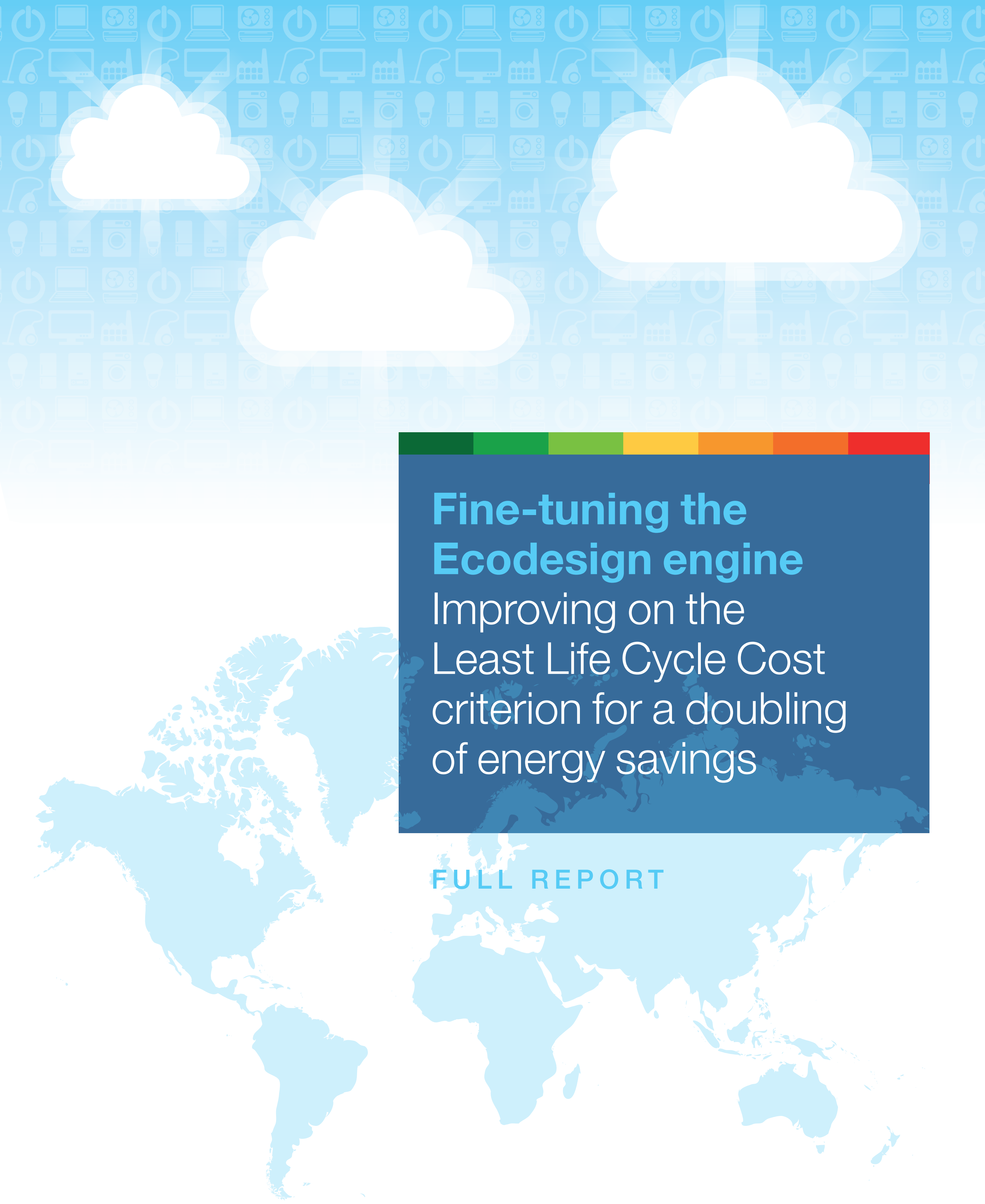


Fine-tuning the Ecodesign engine

Improving on the Least Life Cycle Cost criterion for a doubling of energy savings

FULL REPORT

www.coolproducts.eu

coolproducts
for a cool planet

For a stronger, faster Ecodesign Directive to help save the climate and money.

The Coolproducts for a Coolplanet coalition is a group of European non-governmental organisations working to ensure the EU Ecodesign Directive and related Energy Labelling policies are as ambitious as possible for the good of consumers, businesses and the environment.

The report was commissioned by Coolproducts. It was written by Edouard Toulouse, independent consultant on energy savings policy.

Published December 2013

For further details please contact:
Stephane.Arditi@EEB.org +32 2 289 10 97
Jack.Hunter@EEB.org +32 4 836 385 57

www.coolproducts.eu

Contents

Executive summary

Through the Ecodesign Directive, the EU sets environmental requirements for energy-related products that manufacturers must adhere to. The policy is an essential instrument to improve the environmental performance and harmonisation of the common market, drive down home and business energy bills and trigger industry innovation.

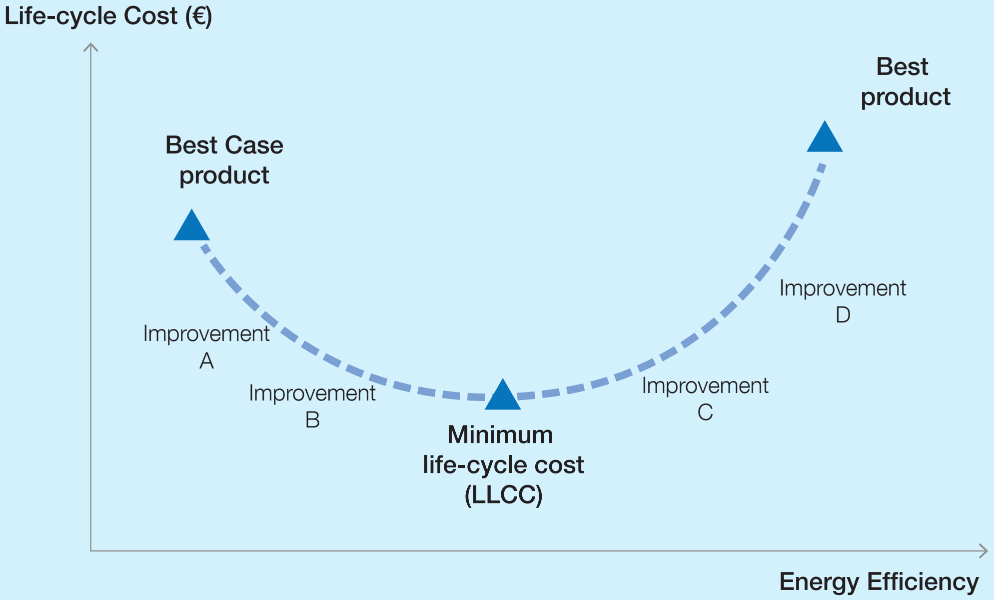
In the legal text of the directive, there is limited quantified guidance on how to actually set these requirements. The most precise criterion is the one relating to energy use: it states that '***the level of energy efficiency or consumption must be set aiming at the life cycle cost minimum to end-users for representative product models.'***

Life cycle cost theory

The standard definition of the life cycle cost of a product is the sum of its purchase price and operating costs over its lifetime (through the use of energy or other resources). The usual assumption is that an improvement in the energy performance of a product requires a change in product design that increases its price. Some of the possible improvements may pay off during the product lifetime (i.e. they reduce its life cycle cost), while others may not. On the graph below, improvements A and B, brought to a base case product, do pay-off, while C and D increase the life cycle cost. Thus, the curve goes through a minimum called the 'least life cycle cost point' (LLCC).

The Ecodesign Directive stipulates that products placed on the market should have an energy performance at least at the level of the LLCC point of representative products. In other words, they should include all available energy saving improvements that pay off during the product lifetime.

Figure 1. Life cycle cost theory



Methodological challenges to identifying the minimum life cycle cost point

Requirements set in Ecodesign regulations are meant to apply to whole product groups and not just to one single model on the market. This means that the life cycle cost analysis needs to be sufficiently generic and as representative of the product group as possible.

The determination of the LLCC level for a product group is carried out in specific preparatory studies and may involve different approaches (product approach, design option approach, engineering approach…). Considering the budget provided by the European Commission for each study, the technical and market analysis cannot dig deep on all aspects, particularly as study consultants are often faced with data availability issues.

Four conditions are particularly critical for a successful analysis:

- Realistic basis for the calculation of operating costs (energy prices, discount rates, etc.);
- Representativeness of the selected base-case products;
- Adequate screening of energy improvement options;
- Accurate estimation and anticipation of improvement costs and price impacts over time.

Regarding the latter, there is considerable literature from around the world suggesting that the cost and price impacts of energy efficiency improvements often tend to be overestimated in engineering analysis, leading to overly conservative calculations.

Relevance of the minimum life cycle cost criterion

The criterion plays a central role in the Ecodesign Directive, but is it the most relevant approach to secure effective energy savings? Five important questions may be asked, spanning conceptual aspects to more concrete implementation issues:

- Is it really necessary to include a precise criterion in the legislation?
- Is a criterion focusing on the end-user's financial gain appropriate?
- Is a life cycle cost approach always suitable?
- Is it relevant to pursue the objective of bringing the life cycle cost to a minimum?
- Is the time gap between analysis and implementation a significant flaw?

The discussion of these five questions leads to the conclusion that the criterion obviously has some merit. Its precision and quantitative nature frames the discussion on Ecodesign requirements and makes decision-making more transparent. Other economies can more easily understand levels set in the EU. The preparatory analysis can bring useful evidence to inform decisions. In addition, the rather deliberative process for implementing the criterion so far allows for some flexibility.

On the other hand, the approach has some serious limitations. The concept is not well suited to product groups characterised by a lack of correlation between prices and energy efficiency, such as electronics. Its narrow focus on the end-user benefit may undermine some broader societal benefits such as human health consequences and natural resources depletion. In terms of implementation, two major risks can be identified: insufficient promotion of combinations of interrelated improvements or integrated designs, and taking decisions based on outdated analysis that do not sufficiently anticipate market dynamics. These issues may lead to sub-optimal Ecodesign decisions that miss achievable energy saving potentials.

Recommendations in this report

- Improve preparatory study analysis and robustness of recommendations, for instance by better aligning and sharing methodological tools with other jurisdictions (such as the US);
- Find ways of improving the approach for product groups characterised by a lack of correlation between prices and energy efficiency;
- Consider targets that go beyond the LLCC point while still guaranteeing lower life cycle costs;
- Progress on the use of more accurate cost/price estimates that take into account market dynamics and societal impacts.

Case studies and policy implications

For two product case studies (fridges and tumble dryers), the implementation of possible adjustments to the minimum life cycle cost approach has been simulated and compared to the original analysis in preparatory studies. These include consideration of increased energy prices, additional societal costs, better estimates of price decline trends and market dynamics, and combinations thereof.

In both cases, the conclusion is that more stringent requirements are justified using the improved analysis. Such requirements would have brought 11 additional TWh of yearly electricity savings in the EU by 2020, compared to the seven achieved through the levels decided for the two product groups.

A hypothetical evaluation of the impact of similarly enhanced requirements on other product groups has been made, although it is not certain that the results of the two case studies can be generalised. In total, for the former two product groups plus washing machines, dishwashers, televisions and portable air-conditioners, setting more stringent requirements in a similar fashion would have secured 30 additional TWh/year of savings by 2020, compared to the 39 TWh/year achieved with current levels.

Proposal for a reformulation of the LLCC criterion in the Ecodesign Directive

Current text:

Concerning energy consumption in use, the level of energy efficiency or consumption must be set aiming at the life cycle cost minimum to end-users for representative product models, taking into account the consequences on other environmental aspects.

The life cycle cost analysis method uses a real discount rate on the basis of data provided from the European Central Bank and a realistic lifetime for the product; it is based on the sum of the variations in purchase price (resulting from the variations in industrial costs) and in operating expenses, which result from the different levels of technical improvement options, discounted over the lifetime of the representative product models considered.

Suggested text:

Concerning energy consumption in use, the level of energy efficiency or consumption is set at a level corresponding at least to the implementation of all existing improvement options that individually pay off for the end user and society during the typical life of representative product models, taking into account the consequences on other environmental aspects. Where feasible and justifiable, the level may be set at a higher performance level as long as it does not deteriorate the financial impact for the end user over the product lifetime compared to a standard product.

The analysis method uses realistic discount and energy price increase rates; it compares the cost of technical improvement options against the savings on operating expenses and monetised societal costs, in particular of pollutants, over a realistic product lifetime. The best available statistical techniques to anticipate future trends in costs/prices – such as learning curves – are used to guarantee the validity of the analysis by the time the requirements enter into force.

Introduction

Through the Ecodesign Directive, the European Union is setting environmental requirements on products that manufacturers have to comply with. A wide range of energy-related products have been already regulated. This policy is an essential piece of the legislation to improve the environmental performance and functioning of the common market. The directive helps save energy and reduce carbon emissions.

What are the rules followed by EU decision makers to decide on the level of ambition of these requirements? This is a crucial question that conditions the effectiveness and integrity of the policy process, as well as the actual environmental benefits that will be realised through the policy intervention.

After seven years of experience and in the context of the ongoing review of the directive planned for 2014/2015, it is an opportune moment to look back at the criteria and methodology of the policy and investigate what may be said about their suitability. This is especially the case if it leads to concrete recommendations to improve the functioning of the policy and unleash further benefits for EU citizens and society.

The Coolproducts for a Cool Planet campaign commissioned this report with the intention of evaluating the criteria stated in the Ecodesign Directive governing the setting of requirements for products. This reports aims to contribute to discussions on the revision of the directive.

The analysis essentially covers the most prominent and quantitative criterion of the Ecodesign Directive, namely the minimum life cycle cost target. After introducing the concept and presenting its most striking methodological challenges, the report discusses its relevance. Due to the lack of robust quantified evaluation of the efficacy of Ecodesign regulations adopted so far, the discussion can only rely on rather indirect and qualitative observations. The discussion leads to suggested policy recommendations that are simulated on two case studies in the last part of the report.

Methodological note: the analysis in the report sometimes required assumptions and data recalibrations (for instance to compare requirements in the Ecodesign regulations and preparatory studies, or for the simulations in the last part). They are not described in detail. Readers interested in background assumptions are invited to contact the author directly.

The Coolproducts for a Cool Planet coalition is a group of civil society organisations from across Europe who are working to ensure the EU Ecodesign Directive and related Energy Labelling policies are as ambitious as possible for the good of consumers and the planet.

This report was commissioned by Coolproducts member the European Environmental Bureau and written by Edouard Toulouse in 2013. The author would like to thank all the experts who have provided views or advice.

Website: www.coolproducts.eu

01 Current rules to set Ecodesign requirements in the EU

The Ecodesign Directive (2009/125/EU) – adopted in 2005 and amended in 2009 – aims at reducing the environmental impact of products placed on the EU market. The directive provides a framework through which the European Commission, with the support of member states and a consultation forum is entitled to develop mandatory regulations covering the environmental performance of specific product categories.

The scope of the directive covers energy-related products, that is household, commercial and professional products that are directly consuming energy or can have a substantial indirect impact on energy consumption (with the exception of means of transports).

The directive specifies that the European Commission shall regulate a product group when:

- It represents a significant volume of sales, indicatively 200,000 units a year or more;
- It has a significant impact on the environment;
- It presents a significant potential for improvement;
- No convincing self-regulation has been proposed by the industry sector.

In this section, we analyse the rules that are specified in the legislation to develop the regulations and Ecodesign requirements applying to product groups.

1.1 Rules to set requirements mentioned in the directive

The Ecodesign regulations developed by the European Commission may include generic (i.e. qualitative) and specific (i.e. quantitative) requirements applying to products placed on the market.

The core legal text of the Ecodesign Directive does not provide extensive methodological guidance on how to set these requirements. It mostly contains general instructions:

- It mentions that all significant environmental aspects across the life cycle of products should be considered, in particular energy consumption.
- It specifies that requirements shall be set in a way that ensures they do not impose proprietary technologies on manufacturers and do not have significant negative impacts on product functionality, affordability, health, safety, industry competitiveness and administrative burden. However, these criteria are not quantified.
- It adds that requirements shall be formulated in a way that ensures they can be verified by authorities charged with carrying out market surveillance.

The first two annexes of the directive provide more details.

The first is about generic requirements and lists a number of environmental and resource efficiency aspects that should potentially be addressed, and how manufacturers should generally evaluate alternative designs to improve product performance. However, the annex does not provide guidance on how generic requirements should or may be concretely drafted.

The second annex is about specific requirements and clarifies that these may take the form of quantified minimum performance values. It requires the Commission to ground decisions on a robust preparatory analysis and leave sufficient time for redesign cycles of products. Then, the text becomes much more detailed when it comes to specific requirements on energy use:

> *'Concerning energy consumption in use, the level of energy efficiency or consumption must be set aiming at the life cycle cost minimum to end-users for representative product models, taking into account the consequences on other environmental aspects.*
>
> *The life cycle cost analysis method uses a real discount rate on the basis of data provided from the European Central Bank and a realistic lifetime for the product; it is based on the sum of the variations in purchase price*

> *(resulting from the variations in industrial costs) and in operating expenses, which result from the different levels of technical improvement options, discounted over the lifetime of the representative product models considered (…) A similar methodology may be applied to other resources such as water.'*

In short, the Ecodesign Directive essentially contains broad and qualitative instructions, except for this rule on the life cycle cost minimum, which stands out.

Following the adoption of the directive, the Commission outsourced to a consultancy (VHK) the task of preparing a methodology for the preparatory studies that have to be carried out before discussing and adopting Ecodesign requirements for specific product groups.

This methodology (so-called MEEuP until 2011 when it was amended into MEErP to cover energy-related products) is a document providing guidance (but no formal obligations) to consultants hired by the Commission to develop preparatory studies (VHK, 2005 & 2011).

The methodology is particularly detailed in the way environmental impacts and improvement potentials of products may be assessed. As regards guidance on how to set Ecodesign requirements, the methodology mirrors the content of the directive: the focus is essentially put on the most explicit criterion relating to the minimum life cycle cost point for energy (and eventually water) use. Several sections of the methodology are devoted to this criterion[1], while much less is said about the way of setting other types of requirements on other environmental aspects.

At the time of writing this report, the Commission is investigating whether additional methodological guidance could be developed for setting Ecodesign requirements on aspects such as resource use and material efficiency (for which the concept of minimum life cycle cost for the consumer does not directly apply). Recent studies have been prepared in this context[2], but it is too early to anticipate any concrete outcome.

1.2 Prominence of the least life cycle cost (LLCC) criterion

As a consequence of the aforementioned background, the most central and refined criterion driving the preparation and setting of Ecodesign requirements so far has been the minimum life cycle cost criterion, applied to energy (and where relevant water) use. We will now focus our analysis on it.

Life cycle cost theory for energy-using products

The standard definition of the life cycle cost (LCC) of a product is the sum of its upfront cost (purchase price) and the operating costs over its lifetime (through the use of energy, water or other consumables to operate it properly). To this can eventually be added the costs of installation, end-of-life treatment and reparation and maintenance over the product's lifetime.

For a typical energy-using product, the dominating aspects are usually the purchase price and energy costs over the lifetime. A higher purchase price will increase the LCC, while an improved energy performance will decrease it.

The starting point of the LCC approach is the assumption that in general, an improvement in the energy performance of a product requires an improvement in the product design that increases the engineering / production costs and therefore increases its price (in short: a more energy efficient product is more costly than a similar less efficient product).

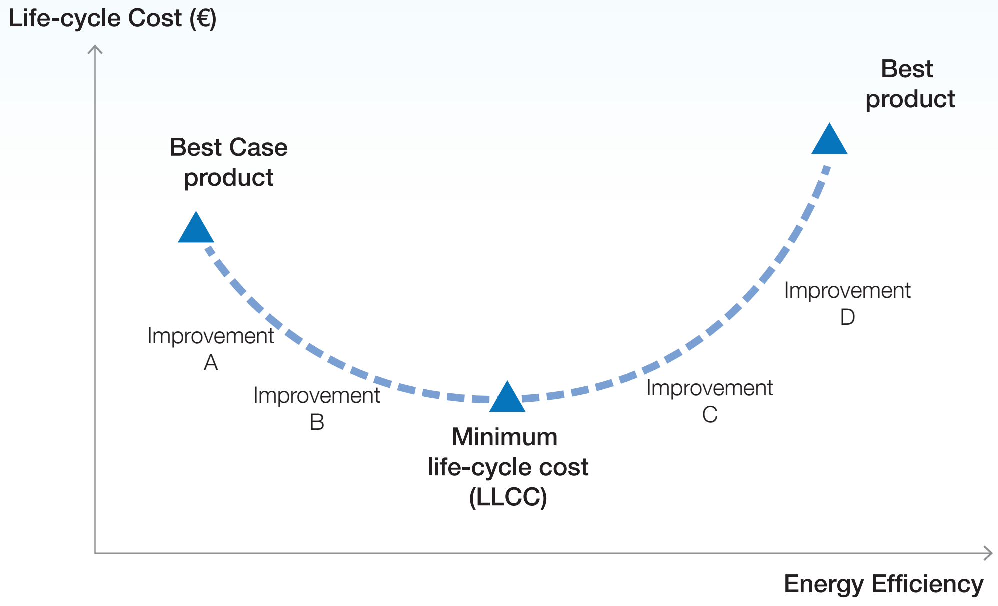
If we assume that improvements in energy performance do indeed raise the purchase price, for some the increased price will be outweighed by the savings in operating costs (i.e. they will trigger a reduction of the product LCC), while other improvements may not pay off over the product lifetime (i.e. they will increase the product LCC).

---

[1] 5.3. Base-Case Life Cycle Costs for consumers, 6.3 Life-Cycle Costs, 6.4. Analysis LLCC (Least-Life Cycle Cost) and BAT, 7.2 Design options incremental costs

[2] http://lct.jrc.ec.europa.eu/assessment/assessment/projects#d and http://meerp-material.eu/

Figure 1. Theoretical LCC graph (real LCC curves may be asymmetrical)



If we rank all available (and quantifiable) technical improvements by their LCC impact and implement them one after the other on a typical product, the LCC of the product will first decrease, reach a minimum and then go back up when the least cost-effective improvements are added. The minimum is the point where it is theoretically impossible to add another improvement that would further lower the life cycle cost of the product. It is called the minimum life cycle cost or 'least life cycle cost' (LLCC). The LCC curve is illustrated below.

Starting from a standard product on the market (with a certain energy efficiency and life cycle cost), some improvements can be implemented that will drive its life cycle cost down (on the graph: improvements A and B). At some point, the minimum is reached. From there, additional energy efficiency improvements can be implemented but will not pay off during a total standardised lifetime. This may be because they entail expensive product redesign or are based on insufficiently mature technologies. Improvements C and D drive the life cycle cost up. At the end of the curve, the product that includes all existing improvements achieves the highest possible energy performance at the time of the analysis, and is often referred to as the theoretical Best Available Technology (BAT). There may be actual products on the market at this level or not.

It is relevant to note that this simple LCC approach supposes that the different improvements are independent from each other. It does not necessarily capture cost synergies that can be achieved by certain combinations of improvements. Besides, the analysis can only be run on improvements that can be robustly quantified. Improvements that are not sufficiently mature to be quantifiable are usually referred to as 'best not yet available' technologies (BNAT).

The minimum life cycle cost criterion of the Ecodesign Directive means that products placed on the market should have an energy performance at least equal to that of the LLCC point. In other words, Ecodesign regulations should ensure that products placed on the market include all energy saving improvements that pay off during the product lifetime. This is achieved by setting a mandatory minimum performance requirement at the LLCC level.

Life cycle cost calculations

The Ecodesign methodology specifies how the LLCC point should be identified. In the 2005 Ecodesign methodology (MEEuP), the life cycle cost of a product has been defined as (VHK, 2005):

LCC = PP + OE + EoL

Where:

– PP is the purchase price of the product (eventually including installation costs if any)

– OE is the discounted operating expenses over the product lifetime, based on a typical or averaged duty cycle

– EoL is the cost of end-of-life treatment of the product

The operating expenses are discounted, to account for the fact that they occur over several years and that the time value of money changes (i.e a present cash flow is more valued than one in some years). This is done by using a discount rate r (interest rate minus inflation rate) in the calculations:

$OE = \{ (1- 1/(1 + r)N) / r \} * AOE$, where N is the product lifetime and AOE the annual operating costs (including e.g. annual use of energy, water, annual reparation costs, annual maintenance costs, etc.). The formula inside the curly brackets is usually referred to as Present Worth Factor (PWF).

Once the discount rate and a typical value for the lifetime N have been selected, and a figure for the end-of-life cost EoL estimated, the LCC of a product can be calculated using its purchase price (observed or averaged on the market) and its annual operating costs (for the energy running costs, it is simply the annual energy consumption of the product multiplied by a typical price of energy representative of or averaged for the EU market).

Applying the LLCC approach to a product group

Requirements set in Ecodesign regulations are meant to apply to whole product groups and not just to one single model on the market. This means that the life cycle cost analysis needs to be sufficiently generic and as representative of the product group as possible.

The approach used in Ecodesign preparatory studies is to select one or several base case products. Then, the identification of the LLCC point is run on these base case products only. The 2005 Ecodesign methodology does not provide a standardised procedure to select the base case product/s. It specifies that the base case should be ‘representative’ or an ‘average’ of the product group in the EU, that can ‘summarise’ it in one product (VHK, 2005). The 2011 version of the methodology clarifies that the base case ‘may or may not be a real product that one can buy on the market. Especially when the market is made up of different technologies, the base case will be a virtual (non-existing) product with the average sales-weighted characteristics of all technologies around. On the other hand, e.g. if the market and technical information is incomplete, the analysts (…) may decide to choose a real product for which there is a consensus that this would represent the average’ (VHK, 2011).

In practice, different approaches have been used in preparatory studies so far, often combining statistical analysis of available market data with educated guesses from consultants. One essential difficulty is to determine a purchase price and its variations for the base case product. This price is most often determined through averaging an EU-wide market sample (covering all the product group or sometimes products that have characteristics close to that of the base case). It is therefore a ‘statistical price’. In reality, product models with similar characteristics may have very diverging prices, depending on when and where they are purchased (manufacturer, retailer, EU country, etc.).

Identifying the LLCC point

To identify the minimum of the LCC curve for the base case/s, analysts may use market and engineering data. This determination may involve different approaches, summarised in the Ecodesign methodology (VHK, 2011):

- A product approach, by which the LLCC point is researched among real product models existing on the market (although there are usually limits to the accuracy and representativeness of one single model).
- A design option approach, in which all possible improvement options that can be applied to the base case are identified separately and their individual impact on the purchase price of a product is estimated through analysis of market price data of different product configurations (this supposes a sufficiently precise and segmented market data collection).
- An engineering approach, through which the improvement options are assessed from a manufacturing point of view, that is by determining the research, engineering and production costs for manufacturers and assuming the cost is passed on to consumers (although part of this information may be confidential or difficult to determine, and only educated guesswork may be possible)[3].

Using these approaches, the analyst is then required to reconstruct the LLC curve, from base case to BAT points and identify the LLCC point. As a consequence, the characteristics of the LLCC, notably its purchase price component, are usually conceptual extrapolations from a statistical average.

1.3 Methodological challenges

Considering the budget and time provided by the European Commission for each Ecodesign study - on average €300,000 over 1.5 years (CSES, 2012) – the technical and market analysis cannot dig deep on all aspects and provide an exhaustive evaluation. Particularly as study consultants (and after them EU decision makers) are often faced with data availability issues (CSES, 2012).

From our overview of the LCC methodology, it appears that some elements are more influential than others in the determination of the LLCC point. For instance, the estimation of the installation, end-of-life, maintenance and reparation costs may be interesting, but will usually have limited impact on the analysis if these costs are more or less constant for different products within the same product group. By contrast, the quality of the determination of the LLCC point can be strongly influenced by the basis for the **calculation of running costs** (that is the choice of the lifetime, discount rate, energy prices and duty cycle), the **representativeness of the selected base case** product/s, the **adequate identification of improvement options** at hand and **the correct estimation of their costs.**

We will now further discuss these four most critical aspects of the LCC methodology in the light of the experience gained since 2005.

---

[3] It can be noted that the engineering analysis applied in Ecodesign preparatory studies is often rudimentary compared to engineering cost analysis tools used e.g. in the US for similar policies

Realistic basis for the calculation of running costs

The choice of parameters used for the calculation of operating costs directly influence the level of cost-effectiveness of the technological improvement options that are assessed.

– Product lifetime:

The product lifetime parameter is an averaged figure for the whole product group[4]. The higher this parameter, the more prominent the operating costs in the LCC calculations, which can change the cost-effectiveness tipping point for energy efficiency improvement options.

– Discount rate:

In the first version of the Ecodesign methodology, determination of the value of the discount rate was left to the consultants in charge of product-specific studies. This led to discrepancies, with rates ranging from 1.8% to 5% from one study to another without obvious reasons. The 2011 version of the methodology stipulates that a 4% figure should be selected (and a sensitivity analysis conducted with extreme values 2.5 and 6%) (VHK, 2011).

A change in discount rate can have a substantial impact on the LLCC analysis. For instance, in the Ecodesign preparatory study for household tumble dryers (PriceWaterhouseCoopers, 2009) the use of energy efficient heat pump dryers has been considered cost-inefficient because of a discounted payback time slightly higher than the selected product lifetime (13 years). If, for example, the lifetime had been e.g. 14 years and a discount rate of 4% applied instead of 5%, this option would have become cost-efficient. The LLCC point would have been at a 50% more energy efficient level.

– Energy prices:

The choice of energy prices was also relatively flexible, leading to similar discrepancies (with figures for consumer electricity tariffs varying from 0.13 to 0.17 €/kWh depending on the study). Besides, these tariffs were constant and not anticipating foreseen energy price increases. The 2011 version of the methodology specifies the tariffs to be used and proposes to apply to them a 4% annual increase (VHK, 2011). Incidentally, a 4% discount rate and a 4% annual increase in operating costs balance each other, and simplify the LCC formula into:

LCC= PP + N*AOE + EoL

Where the operating costs are simply the multiplication of the annual costs by the lifetime.

– Duty cycles:

The actual energy use and operating expenses of a product depend on the user behaviour. There can be significant variations in terms of number of uses or time of use, programs and features selected, from one user to another. LCC calculations need to rely on EU averages. The choice of the typical usage pattern on which the calculation is to be based is a critical step, and often one that remains relatively hypothetical as user behaviour is still under-researched for a number of energy-related products. It also means that the LLCC analysis will make most sense for consumers who have a usage pattern close to the EU average, but less meaningful for users far from this average.

---

[4] This unfortunately does not allow for discriminating producers that may make efforts for increasing the robustness, reliability, reparability and reusability of their products.

Representativeness of base case products

The selection of the base case product/s on which the LLCC analysis is run is an essential and delicate step, especially for product groups composed of varied technologies and functionalities. In some cases, using a statistical average may be fit to represent a product category, in other cases it will not work so well. Ideally, a finer representativeness could be achieved by multiplying the number of base cases (so that many product configurations can be considered). However, due to budget and time constraints the Ecodesign methodology recommends to *'limit the number of different base cases as much as possible'* (VHK, 2005). With a limited number of base cases, there is a higher risk of missing important trends or technological aspects related to the product group.

In general the issue is considered carefully by Ecodesign study consultants, and the selection of base cases is made through an iteration of exchanges with stakeholders. However, in some cases important aspects may have been insufficiently taken into account. Two illustrations:

– The Ecodesign preparatory study for computers has selected only one base case for desktop computers, corresponding to an average PC with a standard built-in graphics card. As a consequence, the analysis of improvement options did not identify the graphics card as a particular item. In reality discrete graphics cards, which are additional cards beyond built-in ones, of powerful gaming PCs can consume a lot of energy, and a huge saving potential can be grasped (CLASP, NRDC, 2012). This significant issue has not been covered in the preparatory study, leading to subsequent delays in the preparation and adoption of the Ecodesign regulation.

– In the Ecodesign study for household washing machines, the use of a statistical average for the base case led to selecting a machine with a capacity close to 5kg. However, within a few years the capacity of washing machines placed on the market had grown considerably. It is now more and more difficult to find a model below 6kg and the majority of new models are in the 7-10kg range (Electrolux, 2012). An analysis of a bigger base case may have modified some of the conclusions on improvement options, especially those related to part-load performance. Was it possible to do better at the time of the analysis? One option could have been to consider two base cases of different capacities, or include the capacity parameter in the sensitivity analysis.

Adequate screening of improvement options

In Ecodesign studies, consultants make a distinction between available improvement options and as yet unavailable technologies; only the former are assessed in detail and incorporated in the LLCC analysis. The distinction is usually based on educated guesswork, but also depending on the amount of available technical information. It may be that some options are dismissed due to insufficient data (e.g. due to confidentiality reasons), while these options are sufficiently mature and ready for mass deployment.

One example can be found in the Ecodesign study for televisions (Fraunhofer IZM et al., 2007). The consultants considered the use of LED backlighting as a 'mid to long-term option' and did not include it in the LCC analysis. In reality, LED TVs have been rapidly deployed by manufacturers in subsequent years with substantial impact on energy efficiency (Toulouse et al., 2012). This major energy saving potential had been overlooked, making the whole LLCC analysis relatively pointless.

Accurate estimation of improvement costs and price impacts

When analysts experience difficulties in estimating the cost or price impact of an improvement option, there is a risk that they rely on overly simplistic or cautious assumptions that often lead to cost overestimation. The consequence is an overly conservative LLCC. The Ecodesign methodology acknowledges that in some cases only ‘rules of thumb to make product cost calculations’ can be used (VHK, 2005).

There seems still to be a relatively widespread belief that energy saving improvements always trigger an increase in product price, of an order of magnitude similar to that of the savings achieved. This hypothesis was, for instance, suggested for a simplified cost analysis to identify the future products to be covered by the 2nd Ecodesign Working Plan. Fortunately, it was challenged during the consultation with stakeholders (Van Elburg et al., 2011). In fact there is a huge variety of improvement options, some entailing zero or very little cost (e.g. better power management features). Only a detailed assessment can lead to sufficiently realistic figures (although obviously a certain degree of simplification will always be necessary, as the complexity of cost distributions and price setting policies among manufacturers can never be entirely modelled).

There is considerable literature suggesting that the risk of overestimating the costs and price impacts is real (e.g. Taylor et al., 2012; Ellis et al., 2007; IEA, 2007). The price of a product is not just a reflection of the engineering costs to produce it, as any brand or supply chain analyst will tell you. Prices may not always be good proxies for costs (Siderius, 2013). In some cases, a manufacturer may want to value a new design by including an initial premium on the product price. Available data on refrigerators shows that premiums in this sector can lead to a price difference of about 30% or more between two consecutive energy labelling classes (Siderius, 2009; Ecorys, 2011). However, initial premiums are not necessarily just reflecting higher production costs. They may be temporary and deflate if the technology starts being mass produced. In other cases, the extra cost of a new technological improvement may have no bearing at all on the eventual product price, for instance due to strong competitive or retailer pressure. As an example, analysis of market data for televisions suggests that for this product group, energy efficiency as such is not a feature that manufacturers can ask a premium for (Siderius, 2013).

For all these reasons, it seems important that cost estimates are not too simplistic or systematically conservative, and rely on robust research and not just generic assumptions.

1.4 How has the LLCC criterion been used in policy decisions so far?

The EU has issued Ecodesign regulations for 18 product groups, with several more in the pipeline. All decisions follow a predefined consultation and adoption process (described in e.g Ecofys, 2012). This process grants importance to the content and conclusions of preparatory studies. The first working document issued by the European Commission for a product group – that serves as the basis for consultations and regulation drafts – typically builds on the material found in these studies.

We will now assess how far the findings of LLCC analysis have actually been taken into consideration in decision-making, and the main consequences.

Focus on energy use

A first visible impact of the prominence of the LLCC criterion in the legislation and methodology can be seen in the way discussions and decisions on Ecodesign regulations have generally centred on energy use aspects and where to set energy efficiency levels (Andersen, 2011). This is partly due to the fact that energy use is indeed a significant aspect for energy-using products, but also partly due to the fact that these aspects have been better documented than others in the preparatory phases (contrary to other policy processes such as those setting eco-labels). 'In the case of some Ecodesign measures already in force (…), *there may have been potential non-energy improvements that were not adopted as a result of policy choices and the underlying technical analysis'* (CSES, 2012).

A rather deliberative approach

For decisions regarding energy use, EU decision-makers have generally taken into serious consideration the material of the preparatory studies. However, they have not necessarily applied the LLCC rule blindly. This is proven by the minutes of consultation meetings and content of the working documents and explanatory notes for the 18 adopted measures. LLCC analysis have been an essential inspiration for the Commission's initial working documents, but then other aspects have played a more or less important role as well. For instance the quality and robustness of the data collected for the analysis, some specificities of the product groups and markets (such as the use of multiple energy sources), affordability aspects, other potential impacts on consumers, the maturity of the product category with respect to energy efficiency, the level of the expected saving potentials, etc.

For some Ecodesign regulations, a literal implementation of the LLCC criterion was simply not possible. One example is the measure for standby and off modes (EC 1275/2008). This broad horizontal regulation covering a wide spectrum of product categories has been mostly inspired by the IEA '1 Watt' initiative. It was not conceivable to run an individual LLCC analysis on all the product categories affected. Another example is the Ecodesign measure for water heaters. A strict implementation of the LLCC criterion would have excluded some product types from the market (e.g. electric storage water heaters); this has been considered by policymakers as inadequate and not in line with some other articles of the directive.

Another illustration that the LLCC criterion is not considered as set in stone is a recent suggestion from the European Commission to envisage more stringent requirements over a longer time period, such as long-term tiers at the level of today's benchmarks (EC-DG ENER, 2012). This may be experimented with for the first time for decisions on kitchen appliances (ovens and hobs). Such an approach could be viewed as going beyond what is allowed by the enshrined LLCC principle.

Comparing policy decisions against LLCC levels

The most direct way of assessing how influential the LLCC criterion has been is by comparing actual levels of Ecodesign requirements against the LLCC levels in the preparatory studies. This comparison has been done for a selection of seven product groups regulated since 2009: fridge-freezers, washing machines, dishwashers, tumble dryers, small air-conditioners, computers and TVs[5]. The findings are presented on a graph showing the position of the preparatory study base case, LLCC and BAT (on a typical LCC graph with energy use on the horizontal axis and life cycle costs on the vertical axis), as well as the levels of Ecodesign limit values for products having the characteristics of the base case.

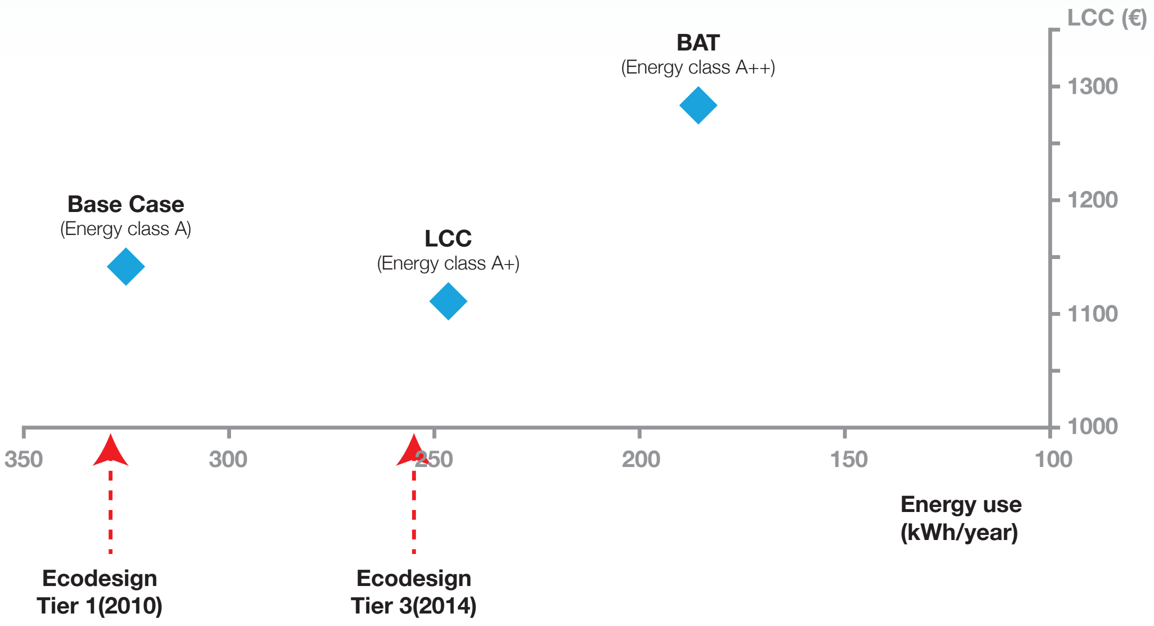
Note: to ensure a meaningful comparison, some data recalibrations and assumptions have sometimes been necessary to realign the metrics and duty cycles in preparatory studies and adopted regulations. It happens frequently that along the development process of an Ecodesign measure, some modifications are made to the methodologies for characterising the energy efficiency of a product.

---

[6] Lighting has not been assessed, however it is easy to conclude that in regulation EC 244/2009 regarding domestic lightbulbs, the requirements are less stringent than the LLCC level for clear lamps. The LLCC corresponds to compact fluorescent lamps, while halogen-based lamps have been left on the market (Coolproducts, 2010).

1.4.1.1 Household Fridge-freezers

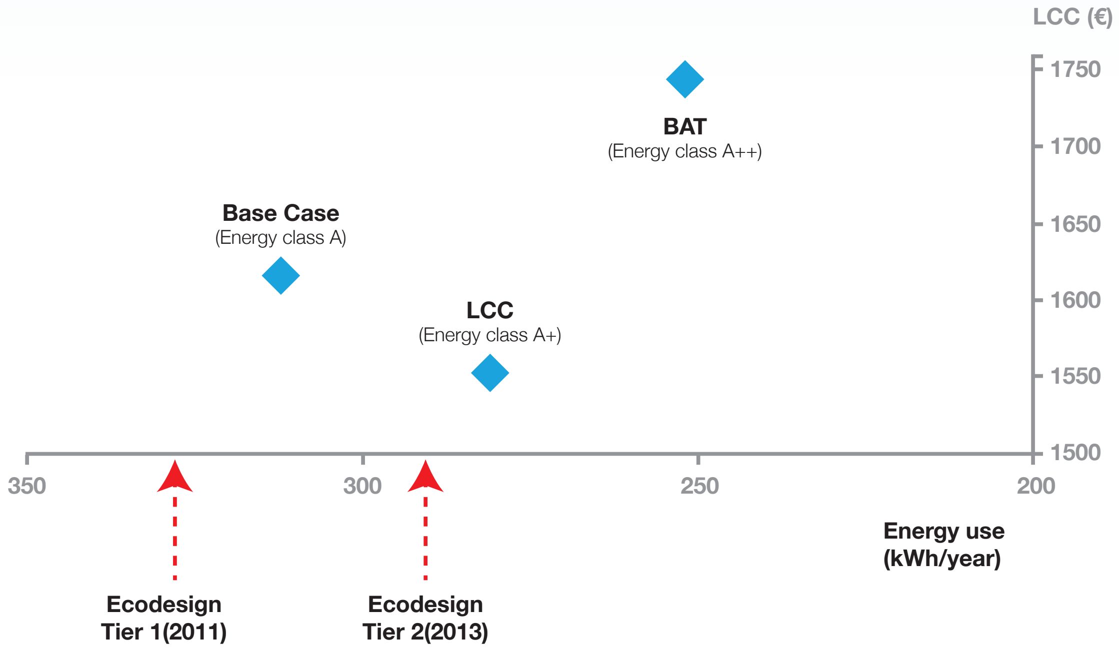
Figure 2 - Ecodesign decisions for a fridge-freezer



The preparatory study is based on 2005 data. The Ecodesign regulation was published in 2009 and the requirements enter/ed into force in 2010 (tier 1), 2012 (tier 2) and 2014 (tier 3). On the graph, the results for the fridge-freezer base case is presented. It corresponds to a two door appliance with fresh food volume of 209 litres and frozen volume of 67 litres, used under standard conditions over 15 years.

1.4.1.2 Household Dishwashers

Figure 3 - Ecodesign decisions for a dishwasher

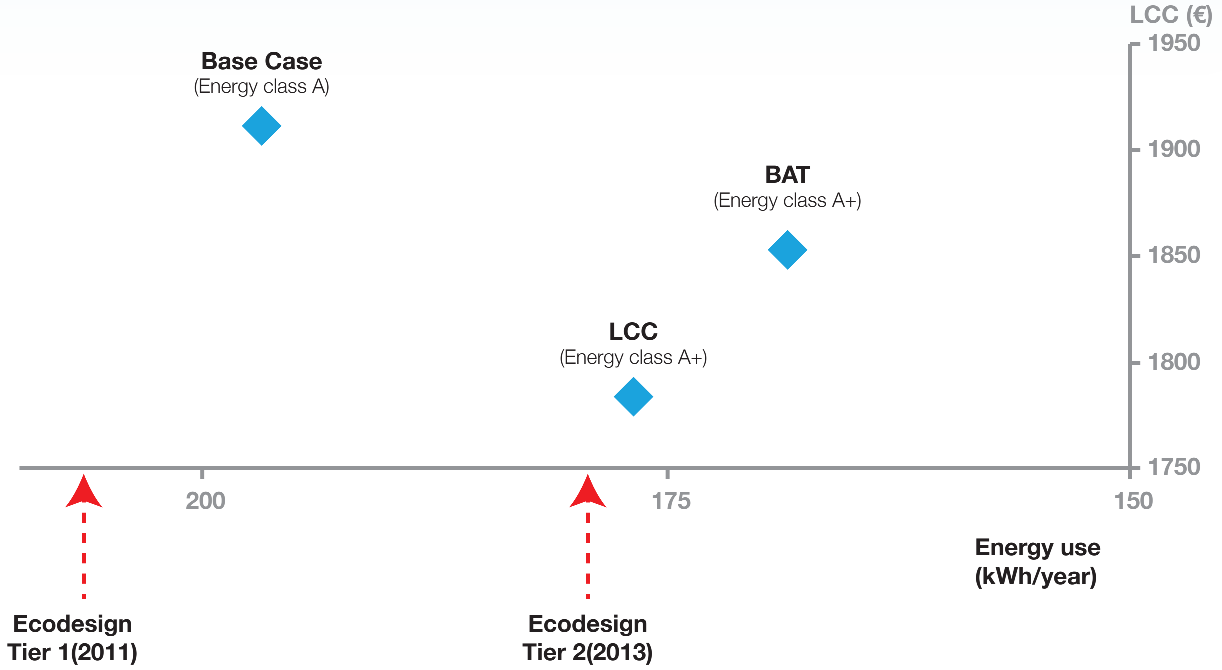


The preparatory study is based on 2005 data. The Ecodesign regulation was published in 2010 and entered into force in 2 tiers (2011 and 2013). The base case is a 12 place settings used 280 times a year over 15 years under standard conditions. The LCC calculations include energy, water and detergent. (An assumption had to be made for the consumption in left-on mode).

The first Ecodesign tier was particularly modest (way above the base case of 2005). The level of tier 2 is closer to the LLCC point of 2005, but still above. (A reason for the gap is the choice from decision-makers to align Ecodesign limits exactly with class boundaries of the EU Energy Label).

1.4.1.3 Household washing machines

Figure 4 - Policy decisions for a washing machine

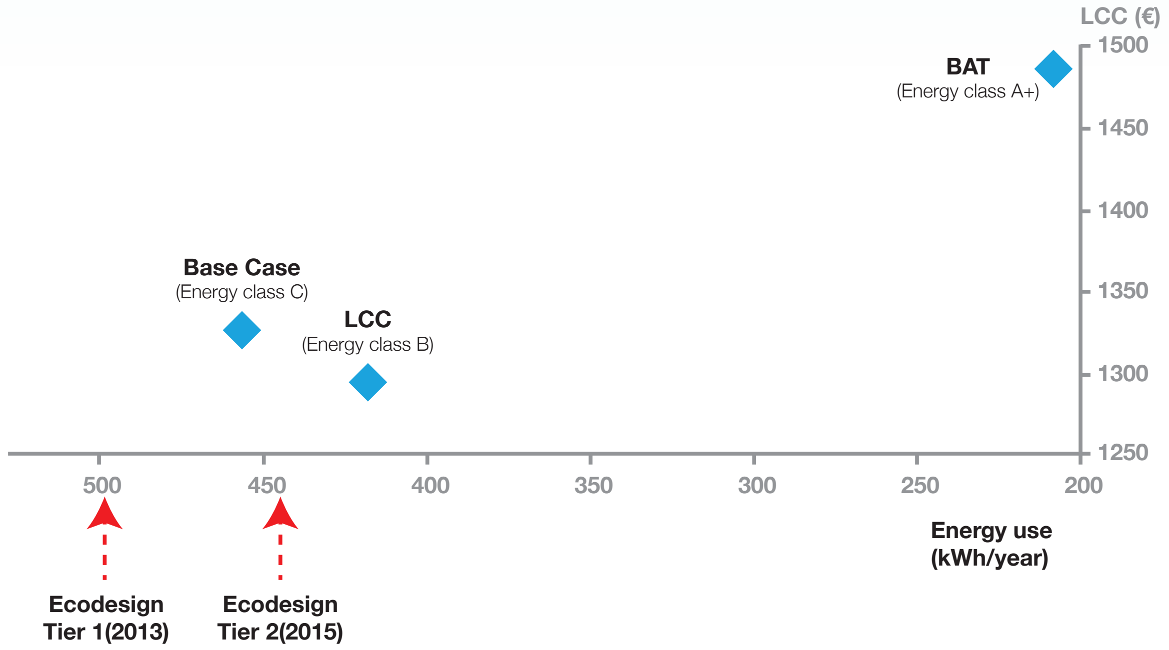


The preparatory study is based on 2005 data. The regulation was published in 2010 with requirements in force in 2011 and 2013. The base case is a 5.36kg machine, used 220 times a year over 15 years in standard conditions. Comparability for this product group is particularly tricky due to major changes in the methodology and measurement methods along the process. Assumptions had to be made about part-load, low temperature programme and standby consumption. Results are only roughly indicative.

The first tier appears to be of modest ambition, while tier 2 seems relatively close to the LLCC point.

1.4.1.4 Household Tumble dryers

Figure 5 - Policy decisions for a tumble dryer

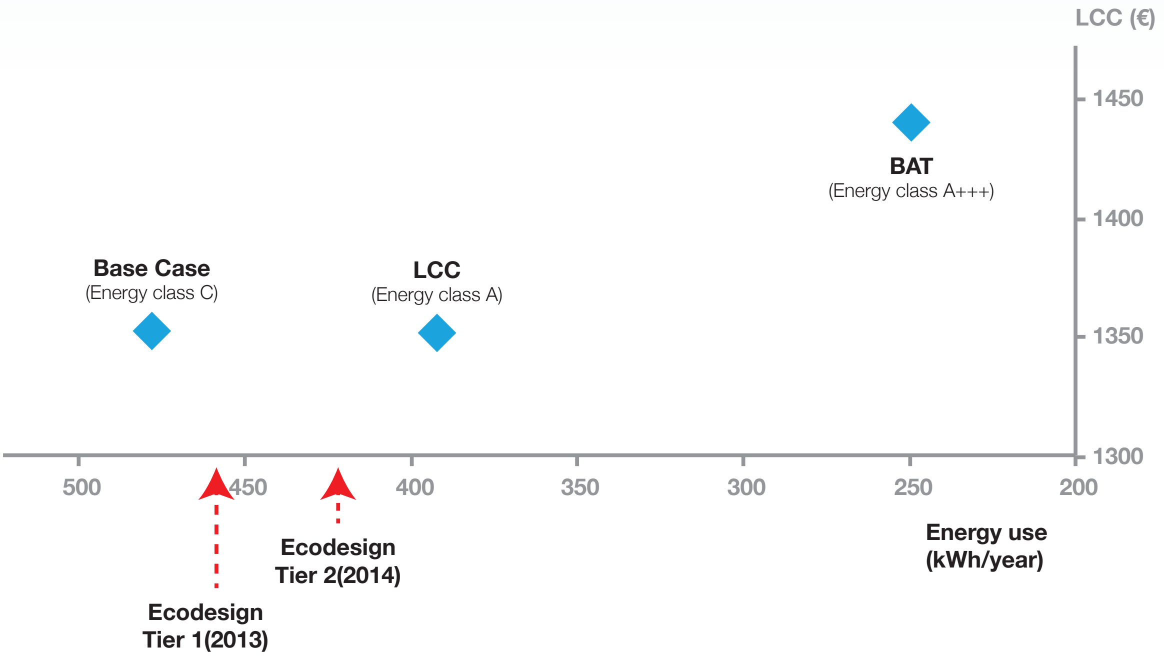


The preparatory study is based on 2008 data. The Ecodesign regulation was published in 2012, with requirements in 2013 and 2015. The condensing dryer case is presented here: the base case is a 6kg dryer using a mix of part and full load cycles (160/year in total over 13 years). A recalibration of the study data had to be made to compare with the regulation, including assumptions on the standby and part-load program consumption.

The level of both tiers appears relatively modest, close to the base case point. It can be noted that Ecodesign requirements for vented dryers (not shown on this graph) are even more modest.

1.4.1.5 Mobile air-conditioners

Figure 6 - Policy decisions for a mobile air-co.

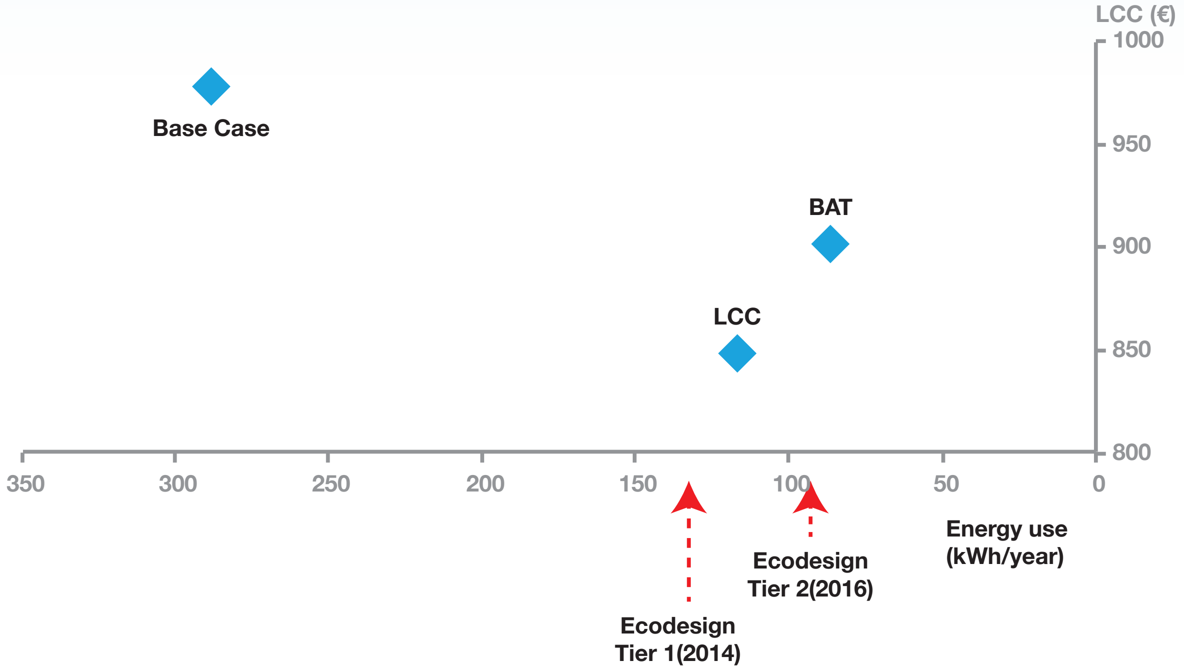


The preparatory study for air-conditioners is based on 2007 data. The regulation was published in 2012 with requirements in force in 2013 and 2014. The base case for mobile air-co. (single duct) is a cooling-only product of 2.2 kW capacity and lasting 12 years on average. As the seasonal performance approach developed in the study was finally dropped for single ducts, a recalibration of the data has been done on the basis of a full load use during 500 hours a year. In these conditions, the BAT point displayed on the graph is rather theoretical as no product on the market today can reach this level.

The first tier appears slightly below the base case, while the 2nd tier does not reach the LLCC level.

1.4.1.6 Desktop computers

Figure 7 - Policy decisions for a desktop PC



The preparatory study is based on 2005 data. The regulation has been published in 2013 with 2 tiers (2014 and 2016). The base case corresponds to a relatively basic PC according to today standards (Energy Star category A) with a lifetime of 6.6 years. Usage patterns have been recalibrated to Energy Star. We have made an assumption for the BAT price (omitted in the study) - 15% above the base case price.

Requirements have been strengthened during the final vote by member states in 2013. This is why tier 2 exceeds the LLCC level. However, this product group is characterised by fast technological change.

1.4.1.7 Televisions

Figure 8 - Policy decisions for a TV

The preparatory study is based on 2006 data. The regulation was issued in 2009, with energy requirements in 2010 and 2012. The base case is a 32 inch LCD TV with a 10-year lifetime. The LLCC point coincides with the BAT level according to the study analysis.

The graph shows that the first tier is close to the base case, while tier 2 seems to exceed the LLCC (and BAT) point. However, this preparatory study is known for having insufficiently analysed some key improvement options (Toulouse et al., 2012), and changes to test conditions have made it easier for manufacturers to display a better performance. As an illustration, TV models performing 60% better than the LLCC/BAT point of the preparatory study were available on the market in 2011.

In light of these seven graphs, two main observations can be made.

Firstly, the objective of targeting the LLCC level is in general more or less met, but only at tier 2. Tier 2 levels are most of time close to this point (although often slightly less stringent). By contrast, tier 1 levels are more modest, rather close to the base case levels. This confirms findings from previous studies (such as Coolproducts, 2010). In short: the LLCC criterion appears to have strongly influenced the setting of tier 2 levels (exceptions include mobile air-conditioners; domestic lightbulbs could also be mentioned[6]).

Secondly, the time period between the collection of data for the preparatory study analysis and the entry into force of the tier 2 at LLCC level appears quite considerable. For the seven product groups, the time gap is on average eight years. This means that the LLCC criterion is formally met, but with a significant delay: eight years can mean a lot for product groups characterised by fast technological change. In the meantime, markets and products may have evolved substantially.

---

[6] Lighting has not been assessed, however it is easy to conclude that in regulation EC 244/2009 regarding domestic lightbulbs, the requirements are less stringent than the LLCC level for clear lamps. The LLCC corresponds to compact fluorescent lamps, while halogen-based lamps have been left on the market (Coolproducts, 2010).

2 Discussion on the relevance of the least life cycle cost criterion

In the previous section, we saw that the least life cycle cost (LLCC) criterion plays a central role in setting EU Ecodesign requirements for energy-related products. This criterion aims at ensuring that products placed on the market include all cost-effective improvements that can help consumers save energy. It has clearly influenced decisions on Ecodesign regulations so far.

In this section, we discuss whether the use of this criterion facilitates the adoption of successful Ecodesign regulations. By this, we mean regulations that trigger significant environmental improvement beyond business-as-usual trends.

A comprehensive assessment would require access to an evaluation of the actual efficacy of Ecodesign regulations in realising energy savings. However, robust evaluations of this kind are lacking. Attempts towards this end have been hampered by a lack of data and difficulties in addressing causality (CSES, 2012). There is partial evidence suggesting that some regulations have been more successful and impactful than others. For example, the regulation for domestic lighting has effectively banned inefficient lamps that would have been sold otherwise, while the regulation for TVs has been lagging behind market development. In the absence of a quantified evaluation, a discussion on the relevance and effectiveness of the LLCC criterion can only be achieved through more indirect observations.

A number of core questions related to the relevance of the LLCC criterion can be derived from the aspects presented in the previous section. We have identified five of them, covering aspects ranging from the conceptual principles to the more concrete implementation challenges:

- Is it really necessary in the first place to include a precise criterion in the legislation?
- Is a criterion focusing on end-user financial gain appropriate?
- Is the LCC approach always suitable?
- Is it relevant to pursue the objective of bringing the LCC to a minimum?
- Is the time gap between analysis and implementation a significant flaw?

Following the discussion of each of these questions, we provide recommendations on possible modifications to the LLCC criterion or the way it is used.

2.1 Is it really necessary to include a precise criterion in the legislation?

EU policymakers have assigned to the Ecodesign Directive the overall objective of *'contributing to sustainable development by increasing energy efficiency and the level of protection of the environment'* in the context of broader EU policy goals on environmental protection, sustainable production and climate change mitigation reminded in the Directive recitals.

As a large part of the rulemaking is delegated to the European Commission, assisted by a balanced consultation forum composed of industry, NGO and expert representatives, these general instructions could eventually be considered as a sufficient framework. The need for a criterion as precise as the LLCC – which requires a long and sometimes difficult analysis, which are thus not necessarily undertaken thoroughly – may be doubted.

International overview

A comparison with other jurisdictions can be useful here. Several economies are implementing minimum energy performance standards and energy labelling programs on energy-related products, some with much longer experience than we have gained through Ecodesign. The policy processes differ on some aspects (Coolproducts, 2012). What most of these policy frameworks seem to share is an overall intention to guarantee cost-effective decisions for consumers, but this does not always take the form of a quantified criterion.

The US seems to have the closest approach to the EU, with an engineering analysis systematically carried out on improvement options and the determination of the most cost-effective theoretical design (using a software tool ranking the options against their impact on production costs and retail prices). In China, there is no strict prescriptive criterion and decisions are mostly ad hoc; a statistical market analysis and some benchmarking against international markets is always carried out, but a techno-economic engineering analysis is not always done. In Australia, the most important principle in deciding on the level of stringency is a comparison with peer economies: the objective is to match the most stringent requirement applied among trading partners. The farthest model seems to be the Japanese Top-Runner approach, in which targets are systematically based on current best available technologies and applied to manufacturer fleet averages.

Other economies use processes inspired by the aforementioned, with some degrees of flexibility. Some decisions are actually more ambitious than LLCC. For example, the 2009 Swiss decision to leave only heat pump dryers on the market is more ambitious than what the EU LLCC analysis concluded (Topten, 2012). Also, the Californian standard for TVs substantially exceeded the EU one adopted the same year (NRDC, 2009).

Comparing the stringency and effectiveness of these different policy approaches is not an easy task. Some studies suggest that there is no general rule and some economies amongst the EU, US and Japan may lead on some product groups and be behind for others (Coolproducts, 2012). This leads to the assumption that the EU LLCC criterion has not been a systematic strength or weakness in comparison to its peers. However, the amount of resources allocated to the preparatory analysis is much less in the EU compared to the US (Coolproducts, 2012).

It is plausible to say that many economies are looking at what the largest markets (EU and US) are doing and expect them to lead in developing credible and well-documented requirements that can be the source of inspiration for them. The EU probably needs to retain an advanced methodological approach based on clear criteria and a thorough analysis. This said, the duplication of preparatory work in the EU and US on similar products is not necessarily indispensable. Increased harmonisation of the methodological tools and sharing of the work between the two regions could optimise public spending and reinforce the global authority of the analysis.

Recommendation

Fully dropping any detailed criterion in the Ecodesign Directive could run the risk of undermining the transparency and credibility of rulemaking towards the rest of the world, which can usefully reuse parts of EU analysis to set national regulations.

However, it is indispensable that any precise and quantified criterion is accompanied by sufficient and adequate resources and tools to support robust and accurate analysis. The EU is investing far fewer resources compared to similar activities in the US.

In this context, getting more inspiration from the US methodological tools could be useful. Furthermore, an increased harmonisation between the EU and US could be a relevant objective: an effort could be made to align the methodological tools on both sides of the Atlantic, so that analysis (on technologies, costs, improvement options, etc.) can be better streamlined and shared when informing policy decisions on both continents.

2.2 Is a criterion focussed on the end-user financial gain appropriate?

The LLCC approach focuses on the end-user perspective. The criterion relates strictly to individual financial aspects. This means that the policy looks at energy issue from a purely micro-economic perspective. In reality, there are other societal consequences of using energy that are not necessarily well reflected in the costs of energy today. Grounding policy decisions on a partial analysis may lead to decisions that have insufficient regard for longer-term and other societal issues.

Consideration of societal costs

In order to widen the perspective, a revision of the Ecodesign methodology in 2011 introduced the concept of societal costs (VHK, 2011). These costs come in addition to the energy costs of a product and reflect the negative impacts of the use of the product on society and nature. As it changes the weight of the different parameters of the LCC equation, this can modify the position of the LLCC point. The higher the societal costs, the more chance there is that the LLCC point shifts to a more energy efficient level. Societal costs considered in the Ecodesign methodology include carbon dioxide emission costs, impacts of regional air pollutants, heavy metals and organic micro-pollutants.

There is a strong limitation though: the calculations with societal costs are restricted to sensitivity analysis performed at the end of an Ecodesign preparatory study. The approach is to check only at the end if the consideration of these costs could have had an impact on the study findings. This step comes late, when consultants have consumed most of the study time and budget and have already completed an advanced draft. The methodology does not clarify what should happen if the sensitivity analysis reveals a substantial impact on the previous findings.

Monetising the costs of pollution and taking it into account in economic analysis is a trend that is likely to grow in the future, as estimates of these societal costs become more accurate. Already in the US, the 30-year national impact analysis that is carried out with every study for energy efficiency product regulations includes a monetisation of carbon and NOx emissions.

Recommendation

A way forward could be to progress on the inclusion of societal costs in the Ecodesign methodology: instead of being restricted to the sensitivity analysis of preparatory studies, or impact assessment studies by the Commission, these costs could be considered from the start in the core LCC analysis.

This would require modification to the definition of the LLCC criterion in the Ecodesign Directive, referring to *'end-users* ***and society****'* and adding a reference to the need to consider *'in particular* ***monetised societal costs of pollutants****'*.

2.3 Is a life cycle-cost approach always suitable?

As explained in the previous section, LCC calculations can only make sense if the purchase prices of products reflect the costs to consumers of different energy efficiency improvement options, at least for the representative or averaged product models considered for the LLCC analysis. In reality, manufacturer and retailer price policies are complex, dynamic and based on multiple criteria. Hence, the LCC approach may work more or less adequately depending on the correlation between market prices and energy efficiency levels.

Correlation between price and efficiency

Within a product group, average product prices and energy efficiency may be more or less strongly correlated. Two aspects seem to have an influence on the degree of correlation.

The first one is the nature of the product group. The correlation rule seems to work better for white appliances (fridges, freezers, dishwashers, washing machines), and industrial equipment (motors, fans, pumps, transformers, etc.) By contrast, the correlation often seems absent in consumer electronics and IT equipment. As an illustration, a recent market analysis of TVs in the EU over the period 2007-2012 has found no direct link between product prices and efficiency (Topten, 2013). Lastly, there are product categories for which the correlation may work more or less well (such as commercial equipment) and others for which the concept of correlation is difficult to apply in the first place (such as the lighting sector, characterised by strong variations in technologies, attributes and lifetimes). These differences may be explained by the fact that energy efficiency is sometimes a relatively independent product feature that manufacturers strive to improve as such, while in other cases energy efficiency is a side effect of other technological improvements or trends and cannot be easily isolated.

The possibility for manufacturers to reflect in product prices an attribute such as higher efficiency can be facilitated when the product sector already has some experience with energy efficiency. It is easier for a manufacturer to claim a higher price for a more energy efficient product when the product market is characterised by a long track-record in taking energy efficiency into consideration and promoting it as an important feature and selling point (e.g. through an energy label that influences market segmentation). The correlation can be expected to be higher for products such as fridges in comparison to newly-labelled vacuum cleaners, for which there is not yet a clear market segmentation related to energy performance.

It is possible that in the future, as energy efficiency becomes a more systematic market driver in all sectors due to societal trends or policy intervention, the correlation increases and becomes standard for all product groups. In these conditions, LLCC approaches would become relevant across the whole spectrum. In the meantime, for product groups where the correlation does not exist, the concept of LCC curve and LCC minimum is more fragile.

Recommendation

A first option could be to introduce a discrimination between product categories. Those for which the correlation is deemed insufficient could be regulated using a more flexible or different criterion. A suggested example would be to enter into a direct negotiation with manufacturers and discuss with them which energy efficiency improvement levels can be absorbed in redesign cycles and how long it would take before all models could profit, regardless of price issues (Siderius, 2013).

Complementing this would be to rephrase the LLCC criterion in a more generic way that could avoid the reference to the product purchase price. For this, the concept of product life cycle cost needs to be removed from the definition, although the general objective can be maintained.

Current text: *'Concerning energy consumption in use, the level of energy efficiency or consumption must be set aiming at the life cycle cost minimum to end-users for representative product models, taking into account the consequences on other environmental aspects (…)'*

Proposed text: *'Concerning energy efficiency or consumption in use, the requirement is set at the level **corresponding to the implementation of all existing improvement options that pay off** during the typical life of representative product models, taking into account the consequences on other environmental aspects.'*

2.4 Does it matter if life cycle costs are brought to a minimum?

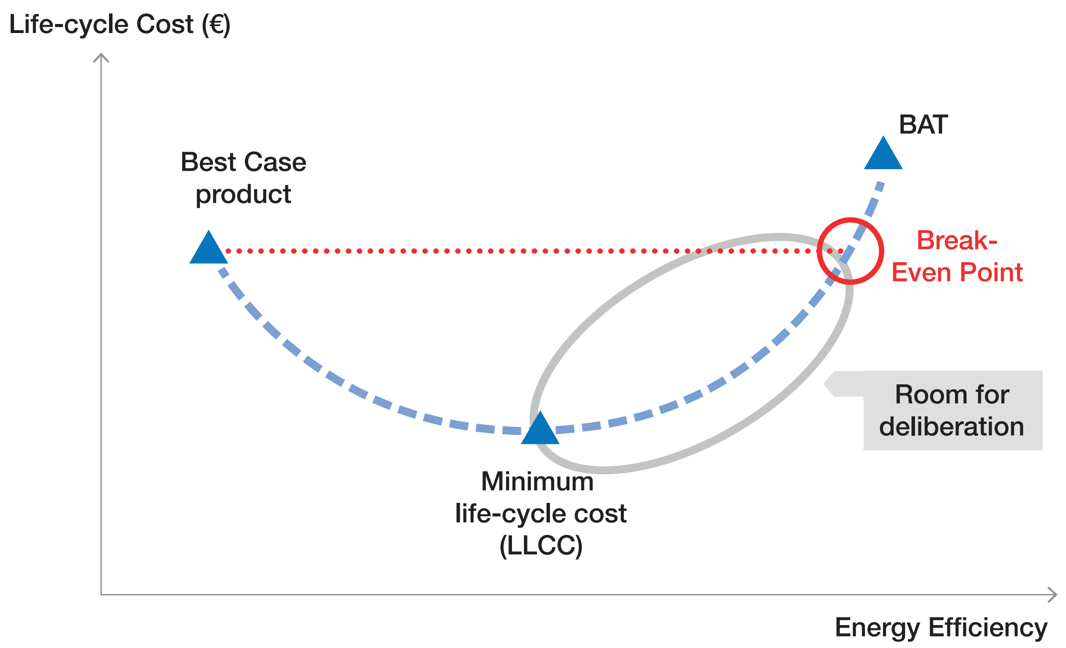
The overall principle of taking policy decisions that do not adversely affect consumer expenses is easily understood. The intention is to avoid decisions that force consumers to buy products that will cost them more over their lifetime than the base case. Nevertheless, the objective of minimising life-cycle cost goes beyond this good intention, and represents an additional constraint to the level of energy efficiency that can be set in Ecodesign requirements.

Individual versus combined improvements

As explained in the first section, the principle of LCC minimisation is that only improvements that are individually cost-effective can be imposed to the market. In reality, new designs placed on the market may be combinations of several improvements that are interrelated and difficult to isolate. With the trend of more integrated components, electronics and materials, assessing the cost-effectiveness of individual improvement options becomes more tricky and uncertain. This may weaken the robustness of the analysis.

In this context, a more flexible approach could be to guarantee that the life cycle cost for consumers is maintained at a level not higher than that of the base case, but not necessarily minimised. This means that Ecodesign requirements could be set at a level of energy performance in between the LLCC point and the point where the LCC becomes equal to that of the base case. The latter point - called ‘break-even point’ or ‘equal LCC point’ - is the maximum efficiency level that still guarantees that the overall LLC of the product does not exceed that of the base case. The following graph illustrates this idea and highlights room for flexibility in setting requirements.

Figure 9. Break-Even Point



The significance of this point was very briefly mentioned in the 2005 version of the Ecodesign methodology. A more prominent reference has been included in the 2011 version, with the remark that identifying this point *'could be helpful in assessing the absolute margin for target levels, possibly to be proposed by the Commission services in their later Working Documents, that go beyond the LLCC point'* (VHK, 2011). The idea of Ecodesign requirements targeting the break-even point instead of the LLCC has been mentioned in existing studies. *'An alternative approach based on equal life cycle costs (i.e. no additional costs to consumers over the life cycle) could be used to determine more demanding requirements while not having an impact on the total life cycle cost of the product '* (CSES, 2012). *'More ambitious requirements could be set without burdening consumers with excessive life cycle costs'* (Ecofys, 2012). However, it is relevant to note that the closer to the break-even point one gets, the higher the risk that a larger number of consumers would experience in reality higher life-cycle costs with their products (because as mentioned previously calculations are based on EU averaged prices and duty cycles, so real life cycle-costs are a distribution around the point considered).

Allowing the setting of requirements within a wider range between the LLCC and break-even points would offer decision-makers more room for manoeuvre and facilitate a more subtle consideration of potential combined improvement options. It would reduce the risk that stems from relying on one single point (the LLCC), as errors and uncertainties are always possible when determining one specific point of a curve. Last, it would enable decision-makers to potentially avoid systematic overcautious approaches when setting requirements if there is other evidence suggesting that more ambition is feasible.

Recommendation

The description of the LCC criterion in the legislation could be widened to open up the possibility to set requirements at an efficiency level between the LLCC and break-even point.

Proposed text: *'Concerning energy consumption in use, the level of energy efficiency or consumption is set at a level corresponding at least to the implementation of all existing improvement options that individually pay off during the typical life of representative product models, taking into account the consequences on other environmental aspects. Where feasible and justifiable, the level may be set at a higher performance level as long as it does not deteriorate the financial impact for the end user over the product lifetime compared to a standard product.'*

2.5 Is the delay between analysis and implementation a significant flaw?

An obvious criticism that may be made to the LLCC criterion is the fragility of determining something as precise as the minimum of a curve that can withstand the test of time, as Ecodesign requirements enter into force several years after the analysis. As shown in the previous section, Ecodesign requirements at the LLCC level usually enter into force eight years after the analysis has been conducted. Much changes in eight years. What guarantee is there that the LLCC point of the analysis still corresponds to minimum least-life cycle cost? In case of discrepancy, the LLCC criterion is in reality not adequately applied and Ecodesign requirements are set at sub-optimal levels.

This risk has been highlighted in other studies: *'The use of the LLCC criterion in combination with the significant time lapse for the entry of the requirements into force may on occasions lead to requirements that are less demanding than common levels in the market'* (CSES, 2012). 'Due to the lead time between original study and a measure going into effect, Ecodesign requirements run the risk of being set at too modest levels of efficiency' (Ecofys, 2012). In short, there is a risk that the Ecodesign directive is lagging behind market dynamics (Coolproducts, 2010).

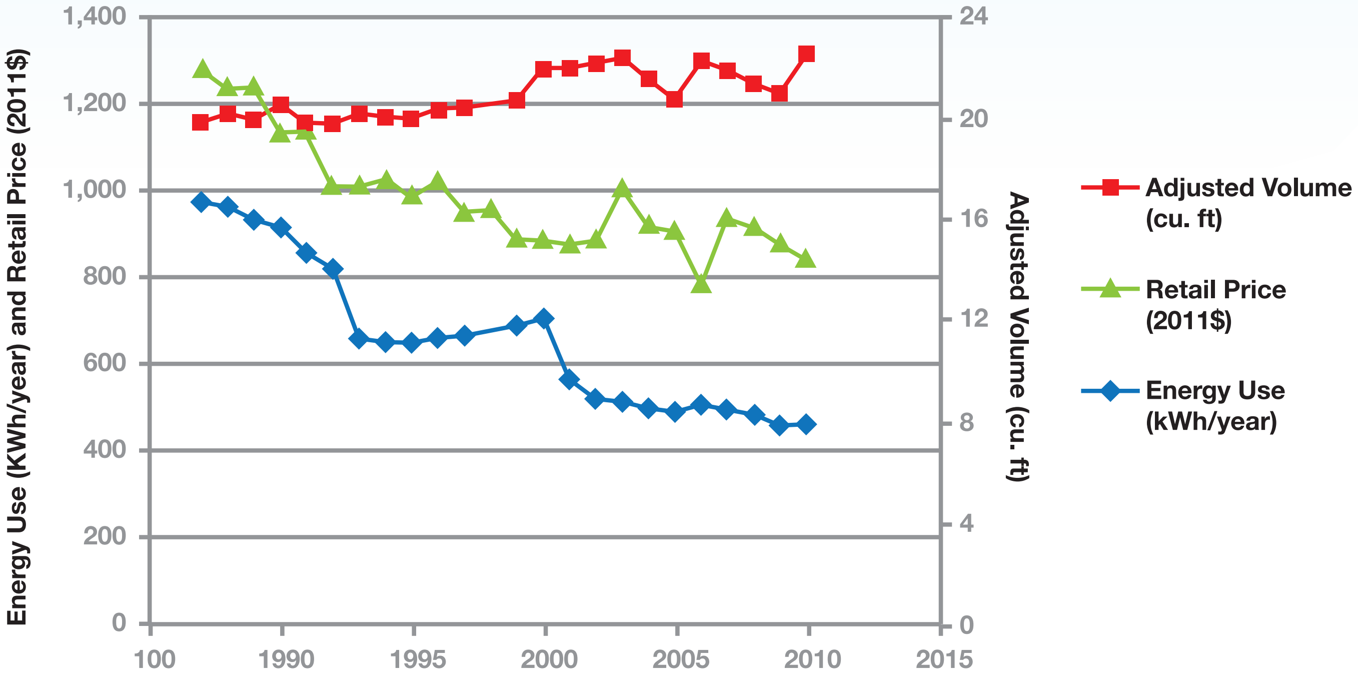
The ideal way of assessing how far LCC curves and LLCC points change over eight years would be to re-run complete analysis on today's markets and compare them to the material in the Ecodesign studies for the first product groups covered by the policy. This would require accessing up-to-date market statistics and doing engineering analysis going well beyond the scope of this study. More modestly, we intend to provide a set of indirect observations that cast light on the issue.

The position of an LLCC point may change if the life cycle cost impact of some of the available efficiency improvements is modified. This can be driven either by increased energy prices or because the improvements trigger a lower cost / price impact on the purchase price of products than before. We will not discuss the energy price aspect here, as it has been covered in the revision of the Ecodesign methodology (see in previous section). As regards the second aspect, several trends may affect the purchase price of efficient products over time.

Price decline trends

In general, energy-using products and appliances are characterised by a natural downward trend on prices. This has been observed for a long time on a large number of product groups. Products tend to become more sophisticated and energy efficient while average prices decrease over time (Mauer et al., 2013; Dale et al., 2009; Ellis et al., 2007). Refrigerators are often used as a typical illustration. As an example, a recent graph for the US covering a large time period (1985 to 2012) and displaying both price, volume and energy use trends for fridges is shown below.

Figure 10. Figure 10 - Historical price trends for refrigerators in the US (source: Mauer et al., 2013)



This downward trend may have several causes: optimisation of production and productivity by manufacturers, moving of production to low-cost countries, outsourcing of components to increase flexibility and competition (Siderius, 2009), concentration in the retail sector (Ecorys, 2011), pressure on prices by retailers, increased competition between dealers (e.g. online shops), etc.

This trend has a consequence on life cycle costs: if purchase prices generally decrease, their weight in the LCC calculations is reduced compared to that of operating costs, which by contrast are likely to increase due to increasing energy prices. This may change the tipping point where an improvement in efficiency pays off over the product lifetime.

Market dynamics for efficiency improvements

Within this overall trend of price decline, incremental gains in energy efficiency and policy decisions to impose efficiency improvements do not seem to cause long-term disruptions (CSES, 2012). This means that the market eventually absorbs the impact of new efficient technologies and designs. This is illustrated in the previous figure by the fact that the average energy performance of fridges improves continuously in parallel to the downward trend in average prices.

At the micro-level, when a more efficient design is brought to market for the first time, prices of products that include this design may be affected by a premium – their purchase price is likely to be higher than that of a mainstream product. Then, the improvement will generally be deployed and move from niche to mass production. This is a natural trend in several markets; for instance, data shows that

44% of the washing machines, 26% of the dishwashers and 24% of the freezers sold in the EU in early 2013 were already rated A++ or better (GfK, 2013) – a level that was still considered a limited niche for top innovative products in the 2007 Ecodesign preparatory studies.

This progressive mass deployment triggers economies of scale, increased competitive pressure, so that the initial premium cannot last. 'In these first few years, the price reflects what the market is willing to pay and not what the new feature would actually cost in a competitive market (…)' (VHK, 2011). The rate at which the price of products at a certain level of efficiency decline may vary, but it can be significantly altered after some years. An analysis of market data for fridge-freezers in ten EU member states shows that alongside an overall price decline between 2005 and 2011, the difference between the average price of an A+ and an A reduced from 38% to 29%. Similarly, the difference between an A++ and an A went down from 82% to 69% (Siderius, 2013).

Cost analysis based on static approaches may adequately identify the initial premium, but insufficiently take into account the market dynamics that affect the price and efficiency distribution of products over time (PSI & BIOIS, 2011; Desroches et al., 2013). As a consequence, estimates made at a certain date may quickly lose accuracy. 'At the time of an engineering analysis, energy efficient products have a low market share and command a high price premium compared to the conventional technology. (…) Often after five or more years, the market for energy efficient products has grown considerably and the price reduced, converging with that of the conventional technology. At the same time, equipment prices generally have fallen, but this has not been as pronounced; so that the price differential between a 'conventional' and 'energy efficient' product has decreased." (Ellis et al., 2007).

Erosion effects

A key process that can drive the premium or price impact of an efficiency improvement down is the introduction to the market of a better performing design or technology, especially when the market has a distinctive way of communicating performance, such as an energy label. The introduction of products with a better energy class has the effect of downgrading previous technologies, triggering a shift in the premium. Some EU appliance markets are strongly structured around energy labels (Europe Economics, 2007). For them this effect is likely to be substantial. As an illustration, an analysis of data for fridge-freezers over the period 2000-2008 shows that the population of a new energy class has been concomitant to a 20% erosion of the average price of products in the two classes below (Siderius, 2009). In short, the premium 'jumps' one class up. And the market price segmentation remains mostly similar but one class up. A similar pattern can be suspected for tumble dryers by observing a collection of German and Dutch average prices in 2011 when the first A++ models were introduced to the market (Siderius, 2013).

It can be expected that the more newly efficient technologies are brought to market, the more this erosion effect on previously available best technologies will take place, thus reducing the cost and price impact of the latter and potentially modifying the LLCC position. To assess how far technology has evolved over the years for a product group, we can compare the LLCC and BAT (best available technology) points identified in the Ecodesign preparatory studies to best performing models found on the market today. We present in the table below the data for five product groups, using as benchmark some models found on the Topten Europe website in July 2013 (www.topten.eu)[7].

---

[7] Mobile air-conditioners and computers are not included because they are not covered by Topten Europe.

Table 1. Comparison of LLCC, BAT and best products 2013

	LLCC in prep. Study		BAT in prep. Study		Best product 2013	
	Energy class	Energy use (kWh/year)	Energy class	Energy use (kWh/year)	Energy class	Energy use (kWh/year)
Fridge-freezers	A+	247	A++	186	A+++	150
Dishwashers	A+	281	A++	252	A+++	213
Washing machines	A+	177	A+	168	A+++	129
Tumble dryers	B	417	A+	208	A+++	172
Televisions	E	183	E	183	A+	43

This comparison shows that for all products examined, substantially more efficient products have been introduced to the market in the last years than was anticipated in their corresponding preparatory studies. Current best products consume less energy than the estimated BAT at the time of the preparatory studies by 20% for fridge-freezers, 15% for dishwashers, 23% for washing machines, 17% for tumble dryers and even 75% for TVs. From this, it can be assumed that the average price for a model corresponding to the preparatory study BAT has been driven down by the introduction of these better performing models.

To further consider this assumption, a survey has been made to collect the actual price of some real models on the market. Models of fridge-freezers, dishwashers and dryers from at least three well-known brands with characteristics close to the preparatory study products have been researched as far as possible[8]. Prices indicated are averages of prices found on the online retailer Amazon UK, Germany, France and Italy in August 2013.

Note: these samples do not have any statistical value. The objective is to provide illustrative examples.

---

[8] These models have been chosen to match if possible the level and characteristics of the representative products analysed in the preparatory studies. Exception is tumble driers for which it has been difficult to find models of 6 kg capacity in the A class on Amazon.

Table 2. Prices of a sample of actual products on the market

	Energy class	Energy use (kWh/year)	Price (€)	Main characteristics
Fridge-freezers				
BAT level in preparatory study (2005 data)	*A++*	*186*	***873***	*2 doors, net volume 276l*
Panasonic NR-B29SW2	A++	240	775	2 doors, net volume 289l
Liebherr CUPSL3221	A++	217	596	2 doors, net volume 284l
Bosch KDV29VL30	A++	205	581	2 doors, net volume 264l
Dishwashers				
BAT level in preparatory study (2005 data)	*A++*	*252*	***836***	*12 place settings*
AEG F65042W0P	A++	258	690	12 place settings
Beko DSN6634	A++	261	574	13 place settings
Hoover DDY 65543 FAM-S	A++	270	588	15 place settings
Tumble dryers				
Heat pump dryer in prep. study (2008 data)	*A*	*261*	***877***	*6 kg heat pump dryer*
Beko DPU8360	A	299	541	8 kg heat pump dryer
Siemens WT46W562	A+	222	824	7 kg heat pump dryer
AEG T65470AH1	A+	237	762	7 kg heat pump dryer

These non-statistically representative, but illustrative, samples show that it is possible to find today efficient models at a substantially lower price than that stated in the preparatory studies. Some products considered top performers at the time of the studies are now sold with limited or no premium. Incidentally, five of these models have a life cycle cost below the LLCC level identified in the preparatory studies. These very limited samples cannot provide conclusions on the market average for these products. Still, the difference between the study prices and the cheapest models in the sample (i.e. -33% for fridges, -31% for dishwashers and -38% for dryers) is worth noting.

Learning curves

In fact, the previous illustrations in the EU context are corroborating conclusions reached through more systematic market research in the US: market dynamics are pushing the price of more energy efficient products down, and the average incremental price to increase appliance efficiency declines over time (Dale et al., 2009). An analysis in the US on four product groups (fridges, room air-conditioners, split air-conditioners and space heaters) has concluded that the estimated cost of a given energy efficiency design option declines very rapidly in a short amount of time, in several cases by more than 50% (Desroches et al., 2013).

In order to be more accurate, LCC analysis should anticipate future cost reductions in a sufficiently robust way to ensure the analysis is still correct by the time policy measures take effect. This is not necessarily an easy task: where past studies have made predictions about future costs, available experience shows that actual life cycle costs were usually lower than those forecasted (IEA, 2007). In the US, studies have highlighted that the usual methods for forecasting equipment prices failed to represent real-world industry trends (Dale et al., 2009).

In reaction, the US administration in 2011 directed its agencies to ***'use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible'*** in the context of policies similar to Ecodesign[9]. The methodology now makes use of so-called learning or experience curves. These capture the fact that when cumulative production of a good increases, its production cost and price tends to fall. Learning curves are based on empirical evidence, but have proven their relevance in several areas due to the robustness of the empirical evidence (Desroches et al., 2011).

Using learning curves requires access to an estimate of the level of cumulative production (that can be inspired by historical trends), and the average experience rate for the sector. The experience rate is defined as the typical fractional reduction in price/cost resulting from each doubling in cumulative production. Empirical values for experience rates for different product groups have been collected in methodological guidance documents (US DOE, 2011). By incorporating such analysis to the price estimates of energy efficient products, a prediction on the price evolution over time can be made. In particular, when a new more efficient product or technology has a small initial market share, its cumulative production will likely double more quickly than that of mainstream products – illustrating the fact that new technologies undergo more rapid experience than already mature technologies. *'The incremental cost of efficiency for the most efficient products appears to decline much faster than the average cost, perhaps by even an order of magnitude'* (Desroches, 2013). This explains why the cost / price impact of efficiency improvements may change over time, having an impact on the the shape of LCC curves and position of LLCC points.

Learning curves have been used recently in the US for product groups such as tumble dryers, air-conditioners, boilers, refrigerators and freezers. In all cases, this has had a substantial impact on the cost-effectiveness calculations over 30 years for efficient products compared to a scenario with a constant price assumption. For refrigerators and central air-conditioners, potential improvements previously presented as economically unjustified for regulatory standards have actually become economical (Desroches et al., 2011). Learning curve models may be more or less sophisticated and have a number of limitations (Desroches, 2011), however they seem to be a significant step in improving the consideration of market dynamics. It is interesting to note that as early as 2000, the International Energy Agency was calling for the incorporation of such learning curves into energy policy analysis (IEA, 2000).

---

[9] Section 1(c) of Executive Order 13563 Improving Regulation and Regulatory Review (2011).

Recommendation

There is an accumulation of evidence suggesting that LCC analysis may be substantially degraded over time, in particular in the EU context of a eight year gap between analysis and implementation, and that constant assumptions for prices or costs of energy efficiency improvements undermine the credibility of the application of the LLCC criterion.

An obvious first recommendation would be to try to ensure that delay between analysis and implementation is reduced as much as possible. However, despite possible improvements, the Ecodesign rulemaking process is characterised by incompressible timelines due to a sequence of unavoidable regulatory steps (Siderius, 2012a). Some of these steps may be cut in the case of the revision of existing regulations, still the total time between preparatory data collection and entry into force of future requirements will remain in the order of several years.

A second recommendation is to improve the quality of the data collection. If the EU could use more systematic market monitoring tools, the market data at hand would be more up-to-date and actualisation of LLCC calculations could be more easily done. The EU is still a long way from this goal (Attali et al., 2013).

The third recommendation would be to impose the use of methods such as learning curves in preparatory studies. The revised Ecodesign methodology makes a limited reference to learning curves (VHK, 2011). They are not introduced as a firm mandatory instruction, but as an option ‘suggested’ by some stakeholders and to be eventually considered in the sensitivity analysis part. Neither background documentation nor guidance is provided. (There are only a few lines recommending that price projections, if possible, distinguish between the impact of better components, cost reduction and premium strategies.)

A way of reinforcing and clarifying the role of learning curves would be to mention them in the legislation. The following reference could be added to the definition of the LLCC criteria:

‘The best available statistical techniques to estimate future trends in costs/prices – such as learning curves – are used to guarantee the validity of the life-cycle cost analysis by the time the requirements enter into force.’

3 Case studies: impacts of potential changes to the criterion

In the previous section, we suggested a number of possible adjustments to the LLCC criterion. It is worth questioning the concrete impact these would have on the analysis and resulting requirement levels. A way of assessing this is to reuse data from preparatory studies and rerun the analysis with the modified criteria, to see if different results are obtained at the end.

There appears to be limited literature available that follows this kind of simulation. Three references have been identified:

- One highlights for domestic air-conditioners the break-even point level (BAM-UBA, 2012). This point would correspond to a seasonal energy efficiency ratio (SEER) of 5.4, to be compared to the LLCC level identified in the preparatory study at a SEER of 4.0. This makes a 35% difference in efficiency.
- One applies a simplified learning curve approach to refrigerators and televisions (Ecofys, 2012), assuming a 22% price decrease in seven years and an efficiency improvement of 2% per year. As a result, the LLCC point/s shift towards a position close to the initial break-even point/s. *'Using equal life cycle cost as criterion at the time of study results in being close to the lowest life cycle cost-point 7 years down the road'* (Ecofys, 2012).
- The last applies in a more refined way the theory of learning curves to fridge-freezers and tumble dryers in the EU context (Siderius, 2013). Fridge models in the A++ class appear to reach the LLCC level after 5 years, compared to A+ in the static analysis of the preparatory study. By setting the Ecodesign requirement at this level, a further six TWh/year of electricity could have been saved at EU level compared to the decision taken in 2009. For dryers the LLCC point also appears to be at the A++ class level after five years, compared to B class in the preparatory study. By setting the Ecodesign requirement at this level, a further five TWh/year of electricity could have been saved at EU level.

These findings are already interesting, but they do not capture all the options discussed in this report.

A wider simulation exercise has been carried out. The fridge-freezer and tumble dryer cases have been chosen for the simulation, since they are good candidates for the LLCC approach and there was a possibility to reuse parts of the analysis performed in Siderius, 2013. For each product group, we display the individual impact of three changes: consideration of increasing energy prices (already included in the revised Ecodesign methodology), addition of societal costs, and methods to anticipate price decline trends over the years. Then we show the resulting LCC curve if all these modifications are combined. Along the way, we discuss how the position of the LLCC and break-even points change.

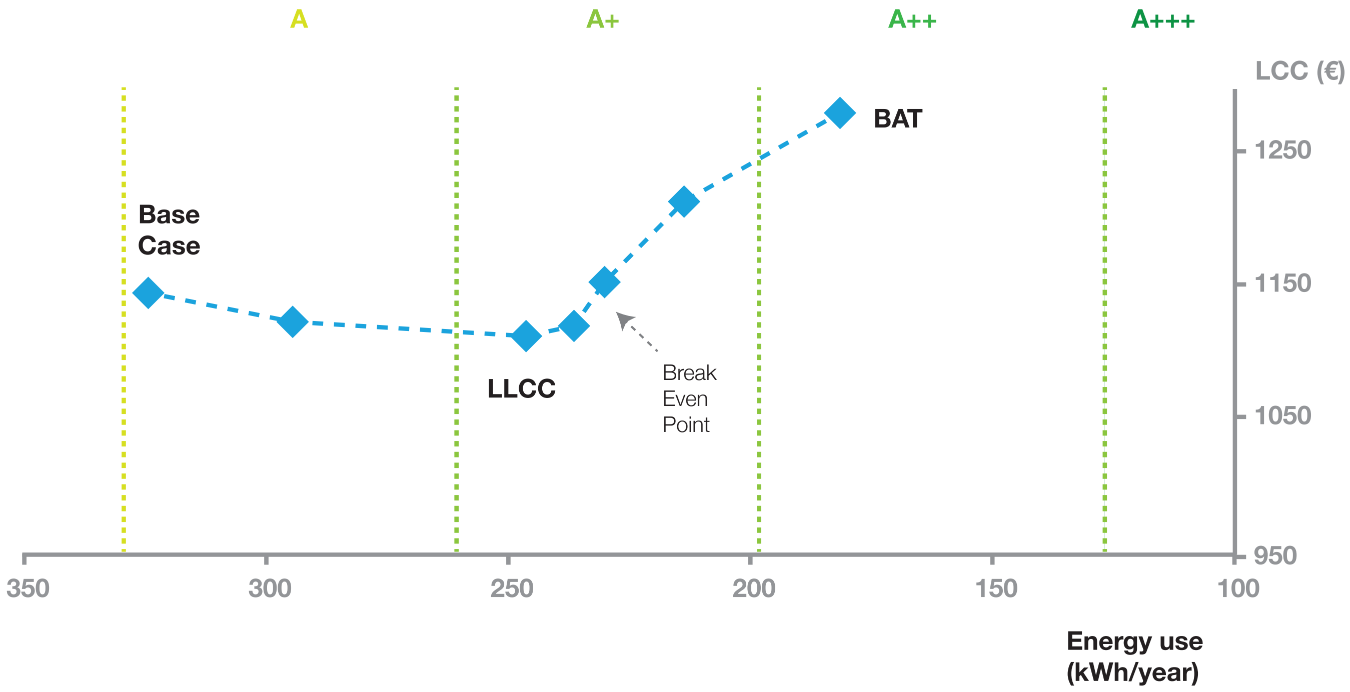
3.1 Fridge-freezer case study

Our starting point is the data in the Ecodesign preparatory study (ISIS et al., 2007). Six possible technical energy efficiency improvements had been identified in this study for the standard base case fridge-freezer product (2-door model with fresh food volume of 209 l and frozen food volume of 67 l). In the study, calculations had been made with a 5% discount rate, constant electricity price of 0.17 €/kWh and typical lifetime of 15 years.

The graph below displays the detailed LCC curve (each dot corresponds to one of the improvements), as well as an indication of the boundaries of the energy labelling classes for the product.

The shape of the curve clearly limits the LLCC point to the lower part of the A+ class, as several of the following improvements heavily increase the LCC. The break-even point[10] is close to the LLCC. In this situation, it does not make a huge difference to set requirements at the LLCC or break-even point.

Figure 11. Fridge-freezer LCC curve in the 2007 preparatory study



---

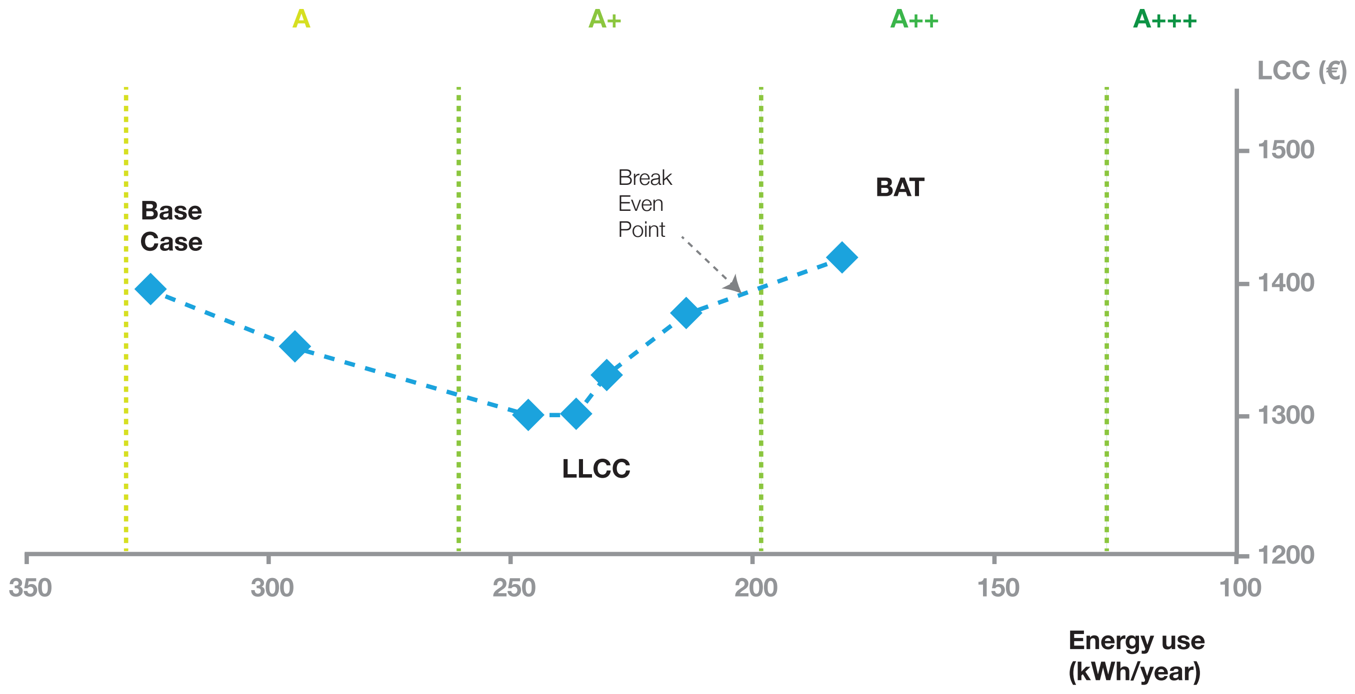
[10] For a reminder on the definition of the break-even point, see 'Figure 9 - Break-Even Point' on page 21.

Impact of increasing energy prices

On the next graph the calculation of operating costs was modified to anticipate inflating energy prices, as is now stipulated in the revised Ecodesign methodology (VHK, 2011). The energy price rate balances the discount rate, so that energy costs over the product lifetime are no more discounted.

Two significant changes can be highlighted. First, the LLCC point has moved towards the right (an additional improvement option has become economical). Second, the break-even point is now substantially further to the right; it is situated close to the boundary between the A+ and A++ class, corresponding to an 18% reduction in energy use compared to the initial LLCC.

Figure 12. Fridge-freezer LCC curve with increasing energy prices

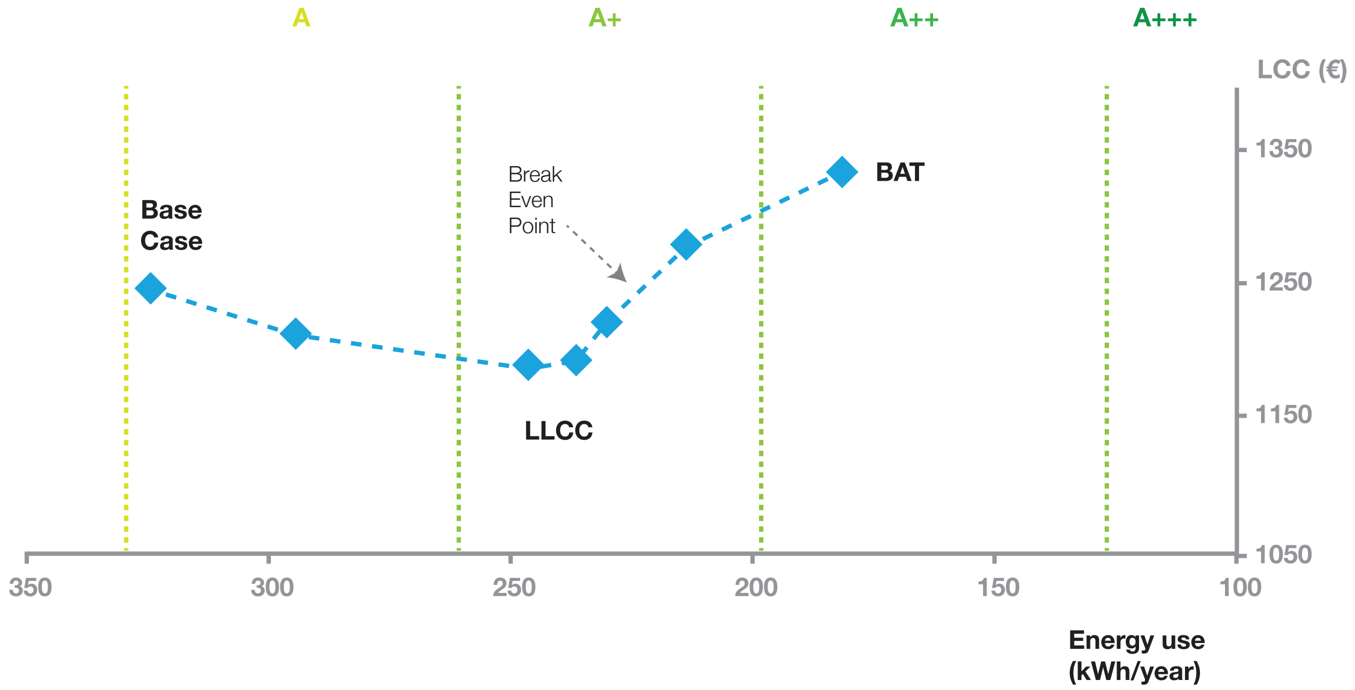


Impact of societal costs

Starting back from the initial curve of the preparatory study, we show on the next graph the impact of adding societal costs to the operating costs. For this, the Ecoreport 2011 tool of the Ecodesign methodology (VHK, 2011) was applied to each improvement option. It enables an automatic calculation of societal costs, including the impact of carbon emissions and several pollutants.

This time, the curve is not so much modified as to change the position of the LLCC point. However, the break-even point has moved slightly to the right.

Figure 13. Fridge-freezer LCC curve with societal costs



Price decline trends

The Ecodesign requirements for refrigerator-freezers at the LLCC level are planned to enter into force in two steps in 2012 and 2014, that is 7/9 years after the data collection used for the preparatory study. We are now looking at the way the initial curve in the preparatory study might change if techniques to anticipate the evolution of product prices over the 7/9 year period are used.

A formal implementation of experience curves as in the US has already been tested (Siderius, 2013). The focus has not been the specific base case model of the Ecodesign preparatory study and its improvement options, but market averages by energy classes for all no-frost fridge-freezers.

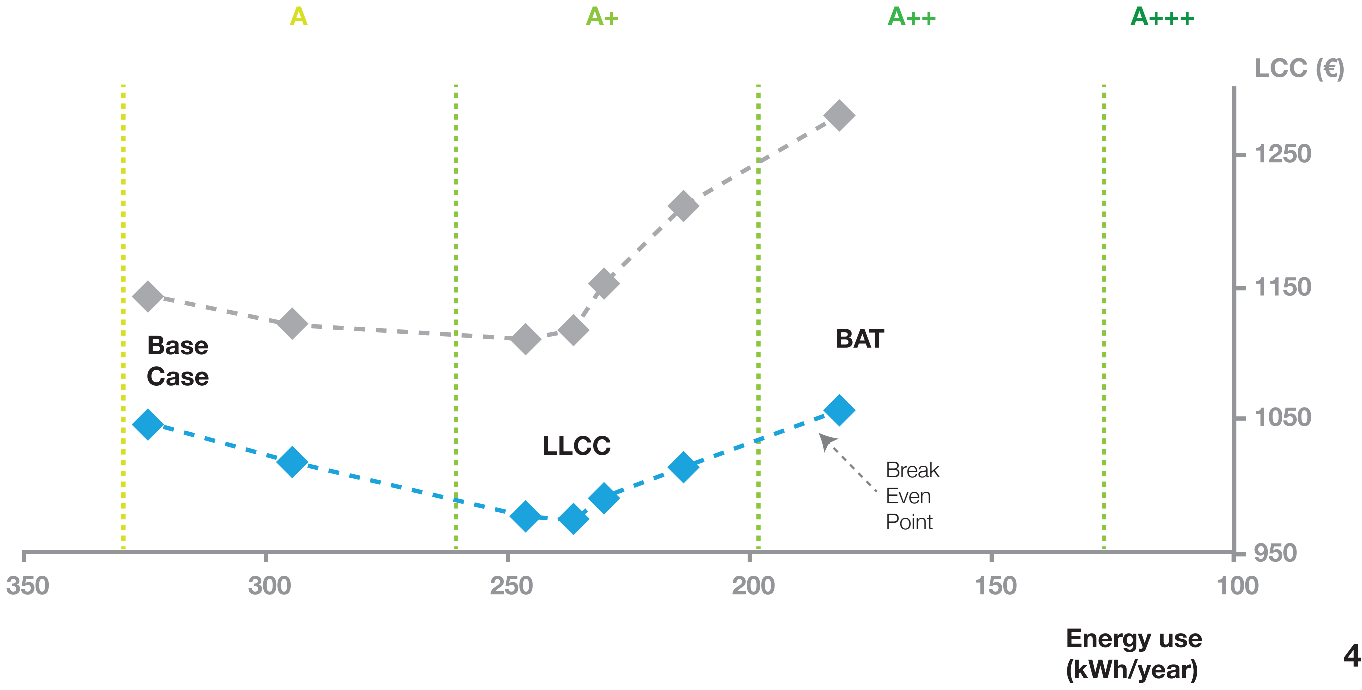
To avoid duplicating work that has already been done, we test here another approach inspired by the assumption of erosion effects (as described in the previous section). The assumption is that each time a new energy label class starts being significantly populated, prices in the following two classes are affected by a downgrading effect of about 20%. Between 2005 and 2014, we can identify two significant events: the A++ class take-off (from 1% market share in 2005 up to more than 15% in 2013), and the appearance of the A+++ class in 2010 (in fact it had been anticipated since 2008). Based on this, we assume that the A+ class is hit by the erosion effect twice over the period considered, while the A and A++ classes are affected once. We apply a 20% decline to the base case model price and to the price impact/premium of improvements situated in the A class category, a 40% decline to those in the A+ class category, and a 20% decline to those in the A++ class category. We can then rebuild an anticipated LCC curve for 2014 this way.

The next graph shows the new curve in blue, against the initial preparatory study curve in grey.

As an indication, the estimated purchase price of the base case falls from €485 to €388, that of the LLCC model from €590 to €457 and that of the BAT from €873 to €652. Retrospectively, an average price of €652 for an A++ model in 2014 does not seem utterly in contradiction with available averaged market data trends compiled up to 2011 (JRC, 2012; Siderius, 2013) or with the small market sample shown in the previous section. It may even be conservative[11].

On the graph, we see that the new curve does not necessarily deeply affect the position of the LLCC point (it moves slightly to the right though). However, the angle of the right part of the curve is much smoother, thus having a substantial impact on the position of the break-even point: it corresponds now more or less to the BAT point.

Figure 14. Fridge-freezer LCC curve with anticipated price decline trends



---

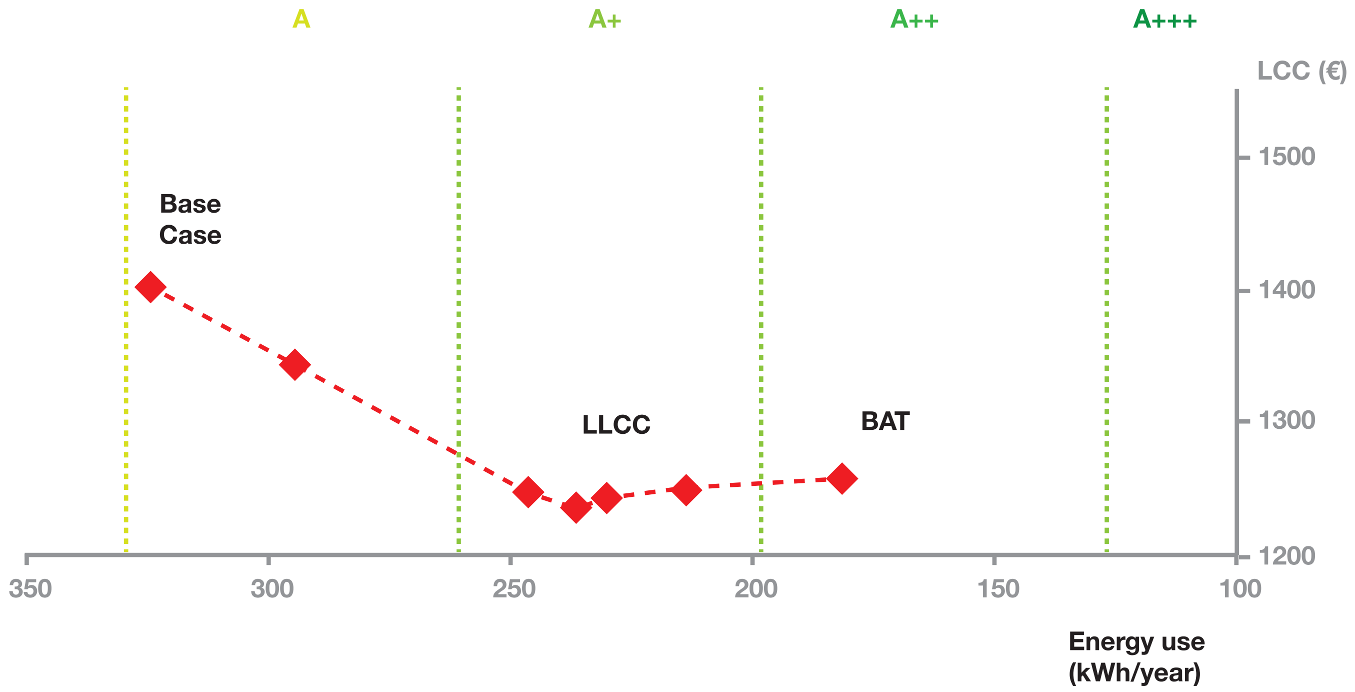
[11] Note: In this simulation, product prices have not been corrected by price indices to account for inflation when comparing prices at different years. The inflation rate in the EU has been around 10% over 2005-2012 in the household equipment sector. We have ignored this aspect in the calculations.

Combination of all changes

On the next graph, we show the curve when all three modifications are applied together.

The result is interesting: the curve has now a noticeably flat aspect in between the LLCC and BAT points. This means that the improvements leading from A+ to A++ have become quasi cost-effective (for each of them the extra life cycle cost is below €10). In this situation, decision-makers could have felt confident to set the requirements at a more ambitious level for 2014, e.g. at the A++ level. This conclusion meets the findings of other studies (Siderius, 2013; Ecofys, 2012). The break-even point is beyond the BAT point, perhaps close to today best performers (A+++).

Figure 15. Fridge-freezer LCC curve with all modifications combined



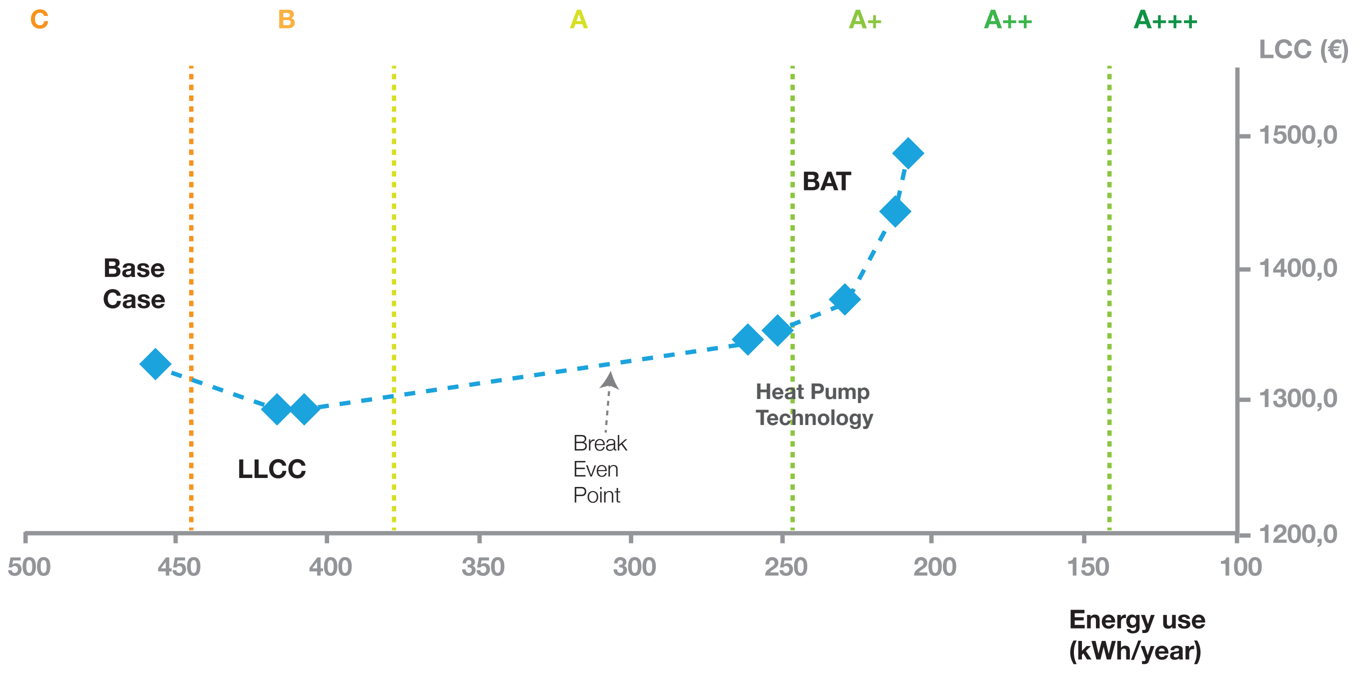
3.2 Tumble dryer case study

Our starting point is the Ecodesign preparatory study (PriceWaterhouseCoopers et al., 2009). Seven possible technological energy efficiency improvements had been identified in the study for the base case condenser dryer (of 6kg load capacity). In the following, we have recalibrated all data to the duty cycles and formulas used in the final regulation, to ease the comparison with energy labelling classes[12]. In the preparatory study, a discount rate of 5%, constant electricity price of 0.17 €/kWh and typical lifetime of 13 years have been used.

The tumble dryer case is characterised by a leapfrog improvement corresponding to switching from conventional to heat pump technology. In reality, it means jumping directly from class C to class A or better. The heat pump technology is more sophisticated and expensive to buy, so the conditions in which this switch becomes economical is essential for this product group.

On this curve, we see that the LLCC point is firmly stuck below the A class – not far from the conventional base case. Even the break-even point does not allow jumping to heat pump dryers.

Figure 16. Dryer LCC curve in the 2009 preparatory study



---

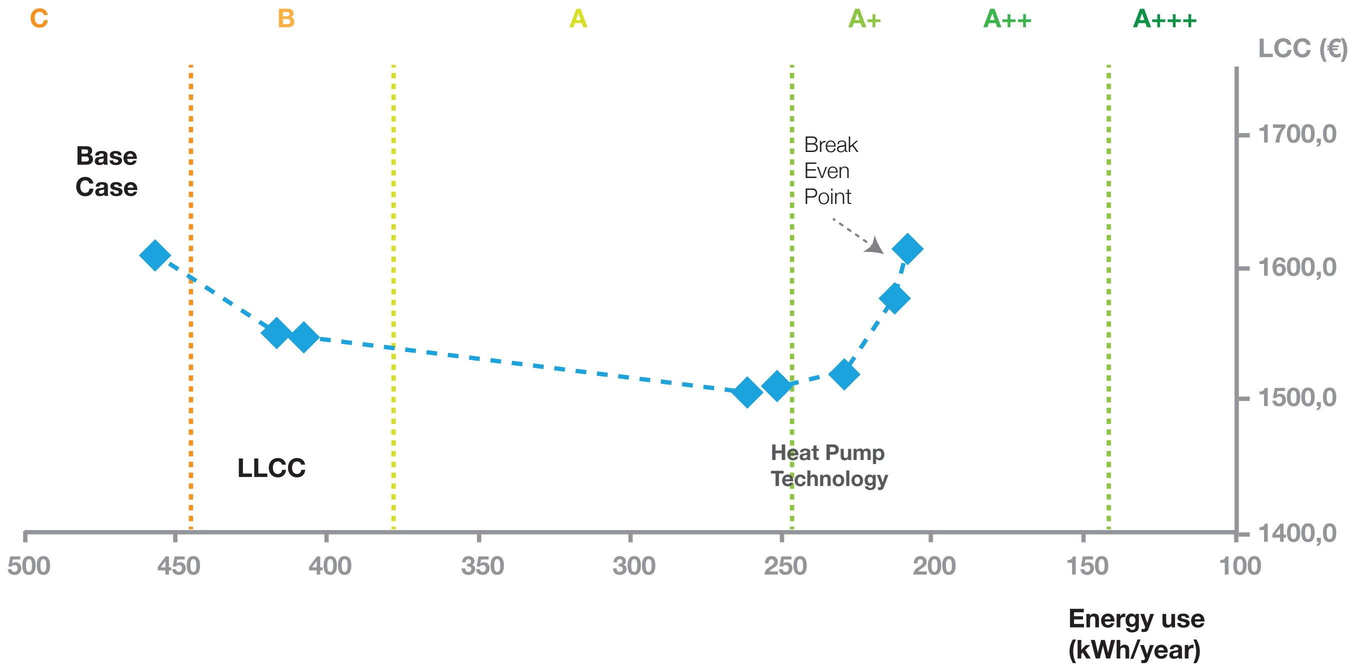
[12] We have assumed that all models had a 13.5kWh/year consumption in low power modes and a consumption in part load equal to 60% of that in full load.

Impact of increasing energy prices

On the next graph the calculation of operating costs was modified to anticipate inflating energy prices, as is now stipulated in the revised Ecodesign methodology (VHK, 2011). The energy price rate balances the discount rate, so that energy costs over the product lifetime are no more discounted.

This modification is sufficient to dramatically change the picture: the LLCC point has shifted to the heat pump technology. The break-even point now lies in the A+ class and corresponds to a 50% reduction in energy use compared to the initial LLCC point.

Figure 17. Dryer LCC curve with increasing energy prices

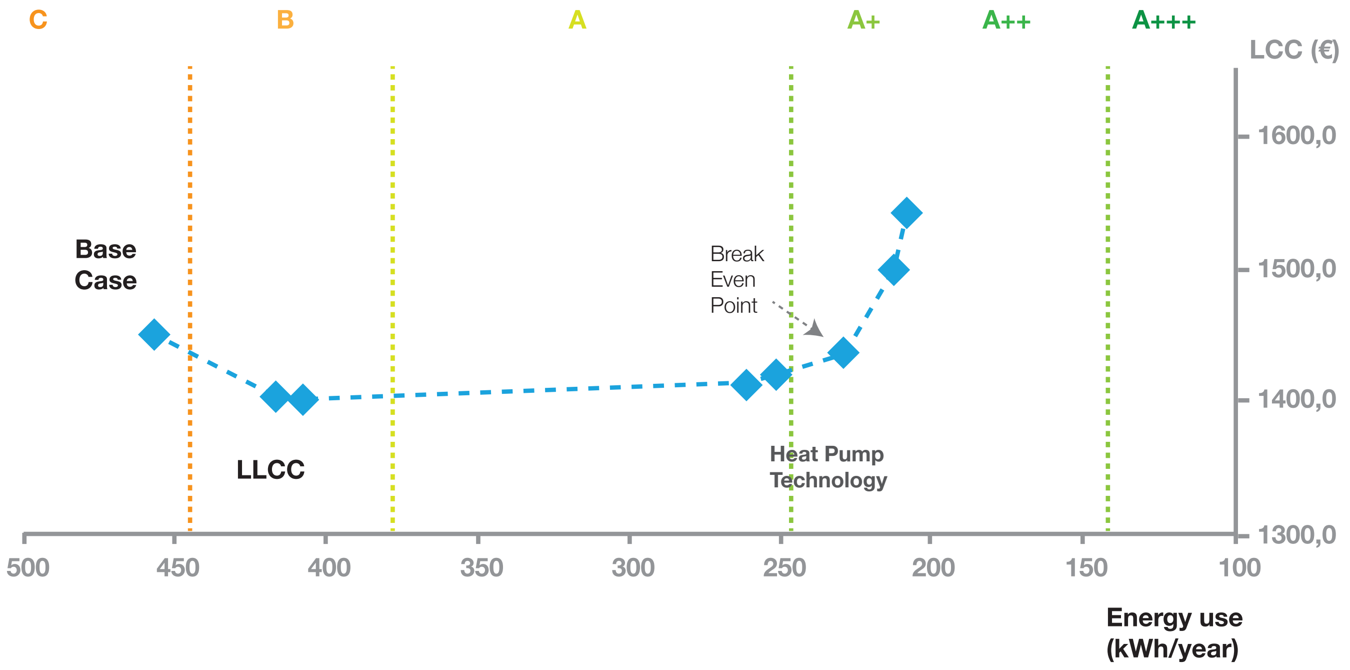


Impact of societal costs

Starting back from the initial curve of the preparatory study, we show in the next graph the impact of adding societal costs to the operating costs. For this, the Ecoreport 2011 tool of the Ecodesign methodology (VHK, 2011) was applied to each improvement option.

The societal cost modification is not sufficient in itself to change the LLCC point, but it moves the break-even point to the A+ class.

Figure 18. Dryer LCC curve including societal costs



Price decline trends

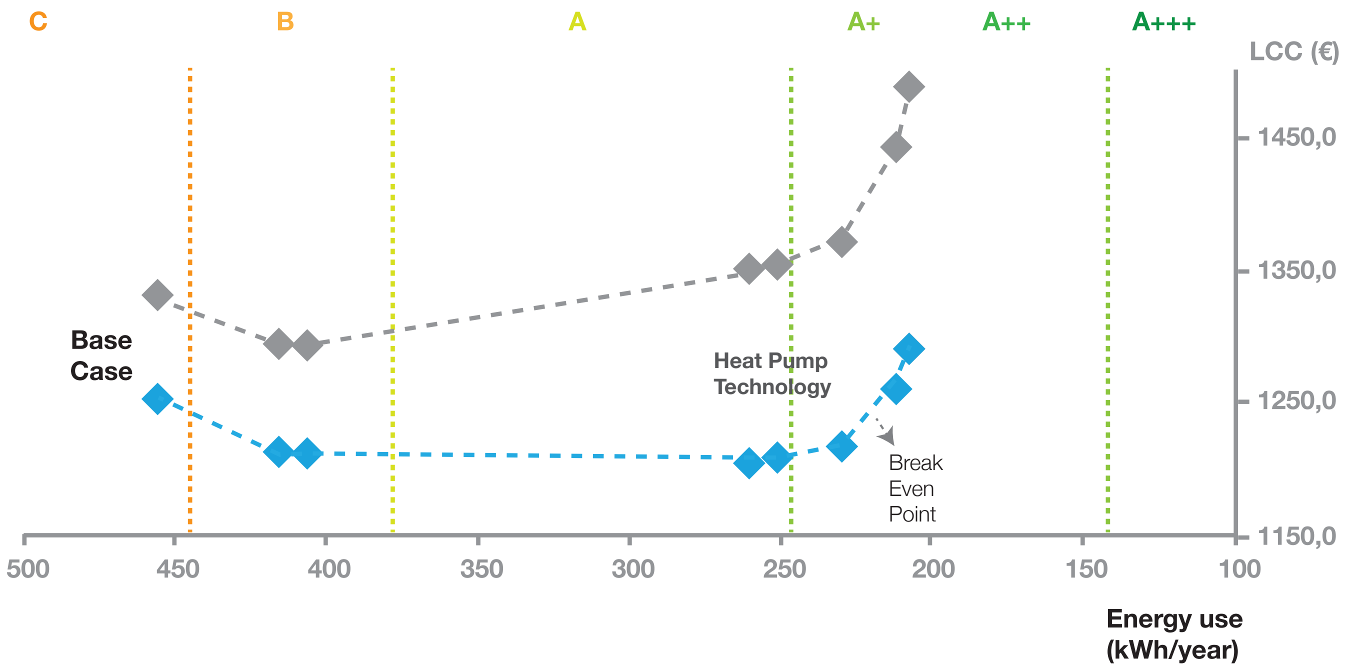
The Ecodesign requirements for tumble dryers at the LLCC level are due to enter into force in 2015, that is seven years after the data collection used for the preparatory study. We are now looking at the way the initial curve in the preparatory study might change if techniques to anticipate the evolution of product prices over such a time period are used.

In the available study testing the use of experience curves in the EU (Siderius, 2013), the calculations for dryers on energy class averages - using a learning rate of 30% - lead to a 20% price decline for products in the A class and 25% price decline in the A+ class over five years. We have re-applied these values on the seven improvements according to their situation vis-à-vis the energy classes. Siderius made the assumption that prices in the base case area (class B and C) remain flat over the period. In order to better account for overall price decline trends, we have readjusted the price of the base case to the average of class B observed in 2011 (€472) and assumed a 20% price decline on improvements in class B.

This leads to a purchase price of €736 in the A class, and €797 to 906 in the A+ class. This is not inconsistent with the market data presented in this report or in Siderius, 2013. It may even be conservative. The result is shown on the next graph (in blue) against the initial curve of the preparatory study (in grey).

This consideration of price decline trends alone is sufficient to shift the LLCC point to the heat pump technology level, and the break-even point to the A+ class.

Figure 19. Dryer LCC curve with anticipated price decline trends



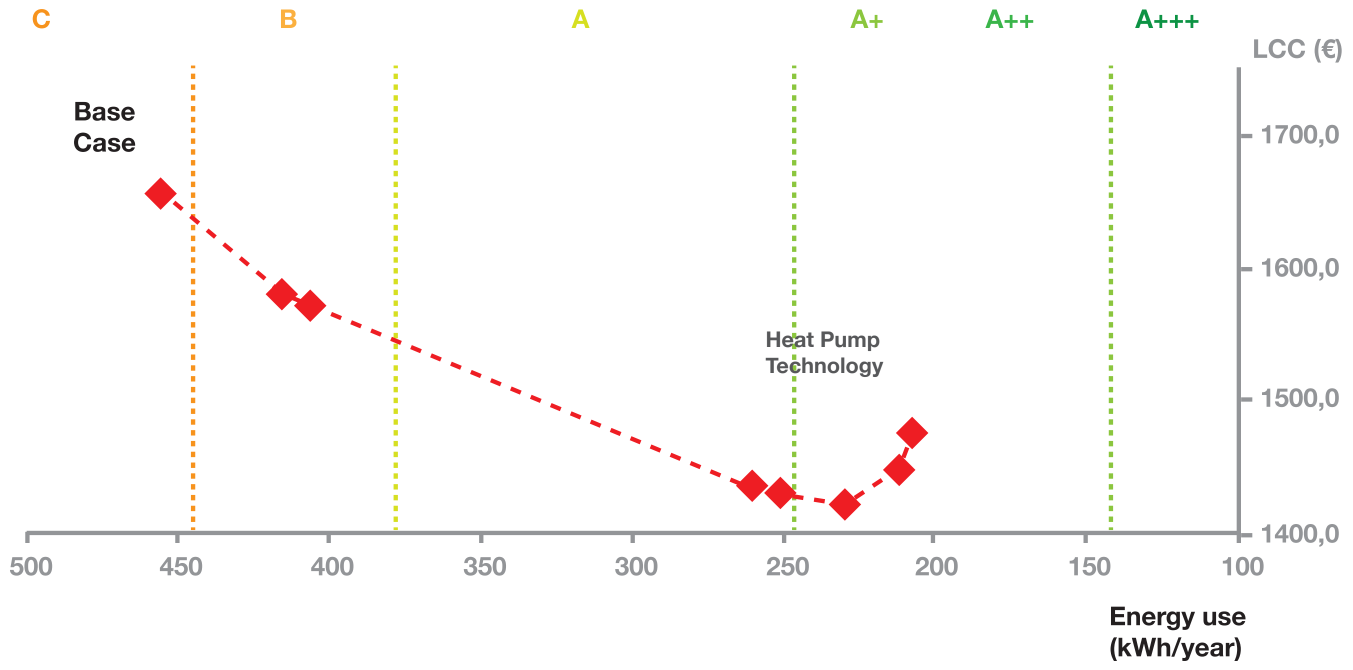
Combination of all changes

On the next graph, we show the result when all three modifications are applied together.

The shape of the curve has fully changed. Now the LLCC lies indisputably with the heat pump models of the A+ class. This conclusion on the LLCC point is more conservative than that in the Siderius analysis (Siderius, 2013). One reason is that Siderius considered products up to the A+++ class in his analysis, while the Ecodesign preparatory study data did not go further than the A+ class.

On the graph, the break-even point would be situated far to the right, in the A++ or even maybe A+++ class (if only more technological data had been available at the time of the preparatory study to continue drawing the curve), that is at the level of today's best performers.

Figure 20. Tumble dryer LCC curve with all modifications combined



3.3 Policy implications

In this last section, we investigate how much additional energy saving would have been achieved at EU level should the Ecodesign requirements be set according to a modified criterion based on the changes we recommended.

For the two case studies, the modified criterion and calculations would have justified setting Ecodesign requirements eight years down the line at the energy class of the best available technologies identified in the preparatory studies (A++ for fridges and A+ for tumble dryers). This echoes in a way the ‘spirit’ of the Japanese Top-Runner program - although the EU and Japanese policy processes cannot be compared side by side and the Japanese programme does not require all products on the market to meet the target (only company fleet averages) (Siderius et al., 2012b).

For a household, purchasing a fridge-freezer at the regulatory level A++ instead of actual A+ means about 20% additional energy savings. For dryers, an A+ instead of a current B means at least 40% additional savings. This is a substantial impact on a home energy bill.

To calculate the energy savings at EU-aggregated level by 2020, in theory, a full and proper stock modelling should be rerun. As it was not possible to do such a fine analysis here, we have opted for more simplified approaches.

- Fridges & freezers: In the impact assessment study accompanying the Ecodesign regulation, it was assumed that with the requirements currently set at the A+ class level in 2014, sales of fridges, freezers and fridge-freezers would gradually improve in efficiency until by 2019 no more A+ models are sold (EC, 2009). Setting the level at A++ in 2014 would have actually advanced this market transformation by five years. Thus, we assume that the energy consumption of the 2020-2025 sales in the impact assessment can be used as a good proxy for the 2014-2019 sales in our scenario. The difference between the original 2014-2019 sale consumption and this new one provides the additional energy savings we can expect from our scenario. This leads to the conclusion that setting the requirements at the A++ class in 2014 would have achieved six TWh/year more savings by 2020 at EU level than the current levels (which are expected to save four TWh/year by 2020). This is comparable to the estimate made by Siderius through another simplified approach (Siderius, 2013).
- Tumble dryers: Unfortunately, the impact assessment study accompanying the Ecodesign regulation does not disclose sufficient details to allow a similar approach (EC, 2012). In this case, we can only refer to the findings from Siderius of an extra savings of five TWh/year if requirements are at the A++ class (Siderius, 2013) (note: this is one class higher than in our case study).

Overview of other product groups

Two case studies are not sufficient to draw overall conclusions on the potential impact of using the modified criterion. Would it systematically support mid-term Ecodesign requirements at the level of best available technologies? This question cannot be answered without further analysis.

As a hypothetical illustration, it is possible to look at what would have happened if Ecodesign requirements had indeed been set at the level of the best available technologies. This should be seen as a theoretical exercise, with no pretention of conclusively answering the previous question.

In the table below, we summarise the findings from our own calculations on a number of product groups. Unless indicated, the estimation of extra savings by 2020 follows a similar approach to fridge-freezers: it is approximated as the difference between the 2014-2020 sales consumption in the case of current requirements and the 2014-2020 sales consumption in the case of the higher requirements. For the latter, we assume that higher requirements trigger a reduction in average energy consumption by a factor commensurate to the difference between the level of requirements. The table includes products for which Ecodesign impact assessments provide sufficiently disaggregated data to allow such calculations.

Table 3. Hypothetical estimates of additional energy savings in case of BAT-level requirements

	Ecodesign level (2nd tier)	BAT level	EU savings from Ecodesign measure (TWh/year by 2020)	Additional savings if the level had been BAT (TWh/year by 2020)
Fridge-freezers	A+	A++	4	6
Condenser dryers	B	A++ [13]	3.3	5 [14]
Washing machines	A+	A++ [15]	1.5	2.5 [16]
Dishwashers	A+	A++	2	1.5 [17]
Televisions	D	E (changed to C)	28	14 [18]
Mobile air-co.	A	A+++ (changed to A+)	0.1(estimated) [19]	0.2 [20]
Total			**39.3TWh**	**29.2TWh**

These examples show that setting requirements at a higher level can have significant positive impacts on the energy savings achieved. For the six product groups, **the total additional savings amount to about 30 TWh/year, to be compared to the 39 TWh/year expected from current levels. This is not far from a doubling of the energy saving potential by 2020.**

If the requirements are indeed to be set at higher levels, a relevant question is: how far would this be acceptable to certain stakeholders, in particular industry? There is now an expectation of eight years attached to the EU Ecodesign policy process, and industry groups are getting used to such policy intervention. They are usually able to anticipate and plan in advance. There is no clear evidence suggesting that EU manufacturers have so far had a harder time innovating and selling products under the constraints of the Ecodesign policy as it is today (eceee, 2013). On the contrary, *'overall, the EU electrical goods industry has performed comparatively well in terms of output and employment growth over the past decade and the EU has retained important manufacturing strengths in household electrical appliances'* (Ecorys, 2011). This could suggest that there are still margins to be more ambitious on energy efficiency policies. However, this should be confirmed by more in-depth analysis of the impact on industry. Incidentally, the economic and social impact assessment studies that are performed by the European Commission with each Ecodesign measure could probably be more robust, as they sometimes seem to be rather formal exercises to back predetermined decisions and lack details on the way the impact on manufacturers has been assessed. Besides, they usually investigate a limited number of scenarios, none of which are at a level beyond the LLCC point.

---

[13] The preparatory study did not mention the A++ class as such, however its BAT level was not far from the limit between A+ and A++.

[14] Figure from Siderius, 2013 based on a requirement set at the A++ level.

[15] The BAT in the preparatory study was in the middle of the A+ class. The A++ has been considered for the calculation.

[16] Assuming a 12% higher efficiency in average for the 2014-2020 sales in case of requirement at A++.

[17] Assuming a 12% higher efficiency in average for the 2014-2020 sales in case of requirement at A++.

[18] As the BAT in the preparatory study was at a particularly inefficient level (worse than the actual requirements), we assume that the use of better data and the modified LLCC criterion would have led to justifying requirements at the C class, triggering a 20% higher efficiency in average for the 2014-2020 sales.

[19] Part of a larger product regulation covering all residential air-conditioners (total saving potential of 11 TWh / year by 2020).

[20] As the preparatory study BAT was quite high, the calculation has been made with requirements at the A+ class. A 16% higher efficiency in average for the 2014-2020 sales is assumed.

Conclusion

This report has analysed the most explicit criterion that EU decision-makers have to rely on when setting Ecodesign regulations on energy-related products: the least life cycle cost (LLCC) criterion.

This criterion has some merits. Its precision and quantitative nature frame the discussion on the ambition of Ecodesign requirements and make decisions more robust and transparent. Other regions can more easily replicate or be inspired by the levels set in the EU. The use of the criterion requires preparatory analysis that can bring a useful evidence base to decisions. In addition, the rather deliberative approach to implementing the criterion so far still allows for some flexibility.

On the other hand, the LLCC criterion currently has its limitations. The concept is somewhat unsuitable for product groups characterised by a lack of correlation between prices and energy efficiency, such as some IT and consumer electronics. Its narrow focus on the end-user benefit may undermine some broader societal benefits of Ecodesign measures. In terms of implementation, two major risks have been identified: it neglects the potential of possible combinations of interrelated improvements or integrated designs, and it leads to decisions based on out-dated cost estimates that fail to anticipate market dynamics.

Ensuing policy recommendations include:

- Increasing the robustness of preparatory analysis, for instance by taking inspiration from methodological aspects and tools used in the US, with gradual alignment and shared approaches between EU and US.
- Finding ways of adjusting the LLCC criterion to product groups characterised by a lack of correlation between price and energy efficiency.
- Considering targets in between the LLCC and break-even points (also favouring a consistency with energy labelling class limits, if any).
- Progressing the use of accurate cost/price anticipations and societal costs in the analysis.

The revised Ecodesign methodology adopted in 2011 already highlighted possible improvements to the LLCC calculations, including the anticipation of increasing energy prices, use of experience curves, and consideration of societal costs. However, the latter two are only recommended for the sensitivity analysis. They could gain a higher prominence by being enshrined in the legislation and systematically included in the analysis from the beginning. The timing is relevant, as the EU intends to prepare a review and revision of both its Ecodesign and Energy Labelling Directives in 2014/2015.

The implementation of these changes on two case studies (fridge-freezers and tumble dryers) has revealed a significant impact on the shape of life cycle cost curves. This could have had an influence on the discussion of Ecodesign requirement levels and the energy savings achieved at the end of the day. This is true particularly if decision-makers had considered setting requirements not only close to the LCC minimum, but at a further level still guaranteeing acceptable life cycle costs for the consumer (i.e. not higher than that of the base case). On the two case studies, this would have allowed setting requirements close to the best performers identified in the preparatory analysis.

Reinforcing the rules to set Ecodesign requirements would reduce the risk of ineffective policy decisions, unleash additional energy savings, and further challenge the EU industry to take the leadership in greening the world economy.

Full proposal for a reformulation of the LLCC criteria

Annex II of current legislation 2009/125/EC

Current text:

Concerning energy consumption in use, the level of energy efficiency or consumption must be set aiming at the life cycle cost minimum to end-users for representative product models, taking into account the consequences on other environmental aspects.

The life cycle cost analysis method uses a real discount rate on the basis of data provided from the European Central Bank and a realistic lifetime for the product; it is based on the sum of the variations in purchase price (resulting from the variations in industrial costs) and in operating expenses, which result from the different levels of technical improvement options, discounted over the lifetime of the representative product models considered.

New text:

Concerning energy consumption in use, the level of energy efficiency or consumption is set at a level corresponding at least to the implementation of all existing improvement options that individually pay off for the end-user and society during the typical life of representative product models, taking into account the consequences on other environmental aspects. Where feasible and justifiable, the level may be set at a higher performance level as long as it does not deteriorate the financial impact for the end user over the product lifetime compared to a standard product.

The analysis method uses realistic discount and energy price increase rates; it compares the cost of technical improvement options against the savings on operating expenses and monetised societal costs, in particular of pollutants, over a realistic product lifetime. The best available statistical techniques to anticipate future trends in costs/prices – such as learning curves – are used to guarantee the validity of the analysis by the time the requirements enter into force.

References

References

Andersen R. D., Remmen A. (2011), Implementing Measures of the Ecodesign Directive – Potentials and Limitations.

Attali S., Bush E., Michel A., Toulouse E. (2013), Can Europe continue deciding on product policies (MEPS, labels, etc.) without monitoring the market?. Eceee Summer Study 2013.

BAM (Bundesanstalt für Materialforschung un Prüfung) – UBA (Umweltbundesamt) (2012), The energy-relevant EU Top Performer Products - A contribution to achieve the EU 2020 goals.

CLASP and NRDC (2012), The Impact of Graphics Cards on Desktop Computer Energy Consumption.

Coolproducts (2010), Energy Savings in Practice – Potential and delivery of EU Ecodesign Measures.

Coolproducts (2012), International Comparison of Product Policies.

CSES (2012), Evaluation of the Ecodesign Directive (2009/125/EC), Final Report.

Dale L., Antinori C., McNeil M., McMahon J. E., Fujita K. S. (2009), Retrospective Evaluation of Appliance Price Trends. LBNL paper.

Desroches L.-B., Garbesi K., Chan P., Greenblatt J., Kantner C., Lekov A., Meyers S., Rosenquist G., Van Buskirk R., Yang H.-C. (2011), Incorporating Experience Curves in Appliance Standards Analysis. LBNL paper.

Desroches L.-B., Garbesi K., Yang H.-C., Ganeshalingam M., Kantner C., Van Buskirk R. (2013), Trends in the cost of efficiency for appliances and consumer electronics. Eceee Summer Study 2013.

Directive 2005/32/EC establishing a framework for the setting of ecodesign requirements for energy-using products, 2005. Revised into Directive 2009/125/EC for energy-related products.

EC (European Commission) (2009), COMMISSION STAFF WORKING DOCUMENT Accompanying document to the PROPOSAL FOR A COMMISSION REGULATION implementing Directive 2005/32/EC with regard to household refrigerating appliances - FULL IMPACT ASSESSMENT.

EC (European Commission) (2012), COMMISSION STAFF WORKING DOCUMENT - IMPACT ASSESSMENT Accompanying the document Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for household tumble driers.

EC-DG ENER (European Commission – Directorate General Energy) (2012), Presentation on the challenges faced at EU level in the implementation and application of the Ecodesign and Energy Labelling Directives.

Eceee (European Council for an Energy Efficient Economy) (2013), Seminar on Ecodesign and Innovation (http://www.eceee.org/events/eceee_events/seminar-ecodesign-and-innovation).

Ecofys (2012), Economic benefits of the EU Ecodesign Directive.

Ecorys (2011), Study on the Competitiveness of EU electrical and electronics goods markets with a focus on pricing and pricing strategies.

Electrolux (2012), A Business Perspective. Presented by J. Samuelson at the A.I.S.E. Information Day, Dec. 2012.

Ellis M., Jollands N., Harrington L., Meier A. (2007), Do energy efficient appliances cost more?, Eceee Summer Study 2007.

Europe Economics (2007), Impact assessment study on a possible extension, tightening or simplification of the framework directive 92/75 EEC on energy labelling of household appliances - Appendix 1, Literature review carried out by Europe Economics.

Fraunhofer IZM et al. (2007), EuP Preparatory Study Lot 5 (TV).

GfK (2013), Home Appliances. Presented at IFA 2013 by Friedemann Stöckle.

IEA (International Energy Agency) (2000), Experience Curves for Energy Technology Policy.

IEA (International Energy Agency) (2007), Experience with Energy Efficiency Regulations for Electrical Equipment.

ISIS, ENEA, University of Bonn (2007), Preparatory Study for Ecodesign Requirements of EuPs – Lot 13: domestic refrigerators and freezers.

JRC (Joint research Center) (2012), Energy Efficiency Status Report 2012 - Electricity Consumption and Efficiency Trends in the EU-27.

Mauer J., DeLaski A., Nadel S., Fryer A., Young R. (2013), Better Appliances: An Analysis of Performance, Features, and Price as Efficiency Has Improved.

NRDC (2009), California Adopts the Most Advanced TV Efficiency Standards in the World (press release).

PriceWaterhouseCoopers, Ecobilan, CODDE, KERP (2009), Ecodesign of Laundry Dryers - Preparatory studies for Ecodesign requirements of Energy-using-Products (EuP) Lot 16.

PSI (Policy Studies Institute) & BIOIS (2011), Impacts of Innovation on the Regulatory Costs of Energy-using Product Policy.

Siderius Hans-Paul (2009), The relation between energy class and price of appliances.

Siderius Hans-Paul (2012a), The ecodesign and energy labelling process – challenges and solutions.

Siderius Hans-Paul, Nakagami H. (2012b), A MEPS is a MEPS is a MEPS: comparing Ecodesign and Top Runner schemes for setting product efficiency standards. Energy Efficiency 6: 1-19.

Siderius Hans-Paul (2013), The role of experience curves for setting MEPS for appliances. Energy Policy 59: 762-772.

Taylor M., Fujita K. S., Dale L., McMahon J. (2012), An Exploration of Innovation and Energy Efficiency in an Appliance Industry.

Topten (2012), Topten Focus 30th April 2012 - Heat pump dryers: 50% energy saving potential.

Topten (2013), European TV market 2007-2012 – Energy efficiency before and during the implementation of the Ecodesign and Energy Labelling Regulations.

Toulouse E., Sivitos S., Arditi S., Reintjes N., Spengler L. (2012), EU Ecodesign and Labelling regulations for TVs: is the picture half full or half empty? Electronics Goes Green Conference 2012.

US DOE (Department of Energy) (2011), Using the Experience Curve Approach for Appliance Price Forecasting.

Van Elburg M. et al. (2011), Study on Amended Working Plan under the Ecodesign Directive.

VHK (2005), Methodology Study Eco-Design of Energy-Using Products (MEEuP).

VHK (2011), Methodology for the Ecodesign of Energy-related Products (MEErP).

All preparatory studies of the Ecodesign Directive can be accessed here:

http://ec.europa.eu/energy/efficiency/ecodesign/eco_design_en.htm

www.coolproducts.eu

@coolproductseu

coolproducts
for a cool planet