Halving worldwide electricity demand for residential cold appliances through appropriate policy packages

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Abstract

Refrigerators and freezers (subsumed under the term 'cold appliances') are among the most widely used electrical appliances in the residential sector all around the world. Currently, about 1.4 billion domestic cold appliances worldwide use about 650 TWh electricity, which is 1.2 times Germany's total electricity consumption, and cause CO_2 emissions of 450 million tons of CO_2eq.

Although the specific electricity consumption per volume of cold appliances has decreased during recent years due to technical progress and policy instruments like labelling and eco-design requirements, total worldwide energy consumption of these appliances is on the increase. Scenario calculations were carried out for 10 world regions by the Wuppertal Institute. Results show that about half of the energy consumption could be saved with the most energy-efficient appliances available today, and even higher savings will be possible with next generation technologies by 2030. According to the analysis, these savings are usually very cost-effective.

All these aspects are part of the new website "bigEE.net – Your guide to energy efficiency in buildings" which aims to provide information about technical options but also about policies to support the development of energy-efficient appliances.

To initiate and foster market transformation of energy-efficient appliances it is highly advisable for policymakers to generate appliances-specific policy packages. Since each regional market has its specificity (e.g. energy prices, typical appliance affecting the cost effectiveness of efficient appliances), the barriers for the market transformation of single product groups are also specific and need to be addressed by appropriate policies and measures. Elements of measures to build appropriate specific policy packages for refrigerators will be presented in the paper, and the refrigerator package from California (USA) demonstrates the successful implementation of a sector-specific package.

Introduction

Domestic refrigerators and freezers are among the most widely used electrical appliances in the residential sector all around the world, contributing significantly by their electricity consumption to the greenhouse effect and are therefore the focus of political instruments like the introduction of labels, minimum energy performance standards (MEPS) or subsidies for efficient appliances to limit their electricity consumption.

This raises the question of how high the worldwide energy consumption of cold appliances in the different regions of the world is today and how the number of devices and the power consumption per unit and so the total electricity consumption for cold appliances will develop in the future in the business as usual case.

It is well known from international appliances databases like "Topten" (www.topten.info), which present the most efficient cold appliances worldwide, that huge differences between the average and the most efficient appliances exist. Based on this, the question arises, what is the saving potential if most efficient cold appliances are applied and by what kind of policies and policy instruments these potentials can be tapped.

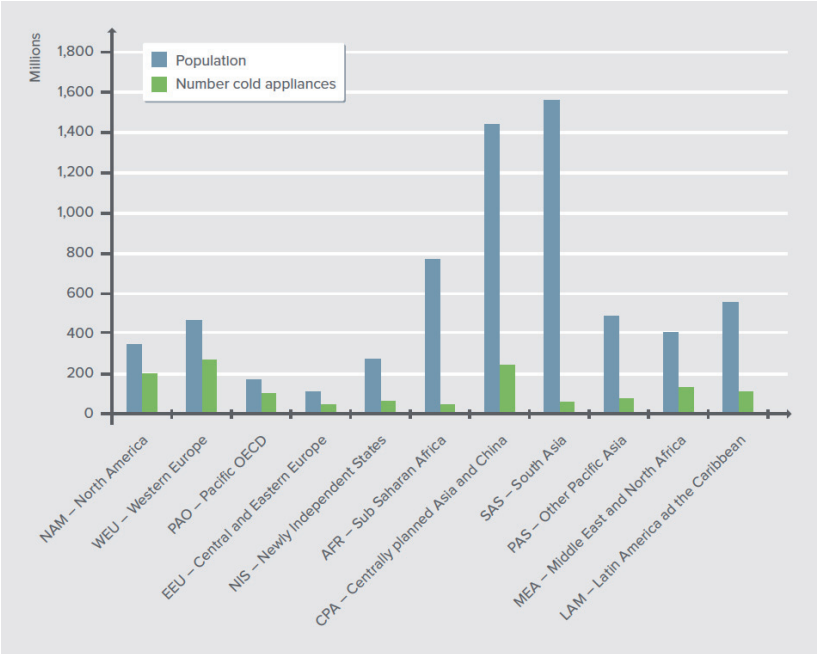

Figure 1. World population and number of cold appliances in the different world regions according to IPCC systematic. Source: WEC 2009, IEA 2010 and own calculation.

Distribution of current worldwide electricity consumption of domestic refrigeration

Country specific bottom-up analysis – based on several sources[1] all around the world show that households are currently using 1.4 billion refrigerators, fridge freezers and freezers. The average electricity consumption of these cold appliances amounts to about 450 kWh per year and appliance. With an annual total electricity consumption of 650 TWh, they account for almost 14 % of the electricity consumption of the residential sector and cause worldwide annual greenhouse gas emissions of 450 million tons of CO_2eq.

Thereby, the distribution of domestic refrigerators and freezers is very uneven between different world regions. In North America, Western Europe and Pacific OECD 1.6 to 1.7 people own one cold appliance, whereas in other world regions the level of ownership is still well below saturation (see Figure 1). This is expected to change significantly in the future, especially due to the booming markets in Asia (CLASP/LBNL 2007).

The worldwide uneven distribution of domestic cold appliances as well as their different size and efficiency levels lead to large differences in electricity consumption of this group of appliances in different world regions. The results of the bottom-up analysis are shown in Figure 2.

Techno-economical saving potentials for domestic cold appliances

The bottom-up model used for the purposes of this paper is a simplified version of the DEESY Stock Model developed by the Wuppertal Institute, which assesses scenarios with focus on energy consumption and cost.[2] According to the development of the stock volume[3] and the typical lifetime of an appliance (15 years for domestic refrigerators and freezers), the model calculates the per-annum market volume for each year of the covered scenario time period (2010 to 2030), including the first-time acquisition as well as the replacement of end-of-life appliances. The techno-economical characteristics of the typical product purchased in a certain year are dependent on the Base Case and Best Available Technology (BAT) available at the time of purchase and on a weighting factor reflecting the level of energy efficiency for the respective scenario. The modelling of the historical appliance stock purchased within the 15 years in advance of the covered scenario time period (1995 to 2009) is essentially based on the same methodology. However, the development of these preceding years is additionally calibrated for the base year (2010) to meet the expected stock volume in this year[4].

In order to assess the techno-economical saving potential of the most efficient cold appliances, subsequently two scenarios are compared: a Baseline scenario, in which Base Case products have 100 % market share after 2010, and an Energy Efficiency scenario, assuming a 100 % market share of BAT products. The

1. IEA 2010, WEC 2009, Department of the Environment, Water, Heritage and the Arts 2008, Hollanda 2010, Schaeffer 2008, Vendrusculo 2008, Natural Resources Canada 2010, Fridley 2007, 2008, Lin 2006, Lu 2006, Bertoldi 2006, Ademe 2009, Presutto 2007, Qader 2009, Hagan 2006, The World Bank 2006, 2008, 2009, De la Rue du Can 2009, Letschert 2007, Murakami 2009, Cabanas 2009, WECS 2010, Ministry of Economic Development 2010, Foran 2010, DOE 2009.

2. For more information on the DEESY stock-based bottom-up accounting model see ECN (2011).

3. Future stock volume (2020, 2030) based on CLASP PAMS2007 model (CLASP/LBNL 2007).

4. Existing stock volume of domestic cold appliances in 2010 is based on own elaboration by Wuppertal Institute.

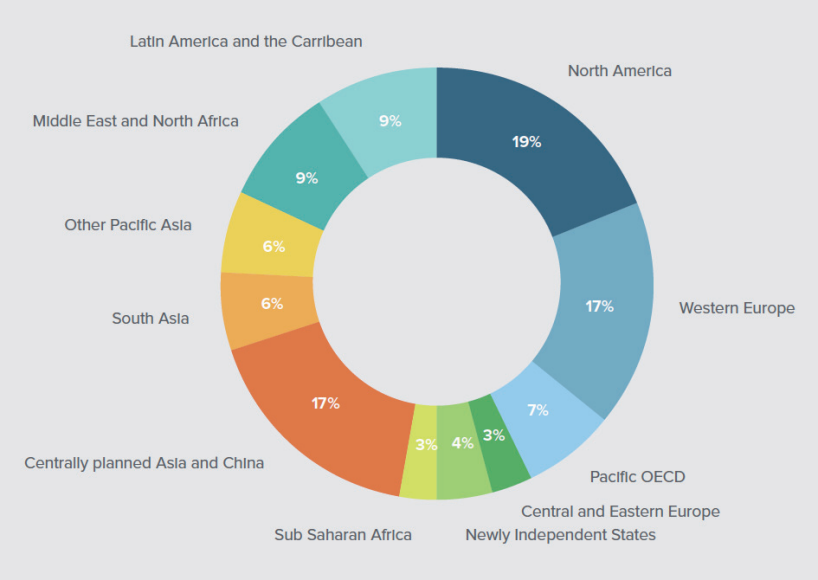

Figure 2. Worldwide distribution of electricity consumption for domestic cold appliances. Source: WEC 2009, IEA 2010 and own calculation.

characteristics of the Base Case and BAT products are based on the country specific bottom-up analysis, which was performed as preparatory work for the modelling[1]. Although, in principle, the same technology and types of cold appliances are used worldwide, there are also major regional differences regarding the dominating types of appliances, refrigerants, efficiency standards and recycling procedures. Consequently, the savings in terms of energy and costs depend on the year and the world region considered respectively.

As the results from the model calculations show, large efficiency improvements can be achieved globally if the most energy-efficient appliances available on the market are systematically purchased instead of standard technologies. Despite the expected 27 % increase of the worldwide cold appliance stock in use by 2020 and the 62 % increase by 2030, the annual electricity consumption by domestic cold appliances could be reduced from 650 TWh to 475 TWh by 2020 and to about 400 TWh by 2030 (see Figure 3) with the best available technologies on the market. The potential would be even larger and achieved faster if old and inefficient cold appliances would be replaced and recycled before they have reached the end of their technical lifetime.

These calculations are based on the assumption that in the energy efficiency scenario every time a new cold appliance is bought, always the most energy-efficient BAT model is chosen, both as end-of-life replacement or as first-time acquisition. They include anticipated technical improvements in the most efficient future models as well as an increasing saturation and the trend to bigger models.

Based on the assumptions of the performed model calculation[5], over the lifetime of the energy-efficient refrigerators and freezers in use by 2030, consumers worldwide would benefit from total net savings of around €13 billion (including energy taxes and value added taxes) and benefits to society would be about €10 billion. However, the actually achievable savings are dependent on varying investment costs and electricity prices in the different world regions. For example, the incremental investment costs for the best available technology (BAT) could be very low in countries where already high efficiency standards are established and high where no market and no manufacturer of efficient refrigerators and freezers exist.

Therefore, regionally optimized policy measures and programmes have to address this technical efficiency improvement potential under consideration of cost-effectiveness for society as well as for end-users.

A policy package for appliances

The previous section has illustrated the possible energy savings of refrigerators and freezers worldwide and in different world regions. However, there are still lots of inefficient appliances available on the market and market forces alone are often unlikely to bring a very high energy-efficient market development about. There are various barriers to manufacture, sell or buy energy efficient products that hinder a market transformation towards energy efficiency. All elements and levels of the appliances value chain have their own and specific characteristics. Financial, knowledge and technical barriers as well as lack of interest and the investor-user dilemma are some of the major reasons why there is a gap between the saving potentials and the energy savings actually realised by markets alone (Thomas 2006; IEA 2008).

Policy is needed to overcome the respective barriers and to exploit the existing potentials. Policy-makers have to intervene and develop adequate strategies including a comprehensive policy package to change this market development. The overall goal for policy makers should be to move the market towards to the best available technology and perspectively to the best not yet available technology (BNAT) with very high energy efficiency levels.

To reach this goal policy has to pay attention to every actor in the value chain. By knowing the barriers of each type of actor, the policy package can be adapted to guarantee de-

5. Presuming an average worldwide electricity price for all world regions.

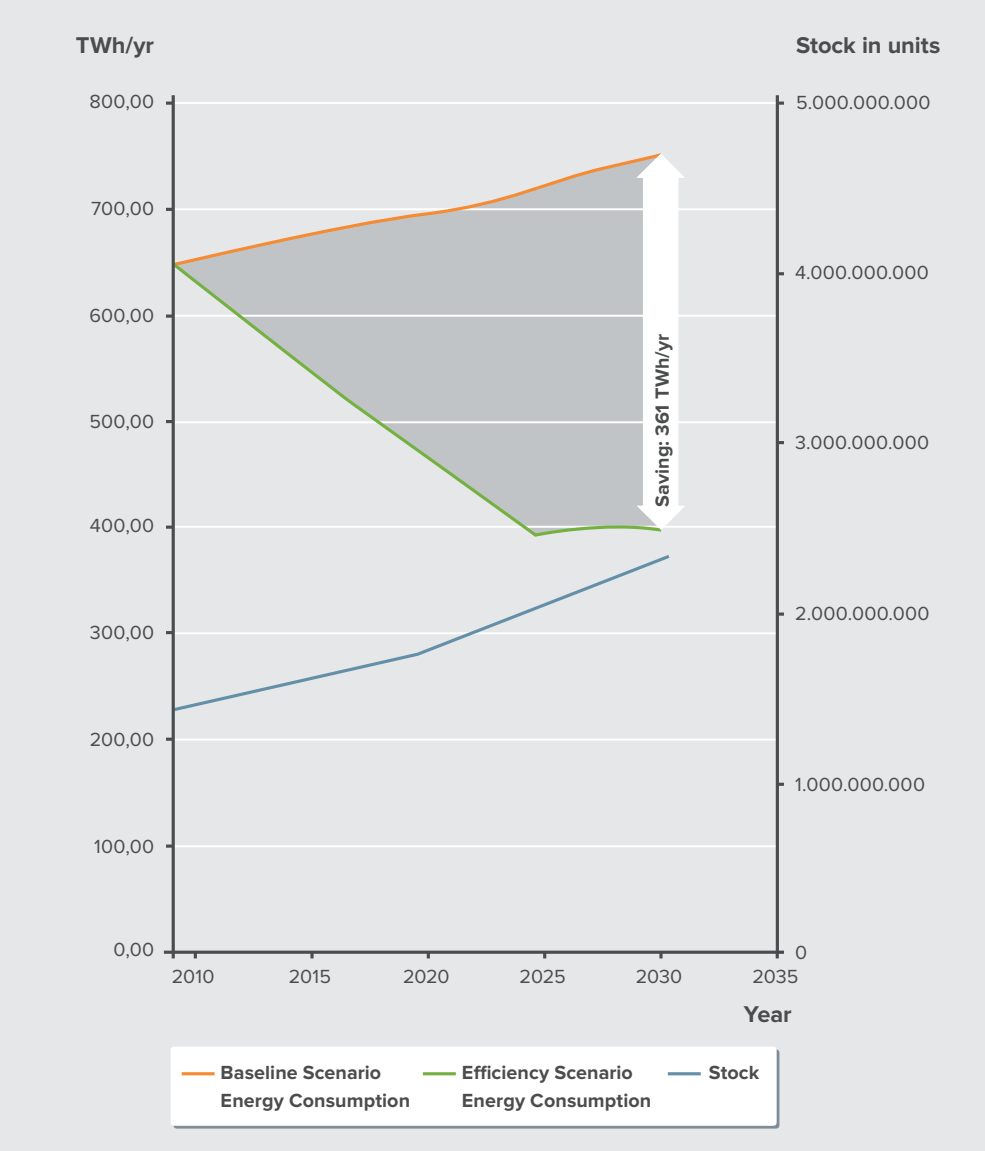

Figure 3. Development of the worldwide domestic cold appliances stock 2010-2030 and the total electricity consumption in the Baseline Scenario versus the Efficiency (BAT) Scenario. Source: own calculation; WEC 2009 and IEA 2010 for current electricity consumption and population data.

sired results and achieve the greatest possible energy savings. Experience from pro-active countries and an analysis of market barriers show that several instruments need to interact and reinforce each other in a comprehensive policy package. Every policy measure is tailored to overcome one or a few of the mentioned market barriers, but none can address all these barriers (Tholen & Thomas 2011). The impact of well-combined policies is often synergistic i.e. the impact of two or more instruments is often larger than the sum of the individual expected impact. Therefore different policies addressing the demand- and supply side of markets should be properly combined according to regional circumstances. As pro-active countries have demonstrated, a comprehensive and coherent policy package for energy efficiency will usually provide a sound balance between clear ambitious mandatory measures, incentives, information and capacity building. It also needs a governance framework to enable implementation of these policies.

Legal provisions on minimum energy performance standards (MEPS) reduce search and transaction costs and partly overcome the investor-user dilemma. They are a cost-effective way to eliminate the segment of the worst energy-performing products from the market. However, they do not harness additional savings potentials due the most energy-efficient products in such cases. Therefore, appliance standards are often combined with labelling and rebates in order to give incentives for investments beyond the level required by the MEPS. Financial or other incentives can give the decisive push that makes people opt for the more energy-efficient investments. In addition, financing instruments such as soft loans can be needed to overcome potential incremental costs for BAT products and to enable investors to make more sustainable upfront investments.

To pull the market even more into an energy efficient direction, information programmes, trainings for sales staff and manufacturers, and especially procurement programmes can influence the market to promote energy efficient appliances.

Table 1. Results of model calculations by world regions (model calculation by Wuppertal Institute 2012).

World regions	Present situation			Results of model calculations for 2030			
	Stock number domestic cold appliances [m]	Electricity consumption [TWh/year]	Average electricity consumption in the stock of a domestic cold appliance [kWh/year]	Stock number domestic cold appliances [m]	Baseline Scenario electricity consumption [TWh/year]	Efficiency Scenario electricity consumption [TWh/year]	Electricity savings Efficiency Scenario vs. Baseline Scenario
North America	209	123.3	590	265	117.7	62.0	47 %
Western, Central and Eastern Europe	335	126.3	377	411	111.1	59.1	47 %
Pacific OECD	108	48.6	450	137	49.6	28.0	44 %
Newly Independe nt States	69	28.5	413	125	39.2	17.8	54 %
Sub Saharan Africa	49	20.4	416	107	33.7	18.1	46 %
Centrally planned Asia and China	260	108.3	417	570	179.7	96.5	46 %
South Asia	63	40.2	638	138	54.5	29.4	46 %
Other Pacific Asia	82	31.8	388	148	48.1	29.2	39 %
Middle East and North Africa	142	60.4	425	256	80.9	43.5	46 %
Latin America and the Caribbean	118	61.6	522	175	60.2	30.1	50 %
Total	**1,435**	**649.4**	**453**	**2,332**	**774.8**	**413.8**	**47 %**

With procurement programmes but also with bulk purchasing projects and competitions it is even possible to go beyond the best available technology and to support a market development towards BNAT with very high energy-efficiency levels.

Summarising it is essential to promote market penetration of BAT and to ensure that standards have a dynamic impact. In addition is necessary to add consumer-oriented instruments to push the manufacturers to create even more energy-efficient appliances and to educate consumers about further saving possibilities.

Figure 4 illustrates exemplarily a comprehensive policy package for appliances and describes the interactions between minimum energy performance standards, energy labels, financial incentives, energy-efficient procurement, RD&D (Research, development and demonstration) promotion as well as education and training programmes.

An established policy package for refrigerators

To initiate and foster market transformation of energy-efficient appliances it is highly advisable for policymakers to generate appliances-specific policy packages. Each appliance and each market has its own specificity and the barriers as well as incentives for the market transformation are also diverse. Therefore the general appliance package presented in the last paragraph must be adapted to specific circumstances of single product groups – in this case refrigerators and freezers.

Cold appliances are one of the most regulated product groups worldwide and policy makers already have lots of experience with these appliances (Harrington & Holt 2002). Furthermore refrigerators and freezers have several specialities like the high energy and cost saving potentials (the life-cycle costs are commonly more than double of the purchase price, see results of the techno-economical modelling) as well as many differing technical characteristics (volume and additional features like

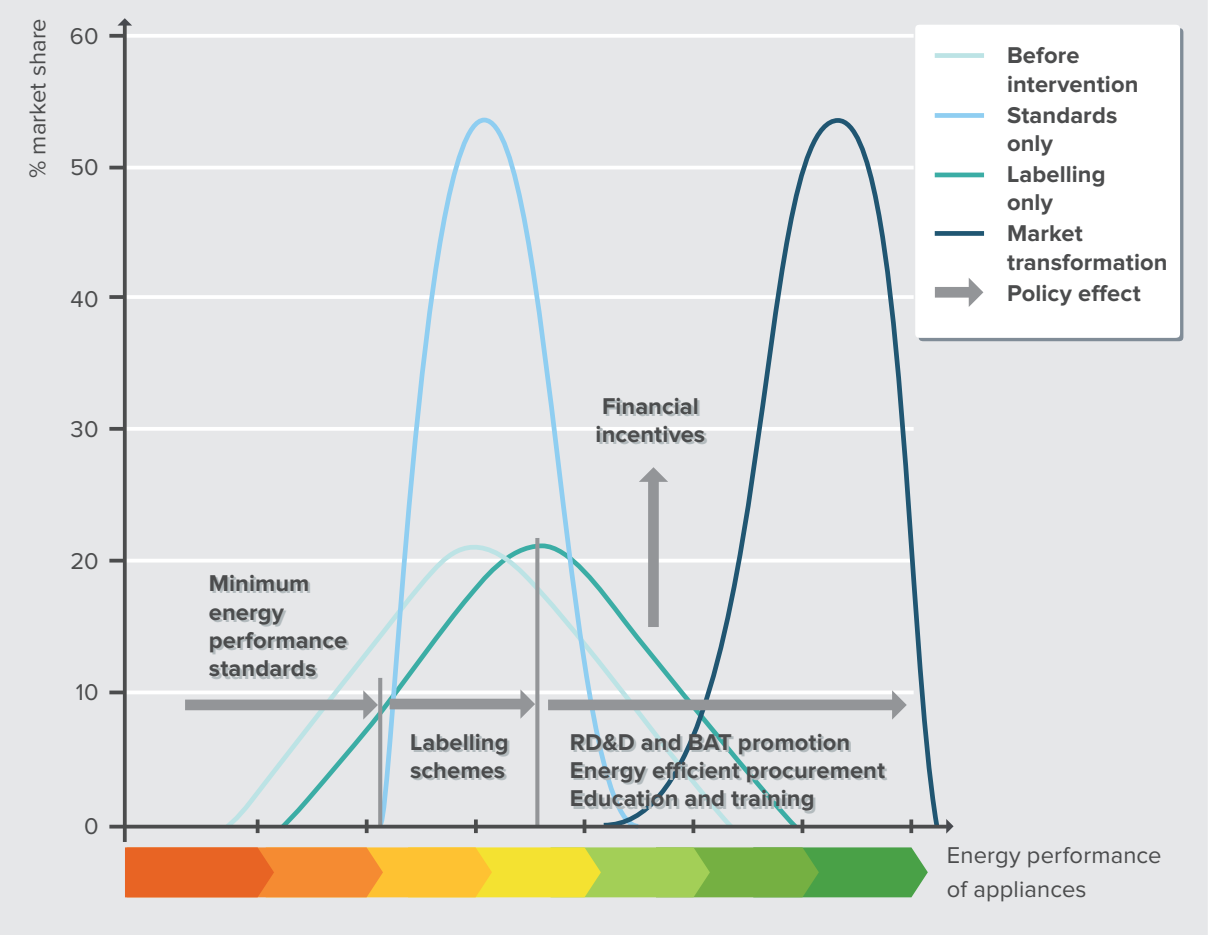

Figure 4. The interactions of policy instruments for energy efficiency in appliances. Source: Wuppertal Institute 2012.

climate class, built-in appliance, free-standing freezer, 'no-frost' function, etc).

The next table lists and describes the different policy options, which can be used for an overall policy package. This does not mean that governments seeking to improve the energy efficiency of cold appliances have to implement all of these policies in order to be successful, but they should combine a selection of instruments tackling the most important market barriers. A sound balance between regulations, financial incentives, information campaigns, capacity building measures and BAT promotion should be provided. The different policy options, their alternatives and the specialities regarding refrigerators and freezers are listed in Table 2.

In addition to these specific policies another important part of an effective policy package and a precondition for the implementation of single policy measures is the governance framework. This includes a concrete and ambitious roadmap, an organisation to design, implement and monitor the policy, an independent test procedure, and financial mechanisms such as Energy Saving Obligations and Energy Efficiency Funds to realise a successful implementation of specific policies in this package. Several countries already implemented these kinds of policies successfully. Good practice examples can be found on www.bigee.net/.

Every government has to find a specific own way to implement a comprehensive policy package to address the demand and supply side and to increase the energy efficiency of appliances significantly. Guidance for every country how to combine policies and how to implement appliance-specific policies cannot be demonstrated here due to national circumstances, already implemented policies and different policy strategies.

An example of a successfully implemented policy package for refrigerators comes from California (USA). This is not transferable to every other country but it gives an idea what can be done to increase the energy efficiency of a specific product group.

Case study: A refrigerator package from California (USA)

The refrigerator package from California (USA) demonstrates the successful implementation of a sector-specific package. California's comprehensive policy package for energy efficiency in general and for refrigerators in particular consists of several federal and state measures in order to reduce electricity consumption. The state follows a push and pull strategy with policies and measures for manufacturers and consumers to increase the energy efficiency of refrigerators.

First of all, minimum energy performance standards (MEPS) form the central element of the policy in California. The standards were firstly mandated in the U.S. by the state of California in 1976. This regulation was followed by U.S. standards that became effective in 1988. Today, California's 2010 Appliance Efficiency Regulation comprises federal and state-specific

Table 2. Policies and measures for refrigerators and freezers.

Policy instrument	P&M for refrigerators	Specific policy package for energy-efficient refrigerators
Regulation	• MEPS • Top Runner Approach	Regulatory instruments like minimum energy performance standards (MEPS) are one if not the most important instrument to increase the energy efficiency of refrigerators and to remove the worst products from the market in a cost-efficient way. MEPS should be created by law and strengthened regularly. With ambitious requirements significant energy savings can be achieved. Experiences from all over the world confirm the success of MEPS for refrigerators (see for example the next chapter). This instrument can address the energy consumption but also noise and other aspects. The TopRunner programme follows a similar approach. Thereby, the definition of national or preferably internationally harmonized test standards is a basic requirement to adjust and initiate appropriate regulatory instruments. (Currently, for cold appliances there is still the issue that the product group is "subject to the most complex and diverse range of […] test procedures" including different methods for calculating the temperatures, door openings, defrost mechanism, having freezers loaded or unloaded etc.; Harrington & Shane 2002).
Transparency and information	• Mandatory and voluntary labelling schemes • Provision of information • Feedback measures	Based on the MEPS regulations, mandatory labelling schemes (e.g. a rating between A and G or 1 and 5) are an important instrument to target energy-efficiency. They give incentives beyond the level required by MEPS (WEC & ADEME 2004). Consumers get information about the energy consumption and other aspects (size of the refrigerator, life-cycle costs, noise) and can compare different products. To be effective these labels should be updated regularly. Voluntary labels can be an alternative and inform consumers about the most efficient products in the markets. Information campaigns to educate end-users should be implemented at the same time to guarantee the success of the label. They should raise the awareness and inform end-users about energy and cost-savings, noise aspects, and the usability ("choose refrigerators suited to your room size and needs", "keep the refrigerator between 6 and 8 degrees Celsius" etc.). Smart meters are another method to provide information to consumers. These information programmes can be used to underpin other programmes such as financial incentives, MEPS and procurement programmes (OECD & IEA 2003).
Incentives and Financing	• Financial incentives • Financing	Financial incentives work very well to support energy-efficient refrigerators and to guarantee a broad market introduction. Incentives like rebates (the most common incentive), tax rebates or loans have already realised the replacement of old and inefficient appliances in many countries (IEA & OECD 2003). In combination with a programme for low-income households and a recycling programme the instrument can realise high energy savings (see for example the rebate scheme from the Netherlands or the Utilities' Refrigerator Replacement Programme from Brazil). Ideally, the mandatory label is used to inform the consumers for which product an incentive is possible. Furthermore the label can guarantee a transparent procedure. All incentive programmes are dependent on information campaigns for reaching their full effect (Irrek & Jarczynski 2007). Limits of this kind of policy are the possible free-rider effects and restrictions of the public budget. Is the incentive too high compared to the purchase price, additional purchase of appliances may be induced. Financing is essential to address the potential incremental costs of BAT products and the lack of finance or willingness to make an advance investment into energy efficiency.
Capacity building and networking	• Voluntary Agreements with manufacturers • Education and training	Voluntary Agreements (with hard targets) can be an alternative to MEPS. High energy savings can be realised with ambitious requirements and a broad consensus. Their ecological effect depends on the agreement on and the realisation of concrete and ambitious reduction targets. Education and training of professionals is important to stimulate the understanding of energy efficiency in order to increase the demand for energy efficient solutions. In addition the public will be informed about the most relevant performance factors of the respective appliance (like size, usability, noise, costs, energy savings).
RD&D and BAT promotion	• Public procurement Co-operative procurement • Research and development • Competitions and awards	Energy-efficiency procurement is an important instrument for office equipment but also refrigerators can be part of a procurement programme. With the purchase power of the public sector, the procurement programme can push the market for energy-efficient appliances. Moreover leadership by example is performed on a large scale and spill-over effects can be realised. A successful refrigerator programme is for example the Energy-Efficient Product Procurement (EEPP) programme from the USA. Bulk purchasing programmes can have a similar effect as this can build a pressure on manufacturers to produce energy-efficient products. Bulk purchasing programmes can have a reinforcing effect through a rebate programme and information campaigns (Irrek & Jarczynski 2007). Competition and awards are another possibility to pull the market towards more efficient appliances. A monitoring system as well as a research and development funding to determine BAT and to analyse the technical and political potentials complete the policy package (and prepare the knowledge base for the next MEPS tiers).

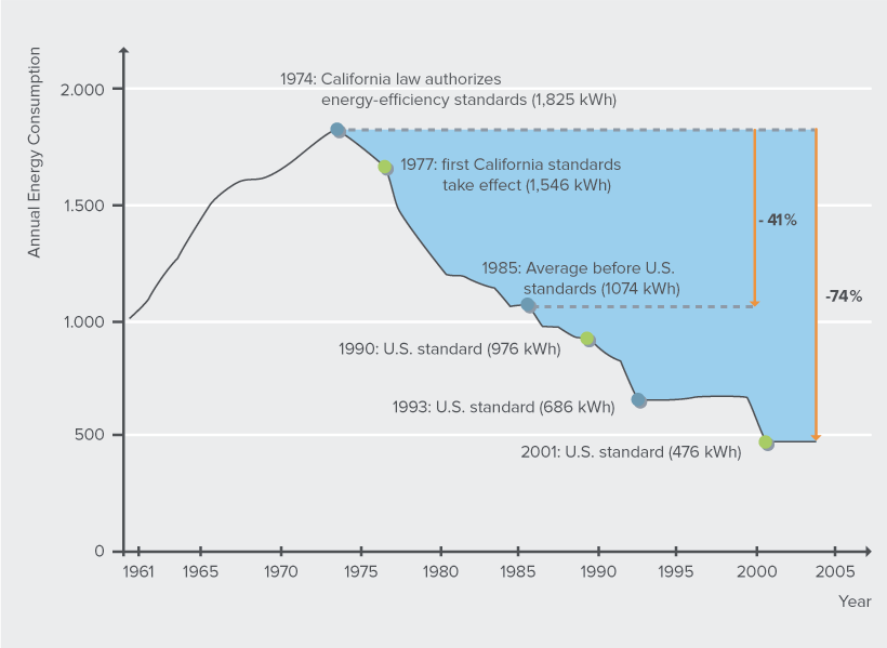

Figure 5. The power of ratcheting the stringency of regulatory standards: the U.S. example. Source: CLASP (2005).

MEPSs on 21 categories (CEC 2010) while the U.S. Department of Energy has only set more than 12 standards for the federal level (Neubauer 2011). Thus, California can still be regarded as the pioneer in establishing MEPS. As a result, the maximum allowed energy consumption of a typical fridge-freezer in the United States has dropped from 1,546 to 476 kWh/year between 1977 and 2001. Due to a further tightening of the standards, it is expected to reduce energy consumption to about 390 kWh per appliance and year after 2014 . In order to document that their appliances meet the standards, manufacturers have to pass certain tests (developed by the Department of Energy, DOE) measuring energy efficiency and energy use as well as assessing the approximate operating costs of the appliances. Figure 5 illustrates the development of energy efficiency standards in the USA.

An overall reduction target was developed in 2006. Assembly Bill 32 ("The California Global Warming Solutions Act") regulates mid-term and long-term GHG reduction levels in California. While a roadmap (Scoping Plan) specifies the overall strategy, the Strategic Plan emphasises measures on energy efficiency in particular. The plan sets ambitious goals to reduce the energy consumption by 80 % compared to the 1990 level and recommends the continuous strengthening and expanding of the appliance standards.Phasing out least efficient appliances through MEPS is as important as financially incentivising the purchase of highly efficient products. Such financial incentives are offered by investor-owned utility companies under supervision of the regulator and by municipal energy companies alike. Funds are mainly generated through the Public Goods Charge, a surcharge on electricity bill. Although this charge increases the electricity price at first, the programmes are designed in such a way that the consumer's total electricity bills and costs for purchasing and operating energy-efficient appliances will be reduced.

An example of such a financial incentive programme is the programme by the company Southern California Edison. The utility offered a refund of US$ 35 on a refrigerator, if a customer purchased an Energy Star rated model, and even of US$ 75 for the most efficient product. Between 2008 and 2010 about 96,000 appliances have benefitted from this programme. In addition to the rebate programme, a recycling programme was introduced which offers money for the recycling of an inefficient refrigerator or freezer. The introduction of a cap-and-trade programme on greenhouse gas emissions in California, in which utilities must participate, makes customer rebate programmes even more attractive.

In order to promote the rebate scheme and to increase the sales volume of very efficient products, the California Energy Commission developed a product database, in which customers can easily find products eligible for funding. In the United States, furthermore two labels – the voluntary Energy Star label and the mandatory EnergyGuide label – make it easy for customers to identify energy efficient products. The EnergyGuide label shows the energy consumption of the product in kWh/year and the estimated operational cost per year. The Energy Star label aims to enable the identification of even more energy efficient appliances. The Energy Star Programme also provides information and education programmes. The programme offers campaigns and training courses for consumers and retailers. In addition to these projects, California's government started a marketing and outreach campaign. It forms a consortium of California's utility companies, residents, businesses, institutions, government agencies and non-profit organisations that aims to save energy.

To support research and development activities California gives awards to stimulate demonstration projects. This research has also been used for California's efficiency standards.

Another policy is the energy efficient public procurement. California's public sector has the vision to become the leader in using energy efficiency to reduce both, energy use and global warming emissions. An 'innovation incubator' helps the public purchasers to select energy efficient technologies. At federal level, an energy-efficiency product procurement programme

(EEPP) was introduced in 1992. The EEPP programme provides guidance for public purchasers and it is mandatory to purchase energy-efficient products. Products have to be labelled with the Energy Star label or have to meet the standards of the designated product categories.

The complete and detailed analysis of the refrigerator package from California can be found at: http://www.bigee.net/en/policy/guide/appliances/package/3/.

Conclusion

For the BigEE project an extensive data gathering was carried out for domestic cold appliances worldwide. A modelling based on this comprehensive database has shown a growing stock of cold appliances by more than 60 % worldwide in the next 20 years. As consequence of this increase the electricity consumption is to be expected to rise by 20 % in the bigEE-appliances baseline scenario. This increase is limited due to the moderate efficiency improvement, which is assumed for the baseline.

However the modelling has also shown that with existing and expected technologies it is even possible to halve worldwide electricity demand for residential cold appliances in comparison to this baseline. In the efficiency scenario absolute reductions are possible in all regions, even in developing and emerging regions such as CPA with China, where the stock is expected at least to double within the next 20 years. One additional outcome of this study is that these electricity savings are cost-effective both for end-users and society.

However, this market transformation towards energy efficient appliances is unlikely to happen itself, therefore policy packages are needed. Within the bigEE-project a new theoretical and empirical foundation has been developed that shows what is a necessary and advisable package of policies for energy efficiency in appliances.

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