Disentangling definition issues in determining the costs of energy efficiency measures

Joost Gerdes, Energy research Centre of the Netherlands, Amsterdam, The Netherlands
Michiel Hekkenberg, Energy research Centre of the Netherlands, Amsterdam, The Netherlands
Piet Boonekamp, Energy research Centre of the Netherlands, Amsterdam, The Netherlands

Abstract

The cost-effectiveness of energy efficiency measures is a source of ongoing debate. Governments generally intend to set cost optimal targets and policies, and depend on accurate and consistent information to do this. However, different studies contributing to the debate present different results for energy saving potentials and their associated costs, which may hinder optimal policy choices.

It is found that differences may arise not only from different data, but also from differences in scope and methodology for the calculations of costs and of energy efficiency potentials. Cost calculations apply different cost perspectives (like national costs and costs for end users of energy), include or exclude external costs and benefits, and apply different discount rates. The significance of definition issues for presented results often gets limited attention in reports. The resulting statements about cost-effectiveness should only be considered robust within their applicable scopes.

This issue is not merely academic, but is also highly relevant for the current political debate. The effort needed to achieve a given policy target and the corresponding costs depend on the applied definitions. It is therefore imperative that all parties involved in the debate are aware of the significance of differences between definitions and build a common understanding of the definitions that each party applies.

Introduction

If the ambitions formulated at the COP21 are to be realised, major investments in the energy transition are required. All the more reason to ensure that money will be spent in the most effective way possible. In this paper we will focus on the definition of cost-effectiveness of energy savings measures for different stakeholders. That should, together with scope and policy effectiveness, make clear which energy savings measures should be part of the set of measures for a cost optimal energy transition.

Diverging cost effective potentials for energy savings measures are reported in literature as a result of different underlying assumptions

Recently, a discussion took place at EU level on the use of discount rates when calculating the energy savings to be expected [Hermelink & De Jager, 2015; Euractiv, 2016]. Discount rates define the cost-effectiveness of saving measures and indirectly define the (cost-effective) savings potential, provided by for example Fraunhofer [FhG 2009, ECF 2010 and FhG 2014] and in the PRIMES scenarios [EC 2013]. The cost-effectiveness of savings has also been discussed in the Energy Efficiency Review [EC 2014] of the European Commission with different variants for the amount of savings to be realised. In reaction to these EC documents a study was performed on the consequences for the Netherlands [ECN 2014]. The ECN study [ECN 2014] shows different results for the costs of energy saving measures and the related total potential for cost effective savings. Finally, the IEA has advocated using a broader concept of cost-effectiveness which takes into account other benefits of energy savings beyond direct energy cost savings [IEA 2014].

The differences result from diverging assumptions and approaches which often remain undisclosed. These differences make comparing study results for different countries cumbersome. This lack of transparency in turn makes the political debate on cost-effective target setting more difficult, which may lead to a suboptimal energy efficiency policy in Europe.

Comparing the approaches to estimate cost effective saving potentials can identify the important differences. Clearing up such methodological differences will help to better inform the European as well as national policy debates and energy efficiency policies. This paper aims to contribute to this process by discussing the observed differences.

A first important difference is caused by the **perspective** taken. The cost effectiveness of saving measures can be calculated from

- the perspective of the end user of energy
- the perspective of policy makers
- a national perspective.

The end user perspective takes into account costs and benefits as perceived by the energy user that invests in saving measures. Thus, investments are corrected for government support, and saved energy costs include the savings on energy related taxes [ECN 2005a, ECN 2005b].

The policy perspective has a more narrow focus, as it regards only government outlays for stimulating implementation of saving measures and the adjacent realised energy savings.

In the national perspective, the costs include costs for both government (e.g. civil servants working on energy policy) and end users (investments in saving measures), but not money transfers between them (e.g. tax facilities for investments). The national perspective [ECN 2005a, ECN 2005b] is considered the most appropriate approach to evaluate energy saving measures on a national or European level. ECN used a national cost approach in its report about the impact of EU energy and climate policies for the Netherlands in 2030 [ECN 2014].

These three perspectives will be described in more detail later.

Another, partly related, important difference is the choice of applied **discount rates** which are used to value expected future yearly benefits and costs from energy savings in order to compare them with the investment needed for the savings. A related quantity is the interest rate to be paid for investment loans. This interest rate in turn defines the annuity factor used to convert a one-time investment into yearly capital costs. The choice of the discount rate can have a large impact on the costs effectiveness of energy efficiency measures. Therefore it should be clear which discount rate is used and on what it is based. This issue has been discussed in a report by ECEEE [Hermelink & De Jager, 2015] about discount rates used for the PRIMES scenarios [EC 2013]. This report questions the use of discount factors in ex-ante analyses of the implementation of savings measures that also incorporate the effects of (non-economic) barriers.

A third source of confusion is mixing up the terms “cost effectiveness” and “cost optimal”, a.o. when reporting about the potential for energy savings. Cost effective means that a measure pays back for itself within agreed boundary conditions. Cost optimal means that a savings measure is not more expensive than necessary to achieve a certain policy goal, which can mean that some measures will not be cost-effective while the overall package is still cost-optimal. In this paper the focus is on cost effectiveness only.

Finally, there are differences due to diverging **scopes** for the energy consumption taken into account. Savings potentials can be defined for:

- Total energy consumption or only the energy consumption in the non-ETS sectors
- Final rather than primary savings (like in the saving potentials for the Netherlands [ECN 2014])
- Only measures that count towards the goal for EED article 7 savings
- Technical potential versus feasible potential (in [ECN 2014] only 50% of the technical potential has been estimated to be achievable, due to various practical barriers).
- Different background or baseline scenarios that will result in different outcomes
- A cumulative goal instead of a savings goal for a selected end year.

In the following sections differences regarding scope, policy effectiveness and perspective will be analysed.

Factors influencing savings potential: scope and policy effectiveness

The effect of scope

The savings potential for cost effective measures depends on the applied scope, meaning the sections of the energy system included in the calculation of savings potentials. The scope can be limited by certain policy goals, may include primary energy or final energy consumption, energy consumption by all sectors or non-ETS sectors only, or savings potential addressed by national policies only, like article 7 of the EED demands. A schematic overview of the different scopes is shown in figure 1. Limiting the scope to final energy excludes energy saving potential in conversion sectors. Only including measures that count towards the goal for EED article 7 savings will also limit the savings potential, as this regards not all final energy and excludes autonomous energy savings and energy savings induced by European policies. A limited scope will often also mean that less cost effective potential will remain.

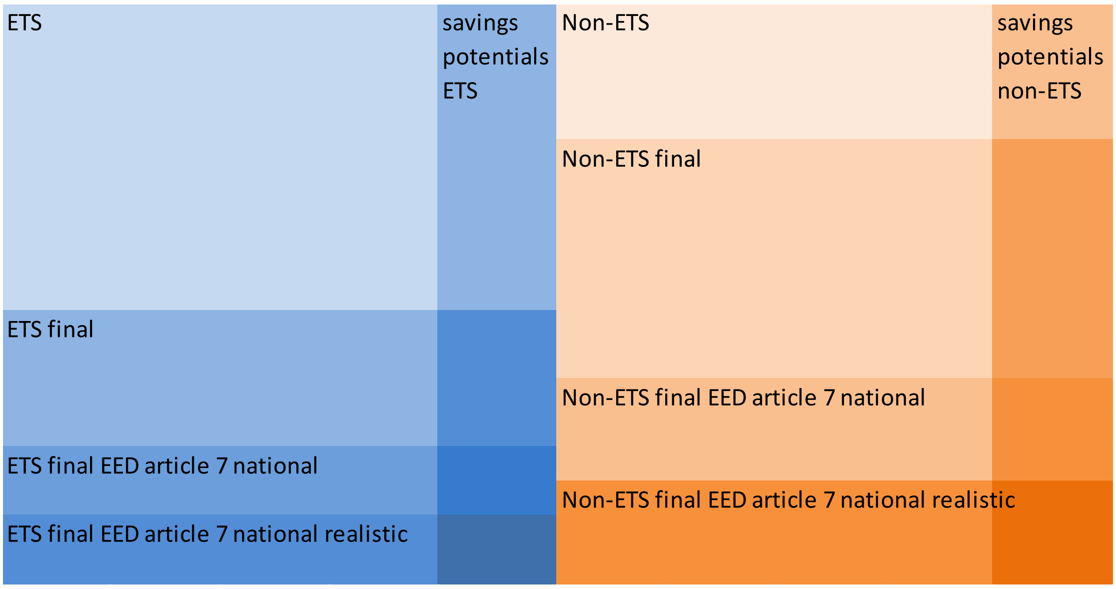

Figure 1. Schematic overview of the total energy consumption of a EU member state, including savings potentials related to scope

Policy effectiveness

To avoid inconsistencies between savings potentials, attention also needs to be paid to policy effectiveness. Savings policies in practice do not result in the desired effect for all of their targeted energy use. This means that an amount of money spent can have less results than anticipated, which means the costs of the policy per unit of energy saved will be higher than in the case of 100% policy effectiveness.

- Total savings can not all be attributed to policy. Some savings are autonomous, and occur without any policy present, for example when an appliance is replaced by a newer and usually more efficient one. A related phenomenon is the occurrence of 'free rider' savings, where investment subsidies are used for investments in efficiency that would have happened without the subsidies as well. Correcting for these effects results in the net policy savings. This has an effect on the funds spent per amount of energy saved, and thus on the cost of saving measures.
- Interaction of savings measures. Policy measures for energy efficiency can interact, leading to either a higher effect than the sum of the effects of measures if they would have been

implemented on their own, or to a lower effect. An example of positively interacting measures is a combination of product efficiency labels and subsidies. When only information about energy consumption of different appliances is available in the form of labels, the price of the more efficient appliances may be too high to attain a high market share, so labelling in itself will have a limited effect. Only providing subsidies for the purchase of new appliances will lead to less efficiency gains if no clear information is available about the efficiency of different products. The combination will thus have a larger effect in this case. An example of negatively interacting measures is product efficiency standards and an information campaign. In this case the information will not have much effect as inefficient products will not be available anymore anyway.

These effects should be taken into account when estimating the results of measures.

The influence of perspective on the costs of savings measures

The effect of perspective in financial evaluations of savings measures

As described earlier, costs and benefits of energy savings measures can be calculated from various perspectives and with varying discount rates. Discount rates are used to value expected future yearly benefits and costs from energy savings in order to compare them with the investment needed for the savings, so they play a crucial role in deciding about investments. The idea behind using a discount rate is that benefits in a more distant future are valued lower than benefits that will come sooner. This time preference is often based on the risk that benefits might be lost due to changes in the longer run.

Depending on the perspective taken, different cost and benefit items and different discount factors/interest rates will be applied. Discount rates can include a variety of components that strictly speaking should not be part of it: inflation, the perceived risk of investments and perceived investment costs.

In addition to this approach for (individual) investment decisions there are approaches to compare costs and benefits in a more general way, e.g. to know whether national energy savings are cost-effective. In these approaches the yearly cost are compared to the yearly benefits. To this end the investments are converted into yearly costs using an annuity factor that depends on an interest rate and the lifetime of the saving options. The benefits arise from the amount of savings and the price of energy. The interest rate can also incorporate risk factors like mentioned for the discount rate.

In some modelling approaches, like for example in PRIMES scenario modelling, used for the EC, discount rates are used in a specific way. On the one hand they reflect the decisions of investors but on the other they also account for differences in policies, national circumstances and other non-financial obstacles [E3MLab/ICCS, 2014].

The benefits can incorporate other positive effects than energy cost savings, such as a healthy and comfortable house due to insulation, which is an example of so-called additional benefits, described extensively by IEA [IEA 2014]. This broader perspective with other benefits is used in societal cost-benefit analyses and can be seen as a variant on the national perspective.

Also, a distinction can be made between the perspective of the energy user in general and that of the individual investor in energy saving measures.

Finally, financial evaluations are also performed by modellers in ex-ante evaluations. Often, the effect of non-economic factors, such as barriers to implementation of saving measures, are incorporated in the applied discount factors by modellers. This approach can be seen as a variant of the end-user perspective.

This leads to the following set of financial evaluation cases to be compared:

1. The end user perspective,
2. The national perspective,
3. A policy maker perspective,
4. A broader societal perspective (incorporating additional benefits)
5. The individual investor perspective
6. A perspective for modelling energy savings.

Almost all differences found in the reports mentioned above are caused by different perspectives and associated discount rates.

Depending on the perspective taken, energy taxes and subsidies are included or excluded, different payback times are used and different discount rates are applied, as are different rates for the cost of capital.

The main characteristics for each of the perspectives on costs and benefits of energy savings are as follows.

- **End user perspective**. The costs of measures from the perspective of end users include all costs and benefits that end users experience when taking energy saving measures.
  - End users encompass all final users of energy (e.g. companies, households)
  - Costs include any capital expenditure for installations, operation and maintenance
  - The benefits are energy costs savings based on marginal energy prices that incorporate wholesale prices, distribution costs and margins, taxes and feed-in premiums as their main components
  - Investment subsidies are subtracted from gross investments made
  - The discount rates used are based on usual interest rates for loans and a risk premium; they are higher than those for the national or policy perspective.

    Effect on measure costs: although the financial benefits from saved energy are high due to the included energy price components, relatively high discount rates and short demanded payback times mean that the measure costs can become relatively high for large end users. For households, the higher energy tax and longer payback times often lead to lower costs of measures than for large end users or for the national perspective.
- **National perspective**. In the national costs methodology, costs that are incurred for a country as a whole are assessed from a macro-economic perspective.
  - Costs regard investments in energy savings, converted to yearly national costs with an annuity factor based on technical lifetime and a societal interest rate (related to the rate for risk free government loans and a low time preference)
  - The Benefits are energy cost savings based on import prices, without distribution costs and margins
  - Taxes and subsidies are not included, because they are seen as a transfer of money; the expense of one actor is the income of another.
  - Avoided investments, for example in infrastructure, count as gains

    Effect on measure costs: the financial benefits from saved energy are lower as taxes are not included, but the interest rate for investments is lower too and the discount rate is much lower, so measures can become cheaper than for large end users.
- **Government perspective**. The government perspective on costs includes all costs or benefits that the government experiences from stimulating energy saving measures.
  - The costs for policy are usually positive (i.e., money is spent) because of the missed energy tax income and the support given (tax reductions and investment subsidies)
  - Administrative costs for government are to be included (e.g. energy research centres, agencies that implement policies, etc.)
  - Direct benefits could be the extra VAT from implemented savings measures, but it can be argued that the money would be spent anyway. Indirect effects apart from energy savings, like

less air pollution and more employment are not counted here but in the broader societal perspective,

- **Broader societal perspective**. This perspective is based on the national perspective, but it includes not just the financial benefits due to lower energy consumption but also other benefits.
  - Employment related to investments in energy saving
  - Health and environmental effects
  - All other benefits described in the IEA publication "Capturing the multiple benefits of energy efficiency" [IEA 2014].
  - The scope can is thus widened to include non-energy effects like job growth, less environmental pollution and lower health costs. These kinds of effects have an effect on the value of the energy saved.

    Effect on measure costs: if the additional, non-energy benefits are translated into financial benefits, there will be a diminishing effect on measure costs. The non-financial benefits can also be weighted in investment decisions without first being expressed in financial terms, so the eligible potential increases nonetheless.
- **Individual investor perspective.** The investor perspective is closely related to the end user perspective. It does not only look at the costs of savings measures, but also compares these to alternative investment options.
  - Investors will weigh the benefits of investing in energy savings measures against possibly more profitable alternatives, like expanding production capacity
  - The choice what to invest in is determined by the net present value for savings and the alternative only (assuming an own financing capability), without a need to calculate yearly capital costs
  - Discount rates as applied in the end-user approach do not play a role, as two equally sized investment options are compared
- **Modelling implementation of saving measures.** In order to simulate actual/observed investment behaviour as accurately as possible, modellers adapt discount factors (or related interest rates) in such a way that the calculated implementation matches reality.
  - The adaptation means that non-financial barriers are included in the discount factor used in models
  - The component for non-financial barriers is only present in this perspective and distorts cost-benefit comparison with the other perspectives.

    Effect on measure costs: the result of including other barriers is that the calculated costs of measures becomes higher, and the apparent cost effective potential will be lower

Table 1 contains an overview of similarities of and differences between the described perspectives. Shared quantities and parameters, although their size can differ between perspectives (items with a green background) are

- Gross annual savings measured in energy units
- Investments in the savings measure
- Life time of the savings measure
- Interest rate for loans
- Discount rate to value future benefits of saved energy costs
- Operation & Maintenance costs
- Energy cost savings (reduced energy bill

Perspective-specific quantities and parameters (items with a yellow background) are

- Autonomous savings and free rider effect (only for government/modellers perspective)
- Investment support and energy taxes (not for national perspective)
- Administrative costs to implement savings measures (for government/societal perspective)
- Barriers covered in discount rate (modellers perspective)
- Effect of non-energy benefits (only for broader societal perspective)
- Surcharge compared to alternative investments (for individual investor)

- External cost of energy (only for broader societal perspective)
- Various financial ratings such as payback time, net present value (dependent on perspective)

Table 1. Overview of quantities and parameters determining the cost (effectiveness) of saving measures depending on perspective.

Financial evaluation methods >		Broad societal	ECM-National	ECM-User	Investor	Model-ling
level >		national	national	sector	individual	various
Quantities and factors						
Gross savings per measure (a1)		yes	yes	yes	?	yes
Overlap measure-effects (a2)		yes	yes	yes	?	yes
Gross savings package (a = a1 - a2)		yes	yes	yes	yes	yes
Autonomous savings (b1)		x	x	x	x	yes
Free rider savings (b2)		x	x	x	x	yes
Net policy savings (c = a3-b1-b2)		x	x	x	x	yes
Investments for savings (d)	one-time	yes	yes	yes	yes	yes
Investment support (e)	one-time	no	no	yes	yes	yes
Administrative costs (f)		yes	yes	x	x	(yes)
Life time technical (g1)		yes	yes	yes	yes	yes
Interest rate banks (g2)		yes	yes	yes	yes	yes
Risk surcharge (g3)		x	x	yes	yes	yes
Barriers covered in discount rate (g4)		x	x	no	x	yes
Surcharge alternative investment (g5)		x	x	x	yes	yes
Discount rate future benefits (g2 … g5)		yes	yes	yes	yes	yes
Annuity (g = g1 and g2 … g5)		yes	yes	yes	x	yes
Capital costs (h = [d-e] * g)		yes	yes	yes	no	yes
Operation & Maintenance costs (i)		yes	yes	yes	yes	yes
Total costs (j = h + i)		yes	yes	yes	no	yes
Energy prices-world market (k1)		yes	yes	yes	no	yes
Energy taxes (k2)		no	no	yes	no	yes
Distribution and margin (k3)		no	no	yes	no	yes
Energy prices-end users (k = k1+k2+k3)		no	no	yes	yes	yes
Reduced energy bill (l = k * a)		yes	yes	yes	yes	yes
External cost of energy use (m)		yes	?	no	no	?
Non-energy benefits (n)		yes	no	no	no	?
Total benefits (o = l+m+n)		yes	yes	yes	no	yes
Net costs/benefits (p = j - o)		yes	yes	yes	x	yes
Cost/benefit ratio (q1 = j/o)		yes	yes	?	?	yes
Pay-back period (q2 = [d-e] / p)		x	x	yes	?	yes
Net present value (q3 = [d-e] + p1, p2, …px)		x	x	x	yes	yes
Cost-effectiveness (r = p /a)		yes	yes	yes	x	yes
Government costs (s = e+f+k2)		x	x	no	x	yes
Government-efficiency (t = s / c)		x	x	no	x	yes

Key to table - Application of quantities/parameters: yes: applied; no: (normally) not applied; ?: applied depending on case; X: not relevant

In summary, the findings as shown in table 1 are:

- All perspectives have a number of quantities, parameters and indicators in common, but that concerns only a small part of the items used in each of the cases
- Each perspective has its unique quantities, parameters and indicators, i.e. non-energy benefits for the societal cost-benefit case, the surcharge on the discount factor for individual investors and the non-financial barriers in the modelling of implementation case
- The policy case is differing the most from all other cases as it only regards savings that are supported financially by government, with its own indicators
- The financial evaluation for modelling of implementation is, in principle, the most elaborate one. It has the most in common with all other perspectives.
- To a certain extent, differences in results, as presented by the indicators, can be explained by the in- or exclusion of factors shown in the table, but in many cases the used indicators themselves differ and/or inputs are taken into account or not.

Overall, one should accept that cost-benefit analysis can be done from different perspectives, each with its own value for their respective stakeholders. But to avoid confusion and drawing wrong conclusions it is of utmost importance that each cost-benefit study specifies which perspective has been taken, which inputs have been used and what the indicators are telling us.

Example: the effect of perspective and discount rate on the costs of savings measures

Table 2 illustrates the effects of different perspectives and the associated discount rates on the costs of savings measures for the sample case of condensing boilers. The narrow discount rate type indicates that only financial effects directly related to the investment, cost of capital and lower costs of energy have been included. The wider discount rate type indicates that a wider range of non-financial obstacles has been incorporated. Constant for all cases are investment costs (1000 euro), O&M costs (25 euro/year), energy effect (-15825 MJ/year) and the wholesale gas price (0.0066 euro/MJ).

Table 2. The effect of different perspectives and associated discount rates on the costs of savings measures for the sample case of a condensing boiler.

Perspective	discount rate type	gas energy tax	total gas price	payback time	discount rate	annualized costs
		EUR/MJ	EUR/MJ	Years	%	EUR/year
Companies (end-user)	Narrow	0,0021	0,0087	5	10	150,50
	Wider	0,0021	0,0087	3	15	324,68
Households (end-user)	Narrow	0,0060	0,0126	15	4	-85,05
	Wider	0,0060	0,0126	15	15	-3,98
National	Narrow	n.a.	0,0066	15	4	10,50
Government	Narrow	-0,0021	-0,0021	n.a.	n.a.	33,85

Table 2 shows that as a result of differences in energy taxes and the applied payback times and discount rates, the cost effectiveness of measures differs significantly depending on the perspective taken. For households, measures are most cost effective due to the high energy taxes that apply, relatively long payback times and relatively low discount rates. From a national perspective the same measures are less attractive because energy taxes are not taken into account. The least cost effectiveness is found for companies, as they often demand a short payback time, energy taxes are low and the applied financial discount rates are high.

Improved modelling of the costs of savings measures and policy decisions

Energy policy decisions are often based on models of the energy system. The choices made in model setups therefore have a large influence on energy policy measures proposed and implemented. This puts great responsibility into the hands of the model makers. Incorporating non-financial elements through (higher) discount rates may lead to the impression that there is a lower potential of viable measures than in reality. This will lead to a lower target for energy efficiency if the target is based on the cost effective potential, or lead to subsidies that are too generous because the saving measure is presented as not being cost effective. To avoid this, only financial parameters should be included in the applied discount rates. If it appears in practice that not all measures are taken despite their financial feasibility, then, for reasons of clarity, this can be handled in models in a different way, for example by using estimates of the fraction of cost effective savings measures that will applied. This is more transparent than changing discount rates until model projections match reality. Such an approach will also help to discover cost effective savings potential that can be realized without the need for direct financial support, but rather by other means to overcome non-financial barriers.

Cost effective savings potentials can also be estimated too low if the scope does not include the entire energy system. On the other hand, limited policy effectiveness will result in lower savings potential than a pure cost effective potential would suggest. All these effects should be taken into account when setting an optimal target for climate policy, of which energy efficiency policy is obviously an indispensable part. How to approach an optimal climate policy target setting is addressed in a simultaneous paper by Hekkenberg [Hekkenberg, 2016].

Conclusions

Costs and savings potentials of energy efficiency measure should be calculated and reported in a well-defined, consistent and transparent way to allow for meaningful comparison and to avoid ill-informed policy decisions. Of course, calculated cost (effectiveness) levels, resulting from taking into account various cost types, parameter values and calculation algorithms, can still differ for different purposes, but it is crucial that the definition of these cost types and which definition has been chosen is crystal clear and unambiguous.

Additional benefits can also be included in the calculations for the cost of measures if so desired. However, for this new cost-effectiveness approach, definitions and calculation approaches still have to be developed.

Calculations of cost-effectiveness and potentials for energy savings should be viewed in the larger picture of limiting climate change where renewables, carbon capture and storage (CCS) and other emission reduction options are also available.

Without a doubt there will be reasons why the optimal set of measures will not be exactly equal to the set of measures that follows from a future EU policy, but it is still important that the correct optimal situation, based on consistent measure costs, is available as a reference for policy making and target setting.

References

E3MLab/ICCS, 2014: PRIMES model 2013-2014 – Detailed model description, E3MLab/ICCS at NTU of Athens.

EC, 2013: EU Energy, Transport and GHG emissions – Trends to 2050 – Reference scenario 2013, E3M and IIASA, EC, December 2013.

EC, 2014: Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy. EC, COM(2014) 520 final.

ECF 2010: Energy savings 2020 - How to triple the impact of energy saving policies in Europe, B. Wesselink and R. Harmsen (Ecofys), W. Eichhammer (Fraunhofer ISI) for ECF, 2010.

ECN 2005a: Indicators of domestic efforts to reduce CO_2 emission in The Netherlands, P. Boonekamp et al, ECN-C-05-024, ECN, Petten, February 2005.

ECN 2005b: Evaluation of effectiveness of domestic climate policy – Costs and effects 1999-2004 (in Dutch), CE Delft, July 2005.

ECN, 2014: EU-doelen klimaat en energie 2030: Impact op Nederland, ECN-E--14-033.

EurActiv, 2016: Cañete confirms Commission climbdown over 'Modelgate', EURACTIVE 26 January 2016, http://www.euractiv.com/section/science-policymaking/news/canete-confirms-commission-climbdown-over-modelgate/.

FhG, 2009: Study on the Energy Savings Potentials in EU Member States - Final Report for the EC, Fraunhofer ISI, Enerdata, ISIS, TU Vienna and Wuppertal Institute, March 2009, revised.

FhG, 2014: Study evaluating the current energy efficiency policy framework in the EU and providing orientation on policy options for realising the cost-effective energy efficiency/saving potential until 2020 and beyond. W. Eichhammer (Fraunhofer ISI), L. Kranzl (TU Vienna) and S. Dovidio (PwC), September 2014 (revised).

Hekkenberg et al, 2016: Defining sub-targets for deep decarbonisation — Keeping our eye on the ball, M. Hekkenberg et al, ECN, IEPPEC conference paper 2016.

Hermelink & De Jager 2015: Ecofys for ECEEE: Evaluating our future (http://www.eceee.org/policy-areas/discount-rates).

IEA, 2014: Capturing the multiple benefits of energy efficiency, IEA 2014/2015.