Energy Efficiency Policies and the Rebound Effect

Review of International Instruments and Recommendations for Austria

LITERATURE REVIEW

Authors: Shruti Athavale

Karina Knaus

Project: CATCH

KR14AC7K11808

Date: Vienna, April 2017

IMPRINT

Published and produced by: Österreichische Energieagentur – Austrian Energy Agency

Mariahilfer Straße 136, A-1150 Vienna, Phone +43 (1) 586 15 24, Fax +43 (1) 586 15 24 - 340

E-Mail: office@energyagency.at, Internet: http://www.energyagency.at

Editor in Chief: Peter Traupmann | Reviewing: Herbert Lechner | Layout: Margaretha Bannert

Produced and published in Vienna

This research received financial support from the Austrian Climate and Energy Fund and was carried out within the ACRP program.

Abstract

The paper reviews a number of policy instruments related to the improvement of energy efficiency, such as fiscal, awareness-raising and regulatory measures. We conclude that based on the reviewed literature rebound may play an important role in designing policies aimed at increasing energy efficiency, although estimates vary widely between 1 and 60 per cent. Looking at various sectors, namely transport, consumer goods and buildings & heating, we therefore conclude that rebound effects do play a potential role in all energy efficiency polices. However, numerous rebound mitigation and accompanying measures exist that can address at least some of the adverse effects created by direct, indirect and economy-wide rebound. In particular, we find that the interaction between fiscal and other measures such as labels & standards or awareness raising campaigns can provide a useful avenue towards the optimal policy mix.

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1 Introduction

In recent years, the rebound effect of energy saving policies has entered the foreground of academic discussions and policymakers have expressed concern that the rebound effect may significantly reduce the impacts of energy efficiency (EE) programmes. If rebound effects are very high, strategies designed to increase energy-efficient behaviour cannot contribute to sustainable development, but may be part of the problem rather than the solution. However, strong rebound effects can be countered by targeted policy measures, a fact that will be looked at more closely in the remainder of this paper.

Energy efficiency-related "rebound effects" refers to the predilection of consumers to increase their use of energy services in response to the EE measures that had initially reduced their energy costs (de la Rue du Can, et al., 2015). Rebound effects can be sub-divided into direct rebound effects (i.e. the increase in consumption of the targeted energy service due to lower cost) and indirect rebound effects (i.e. increased consumption of non-targeted energy services due to a rise in disposable income) (de la Rue du Can, et al., 2015). In addition, economy-wide rebound effects may apply.

Throughout the paper, we aim to follow the definitions below (Barker, et al., 2009):

- **Direct Rebound Effect:** Energy efficiency measures may decrease the effective price of a good or service, thus increasing its consumption;
- **Indirect Rebound Effect:** Lower effective prices imply a relative increase in income leading to higher consumption of other goods and services;
- **Economy-wide Rebound Effect:** Energy efficiency measures may decrease the price of intermediate and final goods and services throughout the economy increasing the competitiveness of all energy-intensive sectors.

Microeconomic direct and indirect rebound effects can further be subdivided into income and substitution effects (Borenstein, 2013). In a basic theoretic model of an energy efficiency upgrade, it can be shown that unless the cost of the upgrade is equal to the cost of energy saved, income will be higher and purchases across the consumption bundle will rise, increasing energy use. However, Borenstein (2013) also points out that cross-price elasticities do matter, in the sense that it should not be assumed that the substitution-driven change will always be from goods with no energy content to the newly efficient good. As an example, we could think of a two-car household, which may change the relative amount of travel for each car, if only one of the cars is replaced by a more efficient model, counteracting some of the other rebound effects. Generally speaking, the more elastic the demands for energy or energy service, the higher the rebound effects from energy efficiency programs.

To assess the effectiveness of different policies and how the rebound effect is addressed, we select a variety of policy instruments covering the three broad categories: (a) fiscal policies, (b) awareness raising, and (c) regulatory measures. Table 1 below provides an overview of the measures reviewed in this paper. The selection of measures was based on the premise that they should reflect a broad set of policies across different sectors and secondly, that sufficient (empirical) evidence on the effect of the selected instrument was available.

Table 1: Overview of Reviewed Policy Measures

CATEGORY	MEASURE	SECTOR	TARGETED STAKE-HOLDERS	EXAMPLES
Fiscal	Carbon taxes	Fossil Fuels	Mostly households as exemptions for industry are common	FI, NL, SE, DK, CH, JP, FR
Fiscal	Green car ownership taxes	Transport	Vehicle owners	DK, LU
Fiscal	Congestion taxes	Transport	Urban drivers	SE - Stock-holm, UK - London
Fiscal	Subsidies, grants or tax credits	Building	Renovators	EU
Awareness	Information platform for ener-gy-efficient products (incl. light-ing)	Consumer Goods	Final consumers	EU, US, CN
Awareness	Campaigns for highly-efficient appliances (incl. lighting)	Consumer Goods	Final consumers	EU, TH
Awareness	Smart Meters & Energy Moni-tors	Building	Mostly households	EU (SE, FI)
Awareness	Green Public Procurement & Energy-Efficient Procurement	Building	Final consumers	US, MT
Awareness	Green Public Procurement & Energy-Efficient Procurement	Consumer Goods	Mostly households	EU (SE, UK, AT – Vienna), MX – Mexico City
Regulatory	Labels and standards for highly-efficient appliances	Consumer Goods	Mostly households	US
Regulatory	Labels, standards and codes for efficient buildings	Building	Final consumers	EU (NL, GR, UK), CN, US
Regulatory	Labels and standards for vehi-cles	Transport	Vehicle owners	EU (UK)

The remainder of the paper is structured as follows: Chapter 2 reviews the literature on international policy instruments for energy efficiency and their effect on energy consumption, emissions and re-bound. Starting with fiscal measures, other types of measures such as awareness raising and regula-tory policies are analysed in turn. Based on the literature review, Chapter 3 derives implications for policy design and recommendations for Austria. We conclude by offering a summary of reviewed instruments and their interaction as well as potential rebound mitigation measures.

2 Review of International Policy Instruments

In this section, fiscal, capacity building & awareness, and regulatory measures will be reviewed with a special focus on methods to counter rebound effects. Good practices, where relevant, from a broad palette of countries will be drawn on to highlight similarities and to compare differences in policy approach. The first part of this section looks at fiscal measures such as taxes, grants and subsidies. This is followed by a review of capacity building and awareness raising instruments such as smart meters, awareness raising apps and green public procurement. Finally we focus on regulatory instruments with a particular emphasis on the buildings and transport sector.

2.1 Fiscal Measures

Economic and financial incentives can be among the most powerful tools to induce economic agents, to perform or to cease a certain action. Within the context of energy efficiency, the aim is to steer consumers towards purchasing more energy-efficient goods, induce them to consider energy efficiency when making longer-term investment decisions, or to adapt their behaviour in terms of using existing resources or products more efficiently. Since the first two options directly relate to consumer expenditure, financial and economic incentives can play a central role in guiding those decisions towards more energy-efficient products or assets.

When thinking about economic incentives such as taxes or subsidies, it is crucial to consider the role of the rebound, both in terms of direct and indirect effects. This relates in particular to subsidies, grants or any fiscal policy that will change prices and/or income. Assessing the impact of fiscal measures empirically poses significant challenges. Below, only instances where sufficient data or sound models can demonstrate tangible (positive or negative) effects will be discussed. To facilitate the discussion of available economic instruments, we group them into the following two subcategories: (1) taxes, and (2) subsidies and grants.

2.1.1 Taxes

2.1.1.1 Carbon Taxes

If the policy goal is the reduction of carbon dioxide emissions, then possibly the most obvious economic instrument to induce energy-efficient consumption patterns is to directly impose a tax on carbon itself. Typically, such a tax is levied on fossil fuels according to their carbon content. The effects of imposing such a tax can be manifold. Firstly, carbon taxes can lead to substitution effects and income effects, the former implies that with fossil fuels comparatively more expensive switches to other means of production or consumption will become more profitable. Income effects, on the other hand, may lead to increases in energy efficiency by reducing or shifting consumption patterns.

Secondly, if revenues of carbon taxes are used to promote or subsidise other carbon-saving policies, then spill-over effects can also be achieved (Lin & Li, 2011).

On the other hand, the effect of carbon taxes will be limited in cases where price elasticities are low and taxation leads primarily to an increase of fiscal revenue. Other concerns with regard to carbon taxes include carbon leakage and decreases in competitiveness. Some evidence on the latter is provided by Miltner & Salmons (2007), who empirically assess the effect on environmental tax reform on competitiveness in seven EU countries and across industries. They find that there was no significant or widespread negative impact of carbon and energy tax reform and that in two instances competitiveness even increased slightly.

However, concerns with regard to economic effects have certainly meant that many countries have long been hesitant to implement a full scale carbon tax system. Early adopters of carbon taxes were Denmark, Finland, Sweden, Netherlands and Norway; however, recently other countries like France or Japan have implemented this reform. An overview of tax levels and coverage is provided in Table 2. Carbon taxes are typically levied on fossil fuels. However, some type of fuels may be exempt. Denmark, for example, does not levy a carbon tax on biomass fuels, whereas Switzerland's tax does not cover motor fuels. Table 2 also shows that the tax level in terms of Euro per tonne CO_2 (EUR/t) varies widely across countries. In part, this can be explained in terms of the widely different tax systems in the countries concerned, so that the absolute value of a carbon tax should only cautiously be viewed in isolation.

Table 2: Overview of Selected Carbon Tax Approaches

COUNTRY	YEAR OF ADOPTION	CARBON TAX LEVEL[1]	COVERAGE
Finland	1990	50 EUR/t for transport fuels in 2011 30 EUR/t for heating fuels in 2011	Gasoline, diesel, light fuel and heavy fuel, heavy fuel oil, jet fuel, aviation gasoline, coal and natural gas. Combination of energy content and carbon dioxide tax.
Netherlands	1990	1.38 EUR/MWh natural gas in 1996 18.2 EUR/MWh natural gas in 2015 0 EUR/MWh electricity in 1996 119.60 EUR/MWh electricity in 2015	Initially specific fuel sectors exempted, later energy-intensive industries also exempted. Later turned into energy tax of electricity, natural gas, gas oil, semi-fluid oil, liquefied petroleum gas. Fixed refund for each electricity connection amounting to 377.33 EUR/year.
Sweden	1991	29 EUR/t in 1991 125 EUR/t in 2014	Natural gas, gasoline, light and heavy fuel oil, liquefied petroleum gas, home heating oil.
Denmark	1992	12.10 EUR/t[2]	Natural gas, petroleum and other mineral fuels except biomass fuel.

[1] Figures are reported for year where data were last available in the referenced sources.
[2] The figure of 90 DKK/t is taken from Sumner et al. (2009) as neither MURE nor IEA databases report specific values for Denmark.

Switzerland	2008	8 EUR/t in 2008 77 EUR/t in 2016	Only thermal fuels (oil, gas, coal) are covered not motor fuels (petrol, diesel).
Japan	2012	0.9 EUR/t in 2012 2.4 EUR/t in 2016	The carbon tax is surtax on the existing upstream petroleum and coal tax.
France	2014	7 EUR/t in 2014 56 EUR/t in 2020	Energy products such as diesel or gasoline.

Source: MURE Database, http://www.measures-odyssee-mure.eu/, Lin & Li (2011) *and IEA Policies and Measures Database, https://www.iea.org/policiesandmeasures/.*

Where applicable historical exchange rates were taken from http://www.finanzen.net/.

In particular for the early adopters, empirical studies have attempted to quantify the effect of these reforms. As with any policy measure, the effects of carbon taxes are difficult to assess empirically because of the problem of the counterfactual. In an attempt to estimate the impact of carbon taxes on per capita CO_2 emissions, an empirical study uses GMM estimation to look at the effect of reform in Finland, Netherlands, Norway, Denmark and Sweden (Lin & Li, 2011). Thirteen OECD and EU countries serve as a control group to obtain difference-in-difference estimates of CO_2 emissions per capita. The authors find that the treatment dummy is indeed negative for all four countries except for Norway, so that the growth of CO_2 emissions in countries with a carbon tax reform would appear to be slower than in the control group. However, all coefficients except for the case of Finland are statistically insignificant. Therefore, the study would appear to show that the effects in terms of CO_2 emissions per capita are limited. The authors attribute Finland's positive exception to the fact that compared to the other four countries exemption policies were less widely adopted. In terms of magnitude of the effect, the econometric results suggest that in Finland CO_2 emissions per capita were 1.69% lower than in the absence of a carbon tax. Overall, the growth rate of total CO_2 emissions in Finland fell from 1.5% in the period 1981-1990 to −0.01% between 1990 and 2008, despite an increase in energy consumption. In the Netherlands, Norway, Denmark and Sweden, the paper can provide no empirical evidence for any mitigation effects. (Lin & Li, 2011)

On the other hand, in a large-scale macro-econometric simulation exercise Barker et al. (2007) find more promising results. Looking at environmental tax reform in Denmark, Germany, Netherlands, Finland, Sweden and the United Kingdom, the study claims that fuel demand was reduced by roughly 4% as opposed to the counterfactual scenario, with Sweden and Finland experiencing higher effects. The report also provides evidence that the interaction between taxes and price movements is a crucial factor. In several of the examined countries, fuel demand picked up in 2004/2005, since price increases implied a relative tax decrease. As a consequence, revenues were highest in the 1990s and the largest effects occur at the beginning of the observation period:

> *"This would appear to illustrate the fact that the Danish government could have achieved a larger decrease in emissions if it had kept environmental tax as a share of energy prices constant in the period when energy prices rose."* (Barker, et al., 2007)

In line with fuel demand, the simulations greenhouse gas emissions in the counterfactual reference case did also decrease compared to the base case. In the case of Finland, emissions decreased at an even higher rate than total fuel use (around 6%), because of a comparatively large decrease in demand for coal and heavy oil. The study also demonstrates that greenhouse gas emissions in countries without environmental tax reform did not increase, suggesting that carbon leakage within the EU did not take place. A possible conclusion is that even unilateral environmental tax reform can have a positive impact on emissions without generating emission elsewhere. (Barker, et al., 2007)

Another simulation deals with the more specific case of the potential impact of carbon taxation in the French transport sector. Scenarios based on panel data do show that motorized households will be affected by a carbon tax on car fuels. The decrease of consumer surplus is, however, at least partially offset by less congestion and an associated reduction in travel time. Compared to an estimated welfare loss of EUR 69, the benefits of time savings can be significant and in the region of EUR 7 to EUR 12. (Bureau, 2011)

One advantage of carbon and energy taxes is that in principle they are among the recommended policies to mitigate rebound. Surveying the literature, Vivanco et al. (2016) conclude that sector-specific environmental taxes mitigate the rebound effect and push consumers and industry towards more efficient consumption patterns. They do point out, however, that the way additional revenue is spent does also matter. Ideally, revenue re-distribution should further GDP decoupling and support measures such as investment in clean energy sources. With regard to energy or carbon (product) taxes, these should be set endogenously so that all relevant variables can be taken into account. This includes behavioural and market aspects and should ensure that new rebound effects can be accommodated (ibid.)

2.1.1.2 Green Car Ownership Taxes

Green ownership taxes or fees are meant to encourage the purchase of fuel efficient cars. Mandatory data reported (see EU Regulation (EC) No 443/2009) to the European Environment Agency (EEA) reveals that fuel efficiency for newly bought passenger cars varies drastically across EU Member States. While Estonia and Latvia average emissions well above 130 g CO_2/km, cars bought in 2015 in the highest ranked countries emitted on less than 110 g CO_2/km. Apart from carbon taxes and fuel taxes, green ownership taxes can be a way of discouraging the purchase of inefficient cars. Denmark, with average emissions of 106 g CO_2/km, placed well ahead of Austria with 124 g CO_2/km, introduced an annual green owner fee in 1997[3].

[3] A Factsheet is provided by the Danish Ecological Council: www.ecocouncil.dk/documents/andet/1733-150417-motor-vehicle-taxation

Table 3: Average CO_2 Emissions for New Cars 2015 (in g CO_2/km)

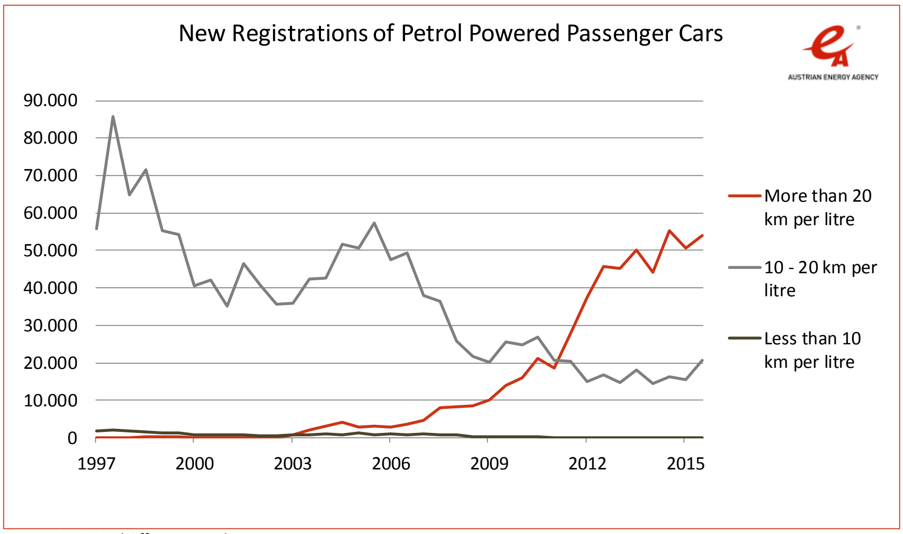
RANK	COUNTRY	AVERAGE EMISSIONS
1	Netherlands	101,2
2	Portugal	105,7
3	**Denmark**	**106,2**
4	Greece	106,4
5	France	111,0
…	…	…
15	**Austria**	**123,7**
…	…	…
24	Hungary	129,6
25	Lithuania	130,0
26	Bulgaria	130,3
27	Latvia	137,1
28	Estonia	137,2

Source: EAA CO_2 Emissions for New Cars Report 2016, Data for 2015.

The Danish green owner tax is paid on an annual basis and determined by the degree of energy efficiency of a car. The relevant measure is the number of kilometres driven per litre of fuel, e.g. in 2013 the fee ranged from EUR 2,740 (< 4.7 km per litre) to EUR 83 (> 20 km per litre). As a result the number of newly registered passenger cars has shifted dramatically across categories. Figure 1 shows the development from 1997 to 2015 and highlights the dramatic changes in registration patterns. Statistical data alone can of course not be taken as evidence of causality but they do highlight that the tax could have certainly contributed to the developments.

A paper examining the impact of different types of car taxes on car sales and CO_2 does find evidence that (annual) circulation taxes on car ownership that have a significant impact on purchasing behaviour. In a sample of EU countries over a period of 1995 – 2004, a fixed effects and 2SLS model are used to explain new car sales and CO_2 emissions intensity. The results suggest that fiscal measures do affect consumer's purchasing decision. In particular, out of all fiscal measures, such as registration taxes or VAT, it is only annual circulation taxes that promote the purchase of more efficient cars. With regard to emissions, registration taxes do not show any relation to the CO_2 intensity of the new car fleet, whereas the coefficient for annual circulation taxes is negative and statistically significant, indicating that circulation taxes are effective in reducing emissions intensity. (Ryan, et al., 2009)

Figure 1: New Registrations of Petrol Powered Passenger Cars in Denmark by km/litre



Source: Statistical Office Denmark

Since measures such as green ownership or circulation taxes do appear to have an impact on fuel efficiency, the issue of rebound is relevant. Econometric estimates based on US data would suggest that the rebound effect due to changes in fuel efficiency could amount to as much as 20-25% over a period of 30 years. The results also suggest that rebound is becoming less important as incomes rise and fuel costs become a lesser factor in determining travel time. The authors also suggest that in urbanised areas congestion may lower those estimates. (Small & Van Dender, 2007) The next section will therefore look at congestion taxes and the rebound effect.

2.1.1.3 Congestion Taxes

In London, the inner-city congestion tax was introduced in February 2003 with an initial charging zone of 21km^2 and initial charging hours of 07:00-18:30 on weekdays. Since then charge increases as-well as extensions of the charging zone have taken place. In Stockholm, congestion charges were introduced on a trial basis in 2006 and made permanently in 2007. Similar to London, the charging system spans inner-city Stockholm. However, the charge is not uniform across time slots with an additional fee during weekday peaks.

In London, empirical evidence overwhelmingly shows that the introduction of the scheme was initially associated with decrease in car travel into central London. Based on an evaluation of descriptive statistics and interviews, freight travel on the other hand, appears not to have been affected, with estimates showing perfect price inelasticity for medium and heavy goods vehicles in the long run. In particular, the 2005 and 2011 increases in congestion charge appear to have had no significant impact on inbound goods vehicles entering the zone. However, interviews with operators do suggest that the charge may have incentivised freighters to improve operational and spatial efficiency. (Broaddus, et al., 2015)

The overall economic effects are also not clear cut. While the number road usage initially decreased from 1.39 Mio vehicle kilometres/day pre-charge to 1.16 Mio kilometres/day and average speed increased from 14.3 km/h to 16.3 km/h, the collection and implementation costs of the scheme proved to be substantial. Although the increase in speed and the decrease in travel distance can be translated to environmental benefits, the actual increase in measured air quality, however, appears negligible because the charging zone represents only a small fraction of total traffic in Greater London. Overall, it is suggested that the economic benefits of a reduction of congestion costs, bus travel time and environmental costs amounted to 104 Mio Euros per year, whereas the costs for annual implementation and bus subsidies amounted to 177 Mio Euros per year. (Prud'homme & Bocarejo, 2005)

There is also evidence that the effects represent a one of shock with traffic and congestion levels rising again after the initial decrease. Moreover, rebound, in particular substitution effects can be very relevant. In the first year of its operation, the congestion charge in London led to a decline in chargeable vehicle kilometres by 25 per cent, whereas non-chargeable vehicle kilometres increased by 18 per cent. The congestion charge did have an impact on bus travel as up to 40 per cent of former car drivers may have shifted to using buses, translating to 30,000 additional bus passengers on weekdays. (Givoni, 2012) Environmental adverse effects of the increased bus use appear to have been mitigated by the widespread installation of particle traps to the new and existing fleet as well as newer technology engines. (Beevers & Carslaw, 2005)

Similar to London, the introduction of the Stockholm congestion charge appears to have led to a one-off but stable reduction in traffic volumes within the zone by around 20 per cent. Even factoring in external factors such a fuel prices of changes in employment, the reduction in non-exempt traffic has remained fairly stable at 30 per cent in the five years following the introduction of the charge. More importantly, traffic on potential relief routes around the cordon did not appear to be negatively affected. The charge was also successful in increasing the purchase of exempted alternative fuel vehicles, in particular for company cars. The exemption contributed only to a minor increase in traffic volumes, since commercial vehicles and taxis are least price-sensitive. (Börjesson, et al., 2012)

2.1.2 Subsidies and Grants

Subsidies and grants are commonly applied in the buildings sector to stimulate renovation leading to energy efficiency improvements. In Germany, the federal *Kreditanstalt für Wiederaufbau* (KfW) offers both, grants and loans at subsidised interest to those aiming to renovate residential properties. To qualify for a subsidy, renovations have to have a certain standard, which is typically higher than the minimum requirements of building regulations. Since the marginal cost of thermal renovation rises substantially in relation to the strictness of the standards, the question arises, what the optimal standard/subsidy relation is. While it could be argued that the subsidies encourage renovations to high levels, the question remains, whether lower standards would encourage more renovations because homeowners' money is spent more efficiently, if energy saved is higher relative to Euro invested. (Galvin, 2009)

When it comes to building thermal renovation, rebound effects have to be considered. Residents may well trade-off some of the potential savings for added comfort. Using data from over 3400 dwellings, Galvin & Sunikka-Blank (2012) look at the gap between performance and actual energy consumption. They find that in particular for low-energy dwellings, occupants tend to consume more than calculated energy performance ratings (EPR) would suggest. On the other hand, for buildings with a high EPR, actual consumption tends to be much lower. This has acute implications for subsidy schemes based on standards such as they are offered by the KfW. In particular, economically feasible fuel savings through retrofits may amount to only 25-35 per cent as opposed to 70-80 per cent envisaged by policy makers. In light of this evidence, tying subsidies to “draconian thermal standards” might restrict the amount of energy that can actually be saved. (ibid.)

A meta-analysis compares retrofit programmes in Germany and Britain, in particular Germany’s CO_2 Building Rehabilitation Programme (CBRP) with the UK’s supplier obligation scheme. Results suggest that while both schemes led to comparable reductions in CO_2 emissions, the necessary subsidies spent by energy suppliers (EUR 1.7 bn) within the framework of the obligation scheme were much lower than funding for the CBRP (EUR 4 bn). In terms of subsidies in Euro per tonne of saved CO_2 the obligation scheme compared favourably (21 EUR/t CO_2) to the building programme (48 EUR/t CO_2). Again the authors highlight that one of the main reasons is the fact that subsidies of the CBRP are geared towards high-end retrofits, where the rebound effect is most prominent. (Rosenow & Galvin, 2013)

2.2 Capacity Building & Awareness

Capacity building and awareness campaigns are often instrumental in achieving widespread behaviour change. In most cases, such campaigns help improve the effectiveness of other policy instruments, which is why they should be combined with fiscal or regulatory measures for maximum gains. In particular, market transformation programs should be designed to directly target identified market barriers and to have long-lasting, if not permanent, market changes (Birner & Martinot, 2005). Campaigns targeting consumer behaviour and informing consumers about their energy use can help reduce the (direct) rebound effects of other energy efficiency measures.

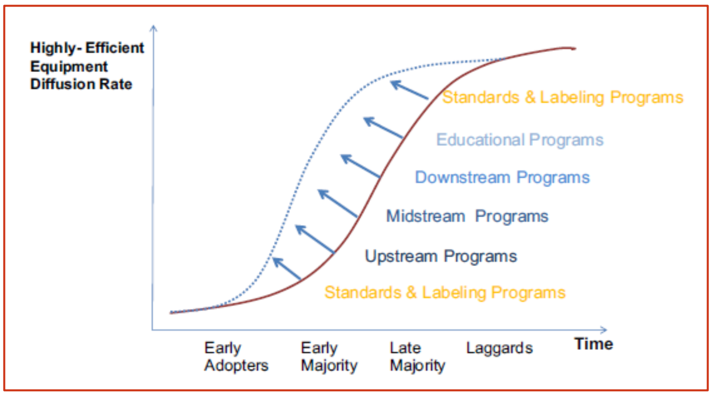
2.2.1 Campaigns for Highly-Efficient Appliances

Studies show that incentive programs have a greater impact when they focus on highly-efficient products, so called "top of the market" products. A policy mix, consisting of an incentive program coupled with complementary mandatory standards and labelling, can be more effective for market penetration (de la Rue du Can, et al., 2014).

Numerous countries are trying to increase the use of energy-efficient products through incentive programs, informational platforms and tools. Such an increase not only lowers the product costs for consumers (de la Rue du Can, et al., 2014), but also plays a part in contributing to the reduction of energy consumption in the country. Park et al. (2013) calculated that the average energy consumption of CCFL-LCD and LED-LCD TVs will reduce by 30% and 55% respectively from 2010 by 2015, even without additional policy measures. Though the analysis does not directly take rebound effects into consideration, it does, however, mention the importance of taking technological advancements into account when developing new policies. Additionally, it emphasises that market transformation programs need to constantly update efficiency targets in order to foster the uptake of energy-efficient products.

One of the main barriers to the purchase of energy-efficient products, however, is the rather high up-front costs, which tend to dissuade consumers from their purchase, unless information to their cost-effectiveness is provided. Supporting efficient products, for example through incentive programs, at an early stage of development can help the technology and the market, while also spurring private-sector investment (de la Rue du Can, et al., 2014). One of the main difficulties of such incentive programs is the need to achieve robust market transformation (ibid.). The programs should appropriately address the various stages of the market diffusion of the product.

Figure 2: Impact of Market Interventions on Highly-Efficient Technology Diffusion Rate



Source: (de la Rue du Can, et al., 2014)

Several complementary measures targeting energy-efficient products should be implemented to accelerate the diffusion of these products and to guarantee increased energy savings and long-term behavioural change. Incentive programs can help to make more ambitious standards acceptable to stakeholders from the industrial sector (ibid.). Such programs coupled with labelling programs can increase awareness of the public about the benefits of products. Continuous monitoring and verification of the programs' impacts should also be guaranteed in order to assure success. One of the most important prerequisites for success is that policies must be developed in cooperation with all relevant stakeholders and should be tailored to local conditions on a case-to-case basis (ibid.). "The cost of energy efficiency programs varies widely according to the measure considered and the region-specific regulatory eligibility criteria." (de la Rue du Can, et al., 2014)

In Thailand, a comprehensive five-year demand-side management (DSM) program launched by the Thai national electric power utility (EGAT) in 1993, resulted in a 21% reduction in overall refrigerator energy consumption (Birner & Martinot, 2005) due to the introduction of labelling schemes (for more information on regulatory measures, please see Chapter 2.3). Programs in Thailand, Mexico and Poland have resulted in the installation of more than 4.6 million compact fluorescent lamps (CFLs), corresponding to annual savings of at least 3,500 GWh (Birner & Martinot, 2005).

Unfortunately, methods of accounting of (net)energy savings vary significantly from one country to another and thus have a pronounced impact on the final results (de la Rue du Can, et al., 2014). Net savings, for example, exclude free riders, but include savings resulting from spill-over effects. Calculating net savings, when different bodies/entities offer financial incentives to the same group of customers for the same appliance (ibid.), can result in data inconsistencies or even double-counting. A common rebound effect is that reductions in energy costs often cause customers to increase their energy use, thereby reducing the actual energy savings achieved. In this case, pro-active measures designed to inform consumers about the importance of shifting to greener consumption patterns or of downsizing consumption can help mitigate rebound effects (Vivanco, et al., 2016). Actions targeting consumer behaviour should be developed hand-in-hand with fiscal measures (see Chapter 2.1) as they can be very effective tools in countering rebound effects:

> *"Additionally, the use of consumer behaviour actions such as consumption information and standardisation to shift consumption patterns, may strengthen the effects of carbon taxes."* (Vivanco, et al., 2016)

2.2.2 Apps & Tools & Platforms

Awareness raising and informational programs can also take the form of easy-to-use apps, tools or platforms. Due to the wide variety of brands and models of products available on the market, customers have a tough time trying to choose the best performing products. Such tools can help customers make smarter, more energy-efficient decisions by providing them with pre-selected products based on certain criteria.

Platforms like Topten provide a good overview of the "best" products available in each product category, while using energy efficiency as a key criterion. Such targets not only offer reliable information for customers, but also for manufacturers, public procurement officials, retailers and large-scale buyers. Additionally, information learned from such platforms can help provide an input to policymakers to develop new information and awareness-raising campaigns. These platforms describe the functionality of products, use pictures, list information regarding product costs and the availability of products on the local market. Since the products are limited to the most energy-efficient products on the market, customers are able to choose from a much smaller list of products. Products, including refrigerators, freezers, tumble driers, TVs, air conditioners, dishwashers and washing machines, are included on the platform. Platforms such as Topten help stimulate market transformation toward more energy-efficient products, while contributing toward GHG emission reduction goals.

The success of the Topten program can be linked to the ability of the platform to work together with a number of stakeholders, for example energy agencies, utilities, government officials, manufacturers and utilities (Granda, et al., 2013). After the initial success of the Topten platform in Europe, the initiative has now been launched in the US and China (2010), as well as in Chile and Argentina (2015). A quantitative analysis, taking into activities of the Topten International program in Europe, China and USA from 2006-2014, demonstrated cumulative savings of 15 to 18 TWh, corresponding to approximately 7.5 to 9 million tons CO_2 emissions; Topten Europe had an impact of approximately 4 to 5.4 TWh/a in terms of annual savings in the year 2014 (Iten, et al., 2015). The electricity savings cannot, however, be considered as a full impact from Topten activities, since energy efficiency is only one of the many factors affecting consumer decision.

Davis (2008) conducted a study that looked at the direct rebound effects for household washing machines in the US and that involved 98 voluntary participants. The resource-efficient washing machines used 48% less energy per wash and 41% less water than less efficient alternatives. The study concluded that only a smart portion of energy saving gains will be offset by increased utilisation of the more energy-efficient machines.

These results could also be extrapolated for other time-intensive energy services that are consumed by households (i.e. dishwashers, televisions, vacuum cleaners) (Sorrell, 2007). Direct rebound effects may be even smaller, if energy-efficient equipment or appliances tend to be more expensive than their less efficient counterparts over a longer period of time. Indirect rebound effects may occur due to the use of energy-efficient products: cost savings resulting from the purchase of energy-efficient appliances and goods, may result in households purchasing additional goods, which in turn lead to an increase in the overall consumption of energy.

Such apps, tools and platforms can draw attention to best performing energy-efficient products on the market, by offering easy comparisons and cost-effective arguments for their purchase. In addition, platforms could also be expanded to include other sectors, such as transport, where a comparison between fuel-efficient cars or electric cars is given. Due to the simplicity of such platforms, they can be applied to other sectors quite easily; example, to the heat sector, where heaters or renewable energy options are compared to one another.

2.2.2.1 Smart Meters & Energy Monitors

Many studies show that providing customers about information regarding their energy consumption can result in one-off energy savings between 5-20% (Buchanan, et al., 2014). The average consumer can reduce their energy costs by 3% without too much effort; cost-benefit analysis conducted in Finland showed average savings of 1-2%, while Sweden had a range of 1-3% (Zgajewski, 2015). This was the main idea behind the introduction of smart meters: the belief that providing customers with real-time information about the energy consumption habits would motivate them to reduce it (Buchanan, et al., 2014). In this section, the main advantages and disadvantages of smart meters and energy monitors will be examined.

Though studies demonstrate energy savings through the use of feedback devices (e.g. smart meters), many other studies point out that information from such devices, may appeal most to those individuals who are already environmentally motivated. Feedback devices can help fill the information vacuum can act as a learning tool or can increase visibility (by transforming the abstract concept of energy into something that is transparent and easy to understand) (Buchanan, et al., 2014). Limited studies on this feedback mechanism show that though smart meters/feedback devices can increase individuals' knowledge about energy use, this knowledge alone does not necessarily influence an individual to reduce their consumption. Many customers end up purchasing energy monitors for financial rather than environmental reasons (ibid.). After buying a smart meter, individuals mentioned that increased awareness of their energy consumption helped them be more conscious about their energy practices. A common positive after-effect of the use of energy monitors is that consumers tend to switch off unnecessary appliances, instead of switching them to standby as they had done before. Indirect benefits may also occur, if consumers purchase enabling technologies, technologies that respond to smart meter signals (ex. smart thermostat, in-home displays). Such technologies can provide customers with further information related to appliance-specific usage as well as projected bills (Krishnamurti, et al., 2012), thereby allowing customers to make more informed electricity usage decisions.

Public resistance to smart metering is most often related to fear of privacy infringements, increased financial burden and health risks (Hoenkamp, et al., 2011) (Krishnamurti, et al., 2012), as well as issues related to loss of control and autonomy, and disruption to household routines (Buchanan, et al., 2016). Many customers have stated that smart meter installation can lead to increased electricity bills as a result of improved bill accuracy (Krishnamurti, et al., 2012).

Drawbacks of energy monitors were the occurrence of technical difficulties, questions about the accuracy, decrease in novelty factor over time[4,5] and the fact that in order to reap true benefits, one needed to be more engaged.

> *"Moreover, given that consumers may use and respond to feedback in unexpected ways, there is the potential that IHDS may result in a range of undesirable consequences such as dangerously cold homes for vulnerable populations or legitimizing and/or even increasing existing levels of "over" consumption."* (Buchanan, et al., 2015)

The largest drawback is that the simple act of installation does not result in energy consumption, because it only provides information. In order to achieve effectiveness over a longer period of time, consumers have to continuously engage with the energy monitors. For less-motivated consumers, it may help if energy monitors "[alerted] consumers to abnormal usage or [specified] which appliances are on, or even [provided] specific energy saving recommendations." (Buchanan, et al., 2014).

Italy and Sweden were the first countries to initiate smart meter rollouts even before the EU Energy Efficiency Directive 2006/32/EC[6] required the rollout in all Member States. As a result, Italy has a smart meter penetration of more than 85% (Krishnamurti, et al., 2012).

Smart meter implementation should be coupled with an information campaign to counter misconceptions and to inform customers about the benefits of these tools, while simultaneously their concerns:

> *"Thus, our findings suggest that the misconceptions of benefits tend to favour utilities, at a potential cost to customer happiness. In contrast, those people overestimating the risks of smart-meters may pass on a technology that has the potential to greatly benefit them and that they would otherwise favour if they possessed better information."* (Krishnamurti, et al., 2012)

Awareness raising programs can help improve understanding in households (and businesses), so that reductions in energy consumption are not invested in alternate environmentally intensive categories (Vivanco, et al., 2016). Alternatively, in order to counteract the rebound effect of smart meters, electricity providers could launch a campaign that emphasizes the importance of saving energy. A good example of a similar campaign comes from Germany, where the German green electricity company

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[4] Pereira et al. (2012) found that users started to pay less attention to feedback after 4 months.
[5] Smart Meters suffer from the "fallback effect" (Wilhite & Ling, 1995), the moment when the devices stop offering new information and fade into the background of everyday life.
[6] Energy End-Use Efficiency and Energy Services Directive (2006/32/EC) - repealed by Directive 2012/27/EU

"Lichtblick" offered customers a bonus, if they succeeded in achieving an absolute reduction in energy consumption. Consumers were awarded in a bonus of 20€, if they reduced their electricity consumption by 10% within a duration of 12 months.

2.2.3 Green Public Procurement (GPP) & Energy-Efficient Procurement (EEP)

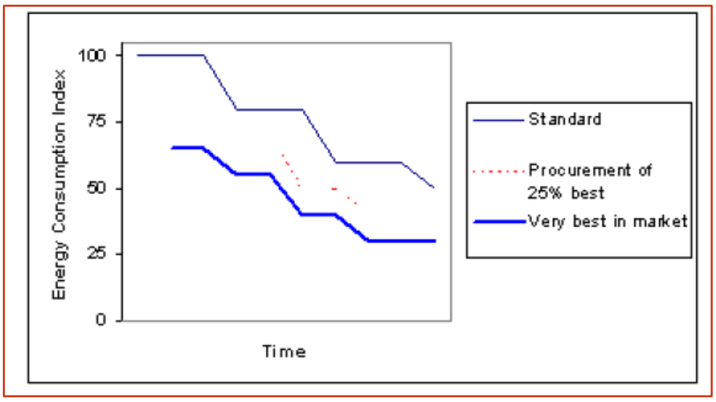
Technology procurement is a quite common market transformation tool used in the energy sector and has been performed since the 1990s. Technology procurement can be a powerful instrument, if the right legal and financial supporting conditions exist.

Countries, like Sweden, the United Kingdom, Canada, India, Mexico, South Africa, and the United States[7], have developed policies to enhance existing business processes without adding extra administrative burden. In many countries, policies started off as voluntary, before moving towards mandatory in order to bring about lasting societal transformation. However, mandatory policies are not a must if voluntary policies are enough to encourage change in the society. Common factors for program failure include lack of overall leadership from the national government, the non-existence of at least one operative body to support the overall process (and serve as an info centre), and lack of industry incentives or lack of funding (Singh, et al., 2012).

Policymakers must find a way to maintain purchasing efficiency, while asking consumers to take environmental (ex. energy use, product lifespan) and social criteria (ex. based on fair-trade principles) into consideration. It is of utmost importance that customers have complete certainty regarding the cost effectiveness of energy-efficient products (Payne, et al., 2013); successful technology procurement will not only lead to commercial availability of new technologies, but will open up new choices for consumers, while leading to sustained market acceptance of new energy-efficient products (ibid.). Furthermore, industry stakeholders should be included in the development of standards from the early stages, in order to prevent challenges from industries that may be excluded by these standards. In the EU, for example, training green procurement experts has created a multiplier effect since the trained experts go on to share their knowledge with others. Furthermore, procurement of the "best products on the market" (see Chapter 2.2.1) can help drive demand for products that already exceed energy efficiency standards, when there is still room for improvement (ten Cate, et al., 1998). Technology procurement can also help stimulate the development of alternative technological paths in the long-term (Teubal, et al., 1996).

[7] See the ENERGY STAR Office Equipment Program for more: https://www.energystar.gov/index.cfm?c=ofc_equip.pr_office_equipment

Figure 3: Combinations of Technology Procurement, Market-Pull and Standards Influence Efficiency Trends Over Time



Source: (ten Cate, et al., 1998)

Since 2010, all central government departments in the UK were required to buy energy through the Government Procurement Service (GPS), which resulted in savings of GBP 51 million. "GPS buys energy for 75% of the entire public sector which accounts for 3% of total UK energy demand." (Payne, et al., 2013) In Vienna, Austria, there has been a mandatory green public procurement policy since 1999, which includes energy efficiency criteria. The policy provides guidelines for more than 23 goods and services categories, resulting in annual savings of EUR 17 million and 30,000 tons of CO_2 emissions (Singh, et al., 2012). Mexico City, in its goal to meet its environmental commitments, has also invested in the purchase of sustainable products, resulting in savings of 340 GWh and 6,500 metric tons of CO_2 emissions annually (ibid.). As Payne et al. (2013) show, the Swedish Environmental Management Council (SEMCo) has developed procurement criteria covering more than 40 product and service categories since 2003. These criteria are meant for use in tender documents and can also serve as a source of information for suppliers and procurers regarding future requirements. Though the use of the criteria is not mandatory, over 75% local governments in Sweden use them; a fact that greatly contributes to the success of green technology procurement in the country is the development of the criteria through a transparent development process. As a result of the computer procurement process, government agencies reduced their annual energy consumption by 3,750 MWh (The Swedish Environmental Protection Agency, 2009).

Green public procurement can also be used in the building sector. In Pembroke, Malta, a green public tendering process was initiated to construct the first energy self-sufficient school that relied only on on-site produced solar and wind energy for electricity and warm water. The new primary school is now able to produce 35,000 kWh from photovoltaic and wind turbines, with surplus energy being sold back to the national electricity grid (European Commission, 2012). As a result of this tendering process, the Maltese government was able to minimise the impacts of future construction projects on the environment. In the US, the implementation of the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) standard for sustainable building practices led to a sudden surge in green buildings across the country. In many cases, the use of municipal green building procurement policies led to a wider diffusion of the LEED standard among private-sector developers. Neighbourhoods that adopted the LEED resulted in spill-over effects in neighbouring areas (Simcoe & Toffel, 2012). Another positive procurement spill-over effect is that government preference for a particular standard may help overcome initial inertia in its adoption. Government procurement policies in the U.S. helped create demand for certified green building experts; analyses show that increased competition for such certifications could drive down the cost of developed energy-efficient, LEED-certified buildings in the long-term. In their analysis, Simcoe and Toffel (2012) point out that procurement policies in the U.S. reinforced the use of LEED standards in building design at a time when the market was still nascent and helped “jump start” the adoption of the standard by private-sector actors; however, further analyses are needed to understand, if the policies would have had the same effect in a mature market. Green buildings can, however, lead to an inadvertent rebound effect: occupants of green buildings, especially public buildings, may not feel the need to reduce their energy consumption since the buildings are already energy-efficient (Mokhtar Azizi & Wilkinson , 2015).

In addition to capacity building and information campaigns, other non-fiscal measures, including labelling, standards and obligations, can help to bring about changes in consumer behaviour. The next section will take a look at such policy instruments.

2.3 Regulatory Measures

In this section, regulatory measures, such as labelling, standards and obligations, will be reviewed, with particular focus on the household appliance sector, the buildings sector, and the transport sector.

Energy-efficient labelling is one of the most common regulatory methods governments use to provide information related to energy consumption to consumers. Eco-labelling has shown to have a number of benefits including informing consumer choice, stimulating market development, encouraging continuous improvement, assisting in monitoring, promoting certification and promoting energy efficiency. Different types of energy efficiency labels exist around the world: (a) endorsement labels (ex. ENERGY Star - USA), which demonstrates if a product satisfies certain criteria and acts as a "seal of approval", and (b) comparative labels (ex. EU Energy Label, Chinese Energy Label) allow for a comparison of products with respect to a certain criterion (Rohling & Schubert, 2013).

Standards and obligations can help increase energy saving efforts and the promotion of renewable energy in various sectors, when voluntary measures, awareness-raising campaigns or fiscal instruments prove to be insufficient. Standards help to establish uniform technical criteria and practices within a sector, thereby helping manufacturers to produce products that are in line with energy-efficient targets. Additionally, regulatory measures can promote good practice in energy management and can open up new markets for renewable energy technologies and energy-efficient products. Such measures can help shape consumer behaviour by drawing consumers’ attention to the impact their behaviour has on the environment. By making standards or labels a part of daily life, energy savings concepts become less abstract and environmental consciousness becomes more attainable.

Unlike previous chapters, this chapter has been subdivided according to sector, rather than the type of measure, since many regulatory measures targeting a particular sector are enacted in parallel.

2.3.1 Consumer Goods

The introduction of energy labelling schemes can strongly influence consumer choice, thereby making them an important component of a manufacturer's market strategy (Granda, et al., 2013). Manufacturers will be more inclined to invest in energy efficiency and the production of energy-efficient products, if they believe that a larger share of stakeholders could be reached. Labelling standards should be clear and the requirements for the most energy-efficient products should not be easily met, which could have the inverse effect of hindering market transformation (ibid.).

As mentioned in Chapter 2.2.1, awareness-raising campaigns designed to showcase the most energy-efficient products on the market can help customers to make well-informed, environmentally friendly decisions, while also bringing attention to cost saving benefits. Many such campaigns targeting energy-efficient products are developed alongside labelling or standardisation schemes.

The ENERGY STAR program created by the United States Environmental Protection Agency (EPA) and the Department of Energy is currently being used in Australia, Canada, the EU, Japan, New Zealand, Switzerland, Taiwan and the US. When it was initiated back in 1992, it started as a voluntary labelling program for computer and printer products. It was later expanded to include a wide range of products, including lighting, home electronics, and heating and cooling systems for homes. Some of the ENERGY STAR energy performance ratings have now been incorporated in green building standards, such as LEED for Existing Buildings. The specifications used by the ENERGY STAR are based on international standardised processes and maintain a threshold, where only the top 25% of energy-efficient products may be branded with the label. The programme has established long-term business relationships with retailers and manufacturers to create strong brand recognition. According to the United Nations Economic Commission for Europe (UNECE) (UNECE, 2015), 300 million ENERGY STAR products were purchased in the US alone, leading to a reduction in 0.5 TWh of energy demand. Though the effects of rebound depend on the product category, a direct rebound effect of approximately 10% can be assumed for household appliances (Sorrell, 2007) (International Energy Agency , 2015).

2.3.2 Buildings Sector

Countries around the world are enacting building laws to improve energy efficiency in buildings. The building sector offers numerous opportunities for energy savings as approximately 40% of the total fossil fuel consumption (in the USA and the EU) comes from the building sector (Koo, et al., 2014). Energy efficiency measures in buildings not only result in a reduction of energy costs for owners and tenants, but can also lead to an increase in the living quality through a positive change in the comfort level of the building.

Labelling programs help provide recognition for energy-efficient constructions, thereby also motivating professionals working in the building sector to actively give more priority to incorporating energy efficiency measures in new constructions or during refurbishment of existing buildings. Excellent grades as demonstrated by building energy certificates can help motivate prospective owners/tenants to choose that building, but do not significantly motivate the existing tenant by offering additional benefits for their energy saving efforts (Koo, et al., 2014).

A study conducted by Liu and Lin (2016) showed how important it is to consider rebound effects when analysing improvements in energy consumption: using the year 2010 as a basis, 6.95 Mtce worth of energy would have been saved due to technological improvements in energy efficiency in the construction industry in China. However, 1.52 Mtce worth of energy were offset due to the rebound effect. Despite the rebound effects, investments into energy-efficient construction have spill-over effects, which lead to an increase in the production of energy-efficient building materials and buildings. Liu and Lin (2016) go on to emphasize that the strong rebound effect in China is a result of regulated low energy prices, which effectively weaken the incentive for more efficient use of energy. It can be concluded that policies on energy prices (ex. taxes) must go hand-in-hand with other regulatory policies to truly maximize energy conservation goals.

The EU has, through Directive 2010/31/EU, set stringent standards, including minimum energy performance requirements for new buildings and minimum requirements for the energy performance of existing buildings undergoing significant renovation, for the building sector. The Directive covers all buildings irrespective of size in the tertiary, as well as the residential sector. Additionally, it requires that all new buildings must fulfil a near zero-energy standard by the end of 2020, while public buildings must fulfil the standard by 2018. Energy efficiency requirements in building codes or standards are one of the most important measures for ensuring the construction of energy-efficient buildings. It is, however, very important that the building codes are tailored for each individual country, since they need to take the local environment and the market conditions into consideration.

In the Netherlands, the implementation of the 2010/31/EU Directive included the expansion of its building code ("Bouwbesluit") and the creation of new standards for determining the energy performance of new buildings. In order to support the application of the building code in the Netherlands, schemes (i.e. tax system for investing in energy saving technologies, grants and tax deduction schemes) were rolled-out to promote green buildings. These initiatives were designed to counteract the increased costs of construction under the new guidelines.

Other countries have taken it upon themselves to set obligations for the installation of renewable energy systems in residential buildings. In Greece, for example, the installation of central thermal solar systems in new and existing buildings, which are undergoing renovation, was made compulsory in 2008. The installed systems must cover at least 60% of the heat required for hot water production. This obligation is coupled with further fiscal incentives (subsidies, loans, VAT reduction for purchase system equipment) and awareness building measures to boost the penetration of solar systems in existing residential buildings. The combination of measures is expected to result in a replacement of conventional fuels and electricity for hot water production of approximately 50 - 100% (ODYSSEE-MURE, 2016).

Relatively few studies have attempted to quantify the full rebound effect with regard to energy efficiency measures implemented in the building sector. Comparisons between studies also prove to be difficult at times, since they employ different approaches and different assumptions. Direct rebound effects, which tend to be divided into income and output effects as well as substitution effect, are rather common in the building sector. Studies have shown that consumers have increased the indoor temperature of their apartments or houses after energy-efficient measures or refurbishment (i.e. insulation and window replacement) were undertaken. In his analysis, Sorrell (2007) showed that the majority of studies show a rebound effect varying between 10% and 50% as a result of energy savings from space heating efficiency measures; however, a study on the effect of the introduction of efficient space heating in low income households in the UK had no impact on reducing fuel consumption (Hong, et al., 2006). Estimates for the direct rebound effects for household heating range from 10% to 58% in the short-term and 1.4% to 60% in the long-run, with stronger rebound effects for low income households (Sorrell, 2007). However, direct rebound effects from EE improvements in household heating systems should decrease as soon as the indoor temperature approaches the limit for thermal comfort.

The large variation in estimates of rebound effects and the potential magnitude imply that mitigation measures are particularly important in this area. Obligations or standards designed to increase the penetration of energy-efficient buildings should be bundled with fiscal and awareness measures to prevent rebound effects. By trying to raise awareness of the importance of leading a sustainable lifestyle (measure: informational campaign) and by tying monetary benefits to energy-saving efforts (measure: fiscal), rebound effects can be mitigated.

2.3.3 Transport Sector

Energy efficiency improvements undertaken in the transport sector can lead to a change in demand for other goods and services. As Binswanger (2011) found, the purchase of a more fuel-efficient car may end up reducing the demand for public transport, but may also increase the demand for leisure activities that are only accessible with a private car. In other cases, analyses show that if an energy-efficient car leads to a reduction in fuel consumption, consumers are tempted to drive more and for longer distances, since mobility is now cheaper (ibid.). After conducting a review of seventeen studies, Sorrell (2007) found that the long-run direct rebound effect for personal automatic transport was between 10 - 30%. Another common rebound effect is that consumers end up buying a second car using the savings from the drop in fuel consumption. Communication campaigns that publicise practical driving tips have proven to be useful in getting consumers to be more aware of fuel-efficient cars and the need to reduce GHG emissions, thereby reducing rebound effects.

As a result of the European car labelling Directive 1999/94/EC, certain information regarding the vehicle is provided to the consumer at the time of purchase. In addition, fuel standards regulating the emission of sulphur dioxide and benzene, have led to a significant decrease in toxic pollutants. As Clerides and Zachariadis (2008) showed, the adoption of tighter standards led to a faster decrease of fuel consumption over time in Europe, Japan and the US.

Due to the Renewable Energy Directive (2009/28/EC) and Fuel Quality Directives (98/70/EC) of the European Union, all EU Member States are required to achieve 10% renewable energy in transport and a 6% GHG reduction in fuel emissions by 2020. A number of countries, for example, the UK, decided to set obligations for fuel suppliers, namely that road transport fuel suppliers must ensure 4.75% of fuel comes from renewable sources that fulfil certain sustainable criteria (i.e. biofuels must achieve a minimum of 35% in GHG savings). The Renewable Transport Fuel Obligations (RTFO) provides incentives to invest in biofuels by subsidising the higher cost of biofuels through the Renewable Transport Fuel Certificate (RTFC), which can be traded to offset the costs. Though the RTFO led to a meeting of obligations in the first two years (2008-2010), mainly as a result of the tax relief set for biofuels at the same time, it failed to do so on the long-term (Fraunhofer ISI et al. , 2014).

The EU has also laid down very stringent vehicle fuel economy standards (VFES) for passenger light duty vehicles (LDV). The Regulation (EU) No. 333/2014 required that the new cars registered in the EU do not emit more than an average of 130 grams of CO_2 per kilometre (g CO_2/km) by 2015. In other words, this means a fuel consumption of approximately 5.6 litres per 100 km (l/100 km) of petrol of 4.9 l/100 km of diesel. By 2021, the fleet average for all new cars must be 95 grams of CO_2 per kilometre (i.e. fuel consumption 4.1 l/100 km petrol or 3.6 l/100 km diesel). When compared with the 2007 fleet average of 158.7 g/km, the 2015 target corresponds to a reduction of 18% and the 2021 to 40%. In order to enforce the policies, manufacturers are required to pay an excess emissions premium if a manufacturer's average emissions levels are above the target set by the limit value curve. The limit value curve allows heavier vehicles to have higher emissions than lighter cars, while still maintaining the overall fleet average. However, the EU has faced recent criticism due to cases of falsified emissions; while the EU sets vehicle standards, it leaves most of the enforcement and implementation up to its Member States, leading to a fragmented system of vehicle testing standards and monitoring.

VFES is just one of many policy instruments available to increase fuel efficiency of new vehicles, while also encouraging the purchase of fuel-efficient vehicles. Countries tend to use a combination of fiscal instruments (ex. fossil fuel taxes, alternative vehicle subsidies – see Chapter 2.1), labelling (ex. the EU has introduced tyre labels) and mandatory sales targets in addition to VFES programs to achieve overall goals. Vehicle labels can provide useful information to consumers about the CO_2 and other emissions, fuel consumption (ex. l/100km), annual fuel costs, among others.

Tighter transport-related regulations can lead to rebound effects, which can manifest themselves either in an increase in the number of vehicles, an increase in the miles/kilometres driven and/or in an increase in fuel consumption. For example, Greening, Greene and Difiglio (2000) who summarised 22 studies, found that the short-run rebound effect was 10%, while long-run rebound effect was 20-30%. On the other hand, Greene and Schafer (2003) found that a 10% increase in fuel efficiency leads to a 1-2% rebound effect. A long-term increase in fossil fuel prices can lead to a reduction in fuel consumption in the long-run, since consumers choose to buy more fuel efficient vehicles or relocate to lessen their commute to work. Rebound effects can be mitigated through smart, targeted awareness campaigns and trainings, such as eco-driving. Aggressive driving practices can waste up to 50% of fuel, a practice that can be changed through eco-driving techniques, which lead to a reduction in vehicle operating costs, in fuel costs and GHG emissions. Standardisation of eco-driving practices in driving lessons help to shape consumer behaviour from the beginning (Maxwell, et al., 2011). Such programs can also help to complement other efforts to save energy and reduce emissions in the transport sector.

2.4 Summary of Reviewed Measures and Associated Rebound Effects

Table 4 below summarises the above-mentioned measures and their relationship to rebound. We continue to follow the definitions provided in Barker et.al. (2009), so that the *direct rebound effect* decreases effective prices thereby increasing consumption, the *indirect rebound effect* refers to changes in the consumption of other goods and services and finally the *economy-wide rebound* effect relates to a real fall in prices for intermediate and final goods throughout the economy. For each type of measure the way in which either or all of these effects may take place is described. In addition, based on the literature reviewed above, we qualitatively assess the likely strength of the rebound effect into three categories: high or very likely (red), medium or possible (yellow), low or unlikely (green).

Table 4: Overview of Selected Measures and Associated Rebound Effects

TYPE OF MEASURE	DIRECT REBOUND EFFECT	INDIRECT REBOUND EFFECT	ECONOMY-WIDE REBOUND	STRENGTH OF REBOUND
Carbon Taxes	Unlikely, as taxes increase effective price		Possible in medium to long run if competitiveness of economy increases as opposed to fossil fuel economies	
Green Car Ownership Taxes	Increase in car usage due to lower cost per kilometre	Transport expenditure may fall leading to an increase in spending on other goods	Possible, in particular if taxes also apply to (light) commercial vehicles	
Congestion Taxes	Possible, if (daily, weekly, etc.) one-off payment increases effective price of additional travel; Substitution effects can occur.	In principle unlikely, as congestion tax increases cost of travel; substitution to bus travel may impact emissions	Unlikely, unless city wide-fuel switch takes place (e.g. exemption of electric or commercial vehicles)	
Subsidies and Grants in Building Programmes	Likely, as some of the decrease in effective price may translate to higher demand for in-	Very likely, since some of the energy and income savings may result in higher expenditures else-	Depends on the programme, more likely if commercial buildings are included;	

	creases in comfort (room temperature, hot water consumption etc.)	where;		
Campaigns for Highly-Efficient Appliances	Possible, ex. lighting sector - if consumers end up up-sizing to the next lumen (or higher wattage) light	Lighting expenditure may fall leading to an increase in spending on other goods	Unlikely	
Apps & Tools & Platforms for Highly-Efficient Appliances	Possible, if increased disposable income from energy savings leads to increased usage of appliances (ex. TV) or the purchase of more appliances	In principle, possible, if consumers end up making high carbon purchases (ex. flights, using the money they saved by using less energy	Unlikely	
Smart Meters & Energy Monitors	Possible, if increased disposable income from energy savings leads to increased usage of appliances (ex. TV, lighting) or the purchase of more appliances	See above	Unlikely	
Green Public Procurement (GPP) & Energy-Efficient Procurement (EEP)	Possible, if increased disposable income from energy savings leads to increased usage of appliances	See above	Possible	
Building Standards & Labels		Heating/cooling expenditure may fall leading to an increase in spending on other goods	Possible, since production costs may decrease	
Standards & Obligations for the Transport Sector	Possible, since fuel economy standards lead to a decrease in fuel consumption; consumers are tempted to drive further distances	Transport expenditure may fall leading to an increase in spending on other goods	Possible, via logistics sector	

3 Policy Recommendations for Austria

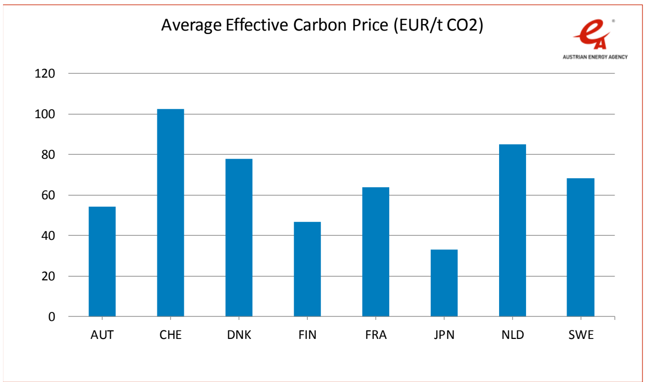
This chapter discusses some important policy recommendations derived from the literature review above. The first part will concentrate on fiscal measures, while the second part of the section concentrates on all other measures, including the effectiveness of mixing different policies to generate the socially optimal outcome and mitigate rebound.

3.1 Fiscal Measures

The reviewed literature has demonstrated, albeit not unequivocally, that carbon and energy taxes can lead to decreases in fuel demand and thereby increases in energy efficiency and a reduction in emissions. The magnitude of the effect appears to be related to the exemption policies associated with the tax, i.e. significant exemptions undermine the effectiveness of the instrument. Secondly, carbon or energy taxes should be designed endogenously to mitigate effects of price and other market factors and help address the rebound effect. For households distributional effects may also matter, however potential benefits such as decrease in traffic congestions and the associated time savings, can mitigate these effects. With regard to industrial competitiveness, there is evidence that carbon leakage is of a lesser importance. On the other hand, the great variety of exemptions does hinder comparisons and a final conclusion on the topic seems premature.

It has to be noted that viewing carbon taxes in isolation to develop policy recommendations is problematic due to the widely different tax systems and the fact that in general a number of taxes may apply for a specific product or to a specific sector. Data published by the OECD in 2016 attempts to overcome those difficulties by calculating effective carbon prices derived from various applicable taxes. Out of the countries reviewed in Table 2 with the exception of Japan, Austria has the lowest implied carbon price of around 55 EUR/t, whereas Denmark and Sweden have an effective carbon price of 78 EUR/t and 68 EUR/t respectively. While the tax-based carbon price in the transport sector in Austria is comparable, for the other evaluated sectors agriculture, electricity, industry, off-road transport and residential & commercial, the implied carbon price is in some instances much lower.

Figure 4: Estimated Average Effective Carbon Price in Selected Countries



Source: OECD 2016

In its review of Austrian environmental performance, the OECD (2013) does recommend a carbon tax to ensure the burden is effectively spread across all relevant sectors. Apart from spreading environmental responsibilities across the economy, taxes can be an effective way to capture emissions that may not be regulated elsewhere. In the case of Norway, its carbon tax covers 68% of all CO_2 emissions, corresponding to half of the total greenhouse gas emissions (Sumner, et al., 2009). If carbon taxes are, as is often the case, limited to specific sectors such as energy and transport then supplementing other policies is sensible. Examples of policy mix approaches include Denmark, Finland and Sweden where, for example, the EU ETS, building and waste management regulations, and CO_2 or efficiency based vehicle taxes play a prominent role (ibid.).

Lessons that can be learned for Austria from experiences so far can be summarised in the following way: (1) in principle taxes should be set high enough to impact consumer behaviour by increasing the cost of fuel use, except in the case where carbon taxation is used solely to raise revenue for other mitigation programs (ibid.). To this end tax levels of 50 EUR/t CO_2 or more have been implemented or proposed; (2) a carbon tax system should be endogenous and take into account market developments to mitigate rebound effects. This also avoids that large fuel price increases counteract the impact of the tax such as it appeared to be the case in Denmark; (3) as an interesting option the level of carbon taxation could also be related to specific greenhouse gas emissions reductions goals; (4) carbon taxation interacts with other policies and should neither necessarily be viewed in isolation, nor lead to an increase of the overall tax burden; and (5) with regard to the rebound effect it does matter how tax revenues are spent. Ideally, they will contribute to financing other mitigation measures.

For the transport sector, a number of other tax instruments exist. This paper has reviewed green vehicle ownership taxes as-well as congestions taxes. With regard to green ownership vehicle taxes are an instrument most effective in bringing about the adaption of energy-efficient technology. However, it is also clear that seen on its own, the potential for rebound will be very high if other measures are not introduced simultaneously. The reasons for this are twofold: (1) a green ownership tax will increase the fixed cost of owning a car thereby increasing the incentive to drive “as much as possible” and (2) it decreases the cost per kilometre of travel, leading to direct and indirect rebound effects. Potential mitigating measures might include fuel taxes (carbon taxes) or for urban areas congestion charging.

Changes following the introduction of a congestion tax are typically associated with a one-off effect. It also appears to be the case that the relationship between chargeable traffic and congestion is not clear cut. After the initial shock following the introduction of the congestion charge in London, traffic again went up by 1 per cent in 2005 and 2006, but the level of congestion increased by more than 10 per cent in both years (Givoni, 2012). For a charging scheme to be successful in terms of reducing congestion, a detailed local model of traffic flows should thus precede the implementation of the scheme. When designing congestion charging schemes the potential for rebound should also be taken into account. As was discussed in the previous section, there is some indication that traffic may have shifted to non-chargeable travel and that bus usage did increase considerably. Mitigation policies include a public transport initiative, including resources for increasing the efficiency of the public transport fleet.

In addition, if congestion charging is aimed at keeping traffic constant, then the charge should increase in line with economic development and population growth. For Stockholm, with a projected employment growth of 2 per cent per annum this would amount to a real term charge increase of also 2 per cent per year. (Börjesson, et al., 2012) Finally, it should also be noted that due to the associated costs of implementing large-scale schemes congestion charging might not generate positive net revenue and as such any Austrian city considering such a scheme should be clear on the fact that its primary aim is to reduce congestion and traffic in urban areas and not to raise additional revenue for city councils.

In the building sector, subsides and grants play an important role to incentivise retrofitting and renovation thereby improving the energy efficiency of the building stock. However, subsidies and grants are usually tied to very high standards for renovation, which implies that they operate in the part of the cost curve where marginal costs are high. Building programmes should therefore be combined with tools and apps, which allow households a better monitoring of their consumption patterns, ideally the installation of those tools, such as smart meters, should precede the renovation or retrofit. When designing or analysing subsidy programmes the potential trade-off between cost effectiveness and the highest renovation standard should be explicitly modelled.

In terms of general energy and climate policy, the building sector often plays an important part in achieving national consumption and emissions targets, with Austria not being an exception. It is therefore key to include realistic estimates of the rebound effect when improving energy efficiency in residential buildings, so as not to overestimate achievable savings. The rebound effect for domestic heating for example could be in the range of 10-30 per cent and even up to 50 per cent for low-income households. In addition, free-rider effects, i.e. renovators who benefit from subsidies even though they would have renovated anyways, should at least be considered when designing a building programme. Paying out subsidies to those who would have taken action in any case is economically very inefficient. The magnitude of this potential effect is currently not well known since figures where provided vary widely (0-30 per cent). (Rosenow & Galvin, 2013) This uncertainty with regard to the free-rider effect highlights the need for further research in this area.

3.2 Other Measures

The IEE-funded project Energy Efficiency Watch evaluated various energy efficiency measures in different sectors in Austria. The results showed that Austria already has comprehensive policy instruments, with numerous good practices in the buildings and public sector; however, main improvements could be undertaken in the appliances and transport sector (Schüle, et al., 2013). The nationwide klima**aktiv** (Austrian Climate Protection) initiative[8] is a good example of how umbrella programs can help raise awareness through a variety of targeted programmes and actions. The transport sector is listed as the sector needing the most improvement in policy measures. Though useful information tools, such as the energy-efficient product platform topprodukte.at, exist in Austria, economic incentives for the purchase of energy-efficient products could be improved.

[8] http://www.klimaaktiv.at/english/

The careful analysis of the above-reviewed literature has demonstrated that a broad policy mix is often the best way to counter rebound effects. Policy mixes can help overcome different market barriers and can adapt better to changes to the regulatory and financial landscape than singular policy measures. Experiences with countries have shown that technology procurement is more likely to lead to widespread, long-lasting change in the market, if it is linked to further actions, either concurrent or subsequent (e.g. buyer education and promotional campaigns, energy efficiency labels, efficiency standards) (ten Cate, et al., 1998). Certain policy measures, such as financial incentives, are best introduced to stimulate early adopters to achieve a higher penetration of energy efficiency products, while other measures, such as codes or standards, can help eliminate inefficient technologies from the market at a later stage (Rosenow, et al., 2016). Technology procurement can play an important part in a country's technology infrastructure policy (TIP), the ability of a country to specify the functional characteristics of products and systems and the generated technology capabilities (Teubal, et al., 1996).

As demonstrated above, fiscal measures such as carbon or energy pricing can help reduce rebound effects by ensuring that the cost of energy services remains stable, while energy efficiency continues to improve (Sorrell, 2007). Standards and regulations targeting the transport sector are only supply side mechanisms, which help stimulate promote research and development and create new markets. However, policy measures designed at targeting the demand side, such as economic incentives (ex. fossil fuel taxes, CO_2 taxes), should also be implemented alongside other measures to help accelerate the diffusion of alternative vehicles, while also helping to raise awareness of more environmentally friendly technologies.

Fiscal measures on their own may be insufficient to fully counter the rebound effect, since other barriers (i.e. diffusion of energy-efficient products) are not targeted. A policy mix is therefore the best option for targeting rebound. As shown in by Rosenow et al. (2016), information and advice programs are generally complementary, such that savings from a combination of policies would be greater than the savings from one single policy measure. Complementary measures targeting sectors should be implemented to guarantee increased energy savings and long-term behavioural change, while mitigating rebound effects. The design of standards, labels and codes should be developed on a case-to-case basis in order to take local environmental conditions and the local market conditions into consideration. Enforcement and monitoring of standards is also of utmost importance, especially in the transport and building sector, since policymakers can learn from experiences to better develop new policies. Though the rebound effect presents an important caveat to programs designed to improve energy efficiency, it usually does not negate overall efforts. Policies should be designed with the direct, indirect and economy-wide rebound effects in mind, so that standards, taxes and other measures can be set at the most appropriate level. In developing energy efficiency policies, it becomes necessary to advocate the need for a shift from increased consumption practices to sustainable living practices to guarantee an absolute reduction in energy consumption (Maxwell, et al., 2011).

4 Summary

To summarise all energy efficiency policies introduced above, Table 5 provides an overview of main instruments and highlights any accompanying measures, which could be aimed at mitigating rebound effects. In general it can be concluded from the literature review and recommendations above, that while rebound effects do play a potential role in (almost) all energy efficiency polices, there do exist rebound mitigation and accompanying measures that can address at least some of the adverse effects created by direct, indirect and economy-wide rebound. In particular, we find that the interaction between fiscal and other measures such as labels & standards or awareness raising campaigns can provide a useful avenue towards the optimal policy mix.

Table 5: Main Instruments with Accompanying Measures Aimed at Mitigating Rebound

MAIN INSTRUMENT	USAGE OR ADAPTION	REBOUND MITIGATION	ACCOMPANYING MEASURE
Carbon Taxes	Usage	Rebound mitigation generally not necessary; economy-wide rebound should be monitored	Tax design should address issue of general increases in price level across the economy; Information and awareness raising campaigns can improve technology adaption
Green Car Ownership Taxes	Adaption	Rebound mitigation strongly recommended	Fuel taxes, carbon taxes or any other measures related to car usage
Congestion Taxes	Usage and Adaption (if alternative fuel vehicles are exempt)	Rebound should be taken into account when designing scheme; substitution towards out-of charging hours, buses or exempted vehicles might occur	Adaption measures geared towards alternative fuel vehicles; Public transport initiatives (investment in increased frequencies, efficient bus fleet etc.)
Subsidies and Grants in Building Programmes	Adaption	Rebound can be a major issue; Policy evaluations that are based on EPR may substantially overestimate actual energy savings	Standards and labels for buildings are usually a prerequisite for subsidies; Awareness campaigns and installation of smart meters necessary to mitigate rebound
Campaigns for highly-efficient appliances	Adaption	Rebound mitigation highly recommended	
Information platform for highly-	Adaption	Rebound should be considered, in particular if additional	Energy Monitors and Smart Meters can address some

efficient appliances		appliances instead of replacements are purchased	rebound issues
Smart Meters & Energy Monitors	Usage	Rebound should be considered, if the use of smart meters leads to purchase of additional appliances	Essential in relation to retrofit programmes
Green Public Procurement (GPP) & Energy-Efficient Procurement (EEP)	Usage	Rebound mitigation generally not necessary	Labelling and standards related to energy-efficient appliances or buildings
Labels and standards for highly-efficient appliances	Adaption	Rebound mitigation generally not necessary	Awareness raising measures coupled with selected fiscal benefits (e.g. subsidies)
Labels, standards and codes for efficient buildings	Adaption	Rebound mitigation in particular for non-commercial buildings necessary	Awareness raising measures with regard to optimal use of heating/cooling systems
Labels and standards for vehicles	Adaption	Rebound mitigation highly recommended	Fiscal measures related to usage such as fuel taxes; adaption measures such as grants for alternative fuel vehicles

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About the Authors

SHRUTI ATHAVALE, MSC

Shruti Athavale is an expert in energy and climate policy at the Austrian Energy Agency (AEA). Her main fields of work are renewable energy, energy efficiency and international development cooperation. Shruti has been working on projects in the EU, Central and Eastern Europe, West Africa and Asia and has co-authored several publications on renewable energy. She holds a Bachelor's degree in international development from the University of Vienna and a Master of Science degree in environmental technology and international affairs from the Vienna University of Technology and the Diplomatic Academy of Vienna.

KARINA KNAUS, PHD

Karina Knaus heads the Centre Economy, Consumers & Prices at the Austrian Energy Agency. She coordinates and contributes to projects dealing with energy and climate policy and the impact on the economy and all relevant stakeholders. Previously she has worked for the Austrian energy regulator and lectured and researched at the University of Vienna in the fields of public utilities, industrial organization, energy and transport. Ms Knaus holds undergraduate degrees in Economics from the University of Bristol, a PG Diploma in Economics for Competition Law from King's College London and a PhD in Economics from the University of Vienna with a thesis on "The Privatisation of Public Utilities".

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