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ENERGY EFFICIENCY ACTIONS RELATED TO THE ROLLOUT OF SMART METERS FOR SMALL CONSUMERS

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Abstract

The installation of electricity Smart Meters (SM) brings about new opportunities for enhancing the interaction between consumers, generators and energy service providers. SM are needed to exert certain sets of actions upon consumers aimed at producing changes in the functioning of the system that can potentially greatly benefit consumers and other parties. Actions to be applied on consumers may be aimed at encouraging them to adapt their behavior to the conditions existing in the system or may directly control their load.

The final benefits resulting from the application of SM related actions depend on the nature of the actions, but also on the characteristics of the system and the specific consumer group where these actions are applied. We first lay out the analytical framework to be used to assess the application of different sets of actions in a generic system. Afterwards, we use this framework to determine the SM related actions that should be first implemented in the Austrian system according to the benefits and costs of their application to this specific system. Based on our analysis, the provision to Austrian consumers of advanced indirect feedback on their electric load, together with the application of critical peak prices and simple time-of-use tariffs should already be considered in the short term.

Keywords

Smart Meters, Demand Side Management, Electricity consumer benefits, Consumer segmentation.

1. Introduction

Directive 2006/32/EC on Energy End-Use Efficiency and Energy Services mandates the installation of smart meters according to a pre-defined agenda for various sectors including electricity and gas distribution. Thus, smart meters are expected to be installed in the coming years in most, if not all, European countries. However, the installation of smart meters should not be analyzed in an isolated way but together with the implementation of different sets of smart-meter enabled actions that are aimed to increase end consumer energy efficiency and that have an impact on the system as a whole.

We analyze different sets of actions that may be directly or indirectly applied upon electricity consumers given a successful rollout of smart meters. Sets of actions related to the use of gas have not been explicitly considered. The potential for increasing the efficiency in the use of gas is limited by the fact that the techno-economic functioning of the gas system is more flexible than that of the electric one due to the availability of gas storage capacity. Besides, the use of gas by domestic consumers tends to be far less flexible than that of electricity. In order to increase the efficiency in the use of gas, consumers should be provided with more informative consumption feedback and some relevant advice on efficient practices and equipment.

This report is structured as follows. Chapter 2 introduces the general analytical framework used for the analysis of different sets of smart meter related actions. Chapter 3 provides a quantitative assessment of the impact of different sets of actions on the behavior and electricity expenses of consumers in Austria. In Chapter 4 we discuss the implementation of those sets of actions which, according to the previous analysis, would produce the largest benefits for consumers. Finally, Chapter 5 concludes. The analysis presented here has been carried out in the context of a project commissioned by the Austrian energy regulator (E-Control). For a detailed discussion on the topic, please consult the full version of the project report (FSR, 2010).

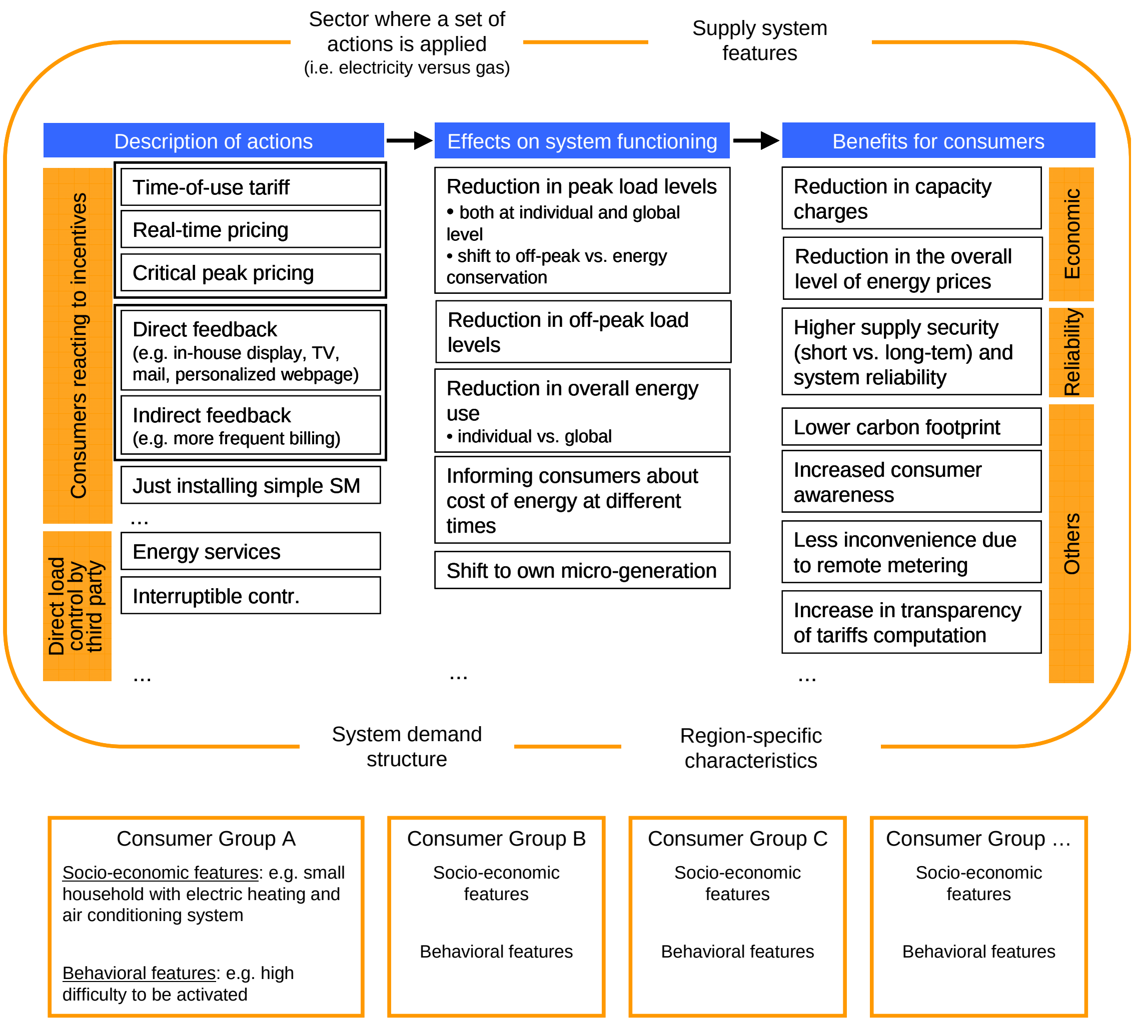
2. Analytical Framework

When analyzing different sets of energy efficiency actions taken upon consumers, one may distinguish between the actions applied, the effects they cause on the functioning of the system and the measurable end consumer benefits resulting from these effects. Effects and benefits resulting from actions depend on the characteristics of consumers targeted by these actions as well as on the characteristics of the sector and the system where actions are applied (see Figure 1).

Some of the main sets of actions to be considered are the provision of feedback to consumers on their electricity consumption (FB), different time-varying pricing arrangements including real-time pricing (RTP), critical peak pricing (CPP), peak time rebates (PTR) and time-of-use tariffs (ToU tariffs), as well as the direct control of consumers' load by third parties (DLC).

Based on their nature, actions can be characterized from a consumer perspective according to the potential relative advantage consumers may gain from their application, the complexity of the process of implementing them (representing an extra cost that cannot be easily measured but is affecting the reaction of consumers) and the cost of the implementation process. Potential benefits for consumers from the application of FB and ToU tariffs are medium (advanced FB and ToU) to low (simple FB), while the cost and complexity of their implementation process is low (given a simple tariff structure). Benefits from CPP or PTR are expected to be medium as well. However, the complexity of the implementation of these sets of actions is low and their cost of implementation is medium to low. Finally, RTP and DLC may likely result in high individual and system benefits but the cost of implementation of both sets of actions tends to be also high. The complexity of their implementation process is medium (RTP) to medium to low (DLC).

Figure 1: Analytical framework



The characteristics of an action, those of the system where the action is to be implemented and the ones of consumers in this system jointly determine the actual benefits that consumers will get from the implementation of this action. Consumers can be characterized based on their attitude towards the application of these new actions. We distinguish between active consumers willing to embrace new efficient actions and passive consumers who resist their implementation. In addition, one can also classify consumers according to the uses they make of electricity, thus, distinguishing between those consumers whose electricity consumption is flexible and can therefore be actively managed and those consumers whose load is not flexible. Supply conditions in a system where smart meter related actions are to be implemented may be highly variable, resulting in volatile electricity prices that consumers can arbitrage, or quite stable, implying that consumers would not profit from shifting their load from peak to off-peak hours.

The actual benefits produced by actions together with their implementation costs should guide the final decision on which actions to apply. Based on the previous discussion and assessment of the considered sets of actions, we now provide conceptual recommendations on the sets of actions to be implemented depending on consumer, sector and system characteristics. Ambitious, cost expensive and probably complex actions should be exerted upon active consumers who may greatly benefit from the efficient management of their load. Less ambitious, cheaper and simpler sets of actions should be exerted upon consumers that are active but may probably not get significant benefits from the application of these actions as well as upon passive consumers that should greatly benefit from their application. Finally, no set of actions might be effective in changing the electricity consumption behavior of passive consumers who would only obtain modest benefits from embracing them (see Table 1).

Table 1: Guidelines for the implementation of smart meter related sets of actions

	High potential benefits from SM	Low potential benefits from SM
Consumers easy to activate	+++	++
Consumers difficult to activate	+	-

3. Quantitative Assessment of the Benefits of Smart Meter Related Sets of Actions

Once the application of smart meter related sets of actions has been analyzed from a conceptual point of view, we now focus on the quantitative assessment of the impact on household consumers in the Austrian system of these sets of actions. We aim to assess the effect that each of these sets of actions is expected to have on both the household load and the electricity bill paid by consumers. We have characterized changes to consumption behavior caused by these actions according to the resulting reduction in households' peak load and the decrease in their overall electricity use. Given that finding quantitative estimates of the impact of smart meter related sets of actions on consumers in a third system similar to the Austrian one is extremely difficult, if not impossible, we have opted for computing the impact of the selected sets of actions by ourselves.

When computing the impact of different sets of actions on the consumers' electricity bill, we have assumed for simplicity reasons that changes to the consumer behavior triggered by these actions do not have any impact on the functioning of the rest of the system (i.e. electricity prices, investments in generation and network capacity, the reliability of the system, etc.). Therefore, we have only considered part of the benefits rendered by each set of actions and, thus, cannot draw definite conclusions on the overall relative merits of different sets of actions.

Sets of actions considered in the assessment include a ***simple package of feedback*** (more frequent and informative billing), an ***advanced package of feedback*** (simple package + comparative feedback + in-home display + personalized energy saving advice); ***real-time pricing***; simple two-level ***time-of-use tariffs***; ***critical peak pricing***; ***peak time rebates*** and ***direct load control***. For a detailed description of the characteristics of these sets of actions, see (FSR, 2010).

3.1 Methodology

We have computed the impact of different smart meter related sets of actions on electricity consumption patterns, as well as on the electricity bill, both for individual consumers of each of the types considered and for the whole set of domestic consumers in the Austrian system. Daily load profiles specific to each consumer type have been computed taking into account the characteristics of the corresponding consumers. In order to do so, we have produced synthetic load profiles for each of the main combinations of electric uses occurring in households in the Austrian system, which are in turn defined in terms of the use of air conditioning and electric heating systems. Thus, the load profile defined for each combination of electricity uses may be specific for a certain season of the year. These load profiles consider two load levels: peak and off-peak. The characteristics of the Austrian system that are relevant to the computation of the impact of each set of actions have been modeled through the use of stylized price profiles defined for two types of days: normal and critical, or emergency, days (i.e. those when the reserve margin in the system is especially tight).

Based on the information available in the existing literature and the characteristics of the Austrian system and its consumers, we have estimated the impact of the application of each set of actions on the peak load and daily electricity consumption levels of a consumer of each type in each season (this corresponding to a particular combination of electricity uses) and for each of the type of days considered. As an illustrative example, Table 2 provides the values we have estimated for these parameters under real-time pricing.

Table 2: Parameter values of the response of Austrian household demand to RTP

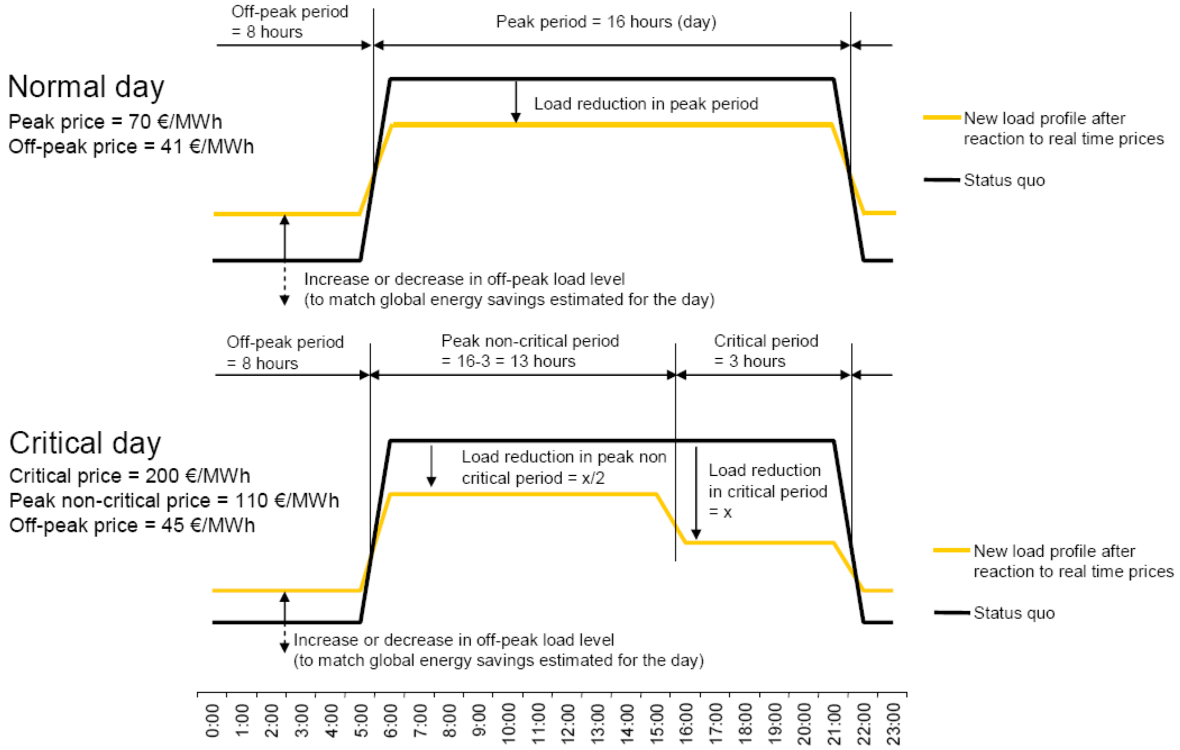
	Reduction in peak load		**Electricity savings**	
	Normal day	Critical day	Normal day	Critical day
No AC, no EH [winter and/or summer]	6%	10%	1%	4%
EH w/o automation [winter]	4%	10%	1.5%	4%
EH with automation [winter]	10%	30%	1.5%	8%
EH heat pumps [winter]	6%	10%	0.3%	1.2%
AC with or w/o automation [summer]	6%	10%	0.7%	2.7%

Table 2 shows how the implementation time-varying pricing arrangements, like RTP, mainly results in a reduction of peak load levels, which, in this case, is especially significant for critical days. Part of the electricity consumption that no longer takes place in peak hours is shifted to off-peak hours, while another small part is avoided. Thus, the application of this type of actions (time-varying pricing arrangements) has also a small but non-negligible electricity conservation effect.

Assuming that changes to load levels are homogeneous across the corresponding period (peak or off-peak), we have computed the modified daily load profile corresponding to each consumer type, in each season on each type of day after the application of a certain set of actions. Using the original and modified load profiles for this consumer type, season and day type, together with the new price profile applied to this consumer on this day (which depends on the sets of actions applied) and the original one (deemed to be a fixed electricity price for every hour and day of the year), we have computed the impact of this set of actions on the cost for a consumer of this type of buying the electricity used on a day of this type in this season.

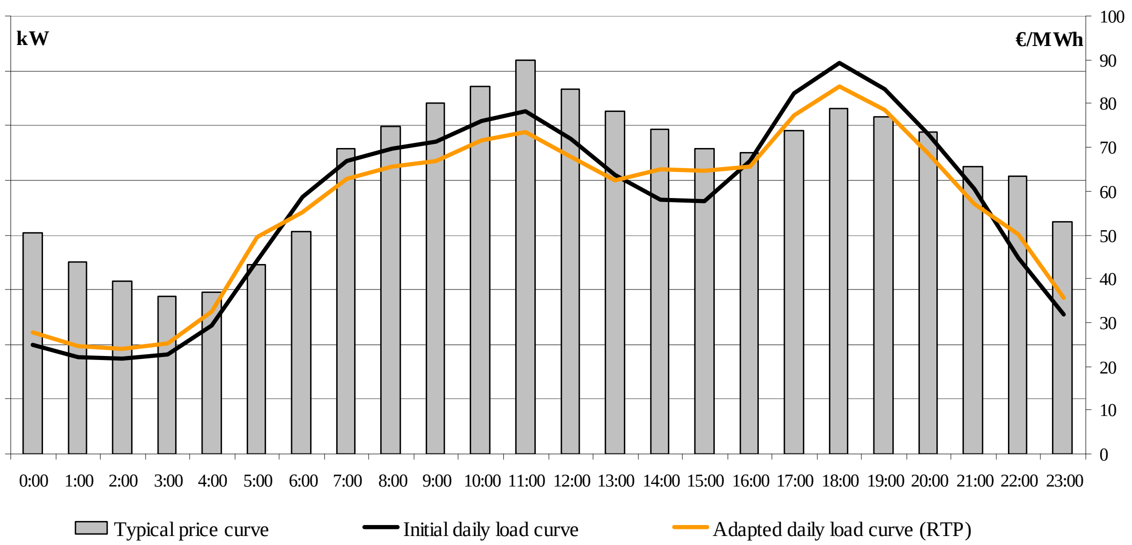
Taking into account the number of days of each type in each season we have then computed the impact of each set of actions on the annual bill paid by an average consumer of each type. Finally, taking into account the number of consumers of each type, we have computed the impact of each set of actions on the overall annual electricity bill paid by all households in Austria.

Figure 2: Modeling of real-time pricing



As an example, Figure 2 illustrates the modeling we have carried out of the impact of the application of real-time pricing on the daily load and price profiles faced by a consumer both in normal days (upper part of the figure) and in critical days (lower part). On the other hand, Figure 3 illustrates the more detailed, real impact of RTP on the load curve of a typical consumer.

Figure 3: Impact of time-varying prices on load curve – RTP



3.2 Numerical results of the analysis

This subsection provides numerical results corresponding to the quantitative impact of the considered sets of smart meter related actions on the peak load of Austrian households as well as on their overall electricity consumption level. We also provide *partial* results on the impact of these sets of actions on the electricity bill paid by consumers (partial meaning that the results on the economic impact of actions only consider benefits from their application that result from changes in the behavior of consumers, as already discussed above).

3.2.1 Impact of the sets of actions on electricity consumption and peak load levels

Table 3 provides the overall system peak load reduction and overall system electricity savings caused by the application of each of the considered sets of actions to domestic consumers in the Austrian system. Overall annual electricity savings resulting from the implementation of the considered sets of actions are in the range between 14 GWh (for CPP without automation of load) and 1,355 GWh (for the advanced set of feedback), which represents more than 7.5% of total Austrian domestic electricity consumption. Feedback, both in its simple and advanced form, is best suited to achieve significant reductions in the amount of electricity consumed. Simple and advanced feedback packages result in 3.68% and 7.68% reductions in total domestic electricity consumption, respectively. Low, but non negligible, electricity savings ranging between 1 and 1.5% of domestic consumption, can be achieved when implementing time-varying prices in the form of RTP and ToU tariffs, or DLC.

Global peak load reductions achieved in normal summer days are between 60 MW (3.63% of the overall system domestic peak load) for simple feedback, and 130 MW (7.63%) for advanced feedback. In normal winter days, peak load reductions are between 86 MW (2.81%) for DLC and 235 MW (7.69%) for advanced feedback. Thus, the impact of feedback on peak load levels on normal days may be high or low depending on the amount of information provided. Reductions obtained from RTP and ToU tariffs are substantial. They range between 4.34 and 7.32% of total domestic load and increase with the level of load automation. Reductions computed for DLC are lower due to the fact that this measure can only be applied to consumers with standard electric heating when this appliance is used (winter). Peak load reductions achieved in these days from the application of CPP and PTR are zero, since no change in prices is assumed for these actions in normal days.

Peak load reductions in critical days are highest for CPP, RTP and PTR. They amount to up to 200 MW, or 12% of the domestic system peak load, in summer, and up to 550 MW, or 18% of the domestic system peak load, in winter. Reductions are lower for feedback, ToU tariffs or DLC. Thus, they are between 60 and 130 MW in summer, or 3.6 to 7.6% of total domestic peak load, and between 110 and 250 MW in winter, or 3.7 to 8.3% of peak load. Again, DLC results are penalized by the fact that it is only considered for conventional electric heating. One can conclude that peak load reductions achieved in the Austrian system must be considered to be modest for most sets of actions under most circumstances. They tend to increase with the presence of air conditioning or electric heating equipment and with the level of automation of load response. These reductions are highest in critical days for those time-varying pricing arrangements that consider the application of critical or emergency prices.

Table 3: Global electricity savings and peak load reduction for the residential sector

Actions		Global savings [GWh and %]	Global peak load reduction [MW and %]			
			Winter		Summer	
			Normal day	Critical day	Normal day	Critical day
RTP	(automation)	204.3 (1.16)	223.2 (7.32)	506.6 (16.62)	102.3 (6)	170.6 (10)
	(w/o automation)	200.4 (1.14)	162.7 (5.34)	304.8 (10)	102.3 (6)	170.6 (10)
ToU	(automation)	252.9 (1.43)	202.8 (6.66)	202.8 (6.66)	85.3 (5)	85.3 (5)
	(w/o automation)	270.7 (1.53)	132.2 (4.34)	132.2 (4.34)	85.3 (5)	85.3 (5)
CPP	(automation)	15.9 (0.09)	-	547.4 (17.96)	-	204.7 (12)
	(w/o automation)	13.9 (0.08)	-	396.0 (12.99)	-	204.7 (12)

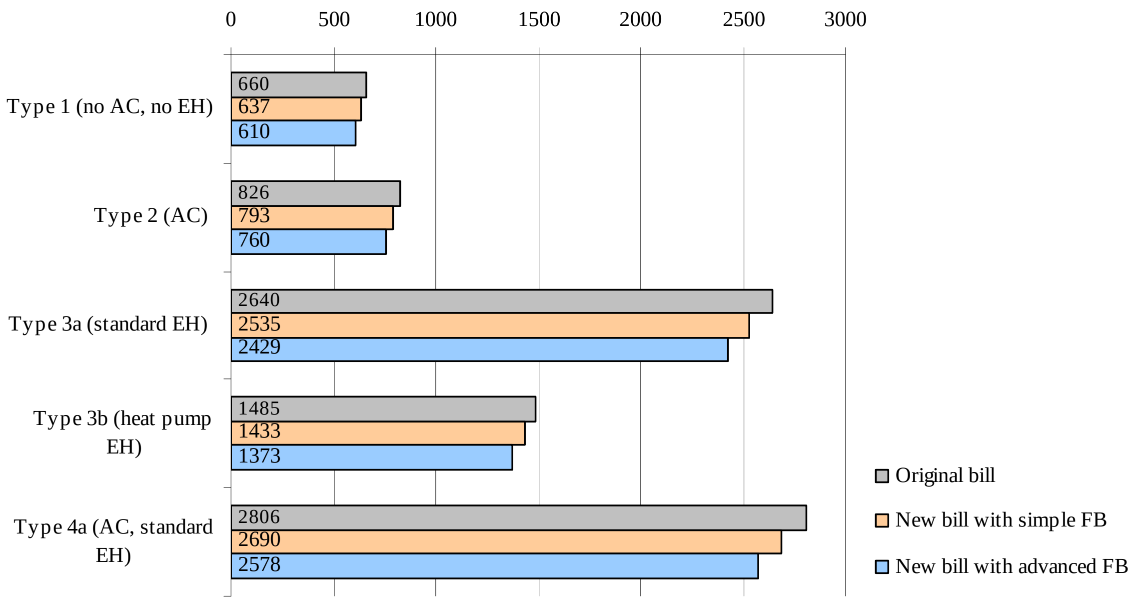
PTR	(automation)	15.9 (0.09)	-	405.7 (13.31)	-	170.6 (10)
	(w/o automation)	13.9 (0.08)	-	324.9 (10.66)	-	170.6 (10)
FB	(simple)	649.9 (3.68)	112.3 (3.69)	112.3 (3.69)	61.9 (3.63)	61.9 (3.63)
	(advanced)	1355.5 (7.68)	234.2 (7.69)	234.2 (7.69)	130.2 (7.63)	130.2 (7.63)
DLC		173.59 (0.99)	85.8 (2.81)	252.3 (8.28)	-	-

3.2.2 Impact of the sets of actions on the electricity bill

Given that, for simplicity reasons, reductions in the electricity bill coming from other changes in the functioning of the system than those directly related to the behavior of consumers have not been considered in our analysis, we have decided not to compare the impact on the electricity bill of different sets of actions. Time-varying pricing schemes, especially real-time pricing, critical peak pricing and peak time rebates, may render significant additional benefits to those considered in our analysis, like those associated with reductions in electricity prices or avoided investments in generation and transmission capacity. Thus, only results corresponding to the impact of feedback on the electricity bill paid by the different consumer types are presented here, see Figure 4.

Reductions in the electricity bill directly stemming from changes in consumption behavior are much higher for feedback measures (especially in its advanced form) than for any other set of actions.[1] For a household without air conditioning or electric heating, monetary savings from the application of the simple and advanced forms of feedback are 23 and 50 €/a, respectively. The highest economic savings can be realized by those consumers using conventional electric heating (i.e. Type 3a: 210 €/a), and those using both electric heating and air conditioning (i.e. Type 4a: nearly 230 €/a). Overall system reductions in the electricity bill computed for the simple and advanced feedback packages amount to 107.2 and 223.7 million €/a.

Figure 4: Impact of feedback on the electricity bill [€/a]



To summarize, the provision of feedback on electricity consumption, especially in an advanced form, is deemed to be able to achieve substantial savings, both in the overall electricity use and in economic terms, for Austrian consumers. On the other hand, the application of time-varying prices, which are

[1] Direct load control does not have a high impact on the overall electricity bill in the Austrian system due to the low penetration level of conventional electric heating.

mainly aimed at reducing consumers' peak load, and direct load control is expected to result in relatively low benefits for consumers. This is probably caused by the low flexibility of those electricity uses in the Austrian system whose shift from peak to off-peak hours is feasible as well as by the low variability of electricity prices in the Austrian market. However, applying pricing arrangements encouraging households to contribute to a reduction in the system peak load under emergency conditions (mainly CPP and PTR) may also render significant benefits to consumers.

4. Implementation of Smart Meter Related Sets of Actions

Finally, we focus now on the implementation of those sets of smart meter related actions whose application in Austria seems sensible. If efficiently implemented, these sets of actions should render net benefits for all the relevant parties in the system. A distinction is made between those sets of actions whose application should already be profitable now and others that should only be applied if the flexibility of household demand and the variability of prices increase substantially.

4.1 Preconditions for the implementation of these sets of actions

In order to achieve the implementation of smart meter related actions, a number of technological and regulatory conditions should be met. First of all, smart meters have to be in place. Their functionality, (such as the minimum set of information to be provided), as well as some basic characteristics of their interface hardware and the communication protocols they use should be standardized at system level (Vasaaet/Capgemini, 2008; ERGEG, 2009). The same should apply to the communication and control equipment.

From a regulatory perspective, DSOs, which are supposed to be responsible for the installation and maintenance of all metering infrastructure, should be allowed to recover the cost related to the rollout from consumers (either through tariffs or third party financing arrangements). DSOs will have to provide all the relevant information on each customer's consumption to the corresponding supplier, which is responsible for billing and therefore also for providing indirect feedback (ERGEG, 2007). Suppliers furthermore need access to information on the past consumption of their customers.

Allowing the application of time-varying tariffs to small consumers is another pre-requisite for the adoption of many of the proposed sets of actions. Allowing third parties to develop will be central to the creation of a market for energy services (Sustainability First, 2007; Vasaaet/Capgemini, 2008). Finally, some level of firmness of the expected changes to load behavior will be required for demand response to influence major investment and operation decisions by the relevant parties (see also Sustainability First, 2007) including i) the level of investments in network assets by DSOs/TSOs, ii) the level of investments in generation capacity, and iii) the level of operational reserves. This may be achieved through a variety of means, including more accurate analyses – by DSOs or suppliers – of load behavior or the arrangement of voluntary contracts between consumers and suppliers or third parties.

4.2 Common recommendations on the implementation of sets of actions

In order to ensure the active participation of parties in the implementation of socially efficient sets of actions, Member States can subsidize the application of these actions (EC, 2006). Organizing communication campaigns about the potential benefits for consumers of the application of these actions could increase their acceptance (Vasaaet/Capgemini, 2008). Apart from this, alternative schemes for the recovery of the costs of smart meter related infrastructure could be used to overcome the opposition of countries and consumers to the installation of this infrastructure (see also ESMA, 2010). Regarding the cooperation among states and regions, the set of instruments affecting the remuneration of utilities and encouraging them to contribute to the efficient management of the load of their customers (white certificates, market of energy services) should allow the creation of a level playing field for these utilities. Finally, authorities should make sure that an appropriate scheme for the measurement of changes to the load of consumers resulting from the application of the sets of actions proposed is in place.

In order to achieve the involvement of DSOs in the implementation process, their remuneration should not be based on the cost they incur in the provision of system services but should rather be linked to the operator's performance compared to some reference. This would encourage them to become more efficient in the provision of these services, probably through their participation in the efficient management of load and the minimization of the life cycle cost of smart meters. Furthermore, the structural characteristics of demand and potentially existing distributed generation should be taken into account when computing the DSOs' remuneration level. This would in turn encourage them to consider demand response and distributed generation in the planning and operation of grids.

4.3 Sets of actions to be implemented in the short-term

Sets of actions with the highest potential to render significant benefits to consumers (and the system in general) should be implemented immediately. Some of these actions are aimed at reducing the overall level of electricity consumption (i.e. an advanced set of feedback); others are mainly aimed at achieving a reduction in peak load (i.e. critical peak pricing and time-of-use tariffs).

4.3.1 Advanced feedback

Advanced indirect feedback should be provided in the form of more frequent (i.e. monthly or bimonthly) and more informative billing. It should include the following information: 1) Current consumption and price levels (for the respective billing period as well as the cumulated consumption level for a longer period, such as the current year); 2) historical feedback providing information on the development of own consumption (comparison on a period and year-wise level; corrected for outside temperature); 3) comparative feedback with respect to the consumption level and profile of a suitable benchmark consumer (see also Egan, 1999; Iyer et al., 2006); 4) the environmental impact of electricity consumption (mainly CO_2 footprint) and, finally, 5) energy saving advice. Whenever possible, this advice should be adapted to the characteristics of each specific consumer.

Assessment of this set of actions

In the quantitative analysis of the impact of different sets of actions that we have carried out, feedback has proven to be the most effective option in achieving a reduction in the global use of electricity, as well as in CO_2 emissions. Besides, it is expected to result in substantial reductions in peak load levels. Advanced indirect feedback has a significantly higher energy saving potential than simple feedback, which does not include comparative feedback or energy saving advice. The implementation costs of both types of feedback do not differ significantly and tend to be relatively low, except for paper bills when they are necessary. Thus, advanced direct feedback clearly dominates the simple one. The use of direct feedback including real-time consumption data provided by some form of in-home displays is not regarded as a valuable option for its massive application to small-scale consumers. On the one hand, the necessary infrastructure would increase upfront investment costs substantially. On the other hand, the long-term effect of direct continuous feedback is not proven. Therefore, extra investments required to provide this direct feedback are not justified.

Physical means used to provide information

Information on their use of electricity should be provided to consumers using electronic means as far as possible, including a personalized website managed by the DSO. This is by far the most economical way to reach consumers. Those consumers who do not have access to these means should get paper invoices including all required information on their electricity consumption and energy saving advice. Additionally, a hotline should be made available to provide personalized advice.

Allocation of responsibilities

Given that suppliers are selling electricity to consumers and bill them according to their consumption, they should also be responsible for providing feedback when this is done on an individual basis (mainly through any type of bill, but also through hotlines). However, DSOs could also make available some information to consumers using a central platform, like a website. This could include each consumer's load profile and load level, historical and comparative feedback and even some form of personalized energy saving advice.

Achieving its application

In order to ensure the involvement of both suppliers and DSOs/TSOs in the provision of feedback to consumers, they should receive extra incentives to achieve a reduction in electricity consumption. Incentives for suppliers could result from a system of white certificates or the development of a market for energy services. White certificates thereby could refer to actual reductions of electricity consumption achieved by consumers. Alternatively, a standard electricity saving capability could be assigned to all the different efficiency actions that can be undertaken (Eurelectric, 2007). Volume-driven remuneration incentives for suppliers and TSOs/DSOs should be removed.

Consumers could receive extra incentives to reduce their electricity consumption in the form of funds to implement energy efficiency actions including the upgrading of their facilities or homes (EC, 2009). Energy audits should be made available by DSOs or suppliers. Finally, the public sector should probably adopt an exemplary role (EC, 2006).

Given that there is strong evidence, backed by the results of our analysis, that the application of advanced feedback should render large net benefits for consumers and the system, and taking into account that there is a mandate by the European Commission to provide feedback, the application of this measure should be made compulsory by authorities. In order to make sure that consumers are able to understand the information provided, its general format should be standardized.

4.3.2 Critical peak pricing

Electricity prices must be significantly higher than average prices at times when the reserve margin in the system is below a certain threshold in order to reflect the extra supply costs incurred by the system to serve the load existing at these times. In order to ensure that emergency or critical prices are not applied very frequently, authorities may set a maximum number of emergency hours throughout each year. Critical prices should be set at the average price of electricity during emergency hours (50-100 hours). According to the data gathered for the years 2008 and 2009, critical prices for the Austrian system should be about 200 €/MWh. The electricity price should be set at a common level for the rest of the hours in the year. This price level, together with emergency prices applied at certain times, should result in an average electricity price that is equal to the one that would have been applied if pricing arrangements had not changed.

Assessment of this set of actions

Benefits in the short-term from the application of CPP are mainly related to the expected increase in system reliability. In the longer-term, potential savings in generation and network capacity costs due to a reduction in investment requirements could also be substantial. Implementation costs of applying critical prices should not be high. The largest part of total costs would be incurred by the supplier when sending an emergency signal to its customers through a variety of means (website, SMS messages, etc.).[2] Given that emergency signals would be sent very few times and these have

[2] Implementation costs would increase substantially for those customers where a form of in-home display or in-home visual alarm would have to be installed.

substantial positive effects on the system reliability and the quality of service, the implementation of CPP is unlikely to face strong opposition.

Physical means used to provide information

Emergency signals should be sent by electronic means (website, e-mail, SMS messages, etc.) not including an in-home display if possible. Only when a large number of potential users are not willing or able to use cheaper communication means, the installation of an in-home display should be considered. Related costs would have to be beard by these customers.

Allocation of responsibilities

Given that suppliers are in charge of computing and applying electricity prices to consumers, they should also be in charge of computing and applying critical prices. In fact, they could be the only party being aware of which of their customers have opted for this pricing scheme. Suppliers hence have to be immediately informed about the occurrence of an emergency situation by the system or market operator.

Achieving its application

There is no clear mandate from the European Commission to implement time-varying pricing schemes. Besides, evidence suggesting the advisability of their implementation in the Austrian system regarding their short-term impact on the electricity bill paid by consumers is not as strong as that found for indirect feedback. However, we believe that implementing CPP or ToU tariffs could increase the efficiency and robustness of the system and will result in significant benefits for all parties. Thus, we suggest that, once the right incentives are in place, the decision on the implementation of these sets of actions is left in the hands of the parties involved in their application (suppliers, TSOs, DSOs and consumers).

Simple time-varying network and capacity charges (if the latter exist), to be initially paid by suppliers, should be applied to encourage suppliers and consumers to reduce the latter's contribution to system peak load at critical times (see also Faruqui et al., 2009). Default regulated (energy) tariffs for consumers should disappear, since consumers choosing not to enter the market and being subject to these tariffs would not have incentives to shift their load to off-peak times. Apart from this, the remuneration scheme applied to DSOs (mainly) and TSOs (to a lesser extent) should be based on incentives. This would encourage them to facilitate the adaptation of load to system conditions so as to reduce the costs the former incur in providing network-related services. Efficiency incentives for TSOs should supplement and not replace their traditional remuneration scheme.

4.3.3 Time-of-use tariffs

If this pricing scheme, different electricity price levels, to be applied at predefined periods within each day, should be computed well in advance of the operation of the system and updated regularly. Price levels not necessarily have to change between seasons, since prices in the Austrian system are quite stable and short-term supply and demand conditions seem to have a stronger impact on the market price than season-specific weather conditions. The structure of the tariff applied should be kept as simple as possible so as to facilitate the understanding and acceptance of new tariffs by consumers. Thus, defining only two price periods (i.e. a peak period mainly covering day hours and an off-peak period covering night time) would be advisable. Peak and off-peak prices should be computed as the average price of electricity during the corresponding periods. According to information on the Austrian system gathered for the years 2008 and 2009, peak prices should be set at about 70 €/MWh and off-peak prices at about 45 €/MWh if ToU tariffs would be implemented today.

Assessment of this set of actions

The impact of time-varying prices in the Austrian system may be less significant than that in other countries due to Austrian specific supply and demand characteristics. According to our findings, ToU tariffs should prompt some low but non-negligible shift of load from peak to off-peak hours in the Austrian system. Modest reductions in global energy consumption may also take place, though much smaller than those from feedback measures.
However, extra implementation costs resulting from the use of ToU tariffs are expected to be almost negligible, especially when combining this tariff scheme with the use of indirect feedback and CPP. Since price levels are determined in advance, consumers face no short-term uncertainty on prices, which should facilitate the implementation of this set of actions.

Physical means used to provide information

Possible pricing arrangements, including ToU tariffs, should be periodically announced by suppliers using different physical means. Those consumers receiving paper bills should also receive together with them, at least once a year, some information on the possibility of signing in for ToU tariffs. At the same time, electronic means (website or hotline) could also be used to advertise these tariffs. Consumers subject to these tariffs should receive within their bill detailed information on the amount of electricity consumed within each price period together with the respective tariffs.

Allocation of responsibilities

Suppliers should be responsible for advertising (marketing) newly available tariffs, including ToU tariffs, and billing consumers based on them. Suppliers should be provided by DSOs with relevant information on the amount of electricity consumed by their customers in each of the price periods defined.

Achieving its application

Conclusions and recommendations to achieve the implementation of ToU tariffs are not significantly different from those applying for CPP.

4.4 Measures potentially becoming relevant in the longer-term

The following paragraphs discuss those sets of actions whose application in the Austrian system may be advisable in the longer-term future given the development of certain exogenous conditions. These are real-time pricing (RTP) and direct load control (DLC, i.e. the provision of advanced energy services by a third party).

4.4.1 Description of these sets of actions

Real-time pricing

RTP involves the direct application of prices resulting from the electricity market to households. Electricity prices to be applied shall be those in the day-ahead or the real-time (balancing) markets. As a compromise between the operability of the system and the accuracy of prices applied, these could be hourly differentiated.

Prices applicable at each time should be sent to consumers via an in-house device directly connected to the suppliers' facilities. This could be an advanced smart meter being able to support bidirectional communication. Otherwise, the communication infrastructure in the house should be adapted accordingly.

Suppliers should be in charge of sending real-time prices to consumers as well as advertising these new pricing arrangements to get their customers enrolled on them. They should also be in charge of installing the required communication equipment.

Direct load control

DLC involves the provision of advanced energy services associated with space and water conditioning, or even the management of domestic appliances, by a third party. In order to provide these services, this third party would remotely manage the use of electricity in households. Thus, the implementation of DLC requires that the management of load is automated using the corresponding communication and control equipment. Control signals produced by the service provider could be sent through a variety of means including the electric wires (PLC technology) or radio frequency.

Consumers subject to DLC adopt a passive role. They would only be actively involved in the process of contracting the corresponding energy services. The energy service provider would be responsible for controlling part of the in-house electricity consuming equipment in order to provide the contracted services. It would also be responsible for installing and maintaining the required communication and control equipment except for that part of the equipment which is already installed as part of the distribution grid, which would remain in the hands of the DSO.

4.4.2 Assessment of both sets of actions

Both RTP with a partial automation of load and DLC can produce significant reductions in the cost of operating and expanding the system if some conditions are in place. These conditions are discussed in Section 0. If these conditions are not met, the implementation of these actions at large scale would probably not be profitable.

Implementation costs of both RTP with automation or DLC are very significant. This would include the cost of communication and control equipment necessary to apply them, but also the cost associated with the complexity of their implementation process itself.[3] Incurring these costs could only be justified if the whole load management potential to be achieved through the application of these sets of actions is realized. Implementing these actions when the number of potential clients for them is small could be uneconomical since a significant part of the equipment required (central data processing and control centers) would probably have to be installed regardless of the number of consumers making use of it.

4.4.3 Conditions to be met for the implementation of these actions

The main conditions to be met (all or part of them) to make the implementation of these actions attractive both for suppliers of these services and electricity consumers include the following:

- A significant number of small consumers (households or small businesses) should use air conditioning systems during the day, contrary to what currently occurs in households. Then, RTP and DLC could be used to shift part of this load towards off-peak hours.
- An increase in the flexibility of households' electricity demand should take place, probably as a result of smart appliances being developed and embraced by consumers.
- System conditions should be far more variable than today, resulting in far more variable electricity prices as well. This could be the result of the installation of significant amounts of intermittent renewable generation (mainly wind generation in areas that are not accessible now).

[3] According to Sustainability First (2010), "RTP is generally considered too complex for small electricity users […] these types of tariff may become more likely, closer to or post-2020, when continuous automated switching of load could be valuable".

4.4.4 Achieving the application of these sets of actions

Both sets of actions – assuming demand is flexible enough and system conditions are variable – could bring significant benefits to all the parties involved in their implementation. Some sort of automation of the response of consumers to dynamic prices would be most advisable under RTP so that it has a high impact on consumers' behavior. Peak load reductions achieved could be very significant, while energy savings obtained if a significant part of the households' electricity use is automated could also be very important.

Communication and control equipment to be installed as a result of the application of RTP or DLC schemes would finally have to be paid by consumers either through the non-regulated tariff or through third party arrangements (paying these investments from the savings in their energy bill they achieve). In order to provide suppliers with some certainty about the recovery of the corresponding investments, contracts between suppliers and consumers should include a compensation to be paid to the supplier if this contract is ended before a certain amount of time has passed after the installation of communication and control equipment. This compensation could be paid by the consumer or the new supplier.

As explained earlier in general terms, the standardization of interface hardware, communication protocols and the functionality of systems would be needed in order to achieve the desired level of interoperability among alternative energy service providers. Other recommendations corresponding to the implementation of indirect feedback or simple time-varying prices apply here as well.

5. Conclusions

The implementation of different sets of smart meter related sets of actions in the residential electricity sector shall be assessed in the light of the specific characteristics of the targeted consumer group and the system where these measures are to be implemented. Conditions existing in the Austrian system advise applying some form of advanced indirect feedback in order to increase the efficiency in the use of electricity. According to our own estimates, electricity savings in this system achieved through the application of advanced feedback could be as high as 8% of the households' bill. Based on the mandate for the provision of feedback in the European legislation, and the strong evidence collected on its electricity saving potential, we recommend that a basic feedback package including historical and comparative feedback, as well as personalized energy saving advice is provided on a compulsory basis by suppliers and DSOs. The format of information provision should be standardized. In order to align suppliers' interests with those of the system, regarding the application of feedback, inefficient volume-driven incentives faced by these parties should be replaced with efficiency-driven incentives in the form of a white certificates system or a market for energy services. DSOs/TSOs' remuneration schemes should include some efficiency incentives and should take into account the specific situation existing in each area regarding the penetration of distributed generation and load management practices.

Furthermore, the application of critical peak prices and simple time-of-use tariffs should also be considered in the short-term. This should result in peak load reductions during normal days amounting to 4 to 8% of global system residential peak load in Austria. Reductions would be higher, the higher the level of automation of the reaction of household load to system conditions. Peak load reductions in critical days achieved through the application of CPP would range between 10 and 16%, depending on the load automation level. This is expected to result in a significant increase in system reliability levels and significant long-term savings due to the avoidance of generation and network capacity investments. The decision on the application of CPP or ToU tariffs should be left in the hands of suppliers, who should be provided with efficiency-driven incentives in the form of cost reflective time-varying network charges reflecting the true system cost of the use of the network by agents. Capacity charges, if they are to be applied in the Austrian system, should also be of a time-varying nature. Implementing an efficiency-driven remuneration scheme for DSOs and TSOs would also be necessary.

Finally, if the domestic load in the Austrian system became more flexible in the future, or the volatility of electricity prices increased, implementing a scheme of real-time prices or the direct control of consumers' load by third parties could be advisable despite the high implementation costs of these sets of actions. Incentives to be sent to relevant parties (mainly suppliers and service providers) for them to decide on the application of these sets of actions would be those already discussed for ToU tariffs and CPP.

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