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Energy Efficiency — the Focus for Transition from an Energy Supply to an Energy Service Policy

By Eberhard Jochem*

Summary

Until to date, improvements in energy efficiency have been focussing on conversion technologies producing secondary or useful energy. Possible reductions of useful energy demand, however, have been widely neglected. In addition, energetic considerations (according the first rule of thermodynamics) have dominated to the expense of exergetic considerations, i. e., a better orientation of the potential of work of the different energies used on the quality of useful energy (e. g. the temperature level) will contribute to further potentials of energy efficiency. On the basis of these facts and of an evaluation of energy efficiency potentials in Western Europe until 2020 the author suggests the idea of a permanent economic energy efficiency potential of about 25% for the next 20 years that could be continuously used by investments and organisational measures on the one hand and refilled by innovations and cost reductions of known technical potentials on the other (similar to the static proven reserve to consumption ratio for oil or natural gas). This efficiency potential, however, is only partly realised due to market barriers and imperfections. An energy policy aiming at the full exploitation of the profitable energy efficiency potentials has not only to define general framework conditions, but must also realise target group- and technology-oriented bundles of policy measures.

1. Introduction

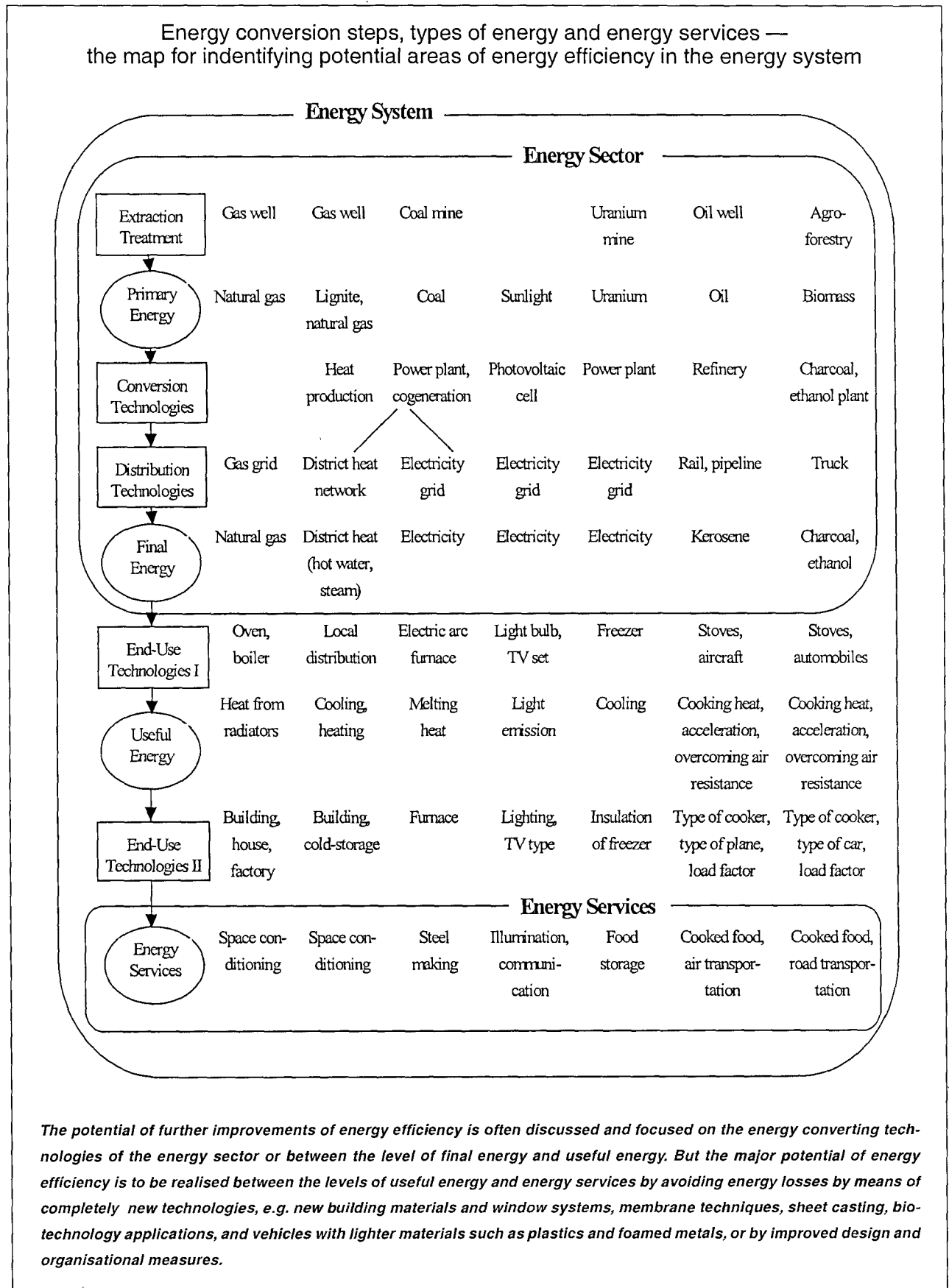
Today, more than 400,000 PJ of world primary energy produce almost 300,000 PJ of final energy delivered annually to customers, resulting in an estimated 150,000 PJ of useful energy after conversion in end-use devices of the world. The delivery of 150,000 GJ per year leaves 250,000 PJ energy losses mostly as low-temperature heat. The resulting global energy efficiency of converting primary to useful energy is estimated for commercial energy to be about 37% today. But the most promising step for improving energy efficiency is the step between useful energy and energy services by avoiding energy losses (see Figure 1). Considering the capacity to work (i. e. the exergy) of the primary energies in relation to the exergy needed by the useful energy according to the second law of thermodynamics, the efficiency of today's energy systems in industrialised countries is even less than 15%. One main goal of energy analysis and policy in the context of sustainable development is, therefore, to explore ways to reduce the amount of energy used to produce a desired service or a unit of economic output and, indi-

rectly, to reduce the energy-related emissions. The key question is how strict is the link between final energy use and the energy service in a given end-use, and what is the potential for technological, but also organisational changes to decouple them in the next two or three decades. As the technologies used in the different world regions differ quite substantially as energy prices do, the economic efficiency potentials may also vary. But despite those differences, more *efficient use of energy* has to be considered as one of the major options *to achieve a global sustainable development* in the 21st century.

This paper is focused on end-use efficiency, i. e. the more efficient use of final energy or of useful energy in the various sectors such as industry, transportation, services, agriculture or private households (see Figure 1). The issue of supply-side energy efficiency, i. e. of energy extraction, production, energy transport and distribution, is of every day concern of energy supply companies and

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Figure 1



has been in the focus of investment and Research and Development (R&D) decisions since the beginning of this century. In contrast, end-use energy efficiency only received similar attention for one decade after the first oil price shock, and since the Mid-1980s hardly more than lip service, while reduced policy action could be observed in almost all OECD countries.¹ End-use energy efficiency, however, has been proved to be economically very attractive in many cases (see Section 2), but often not easy to realise due to various reasons (see Section 5).

Energy efficiency — and indirectly improved material efficiency (see section 3) — *alleviates the conflict between the objectives of energy policy*: Competitive and low (but full cost) energy prices support economic development. However, they tend to increase the environmental burden of energy use, they are likely to augment net energy imports of conventional energies by shifting electricity generation towards gas-based combined cycle plants, and they decrease the diversity of supply by reducing the economic competitiveness of renewables and nuclear plants. Hence, using less energy for the same service is one way out of this conflict. The other way out, as a long-term option at least, is the promotion of renewable energy resources.

1.1 Trends of sectoral energy efficiency indicators of OECD countries

To understand differences in the efficient use of energy by sector, country, or time periods, the energy use of a sector divided by the gross domestic product (GDP) is used as a starting point. With a few exceptions, such analyses have only been carried out on OECD countries for longer time spans.² These ratios are instructive for what they say about energy use in the different economies in a given point in time. They can further be broken down to measure changes in energy efficiency and other components of energy use such as structural changes and changing consumption patterns of a given end-use sector or sub-sector. Changes in energy efficiency are driven by higher prices, incremental technical improvements, new technologies, cost competition, and energy conservation programmes.

A substantial decline of energy/GDP ratio occurred everywhere in OECD regions or countries during the last three decades (see Figure 2). Changes in energy use were distributed unevenly among sectors, and only part of the decline was related to improved energy efficiencies:

- The largest reductions in energy/GDP ratio (between 20 and 50%) were in *manufacturing*. Energy efficiency (if structural change is excluded by keeping the mix of output of 1990 constant) maintained that trend through the late 1980s of more than 1% annually, when lower fuel

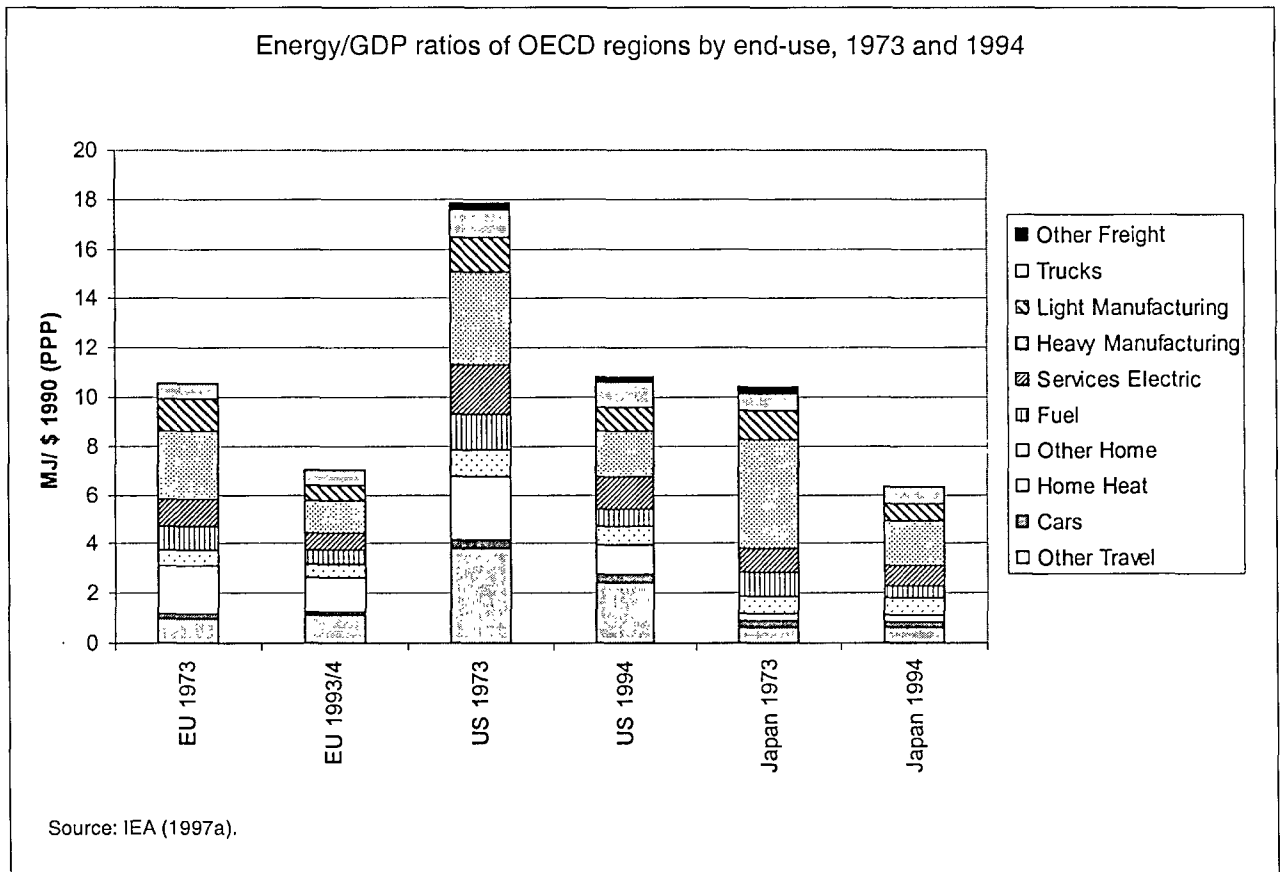
prices saw a slow-down but little immediate reversal in improvements. In Japan, the U.S., and West Germany, energy demand was lowered in this sector in absolute terms by roughly 10% because of changes in product mix as well, but in other countries this structural component of changes in energy use had little impact.

- Specific energy requirements per unit of floor area of *households* fell modestly, led by space heating. In spite of great improvements in indoor heating standards (more central heating), specific energy use in the 1990s was lower in almost all OECD countries than it was in the early 1970s. The only notable exception was Japan, where income-driven improvements in heating conditions exceeded savings from added insulation in new buildings and from more efficient heating equipment. Furthermore, in most countries, the unit energy consumption of appliances (in kWh/year) fell. Improvements in efficiency were stronger than trends towards larger sizes of appliances. On the structural side, however, household size continued to shrink, which raised per capita energy use. New homes had larger areas per capita, and appliance ownership increased, both with increasing income, continuing a long-established trend of the income effect from the early 1950s.
- Space heating in the *service sector* also fell in terms of specific energy requirement, that is in heat per square meter in most OECD countries. Electricity use remained strongly coupled to service-sector GDP, but showed little upward trend except where electric heating was important. This may be surprising, given the enormous importance of electrification and office automation in this sector. There is a strong relation between electricity use and floor area over time, and the gradient is obviously influenced by electricity prices.
- *Passenger transportation* energy use is dominated by cars. In Europe, there were only small (<15%) reductions in fuel use per km of the car fleets, almost all of which was offset by a similar drop in load factors. Taxes on gasoline and diesel seem to have major influence on the car fleet average efficiency, given the lowest taxes in North America and the highest in Italy. For air travel, by contrast, most of the OECD countries experienced a drop of more than 50% in fuel use per passenger-km of air travel due to both, improved load factors and improved energy efficiencies. The impact of both higher mobility per capita and shifts from trains, buses and local transport towards cars and air travel, however, compensated the efficiency gains in most countries.
- Changes of specific energy use per tonne-km in the freight sector have been rather small. Fuel efficiency im-

¹ IEA (1999).

² See IEA (1997a), Morovic et al. (1989) and Diekmann et al. (1999).

Figure 2



provements have been compensated by shifts towards trucking. The modal shifts were driven by higher GDP, a result of less shipping of bulk goods by rail and ship and more lifting of partially manufactured goods and final goods of high value by trucks and also air planes.

In the majority of OECD countries, energy intensities are decreasing less rapidly in the 1990s than before. One clear reason — besides higher income — is lower real energy prices since 1986 and lower electricity prices during the 1990s (due to the liberalisation in many OECD member countries), that slowed down the rate of energy efficiency improvement of new systems and technologies actually bought.

1.2 The potential benefits of transfer of energy-efficient technologies

In many cases, used and written off plants and vehicles from developed countries are transferred to developing countries or to countries in economic transition leaving them with relatively inefficient equipment and vehicles for many years. The importance of technology transfer of

highly energy-efficient equipment and vehicles to countries in economic transition and to developing countries has been identified among experts as an important *opportunity of "tunnelling through"* the typical development curves of energy intensity of national economies. The transfer of energy-efficient technologies to countries in economic transition and developing countries has come to be seen as a major element of global strategies to achieve sustainable development while maximising know-how transfer and employment (including local content). Transfer of energy-efficient technology represents a win-win-situation as it is beneficial for both the technology provider and the recipient. Benefits to the receiving side range from reduced energy imports, demand for more skilled workforce — thereby more job creation, reduced operating cost of facilities and faster progress in energy efficiency improvement. The scope of improving energy efficiency through technology transfer can be seen by comparing specific energy uses in selected industries and countries (see Table 1).

The reasons of the trade of used and inefficient equipment and vehicles are lack of capital, lack of life cycle costing by the investors, investor/user dilemma, lack of

Table 1

**Specific energy use in selected basic products
industries and countries**
(in GJ/tonne), Mid-1990s

Country	Steel	Cement	Pulp and Paper
India	39.7	8.4	46.6
USA	25.4	4.0	40.6
Japan	17.5	5.0	-
Sweden	21.0	5.9	31.6

Source: UNDP/WEC/DESA (2000).

public transport in developing countries.³ The diffusion of high efficiency standards of products and plants in OECD countries will therefore also affect the technical standards in developing countries and countries in economic transition, particular in cases of mass-produced and tradable products and of world-wide investments of global players. Opportunities of technology transfer amongst developing countries gain increasing importance and should be encouraged. Many of these countries have already well established in-house expertise and produce goods, technologies and services-suitable to operate well under developing countries conditions and climates.

2. The Economic Potentials of Energy Efficiency in the Energy Sectors Within the Next 20 Years

The global energy efficiency of converting primary energy to useful energy is about 37% at present, but even the useful energy for a desired energy service can be reduced and contribute to further efficiency improvements (see Figure 1). Estimates of those improvements are based on known technologies, expected costs, on consumer behaviour, rates of market penetration, and policy measures. When considering *potentials for efficiency improvement*, it is essential to distinguish between several terms of energy efficiency potentials describing future technological achievements with different time horizons and different boundary assumptions, but also on the level of analysis in the case of the economic potential. The report here uses the following definitions (see Figure 3):⁴

- The *theoretical potential* represents the achievable energy savings in theoretical considerations of thermodynamics where energy services (e.g. room at 20°C, tonne steel produced) are kept constant, but useful energy demand and energy losses can be minimised by process substitution, heat and material reuse and avoided heat losses. The limitations of theoretical potentials of energy efficiency are the laws of thermodynamics.
- The *technical potential* is the achievable energy savings resulting from implementing the most energy-efficient

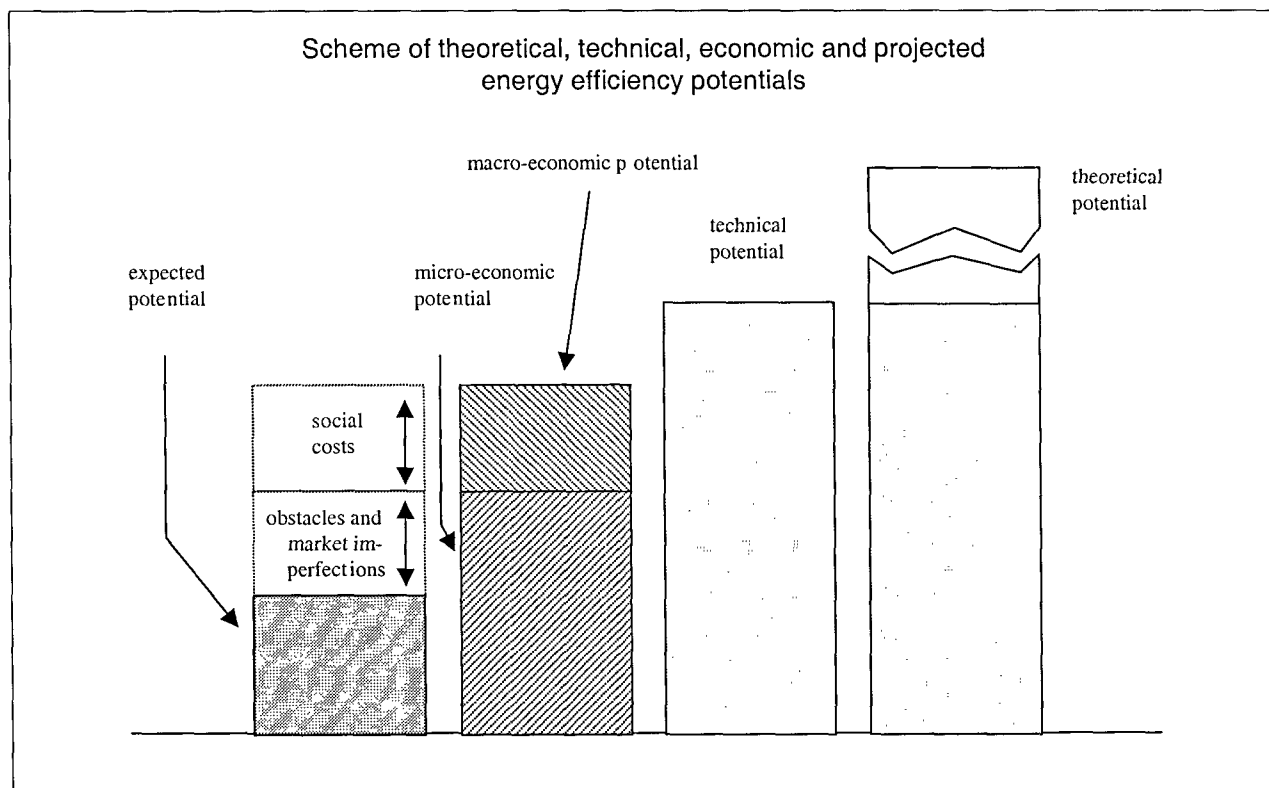
versions of the commercial and near-commercial technologies available at a given time, regardless of cost considerations and re-investment cycles. This can be expressed as a phased-in potential that reflects the total replacement of the existing energy-converting and -using capital stocks.

- The *market-trend potential* — or the expected potential — is the efficiency improvement that can be expected to be realised in practice for a projected year and a given set of boundary conditions (e.g. energy prices, consumer preferences, energy policies in a particular country or world region). This market-trend potential reflects the continued existence of current obstacles and market imperfections hindering profitable efficiency potentials from being fully realised (see also Paragraph 5).
- The *economic potential* is the energy saving that would result if each year over the time horizon in question all replacements, retrofits and new investments were shifted to the most energy-efficient technologies that are still cost-effective against energy supplies. It also includes all organisational measures such as maintenance, sensitive operation and control as well as timely repairs. There are sub-definitions for economic potentials depending on the economic perspective being used (see Box 1): the micro-economic project cost perspective, the macro-economic perspective, and welfare-based perspective (see below). The economic potential implies a well-functioning market competition between investments in energy supply and demand side energy efficiency. It is also assumed that the various barriers preventing such well-functioning competition in current energy service markets have been corrected by related policies. It is assumed that as a result of such policies, end-users in all sectors have easy access to reliable information about the cost-effectiveness and technical performance of both existing and newly emerging energy efficiency options. The transaction costs for individual investors, and the indirect costs of policy programmes associated with implementing these options, are assumed to have been lowered to their irreducible minimum.
- The *welfare-based — or societal — potential* represents the “cost-effective” savings when externalities are taken into consideration. These include damage or avoided damage cost from health impacts, air pollution, global warming and other ecological impacts, as well as energy security and accidents that accrue to society. Here, the definition of cost-effectiveness is based on the more comprehensive measure of welfare that includes but goes beyond economic output. This wider definition of

³ IPCC Special Report (1999).

⁴ Enquête Commission (1991); IEA (1997).

Figure 3



cost-effectiveness is the most important measure for a holistic energy policy including energy security and environmental quality.⁵

- Finally, the *policy-based achievable potential* represents the energy savings which can be realised with various policy instruments or packages of policy instruments. Here, field data from evaluation research are used to estimate participation rates and per-participant savings in voluntary or standards-based technology programmes. The policy-based achievable potential lies between the market-trend potential and the economic potential (which can also be changed by taxation).

The focus of this paragraph is the *economic savings potential*. The specific economic perspective underlying the potentials reported here, however, varies from study to study. Currently available estimates are predominantly based on a microeconomic project cost perspective, though hybrids with macro-economic potentials are also found (see Box 1). Quantitative comparisons between micro-economic and macroeconomic efficiency potentials suggest that micro-economic approaches underestimate the cost-effective savings potential.⁶ Similarly, macroeconomic approaches inherently underestimate cost-effective savings potentials relative to a societal perspective. These relationships indicate that the profitable savings

potentials reported in the literature are very likely to represent only a lower limit, and that somewhat larger savings are cost-effective.

Economic energy efficiency potentials by sector in Western Europe

The *economic efficiency potentials* depend on today's and the foreseeable technology development and on today's and anticipated energy prices. In a world of low energy prices, profitable potentials are relatively small compared to those of high energy prices, which may be politically achieved by energy taxes on a national or world-regional level. The calculations on the profitable potentials cover *different types of efficient end-use technologies*:

- Mono-functional and concise energy-converting technologies such as boilers, heat exchangers, electrical motors are usually determined by standard profitability calculations comparing full cost of alternative and statistically relevant conversion technologies.

⁵ OTA (1993).

⁶ Krause (1996).

Economic potentials of energy efficiency: different perspectives

In all definitions of the economic potential, the core cost-effectiveness test are the life cycle costs for providing a given level of energy services. Different definitions of the economic potential arise on account of different cost-benefit perspectives. These perspectives influence how costs and financial parameters are defined, and whether policy-dependent implementation costs or reductions in external costs are included or not.

- The *micro-economic potential* is calculated from the perspective of an individual investor on the basis of engineering-economic life cycle costs, using a project cost perspective. In this narrowest of all definitions, total costs consist of the levelised capital costs of energy efficiency investments, plus changes in annual energy and non-energy operating and maintenance costs. Because a project cost perspective is used, neither the costs of large-scale policy implementation nor the cost savings from policy-induced feedback effects are included in this micro-

economic potential. The discount rate for evaluating the cost-effectiveness of energy efficiency investments is typically set to reflect the costs of capital of particular sectors, industry branches, or households (including investment risks). After-tax energy efficiency investments are compared to after-tax average energy prices as projected for each sector or group of energy users.

- The *macroeconomic potential* is based on a more comprehensive accounting of costs and on a different financial perspective. Here, the administrative costs associated with implementing the various requisite policy programmes are included. Also, energy efficiency investment costs and policy implementation costs derived from field experience are corrected in a forward-looking manner to account for changes in manufacturer pricing strategies, economies of scale, and learning curve effects.

- Process substitution, new building concepts or transportation systems also include other changes in economic efficiency (capital, labour, etc) and/or product or service quality. Here it becomes difficult to talk about the profitability of the technology in the narrow sense of energy efficiency, defined as economic, if the new technology is considered to be competitive with its higher efficiency (e.g. new catalysts in production of petro-chemicals, separation by membranes instead of distillation, low energy houses or low fuel cars instead of conventional house or car concepts).
- Branch-specific, but technology-clustered energy efficiency potentials of low energy-intensive sectors in industry or the commercial sector are estimated by trend extrapolation of statistical data or by generalisation of calculations made for representative or typified plants or factories. The data on branch-specific energy efficiency potentials should not include intra-branch structural changes avoiding misinterpretation.

These different cost assessments depending on the type and aggregate level of technology may contribute to understand the differences in certainty about the cited economic potentials. The data on economic potentials cover the *time horizon 2010 and 2020*. This means that in cases of re-investment cycles of more than two decades

(e.g. public transport, buildings, plants of basic product industries) the economic potentials are only partially realised until 2020. The reader may consider deviations from given numbers on economic potentials representing different situations of energy prices, economies of scale or local differences. In many cases the life cycle cost functions have rather broad minima (e.g. optimal insulation thickness); this means that there is little risk of over-investing in energy efficiency.

The *manufacturing industry* lost its role as largest final energy-consuming sector in Western Europe in the early 90s. In 1996 the Western European manufacturing industry accounted for 28.2% (11,540 PJ) of the final energy use. Although the final energy demand of the Western European manufacturing industry is stagnating during the last two decades despite a yearly production growth of 2%, there are still substantial economic efficiency potentials (see Table 2). This applies even in the energy-intensive sectors where efficiency improvements have been in the focus of investment considerations for decades in order to reduce high energy cost in those branches.⁷ Examples are:

- De Beer (1998) concludes, for example, that future paper mills operating a combination of new pressing and drying techniques, latent heat recovery systems, and a

number of minor improvements can reduce specific heat demand by at least 50% compared to current average and that investment costs will be lower than for conventional paper making processes.⁸

- The economic efficiency potentials of steel making are less extraordinary between 9 and 15% due to thin slab casting, improved efficiency in the blast furnaces by small changes and minor improvements in the oxygen steel process by 2010 to 2020 in Western Europe at today's energy prices.⁹
- Similar economic efficiency potentials have been described for the refineries, petrochemical processes, the construction materials industry, glass production and the food industry. Co-generation in Western Europe has still some economic potential.¹⁰
- For the Dutch light industry altogether, the economic efficiency improvements in the year 2000 (relative to 1990) are estimated at 30% (5% discount rate) and 27% (10% discount rate).¹¹
- Baumgartner and Muggli (1996) evaluate the efficiency improvements of cross-cutting technologies in the Swiss industry. For electrical and mechanical drives savings between 15 and 35% are mentioned.¹² Metering, controlling and optimal regulation alone can lead to efficiency improvements of up to 15% in most industrial processes.

The economic efficiency potential in *heating of residential buildings* depends — besides regional aspects — on the existing stock of boilers and their reinvestment cycles, the rate of new buildings and the potential rate of refurbishing existing buildings. Condensing boilers represent an economic efficiency potential of around 10% compared to a new low temperature boilers and between 15 to 25% compared to the existing boiler stock. Insulation of building elements high efficient window systems and adequately thick insulation material are economic within the cycle of refurbishment. Regarding new buildings, low energy houses with yearly heat demand below 50 and 100 kWh/m² are presently cost-effective due to better design and low cost insulation techniques and window systems. Around 600 houses with a yearly heat demand of 15 to 20 kWh/m² (solar passive houses) have been built in the 1990s in Germany.

In the *electric appliance* sector the economic efficiency potential for the next 10 years can be best evaluated by comparing the equipment in use with the equipment available on the market. But the market is not homogenous: an EU-wide market-survey of washing machines, dryers and dishwashers showed ratios of minimum/maximum specific consumption between 1:2.5 for washing machines and 1:4 for condenser tumble dryers.¹³ First costs are sometimes higher for efficient equipment, but life cycle costs are in general lower for the efficient equipment. In

France, a detailed end-use measuring campaign demonstrated that cost-effective electricity savings of the order of 40% are achieved by replacing the average in situ equipment by the most efficient appliance readily available on the market.¹⁴ These results are confirmed by multiple other studies.¹⁵ Due to the relatively short life-time of lights and appliances, savings of 30% could be achieved in Western Europe as soon as in 2010 by the widespread adoption relative to a business as usual scenario including itself some efficiency improvements.

The International Energy Agency (1997) quotes that careful examination of the evolution of electricity use shows little rebound effect, either when prices fell or efficiency improved significantly, or both. Space heating and the use of electrical appliances is a domain of behaviourally influenced efficiency potentials with an average immediately available potential of around 15% for space heating.

The fraction of *electricity consumption of office equipment* in 1990 is a rather small fraction of the total electricity used in the commercial/service sector (3% to 4%).¹⁶ But office equipment is considered to be the fastest growing electricity consuming segment. About two thirds of this electricity is used in standby- and off-mode. Therefore, easy and cost-effective savings are possible in most equipment categories.¹⁷ Due to the fast increase of the number of equipment and due to the relatively short life time these improvements could be realised within 10 years. These figures are based on detailed analyses in Western European Countries. 188 electricity saving measures were used to compile the cost curve for saved electricity at 10%, 22% and 37% at marginal costs of 4.7 and 10 cts/kWh.¹⁸

Economic potentials to reduce space and process heat demand are ranging in the same dimensions of 15 to 25% as the residential sector (see Box 2).¹⁹ The efficiency of heat generation and distribution could be improved by some 10 to 15% by re-investments of boilers, burners and

⁷ Philipsen et al. (1998).

⁸ De Beer (1998), pp. 75–102.

⁹ Jochem, Bradke (1996), De Beer (1999).

¹⁰ Böde et al. (1999).

¹¹ Blok et al. (1996).

¹² Almeida et al. (1997).

¹³ GEA (1995).

¹⁴ ECODROME (1998).

¹⁵ See Lang and Lingenhel (1996), Worrell et al. (1997), Henniske (1998) and Ziesing et al. (1998).

¹⁶ Aebischer et al. (1996).

¹⁷ Hallenga et al. (1998); Rath et al. (1997); Aebischer (1996).

¹⁸ Neyer/Strebel (1996).

¹⁹ See also Ziesing et al. (1998).

Table 2

**Summary of economic energy efficiency potentials 2010 and 2020
in the end-use sectors of Western Europe**

Sector and technological area	Economic potential ¹⁾ in %		(sectoral) energy price level assumed	Base year
	2010	2020		
Industry				
– iron and steel, coke ovens	9–15%	13–20%	1998	1995
– construction materials	5–10%	8–15%	1997	1997
– glass production	10–15%	15–25%	1997	1997
– refineries	5–8%	7–10%	1998	1997
– basic organic chemicals	5–10%		1997	1996
– pulp and paper		50%	1998	1997
– investment and consumer goods industries	10–20%	15–25%	1998	1995
– food industries	10–15%		1997	1997
– co-generation in industry		10–20%	1997	1997
Residential				
– existing building stock				
– boilers, burners	15–20%	20–25%	1998	1997
– building envelop	8–12%	10–20%	1998	1995
– new buildings		20–30%	1998	1995
– electric appliances	20–30%	35–45%	1997	1997
– behavioural changes	15 % (space heat)			
Commercial/public/agriculture				
– commercial buildings	10–20%	30%	8–13 cts/kWh	1995
– electricity	10–25%		4–10 cts/kWh	1997
– heat		20–37%	1198	1198
– public buildings		15–25%	7–15	1992
– agriculture/forestry		30–40%	1998	
– horticulture		15–20%	1998	
– decentralised cogeneration		20–30%	1998	1995
– office equipment		40–50%	1995	1995
Transportation				
– cars		25%	1998	1995
– door to door integration		4%		1995
– modal split of freight transport		3%*		1995
– trains and railways		20%	1998	1999
– air crafts, logistics	15–20%	25–30%	1998	1998
	20–25%	30–40%	1998	1999
¹⁾ assuming constant structure or use of the sector or technology considered; the percentage is generally related to the final energy consumption of the particular sub-sector or technological area; if it is related to final energy use of the sector as a whole, it is marked by *. Source: UNDP/WEC/DESA (2000).				

improved insulation and control techniques, in some cases by direct process heat generation, avoiding steam or hot water systems, and by engine-driven co-generation).

At present rates, final energy use by *transport* is likely to increase by a further 40% between 1990 and 2010 in Western Europe. Around 50% of the energy for transport is used by passenger cars and almost 40% by road freight. The voluntary agreement concluded by the Association of European Car Manufacturers (ACEA) reflects the potential of efficient energy use of cars: new cars will be sold with a 25% higher fuel efficiency from 2008 compared to 1995. The internalisation of external costs of road

transport, being estimated at some 20 to 70 billion US\$, by taxes and insurance would bring further efficiency improvement of 7 to 16%. In Switzerland, transportation by rail is about 3 times less energy-intensive than passenger transport on road and up to 10 times less energy-intensive for transportation of goods.²⁰ With lighter trains, reduced air-drag and improved drive-concepts a reduction of the specific electricity consumption of transport by rail of almost 50% is possible.²¹ A 25% reduction in railway freight tariffs due to increased productivity and cross-border

²⁰ Maibach et al. (1998).

²¹ Brunner et al. (1999).

Best Practice Programme for Office Building in the United Kingdom

In UK, the *Best Practice Programme* compares energy consumption in 200 typical office buildings with energy consumption in 200 offices considered for inclusion in the Energy Office series of Good Practice Case Studies. With mostly cost-effective measures energy consumption of the typical buildings can be brought down by some 25 to 35% to the level of "best practice".

	Type 1 Naturally ventilated cellular	Type 2 Naturally ventilated open plain	Type 3 Air conditioned standard	Type 4 Air conditioned prestige
Heating + hot water	-52%	-52%	-55%	-52%
Refrigeration			-49%	-41%
Fans, pumps, controls	0%	-17%	-36%	-34%
Lights	-38%	-40%	-42%	-43%
Total electricity	-25%	-28%	-35%	-28%

Source: UNDP/WEC/DESA (2000).

der harmonisation is expected to induce mode shift from road to rail allowing a reduction some 3% in final energy use of the transport sector as a whole. Although air planes and related logistics have substantial efficiency potentials²² they are not expected to compensate for the growth of mileage of air transport in the upcoming decade.

3. Technical and Theoretical Potentials of Rational Energy Use After 2020

Many energy economists expect a further increase in energy demand of developed countries and, hence, a substantial shift to natural gas, nuclear power and renewables to avoid climatic changes due to energy-related greenhouse gases. Explicitly or implicitly those projections assume that substantial cost-effective efficiency improvements will be exhausted within the next one or two decades contributing to a new growth of energy demand after a period of stagnation of 25 years now ("stare case" effect). The judgement that feasible improvements of energy efficiency are limited to 30 to 40%, however, is questioned by several authors from science and engineering.²³ These papers and studies argue that the long-term technical potentials of rational energy use depending on new technologies and scientific knowledge may even be higher than 80% in the next century by the following drivers:

- *improving the exergy efficiency* (which is today less than 15% even in developed countries) by exploiting the differences of temperatures of heat streams and using the

adequate form of final energy required by the individual energy service,

- *decreasing the level of useful energy* by reducing losses (e.g. heat insulation, heat recovery) and by substitution of energy-intensive processes (e.g. membrane and absorption technologies instead of thermal separation, thin slab casting of steel instead of rolling steel sheets, new catalysts or enzymes, new bio-technical processes, inductive electric processes instead of thermal surface treatment),
- *applying new materials* (e.g. new compound plastic materials, foamed metals, nano-technology applications),
- *intensified recycling of energy-intensive materials* (e.g. increased shares of recycled plastics, aluminium or flat glass which have still low recycling rates in most world regions), and
- a *re-substitution of energy-intensive materials* by wood, natural fibres, and natural raw materials for chemicals (due to great potentials of genetic manipulation of plants, and a substitution among energy-intensive materials).

Because of the unbalanced perception of these long-term future potentials between efficiency improvement in those end-use and energy services areas on the one hand and of energy conversion technologies on the

²² IPCC (1999).

²³ E.g. Jochem (1991); de Beer (1998); ETSU (1994); Blok et al. (1996).

other²⁴ it is very likely that the high potentials for improving energy efficiency will remain underestimated for some time in the future.

To utilise a maximum of exergy of primary energy sources, it is inevitable to introduce the *cascaded energy utilisation* concept in the energy and end-use sectors. Cascaded energy utilisation involves fully harnessing the heat produced by fossil fuel combustion, from its initial 1700°C down to near ambient temperatures, with a thermal 'down flow' of heat analogous to the downward flow of water in a cascade.²⁵ Applications for *exploiting the full exergetic potential* of energy in multiple stages (cascaded) are not very common. To utilise exergetic potential of industrial waste heat, the promotion of energy transfer between the industrial and residential/commercial sectors is highly recommendable. In terms of refrigeration, air-conditioning and hot water supply, it is possible to meet most of the heat demand with low-exergy waste heat obtained as a by product of high-temperature, high-grade primary energy utilisation in heat engines or fuel cells, in a cascaded utilisation of co-generation. From a thermodynamic viewpoint, it is appropriate to combine comparatively low-exergy heat sources, such as solar and waste heat, with systems requiring low-exergy heat sources, such as heating, cooling and air-conditioning.

The level of *specific useful energy* demand can be influenced by innumerable technological changes without reducing the energy services provided by energy use or without impairing comfort. A few examples may demonstrate these — almost unconverted — possibilities:

- The quality of insulation and air tightness determines the amount of useful energy in buildings, furnaces or refrigerators and freezers. Swedish low-energy houses only need 20 to 40% of the heat per square meter which is used on average in residential buildings in West Germany. A cold-storage depot or a refrigerator could be operated by out-door air in the winter in zones of moderate climate.
- Catalysts, enzymes and new materials will render possible the substitution of many energy-intensive processes. High energy demand of activation of chemical reactions, high pressure and temperatures of processes may be rendered unnecessary by new catalysts of biotechnological processes. Membrane processes will only use a small percentage of the useful energy which is needed today in thermal separation processes. The production of iron which today involves energy-intensive sintering and coke making will be switched to the new coal metallurgy with substantial energy savings. The energy-intensive rolling-mill operation of steel making will be substituted by continuous thin slab casting.
- New materials for cutting edges will improve surface quality, hence avoiding several machine operations. La-

users will reduce the specific energy demand of metal cutting, and inductive electric processes will save energy in thermal surface treatment. New compound plastic materials or foamed metals, thus inducing less energy demand in manufacturing and (because of smaller specific weight) in their use in vehicles and moving machine parts.

- Even a re-substitution of energy-intensive materials by wood, natural fibres and natural raw materials for chemicals is expected in a few fields of application.

Looking back into the past, one observes an average efficiency improvement of the energy system of roughly 1 to 1.5% per year in developed countries over the last decades. Looking at those theoretical or technical potentials of future energy efficiencies, it seems to be possible that mankind can expect a similar *constant rate leading to economic efficiency potential of some 25% within the next 20 years* that is steadily exhausted by implementing efficiency opportunities and steadily fed by technical innovations and cost reductions of new energy-efficient technologies. This observation has its corresponding potential at the energy supply side in the static reserve/consumption ratio of oil lasting for decades now at 30 to 40 years to come.

4. Economic Impacts of Improved Energy Efficiency in End-Use Sectors — the Unknown Double Dividend

As long as profitable energy efficiency potentials are realised the individual energy consumer benefits, but also the economy on the following grounds: re-spending of saved energy cost, substitution of energy imports (in many countries) by domestically produced energy-efficient products and (energy) services, growth of labour-intensive branches in industry, construction and services instead of capital-intensive energy supply, spurring energy-efficient innovations.

Using macro-economic analysis, Jochem and Höhmeyer (1992) or Leitner et al. (1998) show, for Germany and the USA respectively, that policies to improve energy efficiency and to shift the energy mix to advanced technologies and less carbon-intensive fuels will generate four important kinds of benefits for the national economy. Such policies will

- spur overall economic growth to a small degree (i. e. below 1% of the growth rate) due to re-spending of saved energy cost,

²⁴ Jochem (1991).

²⁵ Kashiwagi (1995).

- quickly generate an additional number of jobs within the country (including the sort of entrepreneurial jobs which encourage a resourceful, self-sufficient, and satisfied work force) due to the factors mentioned above; a rule of thumb was a net employment, i. e. after considering the job losses in the energy supply sectors and in their input branches of the economy, of some 50 to 80 new jobs per yearly PJ saved;
- increase exports of high technology products; in the period from 1976 to 1992 exports of 12 energy saving products have increased by more than 50% faster than the total export data of West Germany; the exports of the energy efficiency technologies, therefore, supported the general trend of growing exports;
- reduce environmental and social costs of energy use that were previously uncouned in the market transactions for fuel which may well be as high as 2 cts per kWh electricity²⁶ and almost 1 cts per kWh oil product used without accounting for the impacts of climate change.²⁷

Unlike many other employment effects of investment, the jobs created by efficiency investments are not evenly distributed over time. In most cases, they are *created during the initial period of investment*, e. g. wall insulation, investment in a condensing boiler or high efficient window system. It also has to be stressed that the regional distribution of net employment will be more equitable. Employment in the energy supply sector is concentrated in urban and industrial areas, whereas efficiency involves planners, crafts, trade and banking in the whole country.

5. Obstacles, Market Imperfections and Disincentives for Energy Efficiency

Energy efficiency improvements may have redesigned the energy markets since the second oil price shock in 1979 more than conventional energy supply systems did within two decades. They also offer a huge variety of opportunities and contribute to a sustainable development in all regions of the world. But to judge from the history of today's levels of energy-related knowledge, decision making, and power structures, there is much evidence that the high potentials of rational energy use are and will be overlooked by many companies, administrations and private households or judged as "purely theoretical" or "unfeasible."

Of course, it is not easy to achieve the economic efficiency potentials, the "*fifth energy resource*", because the technologies are decentralised and technologically very different and because achieved efficiency is more difficult to measure than energy consumption. In addition, instead of a dozen large energy supply companies or a few engineering companies in a country, millions of energy consumers have to decide individually on their energy effi-

ciency investments and organisational measures. The heterogeneity and diversity of energy consumers and manufacturers of energy-efficient equipment contribute to a low perception of the high potentials of energy efficiency. Because of this variety and complexity energy efficiency is not appealing neither for the media nor for the politicians.²⁸

In theory, given all the benefits of energy efficiency at the micro-economic and macro-economic level (see above), a perfect market performance would optimally allocate the rewards from these new energy-efficient technologies and strategies. In practice, however, many obstacles and market imperfections prevent profitable, energy efficiency from being fully realised.²⁹ Although the types of obstacles and market imperfections are universal in principle, their importance differs among sectors, institutions and world regions.

5.1 General obstacles and unfavourable boundary conditions

Some of the obstacles can be found in many end-use sectors and all over the world. But they vary in importance from country to country, depending on many factors such as technical education and training, entrepreneurial and household traditions, the availability of capital, existing legislation and many others. Market imperfections include the *external cost* of energy use³⁰ as well as many forms of *subsidies* and traditional legislation and rules, but also traditions and motivation of behaviour in private households, of decision making in companies and administrations. Finally, the inherent policy "obstacle" is the fact that *energy efficiency investments* mostly *remain invisible* and do not contribute to politicians' positive public image. The "invisibility" of energy efficiency measures (in contrast to photovoltaic or solar thermal collectors) and the difficulty of demonstrating and quantifying their impacts are also important factors for private households and car investments due to aspects of social prestige.³¹ Obstacles and market imperfections of energy efficiency in end-use sectors have been observed and reported for more than 20 years. Empirical quantitative research on the size of the barriers while limited, underlines the large diversity of individual investors (e. g. thousands of firms, hundred thousands of landlords or millions of consumers in a single country).

²⁶ Friedrich et al. (1997).

²⁷ Hohmeyer et al. (1995).

²⁸ Jochem (1991).

²⁹ Jochem/Gruber (1990); Hirst (1991); IEA (1997); Jhirad and Mintzer (1992).

³⁰ Hohmeyer et al. (1997).

³¹ Sanstad and Howarth (1994).

Lack of knowledge, know-how and technical skills and transaction cost is one of their major draw backs for psychological reasons. Improved energy efficiency is brought about by new technologies or just minor changes of a known product, process or vehicle and by changed forms of organisation. This implies the ability of the investor and energy user to get to know and to understand the benefit of the technical efficiency improvement as well as to evaluate possible risks versus the perceived benefits. It also implies that the investor or user has to be prepared to realise the improvement and to take his time for absorbing the new information and for evaluating the innovation.³² Private households and car drivers, small and medium-sized companies and small public administrations do not have enough knowledge and market survey about possibilities for energy saving or enough technical skills. The construction industry and many medium-sized firms in the investment industries face the same problem as small companies on the user's side. Managers, preoccupied with routine business, can only engage themselves in the most immediately important tasks.³³ Energy efficiency, with its minor importance or reducing a small share of the energy cost of total production or household costs, goes on the back burner.

Lack of access to capital and historically or socially formed investment patterns

The same energy consumers, even if they gain knowledge, often face difficulties in raising funds for energy efficiency investments. Their own capital may be limited and additional credit may be considered as being expensive. Especially when the interest rate is high, small firms and private households tend to prefer to accept higher current costs and the risk of rising energy prices instead of taking a postponed energy credit.

Disparity of profitability expectations of energy supply and energy demand

The lack of energy efficiency-related knowledge among small energy consumers causes a higher risk perception, so that energy consumers and suppliers expect different rates of return on investments.³⁴ According to available information, energy supply companies in most OECD countries are willing to accept nominal internal rates of return of 10 to 18% after tax for major supply projects. For energy conservation investments, however, energy consumers demand — explicitly or without calculating — pay-back periods between one and five years, which are equivalent to nominal internal rate of return of about 15% to 50%.³⁵ This intersectoral disparity in the rate-of-return expectations favours investments in energy supply. Preliminary estimates suggest that the effect of this intersectoral disparity of profitability expectations is at least a 10 to 15% distortion of energy-saving invest-

ments.³⁶ This also seems to apply to international loans, putting energy efficiency investments in developing countries at a disadvantage.³⁷

The impact of grid-based energy price structures on efficient energy use

Grid-based forms of energy play an increasing role in OECD countries. The structure of gas, electricity, and district heat tariffs for small consumers and the level of the load-independent energy charge are important for energy conservation. Because tariff structures are usually designed in two parts to reflect two services — the potential to obtain a certain amount of capacity at any given time, and the delivered energy — the capacity charge plays an important role in profitability calculations of those investments where efficiency improvements do not reduce capacity demand, such as inverters of electric motors or control techniques in gas- or district heat using processes or buildings. In addition, in most OECD countries utilities do not offer time-of-use or seasonal rates to small consumers, which would reward them for using energy during off-peak hours which, however, may change in fully liberalised electricity markets. Peak demand, a significant cost factor for any power, gas or district heat company, is particularly responsive to energy-efficiency improvement.

Legal and administrative obstacles

There are legal and administrative obstacles in almost all end use sectors. They are mostly country-specific, and often date back to before 1973, when there were low and in real terms declining energy prices and no threat of global warming. For local *government authorities* the *budgeting format* is usually "annual budgeting fixation", which means that they cannot transfer funds from 'recurrent' to 'capital' budget. With a lot of other and probably more urgent pressing needs calling for capital investment, energy efficiency measures are given the least priority.

Other Market Barriers

The *investor/user dilemma* points to the fact that for rented dwellings and copy machines or leased buildings, there are few incentives for the renter to invest into the property that he does not own, similarly for the landlord, builder or owner to invest because of the uncertainty of

³² OTA (1993); Levine et al. (1995); Sioshansi (1991).

³³ Velthuisen (1995); Ramesohl (1999).

³⁴ Hassett and Mecalf (1993).

³⁵ DeCanio (1993); Gruber and Brand (1991).

³⁶ Jochem and Gruber (1990).

³⁷ Levine et al. (1994).

recovering his investment by a higher rent.³⁸ Finally, *the quality of delivered energy*, e. g. unstable frequencies or voltages of electricity or impurities in gasoline or diesel may pose a severe barrier for efficiency investments (electronic control or highly efficient motors).

For every obstacle and market imperfection discussed in this section, there are *interrelated measures of energy-efficiency policy* which could remove or reduce those obstacles or market imperfections as shown by a few examples in Figure 4. But the choice of which policies to pursue must be made with care as their effectiveness depends on many regional, cultural, political, and societal circumstances.

6. National and International Policies to Exploit Economic Potentials of Energy Efficiency in End-Use Sectors and its Supporting Drivers

During the last 20 years, individually implemented and ad hoc policy measures — such as information, training, grants or energy taxes — have quite often produced rather limited results. On the other hand, *integrated energy demand policies*, which consider the simultaneously working obstacles and, therefore, the interdependence of regulations, consultations “on the spot”, training programmes and financial incentives have been relatively successful. The experience of the last 20 years also showed that one should not expect all activities of energy demand policy to be initiated by governments. Companies, utilities, industrial associations and NGOs can also play a very important part. Socio-psychological relationships on the basis of trust, idealistic competition or perceived marketing effects in the use of existing networks may be a preferable choice of using these actors and their networks.

An integrated energy, transportation, financial and economic policy is one of the major opportunities for the realisation of the huge energy saving potentials. There is a strong need to formulate a long-term strategy that promotes energy efficiency improvements in all sectors of the economy and that takes into consideration the existence of both general obstacles and market imperfections as well as target group-specific barriers. In this section, the policy initiatives to be taken as general measures in different end-use sectors are discussed briefly and presented in a linear manner, although they have to be composed to *bundles of measures* to contribute effectively to sustainable development (see Figure 4). These policies may include general policy instruments such as energy taxes, direct tax credits, a general energy conservation law or general education on energy issues in schools and research and development. In some cases, international cooperation of governments or industrial associations may play important supporting role.

6.1 General policy measures

General policy measures of energy efficiency try to overcome existing general obstacles and market imperfections (see section 5.1), but they also may be implemented as new contextual conditions regarding broader economic issues such as shifting the tax burden from labour to non-renewable resources by an ecotax at the national or multinational level. Or re-regulation may be necessary to limit ambiguous impacts of the liberalisation of electricity and gas markets. In addition, the acceptance of policy measures differs among countries and varies over time depending on how much an energy policy objective is violated or in question. Energy efficiency policy had a high acceptance in OECD countries in the 1970s and early 1980s when energy import dependence on OPEC oil was relatively high and increased fuel prices had changed cost structures and weakened competitiveness of energy-intensive industries. With declining world energy prices between 1986 and 1999, reduced energy import dependence in many OECD Countries, and the recent stagnating negotiations of the implementation of the Kyoto Protocol, public attention for energy efficiency policy tends to decline in many OECD countries.

An *Energy Conservation Law*, realised in many countries (e. g. Australia, Canada, Germany, Japan, Russia, Switzerland, the European Union, or the USA) or in the process of passing legislation is an important instrument to establish the legal framework for sectoral regulation (e. g. building codes, labelling, technical standards for equipment and appliances) and implementing other measures such as energy agencies or public procurement.

Education in energy efficiency issues in primary or secondary schools as well as *professional training* are major instruments to raise the level of basic knowledge on rational use of energy and of most recent technologies respectively.

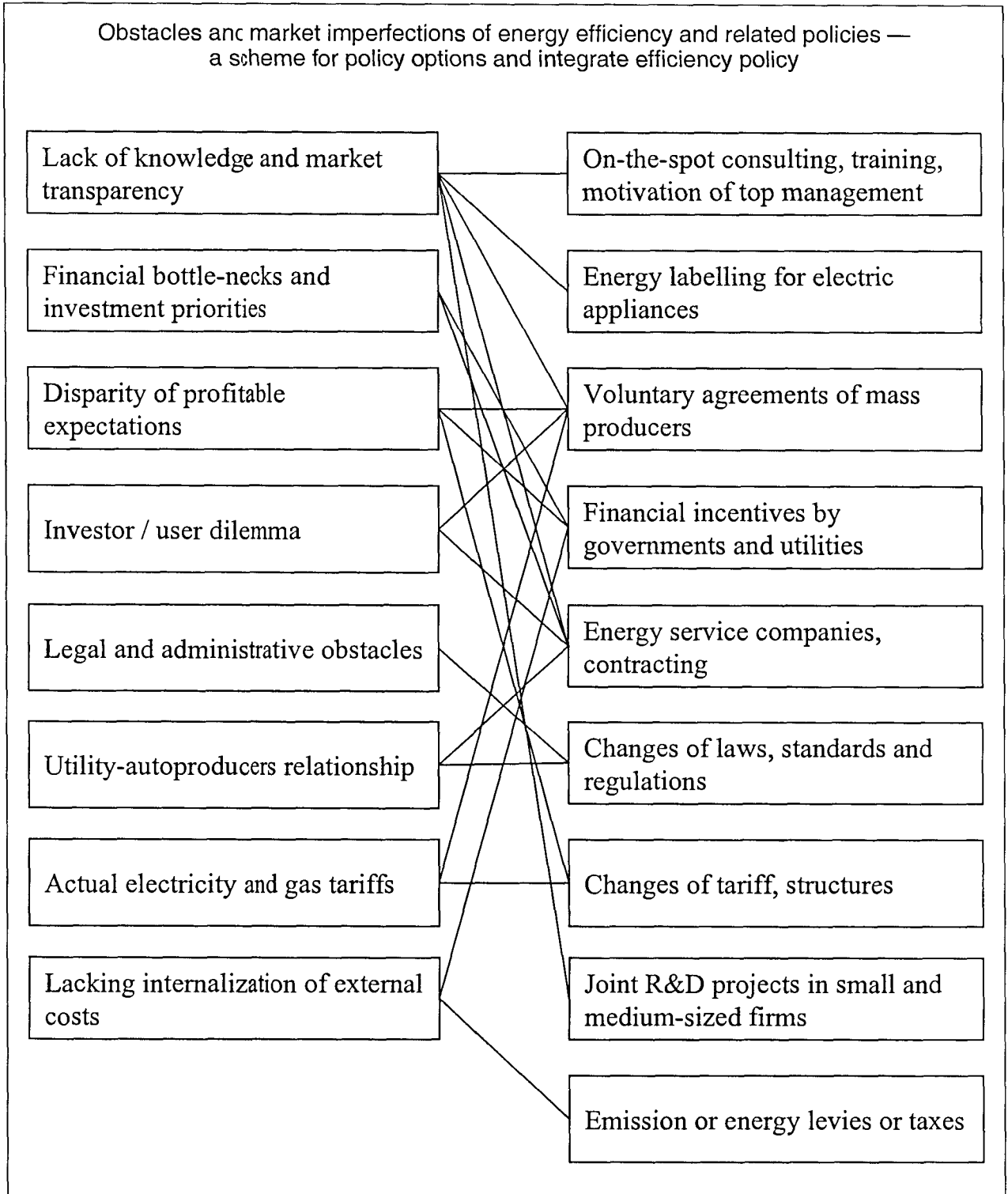
Direct subsidies and tax credits have been a traditional approach for promoting energy efficiency in many sectors in the past. Direct subsidies may often suffer from “free rider” effects when subsidies are used for investments that would be made anyway. Although the evaluation of this effect is difficult, estimates of the share in “free riders” in Western Europe range from 50 to 80%³⁹ to lower values in case of specific target-groups, e. g. low income families supported by a federal grant for weatherisation of their houses in the UK. A more effective type of subsidy seems to be low interest loan funds for energy efficiency projects, although they may have a distribution effect.

Energy service companies (ESCOs) are a promising entrepreneurial development, as they simultaneously

³⁸ Fisher and Rothkopf (1989); Golove (1994).

³⁹ Farla and Blok (1995).

Figure 4



overcome several obstacles by providing professional engineering, managerial and financial expertise and financial resources. They either receive a fee based on achieved savings or sign a contract for the provision of defined energy services such as heating, cooling, illumination, delivery of compressed air, hot water or oxygen.

6.2 Sector- and technology-specific policy measures

Given several obstacles which hinder economic energy-saving potentials on a sectoral or technology level from being fully realised, any actor will look for a “central instrument” that could simultaneously alleviate all obstacles.

In the case of mass products, performance standards are considered to be a very efficient instrument, because standards can be made after some discussions with scientists, engineers, and a few industrial associations. Standards and labelling avoid the need for information, high transaction cost, dissemination among, consultancy with, and training of, millions of households, car drivers, and small- and medium-sized companies.⁴⁰

But no single, most efficient instrument will be available in almost all cases of individual energy-efficient solutions (such as the refurbishing of buildings or efficiency improvements in industrial plants). In these cases, a package of policy measures has to be implemented to alleviate several existing obstacles simultaneously.

Buildings

Jochem and Hohmeyer (1992) conclude that if comprehensive policy strategies are implemented governments will discover that the economics of end-use efficiency are far more attractive than thought: a good example is the refurbishing of residential buildings. Homes and apartment houses consume about 20% of the total final energy in many countries of Western Europe. Refurbishing a building may be primarily an individual event, but its effectiveness depends on such political and social remedies as these:

- advanced education and training of architects, planners, installers and private home-builders, as carried out in the Swiss “impulse programme”, which has had outstanding results since 1978;
- information and education for landlords and home-owners (particularly on the substitution of energy cost for capital cost);
- training professional advisors to perform audits and give practicable recommendations; a subsidy for these energy audits, which may otherwise be considered too costly by the landlords or home-owners; these subsidies have proven cost-effective;
- the subsidising of investments may be bound to a registered energy consultant and a formal heat survey report;
- the government may create a market for these services through a regulation that demands a formal heat survey in the case of a changeover of tenants in dwelling, or a change of ownership of houses and buildings;
- an investment subsidy scheme for specified groups of home owners or multi-family buildings may need to overcome financial bottlenecks or risks of the investor/user dilemma; but the cost-effectiveness of this instrument has often been overestimated;
- an economically justified minimum thickness of insulation and window design may be secured by new building codes which should also cover the refurbishing of buildings;
- finally, research and development is an important long-term policy element to improve building design (low energy house, passive solar building), the properties of insulation material or windows or to reduce building costs.

The Danish, Swedish, Swiss and German energy-saving programmes owe their success, in large part, to this multi-measure character which is increasingly adapted by many other countries. The combination of different measures has led to a permanent transformation of the construction sector in several countries. The result 20 years later is convincing: new buildings are 40% more efficient and retrofits reduce the energy consumption typically by 25% in most Western European countries (see Figure 5).

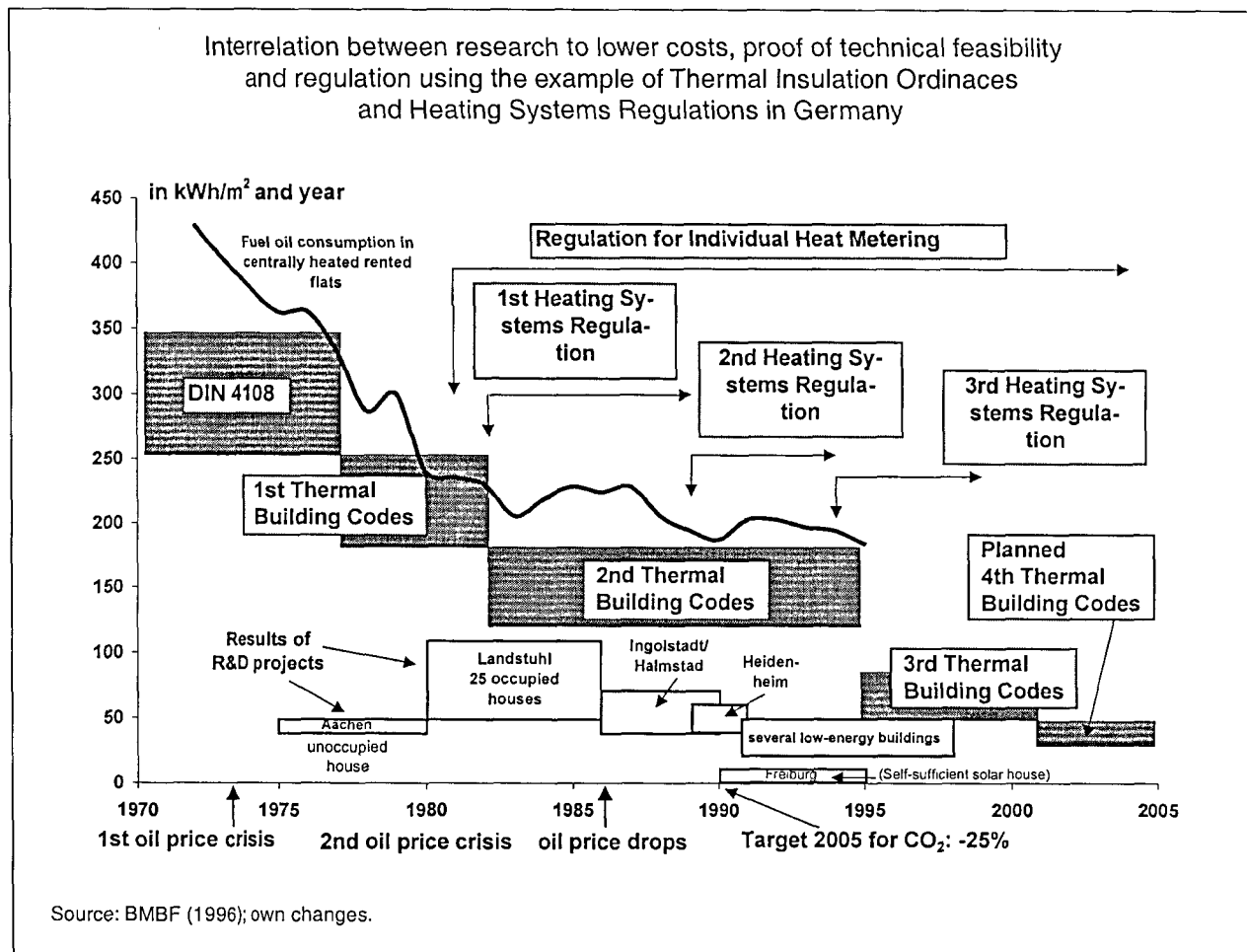
Household appliances and office automation

Household appliances and office equipment are well suited for technical standards and labelling. Varone (1998) compared instruments used between 1973 and 1997 in Canada, Denmark, United States, Sweden and Switzerland designed to promote the energy-efficiency of household appliances and office equipment.

Different attempts have been made in the past 10 years to co-ordinate and harmonise policies on an international or multinational level. Thigpen et al. (1998) consider international co-operation to be the only real means for inducing a market transformation in the domain of office equipment. Varone/Aebischer (1999) prefer to keep a certain diversity of instruments in different countries: this allows the testing of new instruments, it offers the possibility to test diverse combinations of instruments and use the advantage of political “windows of opportunity”, specific to each country, can be taken more easily, e.g. the Energy Star Programme for office equipment in the USA.

⁴⁰ Nat. Res. Canada (1998).

Figure 5



Small and medium-sized companies and small public administrations

Small and medium sized companies and public administrations are typical target groups where several policy measures have to be taken simultaneously: *professional training* of the staff, support for *initial consulting* by external experts, demonstration projects to strengthen the trust in new technical solutions, *energy agencies* for several tasks mentioned above, and *soft loans*. This policy mix seems to be successful in this target group in almost all countries.

Big enterprises and big public administrations

Big enterprises and public administrations have their specialised staff and energy managers, but they still need specific policy measures for implementing their economic potentials, given their specific obstacles. *Motivation* and awareness for energy efficiency potentials of the *top management of companies and administrations* by a "Minister's Breakfast" with the executives or by key note speakers in the yearly meetings of industrial associations

is one of the key elements as well as the exchange of positive experiences with new efficient technologies among the responsible middle management. Local governments should consider *life cycle costs* and increased flexibility between the investment and the operating budget which may need some changes in legislation in several countries.

Road transportation

Policies on road transportation may have technical standards of vehicles by voluntary agreements of car manufactures and car importers or efficiency standards, imposed by national governments. Similar measures on technical efficiency could be taken by air plane manufacturers or for trucks and buses. Higher fuel taxes in countries with low taxation may support this technical progress. A more systematic view relates to several areas of transport systems and policy measures:⁴¹

⁴¹ IEA (1997).

- Subsidies for mobility, e. g. for daily commuting, national airlines or public urban transport, increasing the demand for transportation, and for road transport in particular, should be removed where socially acceptable. An untaxed benefit to employees driving a car bought by companies or institutions may be removed.
- Road-user charges and parking charges may reduce driving in cities, congestion and accidents of road transport and shift some mobility to public transport means; car sharing is a concept that has implications for the level of car use and occupancy.
- Cost decreases of public transport by automation and public international procurement are possible as is a better organisation of rail freight crossing national borders.
- In the long term, intelligent city planning that does not separate an urban area in different functions and related sections opens up a substantial potential of reduced mobility.

Co-generation

Liberalisation of the electricity market has different implications on co-generation in different countries. Former obstacles such as low buy back rates and high rates for maintenance and emergency power are alleviated by the competitive structure, but a legal framework for wheeling and public control seems to be necessary for levelling the playing field, in particular for small and medium sized co-generation plants of independent power producers. Lack of expertise and the trend of outsourcing co-generation plants in industry can be adequately treated by supporting energy service companies by training programmes, standardised contracts for small units, and deductions on fuels for co-generation.

6.3 Internationally relevant policy measures

The globalisation of many industrial sectors opens up an enormous potential for improving energy efficiency at the global scale: harmonising technical standards of manufacturer's products offer new opportunities of economics of scale, thus, reduced cost for energy-efficient products. In order to avoid the import of energy-inefficient products, the governments, associations of importers or NGOs may consider to negotiate minimum efficiency performance of appliances and other mass-produced products that are imported from developed countries. Regarding the import of road vehicles, used cars or busses and trucks should not be older than five or six years (e.g. Bangladesh, Hungary) in order to avoid an inefficient vehicle stock.

The *Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects* entered into force in April 1998. The Protocol is a legally binding instrument requiring participating countries to:

- formulate aims and strategies for improving energy efficiency (article 5),
- establish energy efficiency policies (article 3.2),
- develop, implement, and update efficiency programmes (article 8.1) and establish specialised energy efficiency bodies at appropriate levels that are sufficiently funded and staffed to develop and implement policies (article 8.2),
- create the necessary legal (article 3.2), regulatory (article 3.2) and institutional (article 8.3) environment for energy efficiency, and
- co-operate/assist each other internationally in this area (article 3.1).

The Protocol received significant political support from the EU Environmental Ministers Conference in June 1998. In December 1998 the Energy Charter Conference agreed on the establishment of a Working Group on Energy Efficiency and Related Environmental Aspects. The Working Group will focus on the following issues: reviews (based on a review format as well as on in-depth peer energy efficiency analysis) and activities aimed at facilitating implementation of the Protocol, with special emphasis on the development of energy efficiency strategies, pricing policies and financing mechanisms.

The commitments of the *Kyoto Protocol by the Annex B Countries* are also a major driver of energy efficiency as about 70% of the greenhouse gas emissions of these countries are related to energy use. The ratification of the Protocol and the implementation of the flexible instruments will be of major importance to develop a coherent policy awareness in the developed countries of the substantial mitigation potential that improved energy efficiency at all levels of the energy conversion chain and in all end use sectors offers for meeting the objectives.

Conclusions

As the long-term energy efficiency potentials are in reducing useful energy demand and observing the choice of final energy for producing the useful energy, future energy policy will have to widen its attention from energy supply aspects towards energy services. Of course, this kind of policy will be much more demanding in designing target group- and technology-specific bundles of policy measures. But the success of this policy will be worth the efforts.

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Zusammenfassung

Energieeffizienz — Angelpunkt beim Übergang von der Energieangebots- zur Energiedienstleistungspolitik

Verbesserungen der Energieeffizienz waren bis heute auf die Energiewandler zur Erzeugung von Sekundär- und Nutzenergie konzentriert, aber die Möglichkeiten zur Verminderung des Nutzenergiebedarfs sind kaum ausgelotet. Zudem überwiegt meist die rein energetische Betrachtung (nach dem ersten Hauptsatz der Thermodynamik), und die exergetische Sichtweise (zweiter Hauptsatz) wird vernachlässigt. Eine genauere Orientierung der Arbeitsfähigkeit der jeweils verwendeten Energieträger an der benötigten Art der Nutzenergie (z.B. der Temperatur) eröffnet weitere Effizienzpotentiale. Anhand dieser Fakten und der Auflistung rentabler Energieeinsparpotentiale in Westeuropa bis 2020 schließt der Autor auf ein konstantes rentables Energieeffizienzpotential von rd. 25% für die jeweils nächsten 20 Jahre, das einerseits ständig durch Investitionen genutzt werden könnte, andererseits durch Innovationen und Kostenreduktionen bekannter technischer Potentiale wieder aufgefüllt wird (vergleichbar mit der konstanten statischen Reichweite von Erdöl oder Naturgas). Diese „stationäre Effizienz-Reichweite“ wird wegen Hemmnissen und Marktunvollkommenheiten derzeit nur teilweise ausgeschöpft. Eine Energiepolitik, die rentable Effizienzpotentiale ausschöpfen will, muß nicht nur allgemeine Rahmenbedingungen setzen, sondern auch zielgruppen- und technikspezifische Maßnahmenbündel realisieren.