

Policies for tapping the energy efficiency potential: a review

Kornelis Blok^(*)
Managing Director Ecofys, Netherlands

Abstract

This article provides a review of the developments of energy efficiency policy, with a focus on the European Union. Energy efficiency is generally considered as a key pillar for energy and climate policies. For the time being, technical or economic potential do not form important constraints. The main challenge is to find adequate policies to realize these potentials.

A variety of policies has been applied successfully to improve energy efficiency, including building insulation programs, building codes, appliance labelling and subsidies, and voluntary agreements on industrial energy efficiency. The emphasis of policy making has now shifted from the Member States to the European Union. The focus is on physical regulation policies, but with a lot of built-in flexibility.

If a high rate of energy efficiency improvement is to be achieved also on the longer term, more effort is needed to speed up the rate of energy innovation. Various instruments are available, but experience so far is limited.

^(*) Ecofys
P.O. Box 8408
3503 RK Utrecht
The Netherlands
E-mail: k.blok@ecofys.nl

1. Introduction

Energy efficiency improvement is widely considered as one of the most important options to limit human-induced climate change (IPCC, 2001; IEA, 2004a). Although this is well acknowledged, the actual rate of energy efficiency improvement is limited. An overview study by the International Energy Agency reveals that the actual rate of energy efficiency improvement tends to decline compared to the levels achieved around 1980 (IEA, 2004b). A low rate of energy efficiency is also found back in a detailed study for the food industry (Ramirez, 2005). Hence, the main question is what government policies or other actions can be implemented to speed up the rate of energy efficiency improvement.

The aim of this review article is to give an overview and analysis of recent developments of policy making on energy efficiency. The focus will be on the European Union.

This paper starts with an overview of estimates of energy efficiency potentials. Next, an overview will be given of the dominant energy efficiency policies in the European Union. Subsequently, I will dedicate a section to policies that stimulate the development of new energy-efficient technologies. I will end up with some overall conclusions for the recent policy developments.

2. The medium and long term potential for energy efficiency improvement

Before discussing potentials for energy efficiency improvement, some definitions should be discussed. Energy efficiency improvement is generally quantified in terms of a reduction of specific energy consumption: the energy use per unit of human activity (e.g. energy use per tonne of steel produced, energy use per vehicle-kilometer). Actually, this measure indicates the inverse of energy efficiency improvement.

The effect of energy efficiency improvement can be measured against two different baselines. The first is the so-called frozen-efficiency baseline. This is the hypothetical development in which the level of specific energy

consumption remains fixed. In practice there has always been an ongoing autonomous process of overall energy efficiency improvement, at rates typical between 0.5 and 1% per year. This brings us to the second baseline, which is the business-as-usual development. This baseline already includes all the technologies of which it is expected that they will be taken up autonomously.

In the past, many techno-economic studies measured energy efficiency improvement potentials against a frozen-efficiency baseline. For the purpose of policy analysis measuring efficiency against the second baseline is most relevant – the autonomous part needs no policy attention.

Note that improvement of energy efficiency in general does not mean that the absolute energy use drops; only if the rate of energy efficiency improvement is higher than the rate of economic growth, an absolute reduction of energy use will occur¹.

Many studies have been carried out to investigate the potentials for energy efficiency. In the nineties, in several countries models and databases were developed with very detailed information on energy-efficiency potentials and costs. Examples are the ENUSIM model for the UK (ETSU, 1994), the ICARUS database for the Netherlands (De Beer et al., 1994) and the IKARUS information system for Germany (BMBF, 1995; Markewitz and Stein, 2003). Potentials vary from country to country and from sector to sector. The studies conclude that economic or technical potentials for reduction of average specific energy consumption exist of 15 – 50% in time periods of 10 – 25 years. On an annual basis potential rates for the reduction of specific energy consumption of 1.5 - 3% per year (compared to frozen-efficiency) are found. A compilation for the European Union was made within the so-called Sectoral Objectives project (Blok et al., 2001).

It is a point of concern that, after the detailed inventories that were made in the nineties of the last century, no up-to-date detailed information is available now. Most of the information systems available now are based on piecemeal updates and extrapolations of old material.

For illustration purposes, and to illustrate the contribution of each category of energy conservation measures, in Figure 1 an overview is presented of the options currently available for the Netherlands.

¹ In practice the situation is more complicated as also structural effects play a role.

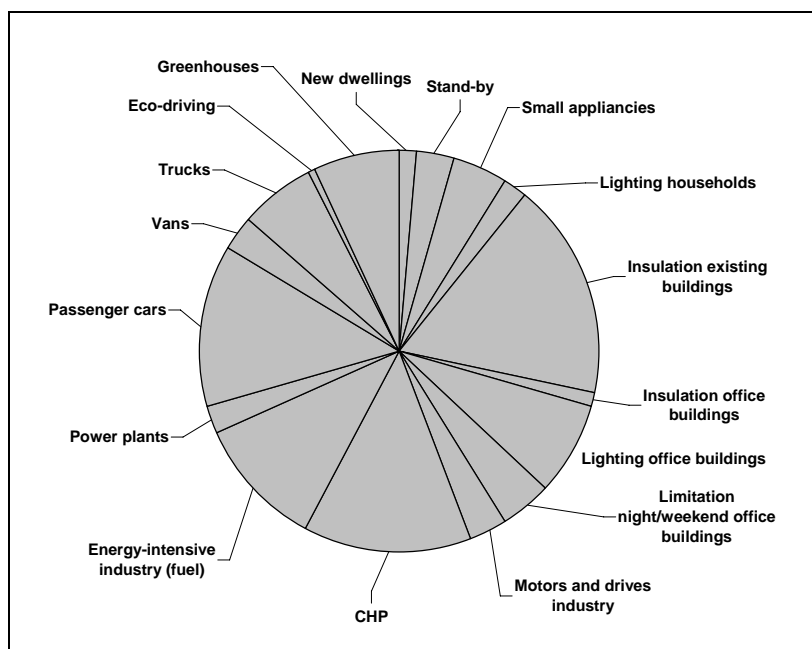


Figure 1. Breakdown of the potential for energy efficiency improvement in the Netherlands for various energy end-use and conversion categories. The potentials are calculated against a business-as-usual baseline. The total amounts to 600 – 700 PJ, enough to enhance annual energy efficiency improvement rates by more than 1% (Blok and Visser, 2005).

For the world as a whole an estimate of the potential for emission reduction through energy efficiency improvement was made by the Intergovernmental Panel on Climate Change. The authors identified potential emission reductions as presented in Table 1. The potentials given in the Table take into account regular turn-over of capital stock and are all cheaper than 100 US\$/tC_{eq} (367 US\$ per ton CO₂-eq.). More than half of the potential can be achieved at negative net direct costs when evaluated against a social discount rate (5 - 12%). The results confirm that energy efficiency improvement can contribute very substantially to greenhouse gas emission reduction.

It is important to stress that the fact that these substantial potential exists, does not mean that it is easy to enhance the rates of energy efficiency improvement. There is a wide range of barriers. Sorrell et al. (2004) give the following classification:

- Risk (technical, financial)
- Imperfect information
- Hidden costs (ranging from overhead costs to costs of disruptions to production)
- Limited access to capital
- Split incentives (e.g. landlord versus tenants)
- Bounded rationality (e.g. lack of management attention)

Table 1. Carbon dioxide emission reductions achievable through energy efficiency improvement (IPCC, 2001). The emission reductions are compared to a business-as-usual development and given in million tonnes of CO₂ or CO₂-equivalents.

Option	Emission reduction potential in 2010	Emission reduction potential in 2020
Energy efficiency in buildings	2,600 – 2,800	3,700 – 4,000
Energy efficiency in industry	1,100 – 1,800	2,600 – 3,300
Energy efficiency in transportation	400 – 1,100	1,100 – 2,600
Total of energy efficiency	4,100 – 5,700	7,400 – 9,900
Total of all options (including low-carbon energy sources, non-CO ₂ greenhouse gas emission reductions)	7,000 – 9,500	13,200 – 18,500
<i>For comparison: projected unconstrained total greenhouse gas emissions</i>	<i>42,000 – 51,000</i>	<i>44,000 – 59,000</i>

The potential estimates quoted so far mainly represent what can be reached with existing technology. Technologies that are still under development and that still need time until market introduction, only play a limited role on a time-frame of one or two decades.

However, for the longer term new technology is extremely important. An important problem is that we only have limited possibilities to foresee potential technological developments, using the conventional methods of techno-economic analysis. Our time horizon is limited to 10 – 20 years. In a previous paper (Blok, 2005), I have analyzed the prospects for a number of end-use categories: dwelling space heating; passenger cars; and selected energy-intensive industries. I made it plausible that for *new* equipment it seems feasible to reduce specific energy consumption by 5% per year. Energy efficiency improvement of new equipment affects energy use only with a delay. The delay time is dependent on the turnover rate of the equipment involved, which may range from 10 – 100 years. In figure 2 the impact on energy use is depicted if rates of the reduction of 3, 4 and 5% per year would indeed be attained. These rates of energy efficiency improvement are equivalent with halving the specific energy use for new equipment every 23, 17 or 13 years. It goes without saying that achieving such rates will require strong efforts for industries and governments to speed up energy innovation. I will come back to this challenge in section 4.

In Figure 2, the effect of such high rates of energy efficiency improvement on energy demand is depicted, assuming a growth of energy-using activities of 2% per year. It can be concluded that there is a potential to cut energy use in half in industrialized countries if the most ambitious tracks are followed, but that limitation of energy use below the current level anyway seems to be possible.

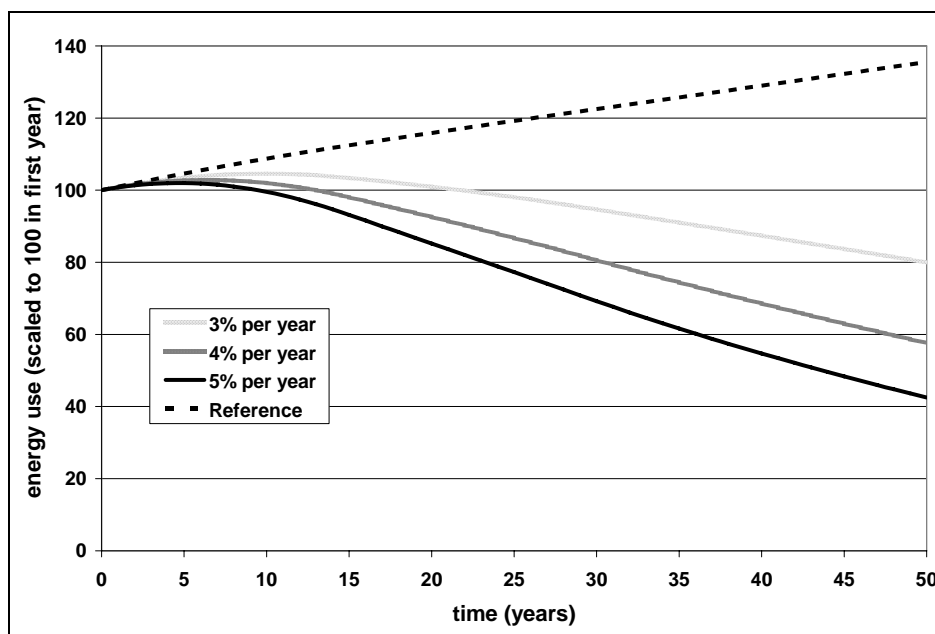


Figure 2. The development of energy use depending on the rate of the reduction of specific energy consumption for new equipment. The analysis assumes a mix of equipment with lifetimes of 15, 30 and 60 years. Effects of retrofitting are neglected. For details of the calculations, see Blok (2005).

3. Review of current policies for energy efficiency improvement

In this overview of the current status of policies, the focus will be on European Union policy making, but also important national policies will be covered. Successively, policies relevant for buildings, industry, transport, energy conversion and general policies will be discussed.

Buildings. Building insulation codes represent an old element in energy efficiency policy making. Already in the seventies of the last century, several countries implemented thermal insulation standards for buildings. According to an overview of building codes, insulation standards exist in many countries (Janda and Busch, 1994; Van Velsen et al. 1998). In 1999 twenty-two countries in the world had mandatory standards, others had voluntary standards or have standards proposed or considered (LBNL,

2005). Thermal insulation requirements were gradually strengthened. In the European Union, the central piece of legislation regarding building energy use is the directive for the Energy Performance of Buildings (EC, 2003a). This directive requires from countries that they implement before January 2006 (some delay possible) the following elements in their national legislation:

- Energy performance standards for new buildings should be introduced; this should also be done for existing buildings with a useful floor area larger than 1000 m² when renovated.
- For new buildings larger than 1000 m² combined-generation-of-heat-and-power (CHP), heat pumps, etc. should be considered.
- When a building is built, hired out or sold, an energy performance certificate is required.
- Regular inspection of boilers with a capacity of more than 20 kW is compulsory.

This directive builds upon the experience in a number of member states, e.g. in Denmark a labeling system for houses already existed, in Germany annual boiler inspection was already in place, and in the Netherlands an energy performance standard was already introduced in 1996 (Van Velsen et al., 1998). The energy performance standard is an interesting example of a development towards more flexibility: in contrast to traditional building insulation codes, standards are not set for individual components of the building, e.g. walls, roofs, windows and the boiler, but one standard is set for the energy quality of the entire building. Note that the directive provides requirements about the type of implementation, not about the ambition level.

Building codes and the directive on the Energy Performance of Buildings are most relevant for new buildings. For existing buildings, where still substantial potential improvement still exists (Eurima, 2002) financial incentives are the most important instrument. At least in Austria, Belgium, France, Germany, the Netherlands and the UK subsidies or fiscal support schemes are in place or have been in place (IEA, 2005).

A part of building energy use is for (electric) appliances. The first energy-efficiency standards for electric appliances (refrigerators and freezers) were already introduced in the seventies in the United States (Geller and Nadel, 1994).

A European Union framework directive on energy efficiency labeling entered into force in 1994 (EC, 1992), with first labels for refrigerators and freezers introduced in 1995. Nowadays, a labeling system is in place for all the 'big' electric appliances and lighting. Minimum energy-efficiency standards came in place for the first time in 1999, again for refrigerators and freezers (IEA, 2003). Standard-setting in the European Union turned out to be a cumbersome process. As an alternative, for some appliances voluntary agreements were reached, e.g. for washing machines, dishwashers, TV and VCR equipment, and office equipment (IEA, 2003) The most important development in recent years is the adoption of the directive on ecodesign requirements for energy-using products, generally called the ecodesign-directive. This directive is a framework directive, allowing the European Commission to take two kinds of action for specific appliances:

- either set minimum energy-efficiency standards
- or impose an ecodesign requirement, i.e. companies are obliged to actively investigate and apply options for environmental optimization of their products.

Note that this approach is different from the Energy Performance for Buildings directive where implementation of the regulation is decentralized to the Member States. The logic is that building habits still are very local, whereas the appliance industry for each appliance only has a few manufacturers in the European Union.

According to a recent call-for-tenders for preparatory studies (EC, 2005a), the European Commission considers regulation for the following equipment:

- boilers
- water heaters
- personal computers and computer monitors
- copiers, faxes, printers, scanners and multifunctional devices
- televisions
- equipment with standby- and off-mode losses
- battery chargers and external power supplies
- office lighting
- street lighting
- residential room-conditioning appliances
- electric motors, including selected pumps and fans
- commercial refrigerators and freezers

- domestic refrigerators and freezers
- domestic dishwashers and washing machines

Manufacturing industry. In the industrial sector we have seen a variety of policies. In the nineties so-called voluntary agreements were dominant. Voluntary agreements generally are closed between national governments and companies. First agreements were the Long-Term Agreements on Energy Efficiency in the Netherlands, the Danish Agreement on Industrial Energy Efficiency and the Declaration of German Industry on Global Warming Prevention. An overview of voluntary agreements in OECD countries is given in Figure 3 (Price, 2005). Several of the agreements have been effective means to improve the energy efficiency (Rietbergen et al., 2002), but the success highly depends on the efforts from the side of the government (Krarup and Ramesohl, 2000). In a communication, the European Commission has prepared guidelines for environmental agreement in general (EC, 1996). This type of policy has not all across the EU but, as can be seen from Figure 3, voluntary agreements are still in place in many countries.

Probably, the role of voluntary agreements will become smaller now the European Emission Trading System (ETS) came into operation in the year 2005 (EC, 2003b). The latter probably will become the dominant framework for all policies directed at reduction industrial greenhouse gas emissions. The total of allocation plans within the ETS leads to a contraction of allowances, compared to business-as-usual development of a few percent (Phylipsen, 2005). There are, however, more options than energy efficiency to reduce CO₂ emissions, like fuel switching to natural gas, renewable energy or the purchase of credits via the international flexibility mechanisms (joint implementation and the clean development mechanism), so the ultimate effect on energy efficiency is uncertain.

Voluntary agreements may remain relevant for specific goals, e.g. innovation, or efficiency of electricity use. Regarding electricity use, also other elements of European policy are important, e.g. the ecodesign-directive and the Motor Challenge Program.

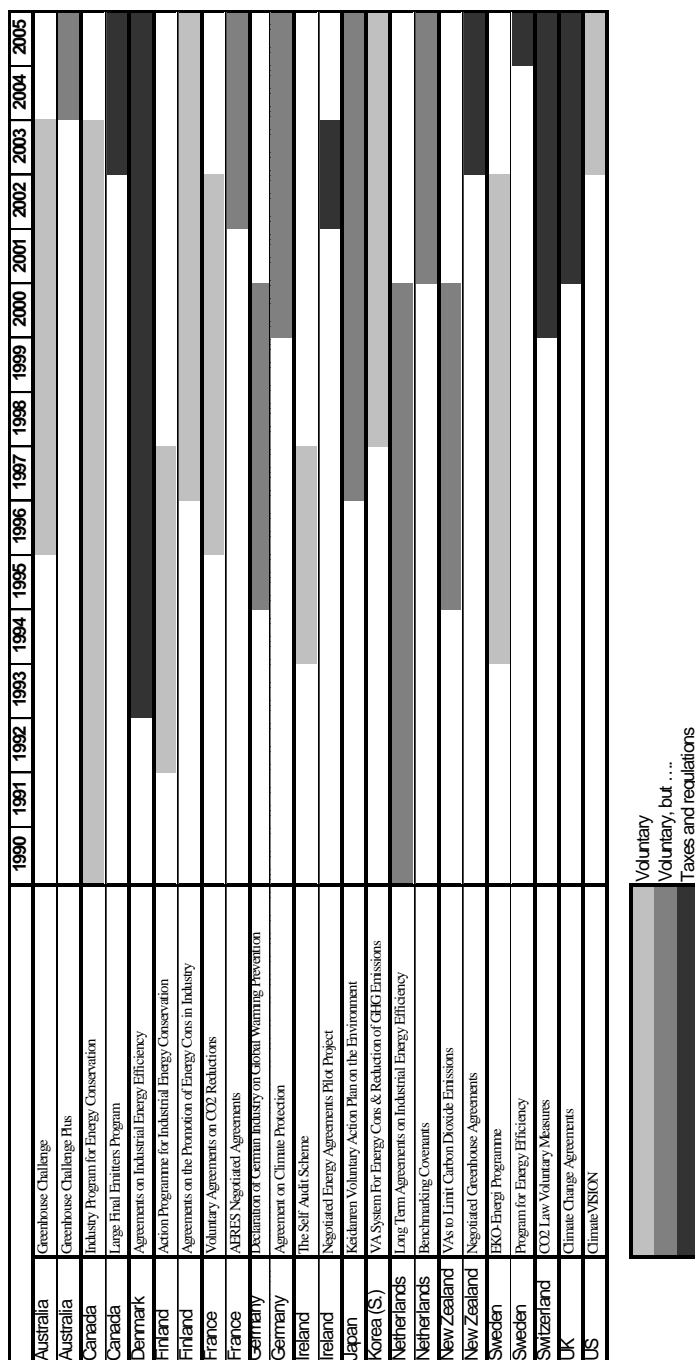


Figure 3. Overview of voluntary agreements on industrial energy efficiency. The colour codes indicate whether the agreements are completely voluntary, whether they are negotiated, or whether they are supported by taxes or other regulation (from Price, 2005).

Transportation. Probably, the most important policy in the area of energy efficiency in transport is the standard that was set in the seventies for passenger cars in the United States. The so-called corporate-average-fuel-efficiency standard required from all companies selling cars in the U.S. that *on average* they would meet a certain energy-efficiency level. The standard has led to an improvement of the fuel economy from 18 to 27 mpg (Geller and Nadel, 1994), a reduction of the specific energy consumption by one third.

Although some regulation already was in place in the seventies, the first big policy step in Europe was made through the agreement between the European Commission and the Association of European Car Manufacturers (ACEA). This agreement was closed in 1998. In the agreement, the target for 2008 is an average across all manufacturers of 140 g CO₂ per km, which is equivalent to 5.8 litre per 100 km when running on gasoline. In 1995 emissions of passenger cars still amounted to 185 g CO₂ per km. An interim evaluation showed that in 2002 a level of 166 g/km was attained (EC, 2004a).

For cars, also a labelling system has been introduced on a country-by-country basis, according to a directive adopted in 1999. Various member states now in addition have fiscal measures that stimulate the purchase of efficient cars.

Energy conversion sector. Let us now move away from the demand sectors to the energy conversion sector. An important option for energy conservation is combined generation of heat and power (CHP). Only a limited number of countries, like Denmark, Finland and the Netherlands have pursued active policies on CHP. In 2004 for the European Union a Directive on CHP was adopted. This directive calls on countries to stimulate CHP but no quantitative targets, nor concrete policies are included in this directive (EC, 2004b). Probably more important is the European emission trading system. Anyway, the ETS currently has an impact on fuel choice (coal versus natural gas) in the power sector, but whether CHP will be stimulated is still uncertain.

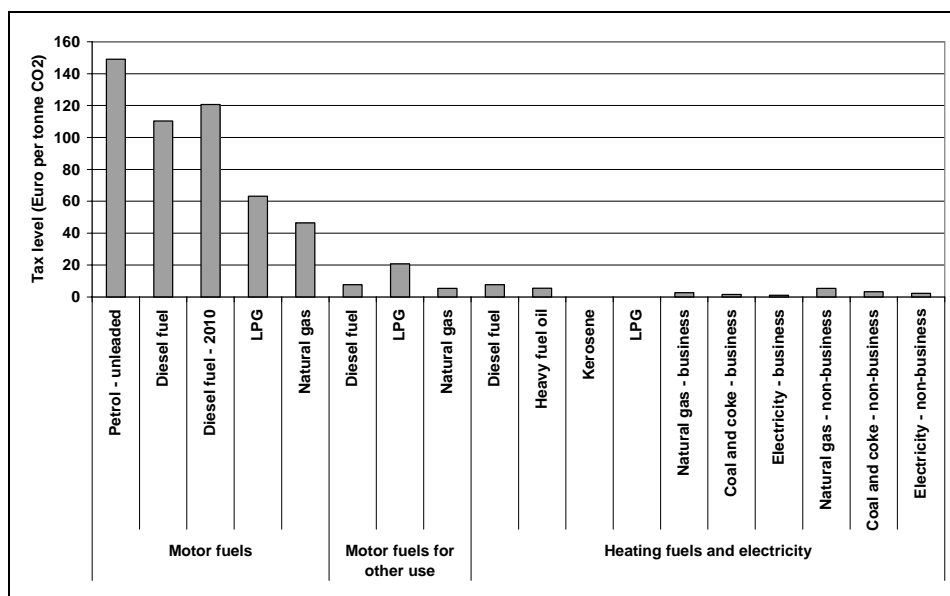


Figure 4. Minimum tax rates for energy carriers in the European Union. In the energy taxation directive (EC, 2003c), the tax rates are given in Euro per physical units. They are converted to Euro per tonne of CO₂ using the regular conversion coefficients to energy content and from energy content to CO₂ emissions. For electricity an average emission factor for the European Union is used.

Generic policies. The standard example of a generic policy is an energy or carbon tax. Several countries have introduced such taxes, e.g.

- In Denmark, energy and CO₂ taxes were introduced in 1992/1993.
- In the Netherlands' a tax was introduced in 1996 for small consumers of energy.
- In the UK only the large consumers are taxed through a so-called climate change levy.

The tax levels amount to about 10 € per tonne CO₂ for large consumers and up to 100 € per tonne CO₂ for households. Both in Denmark and the UK companies that enter into a 'voluntary' agreement are charged substantially lower tax rates.

At the European Union level there is already a discussion on energy or

carbon taxes from the early nineties onwards. The only concrete result so far is the decision about the introduction of minimum excise duties for energy carriers (EC, 2003c). Except for motor fuels, the tax rate is low; for the most common energy carriers outside the transportation sector the tax rate ranges from 1 – 5 € per tonne of CO₂ (see Figure 4). A substantial impact on energy consumption is not to be expected.

Even if tax rates would be higher, one should not overestimate the total impact. For instance, in the Netherlands, with a carbon tax for households that increases energy costs by about 50%, the impact on energy use is estimated to be a reduction by $5 \pm 2.5\%$ (Joosen et al., 2004). This is a worthwhile reduction but by itself not sufficient to enforce a substantial part of the potential for energy efficiency improvement.

A new policy instrument is the energy efficiency obligation, also indicated as *white certificate system*. In an energy efficiency obligation system certain parties are obliged to carry out programs to conserve energy. Successful implementation of the program leads to the generation of so-called white certificates. These certificates generally are tradable. Italy, France and the UK have already introduced variants of this system (Voogt, 2005).

Conclusions. In general three basic mechanisms can be distinguished that can be used to influence behaviour: i) communication; ii) economic incentives; and iii) physical regulation. Overlooking the package of policies we see that norms, permits and energy efficiency standards, for which physical regulation is the key mechanism, play an important role. This is to some extent surprising. For a long period economic instruments and voluntary approaches were considered important as important new policy instruments (by different scientific schools). Physical regulation, also called command-and-control, was considered old fashioned. A typical assessment can be found in one of the earlier reports of the Intergovernmental Panel on Climate Change: “*Although uniform technology and performance standards may be effective in achieving established environmental goals and standards, they typically tend to lead to economically inefficient outcomes in which firms use unduly expensive means to control pollution*” (IPCC, 1995).

When we overlooking the current policy mix in the EU, we see that we no longer can talk about traditional physical regulation. Several approaches have been followed to overcome the lack of flexibility of physical regulation and the associated high costs:

- applying regulation not for components but for complete systems. An example is the energy performance standard for buildings.
- applying regulation not for one product but for the total mix of products. An example is the ACEA agreement where not a standard is set for individual cars, but for the mix of cars in the European Union (strictly speaking this is not pure physical regulation).
- make the requirements tradable. *The* example is of course the European emission trading system, where first permits are granted, which subsequently are made tradable. White certificate systems are another example.

Another important change that has taken place in the past decade is the transfer of initiatives from the Member States to the European Union. Ten years ago the role of the community was limited to stimulation, with an exception of the activities on electric appliances. The choice of policies was mainly left to the Member States. Nowadays, the European Union is leading in policy development in the area of energy efficiency. The EPBD, the Eco-design directive and the introduction of the European emission trading systems are the most important milestones in this respect. However, it is still too early to talk about success. These policies only recently came into operation, and it will take some years before we will see the impact on the energy efficiency levels achieved.

A third observation is that the policies are focusing on the relatively homogeneous large chunks of energy use: space heating of buildings (but with a focus on new buildings), white appliances, passenger cars, and the energy-intensive industrial sector. Important categories of energy use, like energy use in existing buildings, small electric appliances, the non-energy intensive industrial sectors, electricity use in manufacturing industry and freight transport need also be tackled if ambitious targets, like those set out in the Green Paper on Energy Efficiency (EC, 2005b) are to be achieved. These energy use categories are much more diverse which will make policy-making quite a bit more complicated.

4. Policies for energy efficiency innovation

So far, we have focussed on the stimulation of existing technology. For long term objectives, e.g. the objective to reduce greenhouse gas emissions in industrialized countries by 60-80% in the year 2050 compared to 1990, it is even more important to develop new energy-efficient technologies.

The classical approach to promote the development of new technology is to grant subsidies for research and development, either in private or state research institutes. It is certainly important to subsidise R&D: for example a study in the United States found a correlation between the level of funding for R&D and the number of patents in the energy sector (Margolis and Kamman, 1999). However subsidies for R&D also have their limitations. A considerable free-rider effect can emerge, and R&D-subsidies tend to follow the market rather than steer it in a particular direction (Luiten, 2001). Also, one should realize that innovation is more than just research and development.

This section contains a review of policy instruments available to support energy innovation. For the sake of clarity, the innovation process has been divided into three phases (which in practice will often overlap):

- Invention and exploration: coming up with a new idea, limited experiments, and proof of concept. Generally speaking the technology is still largely unknown.
- Technological development: work on developing the technology on a larger scale, with a systematic approach and generally in more than one institutional framework, including pilot projects.
- Market introduction: the first commercial applications, up to a market share of about 5%.

The summary below implicitly assumes that there is no ‘one-size-fits-all’ approach: there is no single instrument that is applicable to all sectors and all phases of the innovation process. We also suppose that ‘big’ instruments intended to encourage the adoption of technology discussed in section 3, such as energy taxes, investment subsidies, emission trading, voluntary agreements and energy-efficiency standards, will have little influence on the energy innovation process. The lead times for technological development are often too long for such measures to generate a carry-over effect. However it is possible to modify these instruments so that they have a

specific impact on energy innovation (for example, see the technology development agreements, technology-forcing standards and energy taxes on energy-consuming equipment, which are mentioned below).

The invention phase

- Focus on improving energy functions. There is a great deal of technology research in the European Union, for instance in the large research institutes. Much of this is organised around specific technologies, such as ceramics or membranes. Structuring this research around specific energy functions for buildings, industry and transport – with a focus on achieving concrete breakthroughs – could greatly increase its effectiveness.
- Stimulating successful innovators. When evaluating scientific research proposals, it is usual to take the researchers' track records into consideration. A comparable approach could be followed to stimulate technology development in the field of energy. People or research groups (in research institutes or in companies) that have been successful in energy innovation could be given extra resources for new innovation projects.
- Competitions. In a competition, institutes are asked to come up with solutions for a specific problem (such as a particular efficiency improvement or a defined reduction in unit cost). Such a competition may take place over a number of phases. A large number of parties are invited to enter initially, and these are then selected out in one or more steps – as in a beauty contest – with increasing development budgets being made available in successive phases.

Technology development phase

- Technology development covenants. Under a technology development covenant, the government and companies reach an agreement to work together to achieve a concrete technological goal. One example is the Partnership for a New Generation of Vehicles. This agreement – made between the US government and the automobile industry in 1994 – was to begin work on a prototype car which should be three times more energy-efficient than cars in 1994. The R&D capabilities of the Federal government as well as those of companies were used (PNGV, 1994). Such agreements could be adopted as a means to stimulate innovation in specific

sectors at the European Union level (which might range from the pulp and paper industry to the manufacturing of aircraft engines).

- Technology-forcing standards. In the case of a technology-forcing standard, the government stipulates a norm that will only come into force after some time (such as ten years). Generally the industry concerned cannot currently comply with the norm, so it is forced to develop new technology. One well-known example of a technology-forcing standard is the Californian requirement that zero-emission vehicles should have a certain market share in the future (Van der Grijp et al., 1994). Technology-forcing standards will generally be practicable only at the European Union level.

The market introduction phase

- Technology procurement. In technology procurement, a large buyer of equipment (or a group of buyers) sets ambitious standards regarding the energy efficiency of the equipment to buy. If the buyer or buyers purchase a sufficiently large share of the production of a particular product, the suppliers will be motivated to develop or market the efficient equipment. This instrument has been applied in Sweden to a number of devices, including heat pumps. A technology procurement approach was successful in increasing the energy efficiency of heat pumps by 30% while lowering their cost by 30% (Suvilehto and Öfverholm, 1998).
- A Gold Standard for energy efficiency. The purpose of a routine energy efficiency standard is to exclude the least efficient equipment from the market. A Gold-Standard stimulates the purchase of the best equipment on the market. The existence of a Gold Standard enables governments and companies (the latter motivated, for example, by the goal of corporate social responsibility) to purchase only products that comply with the requirement.
- Incremental standard-setting. In incremental standard-setting, a norm is regularly made more stringent, for instance every few years. This forces companies to always use the latest technology. Incremental standards can be determined in various ways, such as via a market-leader approach, through technical and economic analysis, or by stipulating a certain percentage increase in energy efficiency every year (IEA, 2003; Blok, 2003).
- Market introduction subsidies. Although subsidies have their disadvantages (free-rider effects, relatively high costs for the government), they can be effective especially in the early stages of

market introduction. One example of this is the energy premium scheme that was introduced in the Netherlands in the year 2000. This scheme applied to refrigerators, freezers and other appliances with an 'A' label. Following the introduction of the subsidy, the entire retail sector in the Netherlands shifted to 'A' label equipment within a short time. Market introduction subsidies could be widely applied, but it is especially important that the subsidies do not continue for too long (to avoid free-rider effects) but also do not stop too early, because then no adequate stimulus would be generated.

- Energy taxes on the purchase of energy-consuming equipment. This is the reverse of a market introduction subsidy. As stated before, the impact of energy and carbon taxes is limited due to the low price elasticity of energy. An energy-related tax can be much more effective if it is levied at the moment when a decision, such as the decision to buy equipment, is taken. An elegant form of an energy tax at the moment of purchase is the variant in which the levy is equal to the net present value of the energy tax that would otherwise be levied over the life expectancy of the equipment.
- Demonstration project schemes. In the case of large-scale industrial equipment, the last step in scaling up to a commercial or near-commercial scale is relatively expensive and it entails considerable risks. New technologies often strand at just this point (see for example Luiten, 2001). Therefore it is still necessary and useful for governments to support demonstration projects.

Conclusions.

As this overview shows, there are a variety of instruments that can be used to promote energy innovations. The use of these instruments is still very limited. Many examples are taken from outside the energy sector.

Particular instruments can be selected and applied, depending on the sector, the phase that technological development has reached in that sector, and the relationship between the sector and the government. Any input from the government will generally require the use of government financial resources. However these financial government support schemes should not be leading, as is the case with many current R&D subsidies. Rather they should depend on selected instruments, each with its total package of government input and associated development goals that the receivers of the subsidies have to comply with.

5. Conclusions and outlook

When we take a look at the total package of policies that is in place now, we see a strong policy development in the last few years:

- Many policies that were in place in only a few countries ten years ago, now are applied in many countries.
- The role of the European Commission has become much more important.
- The character of the policies is strengthened, away from soft measures to measures with a more binding character, like energy-efficiency regulation and emission caps.
- Physical regulation is dominant, but has become more flexible; we could speak of the second generation of physical regulation.

Energy efficiency is back on the political agenda. Nevertheless, we are only in the first stage, and it will take some years before we will see a measurable impact on the development of energy use.

Last year, the European Commission has published a green paper on energy efficiency, “doing more with less” (EC, 2005b). This paper shows a strong ambition and probably comes at the right time given the current interest in energy efficiency. The action plan that is announced in the green paper can build upon a lot of experience with energy-efficiency policies. More attention should be paid to the non-homogeneous categories of energy use, like energy use in existing buildings, small electric appliances, the non-energy intensive industrial sectors, electricity use in manufacturing industry, and freight transport.

Furthermore, it is important that the Commission not only formulates policies for the implementation of existing energy-efficient technology, but also comes up with targets for the development of *new* energy-efficient technology. Development of new technology is crucial for reaching long-term ambitions for a sustainable energy system and cannot be left to the R&D programs.

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