‘Nudging’ Energy Users: Regulatory Measures to Address the Risk of Aggregate Peak Demand in European Electricity Markets

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Abstract

For decades regulators in the energy sector have focused on facilitating the maximisation of energy supply in order to meet demand through liberalisation and removal of market barriers. The debate on climate change has emphasised a new type of risk in the balance between energy demand and supply: excessively high energy demand brings about significantly negative environmental and economic impacts. This is because if a vast number of users is consuming electricity at the same time, energy suppliers have to activate dirty old power plants with higher greenhouse gas emissions and higher system costs. The creation of a Europe-wide electricity market requires a systematic investigation into the risk of aggregate peak demand. This paper draws on the e-Living Time-Use Survey database to assess the risk of aggregate peak residential electricity demand for European energy markets. Findings highlight in which countries and for what activities the risk of aggregate peak demand is greater. The discussion highlights which approaches energy regulators have started considering to convince users about the risks of consuming too much energy during peak times. These include ‘nudging’ approaches such as the roll-out of smart meters, incentives for shifting the timing of energy consumption, differentiated time-of-use tariffs, regulatory financial incentives and consumption data sharing at the community level.

Keywords

European energy markets; Energy regulation; Nudging; Regulated tariffs: Risk of peak demand; Smart grids

1. INTRODUCTION

For decades energy regulators have focused on optimal market-based tools to facilitate access to energy supply in order to meet demand and reduce costs. The emphasis has mainly been on liberalisation and removal of market barriers.[1] More recently, the debate around climate change has emphasised the role of the risk of peak demand in balancing electricity demand and supply, as excessively high energy demand brings about significantly negative environmental and economic impacts. This is because if a vast number of users is consuming electricity at the same time, energy suppliers have to activate dirty old power plants with higher greenhouse gas emissions and higher system costs.

In response to this problem, energy regulators have started considering various approaches to inform users about the risks of consuming too much energy at peak times. Some of these measures are relatively 'soft'. They elude command-and-control, i.e. dictating when citizens should use electricity, and yet introduce elements which are designed to make consumers think twice about their energy consumption. They are based on a combination of libertarian and paternalist philosophies of regulatory intervention.[2] What is more, energy regulators seem to have adopted a new regulatory philosophy, which reconciles libertarian and paternalist approaches.[3] Recent regulatory interventions in Europe, including those in the proposed UK Electricity Market Reform, contain several elements aimed at 'nudging' energy users. These include (i) the roll-out of smart meters, (ii) differentiated time-of-use tariffs, (iii) regulatory incentives for shifting the timing of energy consumption, and (iv) consumption data sharing at the community level.

Before addressing the question of which 'nudging' regulatory approaches can be used to address the risk of aggregate peak demand, a more urgent matter relates to the assessment of such risks. Whilst a vast amount of data is available with regards to the risks associated with generation, transmission, distribution and supply of electricity,[4,5] as well as the public perception of risk associated with specific energy generation technologies,[6,7] the literature on energy regulation is very limited with regards to the timing of demand. No research has endeavoured to model the risk of aggregate peak demand at the European level. Residential electricity demand profiles are highly correlated with the timing of appliance use. This is because at the time of appliance use, consumers are likely to be involved in activities that necessitate consumption of electricity. This paper makes use of occupancy time-series data from the e-Living Time-Use Survey Database with the aim to assess the risk of aggregate peak demand in European electricity markets. To this end, the risk of aggregate peak electricity demand is assessed in terms of changes in occupancy and time-use of appliances in five European countries.

The paper introduces the issue of risk of aggregate peak electricity demand in European electricity markets (Section 2); proposes a methodology for assessing the risk of aggregate peak demand (Section 3); presents the findings on the assessment of risks of aggregate peak demand (Section 4); discusses 'nudging' regulatory practices in the energy sector (Section 5); and concludes with links between nudge concepts and the risk of aggregate peak demand in European electricity markets (Section 6).

2. THE RISK OF AGGREGATE PEAK DEMAND IN EUROPEAN ELECTRICITY MARKETS

2.1 European electricity markets

For the greatest part of the 20th Century European electricity markets have operated as separate national or regional networks. This is due to the historical role of national monopolistic energy utilities which developed grids under the assumption that each country could meet its energy demand through national supply and imports. The slow, but inevitable liberalization of European energy markets over the last ten years has dissolved the traditional nation-state economic model and triggered the need for Europe-wide energy regulation. Although full market liberalization still presents very heterogeneous features and arguably has not been completely achieved,[(8)] the three European Union packages on the liberalization of energy markets have marked the progress towards the highest level of integration of energy markets ever experienced in Europe.[(9)]

The formal integration of energy markets is also marked by the creation of new institutions, like the Agency for the Cooperation of Energy Regulators (ACER), a

Europe-wide supranational regulator which aims to support market integration, advise national energy regulators and monitor the progress of market co-operation.[10,11] ACER presents the hybrid structure of previous networks of utilities regulators.[12]

In addition to the institutional integration, new developments in renewable energy have led several Governments to consider a future European Smart grid, which will consist of an integrated power system network, where electricity demands from one country will be met by generation from another country.[13] This will be achieved through building new cross-border connections which will improve current electricity transmission and distribution systems which were designed over 40 years ago. For instance, UK interconnector projects under investigation include two interconnectors with Norway as part of the North Seas Countries' Offshore Grid Initiative additional interconnection with France, as well as Iceland, Ireland, Denmark and Spain. Interconnectors are supposed to guarantee security of supply at all times by transporting large energy leads across regions.

2.2 The risk of aggregate peak electricity demand: the need for regulatory 'nudging'

Technology optimists argue that in the European Smart grid the risk of power cuts will be mitigated by the diversification of energy generation mixes, from solar to wind to nuclear.[14] However, for a correct balancing between supply and demand to function the implications of aggregate demand need to be explored. Congestion associated with peak demand is a problem for trading electricity across borders not only in terms of regulating blackouts (i.e. excessive demand),[15] but also in terms of regulating intermittent renewable sources of energy: one Member State may be generating so much electricity that the transmission capacity to other countries is exceeded (i.e. excessive supply). Congestion costs across the most congested interconnectors in Europe are currently estimated to be €1.3bn each year.[16]

It has been pointed out that the source of the problem rests in the lack of relationship between regulated energy tariffs and actual energy costs.[17] Most of the retail electricity tariffs in Europe are set by independent regulators and do not reflect the time variation in the cost of supply. As a result, customers are not provided with price signals to promote efficient electricity consumption and may over-consume electricity during expensive peak periods and under-consume electricity during inexpensive off-peak periods. In other words, the lack of any price signalling prevents customers to operate in a responsive manner in the retail market. The image of a supermarket without price labels on the products can figuratively explain the lack of price signals in electricity markets.

One of the unintended consequences of the lack of information on prices is that consumers might simultaneously opt for sub-optimal choices. This resonates with what Thaler and Sunstein define as one of the pre-conditions for ‘nudging’. The nudge approach has been developed on the assumption, drawn from recent cognitive studies, that, from investments to daily actions, people tend to make sub-optimal decisions. In energy economics terms, the risk of aggregate peak demand corresponds to the sum of simultaneous sub-optimal decisions taken by multiple customers to consume electricity when it costs the most.

Large socio-demographic datasets on energy consumption are the most frequent type of source used by EU policy-makers for their macroeconomic modelling on the impacts of energy markets.(18) However, these methodological approaches neglect the risk of peak aggregate demand and miss out on the question of when simultaneous congestion takes place. For European electricity regulators, the scale of aggregate risk depends on the probability of individuals entering and leaving the household at the same time in different countries. For these reasons, any analysis aimed at identifying aggregate peak electricity demand needs to move away from absolute energy consumption and look at patterns of consumption and occupancy.

3. METHODOLOGY

3.1 Review of methodologies modelling energy demand based on time-use data

This section presents a brief review of studies which attempted to model the timing of energy demand from time-use data. Some of them make use of existing national surveys. Others simulate time-use using probability, stochastic modelling and the

Markov–Chain technique. For instance, bottom-up models were deployed for UK electricity demand starting from the UK Time Use Survey.[19] In such studies ‘active occupancy’ is defined as the presence of consumers who are at home and not sleeping. The model generates occupancy data for UK households based upon surveyed time-use data describing what people do and when. It makes use of a probabilistic approach to infer how many other occupants enter or leave the household between a 10 minute interval and the next one.

The generation of occupancy data has been used as a starting point for electricity demand simulations.[20] Similarly, the model by Widen and Wäckelgård simulates household activities based on time-use data.[21] The timing of electricity demand is derived from time-use patterns. In their model, the household activity simulation is produced on the basis of non-homogeneous Markov chains which reduce the time-use dataset to 1 minute intervals.

In other work, a Europe-wide model of occupancy was designed to identify occupancy peaks in 15 European countries. In that work national variances in occupancy levels at the aggregate European level profiles were assessed, based on the Harmonised European Time Use Survey.[22]

Unlike previous studies, the model presented in sub-Section 3.3 makes use of the concept of aggregate peak demand risk to assess in which periods of the day the use of electrical appliances may cause congestions to the power network. In order to make the study as relevant as possible to current regulatory and market conditions another time-use database is used. The e-Living Time-Use Survey Database has the merit of relying on appliance-specific data from different countries. Compared with the aforementioned Harmonised European Time Use Survey, the analysis loses out in representativeness and size (from 15 to 5 countries), but gains in appliance-granularity, which serves the purpose of assessing the risk of aggregate peak demand through electrical appliance use.

3.2 E-Living Time-Use Survey Database

The e-Living Time-Use Survey Database is based on household panel surveys in five European countries, i.e. Norway, Germany, Italy, Bulgaria and the UK. It provides time-related information about family domestic economics particularly with reference to the use of Information Communication Technologies. The database consists of randomly sampled households. Each country is represented by a sample of 1750 individuals. Overall the e-Living Time-Use Survey Database provides 1,260,000 10-minute interval data entries from 8,750 comparable individuals across 5 countries.

A 24 hour time-use diary item was included as part of the questionnaire. Appendix A provides a detailed description of the time-use questions which were included in the diary.

Time use surveys are the main source of data for knowing when people are either inside or outside the household. The time spent in the household creates the necessary conditions for using electricity. The time spent outside the household almost automatically rules out the possibility of household-related electricity consumption, with the exception of base-consumption, i.e. the constant consumption which goes on in the household caused by appliances on standby, which in European households is typically around 0.05-0.2 KWh.(23)

Some of the time-use data can be associated with the timing of electricity consumption. This mainly depends on how appliance-specific the diary entry is. For instance, for the entry called ‘TV and Video watching’ it is possible not only to derive the timing of electricity demand, but also, with some approximation about the average efficiency of the TV and video sets, the actual physical demand in KWh. However, diary entries like ‘household work’ are not appliance specific, making it difficult to associate the timing of that activity with electricity demand.

In order to construct a model which identifies the risk of aggregate electricity demand, some household activities which can be associated with the use of electrical appliances were identified. Those activities in Appendix A which are coded from 2, 3, 5, 6, 7, 21, 22, 23 and from 28 to 33 provide inputs to the model explained below.

3.3 The model

The model focuses on how often the use of electrical appliances exceeds a certain value ω, which corresponds to a fixed level of supply that the European Smart grid can tolerate. In the following Y_1, Y_2, Y_3, Y_4 and Y_5 are the total share of active use of electrical appliances by country. A_K is the total amount for the European Smart grid.

The distribution function Y_1, Y_2, Y_3, Y_4 and Y_5 is denoted by F. Assuming that appliance use can only be positive, means that F(0) = 0 and that F(y) < 1. In addition $\ddot{F}(y) = 1 - F(y)$ for $y \geq 0$, which represents the tail of F. In order to determine, where the share of active use of electrical appliances exceeds a fixed supply ω, this time point is determined by

$X(\omega) = \min \{Y_k > \omega\}$.

Setting

$\rho := P\,(Y > \omega) = \ddot{F}(\omega)$

The random variable X(ω) is distributed according to the risk parameter ρ.

This means that the probability that X(ω) takes the value k is given by

$P\,(X(\omega) = k) = (1- \rho)^{k-1}\, \rho$

Which stands for the probability that in k−1 countries there is no excess of appliance use compared with fixed supply, but in the European Smart grid there is still an excess.

The risk of aggregate peak demand can be represented as:

$$\sum_{k=1}^{N} k\, P\,(X(\omega) = k) = \rho \sum_{k=1}^{N} k\,(1-\rho)^{k-1} = \frac{1}{\rho} = \frac{1}{P\,(Y > \omega)} = \frac{1}{\ddot{F}(\omega)}$$

Having defined the risk of aggregate peak demand, a distinction is made between morning peak period (from 7 AM to 9 AM), evening peak period (from 6 PM to 10 PM). Consequently, the risk of aggregate peak demand is divided into baseline risk, representing all day, including peak periods, morning peak risk, evening peak risk and non-peak risk, which consists of daytime difference between baseline risk and the two peak risks.

4. ASSESSING THE RISK OF AGGREGATE PEAK ELECTRICITY DEMAND

4.1 Use of electrical appliances

Figure 1 shows the percentages of active use of electrical appliances by European residents against time. Figure 1 does not into account population, but simply the percentage of households with at least one active tenant involved in activities which require the use of electrical appliances.

Figure 1-Active use of electrical appliances by residents in 5 European countries

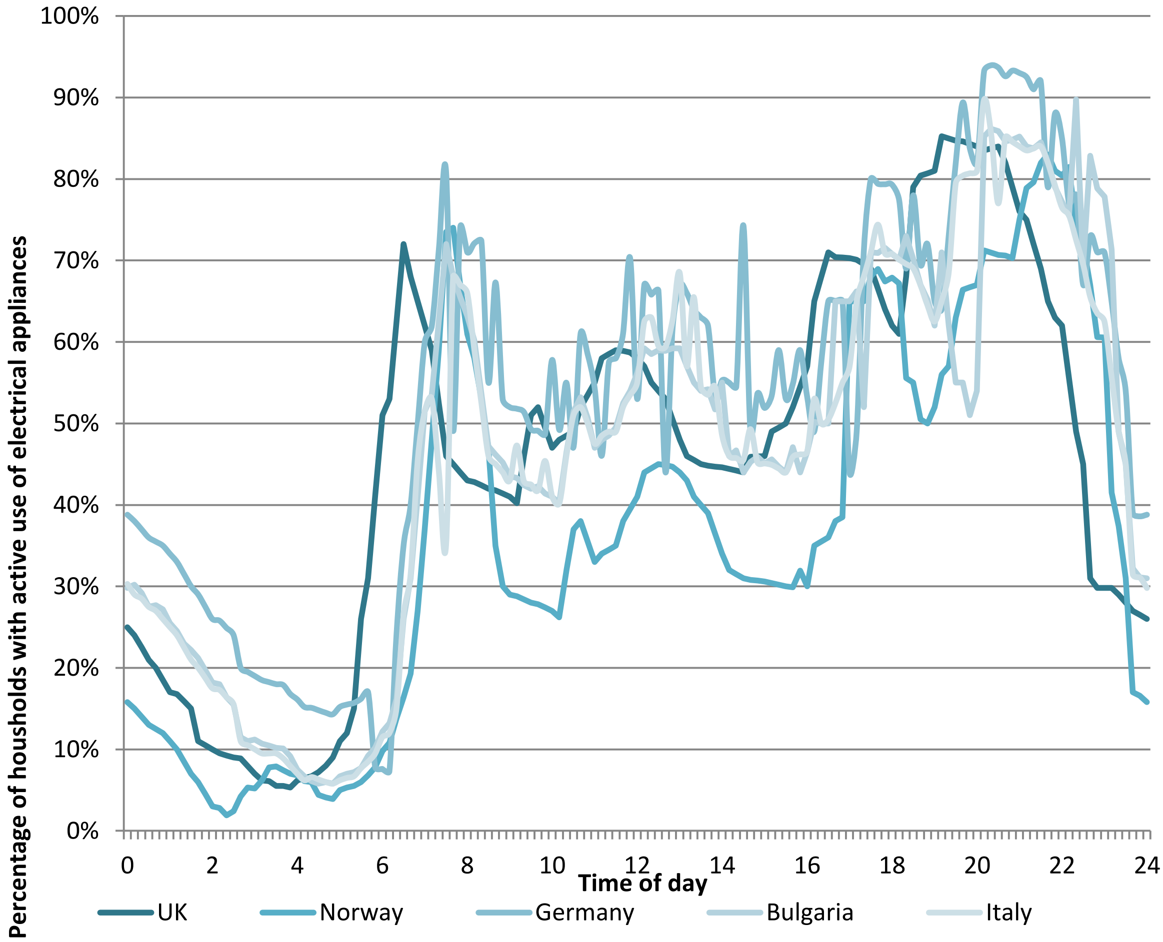


Figure 1 shows extremely low levels of electrical appliance use during night hours and very high levels of appliance use during meal periods for Central European Time (CET). The move of all time use data to CET may underpin some of the variations between CET countries (Italy, Germany and Norway), and the UK, which is one hour behind CET and Bulgaria, which is one hour ahead of CET. However, the differences among countries are not relevant to this analysis.

Table 1 illustrates the break-down of the time spent in each country on activities which involve the use of electrical appliances. The baseline for this measurement varies depending on how many hours per day are spent in overall activities.

Table 1-Share of time use activities related to appliances in the household

Country	Computer	Personal hygiene	Food	At home	Leisure at home
Bulgaria	16.08	3.75	26.53	10.11	38.84
Germany	12.32	3.22	9.83	29.63	38.58
Italy	18.45	4.18	38.97	16.46	15.06
Norway	18.86	2.61	7.86	39.08	23.69
UK	15.18	4.2	9.16	26.44	37.29

The category ‘leisure at home’ involves activities like ‘watching TV/Cable/Satellite TV’; ‘watching videos/laser disks’; and ‘listening to radio, CD, cassette’. Activities like ‘reading newspapers, books, magazines’ and ‘being visited by friends or relatives in own home’ were not included as not directly related to any appliance use. The use of lighting is excluded from this analysis. ‘Leisure at home’ takes about 38% of the time spent in activities which involve the use of appliances in Bulgaria, Germany and the UK. The category ‘at home’ includes ‘care of own children or other adults in own home’; ‘cleaning house, tidying, clothes washing, ironing, sewing etc’; and ‘maintenance, odd jobs, DIY, gardening, pet care’. The ‘at home’ category takes up between 26% and 39% of appliance-related time in households in the UK, Norway and Germany. In Bulgaria and Italy the category ‘food’, which mainly stand for cooking and food preparation represents 26% and 37% of time in Bulgaria and Italy respectively. ‘Personal hygiene’ relates mainly to washing, which is considered here because of the high penetration of combi-boilers in the sample countries.[(24)] This category is limited to 2% to 5% of overall appliance time use.

Figure 2 shows how these activities impact on aggregate in European electricity markets, taking into account the population of end-users and including activities both inside and outside the household.

Figure 2- Aggregate impact of time use activities related to appliances

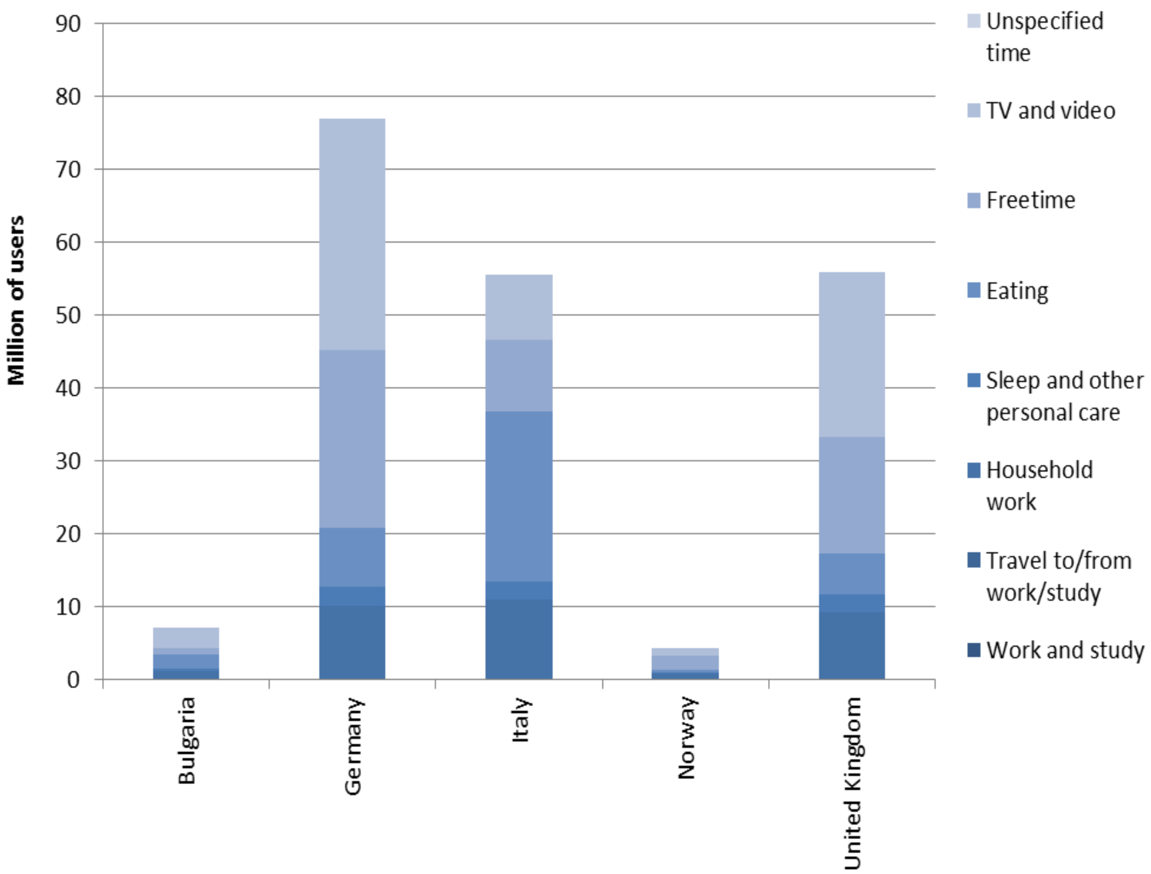
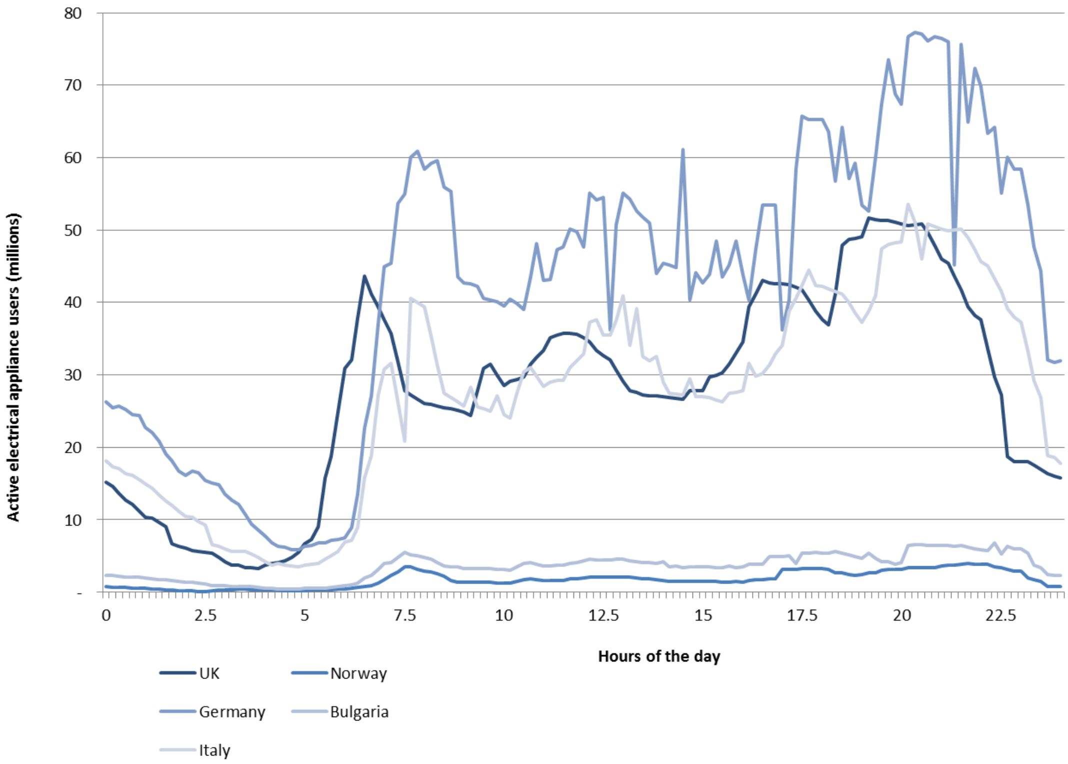


Figure 3 illustrates the impacts of active electrical appliance users when scaling up findings by population in the five European countries. Larger countries like Germany, Italy and the UK are more likely to contribute to the risk of aggregate peak demand than Bulgaria and Norway. These absolute figures are only indicative as they do not take into account the distribution of buildings within a country, nor the number of occupants. The two arrows indicate the morning peak period (from 7 AM to 9 AM) and the evening peak period (from 6 PM to 10 PM).

Figure 2-Active electrical appliance users



4.2 Risks

Baseline risks are assessed using a bottom-up approach from all time intervals. Figure 4 presents the risk of aggregate peak demand in terms of baseline risk, morning peak risk, evening peak risk and non-peak risk in the 5 countries. The findings in Figure 4 are presented as relative figures. This means that the size of the country is controlled for in order to understand the impact of the individual average household electrical appliance use on peak risks. For instance, in Bulgaria the high peak morning risk and peak evening risks combined (ρ=0.168) imply that electrical appliance use at peak time yields potentially significant demand and supply balancing problems on the national transmission grid as well as local distribution networks. The country with the largest baseline risk per household is Bulgaria (ρ=0.194) followed by UK (ρ=0.165). Unlike Bulgaria, a significant share of risk is represented by baseline risk. This means that in the UK base consumption is higher than in other countries, including for night time. Conversely, in Bulgaria much of the baseline risk is explained by morning and evening peaks and non-peak risk in the daytime. The average household in Italy, Germany and Norway has similar characteristics in relation to the risk of peak electricity demand.

Figure 3-Baseline risks, peak risks and non-peak risks (per household)

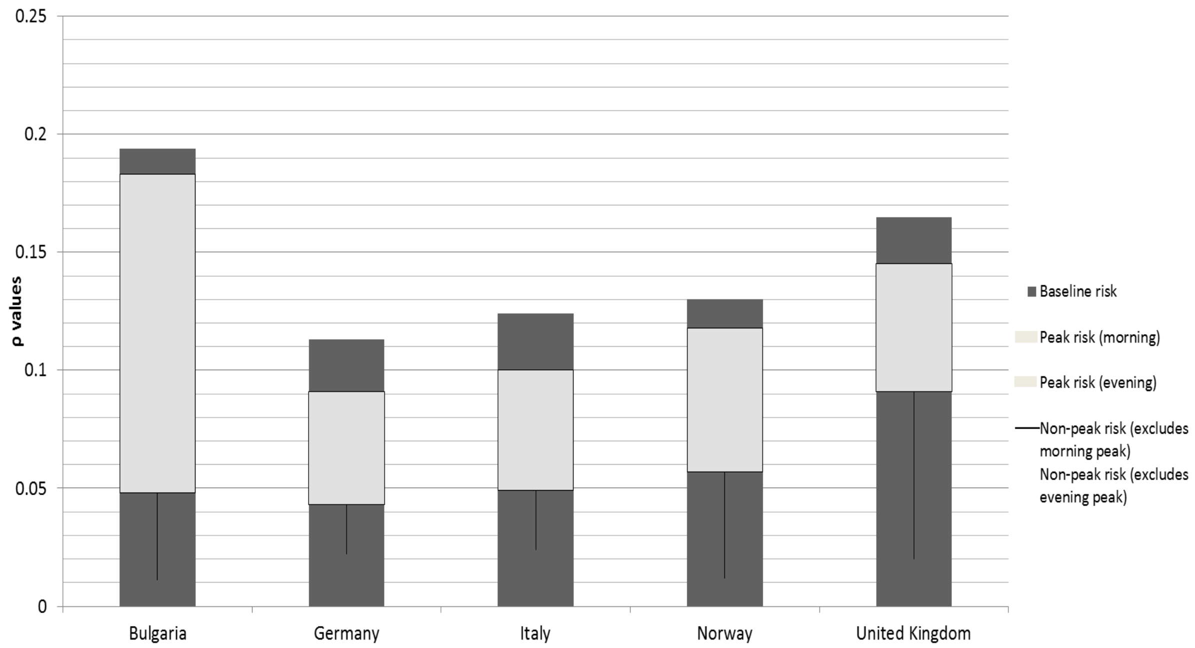
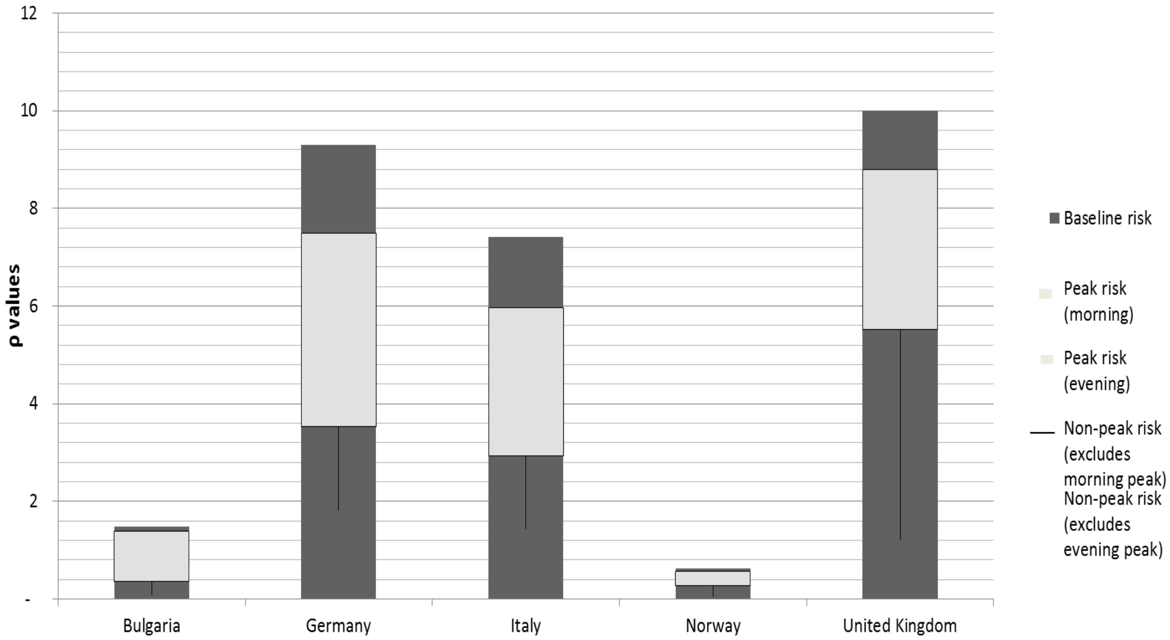


Figure 5 presents the overall country contribution to a hypothetical European Smart grid in terms of aggregate risk of peak electricity demand. The size of the country obviously matters, although the distribution of risk in terms of baseline risk, peak risk and non-peak risk is maintained. This means that peak risks represent a very significant role, i.e. between 23% to 89% of overall ρ values. The UK yields the largest risk portion of risk (ρ=9.99) followed by Germany (ρ=9.29), Italy (ρ=7.40), Bulgaria (ρ=1.48) and Norway (ρ=0.62). One of the most obvious implications of these findings is that any action aimed at addressing the risk of aggregate peak electricity demand for the European Smart grid should take into account larger member states first. What these actions might be will be discussed in the next section.

Figure 4-Overall country contribution to aggregate risk of peak electricity demand



5. DISCUSSION

5.1 Links between 'nudging' and the risk of peak demand

The risk of peak demand can be addressed by energy regulators in a variety of ways. Command-and-control regulatory intervention, which has proven successful for cutting carbon emissions by energy producers (e.g. with the mandatory requirement to install Carbon Capture and Storage for new coal power plants in the UK in 2009), has been arguably discarded when it comes to energy demand.[25] Instead, market and information disclosure approaches are designed with the aim of informing users about the risks of consuming energy at peak times. What is more, some of these regulatory tools are relatively lenient as they are intended to cause reflections about legitimate consumption decisions on behalf of end-users. Recent regulatory interventions, including those in the proposed UK Electricity Market Reform, contain several elements aimed at 'nudging' energy users. These include (i) the roll-out of smart meters, (ii) differentiated time-of-use tariffs, (iii) incentives for shifting the timing of energy consumption, and (iv) consumption data sharing at the community level.

5.2 Governments' national roll outs of smart meters

Smart meters are the technology that enables to inform users about their consumption and the presence of demand peaks in the system. They are the main 'nudging' technology in the realm of energy demand. Without interfering on regulated tariffs, the mere presence of smart meters is designed to nudge users to change demand patterns.

Early smart meters in the 1990s provided near real-time feedback on aggregate home electricity consumption in terms of kWh and cost and required clip-on current sensors installed into the breaker panel of the home. Subsequent larger scale trials from 2000 onwards used devices which provided similar feedback but did not require installation in the breaker panel, and instead uses an optical sensor attached directly to the meter. The newest generation of display technologies is able to communicate directly with a smart meter. This advancement allows for more immediate and accurate feedback and it eliminates the requirement for costly or time-consuming installation processes. The available evidence on smart meters shows that immediate feedback allows homeowners to more closely link consumption decisions with their associated financial and environmental impacts.

Providing feedback on smart meters devices has been shown to reduce electricity consumption by 6-10%, though there is debate on the accuracy and applicability of this figure.[(26)] Higher functionalities for the smart meters will enable more proactive 'nudging' by both regulators and energy suppliers. In 11 European countries the penetration of smart meters level is below 7%, making marginal costs of roll-out very high compared to places like Sweden, Italy, Finland and France, where the penetration level is 20% or above.[(27)] From a regulator's perspective, smart meters

5.3 Regulated Time-of-use tariffs

Time-of-use tariffs are regulated energy prices which nudge consumers to shift consumption at different periods of the day. For instance, in Italy Time-of-use tariffs have gradually been applied to all residential electricity users since the year 2010. The first pilot of Time-of-use ('tariffa bioraria') involved 4 million end users. Lower tariffs are applied to weekends and to weekdays from 7.00 PM to 8.00 AM. The two tariffs, set by the Italian Energy regulator (0.09 cent/kwh and 0.07 cent/kwh for peak and off-peak respectively) are designed to yield savings for end-users whose consumption is concentrated for more than 66% during the lower tariff periods. A preliminary study on the effects of such tariffs shows that that Time-of-use tariffs bring about higher average electricity consumption and lower payments by consumers. A significant level of load shifting takes place for morning peaks. However, issues with evening peaks are not resolved. Also, Time-of-use tariffs lead to increases in electricity demand for substations at peak time.(28) One of the reasons for these findings might relate to what the nudge literature defines as the '*status quo* bias', which in the energy economics literature is better known as the inelasticity of the energy demand curve against time.(29)

5.4 Regulatory financial incentives

Incentives for shifting the timing of energy consumption range from utility-driven dynamic pricing to regulated forms of financial rewards and penalties. In essence, those consumers who proactively engage in shifting their loads and significantly react to price signals are rewarded by paying less for their electricity consumption. Because real-time rewards to consumers tend to fail due to the negligible amounts associated with gains (and losses) for a single consumer, in these financial mechanisms the regulator determines cumulative benchmarks which are matched against responses to price signals.

Existing financial mechanisms implemented by regulators to incentivise peak avoidance programs focus almost exclusively on providers. It is assumed that providers will have to pay for the absence of technological investments in avoiding peaks. The idea behind the regulatory financial schemes in place in the United States, Canada, Australia and India is that losses from capital costs, installations and planning should be recovered under mechanisms such as cost recovery mechanisms, lost revenue mechanisms and shared savings incentive mechanisms based on performance.

Cost recovery mechanisms are designed to eliminate the business incentive to underspend on peak shifting programs. They allow providers to recover the capital and installation costs. The utilities costs for peak shifting are usually ‘expensed,’ approved by regulators and sometimes amortised over several years. Interest is charged on under -or over- recoveries. Because under cost recovery mechanisms the providers costs are amortised over several years, the economic significance of load shifting is lost. In other words, the level of nudging on the consumer side is very limited.

Lost revenue mechanisms pay energy suppliers back for the direct losses that they experience due to decreases in electricity sold. Lost revenues associated with reductions in total amounts of sold electricity are partly offset by a reduction or avoidance of variable costs -e.g. the cost of fuel for power plants. A practical example of lost revenue mechanism can be exemplified through the Lost Revenue Adjustment Mechanism, a means set in place by the energy regulator in Canada. In a given year, the energy supplier calculates the amount of volume or kWh losses due to its own peak shifting programs. This means that all consumers pay for the lack of responsiveness of some. In other words, under this regulatory financial mechanism nudging is not followed up by direct rewards to responsive users.

Shared Savings Incentive Mechanisms are designed to provide rewards to utilities based on the effectiveness of socially beneficial peak shifting. These mechanisms can compensate for energy savings associated with peak shifting by making it possible for the energy supplier to share the consumer net benefits from shifting peaks. This creates a business case for sustainable nudging initiatives that promote energy efficiency on an evolving, adaptive, multi-year basis. A pre-condition of Shared Savings Incentive Mechanisms is that the regulator determines target levels on suppliers. This can represent a forecasting problem under different (e.g. temperature) conditions that might induce peak loads. For instance, a share or percentage of actual net benefits over the target level determined by the regulator can be apportioned to the provider in the form of a positive rate adjustment. In other words, the aim of Shared Savings Incentive Mechanisms is to remunerate a supplier to achieve more than the targets approved by the regulator. However, it is difficult to make such nudging incentives dependent upon objective verification.

5.5 Consumption data sharing

Consumption data sharing is a form of nudging consisting of non-financial incentives to imitate or compete with other consumers. At the community level, consumption data sharing entails bills with comparisons based on historical electricity consumption of other peer groups. Community-level presentations of data are, in principle, more effective than other comparisons because people often resent the household comparison group they are applied to. However, empirical studies show mixed results on the effectiveness of such an approach. Contradictory evidence highlights the fact that people do appreciate normative comparisons, though groups vary widely in what they thought was a good way of presenting this. For instance, the final report by Ofgem of the Energy Demand Research Project in 2011 found that historic and normative comparisons could provide up to 1% reduction in consumption, but that they were highly context dependent and were most effective in conjunction with immediate feedback from smart meters. It has been argued that a zero conservation effect from normative feedback might be attributed to people with lower than average consumption seeing it as a reason to do nothing. Nudging theory relates consumption data sharing to ‘herd mentality’, i.e. the tendency that people have to follow the actions of others.

6. CONCLUSIONS

In his early studies on the methodological fit between technology assessment and policy appraisal, Majone deemed that any analysis of the evidence for policy and regulatory decisions which refrained from entering normative statements required bespoke approaches.[30] It is the case of this study, which is based on an *ad hoc* assessment of the risk of aggregate peak demand in electricity markets as a basis to define which elements of regulatory nudging can be used to address such risk. The paper shows dissimilarities in peak demand risk levels across five different European countries. For instance, the average household in the UK owes much of its baseline risk of electricity peak demand not only to daytime consumption on and off peak, but also to some night consumption. On the contrary, the average Bulgarian, but also Italian, German and Norwegian households present most of the risks of simultaneous electrical appliance usage during the day, and particularly during peak periods.

The political debate on climate change is likely to intensify the pressure on public sector actors to address the risk of peak energy demand not only at the policy but also the regulatory level. Already the European Commission in Directives 2006/32/EC on energy end-user efficiency (Article 13) and 2005/89/EC on measures to safeguard security of electricity supply (Article 5) emphasised the environmental need for policy intervention in the area of peak demand mitigation. However, a coherent framework for regulating the risk of aggregate peak demand is currently missing. Much technological optimism is placed in nudging measures. Ultimately smart meters are seen as the embodiment of nudging. They do not interfere with consumers' decisions, but offer them with the evidence about their energy consumption. In these concluding remarks I consider how key concepts underpinning nudging approaches, such as herd mentality, status quo bias, anchoring and representativeness heuristics [(31)] may relate to the risk of aggregate peak demand in European electricity markets.

Herd mentality is based on the idea that people tend to be influenced by other people's actions. In the energy demand realm, this might translate either into pure imitation of consumption patterns or the need to differentiate oneself on the basis of consumption of others.[(32)] Data sharing programmes might create the preconditions for informing users about the energy consumption of category of other users such as neighbours, relatives, friends via social networks, etc.

Decades of regulated flat tariffs have induced inertial decision-making. This is the main reason why *status quo* bias is dominant among energy users. This means that users would prefer not to switch to new forms of regulated tariffs. The *status quo* bias is often associated with risk aversion towards of new forms of regulated tariffs which do not present the same level of certainty on price as the old tariffs.[(33)] The introduction by energy regulators of time-of-use tariffs and financial incentives is aimed at addressing the *status quo* bias. In the short term this regulatory change is expected to nudge consumers away from flat tariffs. In the medium and long term it may also enable more flexible forms of dynamic pricing, such as real time price and critical peak price.

The regulated flat tariffs which feature in most European liberalised and non-liberalised energy markets do not only trigger *status quo* bias, but also anchoring, which is a cognitive bias based on reliance on only one trait of information. The mandatory disclosure of cumulative energy demand information in bills (normally over two months) does not provide any insight about the timing of consumption throughout the typical day. This means that those users who would like to know what their energy consumption is throughout the day and what price is applied can only rely on cumulative data. In this regard, the real time information concerning price, energy consumption and carbon emissions provided by smart meters is the main nudge for preventing anchoring.

One reason for considering nudging within regulatory practices aimed at addressing the peak of risk demand is that users are not provided with any information about peak demand. The lack of any signals means that representativeness heuristics is a typical approach for making decisions regarding consumption. In the absence of reliable information, such as price labels and peak signals, people are left to guess what causal relations are associated with their energy consumption.

Appendix A: Questions in e-living 24 hour time-use diary

Q1) What were you doing xx/xx/xxxx at yy:yy?

1 RECORD ACTIVITY CODE

1 Sleeping, resting

2 Washing, dressing

3 Eating at home

4 Cooking, food preparation

5 Care of own children or other adults in own home

6 Cleaning house, tidying, clothes washing, ironing, sewing etc

7 Maintenance, odd jobs, DIY, gardening, pet care

8 Travel (to and from work, shops, school, cinema, station etc.)

9 Paid work at work place

10 Paid work at home (not using a computer)

11 Study at home (not using a computer)

12 Courses and education outside home

13 Voluntary work, church, helping people (not in own home)

14 Shopping, appointments (hairdressers/doctors etc)

15 Going to concerts, theatre, cinema, clubs, sporting events

16 Walks, outings etc

17 Eating out, drinking, (pubs, restaurants)

18 Visiting or meeting friends or relatives

19 Sports participation, keeping fit

20 Hobbies, games, musical instruments

21 Watching TV/Cable/Satellite TV

22 Watching videos/laser disks

23 Listening to radio, CD, cassette

24 Reading newspapers, books, magazines

25 Being visited by friends or relatives in own home

26 Receiving telephone calls

27 Making telephone calls

28 Personal Computer - games/games console

29 Personal Computer - email (writing, reading or sending)

30 Personal Computer - browsing the www / Internet

31 Personal Computer - study at home

32 Personal Computer - paid work done at home

33 Personal Computer - Other

34 Doing nothing (may include illness)

35 Other PLEASE WRITE IN

Q2) What time did you finish?

Q3) What did you do next?

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