Bridge over troubled water – spanning the energy-efficiency gap

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Abstract

The existence or non-existence of cost-efficient energy efficiency measures seems to be a constant argue between engineers and economists. Engineers on the one hand point at major potentials for cost-efficient energy efficiency measures. A recently carried out study shows that merely 15 per cent of all cost efficient measures in the Swedish building sector are likely to be carried out, even when taking currently implemented policy measures into account. Economists on the other hand claim the cost-efficient potential to be low. The engineers simply have forgotten to include transaction costs and other important factors in their calculations is a common comment.

Is the main explanation of the energy-efficiency gap the transaction costs? Several studies are available on the existence of transaction costs and various types of such costs. However, only few of these studies manage to quantify them. In an attempt to bridge the energy-efficiency gap, a Swedish study has recently been carried out in joint effort between engineers and economists. The study seeks to quantify to what extent transaction costs, split incentives and other factors can explain the gap. The results of the study indicate that transaction costs only to a surprisingly small part explain the gap. The output from the study provides important knowledge for policy makers.

This paper is presenting the results from the Swedish study on quantifying different parts of the energy-efficiency gap. The presentation is focussed on the buildings sector. The paper also discusses calculation inputs used and sensitivity analyses carried out in the Swedish study.

Introduction

What size is the cost-efficient energy-efficiency potential? What character do the cost-efficient measures have? Does the energy-efficiency gap exist? These questions have been debated during several decades now. They were, together with the question of how to span the gap, if it exists, the key topics for the recently finished Swedish National Inquiry on energy efficiency.[1]

In the debate statements on a vast cost-efficient potential has been equally commonly expressed as views meaning only a minor cost-efficient potential exists. Often the first mentioned argument is voiced by engineers, while the latter mainly seems to be the view of economists. Agreement is seldom reached in these discussions. An important reason for disagreement is that the involved actors tend to use different definitions of the term "cost efficient".

In order to deliver a better answer to the question of what size the cost-efficient energy efficiency potential in Sweden is, and to quantify different factors affecting the energy-efficiency gap, the Inquiry decided to carry out an in-depth study. The study included all sectors of the society, buildings, industry and transport. However, due to better availability of statistically significant data for buildings the Inquiry particularly emphasised this sector.

The study aimed at presenting transparent and concrete calculations, to particularly emphasise components commonly misunderstood. Furthermore it aimed at working with clear definitions to increase clarity and better communication between engineers and economists. The calculations were all

1. Energieffektiviseringsutredningen, the Swedish National Inquiry on implementing the EU Energy Service Directive (2006/32/EU).

based on technically end economically well established sources such as national statistics, the National Energy Agencies forecasts of energy prices etc.

Methodology

Since the study was a part of the Swedish plan for the implementation of the Energy Service Directive (2006/32/EU) the natural focal point of the study was the year 2016. However, to simultaneously provide important input on how the EU 2020 goals can be achieved, the Inquiry decided to also examine conditions for the year 2020. Cost efficiency was calculated as net present value for different measures. Building owners' standard intervals for planned maintenance and refurbishment have been used as natural opportunities for building component exchanges and upgrading when calculating the cost-efficient potential.

CALCULATIONS

The in-depth study included both socio-economical calculations and business or private economical calculations. In the study the term decision makers' economical calculations has been used as a joint description for business and private economical calculations. All calculations in the study are based on a Cost Benefit Analysis principle. The calculations included all kinds of energy-efficiency measures: measures aiming to improving the climate shell, measures to improve the building installations, energy-efficient lighting and appliance etc.

Cost-Benefit Analysis

The carried out socio-economical calculations are all based on a Cost Benefit Analysis principle. All costs were included. Thus the calculations included investments, material and labour etc, but also transaction costs such as time to find relevant information, time for decision making, loss of comfort and other such factors. The benefit part of the calculation included reduced operational and maintenance costs, decreased environmental impact etc.

Several of the costs, particularly transaction costs such as loss of comfort, time for seeking information, included in the calculations are rarely put in monetary terms. Thus these costs are seldom seen in the kind of documents a building owner use for decision making. Still these costs are real, making the investment less profitable than what a calculation merely based on technical input shows. The situation is equal on the benefit side of the calculations, values not usually put or estimated in monetary terms are seldom explicitly included in the decision making.

The study has therefore put major effort into finding good estimates for these costs and benefits. Where available, values already established from other studies have been used. However, despite an extensive literature search few such estimates have been found. Thus several transaction costs and other important factors have had to be calculated and estimated. These estimates have been very carefully made, rather resulting in overestimated than underestimated transaction costs.

Almost all energy-efficiency measures are connected with costs and benefits not usually put in monetary terms. These terms are more or less obvious, obstacles, preferences etc which the decision maker, consciously or not, include in their calculations. One example of this is ordinary light bulbs. Every calculation comparing ordinary light bulbs with CFLs show the benefits of a complete switch to CFLs. Still the ordinary light bulb is the most common light source in residential buildings.

Interest rate

For the socio-economical calculations a real discount interest rate of 4 percent has been used in a base case for both households and businesses. For the decision-maker economical calculations two sets of base cases for real discount interest rates have been used, 4 and 8 percent respectively. Sensitivity analyses have been carried out using other interest rates.

Calculations are based on a statistical sample of buildings

The calculations are based on a statistical sample representing all Swedish buildings. The sample includes sufficient descriptions of the buildings concerning detailed technical status information (on e.g. energy end use, U-values, type of heating and ventilating system, electrical appliances etc.) for calculating cost-efficiency of energy-efficiency measures.

ENERGY COSTS

The size of the cost-efficient energy-efficiency potential depends on what energy prices the calculations are based on. Therefore the in-depth study also included an estimation of *variable* energy costs for decision makers and long term marginal costs for the socio-economical calculations. Estimates were made for electricity, district heating, oil, LPG, and biomass fuel. For the building sector two different sizes of energy end users were analysed for each of these energy carriers, single family houses and multi-family houses respectively. Energy costs were estimated both for today and for the year 2020.

The reason for using the *variable* energy costs in the decision maker's economical calculations is that this part of the energy cost is what really is affected when the energy end use decreases due to an energy-efficiency measure. Using the estimated long-term marginal energy costs for the socio-economical calculations aims at describing the real energy costs affected by the achieved energy efficiency.

External effects in the socio-economical calculations

So called external effects, e.g. costs associated with, environmental impact or health aspects, should be included in socio-economical calculations. The study has here primarily focussed on green house gas emissions; since this is the energy sector's dominating external effect. Several alternatives to estimate external effects can be used. Ideally the estimate should reflect the marginal damage cost an additional unit of emissions would cause. In its base case the Inquiry chose to use carbon dioxide and energy taxes as proxy for external effects. Sensitivity analyses were carried out for several other cases, some of which quite extreme, to check the range of impact of various assumptions.

SENSITIVITY ANALYSES

Sensitivity analyses were carried out both with respect to choice of calculation interest rates and costs of external effects. Sensitivity analyses of the socio-economical calculations were made with two other cases of interest rates, 2 and 6 percent respectively instead of the base case 4 percent. An interval between

2 and 12 percent were used for the sensitivity analyses of the decision maker's economical calculations.

When checking the sensitivity of calculation results with respect to energy costs six alternative cases were used. These alternatives were:

- No energy taxes included
- Marginal electricity 100 percent provided by wind power
- Marginal electricity provided by 70 percent coal condense and 30 percent wind power
- Marginal electricity 100 percent provided by coal condense
- Increased CO_2 tax by 50 percent
- Increased CO_2 tax by 50 percent and marginal electricity provided by 70 percent coal condense and 30 percent wind power
- Increased CO_2 tax by 50 percent and marginal electricity provided by coal condense

The size of the energy-efficiency gap

ENERGY END USE IN THE BUILDING SECTOR

In Sweden the building sector energy end use is approximately 151 TWh per year (whereof electricity 47 TWh), corresponding to approximately 38 percent of the total Swedish end use. Heating, cooling, electricity for operation of the buildings, household and business electricity in residential and non-residential buildings accounts for approximately 135 TWh per year (whereof electricity 44 TWh). In national energy statistics agricultural, forestry, and fishing enterprises and "other services" are also included in the building sector. Between them they share the remaining 16 TWh end use of the building sector.

COST-EFFICIENT POTENTIAL IN BUILDINGS

In an interim report the Inquiry estimated the cost-efficient energy-efficiency potential of the Swedish building sector to be approximately 33 TWh, whereof 14 TWh electricity. Applying the new input, i.e. interest rates and energy costs, the new study concluded that the cost-efficient energy-efficiency potential for 2016 is approximately 34 TWh (end use) when merely looking using a technical-economical perspective. Electricity is estimated to be a large share of this cost-efficient potential, approximately 14 TWh.

Also substantial energy efficiency potential lies in conversion of heating systems. In Sweden electricity is a common heating energy source. Converting electrical resistance heating systems to e.g. district heating or individual bio mass boilers do not lead to a more efficient end use. However, these measures vastly improve primary energy use, thereby leading to a more efficient energy use from a system's perspective.

WHAT PART OF THE COST-EFFICIENT POTENTIAL WILL BE REALISED BY 2016?

In 1995 a national inquiry called the Swedish Energy Commission in their *minimum* scenario assumed a future realisation rate of cost-efficient measures of 30 percent. Was this assumption realistic? Today awareness of climate change and energy-efficiency possibilities is higher than ever. Several energy-efficiency policy measures are currently in use, such as energy and CO_2 taxes, information campaigns, technology procurements, investment programmes etc. Yet only a minor part of the seemingly cost-efficient energy-efficiency potential is realised. Recent analyses, based on actual measures carried out between 1995 and 2003, show that the rate of realisation of measures is merely half of the 1995 minimum scenario assumption. The Inquiry reported in an interim report that, even when taking current policy measures into account, buildings owners are estimated to on average realise only 15 percent of the seemingly cost-efficient energy-efficiency potential.[2] This, discouragingly low, estimate of realisation is supported by a quantitative evaluation of the 10 percent first building energy performance certificates (30 000 buildings). Adding measures carried out by households (mainly appliances and lighting) to the measures carried out by building owners the Inquiry forecasts a mere 8 TWh will be realised by 2016 without further policy measures or other kind of support.

Comparing the cost-efficient potential with the estimate of what part of this potential will be realised if no other policy measures are taken, it is apparent the energy-efficiency gap exists. The cost-efficient potential is more than four times larger than what is estimated to be realised by 2016,34 TWh versus 8 TWh. However, this comparison was made between calculations merely taking technical-economical costs, i.e. cost in conjunction with the investment, into account. What happens with the cost-efficient potential, and what would the outcome of the comparison be if also e.g. transaction costs are included? The obvious answer is that both the profitability of the measures and the energy-efficiency gap decrease. But how much?

THE GAP

The energy-efficiency gap is caused by several different factors. The in-depth study carried out by the Inquiry provided quantified the impact of several of these factors. External effects, transaction costs, split incentives, insecurity and risk aversion, and the influence of the short term real estate investment market were among the factors where quantifications were provided. The question of how other factors affect the size of the energy-efficiency gap, such as lack of knowledge and information, institutional barriers, lack of financing opportunities, and lack of time or interest, still remains to find a better answer to.

A main task for the in-depth study was to analyse what level of energy efficiency is motivated from a socio-economical perspective, and to put this in relation to what level is motivated from a decision makers' perspective. The main results for both these perspectives are shown in figure 1. Figure 1 also shows results from the socio-economical calculation sensitivity analyses. Only technical economical factors are included in this figure. Thus figure 1 represents an ideal case were all actors are assumed to carry out all identified cost-efficient measures.

2. A detailed analysis carried out by Chalmers Energi Centrum shows significant differences in realising cost efficient measures between different kinds of building owners. CEC's analysis shows a variety from 5 to 35 percent, where public non-residential buildings carry out measures corresponding to approximately 35 percent of the seemingly cost-efficient measures, privately owned non-residential buildings approximately 5 percent, owners of multi-family buildings approximately 17 percent and owners of single family houses approximately 15 percent.

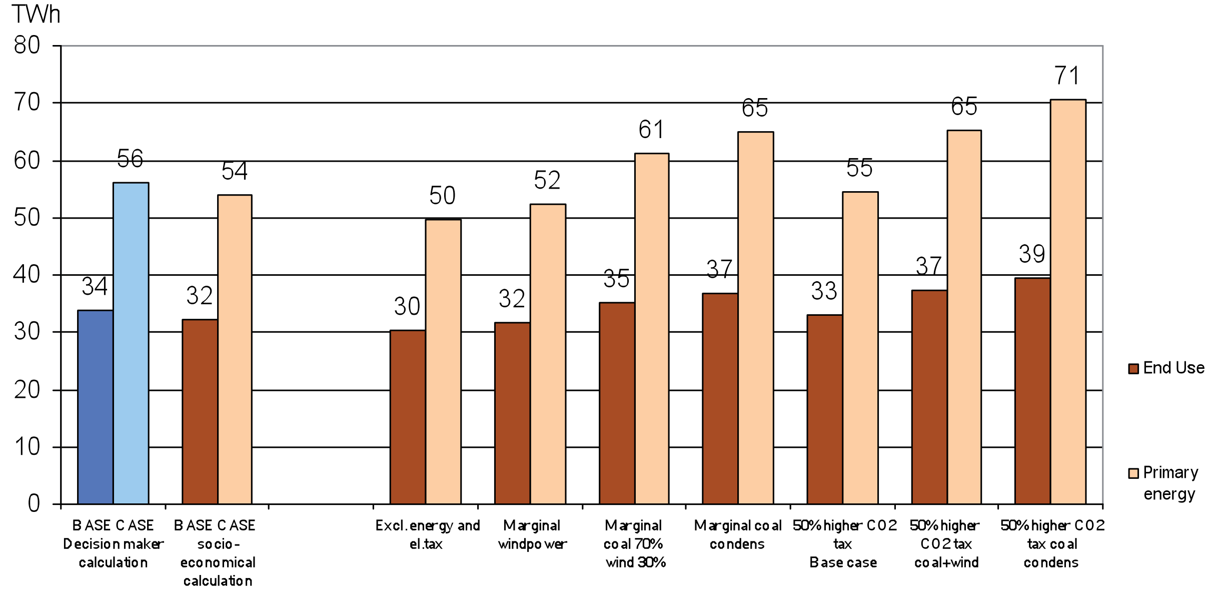

Figure 1. Technical-economical energy efficiency potential for 2016. Base case for decision makers' calculations (blue bars to the left) and socio-economical calculations (brown bars to the left). Sensitivity analyses for the socio-economical calculation (brown bars on the right hand side of the figure).

Other factors influencing cost-efficiency are added in the following description.

Results from the calculations are dependent on assumed future energy costs. The study's forecasts are that the energy costs of 2020 are similar to energy costs of today. One notable example is the oil price, which fluctuates substantially other time. Oil price however, has in the Swedish building sector case a limited impact. This is due to the fact that oil based heating systems to a significant degree has been converted to primarily district heating, and the building sector oil consumption today is small.

The two bars to the left in figure 1 illustrate the base case cost-efficient potential. Here a 4 percent real discount rate and basic assumptions on socio-economical energy prices. As can be seen in figure 1, put in energy terms the energy-efficiency potential from a socio-economical perspective is quite similar to the energy-efficiency potential from a decision makers' perspective. This result is mainly due to the fact that energy prices in the socio-economical base case have shown to be similar to energy prices offered to end users. In addition the energy-efficiency potential is not affected in a one-to-one basis by a change in energy prices. Similar results on elasticity have been found in a Danish evaluation of energy efficiency measures.

As earlier mentioned, the Swedish study base case used energy and CO_2 taxes as proxy for external costs in the socio-economical calculations. This is not equal to using the same energy costs in the socio-economical and the decision makers' economical calculations. Estimating external effects and their costs is a delicate and heavily debated task. So is the question of what marginal electricity production is affected by energy efficiency measures. To provide answers for different aspects of these questions a number of sensitivity analyses were carried out in the study. The right hand bars in figure 1 show the sensitivity analyses results.

An analysis of these results leads to the conclusion that the size of the cost efficient energy-efficiency potential is only to a minor part affected by rather extreme assumptions of electricity costs. Alternative assessments end in socio-economical calculation results both over and under the decision makers' economical calculation results.

Thus, taking the Swedish CO_2 and energy taxes of today into account, it can not generally be concluded that the size of the cost-efficient energy-efficiency potential from a socio-economical perspective should be neither substantially larger nor substantially smaller than the size of the potential from a decision makers' economical perspective. A somewhat simplified conclusion from this is that the results from the decision makers' economical calculations to a reasonable degree also reflect what is socio-economically rational when it comes to energy efficiency. The analysis so far only includes technical-economical costs. However, other factors to be included in the calculations, e.g. transaction costs and losses, costs and benefits of different kinds, are often equally assessed in a socio-economical and a decision makers' economical calculation. Alternatively they do not lend themselves to quantification. Insecurity in conjunction with assessing non-technical economical costs, such as transaction costs and subjectively perceived losses and benefits, can be significant. It is however, a reasonable assumption that they are of equal dignity for both types of calculation. The study thereby concludes there is no particular reason to generally assume that the size of the cost-efficient energy-efficiency potential differs between the socio-economical and the decision makers' economical perspective. The major issue is in both cases how to deal with the gap between calculated cost-efficient energy efficiency potential and what in reality is realised.

GAP REASONS

Based on the results described above, the in-depth study analysis continued focussing on the decision makers' perspective. Arguments are similar in a socio-economical calculation.

Figure 2 shows the calculated cost-efficient energy-efficiency potential for 2016, divided between different building sectors, type of end use and energy source. The two left bars (end use and primary energy consumption respectively) represent an ideal case with merely the technical-economical cost included and assuming all cost-efficient measures are carried out. The two bars to the right in the figure (end use and primary energy consumption respectively) show the calculated cost-efficient potential taking transaction costs, split incentives and certain parts of short term ownership into account.[3]

The study's main results for 2016 are shown on an aggregated level for all building categories in figure 3. It also shows the results from the sensitivity analyses with respect to energy costs. The left part of figure 3 shows what impact different levels of discount rates have on the calculated cost-efficient energy efficiency potential. Here only technical economical costs are included. The bar to the right in figure 3 shows estimated level of energy efficiency 2016 due to spontaneous end user actions and measures carried out taking current policy measures into account. The bars in the middle of figure 3 aim to visualise the difference between these two posts. The middle bars show to what extent the cost efficient potential is reduced by estimated transaction costs, the parts of split incentives estimated not to be affected, and certain long term measures assumed not to be realised.

The study shows in the base case where a real discount rate of 4 percent is used for both households and enterprises a cost-efficient energy-efficiency potential of 34 TWh. Increasing the discount rate to 6 percent decreases the cost-efficient energy-efficiency potential to 31 TWh. Should a 12 percent discount rate be used for enterprises the cost-efficient energy-efficiency potential would be reduced to 29 TWh. This corresponds to approximately 85 percent of the cost-efficient potential of the base case (4 percent discount rate). Thus increased discount rates requirements only to a relatively low degree affect the cost-efficient energy-efficiency potential. The reason for this is that a rather large part of the efficiency measures are relatively simple, with low (or no) need of investments or labour. Examples of these measures are adjustments of operating hours for ventilation systems, commissioning of heating and ventilation systems, adjustments of building operation systems, and replacing ordinary light bulbs with CFLs.

Increased energy costs affects the cost-efficient potential to a limited degree due to four reasons:

- A relatively large part of the cost-efficient measures are low or no cost measures. Thus there is not a one to one relation between potential and energy price.
- The assumed energy cost development mainly affects electricity. The study is based on energy cost forecasts where changes in district heating costs are assumed to be insignificant. The use of oil is small in the Swedish building sector, meaning that oil price changes only to a limited degree affects the total cost-efficient energy-efficiency potential.
- The number of heat pumps is significant in the Swedish building sector. For a building heated with a heat pump with an annual COP of 3 the effect is only a third of an increased electricity price for a large part of the efficiency measures.
- When calculating the effects of replacements of appliances increased electricity costs is assumed to only to a minor degree affect the choice of appliance.

The middle bars in figure 3 show what happens when estimated costs in addition to costs "passing the wallet" are included. These costs has been estimated the following way:

Including transaction costs: Time necessary to find information, purchase, evaluate etc for a building owner, his or her employees or family members has been estimated for all kind of measures. The estimated time consumption for each specific type of measure has then been converted to monetary terms and included in the investment cost. Subsequently the cost-efficiency will decrease in comparison with the cost-efficiency calculation where only the technical-economical factors are included. The added cost can be relatively small for larger efficiency measures (5 to 20 percent). For some low-cost measures like adjusting operating hours and air flows for ventilation systems the building owner's transaction costs can be as big, or even bigger, as the cost of labour and investment.

When including the estimated transaction costs and applying a discount rate of 4 percent the cost-efficient potential decreases from 34 TWh to 28 TWh. This corresponds to approximately 82 percent of the base case cost-efficient potential. The in depth study transaction costs have been calculated with a generous estimate of time consumption and likewise assessment of cost per hour spent.[4]

Including split incentives: Split incentives are commonly mentioned when discussing why seemingly cost-efficient energy efficiency measures are not realised. In the Inquiry's study the effect of this phenomenon has been estimated by assuming that e.g. changes of lighting fixtures and adjustments of ventilation systems will take place, however slower implementation for non-residential rental buildings.[5] Changing to energy-efficient tap-water mixers are assumed not to take place in multi-family houses unless individual tap water metering is installed.

What measures are hampered by split incentives can be discussed. When adding the above mentioned simple assumptions to the transaction cost effects the cost-efficient potential is reduced to 26 TWh when applying a discount rate of 4 percent. This corresponds to 78 percent of the base case.

Including "short term ownership": The Inquiry pointed in its interim report[6] to the fact a large part of the building owners, primarily owners of non-residential buildings, focus on buying, developing and selling buildings rather than own them on

3. The characteristics of building ownership in Sweden have during the recent decade shifted towards an increasing number of short term owners, where the core business to a decreasing degree is the buildings themselves. Short term owners tend to invest less in long term efficiency measures, and the calculations aimed at quantifying the affect on energy efficiency of this shift.

4. 115 SEK per hour for individual's spare time.

5. Affects approximately half of all non-residential buildings according to Elforsk.

6. Based on CECs report from 2007.

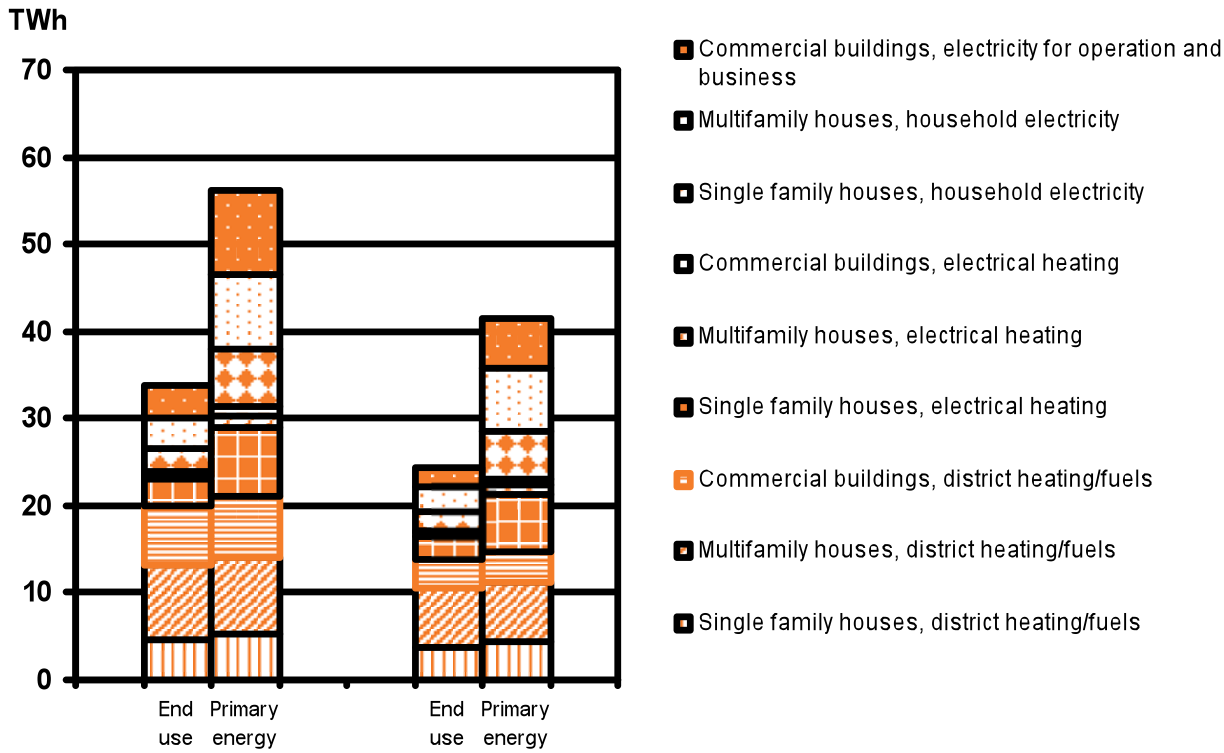

Figure 2. Cost efficient energy-efficiency potential for 2016. End use and primary energy consumption. Divided between different building categories, type of end use and energy source for two cases of the decision makers' economical calculations.

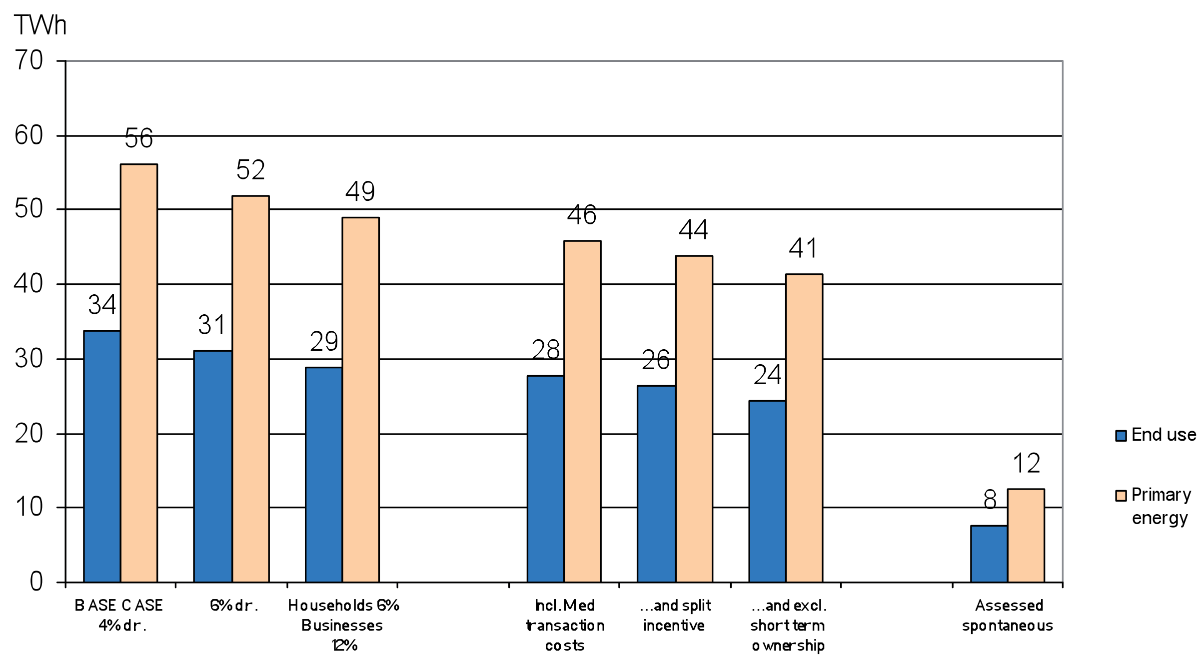

Figure 3. Cost-efficient energy-efficiency potential for 2016, end use and primary energy consumption respectively (Decision makers' economical calculation). To the left: Only technical-economical costs included at different discount rates. Middle: Potential reduction with respect to estimated transaction costs, split incentives and certain long term measures might not be carried out. To the right: Estimated spontaneous energy-efficiency and measures carried out taking current policy measures into account.

a long term basis and focus on low operating costs.[7] In these cases energy-efficiency driven climate shell measures are assumed not to take place. The same assumption has been made for changes to more energy-efficient ventilation systems and commissioning of heating systems.

These assumptions render a further reduction of the cost-efficient energy-efficiency potential, at a discount rate of 4 percent, to 24 TWh. This means that taking transaction costs, split incentives and the "investment market" into account the cost-efficient potential is 72 percent of the base case. It should be noted that this is a rather strict estimate of what part of the cost-efficient measures that not will be realised. Many of the building owners classified as "investment market" are in reality seriously working with energy efficiency.

Spontaneous energy efficiency: The bar to the right in figure 3 shows that spontaneous measures and energy-efficiency measures induced by current policy measures are estimated to be 8 TWh in 2016. It might be notable that spontaneous measures not necessarily are the most cost-efficient. Experiences from other studies and areas show that what measures in reality is carried out show a broad spectrum from simple and cost efficient to major measures with a large complexity and measures that in some cases are not cost-efficient even in a technical economical calculation.

Summary

The in-depth study seeks to go beyond the purely technical-economical perspective and quantify other costs and benefits which should be included in a socio-economical cost-benefit analysis. Factors lending them self to quantification or high quality estimates have been added to the technical costs and benefits.

The study has provided important knowledge on how large parts of the energy-efficiency gap can be assessed in quantitative terms. However, the troubled water has not been possible to fully bridge. A major part of the gap remains. Remaining explaining factors are probably lack of knowledge and competence, lack of time, mistrust, lack of interest, other preferences etc. So far the effect of these factors have not been able to quantify.

One of the conclusions that can be drawn from this study is that however necessary the financial aspects are, especially with "welfare calculations" in order to drive public policies, they do not alone explain market behaviour. It can also be concluded that a major part of the, from a socio-economical perspective, cost-efficient energy-efficiency potential in the Swedish building sector also is cost-efficient from the decision makers' perspective. On the one hand there are uncertainties in e.g. assessments of transaction costs and subjectively perceived benefits and costs. On the other hand some of the transaction costs and problems with split incentives can in a socio-economical cost-efficient way be significantly lowered by e.g. measures like information on energy-efficient appliances.

Based on the above described study the Inquiry concluded for 2016 the building sector cost-efficient energy-efficiency potential is approximately 24 TWh. 8 TWh is estimated to be realised due to spontaneous measures and measures induced by current policy measures. Thus a cost-efficient potential of approximately 16 TWh remains. To span this remaining energy-efficiency gap further policy measures or other stimuli are needed.

7. 32 percent of non-residential buildings and 14 percent of multi-family houses.

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