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Joachim Schleich and Eberhard Jochem

Dr. Joachim Schleich / Prof. Dr. Eberhard Jochem
Fraunhofer Institute for Systems and Innovation Research
Energy Department
Breslauer Straße 48
D-76139 Karlsruhe
Germany
Email: schleich@isi.fhg.de / ejo@isi.fhg.de

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Joachim Schleich and Eberhard Jochem*

Abstract

Empirical studies demonstrate that, although substantial improvements in energy efficiency have already been made, there still exist significant economic potentials - even in energy intensive sectors. Realising these potentials will reduce costs for energy services and improve overall economic efficiency, but employment gains are likely to be small. Technological progress in energy efficiency may foster economic growth, improve competitiveness and create new export markets. Above-average growth and export rates for energy efficient products can be expected to continue, in particular, if policies are appropriately designed to realise untapped efficiency potentials and to encourage innovation in energy efficient technologies.

1. Introduction

Improving energy efficiency through the rational use of energy is - besides fuel switching on the demand and supply sides - a highly cost-effective strategy to achieve national and international greenhouse gas emission targets even in a world of low energy prices (IEA 1999; EC 1999). Thus, improving energy efficiency has to be an integral part of any future climate protection policy. The most promising technology options for the rational use of energy (RUE) in Western European economies have been explored in several studies such as the ATLAS project (EC 1997a), the European research project on *Energy R&D Options for a Sustainable Future* (Blok *et al.* 1996), recent work on *European Energy Technologies - A Global Competitive Review* (Hagler Bailly 1998), and by recent IEA work (1999) on the *Role of Technology in Reducing Energy related Greenhouse Gas Emissions*. More specifically, the identified technologies include

- *Energy efficiency in industry:* process integration, high efficiency motors, drives, and motor-driven systems, high efficiency separation processes or advanced end-use technologies;
- *Energy efficiency in buildings:* heating and cooling technologies (such as heat pumps and condensing boilers), efficient lighting, building envelop (windows and insulation retrofits) for new constructions and refurbishment, building energy management systems, or district heating and cooling systems;
- *Cross-cutting technologies:* combined heat and power, advanced gas turbines, sensors and controls, power electronics;

* Fraunhofer Institute for Systems and Innovation Research, Department of Energy Technology and Energy Policy, Breslauer Strasse 48, D-76139 Karlsruhe, Germany.

- *Energy efficiency in transport:* efficient conventional vehicles, electric and hybrid vehicles, fuel cell-powered vehicles;

These energy efficient technologies may not only serve to significantly reduce emissions, but - as will be argued in the remainder of the paper - they may also increase economic efficiency by reducing total costs of energy services, increase employment, and foster technological innovation, growth and international competitiveness.

2. Direct cost effects

Energy efficient technologies and production processes increase overall economic efficiency

There are numerous empirical studies indicating an extensive economically beneficial energy conservation potential. According to Grubb et al. (1993) this so-called *no-regret potential* for western industrialised countries is about 20 %, and the most recent UNDP/WEC/DESA World Energy Assessment (2000) estimates this potential at 20 - 30 % over the next two decades. Thus, energy efficient technologies and production processes may significantly increase overall economic efficiency. For firms, these cost savings imply more efficient production and improved competitiveness, which in turn generate significant employment opportunities. For households, expenditure savings increase disposable income which can be spent for other purposes and thus create additional jobs.

A summary of the projected economic savings potentials in the various end-use sectors over the next two decades is presented in Table1. The estimated economic efficiency potentials depend on today's and the foreseeable technology development and on today's and anticipated future energy prices. When energy prices are low, economically profitable potentials are relatively small compared to the case when energy prices are high. Higher energy prices may be achieved through policy interventions like energy taxes on a national or world-regional level. Of course, the identified savings potentials in each case vary with the technologies considered, the particular application and the assumed energy prices.

Table 1 indicates that even in the energy-intensive sectors, where energy efficiency has already been improved significantly, and where investment decisions typically account for energy efficiency, there are still substantial economic efficiency potentials. Historically, the manufacturing industry had been the largest energy consuming sector in Western Europe. But it lost this role in the early 1990ies after its final energy demand had been stagnating for over two decades - despite a yearly production growth of 2%.

Table 1: Summary of economic energy efficiency potentials for 2010 and 2020 in the end-use sectors of Western Europe

Sector and technological area	**economic potential[1] in % by 2010**	**2020**	**assumed (sectorial) energy price level**	**if %: base year**
Industry				
- iron and steel, coke ovens	9-15%	13-20%	today's prices	1995
- construction materials	5-10%	8-15%	1997	1997
- glass production	10-15%	15-25%	1997	1997
- refineries	5-8%	7-10%	today's prices	1997
- basic organic chemicals	5-10%		1997	1996
- pulp and paper		50%	today's prices	1997
- investment and consumer goods industries	10-20%	15-25%	today's prices	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%	today's prices	1997
-building envelop	8-12%	10-20%	today's prices	1995
- new buildings		20-30%	today's prices	1995
- electric appliances	20-30%	35-45%	1997	1997
- behavioural changes (space heat)	15%			
Commercial/public/agriculture				
- commercial buildings	10-20%	30%	8-13 cts/kWh	1995
electricity	10-25%	20-37%	4-10 cts/kWh	1997
heat		15-25%	today's prices	1998
- public buildings		30-40%	7-15	1992
- agriculture/forestry		15-20%	today's prices	
- horticulture		20-30%	today's prices	
- decentralised co-generation		20-30%	today's prices	1995
- office equipment		40-50%	1995	1995
Transportation				
- cars	25%		today's prices	1995
- door to door integration	4%			1995
- modal split of freight transport		3%*		1995
- trains and railways		20%	today's prices	1999
- air crafts, logistics	15-20%	25-30%	today's prices	1998

[1] assuming a 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)

Considerable future economic energy-efficiency potentials within the manufacturing industry sectors exist, for example, for paper mills through a combination of new pressing and drying techniques, or latent heat recovery systems, and for steel making through thin slab casting, improved efficiency in the blast furnaces, or improvements in the oxygen steel process. But also cross-cutting technologies, electrical and mechanical drives, metering, controlling and optimal regulation alone can lead to efficiency improvements of at least 15 % in most industrial processes. Within the industry sector, the highest potentials for cogeneration are in the chemical, the paper, the mechanical engineering and the electrical engineering sectors.

The economic efficiency potential for the heating systems in buildings presented in Table 1 may be achieved using condensing boilers, high efficient window systems and insulation material within the cycle of refurbishment. New low energy houses with yearly heat demand below 50 or 100 kWh/m^2 are presently cost-effective due to better design and low cost insulation techniques and window systems.

Although the efficiency of newly marketed domestic appliances has been steadily improving in the past, there still exists a substantial economic potential, in particular for fridges and freezers. For appliances, which are used less frequently such as ovens, dish washers, washing machines, and dryers, it is more difficult to recover higher investment costs through electricity savings.

While electricity consumption of office equipment is a rather small fraction of the total electricity used in the commercial/service sector, office equipment is considered to be the fastest growing electricity consuming segment. Since about two thirds of this electricity is used in standby- and off-mode, savings potentials can easily be tapped in most equipment categories.

The transport sector is the fastest growing energy using sector, with about 50% accruing to passenger cars and almost 40% to road freight transportation. Considerable savings potentials within two to three decades can primarily be realised through improved fuel efficiency for new cars or through weight reductions, reduced air-drags and improved drive-concepts for trains.

These numbers imply that energy-efficient savings potentials are far from being exhausted, and highlight the importance of research and development efforts to extend the frontiers of the technical and economic savings potentials.

3. Employment effects

Energy efficient technologies and production processes exhibit positive quantitative and qualitative employment effects

The extend to which energy efficiency translates into employment and output gains depends on the direct and (through the interdependencies of the sectors) on the indirect demand effects triggered by the investments in the rational use of energy. Equivalently, the direct and indirect effects resulting from a decrease in the demand for the traditional technologies and energy sources have to be subtracted. Further, employment effects also depend on the spending and savings patterns of households.

Since investment in energy efficiency reduces the demand for fuels and electricity, countries exporting oil, coal, natural gas and uranium typically experience a drop in output and employment from increased energy efficiency elsewhere. Likewise, employment increases when the demand for labour intensive sectors (e.g., buildings and construction, or the tertiary sector in general) increases at the expense of less labour-intensive sectors (e.g., energy conversion, or primary goods production).

Former and recent calculations using static Input-Output models for Germany imply, that investment in energy efficiency leads to small, but clearly positive employment effects (Altner et al. 1998). The RUE-measures which include improved thermal insulation, efficient lighting, variable speed drives for electric motors and drives, and cogeneration, result in a net gain of 9000-20000 permanent jobs, most of which are created in the construction and building sector. Qualitatively, these results are confirmed for Europe by Walz et al. (1999) on a more aggregated level. An increase in industrial process efficiency, or the use of cogeneration and more efficient household appliances primarily spur demand for industrial machinery and electric goods. An increase in the fuel efficiency of cars and trucks through more efficient motors and drives accrue mainly in the transport equipment sector. Finally, improving the thermal insulation of buildings raises the demand for labour-intensive construction services and civil engineering. All these measures primarily come at the expense of fuel imports from outside of Europe 'improving' the balance of trade.

According to a recent study conducted by the Deutsches Institut für Wirtschaftsforschung (DIW) insulation measures alone are estimated to create around 77400 additional jobs by 2005 in Germany. However, the effects are expected to be much lower in the long run, because the positive demand effects for construction goods are levelling out (DIW 1997). For the EU, replacing current single- and double glazing windows by high performance double-glazing windows may create additional 127000 jobs over a ten-year period (EC 1995)

Earlier analyses combining detailed technological analysis with static Input-Output models concluded a gain of 100 additional jobs per PJ of energy saved (Hohmeyer et al. 1985; Jochem and Schön 1994). Due to increased labour productivity and lower energy prices, the number of additional jobs per PJ saved may be less than half today.

The efficient use of energy exhibits not only quantitative, but also qualitative employment effects. According to a recent study by the IFO institute (cited in

Wackerbauer 1999), the qualification of workers in Germany employed in the production of RUE is clearly above average: the share of employees with an education beyond high school degree in RUE-industries is 65.7% compared to 38.1% in all industries in the sample. Thus, the sectors with relatively low qualification requirements like construction and buildings are being outweighed by sectors with high qualification requirements like the electric goods and the electrical and mechanical engineering sectors.

To sum up, investing in energy efficiency not only creates jobs in the construction and manufacturing industry sectors, but also in installation, planning, maintenance, consulting and other services. The magnitude of additional domestic employment primarily depends on the profitability of the RUE-investments, the labour-intensity in the benefiting and loosing sectors, and on the amount of (reduced) imports. As Europe's energy dependence is likely to increase from 50% today to more than two thirds within the next two decades, the last effect will become more important in the near future.

4. Innovation, growth and trade effects

Energy-efficient technologies and production processes foster growth, improve competitiveness, and create new export markets

Empirical studies show that historically, the production of RUE-products has been growing very rapidly - more rapidly than the production of equipment goods or consumption goods in general. The production patterns mostly follow the typical take-off phase of a logistic development curve at low levels of the total market. For example, in Germany, the production of 12 RUE-products (burners, boilers, double/triple glazing, heat exchangers, control equipment for efficiency) has increased 50 % above the average of total industry production since 1976. Similarly, for France, production growth of RUE-products from 1990 to 1998 amounted to 29 %, which significantly exceeded the growth of equipment goods in general (16 %) and the growth of the entire industry sector (11 %) (EC 1999).

The future growth potential for RUE-products is also very promising. As displayed in Table 2, the market size for those products in the building sector and combined heat an power (CHP) alone was estimated to be around 20 billion € in 1995, while the world market for these products was about ten times larger (EC 1997a). The assessed *technical* annual growth potential within the EU between 1995 and 2010 would be more than 14%. These numbers also imply significant export possibilities, although, not all RUE-products are equally well-suited for exports. Hence, the export potential for building management systems or for controls, as well as for heating and cooling equipment will be higher than for insulation. The export of RUE-products tends to exceed the average growth for exports in general. For example, in West Germany, exports of 12 RUE-products exhibit an annual growth rate of 8.3 % since 1982, which is about twice as high as for all industrial goods. And between 1992 and 1994, the trade surplus of RUE capital goods more than doubled from 170 million to 360 million €.

Table 2: Present (1995) and future (2010) market and energy-saving potentials for selected RUE-products at EU and world levels

Technology areas	Parameter	EU market (1995)	World market (1995)	EU technical potential (2010)	World technical potential (2010)
Insulation	M€/a sales	3000	25300	90000	925000
	Indicative Mtoe/a saved	46.6	229.0	101.2	1030.0
Glazing	M€/a sales	10500	87000	20200	140000
	Indicative Mtoe/a saved	191	932	394	3344
Lighting	M€/a sales	443	3029	8500	61000
	Indicative Mtoe/a saved	0.5	3.1	12.1	86.0
Heating and cooling	M€/a sales	1524	5700	5850	40000
	Indicative Mtoe/a saved	8.2	31.1	31.5	2221.7
Building management systems and controls	M€/a sales	1600	13500	17000	231000
	Indicative Mtoe/a saved	2.2	11.5	23.8	168.4
CHP	M€/a sales	3500	70500	13200	255000
	Indicative Mtoe/a saved	5.3	107.5	25.0	482.6

Source: Atlas Project, European Commission (1997a)

Let us now turn to a more analytical examination of the innovation, growth and export potential of RUE-products which may also contribute to additional employment. Beyond the rather static effects described in the previous sections, RUE-measures may have an important effect on the long-term competitiveness and the growth potential of an economy. There are two aspects that will be considered here. The first aspect refers to the question of whether *investing in energy efficient technologies and production processes leads to an increase in productivity and growth* or to a decrease by crowding out other, more productive, investments. Among the few studies dealing with this issue Walz' (1999) analysis of the 58 most important energy efficient technologies within the industry sector reveals that most of them increase industrial productivity, especially if they are process integrated. Since improving energy efficiency has been mostly a by-product of the development of new production technologies, the future innovation potential might be much higher if energy efficiency is specifically included as an objective in the traditional R&D process. For co-generation, boilers, burners, electrical motors or heat exchangers, which are monofunctional and energy conversion technologies, and – except for new technologies such as the fuel-cell– already rather well developed, additional innovation effects for boilers and burners are likely to be small. The same is probably true for electrical motors and heat exchangers. The largest future efficiency potentials are in the end-use sectors by reducing the demand for useful energy and by choosing the thermodynamically most appropriate energy form (improving the exergy efficiency). This means, however, that the frontier for innovation shifts to the single process at the end-use level, i.e. industrial processes, building envelop or vehicles.

The second important aspect relates *to innovation as a deciding factor for international competitiveness.* International competitiveness is less determined by cheap inputs or large scale production, but rather by a firm's capacity to improve and innovate continuously (Porter and van der Linde 1995; Blümle 1994). In many instances, measures to improve energy efficiency simultaneously improve the affected product or production process itself. These positive side-effects may arise as better-performing or higher-quality products, lower product costs, safer products or production processes, higher resource productivity, less production interruptions, or safer working conditions. If world demand is moving towards energy-efficient products, early-acting companies may be able to enjoy a *first-mover advantage* in international markets and command a considerable price premium for their products (Porter and van der Linde 1995). In some cases, even the regulated firms themselves manage to turn the imposition of strict standards into first-mover advantages through innovation, efficiency and productivity gains (EC 1997b).

First-mover advantages are particularly relevant in the industrial capital goods sector, where quality is the key determinant for success in international markets. Energy demand model simulations imply that fossil fuels will keep playing an important role over the next few decades. Thus, future market size and export potentials for clean fossil fuel technologies should be large, not only in industrialised but also in Eastern European and developing countries, where demand for clean high-tech plants and equipment is steadily increasing (Fassing 1999). Attractive technology options include combined-cycle gas turbines, which also enjoy increasing market shares for medium-scale combined heat and power, or cooling-by ab/adsorption-technologies, which allow a more efficient application of co-generation. As for the transport sector, there is still a great potential for generating future innovations (Breitschwerdt 1998) ranging from aerodynamic improvements to entirely new power systems (fuel cell technology). Since technological quality is an important parameter in the intense international competition for cars, first mover advantages are very important. Also, trucks will most likely be the dominant means for freight transportation in countries like China, suggesting a huge market for more efficient truck engines.

5. Conclusions and policy implications

While energy efficient products and processes represent cost-effective options to achieve a given emission reduction target, we provide empirical and analytical support for the claims that these technologies may also

- increase economic efficiency by reducing direct production and consumption costs for energy services
- reduce unemployment and improve qualification skills; and
- strengthen growth, improve competitiveness, and create new export markets.

It should be stressed, that the no-regret savings potentials identified in Table 1, may not be realised in practice due to various barriers such as technical and financial risks associated with particular technologies and applications, bounded rationality, split incentives (user/investor dilemma), information and other transaction costs, or general market failures (Jaffe and Stavins 1994; Eyre 1997; Almeida 1998; UNDP/WEC/DESA, 2000). Thus, policies to overcome these barriers will play an important role. These policies may consist of information and demonstration programs (RAVEL in Switzerland), labelling (household appliances, electric motors), standard setting (thermal on heating equipment), cooperative technology and market procurement (for more efficient fridges and freezers), contracting, credits, subsidies, taxes or quota systems. Often, to address the relevant barriers, a mix of several instruments may be required in most cases and target groups.

Those energy demand (and climate protection) policies may also induce additional technological progress through the price mechanism (e.g., Goulder and Schneider 1996). Further technological progress will be achieved, if climate protection is incorporated into the traditional target system of research and development activities of companies.

Properly designed policies may also help generating first-mover advantages by imposing strict efficiency or environmental standards that will later be adopted in other countries. This will create a domestic market for RUE-products, and may enable domestic firms to gain an edge in the evolving international markets. The assumption that the government is able to foresee international developments has been at the core of some critique (e.g. Jaffe et al 1995; Palmer et al. 1995). But, although empirical quantification of first-mover advantages is difficult, there are numerous case studies in support of this hypothesis (e.g. Porter and van der Linde 1995; Blümle 1994).

When designing energy efficiency and/or environmental regulation to encourage innovation, policies should create the maximum opportunity for innovation, leaving the approach to innovation to industry. Rather than mandating energy converting technologies, regulation should encourage product and process changes, and regulate as late in the production chain as practical to allow for more flexibility for innovation. Properly designed policies should foster continuous improvement rather than locking in any particular technology and leave as little room as possible for uncertainty. Thus, when well-designed policies include predictable targets which take into account investment cycles and send clear and credible messages about likely future regulations, firms can anticipate these developments in their innovation and investment efforts.

Not all those requirements are met (yet) by the flexible instruments allowed under the Kyoto Protocol. But emission trading, joint implementation and in particular clean development mechanisms are expected to spur investment in RUE in developing countries and countries in economic transition, and generate innovation and additional export opportunities.

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Bibliography

Joachim Schleich, PhD, works as an economist at the Fraunhofer Institute for Systems and Innovation Research in the department of Energy Technology and Energy Policy. His research projects and publications focus on the design and evaluation of environmental and energy policies, on barriers to the rational use of energy, and on international trade and environmental policy issues.

Prof. Dr.-Ing. Eberhard Jochem is Senior Executive at the Fraunhofer Institute for Systems and Innovation Research, co-founder of the Centre for Energy Policy and Economics in Zürich, and Professor at the ETH Zürich and Lausanne. He is an internationally acknowledged expert in technical and socio-economic research in the field of energy and environment, member of various national and international scientific organisations and advisory committees, and author of several books and publications in the field of energy and environment with regard to R&D, innovation, economics and policy issues.