subdivisions between households with electricity-only accounts (received electricity smart meters) and households with dual fuel accounts (who received electricity and gas smart meters). 194 were offered ToU Tariffs and the control group consisted of 187 participants.

Participants were recruited from EDF's customer base in London and the southeast of England. To be eligible customers were required to have 4 meter readings in the 12 months prior to the start of the trial – but this was reduced to 2 meter readings due to the shortage of customers fulfilling the original specification. Several categories were excluded from participation (e.g. EDF staff; customers making use of consumption reduction products or services; etc)

Estimated annual energy consumption resulted into low, medium and high estimated annual consumption households. Further stratification divided recruits using the following variables:

- Prepayment users
- Fuel poor (based on a model that predicts the likelihood of a geographical area spending 10% of more of their salary on fuel bills).
- Green: customers on a green tariff or have a very high propensity to be a green customer based on a lifestyle code.
- Grey: customers of 55 years or older.
- High consumption
- Low consumption (was amalgated with the fuel poor)

The sampling frames for each trial group were randomised. However, for the „time of use" variable tariff trial, only medium baseline consumption households were recruited.

The variable tariff trial group was difficult to recruit to because customers did not understand the principle of load-shifting and did not believe that the company would want to help them save money. EDF had to provide the recruitment agency with a special training session specifically on this intervention.

Interventions (pricing mechanism; technology; feedback)

ToU rates: The peak period was 16:30-19:30, night period was 23:00-06:00 and off-peak period was 06:00-16:30 and 19:30-23:00. The peak tariff was 161-169% of the off-peak tariff. Night tariff was 56-65%, depending on region. The off-peak tariff was between 8.41 and 9.03 pence per unit (excluding VAT).

Feedback and technology:

In addition to ToU tariffs, participants were supplied with:

- Smart meters
- Accurate billing
- IHD (Real Time Display)
- Energy efficiency advice, sent by post
-

Achievements:

Estimates of the magnitude of shifting effect were up to 10%, with stronger effects in weekends compared to weekdays (EDRP 2011). However, Foster and Mazur-Stommen (2012) mention peak reductions of 8% in weekends and some 4 % during weekdays.

Peak electricity consumption increased with additional household members under the age of 16; and with paraffin/oil/no heating in comparison to electric/gas heating. It was also higher for households in South East England. Overall, EDF found that differences in energy consumption between trial and control groups were more clear-cut for smaller households (one or two people). This finding should be viewed cautiously because the analysis did not take account of baseline data, but it is in keeping with the load-shifting results.

Survey results:

- 38% of consumers in the ToU tariff trial sample were aware of the real-time display in their home, which was the lowest awareness amongst the trial groups in this study (this might have been caused by the fact that the IHD was more basic than that provided to some other groups. Consumers on the ToU tariff also rated the usefulness of the visual display below the ratings given by three of the four other trial groups).
- 65% of survey respondents in the ToU trial sample agreed or strongly agreed that the smart meter technology had enabled them to plan or budget their energy use. This compared to an average across samples of 55% of consumers that agreed or strongly agreed with the statement.

Remarks:

- EDF found a small but significant difference between trial and control group. AECOM, who analysed the data as well, found a large reduction in energy use, taking into account the control group and baseline consumption, but it was not statistically significant (or meaningful) because the sample size was too small for households where both in-trial and pre-trial data were available. The effect on overall consumption is therefore unproven but plausible.

- the IHD provided was more basic than in the other trials and the survey revealed that it was less likely that customers would be aware of its existence; those who were aware rated it as being less useful.

2b. EDRP SSE trial in UK (EDRP, 2011; Foster and Mazur-Stommen 2012; Frontier Economics and Sustainability First, 2012)

Duration: 2007-2010

Scope: 1,352 participants

Aims: Aim of the ToU as part of this intervention was to shift peak consumption

Recruitment, response, segmentation used, control group, representativeness
SSE used its national customer base of 1.4 million customers. Participating households were stratified demographically in order to ensure that treatment and control groups were similar. Within trial groups, households were stratified according to being aware of the trial and committed to energy consumption reduction. In some trial conditions, only the Aware and Committed groups were used.
· Committed: customers were aware of the trial and, in a signed statement to SSE, have said that they were committed to reducing energy.
· Aware: customers were aware of the trial.
· Unaware: customers were unaware that they were participating in a trial.
As the initial recruitment rates for the Aware and Committed groups were between 3% and 10%, the recruitment methods were adapted (e.g. withdrawing the recruitment questionnaire; changes in the correspondence; systematically following up letters with telephone calls; accepting a statement of commitment from customers by telephone rather than a written commitment).

Interventions (pricing mechanism; technology; feedback)
ToU was based on electricity tariffs varying with time of day, season and day of the week (weekday vs weekend). Peak period:16:00-19:00; night period: 00:30-07:30; off-peak period: 07:30-16:00 and 19:00-00:30. Low Season: March-October. Off-peak tariff was between 10.29 and 10.88 pence per unit (excluding VAT), varying with region. The peak tariff was 180-190% of the off-peak tariff (for both weekdays and weekends) and the night tariff was 50-60%. High Season was November-February and the off-peak tariff was between 10.87 and 11.46 pence per unit. The peak tariff was 180% of the off-peak tariff at weekends and 210% on weekdays; the night tariff was 50-60%.

Feedback and technology

- booklet
- monthly bills with graphs
- incentive to reduce consumption
- IHD and web information.

Achievements:
Load shifting in the SSE trial was smaller than for the EDF trial. Peak demand reductions were small, some 0,3 % on weekdays, and 0,5% in weekends (Foster and Mazur-Stommen 2012)
- Groups without web information and without a real-time display shifted more load away from peaks – suggesting that too many interventions increase complexity which reduces the response.
- The percentage of usage in the peak period was higher in the high season compared to the low season.
- The percentage of consumption that alls in the peak period is reduced by the incentive to shift but by only a small amount – from 19.8% to 19.5%.
- The percentage shift from peak to night electricity usage is estimated as 8.5-10.1%, based on peak season consumption at night (overall shift from peak is not estimated).

Survey results:

- Survey data from participants with smart meters (and/or RTDs) in the SSE trial found that the most frequent reason for joining the trial was to save money, and the next most frequent motivation was to help the environment.125
- The energy advice booklet had a high recall rate (80%), and consumers were more likely to say it was quite

or very useful, and to still refer to it, if they owned an RTD. • Early survey evidence on the recall of additional billing data was low (32% recalled something different about their bills). • Use of the website by consumers with smart meters was low, at 9%. • Satisfaction with and recall of smart meters was higher for credit and prepayment consumers (who had an RTD) than for consumers without an RTD. • Respondents rated cost information above energy information on RTDs, and the traffic light display was rated the most useful feature. • 40% of consumers aware of the incentive to shift reported that they had shifted their electricity demand and saved money, 33% reported they had shifted their demand but not saved money, and 28% reported that they had not shifted their demand. • Consumers without the incentive to shift or reduce demand reported that the night rate would have to be 19-32% cheaper than the peak day rate in order to encourage them to shift their demand.
Remarks: The report stated that the limited impact might be due to the limited awareness of the intervention and a perception that it was overly complex.

3. TEMPO tariffs in France. (EFFLOCOM, 2004; Faruqui, Hledik and Palmer, 2012; Frontier Economics and Sustainability First, 2012; Stromback et al, 2011)

Duration:
1989-1992 (experimental stage), 1993-1995 (tariff launch), and generalisation after 1995.

Scope: Tempo was first tested by French utility EDF in 1989 and then offered to its residential customers starting from 1995.
• Experimental stage: 800 consumers.
• Launch (1993 onwards): 20,000 by 1995.
• Generalisation: there were more than 300,000 domestic tempo customers in 2004.

Aims: the purpose was to study the effect of dynamic tariff on electricity consumption patterns.

Recruitment, response, segmentation used, control group, representativeness
Different customer classes were identified according to their heating system, typically:
- electric space heating
- electricity space heating and wood-burning fire place
- dual energy system (electricity + oil)
- heat pumps
- without electric space heating.

800 customers were recruited in 6 different geographic regions (Alsace, Lorraine, Massif-Central, Rhône Alpes, Poitou-Charente, Ile de France).
After generalization, opt-in is for consumers that choose to be on the tempo tariff. These end-users are in principle prepared to change their behaviour in order to save costs (FE and SF, 2012)

Interventions (pricing mechanism; technology; feedback)
Combination of ToU and CPP: The number of days of each type is known in advance but the type of any particular day is announced only at the end of the preceding day.
CPP pricing:
The year is divided into three types of days:
- 300 blue days (the least expensive) (weekend days were always blue)
- 43 white days (medium price)
- 22 red days (the most expensive).

ToU rates:
Each day is divided into two fixed periods: peak hours (day) and off-peak hours (night).

The colour of the day is chosen by the national operating system at the end of each day for the next day. Once the colour of the next day is decided, the signal is transmitted to the customer and displayed both on their meter and on a small box which can be plugged into any power socket. The box also indicates the day's colour and the current hourly rating. This system of "traffic light" coupled with various energy control systems offer a cheap and efficient way to inform participants.

For the launch (1993 onwards), four different combinations were offered:
- the standard tempo tariff;
- dual energy tempo, for households with a dual-energy boiler, which can switch source automatically depending on the current price;
- thermostat tempo which adjusts heating depending on the current price; and
- comfort tempo, which manages end uses (e.g. space and water heating and large electric appliances).

Feedback and technology:
For launch (1993 onwards):
- A smart meter displaying the same information as the notification device, as well as the consumption per tariff period.
- A notification device which can be plugged into a power socket which displays the colour of the day and the current hourly rating. It also provides advance notification of the colour for the next day from 8pm.
- Energy control systems that enabled consumers to programme their demand (and communicate this to appliances) according to current prices and their specified indoor temperature.
- information booklets, a start-up visit and advice from a tempo specialist, and option to receive a report after one year to set out the billing differences under the tempo tariff.

Achievements:
The total peak load reduction is 450 MW, which is due to an average peak load reduction of 45% on red days and 15 % on white days (Faruqui, Hledik and Palmer 2012. Load shifting from peak to off-peak hours was 1.3

times higher on white than blue days, and higher again for red days.
The main consumption reductions on white or red days are due to reduced electric heating. Consumers either used fireplaces or accepted a lower temperature.
Consumption reductions on white and red days were stable over the years.

Customers' satisfaction level: a survey showed the following results:
– 84% of the customers were quite or very satisfied with this option,
– 59% told that they had made savings (average or substantial for ¾),
– 53% considered the option as slightly restrictive or entirely unrestrictive,
– 87% understood the tariff principle very well.

The Tempo tariffs, launched in 1989, are appropriate for large households with electric heating. 22 years after its launch it still cut total national peak consumption by 4% (Stromback et al, 2011:63)

Remarks:
The level of price responsiveness is much higher than in most other pricing pilots in different parts of the world. Faruqui,Hledik and Palmer (2012) state that this might be due to the program's long history, its extensive customer education program (including in-home visits), and the wide range of load control technologies and informational devices that are provided.

4. PowerShift, **Northern Ireland** (Gill and Owen, 2007; Frontier Economics and Sustainability First, 2012)

Duration:2002-2003

Scope: 100 keypad (prepayment) consumers on the ToU tariff, and an additional control group of 100 keypad consumers with the flat rate tariff.

Aims: study the response of Keypad users to ToU tariffs

Recruitment, response, segmentation used, control group, representativeness
In 2009, 30% of consumers in Northern Ireland used keypad prepayment meters. Eligible to participate in the ToU tariff group were prepayment consumers with a Keypad meter with an IHD, which allowed them to monitor their current load, tariff rates, the number of units used at each rate, previous costs and remaining credit.
Customers are offered the option to switch to the Power shift tariff - by means of one phone call - and and they can opt out again if they wish to in the same manner.

Interventions (pricing mechanism; technology; feedback)
The trial tested a time-of-use (ToU) tariff with low, medium and high price periods. The hours of operation for these differed between weekdays and weekends.
Weekdays:
Midnight to 8am – green (low)
8am-4pm – amber (medium)
4pm-7pm – red (high)
7pm-midnight – amber (medium)

Saturdays and Sundays :
Midnight – 8am – green (low)
8am-7pm – amber (medium) 7p
m-midnight – green (low)

The applicable rates (including VAT) are :
6.56p/kWh - low (40% lower than standard keypad)
9.84p/kWh - medium (10% lower than standard keypad)
17.50p/kWh - high (60% above standard keypad)

Technology and feedback
- Keypad meter
- IHD
- A leaflet with advice on how to avoid using some appliances during peak hours; estimates of the cost of using specific appliances (tumble dryer, washing machine, and electric shower) during the different periods compared to the standard rate.

Achievements :
Keypad consumption already was 6.4% in 2005-2006 lower compared to average overall domestic electricity consumption in Northern Ireland.
Consumers on the ToU tariff lowered peak consumption (1-2 %) relative to the control group, but *their overall usage slightly increased*.
Still, their bills went down. So the participants saved money, not energy.

Remarks: Because consumers were positive about the trial, some 1000 additional customers were recruited to the Powershift concept in 2007.

5. Norway Demand Side Response (DSR) Pilot Study (2010) (Seale, H. and Grande, O., 2012).

Duration: 1 year, 2013

Scope: 40 households, from the same geographic area and with hourly electricity metering above a certain quality.

Aims:

Recruitment, response, segmentation used, control group, representativeness
- households were not randomly selected
- 10% had hot water space heating with an electric boiler. The remaining 90% used standard capacity electric boilers.

Interventions (pricing mechanism; technology; feedback)
- ToU tariff (a morning and evening peak period on weekdays)
- direct control (during peak periods only).
- 2 information meetings to inform participants about the pilot (e.g. peak hours, pricing, and the possibilities for demand shifting)
- communication material: information on the benefits of demand response.
- hourly metering with use of existing automatic meter reading technology.
- 3 magnets to place on appliances, displaying morning and afternoon peak hours.

Under the direct control regime, a response of electric water heaters was automated during peak periods. Installation costs for remote load control were 80-375 € per participant.

Achievements:
- Survey results showed that participants evaluated the pilot positively. Their main interest was in personal economic benefit, followed by reduced consumption of electricity.
- Participants accepted remote load control, provided it didn't affect their comfort negatively.
- The average reduction during morning peak load was 1kW per hour for participants with standard electric water heaters, and 2.5kW per hour for participants with hot water space heating systems.

Several participants adapted their behaviour to the ToU tariff, by investing in energy control systems; buying firewood in winter; and manual efforts

Remarks
A larger average peak load reduction was achieved compared to a previous pilot. This was understood as indicating that in this trial participants were manually reducing peak load, as well as reducing load via direct control. The reminder magnet might have been helpful in this regard (was not included in previous pilot)
(however, sample size (40 participants) is small.)

6. Elforks pilot 2 in Sweden (Lindskoug, 2006)

Duration: the 2003/2004 and 2004/2005 winter seasons

Scope: the first winter season, 53 customers of Skånska Energi participated; in the second winter season the trial was extended with 40 additional customers of Vallentuna Energi

Aims: an overarching aim of the project is to address the (increasing) risk of capacity shortage in the Swedish electricity supply system during periods of extremely cold weather.The aim of the pilots was to demonstrate approaches that lead to an electricity demand reduction at a national level at times of high spot prices. The need for the measures to be profitable for the parties involved is an important starting point.
The goal of Partial Project 2 was to examine the price sensitivity of customers with various heating alternatives.

Recruitment, response, segmentation used, control group, representativeness
To get around the problem of Hawthorne effect (participants are likely to behave differently when they know that they are being studied), the trials were introduced as an offer from the electricity supplier to take part in a commercial assessment using a new pricelist - and as such conceals the marked research aim. For both cases, a random 200 customers was approaches with an offer.

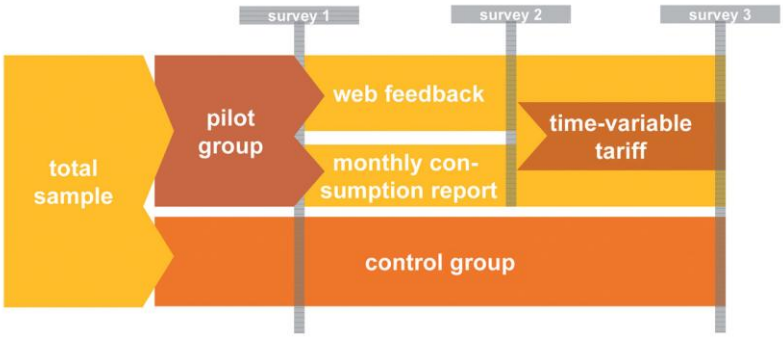
Interventions (pricing mechanism; technology; feedback)
Critical Peak Pricing:
The trials were carried out using relatively moderate price differences compared to the extreme pricing levels expected in a future capacity loss situationThe trial tested price as a control method to persuade customers to shift load.
A special price list was prepared for the trials. This price list allows the electricity supplier to apply a higher charge for a maximum of 40 hours. For the rest of the year the deduction is made from the customer's regular fee. The higher electricity price was in the 3-10 SEK per kWh interval. The customer was notified the day before of the time and level of peak price via text message or e-mail. The price list is designed to guarantee cost neutrality relative to the regular price list as long as the customer doesn't affect any changes.
In the 2003/2004 winter, 15 critical peak moments (amounting to 39 hours of high prices) took place. The winter of 2004/2005 saw high
price notifications to Skånska Energi's customers for a total of 37 hours on 14 occasions, and 39 hours on 15 occasions for Vallentuna Energi's customers.

Feedback and technology
- text message or e-mail
- advice on how to temporarily reduce electricity usage and which actions have significant impact, depending on heating alternatives and systems.

Achievements:
The results from the trials show conclusively that a price sensitivity exists toward temporary price levels in the 3-10 SEK per kWh interval. The technical results, questionnaires and in-depth interviews show a consistent picture of the customer's generally large willingness, ability and persistence to reduce electricity usage during times of high prices. The load was cut back to an average of at least 50% during high price instances.
Another important conclusion from the project is that the results have been achieved without having to install new technology at the customer end. The price interval of 3-10 SEK per kWh for a maximum of 40 hours a year has been sufficient to achieve sizeable load reduction. The load reduction has not become significantly greater at notified prices of 5 and 10 SEK/kWh compared to 3 SEK/kWh.

The results of the interviews summarised:
- It was felt that the trials have gone well.
- Participants had varying motivations for participating: economic profitability; both economically profitable and interesting; good from an environmental perspective; a challenge to see how much could be saved by reducing power usage.
- Realising changes was not viewed as troublesome or time-consuming
- No major drawbacks were experienced in connection with lowering electricity usage.
- The response to the level of reimbursement varied between the households. But overall, it was remarkable that the amount of profit wasn't all that counted. The feeling of being able to help, doing something beneficial to the environment was important as well.
- Despite many not having a clear idea of how they saved, they were happy with the trial.
- A continuation with this type of tariff was viewed positively.
- Households were ready to finance and install some form of control equipment themselves.
- Large-scale roll-out was not considered to present any major problems.

Remarks:

7. **Intelliekon** (Fraunhofer-Institute for Solar Energy Systems ISE, 2011; Schleich et al 2011)
Duration: preparations started in 2008; the ToU trial only lasted only 3 months
Scope: a trial included over 2000 households - of which part was provided ToU incentives
Aims: to examine household behavioural responses to feedback instruments; to gather valuable data on energy saving due to feedback and smart meters
Recruitment, response, segmentation used, control group, representativeness Recruitment: of customers who already had a smart meter installed or would get one. More than 2000 households were motivated to take part, including people of different ages, genders, household sizes and living conditions. Over half of the sample received feedback on their energy consumption for more than a year. They could choose between a web portal or written feedback (monthly). People of this sample were surveyed three times during the trail - addressing their attitudes and motives towards feedback and energy saving as well as their evaluation of the feedback. The other households received a smart meter, but they did not get any feedback on their consumption. They were surveyed twice – at the beginning and at the end of the field trial – and their electricity consumption was also recorded. A control group like this is important to be able to compare households with and without energy feedback. - Part of this group could choose a tariff with two price levels which varied depending on the time of the day. 
Interventions (pricing mechanism; technology; feedback) Choice between **Web portal:** overview of energy consumption (e.g. per hour, day, week, month; showing base load, electricity consumption by cooling appliances (blue) and other electricity consumption (yellow). - practical advice on energy saving. - option to download their consumption data easily and to save it. OR: **Written information:** mainly sent to people who did not have any access to the Internet and those who preferred the written form. It showed the energy consumption of the previous months, weeks and days; provided estimates of base load share of energy consumption; provided advice on energy saving AND/OR **ToU tariff:** there were two tariffs, peak and off-peak with a large difference between peak and off-peak (factor 2,5) Participants in the variable tariff option saved more energy (3 times more) than households that only received energy consumption feedback.
Achievements in experimental stage: Households with a time-variable tariff attained an extra energy saving of 6 % (on top of the average 3.7% achieved by the group without dynamic pricing) , the load shift was only 2 %. Most users judged the feedback as informative, helpful, well-designed, easy to use and understandable. A minority was concerned about data security and a smaller number found being involved consciously in energy-consumption matters was inconvenient and time-consuming. Most people surveyed showed a clear willingness to

save energy. The written information was judged almost as positively as the web portal. Suggestions for improvement included a display of the energy consumption in real time and a breakdown of the electricity consumption for each appliance in the web portal.

Remarks:
The duration is rather short for evaluating durable changes in routine behaviours

8. Efflocom pilot in Norway (Efflocom 2004)

Duration: 2001-2004

Scope: 10,485

Aims: to increase the end-user flexibility in periods of scarcity of electrical energy and power by establishing the basis for the set-up of a an infrastructure based on ICT-solutions for direct communication and load management.; by developing, testing and evaluating different incentives to encourage flexibility in consumption (based on tariffs)

Recruitment, response, segmentation used, control group, representativeness
Technology for direct communication was installed at customers located in the concession areas of the network operators Buskerud Kraftnett and Skagerak Nett.

Interventions (pricing mechanism; technology; feedback)
Residential consumers were placed on one of three tariffs.
- a ToU tariff;
- a dynamic tariff with a real-time element depending on the wholesale spot price; and
- a dynamic tariff with a temperature dependent part.

Of the participating households, 50 % of the houshold customers were to be equipped with potential for load control via the two-way communication link). For the household customers, the boiler for water heating and some floor heating were the appliances that are most relevant for load control.
The variable parts of the dynamic tariffs were only activated in periods of peak load (8-11am and 5-8pm for November-April).
For consumers that accepted remote load control, low prioritised loads (Boilers for water heating) could be disconnected by the energy supplier under certain conditions
Technology and feedback:
- smart meters (two-way communication), including hourly metering
- and a separate channel for remote control

Achievements:
Results for Buskerud Kraftnett showed the following.
- For consumers with remote load control: 12% reduction in morning peak usage, and 14% reduction in afternoon peak usage. (1,230 consumers)
- For consumers with the ToU tariff but no load control, maximum peak use reductions were 10% in the morning and 7% in the afternoon. (39 consumers).
- Results for the ToU tariff and spot price on an hourly basis show peak use reductions of 35% in the morning and 31% in the afternoon, but the sample size was small (6).
- Results for use of power contract with spot price on an hourly basis, without technology for load control, shows peak use reductions of 15% during the morning and 22% during the afternoon (17 customers)

Results for Skagerak Nett showed the following.
- For ToU consumers without load control, the maximum peak period demand reductions were 8% in the morning and 9% in the afternoon (198 consumers)
- Results for both ToU tariff and spot price on an hourly basis: peak use reductions of 16% during the morning and 24% during the afternoon (34 customers)
- For consumers with ToU pricing and an hourly spot price, the maximum peak period demand reductions were 14% in the morning and 28% during the afternoon (24 consumers).

Remarks: study is not providing clarity on methods of recruitment, results, use of control group etc.

Annex 2: Load flexibility for different appliances

Household practice or need: Cleaning and washing: Tumble Dryer	
Flexibility in terms of potential load shifting	Tumble dryer is a large load and can contribute significantly
Options for reduction	Drying without tumble dryer when possible (preferably not indoors due to health issues) Reduction can also be accomplished through the investment in more energy efficient tumble dryer or a washing machine that dries the laundry more effectively.
Type of behaviour	Routine Investment
Flexibility in terms of Willingness to shift and reduce	Shifting: limits to willingness to shift time of washing and therefore drying due to household routines and needs and limits to norms around air drying (some segments might see it as a poor people's thing to do)
Automation/ remote control?	A general problem is that from a technology point of view this load is easily controlled remotely or with automation, but many households express concerns around the clothes getting folds because they lie still for too long if not put in wet and taken out immediately after the cycle is concluded.

Household practice or need: Cleaning and washing: Washing Machine	
Flexibility in terms of potential load shifting	In principle the washing machine can be used flexibly during the day by means of timers or remote control. the shifting potential is high.
Options for reduction	Reduction can be accomplished by lower temperature settings, using the eco cycle, washing only with full loads, and by investing in more energy efficient washing machine
Type of behaviour	Routine Investment
Flexibility in terms of Willingness to shift and reduce	Shifting use of washing machine is a tricky thing because households have concerns about the hygiene and folding of laundry if left in the closed machine for too long.
Automation/ remote control?	The washing machine can easily be controlled remotely or with a timer, and remote control also allows for temporary stops of the washing cycle.

Household practice or need: Cleaning and washing: Dish Washer	
Flexibility in terms of potential load shifting	There usually is a great many hours between the filling and emptying of the dishwasher, in which time the appliance use can be shifted. To avoid perverse use of cost beneficial time of use and the consequential increase in consumption it is important to make sure the dishwasher is only turned on when full. Reduction can be accomplished by washing by hand, but then there is a rebound in gas for water heating.
Options for reduction	Reduction can be accomplished through the investment in more energy efficient dishwasher
Type of behaviour	Routine and investment
Flexibility in terms of Willingness to	The dishwasher can relatively easily be turned on off-peak

shift and reduce	
Automation/ remote control?	Remote control of the dishwasher is relatively easy to manage and relatively acceptable to households in general.

Household practice or need: Eating and drinking: electric cooking	
Flexibility in terms of potential load shifting	Not very flexible since this is linked to cultural routines. some dishes can be prepared before peak hours and then only reheated.
Options for reduction	Reduction can be achieved through tailored tips such as turn off the pasta as soon as it cooks; turn to steam cooking, put lids on pans, cook for more days at a time.
Type of behaviour	Routine
Flexibility in terms of Willingness to shift and reduce	very limited willingness to shift cooking between 7 & 9 pm to later time Cooking routines are strongly linked temporally. Not much options to shift to off-peak unless food is cooked before peak periods and then reheated.
Automation/ remote control?	Cooking cannot be automated, nor are appliances used for cooking.

Household practice or need: Eating and drinking: water cooker, microwave, espresso machine, coffee grinder, blender, oven	
Flexibility in terms of potential load shifting	The theoretical potential is reasonable
Options for reduction	Reduction can be achieved by means of investment in more energy efficient appliances and through tailored tips such as: cook/heat no more than needed
Type of behaviour	Routine
Flexibility in terms of Willingness to shift and reduce	Some things can shifted but has one person commented: "what am supposed to do, have cold tea?" the potential is limited. The use of these appliances and the needs they fulfil are felt frequently during the day and changing them would severely affect feelings of comfort.
Automation/ remote control?	No real options for automation of these functions

Household practice or need: Eating and drinking: Fridge and freezer	
Flexibility in terms of potential load shifting	The fridge and freezer represent a significant load in many households and have great potential for flexible load.
Options for reduction	Reduction can be achieved through the investment in a more efficient fridge or freezer, but also by automated control of the temperature and defrost options (turning of 15 minutes every hour has no impact on temperature or hygiene). in addition tailored tips such as: - set temperature right -do not leave door open too long. -put second fridge/freezer in barn or cellar during winter
Type of behaviour	Routine/one-off
Flexibility in terms of Willingness to	Several projects have been undertaken with this automated control of the fridge and households are in general willing to allow this load management option.

shift and reduce	
Automation/ remote control?	automated turn-off for small periods

Household practice or need: Comfort: lighting	
Flexibility in terms of potential load shifting	In general light is necessary, the amount could be reduced but the load not really shifted.
Options for reduction	Reduction can be achieved by turning off lights in unused rooms, and by installing CFL or Oled bulbs or motion detectors
Type of behaviour	Routine and investment
Flexibility in terms of Willingness to shift and reduce	People will not be very willing to reduce light levels in their homes, except for turning off lights when they leave a room.
Automation/ remote control?	yes (timer; lightning control systems) and movement detection systems.

Household practice or need: comfort: outside lighting	
Flexibility in terms of potential load shifting	This light can be connected to movement detection and can be turned off during peak hours.
Options for reduction	turn off lights & use saving bulbs and motion detection
Type of behaviour	Routine and investment
Flexibility in terms of Willingness to shift and reduce	people might be unwilling to turn off certain types of outdoor lights, such as Christmas lights since the explicit aim is to be visible.
Automation/ remote control?	yes (timer, lightning control systems), motion detectors

Household practice or need: leisure: TV	
Flexibility in terms of potential load shifting	Watching television during other activities can be unlearned. However, the watching of television in the evening is often a non-negotiable activity that is deemed necessary to unwind. Some shifting is possible by watching television on other media such as tablets that have been charged beforehand.
Options for reduction	turn off when no one's watching
Type of behaviour	Routine
Flexibility in terms of Willingness to shift and reduce	very limited willingness to shift watching TV between 7 & 9 pm to later time
Automation/ remote control?	The only real option would be to connect the TV to batteries so that the direct consumption of energy can be temporarily shifted

Household practice or need: leisure: Music installations	
Flexibility in terms of potential load shifting	Listening to music on devices with batteries such as laptops, iPods, mp3 players

Options for reduction	turn off when no one's listening
Type of behaviour	Routine
Flexibility in terms of Willingness to shift and reduce	For many households having the radio or music player on during other activities or when not at home as 'companion 'to pets is a difficult behaviour to change.
Automation/ remote control?	No automation available to shift this behaviour.

Household practice or need: leisure: games	
Flexibility in terms of potential load shifting	With online gaming the only way to shift consumption is by means of battery devices such as laptops. However to have a good gaming experience usually a desktop computer is required.
Options for reduction	limit use of games
Type of behaviour	Routine
Flexibility in terms of Willingness to shift and reduce	This activity is comfort and leisure related and very much linked to relaxation time in the evening
Automation/ remote control?	Automation is not relevant for this activity

Household practice or need: leisure: PCs/tablet	
Flexibility in terms of potential load shifting	the total consumption of these devices is significant, and as such the potential load shifting as well, although these devices are used rather constantly during the day
Options for reduction	turn off when not used, charged in off-peak periods. Buying more energy efficient devices.
Type of behaviour	Routine and investment
Flexibility in terms of Willingness to shift and reduce	The activities related to these devices are usually not very shift able, e.g. servers or work related.
Automation/ remote control?	Not relevant

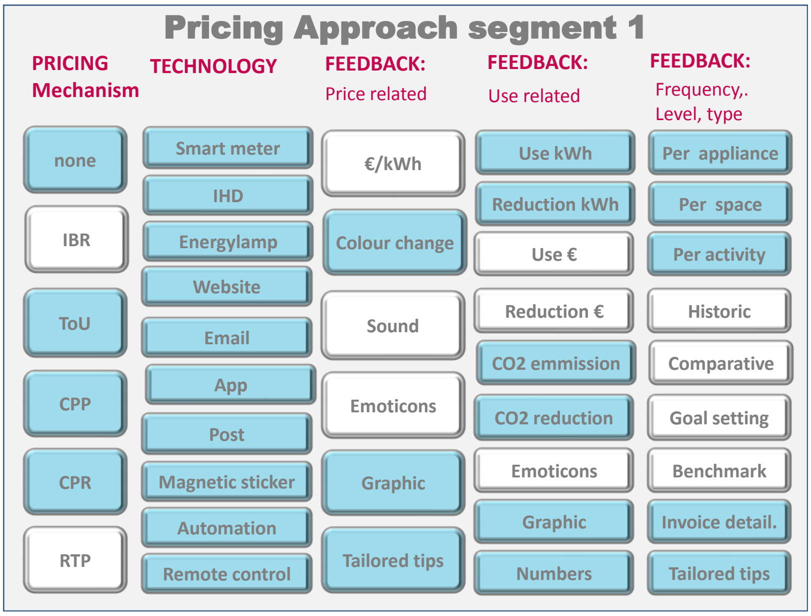
Household practice or need: care: hair-dryer; el toothbrushes, el razors, etc.	
Flexibility in terms of potential load shifting	Not very significant load
Options for reduction	limiting use of hair dryer; not using the electric toothbrush every day, razing by hand etcetera
Type of behaviour	Routine
Flexibility in terms of Willingness to shift and reduce	People could be motivated to perform these activities later in the evening before going to bed, instead of in the morning. However, it requires a change in norms and perceptions of comfort.
Automation/ remote control?	No automation possible here, would even be worthwhile limiting the electronic device use in this area.

Household practice or need: ease: standby	
Flexibility in terms of potential load shifting	Significant load shifting potential
Options for reduction	use stand-by killers
Type of behaviour	One-off/investment and Routine
Flexibility in terms of Willingness to shift and reduce	Turning otherwise standby devices off completely during peak periods could work, if people are convinced that the settings will be preserved.
Automation/ remote control?	Automation can create increased level of comfort

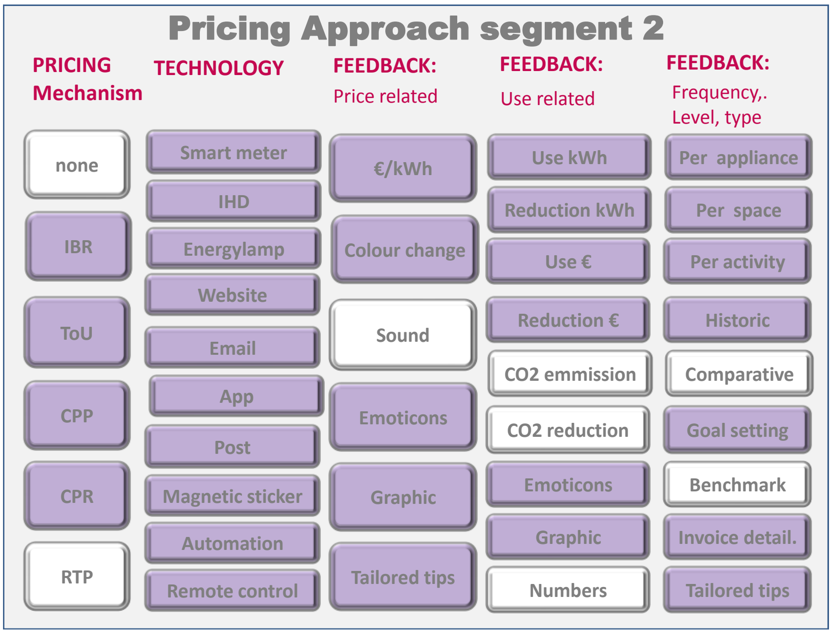
Household practice or need: cleaning and maintenance: Vacuum cleaner; do-it-yourself and garden-related machines (e.g. lawn-mower, drilling machine, terrace heater)	
Flexibility in terms of potential load shifting	These activities can be shifted to off-peak periods, They very often already take place in off-peak periods.
Options for reduction	reconsider usage and frequency of cleaning with electronic devices, stimulate use of brooms, and manual devices or otherwise buy energy efficient machines
Type of behaviour	Routine and One-off/investment
Flexibility in terms of Willingness to shift and reduce	People can probably be motivated to shift the time of use
Automation/ remote control?	Not really possible, mostly requires manual activity.

Annex 3: Dynamic pricing approaches tailored to 6 segments

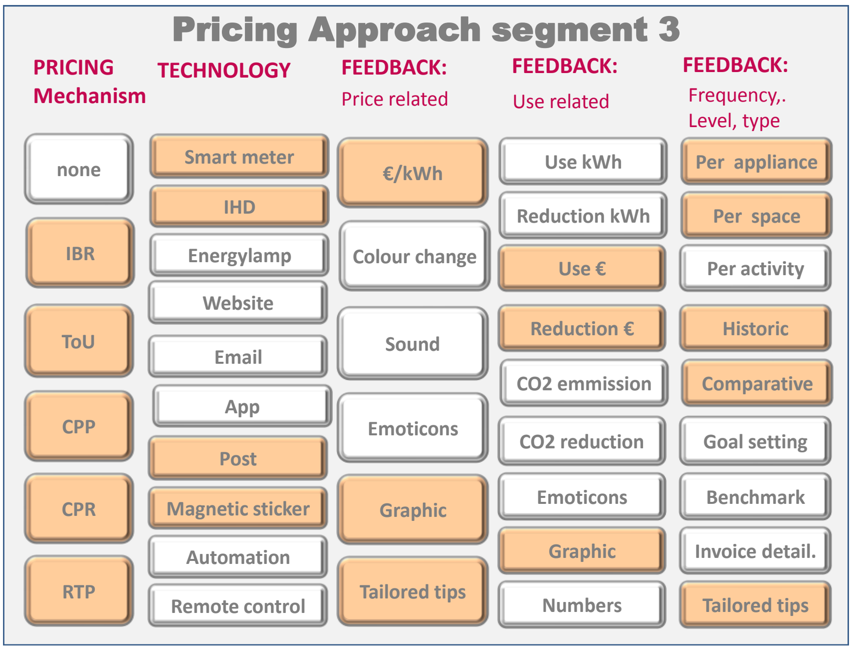
Segment 1	**Idealistic savers**
General Considerations	This group shows most efforts to save energy, and already does a lot in terms of reduction. Driven by idealism, these people are willing to make financial sacrifices and impose restrictions on themselves even if it means loss of comfort. This customer is knowledgeable and consists largely of highly educated women.
Preferred behaviour	Both routine behaviour and efficiency measures
Main motivation	This group could be motivated to shift their consumption but from an environmental motivation.
Choices related to Pricing Mechanism	Saving and shifting will not be financially motivated (no emphasis should be put on money)and a price incentive may not be the best incentive. If a price incentive is used, a combination of ToU, possibly with CPP, is a good option to visualise energy shifting options. Because this segment is not financially motivated, RTP is probably not suitable (because you still need to respond strongly to price). You could also simply CPP (and focus on shifting only).
Choices related to technology	Since this group is highly educated and well informed, different technologies can be used to support further behavioral change. The use of technology should be functional for this group. Almost all options are ticked in the toolbox because these people want information to be provided both at home and at work on PC, smart phone, IHD. This group does not like ceding control (especially to a party that is less environmentally conscious and idealistic than themselves). Remote control by third parties is not an option, automation is possible if this group can control it themselves.
Choices related to Feedback	Detailed and differentiated information is desired. Because this group is well informed, she is well able to interpret the information. Text, graphics, and / or lamp signals when price changes are options. Tailored advice needs to be focused on shift options. What is important for this target group: who gives feedback and how reliable they find this party?



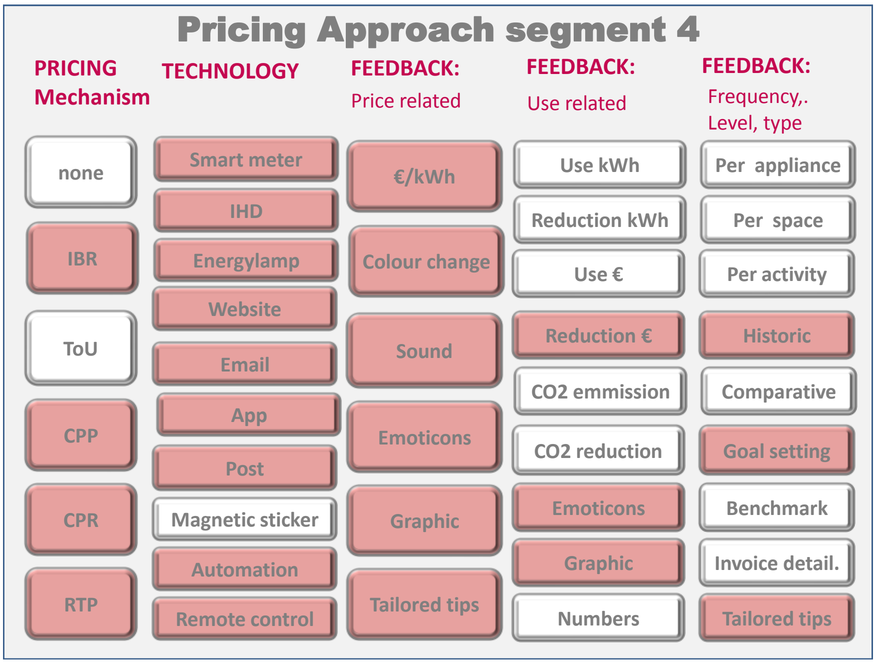
Segment 2	**Selfless inconsistent energy savers**
General Considerations	This customer is already highly motivated, highly educated and fairly reasonably prosperous. This group also shows significant energy-saving activities. At the same time, they are not very consistent: although they do believe that they can make a difference, they are quite inconsistent in terms of energy efficiency measures at home - because at that level they do very little.
Preferred behaviour	More routine and less investment behavior.
Main motivation	This group could be motivated to shift their consumption but from an environmental motivation.
Choices related to Pricing Mechanism	Saving and shifting will not be financially motivated (no emphasis should be put on money). TOU and / or inclining block prices, in combination with CPP or CPR would fit this group. Since the motivation is not primarily financial in nature, RTP is probably not perfect (because you still need to respond strongly to price).
Choices related to technology	Since this group is well-educated (but not as well informed) we can assume that different technologies can be used to clearly and adequately inform the user good about their behaviors and their impact. This group is willing to pay for the technology as long as it is functional. this group is not worried by remote control and automation may be appreciated, but can also put a brake on learning of this group (see below).
Choices related to Feedback	Clear and understandable feedback to the end user is needed to allow them to start a learning process on their own (inconsistent) behavior and opportunities for improvement (also e.g. goals, and advice on investment behavior). Since these users are motivated, this may result in an actual decrease AND shift in energy. Thus, in the beginning especially graphics and light signals can be used, and in time the information can be further differentiated in accordance with the growing understanding of the end user.



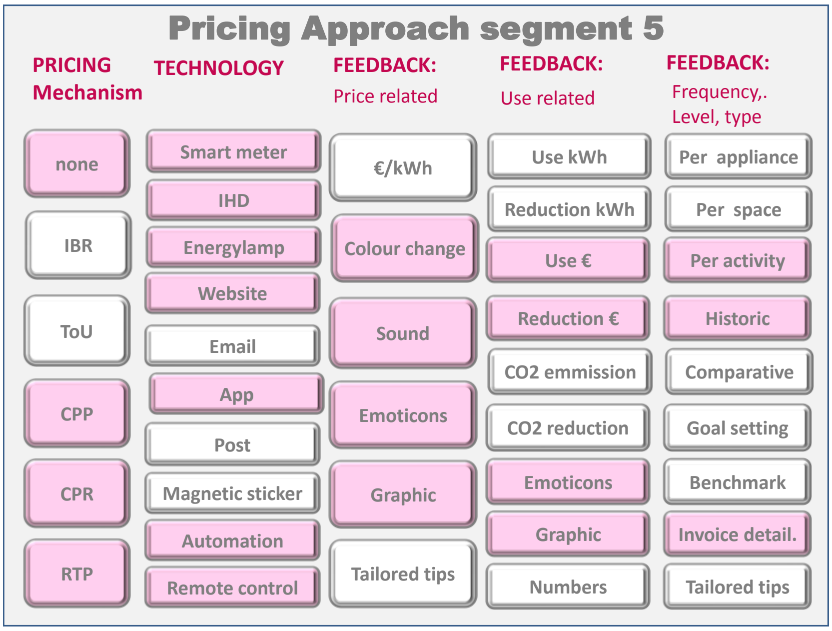
Segment 3	**Thrifty energy savers**
General Considerations	The thrifty savers are into energy-saving as long as this does not bring them any negative financial consequences. This also applies to their acceptance of policies: these should not ask for any additional financial efforts from end users. These are older people with lower incomes.
Preferred behaviour	Focus on routine behavior
Main motivation	Their motivation is not primarily intrinsic- but relates to financial necessity and social pressure. If shifting pays off financially they would be interested.
Choices related to Pricing Mechanism	Since financial motivation is strong dynamic pricing rates are all possible in principle. This segment accepts intervention if it pays off (in any case is should cost nothing extra). ToU, IBR, in combination with CPP or CPR may be used. RTP is an option, especially if it offers additional opportunities for savings. It is important that this segment understands what it all entails and receives clear information and tailored tips.
Choices related to technology	Since these people are older, not very well educated and not very prosperous, we assume a surfeit of technology to do more harm than good. This segment will not want to invest (payback time is probably unfavorable due to old age). The technologies used need to be functional, designed to provide the necessary information via an easily programmable IHD, with postal and magnetic sticker reminders. Remote control is most probably not attractive to this group.
Choices related to Feedback	Good regular guidance accompanying the technology is important. The feedback should clearly show the financial savings and provide tips to save even more. Feedback channels are: oral, mail, TV commercials. Because this segment is sensitive to societal expectations of energy efficient behavior, comparative feedback is also desirable. It is important to keep in mind that this is potentially a vulnerable segment and the behavioral changes should not compromise health or well-being.



Segment 4	**Materialistic energy consumers**
General Considerations	The materialists do little to save energy, but are open to energy efficiency measures for the house. They are not very positive about policies if these have financial implications for them. Majority are male.
Preferred behaviour	(open to) mainly investment measures for the house and perhaps also energy-efficient or smart devices.
Main motivation	This end user is difficult to motivate but financial incentives provide a good entry that matches the motivation. this segment is open to shifting if it pays off financially.
Choices related to Pricing Mechanism	Price is the main consideration for energy behaviour change in this segment and this group accepts intervention only if it pays off. Since the materialist by itself not very motivated, ToU price mechanism is probably too weak an incentive for him to get moving, furthermore toU asks for routine behavior change. A sturdy IBR or CPP / CPR, with large differences between peak and off-peak, can work. RTP is also an option, if linked to an automation or remote control system so that this segment does not have to follow the price fluctuations.
Choices related to technology	The materialist loves technology, gadgets. The common items (smart meters, IDH) and Apps are convenient, but remote control and automation are attractive as well. It may cost some money as long as the return on investment i s short and provides additional benefits such as status. Links with security systems or home automation can also help to stimulate interest because the materialist likes to invest in his own house.
Choices related to Feedback	Clear and understandable feedback that aims to inform the end user about the financial savings as a result of investment in housing and appliances is valuable. feedback should also offer tips to realise even more financial savings. Historical and goal setting feedback and tailored advice can provide additional support .

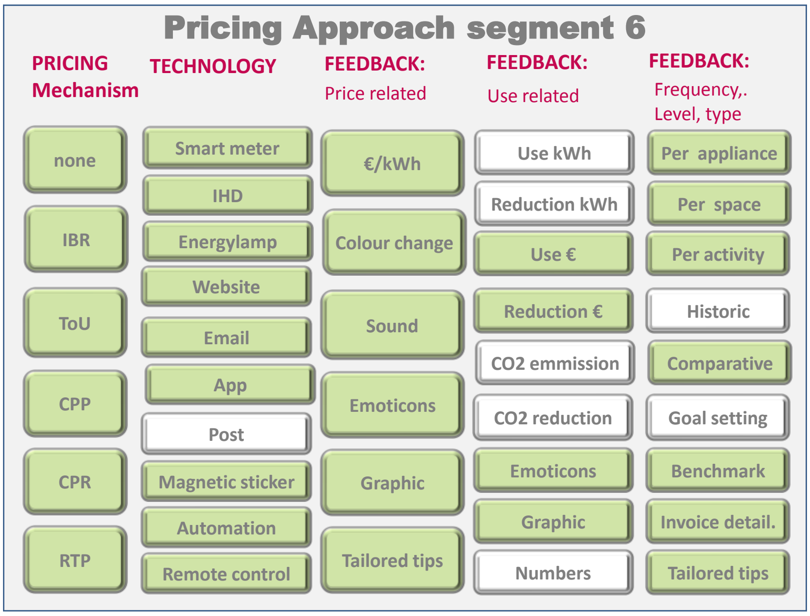


Segment 5	**Comfort-oriented indifferent energy consumers**
General Considerations	The comfort oriented are the least likely to energy saving behaviour. They do not care about the potential societal problems that the increasing energy consumption entails. They do not feel responsible and energy consciousness is nil. Their behaviour is driven by the search for personal comfort. This group of people is opposed to restrictive policies and interventions that discourage this behaviour. Majority is male.
Preferred behaviour	In principle willing to change both routine and investment behavior.
Main motivation	This end user is very difficult to motivate because he / she is really not interested, and because this segment wishes no interference from government or operator. The main motivation is comfort and pleasure in life. Shifting should thus be fun or increase comfort.
Choices related to Pricing Mechanism	As this is the most difficult segment, that is not financially motivated and does not wish interference every incentive to shift focus is acceptable, as long as it's fun and comfort is not affected or even increased, for example by a system that automates activities that are experienced as being burdensome. So RTP or CPP / CPR linked to a automated system so that he / she does not have to follow the price fluctuations. Stimuli that do not work with price but status or comfort will also work. ToU is difficult because it requires permanent routine changes. IBR is probably not suitable because it is focused primarily on savings and this will only work using energy efficient investments in homes or devices that are increasing comfort.
Choices related to technology	A price incentive in itself is not fun, but possibly technology can play a role in increasing fun. Technology should therefore seduce and the more the better as long as comfort is not reduced or even increases. Technology that takes care of burdensome activities is cool, and technology that seduces the group to start being interested - cool apps, beautiful displays, digital rewards (complementary currencies, gaming) could work. Remote control and automation are probably only attractive if they lead to increased comfort, e.g. as part of home automation and security systems.
Choices related to Feedback	Attractive feedback should aim to slowly attract interest in saving and shifting behavior. Historical feedback and feedback on activities to show and feel that energy / shift will not be at the expense of fun activities and comfort is necessary. the challenge is to provide feedback in such a manner that it is not experienced as an infringement of comfort.



Segment 6	**Problem Conscious welfare oriented energy consumers**
General Considerations	This segment consists largely of young people and is reasonably well educated. These people are not enthusiastic about saving energy. Although they are aware of the consequences of their behaviour and also believe that energy-saving behaviour can make a difference, they do not feel called to action. This is possibly because they think that their ability to save energy is very limited.
Preferred behaviour	Willing to change both routine and investment behaviour (has not done much yet).
Main motivation	This end user is quite difficult to motivate but there is an opening because he/ she is energy conscious and believes that their own behavior can make a difference. Although oriented towards comfort, they also feel a certain social pressure to do something about the energy situation and are sensitive to financial motivation. Shifting is attractive only if it is fun and financially interesting.
Choices related to Pricing Mechanism	This segment does little yet, but that could change. Any price mechanism is relevant and can provide an incentive (even if money is not the only motivation). ToU, or IBR, in combination with CPP and CPR is a logical choice. RTP is an option if connected to an automated or remote control system. In addition other non pricing incentives would work
Choices related to technology	Technology is probably not a problem, these relatively young users are accustomed to the use of many technologies. Remote control and automation may be appreciated. At the same time, the question is whether this group is likely to invest in technology in and around the house (probably not). Technology should be fairly easy to use. Gadgets and gaming may increase interest. Combinations with automation and remote control are possible, but this should not be too much trouble and money.
Choices related to Feedback	Bright and nice feedback should be used to increase this user's ability to save energy and to shift without sacrificing comfort and lifestyle (it must be a little trendy). Technology (well-designed course) can contribute to the feeling of

	being trendy. This will be presented as part of a lifestyle, with role models and using (option to) comparative feedback. Communication of "actionable advice" is important, as well as demonstrating that behavioral change is easy, effective, and not at the expense of comfort. Social media plays a major role in providing feedback and as a social pressure mechanism.



Annex 4: Findings from Dynamic Pricing pilots, studies and reviews

Pricing mechanisms + technology + feedback	Impact	Reference and remarks
Dynamic pricing general		
	lower electricity bills over the duration of the pilot.	Stromback et all 2011 - Very general conclusion - Most pricing trials have been done outside of EU
Dynamic pricing general + persistence	**persistence in DR over at least 2 years**	Faruqui and Palmer 2011 Persistence in demand response across multiple years has been demonstrated in pilots in California and Maryland. California's State-wide Pricing Pilot (July 2003 - December 2004 ;transferability to NL context is difficult
Dynamic pricing general + persistence	There is limited evidence on whether demand side responses **persists** over time if it is not automated or directly controlled.	Frontier Economics and Sustainability First (2012)
Dynamic pricing general	pilot **sample size does not significantly influence pricing pilot results**	Stromback et all 2011 -
Dynamic pricing general	end-users respond mainly to ***changes* in the price** of electricity rather than to the price of electricity	Stromback et all 2011
Dynamic pricing general	- "**Arc of price responsiveness**": the amount of demand response rises with the price ratio but at a decreasing rate - larger price differentials between peak and off-peak periods lead to more load being shifted away from high price periods to lower price periods.	- Stromback et all 2011 Faruqui and Palmer 2012:
Dynamic pricing general	Consumers do shift electricity demand in response to economic incentives even if these incentives are accompanied by only basic information (e.g. magnets, info sheets, bill inserts) on the prices being applied, however the size of the shift can vary significantly.	Frontier Economics and Sustainability First (2012);
Dynamic pricing general + **enabling technologies**	- enabling technologies such as **in-home displays**, **energy orbs** and **programmable and communicating thermostats** boost the demand response. **ambient notification** appears particularly efficient and effective to notify participants of upcoming high prices	Faruqui and Palmer, 2011; 2012; Stromback et all 2011 - Baltimore Gas and Electric's Smart Energy Plan pilot It found in 2008-2009 that the peak impact with the energy orb was greater than the peak impact with price alone, and that the peak impact with the price and

		energy orb and the air conditioner switch was even greater. Faruqui and Palmer 2011
Optimum tariff levels and **ratios & role of technology & feedback**	"Time-varying tariffs may play a role in managing energy demand, in controlling total and peak-time consumption. The optimum tariff levels and ratios, and the role of advice and technology in supporting behaviour change, are as yet poorly understood."	EDRP (2011 - reports on 4 trials, conducted by EDF, E.ON, Scottish Power and SSE; attention for recruitment and control groups), p. 14
Equity	Findings on the response of vulnerable and low-income consumers to DSR initiatives vary across studies. **Some but not all studies found consumers from these groups are less responsive than the average consumer to DSR signals**.	Frontier Economics and Sustainability First (2012);
Dynamic pricing general + **alerts/reminders**	**The more ways** in which participants are **alerted** of the event and their response, the better the demand response	Stromback et all 2011
Dynamic pricing general + **alerts/reminders**	pricing pilots, whit **high participant interaction** showed better results	Stromback et all 2011 - - unclear what types of interaction works best, what type is most cost effective?
Dynamic pricing general + **automation**	Automation is highly effective as a means of **shifting or reducing load**	Stromback et all 2011 - costly in low consumption markets. - may change if technology becomes more affordable and/or the price of electricity increases.
Dynamic pricing general + **automation**	generally speaking, **automating several sources of load is more effective than a single source**	especially if the sources use significant amounts of electricity. Stromback et all 2011
Dynamic pricing general + **automation + education**	**Automation** designed to enable **load shifting** must be combined with **education on how to lower total consumption** in order to **avoid increased overall consumption levels**	Stromback et all 2011 this (increase in overall consumption) happened in a number of pricing pilots with automation
Dynamic pricing general + why behaviour changes	There is limited evidence on how consumers shift their electricity use in response to incentives. For example, with the exception of air-conditioning and storage heating, it is not clear which appliances consumers are willing to use in a flexible way.	Frontier Economics and Sustainability First (2012); meta-review of studies and pilots - not all well-designed or well-evaluated;
Dynamic pricing general + feedback	- consumption reduction is highest (10.3%)with a combo of up-to-date consumption, historical consumption and cost (bill) are offered to participants What participants respond best to and they value most in our review is: 1. Up-to-date consumption level (i.e. how much energy they have used between the last bill and now) 2. Up-to-date cost or bill (i.e. how high is their bill since they last paid)	Stromback et all 2011

	3. Historical consumption (I.e. how much electricity have they used during this period compared to the previous periods)	
Dynamic pricing general + technology + feedback	In addition, end-users prefer an in-house display (IHD) that provides this direct feedback. Clear feedback to end-users is a necessary element because it enables them to learn how to control their energy consumption most effectively over a long period of time (Landis+Gyr, 2009). Pricing schemes in combination with direct feedback that is provided with in-house displays (IHDs) have the best results in terms of energy saving (compared to feedback being provided on a webpage or with informative billing) (Stromback et al, 2011; Landis+Gyr, 2009). Key advantage of IHD is that it offers almost real-time and visible aspects of the delivery of feedback. Adding frequent accurate billing to the combination of price incentive scheme and direct feedback via IHD is advisable (Landis+Gyr, 2009)	Stromback et all 2011
	The outcomes vary widely within a given type of scheme: pricing in combination with IHD pilots can attain 3% or 19% reductions. This is because of the impact of surrounding variables on program outcomes (in addition to the supportive technology used or particular pricing scheme) (Stromback et al, 2011).	Stromback et all 2011 -
	Socioeconomic factors and consumption patterns can overcome supportive technology and program type (e.g. a good informative billing pilot can lead to higher savings than an IHD pilot depending on surrounding circumstances despite the fact that on average an IHD is 50% more effective than an informative bill at reducing overall electricity consumption) (idem)	Stromback et all 2011
Time of Use		
ToU - % shifting (peak reduction) - % of reduction	9% peak reduction in European trials (based on 15 trials) 13% peak reduction in Australian trials (based on 10 trials) 5% peak reduction in USA (based on 84 trials) 6 % peak reduction in Canada (based on 106 trials)	Meta-review by Stromback et al 2011 Based on 215 TOU trials, of which only 15 in Europe; 10 in Australia, 84 in USA and 106 in Canada). Some of these ToU trials also included a CPP part
ToU	Peak reduction: 8.8% across all the TOU rates and information interventions. Overall reduction of electricity consumption: 2.5%	CER trial Ireland
ToU	ToU peak reductions are the lower than with CPP/CPR, but occur daily.	Based on 250 samples (Stromback et all 2011);

		transferability to NL context is problematic because most samples (310 out of 340) are from outside of Europe
ToU	- TOU trials: results in terms of **peak clipping** decrease after 12 months but increase again after 24 month(for unclear reasons)	Stromback et all 2011
ToU + **education**	- Participant education clearly determines the success of failure of TOU pilots in terms of **both shifting and reduction** - TOU pilots without education **increased** total energy consumption while TOU with education **lowered** total energy consumption by 4%	Stromback et all 2011
ToU + **reminders** (fridge magnets and stickers)	**Fridge magnets and stickers have proved cheap and efficient** ways to make participants **aware and remind them** of the different prices of electricity during the day	Stromback et all 2011
ToU + **automation + flexible load**	ToU: The size of the shift varies across tariff types and trials (from 0% to 22%). shows that day-in day-out shifting of demand away from peak times can be sustained through the combination of automation and a tariff signal, especially where consumers have a single flexible load (for example storage heaters).	From Frontier Economics and Sustainability First (2012) Based on evidence from the long running Economy 7 scheme in the UK4
ToU + **IHD or ambient displays; regular updates**	**real time and hourly updates** (often displayed on IHDs or ambient displays) are most efficient at lowering overall energy usage in TOU trials	Stromback et all 2011
ToU & **DSM stimuli**	-**ToU tariffs and DSM stimuli** resulted in **reduction of electricity use by 2.5% and peak usage by 8.8%;** - the combination of **bi-monthly bill, energy usage statement and electricity monitor** was more effective than other DSM stimuli in reducing peak usage with a **peak shift of 11.3%;**	(CER,2011) Ireland. 5,028 participants; representative sample; use of control group
ToU **Reduction & consumption pattern**	Overall energy reduction is linked with the level of usage	(CER,2011) - Ireland. 5,028 participants; representative sample; use of control group
ToU & **DSM stimuli**	Of the tariff groups tested, no single one in combination with DSM stimuli stands out as being more effective than the others.	(CER,2011) - Ireland. 5,028 participants; representative sample; use of control group
ToU & **Behavioural change reported**	82% of participants made some change to the way they use electricity due to the Trial with 74% stating major changes were made by their households;	(CER,2011) - Ireland. 5,028 participants; representative sample; use of control group
ToU & **Magnets & stickers**	Simple information can also be effective: The fridge magnet and stickers achieved 80% recall with 75% finding the magnet useful and 63% finding the sticker useful.	(CER,2011) - Ireland. 5,028 participants; representative sample; use of control group
ToU & **IHD**	The electricity monitor was deemed to be effective as a support to those achieving peak reduction (91% rated it as	(CER,2011) - Ireland. 5,028 participants; representative

	an important support) and shifting to night rates (87% deemed it an important support).	sample; use of control group
ToU & **barriers**	Barriers to peak reduction relate to **the difficulty of linking behaviour change to bill reduction.** These perceptions may have contributed to the current recorded reduction. This may be hard to address due to exaggerated expectations of savings and similar exaggerated expectations of consequences if reduction is not achieved **Barriers to shifting to night usage relate to safety and convenience**.	(CER,2011) - Ireland. 5,028 participants; representative sample; use of control group
	The Overall Load Reduction incentive was impacted by a low recall rate (58%). However, the scores for communications, reasonableness of the target and effectiveness of the OLR incentive in motivating change were all very good.	(CER,2011) - Ireland. 5,028 participants; representative sample; use of control group
ToU & **Awareness raising**	The Trial **succeeded in making participants more aware of energy usage** (54% agreed) which is in keeping with the reduction in usage recorded. Only 18% stated that there had been no impact on the way their household uses electricity;	(CER,2011) - Ireland. 5,028 participants; representative sample; use of control group
ToU & **Segmentation-** relevant	**Households headed by individuals with greater educational achievement** or social grade achieved higher levels of reduction than those with lower levels. This was **in part related to the typically higher level of usage** associated with these households. Therefore, the impact of education or social grade on the ability to gain benefit from the tariffs is limited	(CER,2011) - Ireland. 5,028 participants; representative sample; use of control group
ToU & **Segmentation-** relevant	The impact of the time of use tariffs on recipients **of FEA (Free Electricity Allowance)** shows that these individuals exhibited the same level of change as other households and therefore **do not appear to be disadvantaged** over other groups;	(CER,2011) - Ireland. 5,028 participants; representative sample; use of control group
ToU & **Segmentation-** relevant	**Fuel poor** households (which lack financial means to adequately heat their homes) **also benefit from the deployment of time of use tariffs.**	(CER,2011) Ireland. 5,028 participants; representative sample; use of control group
ToU & other **interventions impact on shifting**	Two trials (EDF and SSE) tested time-of-use (TOU) tariffs for electricity in combination with smart meters and other **interventions (advice, historic and real-time feedback, and incentives to reduce overall consumption**). **These trials showed effects on shifting load from the peak period, with bigger shifts at weekends than on weekdays. Estimates of the magnitude of shifting effect vary with trial but were up to 10%.** - The EDF trial showed that the effect is stronger with smaller households (1 or 2 people). The effect was weaker in the SSE trial and this may be because awareness of the intervention was limited and it was seen as overly complex. EDF: ToU + Smart meter + accurate billing; RTD ("basic display");	EDRP (2011) - reports on 4 trials, conducted by EDF, E.ON, Scottish Power and SSE; attention for recruitment and control groups) (overall focus on reduction; with a minority focused on shifting. > 60,000 households; 18,000 with smart meters. Of these, some 195 were targeted with ToU. No data were gathered during the trials to provide evidence on what

	energy efficiency advice: sent by post	appliances or behaviours were responsible for the observed shifting. "The literature shows that time of use tariffs can also bring about reductions in total energy consumption. However, the evidence is almost exclusively from studies in hot regions (where the dominant energy demand is for air conditioning) and cold regions with electric heating. The limited evidence from the UK suggests small reductions (3% or less) in overall electricity demand and no such effect was detected in EDRP."
Critical Peak Pricing and Critical Peak Rebate (CPP and CPR)		
CPP & peak reduction %	CPP: 24% peak reduction in European trials (based on 4 trials) 28% peak reduction in Australian trials (based on 6 trials) 14% peak reduction in USA (based on 54 trials) 11 % peak reduction in Canada (based on 5 trials)	Meta-review by Stromback et al 2011 Based on 69 CPP trials, of which only 4 in Europe
CPP & CPR	- CPP and CPR bring the highest reductions but only for critical peak periods - CCP tend to have higher impacts than Time-of-Use (TOU) rates, likely because the CPP rates have higher peak to off-peak price ratios - CPP and PTR rates tend to have higher peak to off-peak ratios than the TOU rates, with some overlap	Faruqui and Palmer 2012 - transferability to NL context is problematic because most samples (310 out of 340) are from outside of Europe (e.g. different climatic conditions and load profiles)
CPP & CPR	Overall, it seems that CPP and CPR pricing impact are **persistent over time**.	Stromback et all 2011
CPP/CPR:	The size of the shift varies across tariff types and trials (from 5% to 38%).	
CPP & CPR + **education**	**Education has a significant impact on peak clipping**: participants who received education decrease their on-peak consumption by an extra 23% for CPP/CPR pilots compared to participants who did not receive any education	Stromback et all 2011
CPP & CPR + **automation and remote control**	IN CPP and CPR: - With **remote controllers** in appliances which can communicate with each other and react to outside information, such as electricity pricing signals, the **response of a household will approximately double**	Stromback et all 2011
CPP & CPR + **automation and remote control**	**Automated response and flexible loads:** Interventions to automate responses deliver the greatest and most sustained household shifts in demand where consumers have certain flexible loads, such as air conditioners or electric heating.	Frontier Economics and Sustainability First (2012)

CPP & CPR & technology & feedback	After automation, a combination of economic incentives and enhanced information (enhanced billing and e.g. IHDs and Orbs) generally delivers the greatest demand response	Frontier Economics and Sustainability First (2012)
Real Time Pricing (RTP)		
	RTP: 13% peak reduction in European trials (based on 3 trials) 10% peak reduction in USA (based on 12 trials)	Stromback et al 2011 - these trials do not show robust results (they are based on pilots mentioned in next row)
RTP	- limited available evidence suggests that domestic consumers do respond to real-time price signals. There has been limited testing so far of domestic sector real-time pricing. 4 Trials, 1 in Norway: results are non-significant; or overall price decrease on spot market interfered with trial. US project: one Group ToU & CPP, the other Group RTP, showed less response on RTP (17% vs. 20% peak shift). Lower response may also be due to the experienced complexity of RTP's - important question is how to reduce this through improved feedback to end-users. Testing of real-time pricing for households has not produced robust results to date	From Frontier Economics and Sustainability First (2012) looked at four studies : Norway EFFLOCOM Trial (2001-2004) (NW, 81 participants); PowerCentsDC trial (2008-9, USA, 231 participants); Illinois Real-Time Pricing Trial (2003-2006) 1,500 participants; Pacific Northwest GridWise Project (2006-2007, USA, 112)
Inclining Block Rates (IBR)		
IBR	Limited experience with IBR in California, Japan and Belgium Rationale behind IBR can be to help end-users reduce their bills (support weak social-economic groups) or to achieve overall reduction in consumption (general demand reduction aims).	CREG (2001)