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EU Energy Efficiency Policy

How a more cost-efficient decarbonization could succeed

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JEL-Klassifikation:

Q52: Umweltschutzkosten; Verteilungseffekte
Q58: Umweltökonomie: Regierungspolitik

Summary

At EU level, new proposed legislation for a clean-energy policy is being adopted. New policies are currently being discussed regarding the increased reduction of CO_2 emissions, as well as EU-wide energy consumption targets for the year 2030 and national energy efficiency targets and measures to be derived from them. But what happens when the proposed objectives contradict and undermine each other? A restrictive energy consumption target can become a major obstacle to achieving the overall energy and climate-policy objective of cost-effective decarbonization of the energy system. Economic policy instruments for increasing energy efficiency in the EU ETS sectors can make it more difficult to achieve decarbonization at minimal cost. Energy efficiency targets and the corresponding economic policy measures can however make a worthwhile contribution in sectors not included in the EU ETS.

Instruments for increasing energy efficiency should aim at improving technical energy efficiency. With that in mind, the conception of quantitative targets and tools must be improved. The macroeconomic indicators for “energy efficiency” and “energy intensity” used thus far are unsatisfactory as simple political objectives and lead to wrong conclusions regarding the success of the economic policy instruments being used. The indicators must be decisively improved, for example, by considering factors such as business cycle and economic growth, as well as the proportion of renewable energy or of energy-intensive and less energy-intensive sectors. Furthermore, a better database is necessary.

1 Initial situation and background

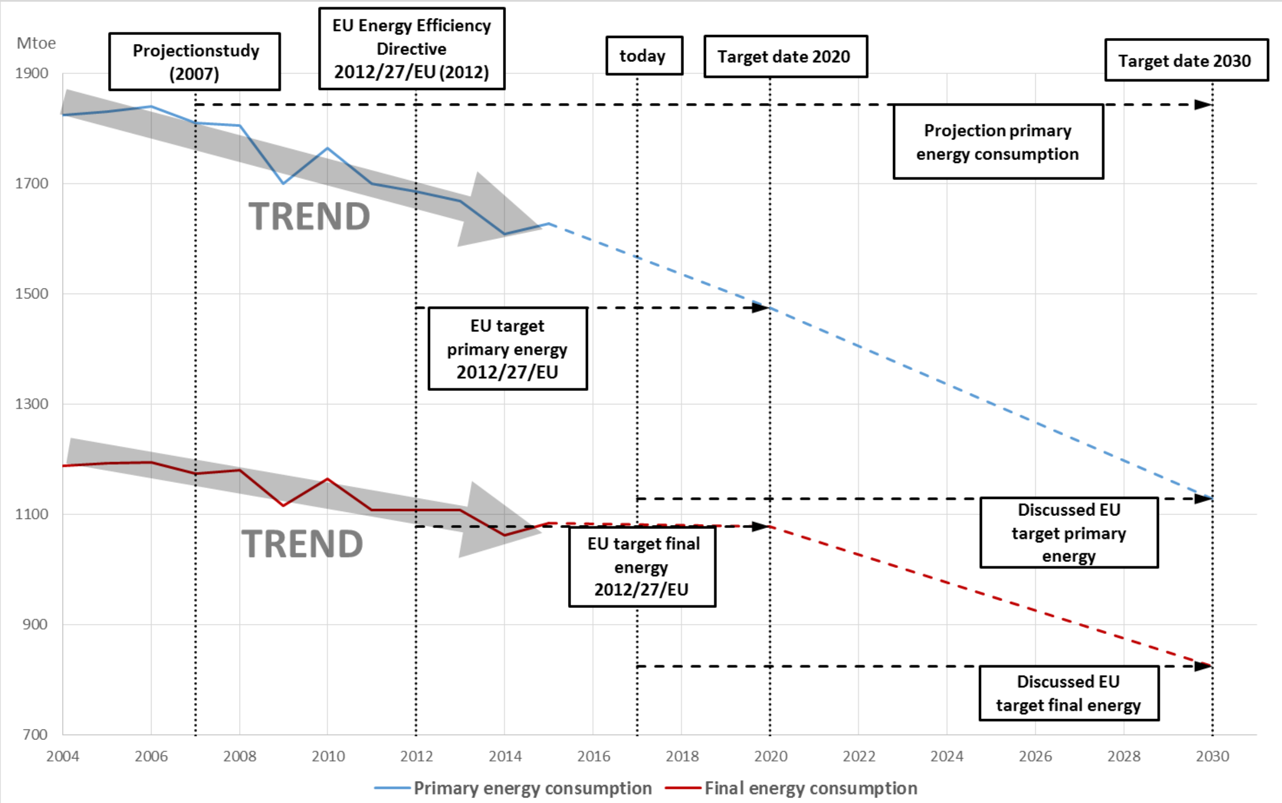
By power of Directive 2012/27/EU, the EU Member States are obliged to formulate national energy efficiency targets and to promote energy efficiency measures. These measures are intended to reduce the EU's primary energy consumption – compared with the projected business-as-usual consumption of 1,842 Mtoe (Million Tonnes of Oil Equivalent) in 2020 – by 20% to 1,474 Mtoe.[1] In addition, a reduction in final energy consumption to 1,078 Mtoe in 2020 is targeted.

Figure 1 shows the change in primary and final energy consumption for the 28 EU Member States together with the projected consumption and the reduction targets. If the trends of the last few years before 2012 – when the Directive was adopted – were to be continued, the energy consumption targets are expected to be achieved. However, the absence of a significant change in the trend following the introduction of the Directive in 2012 leads one to suspect that up until now, the Directive has had little influence on the change in energy consumption. It is possible that behind these figures there have been, for example, improvements in energy efficiency that would have been achieved even without the Energy Efficiency Directive. Moreover, the weak economic climate throughout Europe as a result of the economic crisis is likely to have curbed energy consumption to a significant degree. Even so, after the recovery of 2014 and 2015, energy consumption has not returned to pre-crisis levels. In summary, EU energy consumption targets, and the national energy efficiency targets and measures derived from them, were not necessarily ineffective, but are likely to have contributed to the achievement of the 2020 goals only to a lesser extent.

[1] The projected primary and final energy consumption for the year 2020 comes from a study carried out in 2007 and is based on the PRIMES model (cf. EU Commission 2008).

Figure 1-1: Primary and final energy consumption for the EU-28 – Changes and targets

In: Mtoe (Million Tonnes of Oil Equivalent)



Source: Eurostat (2017)

The Commission, Parliament, and the European energy ministers are currently negotiating a continuation and intensification of the energy consumption targets for 2030. For example, according to the latest proposal from the European Parliament's Committee on Industry, Research and Energy (ITRE), only 1,132 Mtoe of primary energy and 849 Mtoe of final energy are to be consumed in 2030. Once again, the Member States are to formulate national energy efficiency targets and take cost-efficient measures in order to achieve these consumption targets. Consequently, energy efficiency is to increase above all in the industrial, the transport and the building sector.

Reducing losses incurred in the transformation from primary energy to useful energy, and ultimately energy services and, thus, improving technical energy efficiency, must undoubtedly make an important contribution in order to achieve the three-pronged energy policy goal of "cost efficiency, security of supply, and environmental compatibility".[2] The goal of cost efficiency means above all a generation and consumption of energy at the lowest possible total costs to the economy. The lower the costs of the energy system, the greater the amount of wealth that remains for other sectors of the economy and potentially for the end consumers. Similarly, poor security of supply translates into higher costs and less wealth. In the long run, however, theoretically any degree of security of supply can be achieved if an economy is only ready to incur sufficient costs and to expend wealth in order to safeguard itself against supply risks. For example, fossil fuel imports that are subject to geopolitical risks could be completely replaced by renewable energies, and their volatility in the production process could in turn be completely and cost-effectively safeguarded against through storage, and therefore serve to prevent any supply shortages.

For the present examination of longer-term interrelations and for a concise, practical approach, we will simplify by combining security of supply and economic efficiency under the goal of minimizing the total costs of the energy system. Since the reduction of greenhouse gas emissions is probably the EU's most important climate policy goal, the objective of environmental compatibility will be understood to mean only the reduction of greenhouse gas emissions – expressed in simple terms as CO_2 emissions.[3]
In general, the overall objective of European climate and energy policy may therefore be summarized as decarbonization and energy supply at minimal cost.[4]

Since most of the costs of decarbonization are borne by the EU's citizens, one must take into account that higher decarbonization costs may lead to a lower degree of social acceptance and higher political resistance against an ambitious European energy and climate policy. Moreover, a decarbonization process implemented at a cost which is other than minimal also means that more CO_2 emissions could have been saved at the same cost, and thus that resources have been wasted that otherwise would have been available for decarbonization.

Given the current political momentum towards more stringent energy consumption and efficiency targets, the question arises as to whether these targets and the corresponding economic instruments make it easier or more difficult to achieve the overall objective of decarbonization and energy supply at minimal costs. A differentiated debate on the usefulness of a more stringent European energy consumption and efficiency policy is needed, particularly in light of the overall objective.

First, we will analyze whether the currently discussed energy consumption target poses a problem for achieving the overall objective of cost-minimal decarbonization of the energy system. Secondly, we will discuss whether, and if so, just how exactly national energy efficiency targets

[2] In the transformation of useful energy to energy services, not only technical energy efficiency – for example, that of a heating and building insulation system – plays a role, but also consumer behavior (e.g. opening windows for ventilation) is of importance.

[3] When CO_2 emissions are referred to below for purposes of simplification, this shall always mean all relevant greenhouse gases.

[4] Expressed more precisely in mathematical terms, this concerns the minimization of the costs of the energy system, subject to the constraint that European greenhouse gas emissions do not exceed the envisaged emission targets.

and the corresponding instruments of economic policy can make a contribution to cost-effective decarbonization. Finally, the most significant findings will be summarized and recommendations for a goal-oriented energy and climate policy will be formulated.

2 Energy consumption targets and cost-efficient decarbonization

As its main goal, the EU Energy Efficiency Directive specifies the reduction of EU primary and final energy consumption. In contrast, the overall objective of European energy and climate policy can certainly be stated as being cost-minimal decarbonization and energy supply. The reduction in energy consumption is thus a secondary goal subordinate to the overall objective. The question then arises as to whether the desired reduction of energy consumption makes it easier or more difficult to achieve the overall objective of cost-minimal decarbonization and energy supply.

At first glance it may seem intuitively correct that with lower energy consumption, there will be lower CO_2 emissions and also lower costs will be incurred. But this conclusion is not feasible without making certain other additional assumptions.

2.1 Energy consumption target as a potential hindrance for decarbonization

A connection between energy consumption and CO_2 emissions exists only as long as energy (for the most part) is being generated from fossil energy sources. For decarbonization, however, it is necessary that fossil energy be replaced by renewable energy sources. Currently, there are enough economic policy instruments that encourage the replacement of fossil fuel production with renewable energies (e.g. the EU ETS and Germany's Renewable Energy Sources Act (EEG)). With an increasing share of renewable energy production, however, an effectively implemented energy consumption target has a diminishing impact on CO_2 emissions and at the same time even has the potential to slow down the development of renewable energies. But this depends on the exact form in which a mechanism for decrease in consumption is constructed. In order to avoid negative effects on the development of renewable energies, there must be a guarantee that a corresponding mechanism in connection with the decrease in consumption will eliminate fossil fuels rather than renewable ones. Because the goal of decreasing consumption is currently to be achieved by means of national energy efficiency policies, there is no preferential treatment of renewable energies vis-à-vis fossil fuel production.

2.2 Energy consumption targets conflict with cost-efficiency

Even if a decrease in energy consumption may intuitively be related with a decrease in energy costs, this approach does not take the entire picture into account. The intuition is typically based on the incorrect assumption that the costs of the energy system (almost) exclusively result from the costs of the energy used. However, the total costs of the energy system include not only the costs of the energy used – and thus the short-term variable costs of the energy system – but also the costs of the infrastructure for energy generation, transport and consumption.[5] An effectively implemented energy consumption target can indeed lead to a decrease in the amount of energy used and, along with it, lower short-term variable energy costs. However, lower energy consumption can potentially necessitate a far more costly infrastructure for generation, transport, and consumption. As an example, one may cite the use of very expensive building insulation which does in fact decrease the amount of energy consumed but which causes costs that are even higher than what the savings on variable energy costs would have been. In this way, taken together, the total costs of the energy system can be greater than without the energy consumption target.

Similarly, an effectively implemented reduction target for energy consumption can also lead to higher costs of decarbonizing the energy system. Let us assume that we could save the same amount of CO_2 if, instead of insulation, we were generating a part of the energy used for heating purposes through renewable means. If it were more economical to heat with renewable energy instead of using presumably expensive insulation, then an insulation whose use is required by the energy consumption target would also lead to higher decarbonization costs. In turn, this could jeopardize achieving the overall objective of cost-minimal decarbonization.

2.3 Energy consumption leakage

In the worst case, an effectively enforced energy consumption target may even induce energy consumption to “leak” to countries outside the EU. This would be the case, for example, if the insulation material from the above example had to be produced in an especially energy-intensive way and consequently the production thereof migrated to countries where there is no (effectively implemented) energy consumption target. If the energy intensity of producing the insulation material abroad is higher than in the EU, then the EU’s reduction in energy consumption would ultimately lead to the EU’s energy consumption decreasing somewhat but energy consumption outside the EU increasing by comparison. In this case, global energy consumption would even rise as a result of the EU consumption targets.

2.4 Energy consumption targets conflict with sector coupling

An additional problem area of energy consumption targets is the sector coupling likely to be necessary for decarbonization. Sector coupling involves the electrification of a large part of the energy system, which over the long term is to take place primarily by means of renewable energies. A large expansion of renewable energy capacities entails large fluctuations in electricity generation. In order to compensate for deviations between volatile renewable energy generation and the demand for electricity, large additional energy storage capacities need to be created. According to the present state of knowledge, storage technologies such as Power-to-X – which increase energy consumption and have a low energy conversion efficiency – will play a

[5] The “energy system” includes all energy-converting sectors from the extraction, import and/or generation of energy up to the point of its consumption. Total costs of the energy system mean all costs that are incurred by the production and/or generation up to the end consumer. The end consumer’s costs are defined as costs of the energy service, e.g. up to receipt of an apartment at “a comfortable temperature”, not only as the costs of the final energy used (e.g. heating oil.). For an apartment at “a comfortable temperature” in this example, not only heating oil is necessary but also at least one heating unit and some amount of insulation. The utility of the energy service accruing to the end consumer are in this case deliberately disregarded, due to the difficulty of operationalization.

decisive role here.[6] Because the increased use of storage technologies would result in an increase in energy consumption, a more stringent energy consumption target would also conflict with a decarbonized energy system built on renewable electricity.[7] If an energy consumption target were implemented by means of more effective economic policy instruments, decarbonization could be jeopardized as a result of a drastic increase in costs to the economy. The costs of decarbonization could increase severely, because instead of comparatively cost-effective but energy consumption-increasing Power-to-X storage, more expensive options to balance out electricity supply and demand would be used. It could be the case that, for example, instead of Power-to-X storage, disproportionately more expensive demand-side management options such as limitations on production would be used.[8]

In conclusion it can be stated that an effectively implemented energy consumption target has the potential to hinder cost-minimal energy supply and decarbonization. By the same token, it is not at all out of the question that in the course of a decarbonization process implemented at minimal cost, a decrease in energy consumption will not occur as a side effect, either. An energy consumption target which is externally imposed can however lead to significantly higher costs of decarbonization of the energy system, depending on the economic policy instrument deployed to achieve that goal.

Interim Conclusion

Since it stands to interfere with achieving the overall objective of a cost-minimal decarbonization and energy supply, an EU energy consumption target is to be rejected as a matter of principle. Furthermore, an effectively implemented energy consumption target represents a likely obstacle to sector coupling. In addition, there exists the danger that energy consumption will migrate to countries outside the EU and, in doing so, cause an increase in global energy consumption

3 Governance Problems associated with the EU Efficiency Directive

Leaving cost efficiency aside for the moment, the design of the EU Energy Efficiency Directive casts doubt on its effectiveness. Particularly, the question arises as to whether the EU Energy Efficiency Directive gives strong incentives to the EU Member States to implement energy efficiency measures that are sufficient for achieving the EU energy consumption target.

[6] In connection with sector coupling, it is expected that technologies that decrease demand for energy will also play a role. However, it is plausible that the aspects of sector coupling that increase energy demand will predominate and lead to a net increase in energy demand.

[7] As primary energy consumption in the power sector strongly depends on statistical conventions about the conversion efficiency of renewables and nuclear into the final energy form electricity, this line of argument refers mainly to the targets for final energy consumption.

[8] While temporarily shifting production into periods with low electricity prices usually represents a cost-effective demand-side option, real limitations on production are usually very expensive for a nation's economy.

The EU energy consumption target is formulated for the entire EU. The necessary measures however are to be taken and implemented at the national level by the individual Member States. Because there is neither an agreement nor a mechanism that prescribes a certain percentage of the entire reduction in energy consumption for each Member State, there is no one who is made responsible or can even be sanctioned if the consumption target is not achieved. Since an effective and ambitious reduction in energy consumption is associated with expense and economic cost, and any reduction will only be credited against the EU-wide consumption target, each Member State has an incentive to forgo the implementation of cost-intensive and effective policy for reducing energy consumption.[9]

In the end, the EU Directive will therefore not have a direct effect on the course of energy consumption by the EU Member States and consequently by the EU as a whole. This does not mean that the consumption of energy cannot be changed on the basis of other factors such as, for example, economic growth and economic cycles. It just means that the EU Directive will not have an effective impact on the EU's energy consumption, and that political resources utilized in formulating and negotiating the current design of the Directive are being wasted.

Interim Conclusion

With the present design of the EU Directive, we cannot assume that the Directive will induce EU Member States to formulate ambitious policies for the reduction of energy consumption. The EU Energy Efficiency Directive, in its current form, will therefore not make any direct contribution to the reduction of energy consumption.

4 Energy efficiency policy and cost-minimal decarbonization

The EU Directive provides that the EU Member States formulate national energy efficiency targets and corresponding economic policy measures that are suitable for achieving the EU energy consumption target. The question arises as to what extent national energy efficiency targets and corresponding instruments of economic policy are appropriate in order to achieve (a) the reduction of energy consumption and (b) the actually significant overall objective of cost-minimal decarbonization and energy supply.

[9] In addition there are also cases in which measures for decreasing energy consumption are profitable at a microeconomic level even without government intervention, but are hindered due to market imperfections – for example, if investments in a building's insulation are already amortized after only a few years but the building owner does not have sufficient possibilities for financing the initial investment. In these cases, Member States have an incentive for reductions in energy consumption even without an EU Directive, by correcting the market imperfections.

4.1 The role of energy efficiency in cost efficient decarbonization

As point of departure for our further discussion, first, the term "energy efficiency" will be adequately defined. In addition, the objective of successful energy efficiency policy will be explained, and its connection to the overall objective of cost-minimal decarbonization of the energy system will be elaborated upon.

In EU documents, energy efficiency is often understood to mean the ratio between "an output of performance, service, goods or energy" and an input of energy (cf. Directive 2012/27/EU, Article 2). What is meant by "an output of performance, service, goods or energy" is not defined precisely. A more helpful definition is the engineering and scientific concept of technical energy efficiency. Improvements in energy efficiency in the technical sense occur when there is a reduction in transportation or transformation losses when primary energy (e.g. petroleum) is converted into final energy (e.g. heating oil), useful energy, (e.g. thermal energy from heating) and finally to energy services (e.g. a room at a comfortable temperature) or physical goods.

Good energy efficiency policy should not only provide an incentive to reduce the energy losses in transport and transformation (effectiveness), but also in fact ensure that the most cost-effective options for reducing transformation losses, according to the current state of technology, are realized (cost efficiency). As long as large percentages of fossil fuels are used to generate the energy, the greenhouse gas emissions of a process are also reduced in the event of technical energy efficiency improvements.[10] In this way, improving energy efficiency has the potential to make an important contribution to the decarbonization of the EU. For successful decarbonization, energy efficiency therefore plays a role, as long as large quantities of fossil fuels are still used in energy production. The greater the share of renewable energies is in the energy supply, the less important the increase in energy efficiency will be for successful decarbonization.

Furthermore, it must be noted that an increase in energy efficiency for purposes of the decarbonization of the energy system represents only a technical alternative to the expansion of renewable energies.[11] A good body of economic policy instruments should set in motion as many energy efficiency measures as correspond to the cost-minimal mix of decarbonization options. If energy efficiency policy stimulates too many or too few improvements in energy efficiency compared to this optimal decarbonization mix, this would inevitably lead to higher decarbonization costs. This in turn should be avoided because it is incompatible with the overall objective of cost-effective decarbonization.

4.2 Energy efficiency policy ineffective for achieving consumption targets

While the EU Energy Efficiency Directive originates from the European climate and energy policy, it does not prescribe cost-minimal decarbonization and energy supply as its main goal, but

[10] Improvements in technical energy efficiency, however, can also lead to a process being used more often. As explained further below in the discussion of rebound and expansion effects, this may lead to only small reductions, and in some cases even increases, in energy consumption in comparison to technical improvement in efficiency. Given a certain proportion of fossil-fuel energy in the generation mix, CO_2 emissions also decrease or increase.

[11] Other technical decarbonization alternatives to energy efficiency – which are however controversial in many EU countries – are the use of nuclear energy or carbon capture and storage.

rather the reduction of EU energy consumption. Even if an effective energy efficiency policy leads to a large number of energy efficiency improvements, can we hope that doing so will significantly reduce EU energy consumption? There are a number of reasons that militate against this.

Rebound effects

Just because less energy is consumed per conversion step, and ultimately per energy service unit or product, that does not mean that less energy is consumed overall. The rebound effect on the consumer side (cf., e.g., Borenstein 2013) and on the company side can eat up part of the potential for reduction in energy consumption arising from increases in energy efficiency, or in the worst case even overcompensate for them.

Through energy efficiency measures, such as better building insulation, consumers save not only energy but also money. To a certain extent, this money is spent again on energy-intensive products. If, in the case of a higher, effective income level, an overall more energy-intensive basket of goods is consumed, then the energy consumption of a household can even increase.

Companies can produce more cost-effectively through more energy-efficient processes and thus satisfy more demand at the same price. More quantity demanded means that more must also be produced, and increased production means more energy consumption. These two types of rebound effect can lead to increases in technical energy efficiency that have only a weak effect on energy consumption. In rare and extreme cases even an increase in energy consumption is possible.

Efficiency expansion effects

One issue that is more problematic than these immediate rebound effects is that processes that become more energy-efficient, and thus more cost-effective, are often used in new energy-consuming applications – applications that were previously unthinkable for reasons of practicability or cost. For example, the improvement of computer processors has meant that in the past, not only dramatically more time, but also much more energy and thus higher costs per computing operation had to be spent compared with today (cf. Nordhaus 2007). Increasingly faster and more energy-efficient, and thus more cost-effective, computing operations have led to computers being used in an ever-increasing number of applications and in ever greater numbers. For example, battery-powered mobile devices were made possible only through improvements in energy efficiency. Because of this "efficiency expansion effect", computers consume many thousands of times more energy than they did a few decades ago, despite game-changing improvements in energy efficiency.[12]

Rebound and efficiency expansion effects thus make it difficult to reduce overall energy consumption even with a very effective energy efficiency policy in place. When many new applications are potentially available the expansion effect has the potential to significantly increase total energy consumption under a successful energy efficiency policy.

[12] Even though the energy expansion effect can hardly be neglected in the case of computing operations and the power consumption of computers, this effect and its precise magnitude and mode of action have been researched very little until now. The first considerations of how improvements in efficiency lead to new applications can be found at Jevons (1866).

Energy efficiency is only one factor among many influencing energy consumption. There is another reason why an effective energy efficiency policy is neither a necessary nor sufficient condition for reducing energy consumption. In addition to technical energy efficiency, other factors such as economic growth and economic cycles, as well as structural changes in the economy (e.g. contraction or growth of energy-intensive industries due to competitive forces) have a major impact on energy consumption. Even the most effective energy efficiency policy cannot (and certainly does not intend to) prevent high domestic and foreign economic growth from leading to increased export demand, production and thus higher energy consumption.

Interim Conclusion

National energy efficiency policies, even when formulated effectively, are unlikely to make a significant contribution to reducing energy consumption. There is no direct, compelling connection between an effective energy efficiency policy and energy consumption.

4.3 Energy efficiency policy, cost-minimal decarbonization and EU ETS

As explained above, the energy consumption target of the EU Energy Efficiency Directive is not conducive to achieving the overall climate and energy policy objective of a cost-minimal decarbonization of the energy system. In addition to the energy consumption target, the Directive requires the Member States to introduce economic policy instruments in order to increase energy efficiency. In contrast to energy consumption goals, a well-designed energy efficiency policy can play an important role in achieving the overall objective of cost-minimal decarbonization and energy supply.

Policy instruments that promote energy efficiency by overcoming market imperfections such as the Landlord-tenant split generally contribute to cost-efficient improvements in energy efficiency and decarbonization. In contrast, instruments – such as many subsidy schemes – that favor certain abatement options over others (e.g. energy efficiency over renewables) endanger cost efficiency. This is particularly true when such instruments are applied in EU ETS sectors where the cap and trade system would otherwise lead to cost efficient decarbonization. However, policies that directly incentivize energy efficiency can serve as a transitional second best solution in sectors where there is no cost-efficient and effective decarbonization instrument in place.

Why energy efficiency policy in EU ETS sectors often conflicts with cost efficiency

Almost half of the EU's greenhouse gas emissions are covered by the EU ETS, the European Union Emissions Trading System. For the part of the economy covered by the EU ETS, the free trading of emission allowances enables emitters to realize the cost-minimal mix of their own least expensive emission reductions and the redemption of purchased (or freely allocated) certificates to cover the remaining emissions. Because in this way each company can minimize its decarbonization costs and because the total amount of emissions is limited by the cap, the EU ETS guarantees decarbonization at minimal economic costs for the sectors included (cf. Montgomery 1972).[13] In other words, there is no CO_2 reduction measure that could reduce more CO_2 in the covered sectors than the EU ETS at the same economic costs. Therefore, from an economic point of view, it makes sense to include most of the European economy in the EU ETS and to bring the cap in line with the European long run CO_2 reduction targets (cf. Leopoldina et al. 2017). As a result, the European CO_2 reduction targets can be achieved with the greatest possible certainty and at the lowest possible costs to the economy.

The cost-minimal nature of the EU ETS also means that climate and energy policy instruments used in the EU ETS sectors, in addition to the cap and trade mechanism, increase the economic costs of reducing emissions. More specifically, the economic costs are always increased if an additional climate or energy policy forces an EU ETS emitter to emit more or less than it would have emitted if just the incentives of the EU ETS had been in effect. Because the emissions in the EU ETS are fixed by the cap, no additional climate or energy policy measure will be able to further reduce European CO_2 emissions, but will unnecessarily increase the cost of decarbonization.[14] Therefore, additional economic policy instruments to increase energy efficiency, will not result in any additional reduction of emissions below the EU ETS cap. Moreover, when the policy instrument makes energy efficiency measures more attractive than using other decarbonization options with the same (marginal) abatement cost this will increase the costs of decarbonization to the economy.

Additional policy instruments should only be used in EU ETS sectors if additional market imperfections jeopardize the achievement of the overall objective of cost-minimal decarbonization and energy supply or are necessary to achieve other policy objectives, for example in industrial policy. Examples of such market imperfections include knowledge spillovers in the development of innovations, path dependencies, inadequate opportunities to finance risky innovation and research, limited or asymmetric information, and limited rationality (cf. Löschel 2017) as well as institutional problems such as the Landlord-tenant split. Typical policy instruments used in energy efficiency policy, often do not satisfy these requirements as they distort incentives towards energy efficiency and away from other abatement options with the same (marginal) abatement cost. Instead, good instruments should be designed in such a way that they directly remedy clearly identified market imperfections. This can indeed indirectly lead to an increase in energy efficiency. However, good economic policy instruments should not be aimed at improving energy efficiency directly by distortion of perceived abatement costs – since "low" energy efficiency is ultimately not a market imperfection – but rather at remedying above mentioned market imperfections.

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[13] Whether and how much a number of potential market imperfections can decrease the long run cost efficiency of the EU ETS is an ongoing discussion (see for example Edenhofer et al. 2017). However, even in the presence of these flaws the EU ETS is arguably the most cost efficient and effective European decarbonization instrument in place. Moreover, options such as price floors are available to address these flaws.

[14] Only very drastic CO_2 reduction measures, which would be able to bring CO_2 emissions below the cap regardless of the EU ETS, could bring about a reduction beyond the cap.

Why energy-efficiency policies in non-EU ETS sectors can make a valuable contribution

Energy efficiency policies that are tailored to address specific market imperfections (as mentioned above) enable CO_2 emitters to choose the cost-minimal mix of abatement options. Hence, these policies promote cost efficient decarbonization. In contrast, policies that systematically distort incentives towards abatement through energy efficiency can lead to unnecessary cost increases - particularly when used in EU ETS sectors. However, outside the EU ETS there do not exist instruments that are comparable to the EU ETS in terms of effectiveness and cost-efficiency. Hence, energy efficiency policies can serve as a temporary second best option in sectors outside the EU ETS to work towards the overall objective of cost-minimal decarbonization.

In general, in order to induce cost efficient CO_2 abatement a uniform price for CO_2 should exist throughout the economy across all sectors, technologies and abatement options (cf. Leopoldina et al. 2017). Such a uniform price could be obtained when all important greenhouse gas emitting sectors such as traffic as well as buildings and heating are included in the EU ETS and other (explicit and implicit) carbon prices for example resulting from electricity or fuel taxes are removed. However, given the current political situation we cannot expect to include additional sectors into the EU ETS in the near future. As a second best option, we can try to bring about a convergence of existing explicit and implicit CO_2 prices across all sectors and technologies. This allows for cost-minimal abatement throughout the European economy. At the moment, explicit and implicit CO_2 prices differ strongly across European countries, sectors and technologies. Hence, given the political momentum towards introducing energy efficiency policies, energy efficiency instruments could be (re-)designed such that they implicitly contribute to a convergence of European CO_2 prices.

Accordingly, policy instruments for increasing energy efficiency in non-EU ETS sectors should be designed such that in combination with other existing taxes and subsidies the use of the "energy efficiency" decarbonization option is stimulated on an equal footing with other decarbonization options. For example, investments in external insulation should not be stimulated more or less strongly per ton of CO_2 saved than a CO_2-saving replacement of the heating system. Stimulating energy efficiency with regard to CO_2 savings on an equitable basis as other decarbonization options is an important requirement for a sensible energy efficiency policy. This aspect becomes particularly important when we consider the presumably required, stronger electrification of the energy system in the wake of sector coupling. For example, placing ostensibly energy-inefficient technologies such as Power-to-X at a disadvantage per se should definitely be avoided.

Overall, a good energy efficiency policy should therefore seek to promote various options for increasing energy efficiency in a technology-neutral way so that the most cost-effective options for increasing technical energy efficiency and, ultimately, CO_2 savings are used.

Interim Conclusion

Against the background of the overall objective of cost-minimal decarbonization, the formulation of energy efficiency targets and corresponding economic policy instruments makes sense only for sectors outside the EU ETS. Energy efficiency policy for sectors within the EU ETS will not result in any additional decrease in CO_2 emissions below the EU ETS cap and will most certainly increase the economic costs of decarbonization. However, in both EU ETS and Non-EU ETS sectors instruments should be strengthened that address clearly identified market imperfections which might impede the realization of cost-efficient energy efficiency measures. The essential relationships are shown schematically in Figure 2.

Figure 4-1: Interaction of EU ETS and energy efficiency instruments

Effect of EU ETS, energy efficiency instruments or a combination of both to achieve the overall objective of a cost-minimal decarbonized energy system

Wirtschaftspolitisches Instrument	Angereizte Dekarbonisierungsoptionen	Effektive CO_2-Reduktion	Kostenminimale CO_2-Reduktion
EU ETS (exclusively)	Various (energy efficiency, renewable, etc.)	Yes (Cap)	Yes
Energy efficiency instruments (exclusively)	Only energy efficiency	Possible but uncertain	Possible but uncertain
EU ETS & energy efficiency instruments (in combination)	Various (energy efficiency, renewable, etc.)	Yes (Cap)	No

Sources: Author's presentation

5 Improvement of the indicators “Energy efficiency” and “Energy intensity” necessary

As mentioned before, energy efficiency is not an independent goal. It is derived from and subordinate to the actually important overall objective of cost efficient decarbonization. However, the current discussion about energy consumption targets and derived energy efficiency policies makes it necessary to choose meaningful indicators for the formulation and evaluation of energy efficiency targets. The currently used energy efficiency indicators show serious problems when used as targets and may lead to false conclusions.

Currently, energy efficiency targets are formulated primarily by means of the key indicators "energy efficiency" and "energy intensity". The "energy efficiency" indicator is calculated as the quotient of gross value added (in €) of an economy, an industry or a company and the energy input required for this (for example, measured in Mtoe). The "energy intensity" indicator is the reciprocal value of "energy efficiency". If targets of energy efficiency policy are formulated along these indicators, and if these targets are to be evaluated using the indicators after a certain period of time, a serious problem arises – namely, a long series of factors that have nothing to do with climate-relevant improvements in technical energy efficiency exert a great influence on the indicators "energy efficiency" and "energy intensity". Many of these factors affect both the denominator and the numerator of the indicators. For example, the evolution of the economy and economic growth have an impact both on gross value added and on the energy input needed to produce that added value. Moreover, in an economy, there are often sectors with very different levels of importance of input energy for their production processes. If particularly energy-intensive sectors shrink and industries that use less energy grow, this structural effect seems to improve energy efficiency, even though these changes had nothing to do with improvements in technical energy efficiency, but perhaps resulted only from competitive dynamics in these sectors. If energy efficiency improvement is to serve the overall goal of decarbonization, the energy produced by means of renewable energies should not be included in the calculation of the efficiency indicators. However, the question then arises, as to "which part of the gross value added" would have to be assigned to this use of renewable energies. The gross value added would then also have to be adjusted for this production from renewables.

Furthermore, an improvement in the energy efficiency indicator does not say anything as to whether the most cost-effective technical energy-efficiency improvements and the most economically favorable measures to reduce CO_2 emissions were realized.

In order to evaluate whether energy efficiency targets have been achieved, the indicators for energy efficiency and energy intensity must therefore be adjusted for the aforementioned factors. At least with regard to fluctuations in the business cycle, this seems to be possible on an approximate basis by using filters. In principle, sectoral structural effects can also be calculated by a sectoral decomposition from the energy efficiency indicator (cf. Ang/Liu, 2001; Ang/Liu/Chew, 2003; Ang, 2004; Ang, 2005; and Bardt, 2013).

While these adjustments are basically headed in the right direction, overall they are probably too crude for a selective evaluation of the success of energy efficiency policy. Ideally, attempts need to be made to measure improvements in technical energy efficiency in as direct a way as possible. On the one hand, there is a lack of the necessary database, and on the other hand, it is difficult to aggregate the technical improvements for companies, sectors or entire economies in such a way that national or even EU targets can be formulated. However, the comprehensive, direct collection of technical energy efficiency data provides the only way to measure actual progress in energy efficiency. Therefore, if separate energy efficiency targets are to be formulated and evaluated, there is probably no way to avoid making a significant improvement to the database. If the indicator is to provide information as to whether the European economy is developing towards decarbonization, it would also be helpful to dispense entirely with the energy efficiency indicator at the macroeconomic aggregation level, and instead directly use the indicator for CO_2 intensity – and thus the ratio of CO_2 emissions and gross value added. In any case, this indicator would be somewhat more informative with regard to the overall objective of decarbonization, even if it demonstrates the same methodological problems over time as the energy efficiency indicator.

6 Conclusion and recommendations for a worthwhile energy efficiency policy

First Best: Include all economic sectors in the EU ETS while simultaneously improving carbon leakage protection

The most crucial policy recommendation is to include as soon as possible the most significant CO_2-emitting sectors of the economy in the EU ETS and to bring the cap in line with the long-term European emission targets. At the same time, all explicit and implicit charges and subsidies for CO_2 emissions should be reduced to zero in addition to the EU ETS in cases where they are not needed to address additional market imperfections or to finance networks. This would produce as many energy efficiency improvements and reductions in energy consumption as are necessary to achieve the overall objective of cost-minimal decarbonization and energy supply. Since this would include sectors with presumably higher (marginal) abatement costs in the EU ETS, certificate prices would also increase. Higher allowance prices mean a higher risk of carbon leakage for sectors involved in intense international competition if there is an inadequate supply of free certificates. Therefore, the inclusion of the new sectors in the EU ETS should be supported by an improved allocation of free certificates to sectors of the economy that are generally at risk of carbon leakage. As long as the greater part of significant CO_2 emitting sectors have not yet been included, a separate, energy efficiency policy in non-EU ETS sectors that is as cost-efficient as possible can help reduce CO_2 emissions. However, the corresponding energy efficiency measures would have to be suspended again if the sector were subsequently included in the EU ETS. In order to prepare a smooth transition any explicit or implicit carbon prices in Non-EU ETS sectors should be adjusted towards EU ETS allowance prices.

No energy consumption target

An energy consumption target is incompatible with the overall objective of cost-minimal decarbonization and energy supply. An effectively implemented energy consumption target would mean that CO_2 reduction targets can only be achieved at unnecessarily high economic costs. In other words, without an energy consumption target, more emissions could be saved at the same economic costs. Since, in case of doubt, an effectively implemented energy consumption target will favor expensive energy-saving supply options over less energy-efficient but more cost-effective options, the overall costs of the energy system may also increase significantly as a result of an energy consumption target. A consumption target also represents a significant obstacle to successful sector coupling, since sector coupling is likely to be accompanied by an overall increase in energy consumption. Moreover, a consumption target could lead to leakage of energy consumption to countries outside the EU and could even result in an increase in global energy consumption.

Governance problems relating to the EU Energy Efficiency Directive

Due to governance issues, the current design of the EU Energy Efficiency Directive cannot effectively contribute to a reduction in energy consumption. Firstly, there are no economic policy instruments that compulsorily result in achieving the goal. Secondly, the issue of which EU Member State contributes what amount to the consumption target is not clearly regulated. Diffusion of responsibility will mean that no EU Member State feels obliged to contribute to achieving the

EU target with particularly ambitious or effective – and therefore costly – energy efficiency policies.

No energy efficiency targets and measures in the EU ETS sectors
Economy-wide energy efficiency targets are not helpful with regard to achieving cost-minimal decarbonization and energy supply. For a large part of the EU's economic sectors, the EU ETS already ensures cost-minimal decarbonization. Additional energy efficiency policies cannot lead to additional emission reductions in the EU ETS sectors, but in all likelihood will drive up the cost of decarbonization unnecessarily. Only policies that directly address complementary market imperfections such as the Landlord-tenant split are helpful.

Energy efficiency policy in non-EU ETS sectors
Dedicated energy efficiency policy can contribute to cost-minimal decarbonization in sectors that are not (yet) included in the EU ETS. Economic policy instruments for increasing energy efficiency must be designed in such a way that energy efficiency is neither favored nor disadvantaged compared to other decarbonization options. Again policies that directly address complementary market imperfections should accompany the energy efficiency instruments.

Improving the formulation of energy efficiency indicators and targets
The "energy efficiency" and "energy intensity" indicators typically used to formulate energy efficiency targets and to assess the success of energy efficiency measures are misleading. They must be decisively improved or replaced. In order to make sense as a measure of effective energy efficiency policy in the context of the overall objective of cost-minimal decarbonization, both indicators must at least be adjusted to account for the share of renewable energies, economic growth, changes in the economic cycle and the economic structure. Even after a satisfactory adjustment, the indicators can at best only make a statement about the effectiveness of the energy efficiency policy, but not about whether the implemented energy efficiency measures were also the most cost-effective.

Energy efficiency policy has to be clearly subordinated to the overall objective of cost-minimal decarbonization and energy system
Energy efficiency is not an end in and of itself. Therefore, the EU Energy Efficiency Directive should explicitly state which overall objective or objectives the increase in energy efficiency is to serve. A cost-minimal decarbonization and energy system should be clearly established as the overall objective of any energy efficiency policy. New energy efficiency policy should always be aligned with the overall objective. In this way, mistakes in energy efficiency policy can be more effectively prevented in the future.

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