DISCUSSION PAPER

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Unlocking the €53 Billion Savings from Smart Meters in the EU

How increasing the adoption of dynamic tariffs could make or break the EU's smart grid investment

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Introduction

The EU is poised to make a major investment in smart meters. Already, Italy has achieved a smart meter penetration rate of around 85 percent and France has a rate of 25 percent. Last October the UK government announced its intention to mandate smart meters for all UK households by 2020. France, Ireland, the Netherlands, Norway and Spain are also projected to achieve nearly 100 percent smart meter installation by 2020, and it seems likely that many other Member States will follow suit.

We estimate the cost of this smart meter investment in the EU to be €51 billion. This investment is likely to yield improvements in the way that electricity flows through the grid by eliminating meter reading costs, allowing for faster detection of power outages, permitting remote connect/disconnect of service and minimizing power theft. We estimate these improvements to be worth between €26 to 41 billion, leaving a gap of €10 to 25 billion between benefits and costs.

In this paper, we argue that smart meters can provide additional benefits because they enable the provision of dynamic pricing to customers. Examples of dynamic pricing include real-time pricing (RTP) and critical-peak pricing (CPP), a form of time-of-use (TOU) pricing in which prices during the top 100 hours of the year rise to reflect the full cost of building and operating seldom-utilized peaking capacity.[1]

Relying on experience from around the globe, we estimate that if policy-makers can overcome barriers to consumers adopting dynamic tariffs, these benefits could be as high as €67 billion. But if the adoption of dynamic pricing is similar to levels seen for other TOU tariffs in liberalised markets, then the benefits may be only €14 billion. The difference in benefits between high and low adoption rates is €53 billion.

While policy-makers have to date focused on rolling out smart meters, the issue of ensuring that suppliers offer and customers accept smart tariffs has received relatively little attention. And yet overcoming barriers to the adoption of dynamic tariffs could be worth as much as €53 billion – sufficient to pay back the cost of smart meter investment for the EU, even ignoring the operational benefits we cite above. Introducing "dynamic by default" transmission and distribution tariffs, stressing the environmental benefits of dynamic tariffs and making the financial rewards transparent to customers will be the key to landing this €53 billion prize.

Section 1 THE POTENTIAL IMPACT OF DYNAMIC PRICING

The demand for electricity is highly concentrated in the top one percent of the hours of the year. If a way can be found to shave off some of this peak demand, it would eliminate the need to install generation capacity that is used less than a hundred hours a year. Moreover, since this capacity is rarely used it tends to be from relatively old, polluting plants.

For example, in most parts of the EU, between five to eight percent of installed capacity is only used about one percent of the time.[2] In Great Britain (GB), 6.6 percent of capacity is used one percent of the time, and in Italy and Spain the equivalent figures are 5.3 and 6.8 percent respectively. Figure 1 illustrates this, using load data from France for 2008.

Since electricity cannot be stored and has to be consumed instantly, and since generation plants of varying efficiency are used to meet demand, the cost of power varies by time-of-day and day-of-year. The most opportune way to try and reduce the use of peaking capacity is to provide accurate price signals to customers that convey the true cost of power — that is, implement dynamic pricing.[3] Once clear price signals are conveyed to customers, they can decide whether to continue buying power at higher prices or curtail their usage during peak hours. This market-driven concept can save consumers substantial amounts of money.

How much will be saved through dynamic pricing will depend on how much peak load can be reduced by customers, i.e., on the magnitude of the induced demand response (DR), and how much generation investment and fuel would be offset by this demand response. The first item depends on two things: how rapidly suppliers offer tariffs that provide dynamic price signals to customers, and how well customers respond to the price signals.

Figure 1 **Top 15% of the French load duration curve, 2008**

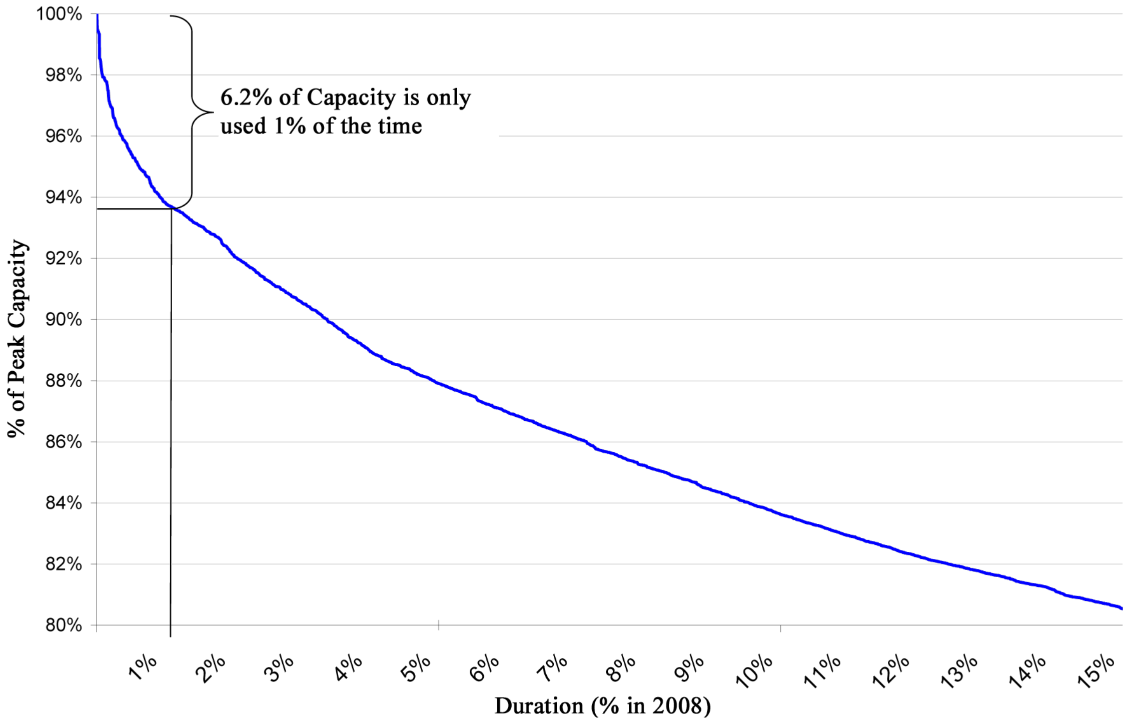


Table 1 Summary of the results of the main demand response trials completed to date[4]

Continent and Trial	Demand Response measured
United States & Canada	
Hydro Ottawa, Ontario, Canada	Ranged from 5.7% to TOU-only participants to 25.4% for CPP participants
California-Anaheim	12% reduction during peak hours
California-Automated Demand Response Pilot System (ADRS)	Reductions as high as 51% on CPP event days and 32% on non-event days
California-State-wide Pricing Pilot	CPP-Fixed: On critical days, average reductions at peak were 13.1%; ranged from 7.6 to 15.8% TOU: Peak period energy use reduced 5.9% CPP-Variable: Reduction range of 16 to 27%
Colorado-Xcel Energy TOU Pilot	TOU: Range of 5.19 to 10.63% during peak hours CPP: Range of 31.91 to 44.81% during critical peak hours CTOU: Range of 15.12 to54.22% during critical peak hours
Florida-The Gulf Power Select Program	41% Reduction during critical peak period
Idaho Power Company Energy Watch Pilot	Average reduction of 5.03 kW for 4 hour event
Illinois-Energy Smart Pricing Plan	2005: 15% reductions 2006: own-price elasticity of -0.067; -0.098 with AC
Missouri-AmerenUE Critical Peak Pricing Pilot	TOU: No statistically significant impact TOU-CPP: 12% reduction in 2004, 13% reduction in 2005 TOU-CPP-Tech: 35% reduction in 2004, 24% reduction in 2005
New Jersey-GPU Pilot	Range from 26 to 50%
New Jersey-PSE&G Residential Pilot Program	TOU: Range of 6 to 21% CPP: Range of 14 to 26%
Washington (Seattle)-Puget Sound Energy (PSE) TOU Program	5% per month
Washington-The Olympic Peninsula Project	15 to 17% reduction for RTP group, 20% reduction for TOU/CPP group
Australia	
Country Energy, Australia	Reduction of 30% across peak periods
Energy Australia	Reductions on days with a CPP event of between 5.5 and 7.8%
New South Wales/Australia - Energy Australia's Network Tariff Reform	24% reduction for DPP high rates, 20% reduction for DPP medium rates
Europe	
Norway	8 to 9% reduction at peak
France-Electricite de France (EDF) Tempo Program	Own price elasticity of -0.18 in off-peak usage to -0.79 during peak

Section 2 HOW MUCH DEMAND RESPONSE?

A prerequisite to the provision of dynamic pricing is the installation of smart meters or, to use the technical term, advanced metering infrastructure (AMI).[5] To date, AMI installation in the EU has been relatively limited. Italy has by far the highest installation of smart meters, with a penetration rate of around 85 percent. The next highest is France with 25 percent, but the majority of Member States have penetration rates of only a few percent.

This picture will be transformed over the next ten years. For example, the UK government announced in October 2008 its intention to mandate smart meters for all households by 2020. France, Ireland, the Netherlands, Norway and Spain are also projected to have close to 100 percent smart meter installation by 2020, and it seems likely that many other Member States will follow suit.

Even countries that have installed AMI systems do not yet have dynamic pricing designs in place. There is also considerable uncertainty as to how customers will respond to such pricing signals. Moreover, some policy-makers are afraid of a customer backlash to potentially volatile prices.[6]

A number of trials have attempted to measure DR via pilot programmes – we summarise the main results in the table above. Several of these trials use relatively simple time-of-use tariffs rather than dynamic pricing. Nevertheless, the trials demonstrate that, on average, customers will respond to higher prices by lowering usage during peak hours and by so doing, will reduce their annual power bills.

Section 3 OVERCOMING BARRIERS TO ADOPTION

Clearly the degree of response varies not only by jurisdiction but by the methods used to stimulate demand response. These range from TOU tariffs with reminders to consumers and the use of "traffic lights" or SMS messages to indicate periods of high prices, to full dynamic pricing with enabling technologies such as smart thermostats and always-on gateway systems.

Smart thermostats automatically raise the temperature setting on an air conditioning unit by two or four degrees when the price becomes critical. Always-on gateway systems turn off appliances (e.g., washing machines and freezers) at periods of high prices, and represent state of the art enabling DR technology. Clearly the difference between tariffs at different times of day also has a strong effect on the degree of demand response.

Perhaps unsurprisingly, these studies have found a stronger DR when more sophisticated, and more expensive, enabling technologies are used than when the customer still has to intervene to reduce demand. In the state of California experiment, the average customer reduced demand during the top 60 summer hours by 13 percent in response to dynamic pricing signals that were five times higher than their standard tariff.[7] Customers who had a smart thermostat reduced their load about twice as much, by 27 percent. Consumers who had the gateway system reduced their load by 43 percent.[8]

This experiment also showed that customers did not respond equally to the price signals. Some responded often and others did not respond at all. In fact, about 80 percent of the collective DR came from just 30 percent of the customers.[9]

While there is now good evidence that at least some consumers will respond to price signals, there is still a question over how applicable these DR experiments are to the EU in general. The studies in the previous table has been carried out in jurisdictions with high rates of air conditioning — California, Ontario, Australia — or, in the case of Norway, a high capacity of electrical space heating.

A recent U.S. study for the Federal Energy Regulatory Commission (FERC) on the potential for DR in all 50 U.S. states, which *The Brattle Group* coauthored, may provide some guidance as to the potential for DR in the EU.[10] The study was the first of its kind, establishing bottom-up, state-level estimates of both the existing amount of DR and the potential peak reductions that could be achieved under three distinct scenarios. A key input to this study was each state's saturation of central air-conditioning (CAC). The study found that even New England states with low CAC saturations, in the 10 to 20 percent range, still had the potential to reduce peak demand by up to roughly 15 percent through cost-effective DR measures.

While the FERC study provides useful guidance for the EU, it is still highly desirable for Member States to undertake their own DR trials, so that the potential benefits can be properly assessed and weighed against the costs. For example, Ireland has recently begun Customer Behaviour Trials, which will involve time of use tariffs, in-home display units giving detailed information on current prices and consumption and bills designed to facilitate demand response and energy saving.[11] Trial participants have already been recruited, and the trials will start in January 2010.

In the GB market, Ofgem, the energy regulator, is managing DR trials that are jointly funded by the government and major energy suppliers. The trials will investigate alternative ways of making customers more aware of their energy consumption. They will include different combinations of real-time display devices, which show energy use in pounds and pence, smart electricity and gas meters, additional billing information and customer education programmes.

The trials are made up of different combinations of these actions and are exploring the responses of around 50,000 different households. There will be smart meters in around 18,000 houses and real-time display devices in about 8,000 homes. Final reporting will be complete in autumn 2010.[12]

France and Germany are also undertaking large-scale trials, with Austria, the Czech Republic and Spain piloting smaller smart-meter schemes.[13]

The rate of adoption of dynamic pricing is a critical point. Adoption could be much lower if customers have to actively switch to the dynamic tariff, rather than having one as the default. This highlights another important difference between EU and U.S. energy markets. In most of the U.S. there is no retail competition; rates for households and small commercial utilities are set by the regulator, who is free to mandate a dynamic pricing tariff as a default. In the EU customers would have to actively choose a dynamic tariff.

The limited literature on the topic suggests that this difference is important. Studies show that about 80 percent of customers would stay on dynamic pricing if it was offered as the default rate and that a substantially smaller number, perhaps 20 percent, would opt in on a voluntary basis.[14]

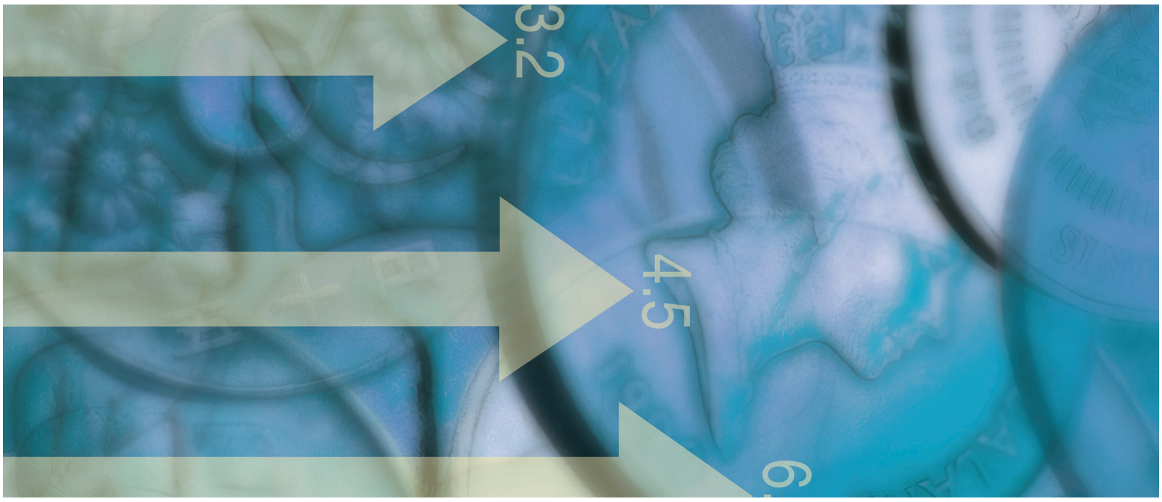
The UK provides another reference point. For many years GB suppliers have offered a simple time-of-use tariff called "Economy 7". Electricity is substantially cheaper during the night (defined as 01:00 to 08:00), and customers take advantage of the lower tariff by using night storage heaters and water heaters on a timer. About 3.3 million of the UK's 22 million domestic meters households have opted for an Economy 7 tariff.[15] This is equivalent to 15 percent, roughly consistent with the research cited above.

The U.S. provides a sobering lesson for EU policy-makers. In Texas, which has full retail competition and is the market that most resembles the EU, adoption rates for dynamic tariffs have been among the lowest in the U.S.

The large potential difference in adoption rates for dynamic prices begs an important question — what can be done to reduce barriers to adopting dynamic tariffs? The recent FERC study identified 24 potential barriers to demand response, which were grouped into four categories:

- ***Regulatory*** — *Regulatory barriers are caused by a particular regulatory regime, market design, market rule or the DR programmes themselves.*
- ***Technical*** — *Potential technological barriers to implementation of DR include the need for new types of metering equipment, metering standards or communications technology.*
- ***Economic*** — *Economic barriers refer to situations where the financial incentive for utilities or aggregators to offer DR programmes, and for customers to pursue these programmes, is limited.*
- ***Other*** — *These are generally related to customer perceptions of DR programmes and a willingness to enroll.*

Arguably, several Member States are making excellent progress in tackling the regulatory and technical barriers. The potential stumbling blocks that may require greater focus in the future are the economic barriers and persuading customers to switch to more dynamic tariffs. For some customers, DR programmes may not provide a sufficient financial incentive to participate, and customers may find it hard to estimate the benefits of switching to a dynamic tariff.



Customers have had similar difficulties in estimating the benefits of energy efficiency measures.[16] Customer may be risk-averse, worrying that their bills will increase if they switch to a dynamic tariff, rather than focusing on the potential savings. Customers may feel that they do not know how to shift demand to make the most of dynamic pricing, and there may also be inertia that contributes to low participation rates in voluntary programmes.

We have studied many successful policies to encourage the adoption of dynamic tariffs. For example, quantifying and stressing the environmental benefits of dynamic tariffs can be appealing to some customers groups. In systems with a large capacity of wind generation, dynamic tariffs could help shift demand to times when wind generation is high, lowering average emissions. Evidence in the U.S. shows that some customers are willing to adopt dynamic tariffs based on environmental benefits.[17]

Ensuring transparent and adequate financial rewards can also help overcome customer inertia. Where technology allows, suppliers can simplify the choice for customers by offering to take over their demand response for them. An example of this is critical-peak pricing (CPP), where customers agree to load curtailment at times of peak demand in return for a lower flat-rate tariff. The advantage of these schemes is that the gains for the customer are predictable and easy to understand. Innovative use of information technology could also help — once AMI is in place, customers could simply enter their meter number into a website to generate an estimate of savings, assuming various levels of DR.

Many Member States also require suppliers to offer a retail tariff that the regulator has approved or set, though the idea is to phase such tariffs out over time as retail competition matures. Setting a dynamic regulated tariff could be one way of increasing adoption rates. Member States that do not have regulated tariffs could introduce them. But this proposal illustrates the tension between progressing with market liberalisation, and ensuring a high adoption rate of dynamic tariffs through a more interventionist approach to retail tariffs.

While policy-makers cannot force customers to adopt dynamic tariffs for their electricity, they could mandate dynamic transmission and distribution (T&D) tariffs, whereby the T&D charges could vary according to when the customer uses power, and oblige the supplier to pass these costs through directly to the customer. The T&D charges for many large customers already depend on when they use power. However, smart meters would allow similar pricing for millions of domestic customers.

Since T&D charges make up around 20 to 30 percent of household customers' bills, a dynamic T&D charge could by itself elicit valuable demand response. Making part of the bill "dynamic by default" could also encourage switching to dynamic tariffs for the electricity commodity itself — if the customer is already making some demand changes as a response to dynamic T&D charges, switching to a "full" dynamic tariff could amplify the benefits.

Section 4 THE VALUE OF DR

What is the value of a reduction in demand during critical periods? We identify several types of benefits. First and foremost is the reduction in the need to install peaking generation capacity. This is a long run benefit and consists of the sum of avoided capacity and energy costs. It can be readily estimated based on the capacity cost of a combustion turbine. The second benefit is the avoided energy costs that are associated with the reduced peak load. Third is the reduction in transmission and distribution capacity. This is also a long run benefit, but is harder to quantify and is heavily dependent on system configurations that vary regionally.

We have estimated these savings under high and low adoption rate scenarios. Our high adoption rate is based on the uptake seen where dynamic pricing is the default, but it can equally be interpreted as a scenario where policy-makers have successfully overcome the barriers to adopting dynamic tariffs. The low adoption rate scenario can be interpreted as where policy-makers fail to sufficiently address the barriers.

As we note above, there is considerable uncertainty in the potential for demand response per customer in the EU. In our estimate, based on the FERC study we assume that the average residential customer on a dynamic pricing tariff in the EU might reduce demand by eight to ten percent in the absence of any enabling technology.[18]

When equipped with enabling technologies, incremental increases in peak impacts can range from 60 to 90 percent of the reduction without technology, depending on the customer class and technology under consideration. Note that other studies have shown the difference for DR potential between different classes of customers, for example industrial users and households.

Given the uncertainties involved, in our estimate we simply take an average DR number which encompasses all classes of user. Based on these findings, and under the assumption that there is a moderate market penetration of enabling technologies for the aggregate level of DR, it is not unreasonable to assume an overall peak demand reduction of ten percent for the high adoption rate scenario and two percent for the low scenario.

To quantify the avoided capacity cost, we first quantify the amount of capacity that will be avoided by a reduction in peak demand and then value it. The amount of peaking capacity that is needed to meet this peak demand can be computed by allowing for a reserve margin of 15 percent and line losses of eight percent.[19] We use a value of the avoided cost of capacity of €87/kW-year.[20]

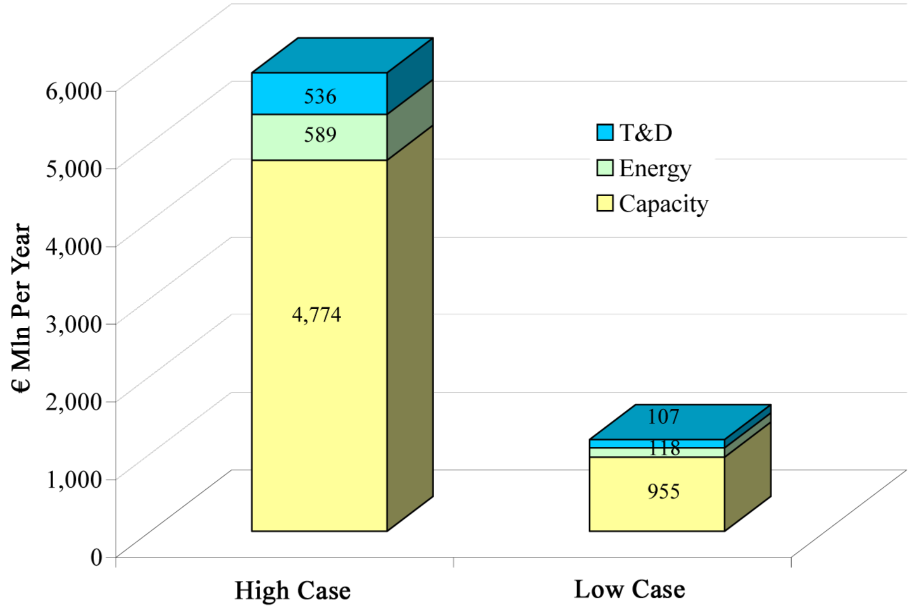
The total value of avoided capacity costs is €4.7 billion per year for the high-case scenario, but only €1.0 billion for the low case scenario.

Using the relationship that was observed between annual capacity and energy benefits in a recent U.S. analysis of DR, the annual value of avoided energy costs is estimated at €589 million and €118 million for the high and low case respectively.[21] In addition, there would be a reduction in transmission and distribution capacity needs. As noted earlier, they are system-dependent and difficult to estimate. However, they are unlikely to be zero. A conservative estimate puts them at 10 percent of the savings in generation capacity and energy costs.[22] Using this estimate results in a reduction in transmission and distribution costs of €536 million and €107 million per year for the high and low case respectively.

Adding up these three components yields long run benefits of demand response of €6 billion per year for the high-case scenario, and €1.2 billion per year for the low-case scenario. Over a 20-year time horizon, these savings represent a discounted present value of €67 billion for the high-case scenario, but less than €14 billion for the low case scenario — the appendix shows the details of these assumptions. In other words, efforts to reduce barriers to the adoption of dynamic pricing could deliver increased present value benefits of around €53 billion.

Demand response and AMI is likely to have other benefits as well. DR could play an important role in increasing energy efficiency and delivering on the EU's commitments to reduced energy consumption. The reduction of less efficient peaking plants would reduce emissions during periods of high demand. Security of supply would improve, as DR delivers improved system reliability and fewer blackouts and brownouts. Customers' increased price responsiveness would make it less profitable to exercise market power, increasing the competitiveness of electricity markets. AMI could significantly enhance levels of customer service. In this assessment, we have not quantified any of these benefits.[23]

Figure 2 **Annual long run benefits of demand response**



Section 5 THE COST-BENEFIT RATIO OF INVESTING IN DYNAMIC PRICING

How do the quantified long-term benefits compare to the cost of installing AMI, a precondition for dynamic pricing? Depending on the features and the communication technology used, AMI investment costs can range from around €70 per meter for household customers to €450 per meter for more sophisticated industrial meters.[24] A large portion of the cost of AMI can be recovered through operational benefits, such as savings in meter reader costs, faster outage detection, improved customer service, better management of customer connects and disconnects and improved distribution management. We do not include these benefits in Figure 2.

Within the EU, Italy has the most experience with the costs and benefits of a large scale role-out of smart meters. Enel, Italy's largest power company, has installed over 30 million smart meters at an average cost of €70 each. While the total cost of the project was €2.1 billion, Enel estimates annual savings of €500 million, implying that the total cost of the project would be recovered in about five years. Enel estimates the savings include:

- *A 70% reduction in purchasing and logistic costs*
- *A 90% reduction in field operation costs*
- *A 20% reduction in customer service costs*
- *An 80% reduction in the costs of revenue losses such as thefts and failures.*[25]

In a recent study, the UK Department of Energy and Climate Change (DECC) estimated that net benefits for installing both gas and electric smart meters in the domestic sector ranged from £2.28 to £3.59 billion,[26] and savings of about £1.75 to £1.76 billion for small and medium businesses.[27]

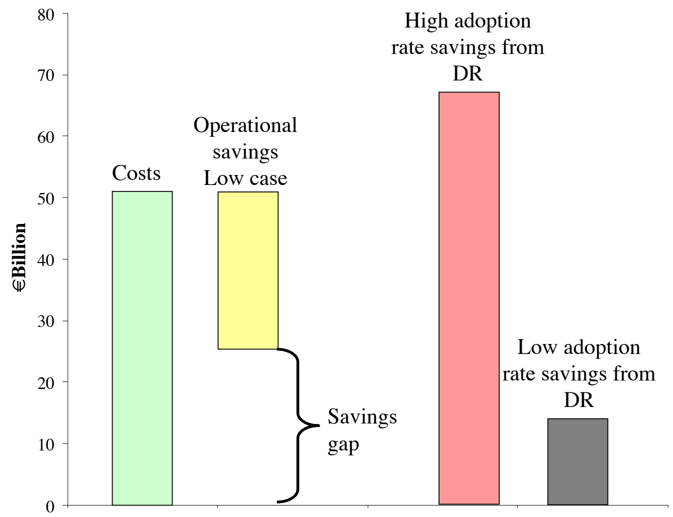
Assuming an approximate cost of €120 per household meter, and €450 per non-household meter, we estimate that a total investment of €51 billion will be necessary to install AMI throughout the EU (our calculations are in included the appendix). This includes the "sunk" costs of meters already installed. If 50 to 80 percent of these costs are recovered through operational benefits, the remaining cost of AMI is between €25 billion and €10 billion.

It seems clear that with high adoption rates for dynamic tariffs there is a great return on investment. The present-value benefits of €67 billion are almost three times the remaining AMI costs to be recovered. But the case with low adoption rates is much more marginal. Under all but the most optimistic scenarios regarding operational benefits, the cost of AMI may not justify the investment.

Figure 3 illustrates how the benefits of demand response can bridge the savings gap, the difference between operational savings and the cost of AMI, if adoption rates for dynamic tariffs are high; the savings gap remains if adoption rates and operational savings are low.

In these instances, to determine the cost effectiveness of an AMI investment it would be necessary to further explore additional benefits that have not been quantified in this study, such as improved reliability, enhanced market competitiveness and reduced rate volatility.

Figure 3 Present value costs and benefits of AMI in the EU with high and low adoption rates for dynamic pricing



Conclusion

The adoption of dynamic tariffs could make or break the pay-off from the EU's investment in smart meters. Even with operational savings from easier meter reading and other measures at €26 to 41 billion, this still leaves a "savings gap" of €10 to 25 billion between benefits and costs; a gap that might not be filled if adoption is at the low end of typical customer participation rates.

To boost adoption rate, policy-makers and energy suppliers need to be innovative to help increase customer participation; quantifying and stressing the environmental benefits of dynamic tariffs, ensuring transparent and adequate financial rewards and offering customers a lower flat tariff in return for providing "automatic" demand response.

For some Member States, setting a dynamic regulated tariff could significantly increase demand response. Countries without regulated tariffs could implement dynamic transmission and distribution tariffs that would vary according to when the customer uses power.

Based on international experience, if policy-makers fail to design effective dynamic tariff programmes, customer adoption rates for dynamic tariffs will likely be around 20 percent. But these rates could increase to 80 percent if policy-makers and suppliers implement some of the policies we highlight above.

If 80 percent of customers reduce their demand at peak hours due to dynamic pricing, the reduction in associated capacity and transmission costs would be €67 billion. However, if the uptake of dynamic tariffs is only 20 percent, then savings are only €14 billion.

The €53 billion difference is the reward that awaits policy-makers if they can persuade customers to sign on to dynamic tariffs in greater numbers.

Endnotes

[1] Ahmad Faruqui, Ryan Hledik and John Tsoukalis, "The Power of Dynamic Pricing," *The Electricity Journal*, April 2009.

[2] The countries included are the EU 27 excluding Latvia, Lithuania, Malta and Sweden.

[3] In addition to dynamic pricing, demand response can also be implemented by providing cash incentives to customers that encourage them to control usage. Examples include direct load control programmes that target end uses such as central air conditioners and water heaters, interruptible and curtailable rates that target large customers and various forms of load curtailment that are practiced by independent system operators and regional transmission operators around the country. In this assessment, we focus exclusively on demand response as implemented through dynamic pricing programmes. Such programmes are triggered by economic, as opposed to system reliability, criteria.

[4] For more details on these trials, see Ahmad Faruqui and Sanem Sergici, *Household Response to Dynamic Pricing of electricity – a survey of the experimental evidence*, 10 January 2009. Available at: http://www.hks.harvard.edu/hepg/Papers/2009/The%20Power%20of%20 Experimentation%20_01-11-09_.pdf.

[5] AMI refers to the entire infrastructure of "smart" meters, communication networks and data management systems required for metering information to be collected and analysed. For a further discussion and description of AMI see "Deciding on 'Smart' Meters: The Technology Implications of Section 1252 of the Energy Policy Act of 2005," Plexus Research, September 2006.

[6] For a discussion of the reasons for this hesitancy, see Ahmad Faruqui, "Breaking out of the Bubble," *Public Utilities Fortnightly*, March 2007.

[7] The 13 percent drop occurred during the six months of the summer season from May to September. Responses during the inner summer months of June-August were a percentage point higher. The 14 percent number might be more applicable during critical-peak conditions.

[8] Ahmad Faruqui and Stephen George, "Quantifying Customer Response to Dynamic Pricing," *The Electricity Journal*, May 2005.

[9] Ahmad Faruqui and Sanem Sergici, *Household Response to Dynamic Pricing of electricity – a survey of the experimental evidence*, 10 January 2009. Available at: http://www.hks.harvard.edu/hepg/Papers/2009/The%20Power%20of%20Experimentation%20_01-11-09_.pdf.

[10] "A National Assessment of Demand Response Potential," Federal Energy Regulatory Commission Staff Report prepared by *The Brattle Group*, Freeman, Sullivan & Co. and Global Energy Partners, LLC, June 2009.

[11] "CER, Smart Metering Project Phase 1," Information paper 2, 31 July 2009, CER/09/118.

[12] See http://www.ofgem.gov.uk/Markets/RetMkts/Metrng/Smart/Pages/SmartMeter.aspx for more details.

[13] Haney, A, Jamasb, T, Pollitt, M, "Smart Metering and Electricity Demand: Technology, Economics and International Experience," Electricity Policy Research Group working paper - EPRG0903, January 2009.

[14] Momentum Market Intelligence, "Customer Performance Market Research: A Market Assessment of Time-Based Rates Among Residential Customers in California," December 2003.

[15] *Ibid*. Table 6 p.14.

[16] For example one recent study found that Irish households had one of the lowest adoption rates of energy efficient light bulbs in the EU, despite an estimated pay-back period of just several months. See, Di Maria, Corrado, Ferreira, Susana and Lazarova, Emiliya A., "Shedding Light on the Light Bulb Puzzle: The Role of Attitudes and Perceptions in the Adoption of Energy Efficient Light Bulbs," 3 May 2009. Available at SSRN, http://ssrn.com/abstract=1417948.

[17] PG&E in California has enrolled roughly 75,000 customers in its Smart AC air conditioning cycling programme based on a one-time payment of $25 and an appeal indicating that participation would be "doing one small thing" that would "actually help prevent power interruptions and protect the environment." (quote taken from a PG&E direct mail offer letter.)

[18] On a dynamic rate with a strong price signal during the peak period, residential customers without CAC might reduce peak demand by between eight and ten percent. A similar magnitude of impacts might be expected from medium and large C&I customers.

[19] This includes both transmission and distribution losses.

[20] Value used is for the Republic of Ireland. "Fixed Cost of a Best New Entrant Peaking Plant, Capacity Requirement, and Annual Capacity Payment Sum for the Calendar Year 2009," SEM Decision paper – SEM-08-109, 11 September 2008, p.29.

[21] Ahmad Faruqui, Ryan Hledik, Sam Newell and Hannes Pfeifenberger "The Power of 5 Percent," *The Electricity Journal*, October 2007.

[22] This estimate is based the filing of PG&E with the CPUC on AMI. From a national perspective, we cite the US Energy Information Administration's estimate that transmission and distribution costs account for some 36 percent of electricity costs. See "Electricity Power Annual," 2007, using data from 2005.

[23] For a qualitative discussion of these benefits, see our PJM-MADRI demand response study, *Quantifying Demand Response Benefits in PJM*, February 2007.

[24] "Capgemini Consulting and CRE – AMM for France: the complete case," 3 October 2007. The UK Department of Energy and Climate Change estimate the installed costs of meters for the domestic sector at between £87 and £102, and the installed cost for advanced meters for small and medium businesses between £384 to £398.

[25] Borghese F., "Evaluating The Leading-Edge Italian Telegestore Project," February 2006.

[26] "Impact assessment of a GB-wide smart meter roll out for the domestic sector," DECC, May 2009. Benefits considered by the DECC study include energy and peak demand reduction of 2.8 percent, avoided costs of carbon, improved infrastructure for microgeneration, avoided costs of meter reading, reduced customer service overheads, remote disconnection and switching, reduced cost to serve customers with pre-payment meter, and reduced theft.

[27] "Impact Assessment of smart / advanced meters roll out to small and medium businesses," DECC, May 2009.

Appendix — Estimating Demand Response Benefits

We first estimate the total costs of smart meter installation. As the costs of domestic and non-domestic meters vary greatly, at €120 and €450 respectively, it is necessary to know the number of each required. The number of domestic meters should approximate the number of households, which Eurostat reported for 2007. However, we still need an estimate of the number of Small and Medium Enterprises (SMEs) which will also require smart meters. To estimate the number of SMEs, we looked at two countries for which we have accurate figures available: the United Kingdom and Italy. The results are presented below.

Table 2 Proportion of non-domestic meters for Italy

		Value	Units	Source
[A]	No. of households in Italy 2007	23,902	'000	Eurostat
[B]	No. of meters installed by Enel	27,000	'000	See note
[C]	Penetration rate	85%		ERGEG
[D]	Implied total number of meters	31,765	'000	[B]/[C]
[E]	Implied SME meters	7,863	'000	[D]-[A]
[F]	SME meters as % of households	33%		[E]/[A]

Note: [B]: Borghese F, "Evaluating The Leading-Edge Italian Telegestore Project," February 2006.

Table 3 Proportion of non-domestic meters for the UK

		Values	Units	Source
[A]	No. of households in the UK	26,649	'000s	Eurostat
[B]	Domestic meters	21,956	'000s	See note
[C]	Total meters	28,000	'000s	See note
[D]	Implied non-domestic meters	6,044	'000s	[B]-[C]
[E]	SME as % of domestic meters	28%		[D]/[B]

Note: [B],[C]: Haney, A., Jamasb, T., Pollitt, M., *Smart Metering and Electricity Demand: Technology, Economics and International Experience,* January 2009, p.15.

From the above results we use 30 percent as a reasonable estimate of the number of SME meters as a percentage of domestic meters. We also note that the number of domestic meters for the UK case differs from the total number of households. While the reason for this is not clear, to calculate costs we use the higher number which is more conservative.

For the 23 countries considered, the above assumptions lead to a total cost of smart meter installation of €51 billion. The calculation is presented in Table 4.

Table 4 Estimate of the cost of AMI for the EU

Cost of household smart meter, €	[A]	120
Cost of industrial smart meter, €	[B]	450
Non-domestic meters as a % of households	[C]	30%

	Number of private households 2007	Estimated total number of SME meters	Cost household meters	Cost SME meters	Total cost
	'000s	'000s	€ mln	€ mln	€ mln
	[D]	[E]	[F]	[G]	[H]
	Eurostat	[D]x[C]	[A]x[D]/1000	[B]x[E]/1000	[F]+[G]
Belgium	4,439	1,332	533	599	1,132
Bulgaria	2,866	860	344	387	731
Czech Republic	4,219	1,266	506	570	1,076
Denmark	2,365	710	284	319	603
Germany	39,291	11,787	4,715	5,304	10,019
Estonia	544	163	65	73	139
Greece	4,221	1,266	507	570	1,076
Spain	16,226	4,868	1,947	2,191	4,138
France	26,734	8,020	3,208	3,609	6,817
Italy	23,902	7,171	2,868	3,227	6,095
Luxembourg	187	56	22	25	48
Hungary	3,810	1,143	457	514	972
Netherlands	7,202	2,161	864	972	1,837
Austria	3,536	1,061	424	477	902
Poland	12,933	3,880	1,552	1,746	3,298
Portugal	3,852	1,156	462	520	982
Romania	7,381	2,214	886	996	1,882
Slovenia	745	224	89	101	190
Slovakia	1,697	509	204	229	433
Finland	2,434	730	292	329	621
United Kingdom	26,649	7,995	3,198	3,598	6,795
Croatia	1,590	477	191	215	405
Ireland*	1,497	449	180	202	382
Total			**23,798**	**26,773**	**50,571**

Note: *Ireland private household data from Central Statistics Office Ireland for 2006.

When calculating benefits, we considered two cases, a high uptake case and a low uptake case. The only difference between the two is that in the high uptake case peak demand reduction is assumed to be ten percent, and in the low uptake case it is taken to be two percent. The calculations are presented below.

Table 5 Assumptions in calculation of present value of DR financial benefits — high case

	Assumption/Calculation	Value	Units	Source
[A]	2008 EU non-coincident peak demand at transmission level	467,140	MW	Demand for EU 27 excluding Latvia, Lithuania, Malta and Sweden
[B]	Market potential of DR	10%	% of peak	Calculation of Market Potential
[C]	Peak demand reduction	46,714	MW	[A] * [B]
[D]	Reserve margin	15%	% of peak	Generally accepted industry practice
[E]	Line losses	2%	% of peak	Generally accepted industry practice
[F]	System-level MW reduction	54,795	MW	[C] * (1 + [D]) * (1 + [E])
[G]	Value of capacity	87.12	€/kW-yr	BNE Fixed Cost of a Best New Entrant Peaking Plant 2009
[H]	Value of capacity	87,120	€/MW-yr	[G] * 1,000
[I]	Total avoided capacity cost	4,774	Million €/year	[F] * [H] / 1,000,000
[J]	Peak demand growth rate	1.7%	% per year	Assumption
[K]	Annual discount rate	8.0%	% per year	Assumption
[L]	Study time horizon	20	years	Assumption
[M]	PV of €1 annuity for 20 years	11.29	€	Assumption
[N]	Energy % of generation capacity cost	12%	% of NPV	2006 Brattle DR Study for MADRI/PJM
[O]	T&D % of energy and generation capacity cost	10%	% of NPV	2006 PG&E AMI Filing
[P]	PV avoided generation capacity cost	53,900	Million €	[I] * [M]
[Q]	PV avoided energy cost	6,645	Million €	[N] * [P]
[R]	PV avoided T&D capacity cost	6,055	Million €	[O] * [P]
[S]	PV of total avoided cost	66,600	Million €	[P] + [Q] + [R]

Table 6 Assumptions in calculation of present value of DR financial benefits — low case

	Assumption/Calculation	Value	Units	Source
[A]	2008 EU non-coincident peak demand at transmission level	467,140	MW	Demand for EU 27 excluding Latvia, Lithuania, Malta and Sweden
[B]	Market potential of DR	2%	% of peak	Calculation of Market Potential
[C]	Peak demand reduction	9,343	MW	[A] * [B]
[D]	Reserve margin	15%	% of peak	Generally accepted industry practice
[E]	Line losses	2%	% of peak	Generally accepted industry practice
[F]	System-level MW reduction	10,959	MW	[C] * (1 + [D]) * (1 + [E])
[G]	Value of capacity	87.12	€/kW-yr	BNE Fixed Cost of a Best New Entrant Peaking Plant 2009
[H]	Value of capacity	87,120	€/MW-yr	[G] * 1,000
[I]	Total avoided capacity cost	955	Million €/year	[F] * [H] / 1,000,000
[J]	Peak demand growth rate	1.7%	% per year	Assumption
[K]	Annual discount rate	8.0%	% per year	Assumption
[L]	Study time horizon	20	years	Assumption
[M]	PV of €1 annuity for 20 years	11.29	€	Assumption
[N]	Energy % of generation capacity cost	12%	% of NPV	2006 Brattle DR Study for MADRI/PJM
[O]	T&D % of energy and generation capacity cost	10%	% of NPV	2006 PG&E AMI Filing
[P]	PV avoided generation capacity cost	10,780	Million €	[I] * [M]
[Q]	PV avoided energy cost	1,329	Million €	[N] * [P]
[R]	PV avoided T&D capacity cost	1,211	Million €	[O] * [P]
[S]	PV of total avoided cost	13,320	Million €	[P] + [Q] + [R]

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Ahmad Faruqui recently lead a state-by-state assessment of the potential for DR for the Federal Energy Regulatory Commission, which was filed with the U.S. Congress in June 2009. Last year, he performed a national assessment of the potential for energy efficiency for the Electric Power Research Institute and wrote a report on quantifying the benefits of dynamic pricing for the Edison Electric Institute.

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