Are current policies promoting a change in behaviour, conservation and sufficiency? An analysis of existing policies and recommendations for new and effective policies

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Abstract

There is a strong consent that reducing or capping global energy demand is a key component to reach ambitious climate targets together with the de-carbonisation of energy production. The EU 2020 and the 2030 energy efficiency targets are expressed as a maximum consumption level. Given the nature and magnitude of these targets, a change of energy consumer behaviour is required in order to deliver the requested energy reduction. Traditionally many energy efficiency policies have targeted and promoted efficient technologies (e.g. appliances standards or prescriptive insulation levels or building energy performance standards), which do not always guarantee energy savings (e.g. larger appliances, larger new buildings) and/or are not enough to reach the ambitious energy and climate targets. To the contrary some policies may have even incentivised larger energy consumption than necessary (e.g. some appliances standards which are easily met by larger appliances).

Policies are needed to influence consumer behaviour and lifestyle and the concept of sufficiency has to be introduced in future energy efficiency policy design. Policies targeting sufficiency should discourage increased energy use due to a variety of factors such as increased floor space, increased comfort levels beyond what reasonable, increased number and larger appliances/equipment/cars and increased usage of energy consuming equipment.

Policy instruments that may target sufficiency includes: personal carbon trading (i.e. carbon markets with equitable personal allocations); property/car taxation (e.g. related to a building's CO_2 emissions); energy taxation; progressive appliance and cars standards, and building codes, including absolute consumption limits (kWh/person/year) rather than efficiency requirements (kWh/m^2/year).

The present paper reviews the concept of energy saving compared to energy efficiency. It identifies existing energy efficiency policies that may induce higher energy consumption, and finally discusses and analyses "new" energy efficiency policies, which may encourage sufficiency and a behavioural/lifestyle change, with focus on the residential sector. The paper gives recommendations on how to promote behaviour change through innovative policies and packages of policies and how to prevent increased energy consumption.

Introduction

There is a strong consent that reducing or capping global energy demand is a key component to reach ambitious climate and energy targets together with the de-carbonisation of energy production.

Reduction in energy demand, i.e. real energy savings (ES) (i.e. reduction of consumption in a specific building or in city or in a country) can be achieved by improving the energy efficiency (EE) [1] of the services provided (technological aspect) and/or by changing the energy consumption pattern without necessarily making technological improvements (behavioural aspect, for instance avoiding overheating/overcooling or reducing driving). In this article we define the energy saving resulting from behaviour change without changes in technologies as energy conservation (EC). In addition, to the energy conservation concept, recently the concept of sufficiency has been introduced [2, 3, 4]. ES in most cases results in economic savings and other sizeable benefits for end-users. ES resulting from EE and/or EC preserve scarce natural resources, contribute to the security of supply, reduce local pollution, reduces CO_2 emissions, improve the competitiveness of companies, reduce household expenditure, and reduce fuel poverty. Additional non-energy benefits have been well described in recent literature [5] and are an additional point to take into account in proposing EE and EC policies.

Many of the advantages of ES for individuals and organizations are also valid for society as a whole at local, regional, national or global level. ES are a virtual source of energy and in fact very often the cheapest ones, the cleanest and the fast to implement at least for a number of end-uses[1]. This is in accordance with the principle of ES first, i.e. to consider energy saving as the first option to meet energy demand.[2]

From a more technical perspective EE describes how much useful work, activity or service can be generated for each unit of energy consumed (examples: EE in motors, EE of industrial plants, EE of lamps, etc.). EE is an important component to achieve ES, as it allows having the same services and goods with reduced energy consumption. However, improved EE - i.e. replacing an installed technology with a more energy efficient one – does not *per se* assure ES, and there are examples where introducing a more efficient technology may result in an increase of the actual consumption compared to the before situation, due to EE definitions and measurement standards, consumer behaviour or the rebound effect (see discussion below), As very often the definition of EE is based on a single unit of the service produced (e.g. one lumen, one ton of steel, etc.) a common example is the increase in consumption due to replacing old inefficient refrigerator with more efficient (e.g. efficiency based on the EU energy label), though much larger than the previous refrigerator. The new efficient appliances in this specific case will use more energy compared to the old inefficient appliance. In recent years, we have witnessed an increasing diffusion of new "efficient" appliances and higher penetration in household of existing appliances (e.g. TVs, computers, set top boxes, numerous appliances and equipment that are used more frequently [6, 7, 8]

A number of well-studied and researched barriers hinder the uptake of EE improvements and also the adoption of EC (behaviour barriers, e.g. social norms [10, 11, 12, 13]. To overcome these barriers and close the energy efficiency gap, governments around the world have introduced policies and programmes over the last 30 years [14, 15], with many different approaches including: regulatory policies (e.g. labels and standards, building codes, etc.), fiscal instruments (e.g. energy tax), financial incentives (subsidies, low interest loans, etc.), voluntary programmes, market based instruments, information campaigns, voluntary agreements and suppliers' obligations.

However most of these policies are designed to improve the technical efficiency of the equipment or systems and not to encourage direct energy savings. Example of this are incentives to buy a new efficient appliance with no limitation on the size of the appliance or no take back of the old appliance (old refrigerators or old TV may remain in use in the house) or incentives for a more efficient boiler, which by reducing the heating cost may induce the household to have a higher indoor temperature (this is also an example of direct rebound effect).

There are even some policy measures which may encourage larger energy consumption. For example some equipment minimum efficiency standard or energy labels may be more favourable to larger equipment as these tend to be more efficient for technical reasons in the case the efficiency would be defined as energy consumption divided by size or volume (this was the case in the EU for refrigerators where the efficiency was defined as consumption per unit of volume and larger refrigerators with a more favourable surface to volume ratio where having a better energy rating). Also building performance standards or certificates (as introduced in the EU by the EPBD) based on kWh/m^2 do not give the correct information on the total building consumption[3].

The risk for the user is that energy labels or building certificates encourage the purchase of more efficient but larger equipment or buildings.

SHORT DISCUSSION ON THE REBOUND EFFECT

In the presence of the rebound effects it is possible that energy efficiency may trigger more energy use over time, through a combination of direct and indirect effects, as the energy productivity effect of energy efficiency stimulates additional growth and energy consumption (also known as the Jevons paradox). This leads to a clear economic benefit, but also to a clear increase in greenhouse gas emissions.

Economic analysis suggests four categories of possible rebound effects in response to the implementation of an improvement in energy efficiency [17, 18, 19]:

1. *Direct rebound effect:* For the buyer of a more energy-efficient technology, the effective price of the energy service produced with it is now lower and this encourages increased consumption of the service. The likelihood that this effect occurs and is substantial varies with the type of energy service involved. For household purchases of various energy technologies, large direct rebound effects are quite unlikely due to the satiation of demand. Once basic needs and comfort levels are satisfied in relation to such services as refrigeration, carpet cleaning and space heating, a reduction in their prices is unlikely to lead to more consumption of them. In other cases there is greater scope; for example, improvements in fuel technologies may play a role in decisions to buy larger and more powerful automobiles. In industry, substantial direct effects depend on the extent to which technologies allow fuel to be substituted for other inputs in production processes and on the effect of improved energy

1. Many energy saving measures can be implemented at low or no cost: a review of 64 studies assessing the costs of CO_2 mitigation in the domestic buildings and the whole buildings stock worldwide attests that for most countries a large amount of potential can be tapped at negative cost i.e. with a net benefit for the society [9]. From 18 % to 89 % of the CO_2 emissions in the residential buildings of developing countries and economies in transition studied, and from 11 % to 25 % of those in developed countries, can be captured at negative cost [9].

2. In this paper we introduce the concept of "energy saving first" in addition to "energy efficiency first", due to the fact that energy efficiency does not guarantee a reduction in energy consumption.

3. Example is a building with a surface of 100 m^2 and specific consumption of 150 kWh/year resulting in a total annual consumption of 15,000 kWh and a more "efficient" building with a surface of 200 m^2 and specific consumption of 100 kWh/year resulting in a total annual consumption of 20,000 kWh.

productivity on a nation's international competitiveness position – that is, on the potential for reduced energy costs to allow firms to expand their markets without taking business away from other firms. For a given firm, the size of the productivity effect will depend on the proportion of its total production cost accounted for by energy and on the market price elasticities of the goods being produced.

2. *Income effects on other goods:* A household undertaking an efficiency improvement will use less energy and this will free a portion of the income that was being spent on energy[4]; some or all of this freed income will be used to buy other goods and services, the production of which will require energy. Similarly firms will have a source of cash to use to expand their activities or distribute to employees and owners, who will spend some or all of it. However, the original reductions in household and business spending on energy also show up as a reduction in income received by the sellers of energy, meaning that some or all of shareholders, employees and input suppliers of energy companies will now have less income to spend. Thus, for the economy as a whole, one effect can offset the other. While this offset is not likely to be exact, the net effect of the redirection of income and spending flows can be either positive or negative and will in general be very small. Secondary rebound effects of this sort are therefore likely to be negligible.
3. *Energy price feedbacks:* The effects of improvements in energy efficiency can be spread throughout the economy through price effects. The most interesting question in this regard is what happens to the physical quantities of fuels saved as a result of the widespread use of a given improvement in energy efficiency. Fuel and electricity companies will find themselves with excess supplies, which they may try to market by lowering their prices. In the economist's idealised model of a competitive economy, prices would adjust until excess supplies are totally used up – the rebound effect would in that case be total.
4. *Long-run effects on productivity, consumer tastes and economic structure*: In this category are the effects suggested by green-critics when they argue that a focus on changing technology in order to solve environmental problems affects how people live and what they buy. Lower energy consumption can also affect decisions made by entrepreneurs to introduce new products. Thus the long-term effect might be to increase purchases of energy-using goods and services and to be more dependent on them than before energy efficiency was improved. For instance, more fuel-efficient cars presumably make people more willing to live far from their place of work, which could mean that higher energy efficiency would lead to more fuel use in the long term than would occur if people had less fuel-efficient cars and lived closer to their work.

Efforts have been made to estimate direct rebound effects for particular categories of energy services, though the kinds of data needed for thorough empirical studies are not readily available and estimates are therefore rough and vary within wide ranges.

The important result of such studies is that estimated direct rebound effects tend to be small, though at levels significant enough to be taken seriously. For instance, a survey of studies of data from the United States [17] reports estimates for household rebound effects in space heating in the range of 10–30 percent, space cooling 0–50 percent, lighting 5–12 percent, household appliances zero and automotive transport 10–30 percent. More recent studies report very high level of rebound. Freire-Gonzales [20] identifies a for the household sector in the EU "The weighted average of the direct and indirect rebound effect estimated using the GDP of all the EU countries provide a value of 73.62 % (using 30 % of direct rebound effect) and 81.16 % (using 50 %)". Other authors [21] find an indirect rebound of 5–15 % in primary energy and CO_2 emissions. Authors of [22] estimate that the total rebound effects are 41 % for measures that improve the efficiency of domestic gas use, 48 % for electricity use and 78 % for vehicle fuel use. Finally author [23] estimates that "for household energy services in the OECD … the direct rebound effect should generally be less than 30 %". In sum, direct rebound effects appear to be relatively small – a direct rebound effect of, say, 10–20 percent signals a direct reduction in energy consumption of 80–90 percent of what was expected without the rebound effect. However, the possibility that the total rebound effect is much larger depends on the feedbacks that occur through the policy-induced energy price reductions and changing consumer tastes referred to in categories 3 and 4 above, but we are not aware of any estimates of the magnitude of these effects. Nevertheless, it is a historical fact that energy demand in IEA member countries has continued to grow since the 1970s despite oil-shock induced price rises and decades of energy efficiency policies and programs. However the EU primary and final energy consumption have peaked in 2016 and since then they have been declining [24], with a clear contribution by energy efficiency policies, thus confirming in an empirical manner that the rebound effect is smaller than 100 %. More research and more analytical work should be performed to better understand and possibly assess the rebound effect. Output of such work is likely to reorient some energy efficiency policies and confirming the energy efficiency policies shall be complemented by energy conservation and energy sufficiency policies.

Policies to address energy conservation, sufficiency and life style change

As discussed above there is the need to trigger a real and effective change in behaviour in consumers and organisations in order to make sure that real ES are achieved, in order to meet stringent energy savings and carbon targets for 2030 and 2050 (e.g. 1.5 °C maximum temperature increase). To this end, there is the need to introduce additional and effective policies.

INFORMATION AND COMMUNICATION CAMPAIGNS

Information campaigns have been a common type of policies adopted by national and local governments to change end-user behaviour. Since the oil crisis in the 1970s, there have been information campaigns trying to stimulate consumers to reduce energy consumption based on different societal goals such as: security of energy supply (e.g. in the '70ties after the oil embargo to reduce transportation fuel and also heating oil; in more recent years to reduce electricity consumption in Cali-

4. This is the net economic gain after repaying the investment in EE.

fornia, Brazil, etc., in order to avoid black outs). Information campaigns have taken several different forms from general advertisement campaigns (e.g. TV ads) to specific and tailored information provided to specific groups of end-users.

The impact of information campaigns has been well analysed in [25] where there is a complete literature review on the topic. Although some authors report large savings in some specific advertisement campaigns [26], most of the authors agree that the effect of advertisement and persuasion campaign have a short life and the effects tend to decrease over time [27].

More targeted campaigns may have more success, but still the energy saving they generate fade way over time [25]. This is also the conclusion of [26]. This study investigated whether there is an underlying consensus in the research literature, and to identify the most effective approaches. The meta-analysis carried out by [28] analysed the results of 156 information campaign experiments involving 525,479 participants in 59 peer-reviewed studies, dating from 1975 to 2012. Overall, information campaigns were effective, and participants reduced their energy use by an average of 7.4 %. Comparing different strategies, the researchers showed that energy audits and consultation, when individuals are informed about their own energy use and given advice on how to lower their consumption, were the most effective [28]. Under this strategy, consumers reduced their energy use by 13.5 % on average. The next best approach was providing individuals with comparisons with their peers' energy use; this reduced consumption by 11.5 %. Surprisingly, strategies that provided information on money savings or provided monetary incentives (e.g. payments for reduced energy usage) actually resulted, on average, in an increase in energy usage by the participants. The researchers suggest that this may be because, if other altruistic reasons (such as environmental concerns) are not considered, many participants may find the potential savings or remunerations too small, and not a big enough reason to conserve energy.

The researchers also noted that rates of energy usage slowly increased under longer studies. This is worrying as it suggests that information campaigns may not have a sustained effect, and the researchers call for further research into the possibilities of repeated bursts of campaigning.

The authors of this study concluded that "non-monetary, information-based strategies can be effective at reducing overall energy usage in controlled experimental studies. This is an important finding, because it suggests that information and education programs targeting conservation through behavioural change should be considered alongside with efforts to reduce energy consumption through technological improvements." [28]. In order to reduce the cost of providing energy-use information, the researchers suggest that newly developed 'smart meters' could be used, which might also help improve the reliability of the information provided.

The behaviour model developed by Ajzen and Fishbein [29, 30] for the understanding of the individual behaviour, such as energy-related conduct and decisions, assumes there is a direct and rational relationship between behaviour and intentions, and it places attitude in front of intentions, as a background for it. Intentions are derived from beliefs that develop according to background factors. As a general rule, the more favourable the attitude and subjective norm, and the greater the perceived control, the stronger should be the person's intention to perform the behaviour in question. While rationality is a characteristic of the intention-behaviour step, the preceding steps may be flawed, biased or even irrational.

A second model introduced by Egmond [31], similar to that of Ajzen and Fishbein, is focused on the determinants. The model is based on the PRECEDE-PROCEED model of Green and Kreuter [32], which also places the intentions as the central input for human behaviour, but on planning interventions to change individual behaviour. Intention to save energy was found to be formed by "predisposing factors".

Literature distinguishes three classic approaches:

- the price-based approach: save money
- the environmental approach: save the planet
- the social approach: be a good citizen.

The *price-based approach* to energy conservation alone is not successful in engaging and promoting a real change in the energy consumer's behaviour.

Even if the money could be a good motivation, it will be more efficient to appeal to people's intrinsic motivation. This because the short term motivation economic incentives may implies no savings in the long term, i.e. consumers will stop as soon as the behaviour is no longer attractive or cost effective [33].

To overcome the problems faced by the price–based the *environmental approach was introduced.* This relies on raising awareness on climate change and making people take personal environmental action seriously. The message used to be negative and extremely pessimistic [33] finally people regard climate change as a non-urgent and psychologically distant risk. Information about climate change risks needed to be translated into relatable personal experiences

Based on the fact that human behaviour and decision making are the very core of the climate change problem and *the social approach*, trying to integrate the social norms (refer to the perception of what is commonly done in a situation) has been proposed as the basis of the measures for information and awareness. Appealing to the fact that people are social beings and respond to group norms (e.g. the knowledge of the energy consumption of our neighbour influences ours). Social norms do have a huge power to influence pro-environmental behaviour [34, 35]. They not only spur, but also guide action in direct and meaningful ways.

The social norms approach is integrating the social norms (refer to the perception of what is commonly done in a situation) as the basis of the measures for information and awareness on energy behaviour [36, 37]. In fact people are social beings and respond to group norms (i.e. the knowledge of the energy consumption of our neighbour influences ours).Social norms do have a huge power to influence pro-environmental behaviour. They not only spur, but also guide action in direct and meaningful ways.

In addition, from the analysed literature researchers and practitioners have recommended that people need to be inspired, to be engaged, to have fun when receiving the message (how people feel about a given situation often has a potent influence on their decisions [38]). The message needs to be carefully selected and kept as simple as possible, key words: entertain, engage, embed and educate! [39]. Once the basic awareness is

Table 1. Types of Feedback.

Type of Feedback	Sub-type of Feedback	Medium	Type of information	Communication
Indirect feedback	Standard Billing	– Paper	– Historical Energy consumption – Historical comparison	One way communication
	Enhanced Billing	– Paper – Electronic environment (e-bill)	– Energy consumption, rewards – Energy Efficiency Advice – Social comparison – Historical comparison	One way communication
Direct Feedback	Direct feedback with IHD	– In-House Display – Web environment	– Real-time information – Social comparison – Historical comparison	One way communication
	Direct with Connected Devices	– In-House Display – Web environment – Smart Meter	– Real-time information – Appliance disaggregation – Social comparison – Historical comparison	Two-way communication

there, the second step would be to provide targeted information on potential energy efficiency measures. It is essential to understand and study the audience targeted.

ENERGY CONSUMPTION FEEDBACK

Among the actions to improve energy efficiency and induce energy savings in recent years through the understanding of the importance of consumer behaviour (from individual psychological and social norm points of view) researchers, utilities and policy makers have focused their attention on energy feedback. The use of this mechanism has also been enhanced by the diffusion of smart meters and the internet.

Energy Feedback is a way to turn a resource, energy, that until recently was more or less invisible to energy consumers into a visible one, creating the possibility of shifting energy consumers from a passive state into an active one. This change of paradigm makes it possible to achieve energy savings thanks to the actions stimulated from the collected and processed energy consumption information and the consequent action from the consumer, when the consumer is properly engaged and has some degree of freedom on choices in relation to energy consumption (both electricity and gas: from switching off equipment, to changing set points, to investing in efficiency).

There are two types of Feedback: Indirect and Direct. Under these two broad categories of feedback it is possible to identify some sub-categories, allowing different types of interaction and response from the energy providers and energy users. Table 1 proposes a classification of feedback systems.

Indirect Feedback Systems are the most common systems accessible for energy consumers, consisting in energy feedback provided after the consumption. Indirect Feedback may be divided into two different sub-categories.

Standard billing: common energy bills belong to the first sub-category of Indirect Feedback and are usually provided by the energy retail supplier or distributor. This type of feedback is usually only describing the amount of energy consumed for a determined period of time through a paper bill or in an electronic format providing little additional information. The frequency of billing as well as whether the bill is based on real consumption (meter reading) or assumed consumption (calculated on the basis of historical consumption)[5] are important elements in relation to consumer engagement. For example by paying the same amount throughout the year irrespective of real consumption may discourage energy savings.

Standard billing is the least effective type of feedback and does not motivate consumers to reduce energy consumption or invest in energy efficiency. The type of information in a typical energy bill does not go much further than the presentation of the cost (e.g. energy, distribution, power), type of tariff and in some jurisdiction a comparison with a similar period of time. This type of feedback, besides informing the final consumer to pay the bill, does not present a call for action in any way. It is only informational and non-engaging. In some countries, the lack of clarity in the bill is noticeable, leading to confusion and lack of interest.

Enhanced billing: the second sub-category of Indirect Feedback relates to both the utility bills with additional info (e.g. comparison with energy consumption in the previous year/month) and a third-party-provided indirect feedback of utility (metered) data. Still depending on measured energy consumption, this type of feedback is sometimes provided by an independent company that analyses the information collected by the utility and provides feedback providing historical and/or social comparison and context

The second type of indirect feedback category may be associated with the energy bill or not, and is provided through mailings and/or through the web. The type of information in these advanced indirect feedback systems is more elaborate than common bills, with some third-party companies using a variety of data sources besides utility data, like assessor parcel maps, home audits or census or weather data. Statistical data is commonly used by third-party companies that develop algo-

5. Traditionally in Europe meter reading was done once or twice a year and intermediate billing was based on estimated consumption based on previous year consumption and adjusted in the bill following the meter reading. With the introduction of smart meters all bills are based on metered consumption. Billing in Europe is usually bi-monthly.

rithms to analyse existing data and user input to provide a more personalized experience for the user. The amount and quality of information is then much richer with household information and advice, web-based energy audits and billing analysis being given. Behavioural principles are also being used in order to engage energy consumers. Tools using gamification principles like social norms and comparisons, goal setting, personal comparison and call-to-action measures are commonly used in these types of feedback systems.

This type of enhanced billing has been being developed in recent years with success, based on social science analysis and data processing. Combined with user-centric design these tools are then used by the utilities to communicate more effectively with their customers, for customer retention and/or as part of energy efficiency programmes.

Descriptive and injunctive norms are used to motivate and reinforce positive behaviour change as the customer can see where he/she stands in comparison with their neighbours and receive immediate gratification (e.g. in the form of an emoticon ☺). The same applies for goal setting where the customer is pursuing a specific goal and more likely to act accordingly.

Besides the common moment to communicate with the customer, energy companies may choose other key opportunities for engagement throughout the year. Some of these moments rely on smart meter availability, while others can utilize traditional meter technologies. For example, a communication might be sent to the consumer in order to adapt their household for the arrival of a new season, often with advice on technologies to implement or simple behavioural changes to be incorporated in the daily life. Other type of moments can be when a high bill is expected to come, on a peak day, on a possible rate change or in the case of extreme weather or outage.

Direct feedback can be divided into the following sub-categories.

Direct Feedback using a web connected devices, where the user can log-in from a computer, tablet or smart phone, or can run an app to have real time information on energy consumption, appliances, on historical consumption, as well as emergency messages and prompt.

Direct Feedback using In-Home Displays (IHD) where a device is installed in the home environment allowing the energy user an access of real-time information on the energy use, allowing energy users to learn about the consumptions of different appliances by turning on and off the home devices, receiving immediate appliance-specific feedback. These devices can give information on the energy use in terms of cost and can be also associated to a web environment providing additional information allowing for alarm setting and goal tracking, if the user wishes.

Analysis of Meta-data studies on Feedback

In order to quantify the effect of feedback on energy consumption, a large number of studies have been carried out in the past 40 years. In this article we refer to the experiences already summarized in recent literature review papers, and in particular to those of E. Zvingilaite and M. Togeby [40], and B. Karlin, J. F. Zinger, and R. Ford [41]. These reviews analysed past empirical studies on consumption feedback through qualitative methods of literature review, in which a set of empirical experiences on a specific topic are collected, classified, and summarized. Doing this task, these authors applied some inclusion criteria to ensure that the studies included in their analysis pass at least a minimum standard of quality (e.g. by excluding studies that did not have a control group as well as those with clear confounding variables).

In this way a final dataset of 118 feedback applications was collected by the papers authors, covering: 3 consumption types (electricity only, electricity and heating, heating only); 16 different countries (mainly in North America and North Europe); 2 feedback types (direct and indirect); 6 media types (bill, card, In-House-Display (IHD), mail, PC or web, mixed mode); a large range of sample sizes (from about 10 to almost 100,000 households); and different duration periods (from 2 weeks to 3 years).

The reviewed literature finds that feedback can reduce the households' energy consumption up to realistic 5 % to 10 % and that it works best when it is:

- tailored to the end-user;
- presented clearly and engagingly;
- accompanied by advice for reducing energy consumptions;
- delivered regularly and with high frequency;
- made through enhanced billing versus standard billing;
- in the presence of In Home Devices, Web Based, interactive and digital (there is a research question on the effectiveness of IHD versus a web-based display (PC, tablet or smart phone));
- capable of providing information by appliance (even if cases are still rare);
- associated with a well-defined and challenging goal (social norms);
- direct feedback, especially when it comes to electricity consumption.

However, there are relevant uncertainties from the literature and significant gaps still remain in our knowledge of the effectiveness and cost benefit of feedback. In particular:

- the effect of feedback on consumers in different social and demographic groups;
- the effect of feedback on appliance purchasing decisions;
- whether feedback continues to work over time or whether it needs to be renewed/reshaped to keep householders engaged and maintain any conservation effects;
- the ability for feedback to facilitate the sharing of energy information between households, friends or neighbours is almost entirely unexplored.

It is important that the engagement of the final energy consumers is constant in order to minimize the novelty aspect of a new way of energy feedback fading away after some time. Two-way communication from the energy provider and final energy consumers is recommended. Gamification and social norms tools such as the comparison with similar energy consumers or the sense of gratification when the consumer's energy performance improves and is communicated towards the final consumer may offer a good solution for the continuous engagement of consumers.

The frequency of the feedback moments is another crucial point in terms of the continuous engagement of final energy consumers. While too many feedback moments may become a nuisance for the final energy consumers, a balance between too many and too few feedback moments should be studied and considered.

Considering evidence from the evaluated studies that a higher frequency of feedback leads to greater energy savings, it may be considered that the consumption readings (at least once a year) and the billing info (twice a year) currently mandated in the EU provisions should be increased for enhancing energy savings.

The smart meter roll-out in Europe is now progressing in most countries. The potential of enhanced feedback associated with smart meters, suggests that even more attention should be given to the implementation of smart meters across Europe. The results of this meta-study analysis are a clear proof of this, with the direct feedback through IHDs presenting the greatest savings.

ENERGY AND CARBON TAXES

There exists an extensive literature on the impact of price signals on energy consumption, even if not all customers will respond to a price increase (it depends on the price elasticity of the demand for energy). Energy taxation is a well-known energy efficiency and fiscal policy, often introduced more to raise revenue rather than discourage consumption. Although Prospect theory formulated by Levy [42] indicates that consumers tend to overweight losses compared to gains and therefore tend to engage in risk-averse behaviour with respect to gains (i.e. very high discount rates for energy efficiency investments) and risk-acceptance behaviour with respect to losses (i.e. reducing consumption if price increases, this is not entirely true for the electricity demand due to the short-term inelasticity [6]of the energy demand [43]. In order to discourage energy consumption, the taxation level should be rather high [7]in order to trigger behavioural changes or investment in efficiency[8].

The price of energy should at least reflect the known environmental externalities. Energy or carbon taxation could be a very powerful policy instrument used in a number of countries around the world, which is also effective in limiting the rebound effect (the tax would penalise additional consumption triggered by the rebound) [44]. It is quite complex to define an optimum level of taxation (also taking into account the variation of energy prices) to achieve the desired level of consumption reduction or CO_2 emission reduction [45, 46]. High energy prices tend to reduce the energy consumption particularly in less affluent households, and thus particular care is needed in order to avoid unintended effects such as fuel poverty. A carbon tax could be more interesting as it could have a double positive results to reduce carbon emissions and to foster the adoption of renewable and energy efficiency energy technologies. Finally, a carbon tax could have an additional benefit to raise revenue. The amount collected could easily be recycled by government back to the economy in investment in energy efficiency policies and clean energy technologies. Hence the introduction of such tax can be neutral or even positive to the economy. It is important in the recycling of the carbon tax revenue in the economy takes care to avoid the rebound effect. In the long term a carbon/energy tax could gradually replace the tax on labour, e.g. double divided [47] , reducing the labour cost (e.g. the example of the German Eco-tax), thus helping creating additional jobs in the economy.

An energy or carbon tax could be a valid alternative to quota systems, such as cap and trade (e.g. the EU emissions trading system).

Tax could also be used to penalise bad behaviour and favour good behaviour. Taxes are already used in some jurisdictions to promote energy efficiency in cars by having the annual road tax (or a specific purchase tax) for each vehicle based on the CO_2 emissions. In addition, vehicle with very low emission could be incentivised, by lowering the car purchase tax and at the same penalise vehicles with high emissions: this measure would promote the efficiency of the vehicle. A carbon tax on the fuel as described above or a road tax based on the kilometres driven would contribute to energy savings (especially in the case valid alternative would be available (public transport, cycling, etc.).

Similarly the building/property tax (at the time of purchase and the annual property tax) could be based partly or totally on the CO_2 emissions of the buildings (estimated as in the Energy Certificate) or based on real emissions due to energy consumption (metered data).

PERSONAL CARBON ALLOWANCES

Personal Carbon Allowances have been proposed and investigated by several authors (Ayres,, Fleming,, Hillman, Starkey and Anderson, Burgess, Fawcett [48, 49, 50, 51, 52, 53, 54, 55, 56, 57]. This policy was also analysed in details by the UK government, but then discharged as a new policy instruments, due to its complexity and other possible drawbacks [58]. In common with other Market Based Instruments it is based on a cap set by a governments, the cap is then apportioned to all the participants, in this case physical persons, which have to meet their annual target.

In practice, the government sets the amount of emissions that a person can emit based on his/her energy consumption (house, transport fuel, air-travel, etc. – in principle could also include the food purchased and/or the carbon content of goods purchased). The scheme will allocate (free allocation, but allowances could also be auctioned) to each person (or household) her/his carbon budget for the year. Each time there is an energy expenditure (e.g. gas bill or fuel for the car at the petrol station) the amount of CO2 emission linked to that purchase will be deducted from the annual budget of carbon allowances. In order to make the system more flexible, the system administrator could have some reserve allowances that could be purchased should any person need more, or allow trade of allowances between people (persons saving energy could have a surplus

6. In the long term it is easier to find alternatives.

7. A low enegy tax (as low as 0.5 cts/kWh could be introduced to raise money for an energy efficiency funds, but not to change consumer behaviour.

8. In Italy over the first five months of 2012 following an average increase of the price of motor fuels of 20 %, the consumption of road transport fuels (petrol and diesel) has decreased by 10.3 %. This result is thought to be due to the combination of the strong economic recession and the fuel price increase. However, motor fuels for transport have a different price elasticity than electricity, among other due to the fact that alternatives are available.

Table 2. Example of progressive minimum efficiency standard for a residential building.

Size in m²	Energy Efficiency index in kWh/m² year
0–50	80
50–100	65
100–200	55
Above 200	45

of allowances and would be able to sell them in the market, while people needing more energy than the ones allocated would need to buy additional allowances). As with the carbon tax, personal allowances will avoid or minimise the rebound effect and will add a carbon price to every energy purchase. In a similar manner, personal carbon allowances will also foster renewable energies (energy consumption without carbon!) both in the grid and in buildings (e.g. solar thermal). In addition, the personal carbon allowances would make the carbon price more explicit to consumers, allowing them to know from the market value the value of each allowance (e.g. 1 kg of CO2). Governments could announce long term plans to reduce each year the allocated allowances in order to meet challenging carbon targets (e.g. -80 % by 2050). Although the accounting technology for the personal carbon allowances is available (via smart cards, smart phones, internet, etc.) the system could be quite challenging in its set up and information and training of end-users. Although in principle personal carbon allowances are very different from a carbon tax (setting of the quantity of emission reduction and by leaving the price to the market vs. fixing the price and leaving the quantity to the market), if the people will not be well informed and engaged, it could appear to consumers as a carbon tax. As already discussed this policy instrument will shift the responsibility to the individual, with some categories having limited ability to change their carbon budget. In addition, in common with many other environmental policies the distributional effects have to be assessed carefully as this policy instrument may favour well off people able to purchase additional carbon allowances or install technologies that reduce their carbon emissions. A simpler scheme could be based on personal energy allowances (e.g. kWh/person/year), which will not promote renewable energy generation as a personal carbon allowance.

BUILDING CARBON ALLOWANCES

The scheme above described for the Personal Carbon Allowances could also be applied to both residential and non-residential buildings. It could be formulated in CO_2 or kWh per building per year (absolute values). The advantages would be a much less sophisticated systems as buildings have usually less energy sources (e.g. gas and electricity), which are regularly metered. Therefore the scheme could allocate the emission allowances to each individual building (with a gradual reduction over the years), and thus stimulate investments in EE and renewable energies and ES resulting by behaviour actions (e.g. lowering thermostat temperature) by buildings occupant or landlords (the allowance could be split between landlord and tenant to take into account the split incentive barrier[9]). This scheme would only address the building emissions, while personal carbon allowances could in principle address also other sectors. For the commercial sector buildings, some policies similar to this already exist, for example the UK CRC or the Tokyo Metropolitan Carbon and Trade Scheme [59], even though the UK scheme is working more as an energy tax. There could be a strong synergy between the innovative policies described in this article such as property tax based on carbon emissions, building carbon allowances and feedback systems, all based on the metered energy consumption. Another possibility is to have a bonus/malus system with the baseline set as example (valid in the EU) on the building Energy Performance Certificate.

PROGRESSIVE MINIMUM EFFICIENCY STANDARDS AND BUILDING CODES

Minimum efficiency standards for equipment and building codes (or building energy performance standards) have proved to be very effective policy instruments and have been adopted by a large number of countries. However both these two policy instruments only set efficiency requirements, but allow consumption to increase with size, as already explained in the introduction. Both these two policy instruments could be made progressive, i.e. the larger the appliance or the building the higher must be the efficiency to compensate for the size. For example for a residential building (single family household) the prescription could be as in Table 2[10]:

It could also introduce a maximum consumption limit for buildings above a certain size, (e.g. in the above example for buildings above 200 m² the maximum allowed energy consumption would be 13,450 kWh year). This policy will be progressive and most probably also socially acceptable and equitable as richer people tend to have larger homes and for them investments in improving energy efficiency and introducing renewable could be more easily implemented. Similar examples could be created for appliances such as TVs, refrigerators. Again this policy could be combined with property taxation based on CO_2 emissions, incentives for low consuming buildings and other policy instruments.

ENERGY SAVINGS FEED-IN TARIFF

Rather than trying to 'discourage' consumption (and inefficiency) with an additional energy tax and get through the complexities of trying to define an optimum level of taxation, public money (or money raised through a small wire charge – see footnote 7) can be used to reward and give incentives to energy saved, as a result of technology implementation, and/or as a result of energy conservation (resulting also from behaviour change) [60, 61, 62]. This can be seen as a core feature of a possible Energy Savings Feed-in Tariff (ES FIT). Unlike investment grants, which are rewarding consumers based on the size of their investment, a FIT rewards end-users based on the operational performance of their investment or behaviour change in terms of ES[11].

9. For example tenants may be only responsible for electricity due to appliances (assuming the tenant is selecting and owning the appliances, while landlord being responsible for heating).

10. This example is valid for a specific climatic zone. It also creates a jump at the end of each class, a curve (not linear) could also be introduced.

11. Normalizing energy savings to account for autonomous savings, which occurred without any action on the side of the consumer (e.g. reduced occupancy levels of times).

With an ES FIT – as in some demand response programs – the consumers could benefit from an additional financial incentive on top of the monetary savings that come from reduced energy bills. The justification for such additional incentive in the case of an ES FIT is similar to this in demand response programs, whereby power saving on the part of private entities is acknowledged to bring additional public (societal) economic benefits of reduced peak power – such as improved reliability of the electricity network, postponement of the grid reinforcement, avoidance of black outs, avoidance of investments in reserve power – and this is a valid reason for providing additional incentives, which are also economically justified.

This is why an ES FIT for ES can be seen as a performance-based subsidy, whereby actions undertaken by end-users – both in terms of investment in EE technology and in terms of behavioural action and energy conservation – is awarded based on the savings achieved, possibly differentiated by type of action or by end-use sector. In terms of design, the ES FIT could be either based on the actual number of saved kWh of electricity or m^3 of gas (referred hereinafter as quantity-based FIT, e.g. based on the actual quantity of savings) or based on a fixed threshold achieved (target-based FIT).

In the case of quantity-based FIT the subsidy can be awarded based on saved amount of energy compared to a predefined and agreed energy consumption (ex-post and based on meter reading) with or without adjustment for climatic and other 'external' conditions (see later).

In case of a target-based FIT, the FIT subsidy can be awarded contingent upon the reduction of the amount of consumed energy by a certain amount (target) or on reaching a certain threshold. It is based on the energy consumption as indicated on the energy bill with possible normalization for exogenous factors such as occupancy levels. A target-based FIT uses data that is compiled and regularly communicated to the end user via the bill. Billing on the basis of actual consumption shall be performed frequently enough to enable customers to regulate their own energy consumption.

Conclusions

More than ever, the challenge of mitigating climate change demands that we revisit the energy consumption paradigms and the role of energy efficiency technologies and policies in our economies. Drastic changes in consumption patterns will be necessary to achieve ambitious, long-term CO_2 emission reductions necessary to stabilise atmospheric concentrations at 1.5 °C as agreed at COP21 in Paris. In addition to energy efficiency, the countries, organisations and citizens from now on should achieve absolute reductions in energy demand. The strategy to adopt is to complement policies focused only on energy efficiency privileging mainly technological innovation, new services and new ways of doing business, with policies taking into account the on consumer and organisation behaviour and solutions that motivate or enable citizens and organisations to reduce consumption. As described in this paper, there some existing and "new' policy instruments such as: strengthening the price signal through energy or carbon taxation; personal or building (or organisations) carbon or energy allowances; energy saving feed-in tariff; progressive building codes and appliance standards; and enhance information and feedback to end-user appealing to social norms and nudging.

In principle there is no silver bullet policy which will deliver the carbon emission reduction goals, but a combination or package of policies combining two or more of the above indicated policies.

Although awareness of energy consumption has been increasing throughout the years, proactive actions towards final energy consumers' awareness of their energy consumptions and actions on how to improve their energy efficiency and/or energy saving behaviour present themselves as a potential effective way to reduce energy consumption.

Our modern societies need an "energy conservation revolution" to respond to the important challenges such as mitigation of climate change and temperature stabilisation within a certain limit. However, only modest steps have been taken so far in this direction. Further research and policy testing is needed starting from increasing research consumer and organisation behaviour and design, ex-ante and ex-post assessment and testing new policy options (some described in this articles) and combinations (or packages) of policies if we want to do meet the challenging targets in front of us. If developed nations do not do it now, how can we even think that developing nations will not duplicate the mistake we made in our past and that still constitute a burden for our economies?

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