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Viewpoint

Stalemate in energy markets: supply extension versus demand reduction

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Abstract

A demand curve for electricity intensity of the OECD economies is discussed. Based on a 1998 sample, the (long-run) price elasticity of intensity is assessed at 1.17, clearly not smaller than 1, refuting the allegation that lower prices guarantee lower bills. The regression shows that electricity efficiency improvement is stronger than the height of the price, and so that industrial nations with a high price (tax) policy reveal the smaller budget shares of electricity bills in GDP. High end-use prices (taxes) are not harmful to the economies, but a necessity to trigger efficiency, while efficiency seems not feasible without high end-use prices. Nations as an aggregate react on electricity budget shares that they try to keep within acceptable/affordable boundaries. The analysis confirms that there still exist huge unexploited efficiency potentials, but once the physical limits of efficiency are attained, that non-energy policies must take over to limit energy consumption.

End-use demand reduction is discussed to be also more efficient and more effective than supply extension for meeting the energy needs. The final question why the better options are overridden by the worse ones, brings us to the discussion of barriers, where the discussion is limited to a distinction between natural and artificial barriers to energy efficiency.

Keywords: Electricity efficiency; Price elasticity; Barriers

1. Introduction

Since the 1970s a continuous debate about the optimal amount of energy consumption is going on. Most scenario builders (IEA, 2002; UNDP and Energy Council, 2000) forecast that more and more conversion of energy commodities (mainly fossil fuels) is necessary to sustain economic growth in affluent societies. Others (Weizsäcker von et al., 1997) contradict this vision and point to the pressure on the sources and sinks of nature, and to the huge energy efficiency (EE) opportunities that were and are foregone. The discussion sharpens when large-scale, long-term irreversible technological and investment decisions have to be taken, e.g., about the future of nuclear power. In Belgium the latter discussion intensified when the federal minister for energy J.P. Poncelet installed in 1998 a commission to put the role of nuclear power on the agenda again.[1] The founding and working of the commission were not organised in a professional way and the objectives were biased from the beginning. The proponents of nuclear power now refer to the work of the commission as a 'proof' that Belgium needs nuclear power for its future. Before engaging in number crunching discussions, it is valuable to set the vocabulary and the framework. The central point of energy policy is whether we should put priority on energy demand reduction through EE, or rather extend the supplies of energy commodities.

Part 1 of the article illustrates the 'law of acceptable energy bills/affordable budget shares' teaching us that end-users adapt energy use to prices for attaining the bills they can afford. High prices stimulate high efficiency but have no significant impact on the height of the bills, and if there is an impact it is rather opposite the one advertised by energy sellers. In part 2 we show that regarding efficiency and effectiveness demand reduction is better than supply extension. Having shown that demand reduction through EE is the better deal, one asks why it remains underdeveloped compared to supply extension. In our conclusion we point to the abundant

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[1] Commission "Ampère".

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literature on the barriers that preclude the way to an energy efficient society. Some are inherent and natural, but many others are artificial.

2. Energy prices, intensities and bills

The discussion between the people promoting demand reduction and people promoting supply extension is always vivid, and the arguments are little dependent on the actual level of EE realised. In nations where energy spillage is occurring and is admitted by most observers, the call for more energy supplies and the refusal to consider the options for reducing demand are perhaps the strongest, as the example of the USA shows. Statements as 'less energy supply will harm our economy' and 'further energy efficiency is impossible, because we already reached the frontiers of development' are to be heard in every country, independently of the level of EE established. To weight the arguments we analyse OECD statistics, that we combine with EIA (DOE) data (Table 1).

There are few reliable data series on energy prices available. We only found information on prices of electricity and we had to limit the analysis here to this energy type, being fortunately the most leading indicator of energy use in industrialised countries. The electricity intensity is expressed by the consumption of kWh divided by the gross domestic product (GDP). So intensity is in kWh/US$ GDP. The source of the data is the IEA (OECD). The electricity price is a weighted average between the prices for industrial customers and for domestic customers, the weights being their share in total electricity consumption (US$/kWh). The source of the data is the EIA (DOE, USA). The multiplication of the respective variables is the share of the country's electricity bill in the GDP of the country (third column of Table 1).

One can compare the performance in electricity efficiency of a sample of 24 OECD member states.[2] We first show the results of a regression analysis, and then we highlight the discussion of three nations, all highly industrialised and wealthy: Japan, Belgium and the USA.

Fig. 1 shows the original sample data (small rhomb) and the results of the regression analysis (small squares). We regressed the electricity intensity of a country on the weighted average electricity price in that country. There is a clear inverse relationship between the height of the electricity price and the electricity intensity of the economy, reflecting the basic 'law of demand' in economics.

Table 1
Indicators of electricity use in 29 OECD member states (1998)

Country	Electricity intensity (kWh/ $US GDP)	Electricity price ($/ kWh)	Share of electricity bill in GDP
Switzerland	0.155	0.1236	1.65
Denmark	0.164	0.1680	2.76
Japan	0.171	0.1612	2.76
Germany	0.182	0.1179	2.14
Austria	0.199	0.1328	2.64
Ireland	0.205	0.0973	2.00
Netherlands	0.210	0.1000	2.10
Italy	0.222	0.1271	2.82
France	0.222	0.0995	2.21
Luxembourg	0.244	na	—
Belgium	0.250	0.1079	2.70
Spain	0.256	0.1129	2.89
United Kingdom	0.257	0.1023	2.63
Portugal	0.293	0.1282	3.75
Greece	0.306	0.0829	2.54
Australia	0.392	na	—
United States	0.393	0.0688	2.71
Turkey	0.425	0.0769	3.27
Mexico	0.426	0.0446	1.90
Korea (Korea, South)	0.428	0.0561	2.40
Finland	0.484	0.0711	3.44
Sweden	0.485	na	—
New Zealand	0.498	0.0571	2.84
Hungary	0.584	0.0660	3.85
Poland	0.628	0.0532	3.34
Norway	0.671	na	—
Canada	0.708	na	—
Czech Republic	0.919	0.0508	4.66
Slovak Republic (Slovakia)	0.974	0.0374	3.65

Source: IEA (OECD) and EIA (DOE, USA).

The double log function ln(Intensity) $= a + b^*\ln(\text{Price})$ has been estimated on the sample of 24 observations, leaving 22 degrees of freedom. The R^2 equals 82.3 and the residual standard error 0.2296.

The estimated elasticity b equals -1.17 (standard error 0.12 and t-value -10.11).

The statistical results indicate that the assumed hyperbolic relationship between average electricity prices and electricity intensity of an economy is most likely true. The height of the elasticity is amazing: a 1% rise in the average electricity price should trigger a 1.17% reduction in electricity intensity.[3] Not only does

[2] The analysis makes use of 24 country observations for the year 1998 (latest year of reliable data set). OECD Member States missing are Australia, Canada, Iceland, Luxembourg, Norway, Sweden, mostly because information on prices is lacking. The author is indebted to Johan Couder (UA, STEM) who collected the data and executed the regressions for this paper.

[3] The hypothesis we wanted to test was whether the elasticity equals 1 or in other words that the electricity budget share remains constant independent of price level (because matched by corollary efficiency levels).

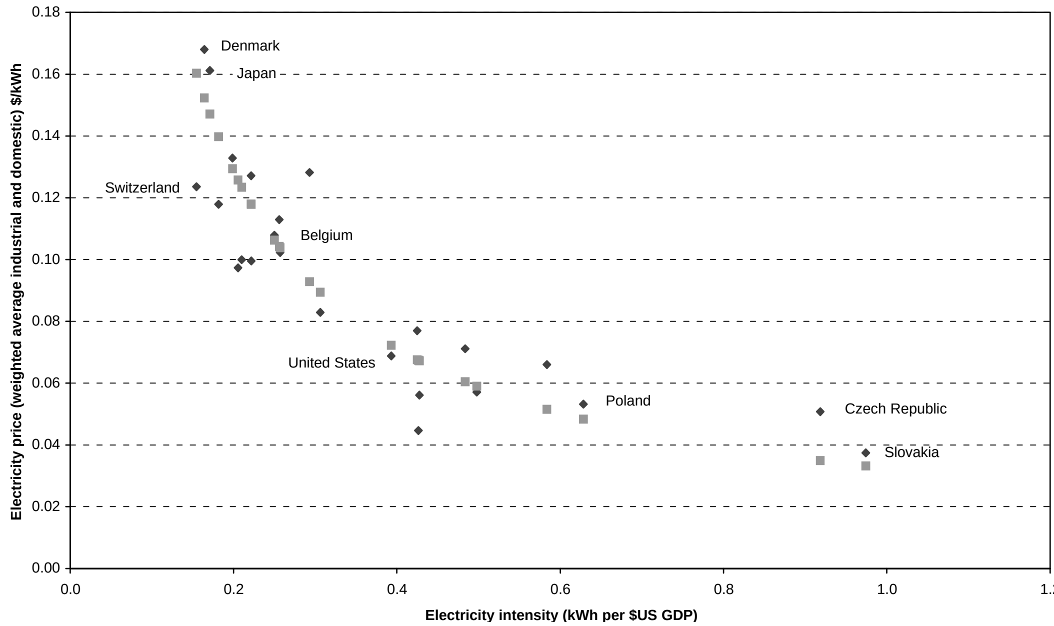

Fig. 1. Relationship between electricity price and electricity intensity in OECD member states (data 1998). *Source*: UA, STEM based on IEA (OECD) and EIA (USA) statistics.

this refute the allegations on the correlation between prices and bills, it also shows that the improved efficiency effect of high prices rather has a more beneficial impact on the final bills than the price has directly.[4]

A non-proven argument the supply extenders bring up in favour of low energy prices is that low prices should be a guarantee for small energy bills. The above analysis (elasticity of -1.17) already shows the argument is not proved by the facts. For purpose of clarity and documentation we control whether there exists a correlation between electricity budget shares in the OECD economies and the price of electricity. Fig. 2 shows the scatter between both variables, and it is obvious that such a correlation is weak, as one could already conclude from the above statistical test.

Applying a double log regression on the data shown in Fig. 2 (again 24 observations, 22 degrees of freedom), the elasticity is estimated at -0.1694 (standard error of 0.1157 and t-value -1.4643).[5] The R^2 is at the low level of 8.9 and the residual standard error at 0.2297.

This analysis shows that higher electricity prices are not the cause of higher electricity budget shares, but that on the contrary a higher price would rather occasion a lower budget share (the regression shows that a 1% price increase would result in a 0.17% decrease in budget shares, but the statistical tests also show that the relationship is not strong).

One should also approach this result with prudence because more important structural factors will finally determine the electricity budget share in the economies. For example on the scatter of Fig. 2 (see also Table 1), the member states with the smallest budget shares (at 1.90% the only ones below 2%) are Mexico (low electricity prices) and Switzerland (high electricity prices). It is known that the economies of both countries are very different in structure. The message we derive from the scatter in Fig. 2 is that there is clearly no positive correlation between the height of the electricity prices and the budget shares spent on electricity. The argument of high prices harming the economy has little solid ground.

One can detail the analysis by comparing smaller samples of countries with a quite similar economic structure. This can be done, e.g., for Belgium, Japan and USA, the former one included because we live there, but also because the electricity budget shares of the three countries are about equal at 2.70–2.75% of GDP (see Table 1).

[4] It is clear that the analysis and the results refer to long-run effects, after the economy has got the time to adapt to the installed price levels. It is in most countries true that electricity prices in real terms do not change much over time. A more detailed analysis of the relationship between electricity intensity and electricity price with more sophisticated econometric tools such as pooled time-series and cross-sectional data analysis, is possible, but we believe that the main structure of the relationship will not be significantly different as the one found. One also can apply the regression on separate sectors when data are available (see Schipper and Meyers, 1992).

[5] The price elasticity of budget shares (being intensity $\times$ price) differs by definition with $+1$ from the price elasticity of energy intensity.

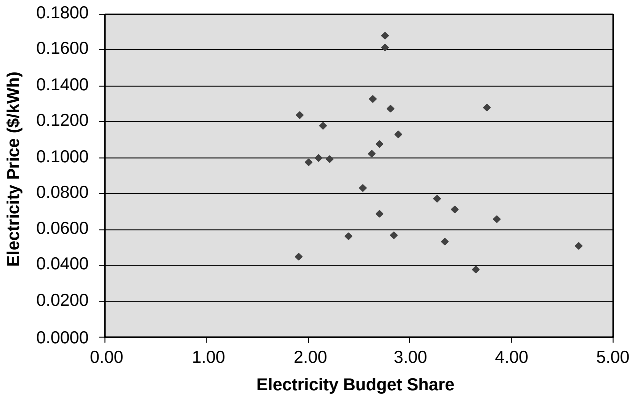

Fig. 2. Scatter of electricity prices and electricity budget shares in GDP. *Source*: UA, STEM based on IEA (OECD) and EIA (USA) statistics. Applying a double log regression on the data shown in Fig. 2 (again 24 observations, 22 degrees of freedom), the elasticity is estimated at −0.1694 (standard error of 0.1157 and *t*-value).

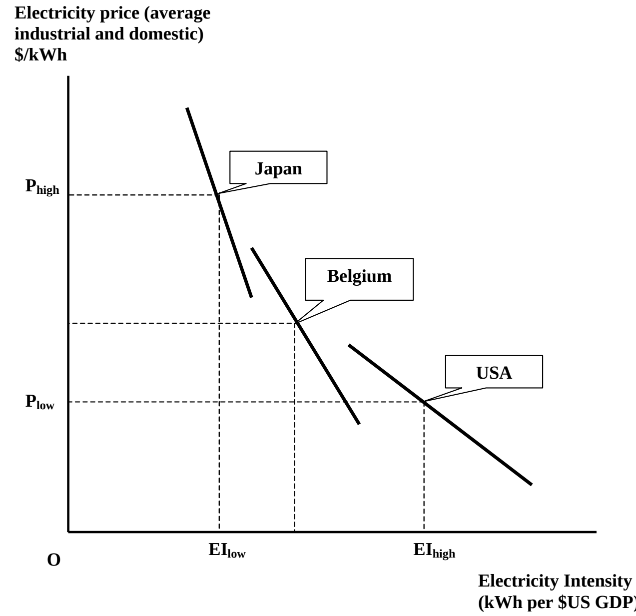

Fig. 3. 'Law of acceptable energy bills/affordable budget shares'.

Overall energy intensity is lowest in Japan, while the USA number is about 2.3 times higher.[6] Belgium is in between the two extremes. There are some geographical and climate related characteristics that can explain small part of the differences in energy consumption. A larger part can be explained by differences in the structure of the economy, but the major source of the observed gap is due to the efficiency of energy use in the various countries.

Regarding electricity efficiency, Japan again is the best, followed by Belgium. The USA is more than double as inefficient compared to Japan. Some other industrialised nations (not in the sample) perform even worse. In, e.g., Sweden enormous over-capacities in (nuclear) power generation during the 1980s were dumped on the market, and occasioned electricity substitution for fossil fuels and the deployment of electricity consuming techniques and customs.

In Fig. 3 the electricity intensities of Japan, Belgium and the USA are related to the average electricity price in these countries (see Fig. 1). The shown linear demand curves represent possible short-run demand curves, when no structural adjustments can take place, assuming that the most efficient user is facing the smallest short-term price elasticity. The area in the graph represents the GDP share of electricity consumption budgets (see also last column of Table 1 and see Fig. 2).

The numbers that we used in our analysis are averages and the shares of industrial and domestic electricity consumption diverge between the countries. Our analysis supports the findings of other researchers such as Rechsteiner and Jesinghaus, reported in Weizsächer et al. (1997, p. 201–202). The former regresses economic performance on energy costs and finds a positive relationship. The latter relates fuel consumption per capita to the height of fuel prices and finds a negative relationship.

On the basis of the long-run demand curve for EE (Fig. 1), we offer following points as conclusion or for discussion:

1. There is a tendency in all industrialised nations to keep the 'electricity budget' of the country limited to some particular percentage of GDP. The average electricity budget in our sample of 24 OECD member states equals 2.83% of GDP, with a range from 1.90% to 4.66%, the latter number being a real outlayer (Czech Republic).

   It seems as if industries, households, institutions, governments, etc. allow spillage of energy when the budget share is far lower than the number they are used to. Efforts to save energy are deployed when the budget share approaches or exceeds particular levels. One could call this phenomenon the 'law of acceptable bills/affordable budget shares'. This law works in both directions. When the bill is lower than the acceptable/affordable amount, spillage will occur and a variety of new end-uses can come up (this phenomenon is called 'rebound'). When the bill is higher than the acceptable/affordable amount, energy

[6] This simple number shows that the USA can scrap more than 50% of its power plants and other power infrastructures when it was as efficient as Japan in using electricity.

consumers will overcome informational and other barriers to realise EE options.[7]

2. Given the above observation, overall and persistent EE can only be realised by adopting high final prices for commercial end-use energy. When the prevailing prices are low, energy intensity is high and overall EE is low. In nations with low energy prices, targeted actions may create high-efficiency islands but they are swallowed in an ocean of spillage.
3. There exists no relationship between the height of the electricity prices in a country and the share of the electricity bills in GDP of the countries. Instead of a generally alleged positive relationship between heights of prices and bills, we find a rather negative relationship.
4. The 'necessity' of extending supplies and the 'impossibility' of significant energy savings are always argued by the vested interests of the energy commodity markets, independently of the level of EE or spillage reached in the economy.[8] What is feasible however depends on the willingness-to-act by society, and this willingness is proportionally related to the height of the energy prices. A deliberate policy of EE works on the transformation of the energy bills of the end-users from a broad and flat rectangle towards a small and tall rectangle (Fig. 3). Practically, this requires an energy tax strategy, because commodity energy prices fluctuate in the short term and can be depressed for longer periods (because there exists a built-in tendency towards infra-structural over-capacities in the commercial energy supply industry).
5. Highlighting the importance of the height of the end-use prices (requiring a well-conceived long-term energy tax policy) for underpinning EE, should not result in an attitude of neglecting other policy instruments that can advance efficiency breaktroughs and dissemination. On the contrary, when the price level pushes end-users to look after their own interest, they should be guided by reliable information on what can be done, they should find in the market place the knowledgeable contractors, equipment and products to realise the most efficient solutions.

   But it remains also true that without overall high price levels of end-use energy, many policy efforts will be in vain, because the gains in one field are eaten up by losses in other fields.
6. The above analysis is limited to the aspect of intensity or efficiency of energy use. It does not answer questions about the absolute extent of energy consumption in particular countries that is related to populations, income levels, life styles, trade balances, etc. When the physical limits of intensity are attained (at 0.10–0.05 kWh/$US-1998 GDP?),[9] further limits on energy consumption depend on non-energy policies.

3. Efficiency and effectiveness of demand reduction and supply extension

De-coupling the consumption of commercial energy from the generation of economic wealth and from living a comfortable life has been the crux of energy policy discussions since the mid-1970s. There are some logical[10] steps in reaching an efficient level of commodity energy use (Fig. 4).

In Fig. 4, present energy consumption is shown as the large grey circle. It is possible to reduce consumption by avoiding spillage, i.e. commodity energy that is consumed serving no purpose. Lights on in rooms not in use, cooling and heating spaces at the same time, idle running engines without a reserve function, etc. are examples of spillage. The borderline between spillage and useful consumption is sometimes rather thin, and therefore there will always be discussion about the 'necessary' level of energy use. For example, some people point to a large part of transport energy as spillage due to a bad spatial planning, because many trips also entail a lot of disutility to the commuter.

The history of energy use in the industrialised nations has been one of neglecting and of rejecting free energy from the sun and from the environment. Buildings are constructed to exclude the impact of free energy in order to provide fully, feedback controlled, commercial energy for all purposes. For a sustainable future it will prove necessary to maximise the use of free energy, and to minimise the supplement of commodity energy. Part of the latter minimisation is obtained by implementing the most efficient energy technologies that are also smart enough to accurately adapt the commodity supply to the free supply in real time. Most advancement here is attained by smart lighting systems that combine

[7] The principle of "budget coefficients" is the heart of the MEDEE model that estimates the development of future energy consumption by the households. When the energy budget exceeds a particular deviation from a trend line (due to, e.g. higher prices), households will reduce energy use to bring the energy budget in balance. When the budget falls below some level, rebound effects occur. For more information see Bertrand Chateau of ENERDATA (France) at Bertrand.Chateau@enerdata.fr

[8] In a draft paper (July 2002) Kornelis Blok argues that improving EE by 5% per year can be achieved for new equipment, installation and buildings (further information at k.blok@chem.uu.nl).

[9] Stretching the use of the regression equation found above, one finds that the intensity of 0.10 corresponds with a price of about 0.26 $US/kWh and 0.05 with 0.42 $US/kWh.

[10] The distinction between the consecutive steps is purely for didactic reasons. Several EE solutions will bridge all steps, e.g. efficient and smart lighting systems will avoid spillage by detecting occupancy of rooms, use the maximum of natural light, and provide the necessary lumens with the least electric power.

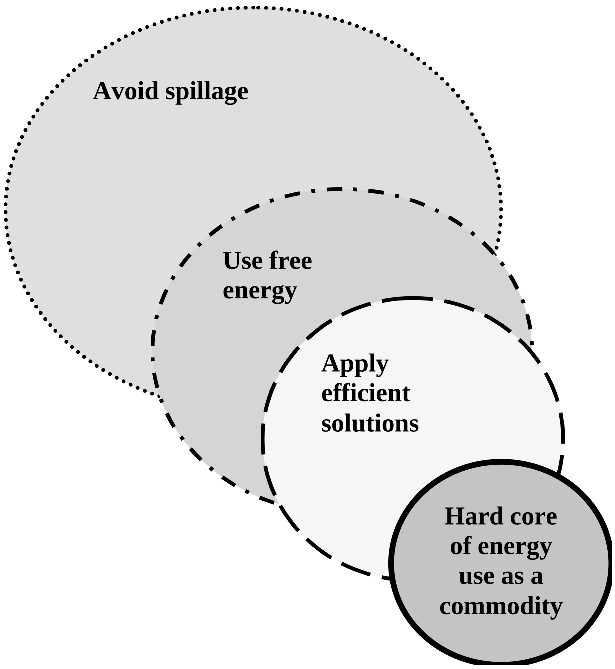

Fig. 4. Logical steps in energy efficiency.

real-time monitoring of lighting needs with the most efficient lighting technologies.

3.1. Efficiency

Commodity energy can be conserved in all phases of the energy supply to energy end-use chains. Mostly a conserved Joule or kWh is added to a conserved Joule or kWh without regard to the place in the chain where it was conserved. It is however well known that every saving at a particular point in the supply chains generates important spill over savings in all phases upstream. This makes savings at the end-uses the most efficient. Fig. 5 highlights the point. In the numerical example at the outset 50 units of energy available for end-use requires the winning of 120 units, 20 of which are consumed abroad for bringing the energy at the nation's border. Primary conversion of the crude energy consumes 30% of the import. Transport, storage and distribution require another 5 units, and secondary conversion looses 15 units.

When a final user saves half of the end-use commodity energy required, e.g., by an improved access to daylight of his building, it is mostly seen as a huge performance to save 50% of the end-use energy consumed before. In reality the overall energy savings due to the daylight access measure are much larger: instead of 120 units of commodity energy harnessed before only 60 units now can meet the job. Real savings therefore are not 25 units but 60 units. As a corollary, end-use energy conservation can "surpass" the 100% efficiency threshold because it can occasion savings more than it directly consumes.

Because of the funnelling structure of the energy chains, measures at the point of primary energy supply never can perform as well. When, e.g., losses in primary conversion can be reduced from 30 to 25 units, overall savings remain modest at this 5 units augmented by 1 unit conserved abroad. This measure has no impact downstream the energy chains.

From the efficiency point of view energy conservation must be focused on the end-uses.

However, the funnelling structure of the energy chains also has the property that primary conversion processes deliver energy into a panacea of end-uses, and therefore are large scale with a huge turnover. End-uses by definition are specific, distributed, and generally of smaller scale. It is argued that the effectiveness of measures at the top of the funnel therefore is larger than by measures at the end of it. Therefore, we consider the question whether supply extension (adding new vintages to the systems) has been more effective than demand reduction in the past.

3.2. Effectiveness

Energy bills that surpass the acceptable or affordable level as they did beginning 1980s trigger a double reaction: end-users reduce demand and suppliers extend infrastructure and capacity. In Belgium (as in most other industrialised nations) the emphasis was put on the suppliers to guarantee 'safe and reliable' commodity energy. Suggestions that one should not put all the money there, but develop a soft path of reducing commodity energy consumption were refuted as lacking sense for reality and credibility. However, the reality developed more alike the soft path scenario than it did follow the expansionist plans of the supply prophets (Lovins and Lotspeich, 1999).

Fig. 6 shows the few energy forecasting scenarios that have been developed for Belgium in the period 1975–1985. In a special 1979 edition (MEZ—Ministerie van Binnenlandse Zaken, 1979) on energy issues and policy addressing the 1973 energy crisis, the minister of Economic Affairs accepted a trend-wise growth of energy consumption. Even after special expert commissions in 1975–76 had pointed to a panacea of EE opportunities, the belief that growth in energy consumption would continue was strong. The country had to organise and to mobilise the resources for raising commodity energy consumption from the level of about 45 Mtoe in de mid-1970s to 64 Mtoe (+40% in the low scenario) or to 75 Mtoe (+65% in the high scenario) by 1990. This forecast was a support for the megalomaniac plans of building nuclear power plants one after the other, of increasing the output of the domestic coalmines, of investing in a vast LNG infrastructure

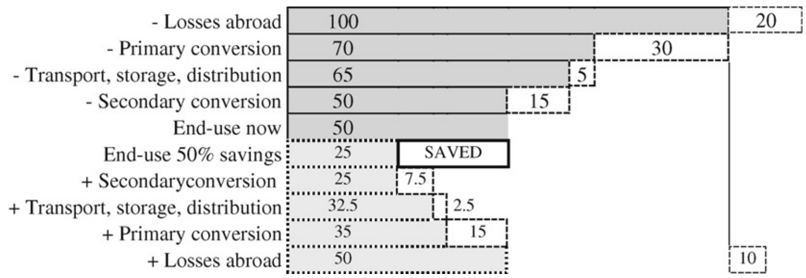

Fig. 5. Efficiency in end-uses is transmitted upstream in the energy supply chain.

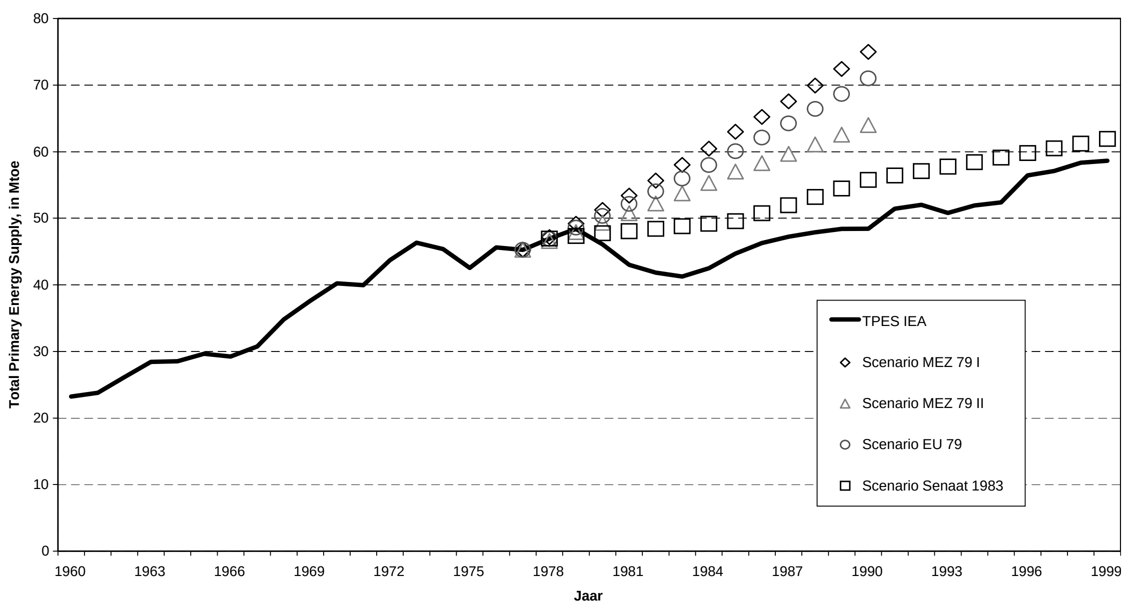

Fig. 6. Commodity energy consumption in Belgium for the period 1980–2000: predictions and reality.

and even of building additional refinery capacity. The execution of this planning was disrupted a lot by the energy price crisis starting February 1979 with the Iranian change in regime. This price rise triggered a slow-down in economic expansion and was a signal for end-users energy should be saved.

Fig. 6 shows that reality did not follow the trend-lines of the Belgian forecasters of the 1970s. In 1990 commodity energy consumption hit 48.5 Mtoe after a dip to lower levels in the first-half of the 1980s.

Another scenario, called Senaat "1983" in Fig. 10, was developed by the National R&D Energy Programme of the Science Policy Ministry (DPWB—Diensten voor Programmatie van het Wetenschapsbeleid, 1988).[11] This scenario was based on modelling and analysis and aimed at providing long-run forecasts. More attention for EE opportunities was included, and Fig. 6 shows that the forecast is nearer to reality, except for the first-half of the 1980s setback in consumption.

Why did the end-users in the beginning of the 1980s not simply wait and see how the supply companies solved the crisis and the problem of high prices for energy? Maybe three factors can provide most of the explanation. First, expectations were that energy prices would stay at a high level forever. Most of the attention during the supply crisis was on finite (oil) resources, partly due to the coincidence of the Report to the Club of Rome and the first oil crisis. The analysis that the crisis resulted from temporary bottlenecks in the energy supply infrastructures and capacities, did not reach the large public. Secondly, the technology was and still is on the end-user's hand. Performing, specific, dedicated solutions were developed on smaller and smaller scale. Light constructions are substituted for heavy ones. Monitoring, measuring and metering equipment has followed Moore's law in doubling capabilities while halving prices. Thirdly, environmental restrictions

[11] The R&D Programme was abruptly aborted in 1987.

impose extra burdens on large-scale supply facilities and favour slim and efficient techniques.

But the perhaps more interesting question is why the particular demand-supply equilibriums were installed at the levels we have been observing, and whether the equilibriums coincide with the societal optima? There is an abundant literature about the shortage in demand reduction due to a wide range of barriers that hinder people to realise the available potentials in energy conservation.[12] Barriers preclude the attainment of the socially optimal equilibriums between supply extension and demand reduction, and public policy faces an important mission in addressing the barriers and in letting less biased market forces install better market equilibriums.

4. Barriers to energy efficiency

The gap between actual efficiency and market potential can be bridged by lifting 'artificial' barriers, such as lack of information and understanding of saving opportunities, opaque tariff systems, biased investment rules, etc. When the market potential is attained, there remain 'natural' or 'inherent' barriers to reach the socio-economic potential, e.g., high interest rates, unequal distribution of wealth and opportunities, etc. Overcoming the latter hurdles requires societal transformations (conform the agenda set by sustainable development).

In the following list of major barriers, their natural or artificial character is commented in brackets, understanding that some barriers are mixed in character.

Factors that lower the propensity of end-users to reduce energy demand:

- *High transaction costs; lack of understanding energy use and possibilities to reduce it.* Energy use is spread over many applications that take place distributed over time and place. People do not own nor develop an accurate forward assessment of the quantity of energy consumed by the applications. Therefore, the conservation target is diffuse and hidden, and badly known.[13] The diversity of energy use and its dependence on several local and specific factors, require creative solutions with contributions from a span of disciplines. Creativity and multi-disciplinary approaches are modern values but not cheap to buy, and seldom directed to energy end-use, except in periods of crisis (high prices).

  [Mainly natural, because one cannot expect that a large share of the population is or should be interested in energy matters. Attenuation by information and communication policies, e.g., labels.]
- *Low budget shares.* Chasing a diffuse and hidden target is worth-wile when it is considered as very important. But—at present energy prices—energy consumption is not considered important because the bills following consumption take up a small share of household budgets and of companies' cost statements. Therefore, the learning about energy consumption is absent or limited, and the willingness-to-pay for assistance and advice about solutions to reduce energy consumption is low. Most of all, people is not willing to devote the own time and attention on the issue.[14]

  [Mainly natural, but can be attenuated by pricing/taxing policy.]
- *Tariff structures.* In many nations tariffs have been set up to discourage rational use of energy and the development of distributed resources. Also the way bills are cashed can conceal the message of energy use costing money.

  [Artificial, to be removed by new tariff and tax policies.]
- *Split incentives*. Important decisions that determine energy consumption are not (directly) taken by the end-users or by decision-makers that pay the energy bills. Others such as architects that design buildings, manufacturers that embody motors and other energy using components in appliances and equipment, central departments in institutions and in companies that rent or install office spaces and equipment, owners that let dwellings to renters, are not responsible for paying the monthly energy bills afterwards.

  [The basis of this barrier is natural, but the way "principal-agent" relationships are practically organised is mainly man-made and artificial.]
- *Cultural trends*. Energy conservation or savings are often triggered in times of crisis, when end-users and policy makers react to sudden price hikes by limiting consumption and not by raising efficiency. Low energy consumption therefore has got a connotation of poverty, shortness of freedom, etc. further stimulated by the dominant images of advertising (see, e.g., advertisements linking the power of the car-engine to the driver's power).

[12] An overview of the state-of-the-art of this discussion is provided by Chapter 5 "Barriers, Opportunities, and Market Potential of Technologies and Practices" of Working Group III (Mitigation) of the Third Assessment Report of the IPCC (2001).

[13] Consumption of energy commodities is compared to a shopper that permanently picks goods from the department store racks that do not announce prices, while the shopper is billed once at the end of the month or the year. Rational shopping is very difficult under such circumstances. See Krause (1993) 'Energy Policy in the Greenhouse', Dutch Ministry of Housing, Physical Planning and Environment, 1993.

[14] The Western energy consumption has been described as an energy addiction. To get rid of an addiction professional help is required but it is seldom solicited by the addicted.

[Mainly artificial, but like every cultural belief difficult to change.]

Factors that raise the propensity of companies to extend energy supply:

- *Earnings of suppliers are proportional to larger capacities and higher energy consumption*. This dominant incentive not only applies to the corporations that sell energy commodities, but also to the formal advisors on end-use equipment (such as architects, contractor–engineers, HVAC providers, etc.). Most energy network companies have been regulated in a way that the more (capital-intensive) investments were built up and the more energy is sold, the higher the allowed profits reach.

  [Natural is that earnings are proportional to performance; artificial is that performance is only measured by scale and through-put.]
- *External costs linked to large-scale exploitation of energy resources are rolled off*. Nuclear power is promoted by public spending on R&D. Nuclear risks are not insured in the insurance market, but governments have taken over the risk burdens. It is impossible to guarantee eternal safeguarding of the nuclear bequest. These costs are not included in the present kWh prices, and it is very difficult to do so because some of the costs are difficult to fix, because risk attitudes are not easy to quantify and preferences of future generations are by definition unknown.

  Large-scale fossil fuel consumption is a threat to climate stability, and imposes a burden on future generations that is unknown but can be enormous. The costs are assessed in some projects[15] but the accuracy of the results can always be doubted. Anyhow, as long as a significant carbon tax is not accepted, the external costs of fossil fuel use are not paid for. Also the option value and bequest value of preserving exhaustible fuel resources for future generations are not assessed and discounted in the present prices.

  [Artificial barrier generally recognised in public economics recommending, e.g., Pigovian taxes to redress the biases.]
- *R&D funds are spent most on supply technologies*. All years documenting the allocation of R&D funds show predominant shares devoted to supply technologies, in particular to nuclear technologies. EE technologies have received very few R&D funding, even less than renewable energy technologies. Not only research money is mostly supply oriented. The energy related curricula of schools and colleges are mostly very poor in educating students in EE.

  [Artificial.]
- *Lock in within established energy systems*. Energy systems are mostly complex and composed of a variety of subsystems that are complementary to one another. Changing over to alternative systems is hampered by the "catch 22" effect: slow development of demand for new solutions limit the market extent resulting in high prices that in turn choke again demand development. This barrier limits the substitution pace of public or other low-energy transport systems for the individual car transport hegemony in the industrialised nations. The transition from the present-day carbon intensive economy to an economy based on hydrogen is delayed by lock-in forces.

  [Natural, the inertia of large-scale systems is by definition large.]

4.1. Payback gap

The gap between the willingness to invest in demand reduction on the one hand and the willingness to invest in supply extension on the other hand has been described as the payback gap. Projects that can reduce end-use demand are submitted to profitability exigencies that are very strict, e.g., a payback of the investment within 2 or 3 years. Projects for extending supply pass when the profitability rate meets the hurdle of a 5–10% discount rate over a time horizon of 15–25 years (Fig. 7).

This unequal approach of investments in demand reduction and investments in supply extension is mapped one-to-one in a stronger exigency regarding the technical performance of the former beyond the latter type of investments. This is illustrated by a graph that combines four major determinants[16] of energy investment decision-making, viz. the initial investment amounts (south pointing axis), the applied profitability criteria (second quarter), technical performances (first quarter) and the price of the next-by alternative solutions (north pointing axis).

The example payback gap of a factor 4.7 in profitability exigency is mapped one-to-one in a 4.7 factor of technical performance gap. It means that conservation projects that are several times more efficient than supply extensions are not adopted in our society. Because the numerical example is based on observed behaviour one may conclude that our energy economy is biased towards too much supply extension and that too little demand reduction is realised.

[15] See, e.g. the Externalities of Energy (ExternE). A research project of the European Commission (http://externe.jrc.es). Also Hohmeyer and Ottinger (1991).

[16] Operational costs (e.g. of fuel combustion) are a fifth major determinant, but not included here to simplify the example. For more detail: Verbruggen (1994) "A tool for evaluating energy investment projects", UA, STEM, January 1994.

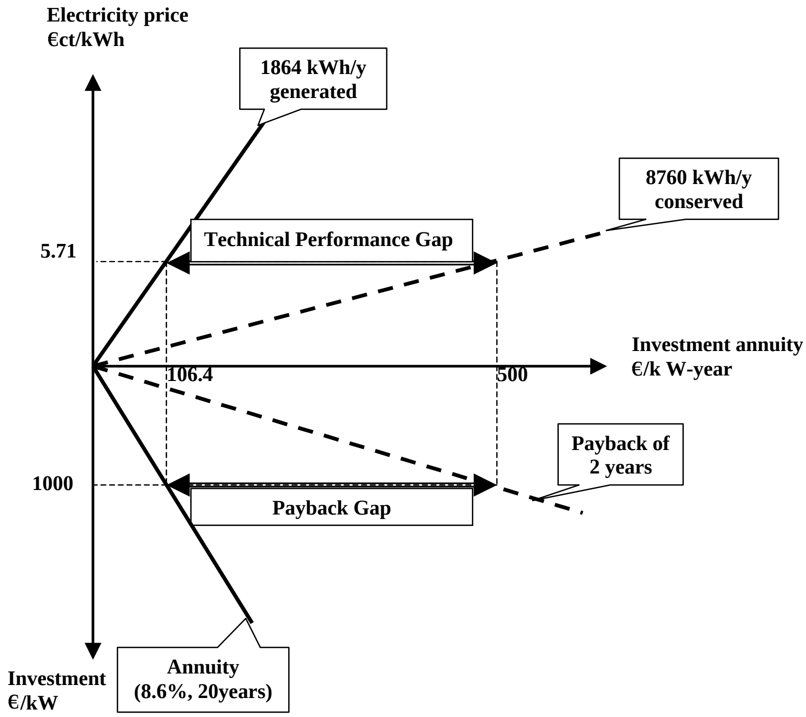

Fig. 7. The payback gap in profitability exigencies is mapped one-to-one as a gap in technical performance requirements regarding demand reduction versus supply extension.

5. Conclusion

The demand curve for electricity efficiency derived on a sample of 24 OECD Member States shows that higher end-use prices trigger efficiency that outperforms the impact of the price on the bills directly. In other words, the electricity bills of nations tend to decrease when end-use prices rise. At least the allegation as should low prices be necessary for affordable bills is refuted by the statistics. One rather observes that all nations tend to stick to some electricity budget share in their GDP. When prices are low spillage occurs. When prices are high efficiency improves.

Regarding efficiency and effectiveness the reduction in end-use demand scores better than the extension of supplies. In practice the economies are biased towards a propensity to save too little energy and to supply too much energy capacities. This generally observed bias is due to a manifold of barriers, some of which are natural while others are artificial or mixed in character. The famous payback gap summarises the impact of the barriers, and shows that a gap in profitability exigency translates as a one-to-one mapping in technical performance requirements.

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