Estimating the impact of labelling high quality compact fluorescent lamps on the energy consumption for lighting in the residential sector

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Abstract
European Climate Change Programme (ECCP) identified residential lighting as an important area, which could result in cost-effective savings of 7 Mtonnes of CO_2 by 2010. However, the residential lighting market is still dominated by inefficient incandescence lamps. Market research indicated that to achieve durable market transformation and to substantially increase the use of Compact Fluorescent Lamps (CFLs) in this sector, it is essential to market attractive and good quality CFLs. One of the conclusions is that after a considerable number of promotion and rebate schemes, organised by national energy agencies, energy utilities and lamp manufacturers, the number of CFLs in household remains marginal. A first reason of pouting CFLs is directly linked to the poor quality of some products that standard customer may find in the European market. One of the objectives of the project EnERLIn (Energy Efficient Residential Lighting Initiative, EIE-05-0176) supported by European Commission (SAVE program) is to establish a list of criteria that should fulfil high quality CFLs and to propose a standard testing protocol. Both criteria list and procedure should be based on scientific arguments taking into account existing technology limitations. The proposed protocol could then be used for labelling high quality products and thus set customer's mind in rest. The use of a CFL Quality Charter instead of imposing new standards has the advantage to be easier to adopt and may phase-out low quality product just by exploring end-user behaviour. The first objective of the present paper is to give a draft of the criteria and of the proposed protocol. Then we will examine the impact of marketing "labelled" high quality CFLs by elaborating scenarios for energy consumption for lighting in residential sector. In those scenarios we propose to extrapolate market size using existing growth rates "filtered" by end-user behaviour ("evolutional", "green" or "consumerist" cases are examined).

The actual situation
Quality Standards and Labelling affect every part of our life. From the quality of air and water, to the assurance that products and services are safe and effective for use, there are several regional, national and international quality labels helping to improve our everyday life. Quality labelling plays an important role in ensuring that products, services and systems meet our needs; for example labels should guarantee that electrical products, like electric appliances, are compliant with the standards, energy-efficient and safe to use. In principle, our modern world should fit together like a jigsaw puzzle thanks to standardization and labelling processes. Labels that have a role in protecting the public's safety and health and may become mandatory through the inclusion in laws and regulations, such as national, European or International codes. However, there still exists a number of domains where labels are cruelly missing and this is a serious handicap that slows down, or in some cases stops, new product development and all associated business. Lighting is one of these domains where an internationally accepted quality labelling system (beyond existing electrical standards) is cruelly missing. Today, even if national or regional quality test protocols exist driven by governments, lighting industry, big retailers and even consumer associations, there is no coordination of these actions, and we are far from a real labelling

system. The obtained results from one test to the other are in many cases contradictory and this seriously jams the situation to the consumer's eyes, however lighting is one of key domains for achieving energy savings and enhancing the quality of life and ensuring user's health.

Currently, more than 33 billion lamps operate worldwide consuming more than 2 600 TWh per year (19 % of the global electricity production world-wide) (Waide 2007). If, for an industrialised country, this amount is substantial (e.g. about 11 % for France, 20–21 % for US) it becomes very important for under-development nations for which lighting is one of the major applications of electricity; for example: 37 % for Tunisia and up to 86 % for Tanzania (Mils 2002). Furthermore, the annual greenhouse gases due to this energy production are estimated to be in the order of 1 800 million tonnes of CO2 equivalent? In future, it can be estimated that the need for light sources will increases by a factor between 1 and 2. This can be calculated by using the average growth rates of GDPs combined with the growth of world population and the progress of electrification First of all, highly efficient light sources are one route to help governments reduce the power consumption of lighting systems and hence reduce the emissions of greenhouse gases in line with the Kyoto agreement., or generally speaking, with any national environmental saving action. More efficient light sources would also:

- limit the rate-of-increase of electric power consumption;
- reduce the economic and social costs of constructing new electricity generating capacity;
- reduce the emissions of greenhouse gases and other pollutants.

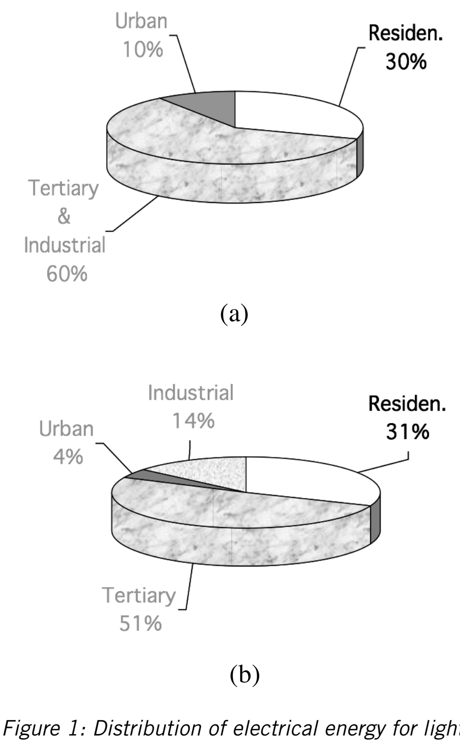


Figure 1: Distribution of electrical energy for light generation for (a) France (ADEME 1999) and (b) USA (Scholand 2002) [Notice: Urban lighting means "outdoor" city illumination]

The household and private and public services sector buildings are important power consumers. In both cases lighting represents a large part of their energy consumption. The following pie charts give the distribution of energy consumption for light generation for two industrialised countries (France and USA).

Figure 1 shows that in both cases the residential sector consumes 30 % of the global lighting energy, this figure is in agreement with the figure given by Mills (Mills, 2002) concerning the world energy consumption for lighting. Several EU and National Initiatives and Directives tented to promote energy efficient lighting for services sector buildings. These efforts can be judged as rather successful because nowadays the Compact Fluorescent Lamps (CFL) market share represent 6 % of the all European countries market whereas the same figure in world scale is limited to 4 %[1]. CFLs typically use 4–5 times less energy to provide a given light emission during the operational phase than incandescent lamps. Energy consumption during the production and disposal phases is also lower, and this includes mercury disposal at the end-of-life of the lamps. It is clear that Residential sector represent a huge energy saving potential especially because in this sector old style and highly inefficient incandescent bulbs (General Lighting Sources – GLS) are still dominant. Thus, even in the case that, in average, every household in European Union replaces one additional 75 W GLS by a 15 W CFL the energy gains are really considerable: the power difference between the two lamp types producing the same quantity of light is 60 W and, in average, a lamp in house operates around 1 200 h per annum (ADEME 1999); however, this value depends on the geographical situation and also on the room type that the lamp is installed). Under these conditions the annual energy gain per household is in the order of 72 kWh per year. There were approximately 140 million dwellings in the EU in 1995 (Joosen, 2001). It is expected that the number of dwellings will rise to 156 million in 2010 (Joosen, 2001). Under these conditions the energy economy of replacing only one lamp per dwelling is in the order of 11 TWh or 3,2 million tonnes of oil equivalent[2]. This energy saving corresponds to a reduction of over 5 million tonnes of CO_2 equivalent or the output from several large power facilities. However, since few years, the observed increase of CFL market share seems to make out of breath and somehow stagnating. For example, in Denmark, Dansk Energi investigations in the frame of EnERLIn EIE project, show that about 30 % of the Danish residential sector hasn't any CFL. Immediately a question arises: why residential end-users pout CFLs?

There are several reasons explaining that residential sector still use a large amount of incandescence lamps:

- Low quality (and probably lower cost) CFLs are widely available in numerous retail stores. A customer buying these devices due to the attractive price, and with lack of information on CFLs quality, is very rapidly disappointed due to reduced lifetime, bad lumen output, long warm-up time. In addition it should be noticed here that even low quality CFL still stay rather more expensive than any GLS.

1. It should be noticed here that CFL sales in western Europe represents today 20 % of the lighting industry annual turnover.

2. 1 MWh of electrical power is taken to be equal of 0,285 TOE (as given by DG-TREN in 2004 based on EU-15 power production)

- It seams difficult to convince individual customers that the payback time is so rapid (in general, less than one year) because the "gain" is completely "diluted" and invisible in the household's global energy/electricity bill. Despite of important effort made in communication by energy providers, energy agencies and others, there is still a non-negligible part of end-users unaware of the environmental and economic benefits of CFLs. On the other hand, for households lighting can be purely practical or a very architectural feature or a combination of both, therefore energy efficiency is often just one consideration and probably not the prevailing one. Find a nice design luminaire suitable for CFLs is, is in nearly all countries, a difficult thing. Many nicely designed luminaries for incandescent are not visually the same if CFLs are used in them.
- Due to actual technology limitations the most of CFLs are not suitable for applications with short on–off cycles as this reduces lamp life dramatically. There is no information accessible and understandable by the every-day user that explains that fact. Therefore it is necessary to educate the customer as well as the retailers on how to use them effectively. This end-user training should be considered as important as any labelling scheme, because misuse of good products lead immediately to a consumer disappointment.
- Older generation of CFLs were almost unable to offer to customers an acceptable ambiance within the residence, this due to poor colour rendering index, limited choice of colour temperatures, ungracious shapes and aesthetic incompatibility with luminaries. Most of these inconveniences are now overcome but there is still a large part of customer unaware of that progress. Once again information lack on these subjects is critical.
- The warm up time of the CFL before full lumen output does that the user should not use in a staircase or elsewhere where they need the full lumen output immediately. Most of CFLs are not accepting dimming, today a new generation of dimmable CFLs is in the market but the price is still prohibitive and the customers aren't informed.
- CFLs are very sensitive to voltage variation. Of course, in western countries the mains voltage is very well regulated, but in other countries the voltage may fluctuate and this is still an important issue for CFLs.

The above list is not exhaustive but shows clearly that it exist a sever lack of information and education of the individual customer concerning CFLs and this is a severe obstacle to developing energy efficient strategies for the residential sector. In the case of service buildings sector these difficulties have been short-circuited by passing though EU or/and National directives. This is not realistic in the case of individual households. Promoting good quality CFLs based on a unified labelling scheme, which answer to the specific individual questions and fears of the customer and then add imitative measures seems to be the right way to act. All in all, beyond of any efficient information, it is of major importance to phase-out from the market low quality CFLs that strongly disappoint any not fully convinced end-user after a first bad experience and discourage him to continue in that direction despite any promotion schemes.

Labelling as tool for promoting "Good quality CFLs"

A quality control process based on scientifically arguments that respect CFL technology is, to our opinion, the best way to impeach low quality CFLs to gain new market shares. However, it should be noticed here that "scientific" arguments are not appropriate for all customer segments and especially for residential end-users. That every-day CFL end-user could recognise is a visible label or sticker on the lamp packaging or on the tags in the store shelves.

Labelling on the packaging or on the store shelves needs an important effort by the manufacturer or the retailer. It is clear that both manufacturer and retailer will refrain this action unless that it becomes compulsory or, better, required by the customer as quality gage. However, labels, stickers and pictograms today submerge customers at any packaging. In many cases common customer ignores completely the meaning of the labels. Even in the case that the significance is known customer is still sceptic about the validity of the information and very often he considers that as a commercial interest artefact. This makes that labelling is commonly accepted as useful but seldom applied.

It is clear that create new label, especially compulsory, without an important information campaign is condemned to be a flop in short term with important economic collateral effects. In addition, creating a new label limited in National level only is also inefficient procedure because it concerns a small fraction of a global market that represents lighting. Furthermore, creating a label with out a standard test procedure acceptable by all actors would be also a disaster especially if the certification procedure is left to the manufacturer's only appreciation. Experience shows that to the customer's eyes "self-certification" is not really a quality gage. In addition to that, today smaller industrial units that they may not have all necessary equipment in order to ensure the correct application of the certification procedure do CFL production also. Making CFL quality label compulsory without establishing an independent test authority is very risky for all actors.

All in all, that we need today, ideally, is an international compulsory labelling scheme based on a control procedure adopted as an international standard and performed by an independent certification authority on the basis of systematic testing.

The most important action to use quality label for CFLs is the ELI (Efficient Lighting Initiative). This Efficient Lighting Initiative is a voluntary international program for certifying the quality and efficiency of lighting products. ELI was initiated in 2000 by the International Finance Corporation (IFC) and funded by the Global Environment Facility (GEF), to promote efficient lighting in Argentina, the Czech Republic, Hungary, Latvia, Peru, the Philippines, and South Africa. The original ELI program tested the quality certification and labelling concept and focused on seven countries during the period 2000 through 2003. The obtained results illustrated clearly the importance of using labels. European teams also invest important amount of time to create the European CFL Quality Charter. Both initiatives proposed to use, on voluntary basis, the use of

Figure 2: Efficient Lighting Initiative and European CFL Quality Charter pictograms

the two "logos" above as mark of compliance with the established rules.

To the authors' knowledge, if the ELI logo displays some success especially in manufacturer and retailer web pages, the Quality charter pictogram is rather unused up to now. Strong to that first success, in 2005, IFC with funding from GEF, supported an establishment of the ELI Quality Certification Institute (ELI Institute) to develop and expand the ELI certification and branding system globally. To its side Europe, in the frame of SAVE program, entrusted EnERLIn project consortium to review and to expend the CFL quality charter but, for the moment, the idea of creating a European testing facility is not investigated. In parallel the consortium of the CFLI-'International CFL Harmonization Initiative'[3] is working on the establishment of performance specifications for CFL quality. During the last meeting of this consortium a major conclusion come up: An internationally consistent methodology for measuring CFL performance criteria is useful and amendments to IEC 60969 should be submitted.

There is a myriad of CFL performance specifications (more than 33). To this point CFLI concluded a reduction in the number of performance specifications in use around the world would be welcomed and beneficial to almost all stakeholders provided it did not inhibit the commercial need to differentiate products.

However, the main question of what should be considered a "good" CFL remains up to now without a concrete answer. First of all, the defined criteria that guarantee CFL quality (safety & performance) to the consumer are not clear neither unified, second, these criteria should apply if possible to all type of CFLs (integral, pin-based, dimmable and look-alike) and this not the case today. In addition the criteria should of course respect existing standards (e.g. IEC, ISO …). However, it should be noticed that in many cases these standards concern some specific aspects (electrical safety, network compliance …) of the component (lamp or ballast). That we need (and that is today missing …) is to have standards that governs the full system and not only at the component level. This is a strait forward advantage to the labelling schemes compared to heavy and long hull standardization procedures.

The following factors may form the basis for a set of CFL-quality indicators that we can divide into four sections:

A. Energy conversion assessment

- A.1 Luminous Efficacy (after 100 h) and luminous efficacy maintenance at 50 % of rated lifetime. This test has to be performed at room temperature (20°C) as well as at colder space (10°C). Look-alike lamps have to be considered especially due to the external bulb.
- A.2 Power Factor and power factor maintenance along lifespan (e.g. at 75 % of the rated lifetime)
- A.3 Transient Protection against mains variation

B. Lifetime assessment

- B.1 Rated lifetime ("median" lifetime should be used instead of "average" lifespan) in continuous operation (for pin-based lamps this criterion should be tested with a standard ballast, for dimmable CFL the lifetime should be also tested on lamps operating continuously at 60 % of their nominal power)
- B.2 Stress Test under accelerated on-off cycle (at least 30 min on – 15 min off for integral non-dimmable lamps, for pin-based lamps with electrode preheating and integral dimmable lamps: 10 min on – 10 min off cycle)

C. Comfort assessment

- C.1 Run-up Time (after 100 h and at 75 % of the rated lifetime)
- C.2 Colour Rendering Index (CRI). A minimum value has to be guaranteed.
- C.3 Correlated Colour Temperature (CCT).

D. Compliance with other standards and regulations

- D.1 Electromagnetic Interference
- D.2 Toxic materials (Mercury, PCBs…)
- D.3 Recyclability
- D.4 Electrical standards

Each indicator should fulfil a specific test and a number of "points" could be awarded to each criterion and can be balanced by a coefficient according its importance. The point system should be defined once and used without modification by each participating country. The total number of points can be then used for a global product ranking. To obtain the quality label, the product has to totalize a minimum number of points, but, in addition, a minimum number of points have to be obtained in each section. Some indicators (especially D.1, D.2 and D.4) are compulsory and if not fulfilled the product is immediately eliminated. Some others, like C.3, could be considered as just informative. The test has to be performed in a minimum number of lamps form different production batches; the sample should be representative of the production of the manufacturer for a given time. The total number of points should be defined as the average of the sample; the standard deviation can be used also as production quality indicator. The test laboratories should be independent and accredited as compliant to international standards.

The qualification protocol should be applied to existing and new products at least once in order to obtain the label. This can be done by request from the manufacturer or vendor. To ensure that labelled-CFLs performance are still accurate and in line with the CFL performance specification, the tests should be performed frequently and at unpredictable time using random sampling off the shelf, without manufacturer involvement: the procedure should consist on obtaining samples from a number of retail locations and sending them to any accredited independent laboratory for testing.

3. http://www.apec-esis.org/www/cfl/

How much energy we can save in Europe by boosting CFL market?

As explained before, energy saving policies and environmental constraints imposed by European regulations push strongly to develop "green" solutions for lighting. At the present case, CFL seems to be the most valid solution. The average observed growth rate concerning CFL numbers is the order of 13.5 % per year (in the order of 11.5 % in western and 17 % in eastern countries). We should notice that the global annual growth rate of the lighting industry is in the order of 1 %.

However, the evolution of CFL efficiency is very slow, someone can expect that it will attain, in average, 63 lm/W in 2030. This value is a little bit higher than the existing "average" value as calculated by today's CFL mix (58 to 60 lm/W) and this because we can expect some slight incremental evolution in that technology. Beyond CFLs, there are two new technologies that can be responsible for a breakthrough in the domain of residential lighting: Light Emitting Diodes (LED) and Organic Light Emitting Diodes (OLED). LED technology seems to be mature enough in order to take some part of the domestic lighting. Today some "design" luminaries with LEDs are proposed for sale, but the price is prohibitive. Also, the efficiency of white LEDs is in the order of 25 lm/W (in series production) but according Photonics21 Consortium (Photonics 2005) this can attain the value of 150 lm/W in 2025-2030 and according to Ronald Haitz the price of LEDs is decreasing by a factor of 10 every decade (this is a generally accepted value even is more recent data shows faster evolution, that has to be confirmed in the next few years). We will use these figures in our projections. On the other hand OLED technology seems to be very promising because of the fact that OLEDs in opposite of LEDs constitute large "etendue" light sources. However, even if Osram shown very recently a OLED panel with 20 lm/W efficiency, this technology is still in experimental stage and it is difficult to expect that can get a significant part of the residential lighting market by 2030. It is also very difficult today to predict what will be the cost of this technology for the next years. Concerning LED and OLED there is not any environmental charge that is included today to these light sources. However, LED industry, like semi-conductor industry, can be considered as relatively harmful for the environment. It is not excluded that by 2030 LED technology will have to support also an environmental charge for recycling like CFLs. Under all that assumptions we construct 3 possible scenarios for 2030:

Basic scenario: In 2030 only CFLs and GLS have a significant part of the market, LEDs and OLEDs quantities are negligible because of slow technological development and high prices. Then taking into account the annual growth rate of CFLs as given above we can consider that in 2030 each household will have 45 % CFLs and 55 % GLS (this percentile is in number of lamps).

Consumerist scenario: In 2030 CFL price still high compared to a GLS and the CFL promotion campaigns fail to convince consumers about the utility of CFLs, in addition LEDs and OLEDs quantities are negligible because of slow technological development and high prices. Under these conditions in a household we will find 75 % of GLS and 25 % of CFL. A second "consumerist + 10 lamps" scenario is also considered, in that case the number of lamps per household is increased by 10 (38 lamps instead of 28).

Green Scenario: In 2030 CFL prices are comparable to GLS, CFL quality is guaranteed by a European label. LED technology is well advanced and price is now affordable for consumer that may use this type of light sources for decorative and punctual lighting. OLEDs are now available but the price is still high, thus the quantity per household is negligible. The light source park of an average household will include 75 % CFL, 15 % GLS and 10 % LEDs. For environmental protection purposes the consumer is convinced that it is not necessary to increase the quantity of light in his home. It is assumed that GLS and CFL average power are 60 W and 15 W (no significant change in the efficiencies since 2006). The requirement of constant light quantity, lead to an average power of 5 W per LED light source. It should be noticed that an efficiency of 100 lm/W is used in our calculations, this value is 50 % less than the targets of Photonics21 but it seems to be more realistic for industrial production in 2030.

Before evaluating the impact of each scenario in the energy consumption of an average household it is necessary to evaluate the expected number of light sources per household in 2030. For this purpose we consider that the number of light points per household increases with an annual rate of 0.5 % (which is lower than the annual growth rate of the lighting industry sited above). This leads to 28 light points per household in average. The following Excel table calculates the impact of each scenario on the average energy consumption per household.

Impact on energy consumprion for Lighting per household in 2030 in Europe

Number of lamps/household	28
Number of hours/year	2000

Reference	2006	Energy (MWh)	2,7
		Flux (klm)	21,4

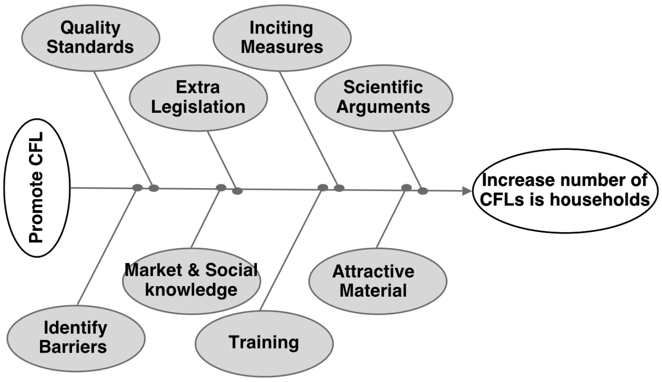
	Efficiency (lm/W)	Average power (W)
GLS	14	60
CFL	63	15
LED	100	5

	GLS				CFL				LED				Total			
Scenario	%	Number	Energy (MWh)	Flux (klm)	%	Number	Energy (MWh)	Flux (klm)	%	Number	Energy (MWh)	Flux (klm)	Energy (MWh)	Variation %	Flux (klm)	Variation %
Basic	55%	15,4	1,8	12,9	45%	12,6	0,38	11,9	0%	0,0	0,00	0,0	2,2	21%	24,84	13,9%
Consummerist	75%	21,0	2,5	17,6	25%	7,0	0,21	6,6	0%	0,0	0,00	0,0	2,7	-1%	24,26	11,8%
Consummerist+ 10 lamps	70%	26,6	3,2	22,3	30%	11,4	0,34	10,8	0%	0,0	0,00	0,0	3,5	-24%	33,12	35,4%
Green	15%	4,2	0,5	3,5	75%	21,0	0,63	19,8	10%	2,8	0,03	1,4	1,2	132%	24,77	13,6%

This calculation shows that, compared with the actual situation, in the case of Basic scenario a decrease of 21 % on the lighting consumption of the household is observed for an increase of 13.9 % of total light quantity. Pure consumerist scenario leads to 1 % increase of the energy consumption for only 11.8 % of light quantity. If we use the "reinforced consumerist" scenario the light quantity is increased by 35.4 % in the household (this is probably not justified by visual comfort considerations…) and the energy consumption is increased by 24 %. Finally, the Green scenario lead to an increase of 13.6 % for available light quantity (compared to 2006) but similar that obtained in 2030 by the basic scenario and that for an energy gain of 132 % compared to 2006.

Are the labels the only way to promote good technologies?

The situation discussed in that paper is the ideal one but it can serve as starting point for reaching our main objective: increase the number of CFLs in households. To achieve that we need to follow an integrated strategy based on scientific but widely accessible arguments, training, socio-economic knowledge, standardization, inciting measures and extra legislation. This is the only way to realise new generations of more reliable and more efficient products. The following "fishbone" graphics summarises all the above issues.



Labelling occupies a predilection place in this strategy and should, for sure, be integrated in any reflection from the real beginning, but labels and standards are not "the panacea" that solves all problems found the way leading from existing (or brand new) concepts to new generations of products.

In all above it shown that, labelling process is as important as standards for protecting consumer and also boosting market segments. However, labelling procedure should involve some more basic researchers and on rely more on scientific criteria. In addition, the structure of labelling process, e.g. their speed and flexibility, is perceived as a major problem for the effective communication between technological and commercial issues. Thus an important dimension of the interaction between these two components is the question of how labelling takes place within organisations. An integrated strategy as proposed in the previous paragraph, and as is experimented (partially) in the frame of EnERLIn project seems to be well adapted for overcoming these problems.

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