The future of energy efficiency in Europe and future energy demand

Wolfgang Eichhammer[1]

Abstract

Energy efficiency can contribute hugely to mitigate climate change, to save money, and to improve security of supply. In this paper we explore the future of energy efficiency in Europe and its importance for the future energy demand. In particular, we look at the improvements in energy efficiency required to achieve our targets for energy consumption. We show that there are huge saving potentials available by the middle of the century (up to two thirds of primary energy demand, large enough to cover the 50% reduction target required in light of greenhouse gas reduction requirements. However, this will need specific policies to address the barriers energy efficiency faces. Indeed, energy efficiency policies need to be given a higher priority in the political and scientific agenda in Europe.

Keywords: Energy efficiency, Europe, potential.

ENERGY EFFICIENCY - THE INVISIBLE POWERHOUSE IN IEA COUNTRIES AND BEYOND

The International Energy Agency (IEA) calls energy efficiency "the invisible powerhouse in IEA countries and beyond, working behind the scenes to improve our energy security, lower our energy bills and move us closer to reaching our climate goals" (IEA, 2014). According to the Agency's analysis, energy efficiency saved 3000 million tonnes of CO_2 in the time period 2000-2015, nearly half of which in China and another half in OECD countries (IEA, 2016). This represents more than 10% of the world's 2015 CO_2 emissions. These few exhibits already show that the contribution of energy efficiency to mitigate climate change, to save money and to improve security of supply has been tremendous.

1 Fraunhofer Institute for Systems and Innovation Research ISI, Germany and Utrecht University, Copernicus Institute of Sustainable Development, Netherlands.

Elder generations still have lived to first and second oil price shocks, whose economic and supply security impacts have been largely mitigated by energy efficiency improvements. Other factors have certainly also contributed to mitigate the impacts, such as enhanced recovery of fossil resources, discovery of new resources in the deep sea, diversification of fossil resources (in particular towards natural gas), penetration of renewable and nuclear energy… but according to the analysis by IEA, the largest contribution has been provided by energy efficiency.

In this paper we will explore the future of energy efficiency in Europe and its importance for the future energy demand. But before doing so we have to dig into the meaning of what we understand exactly by energy efficiency. We will see that this is a rather complex issue.

Later on we will dig into the question why –despite increasing energy efficiency– energy consumption may still be increasing worldwide. At the European level we have nevertheless already entered the phase of lowering energy consumption partly in consequence of energy efficiency policies. We will go further into that direction by investigating how lifestyles and energy efficiency interlink.

We will then look to the improvements in energy efficiency which are necessary to achieve our targets for energy consumption, which are largely determined by the steps to be undertaken to solve major problems: *e.g.* climate change requires the limitation of global temperature increase to 2°C or even 1.5°C compared to pre-industrialized levels. Supply security considerations may lead policy makers to limit the dependency on unstable world regions. Competition among industries make it necessary to reduce energy consumption for economic reasons.

In a central part of this paper we discuss how energy efficiency policy is impacting on energy efficiency and which targets are to be achieved through energy efficiency. Electricity efficiency is a central element in future energy efficiency policies given the fact that the power sector will become increasingly important (due to the trend that more and more energy uses may be electrified:

cars may be running on electricity, buildings are increasingly heated by heat pumps based on electricity, industrial processes are moving towards more electricity-based processes).

We will have also a longer-term view to the limits of energy efficiency in a more far distant future.

ENERGY EFFICIENCY – WHAT IS IT EXACTLY?

When it comes to renewable energy sources, progress is generally easily measured (for example in terms of Megawatt installed renewable power or in terms of shares of energy consumption being covered by renewable) and easily understood. Energy efficiency progress is considerably more difficult to measure and understand. At the level of a country or worldwide, energy intensity improvement is used, *i.e.* by which amount the ratio of energy consumption and value created (Gross Domestic Product) is improving. There are many reasons which may contribute to lowering energy intensity and which may be not easily associated to energy efficiency. The problem stems from the fact that in our mind we associate energy efficiency in one way or the other with some technical improvement: for example a more efficient car uses less energy for the same number of kilometers driven. Or a heating system generates the same amount of heat with less energy. In both cases the devices are considered more efficient than others.

However, there are many more factors that contribute to lowering (or increasing) energy intensity which can be grouped into three main factors: economic factors, technical factors, behavioral factors. In a larger sense they all contribute to improving energy efficiency but in more refined approach to energy efficiency[2]

2 See in particular the ODYSSEE-MURE project on European Energy Efficiency Indicators and Policies (www.odyssee-mure.eu) which has developed an own energy efficiency indicator ODEX which measures energy efficiency in a more narrow technical sense and can be considered as the “Dow Jones” for energy efficiency. This indicator avoids as far as possibly monetary measures of activity such as GDP but uses rather at the detailed level physical units such as tonnes of products, square meters of inhabited and heated/cooled surface, kilometers driven by cars, tones transported by lorries, energy consumed by each employee in services. This approach avoids to a large degree the economic and structural artifacts described in the table below.

the different components are separated and energy efficiency improvements are measured by more technical indices.

The mere volume and complexity of the table shows that energy efficiency is not easy to measure and easy to communicate. This is one disadvantage in the policy sphere which is largely dominated by non-specialists, including in national and European parliaments. The highly technical aspects of energy efficiency and the large number of technologies involved makes it complex to be understood in

Table 1

Factors impacting energy intensity – not all is easily associated with energy efficiency

	Move of societies towards more services and high value industries, away from the energy-intensive industries: these are structural changes which make that societies, the more developed they get rely more on high value services rather than on the production of energy intensive raw materials. These are still needed but to a much lesser degree, as infrastructures have been built up and replacing infrastructures requires less energy. Also newly built infrastructures require less energy-intensive materials due to material efficiency (the twin sister of energy efficiency).
Economic factors impacting energy intensity	Another less evident reason for the improvement of energy intensity are changing exchange rates as frequently energy intensities are converted to the same currency, *e.g.* US Dollar. If the exchange rate between Dollar and the national currency changes then the international energy intensity changes though the national one (measured in national currency) may remain constant. In Europe many countries share the Euro, so the problem arises less among these countries. These factors occur partly autonomously, partly they are influenced by policies but not necessarily energy efficiency policies: these may be industrial policies, monetary policies, trade policies etc.

Table 1 *(continued)*

Factors impacting energy intensity – not all is easily associated with energy efficiency

Technical factors impacting energy intensity	Technical factors impacting on energy consumption may be that what is commonly associated with energy efficiency. For example, as stated above, a more efficient car uses less energy for the same number of kilometers driven. Or a heating system generates the same amount of heat with less energy and a well-insulated home uses less energy than a badly insulated one. A ton of steel is produced with less energy etc. (the latter may be the consequence of a more efficient process or the replacement of a less efficiency process through a new one: *e.g.* recycled steel may replace primary steel). Another less evident reason for the improvement of energy efficiency, this time on the technical side, is the penetration of certain type of renewable in the power sector (in particular wind and solar photovoltaics. This has to do with the fact that a power sector which is mainly based on fossil power plants or nuclear has a poor efficiency (on average 40% in Europe and up to 58% for the best gas-fired plants), while the renewable energy sources mentioned have a high nominal efficiency of 100%. Their massive penetration leads than to a decrease in energy intensity hence to an apparent improvement in energy efficiency. On the other hand, a negative impact on energy intensity may be exerted by an increased penetration of electricity, as long as the conversion efficiency of the power sector is low. For example the penetration of electric cars will increase energy intensity as long as the power sector is not largely based on renewable energy sources. Technical improvements may be occurring in an autonomous manner or may be policy driven: for example industrial processes are improving all the time because energy is a cost factor and reducing that cost can improve competitiveness. On the other hand buildings have been mainly improving by energy efficiency policies *(e.g.* building regulation on heat losses from buildings or subsidy schemes to home owners to put insulation on their home). Frequently, for the analyst it is important to distinguish autonomous energy efficiency improvements from policy driven improvements, as he wants to know how much effort is needed, beyond "business-as-usual" to achieve more reduction in energy consumption and greenhouse gas emissions.

Table 1 *(continued)*

Factors impacting energy intensity – not all is easily associated with energy efficiency

Behavioral factors impacts impacting energy intensity	Finally energy intensity may also be influenced by behavioral factors: more comfort could drive energy intensity up (more heated/cooled surfaces, longer heating/cooling periods, larger cars, penetration of sports utility vehicles SUVs, larger televisions etc.). This is frequently associated with rebound effects, *i.e.* when money is saved with energy efficiency measures –but also when we get richer– part of the additional money is spent on energy consuming activities. Frequently, such behavioral factors destroy part or all of the savings achieved at a technical level. Fortunately, behavioral factors may also impact positively on energy intensity. Lifestyle changes may lead people to spend less time in traffic jams (hence driving less), make them chose less wasteful products, chose cars not according to the social image but functionality or don't own cars at all (car sharing, city cars). Also such factors may be impacted by policy making: for example the choice of car size or between car and public transport may be a societal trend but could also be the consequence of a dedicated energy efficiency policy. However, such behavioral changes may not only be the consequence of energy efficiency policies but also of housing policies, transport policies, fiscal policies etc. which are frequently interacting with energy efficiency policies.

Source: Own elaboration.

the energy field – and is one explanation why energy efficiency is more difficult to tackle. The other one is that improvements of energy efficiency are more difficult to show by a policy maker: An energy efficient building looks still rather similar to a less efficient one; the efficiency is hidden in the walls, windows, roofs and the cellars.

Though energy efficiency shares this complexity with a variety of other fields (possibly it is as difficult to understand the technical aspects of internet technology or genetic modifications) in the energy field this is possibly the most complex field at present. Other fields such as renewables are nevertheless evolving into similar complexity: For example, understanding the market integration of mainstream renewable energy sources into electricity markets implies a solid understanding in electricity markets and their function. Thus, in the future, the whole transformation of the energy system towards a more sustainable one is increasingly complex as various parts of the energy system, policies and the societal levels involved are more and more interlinked.

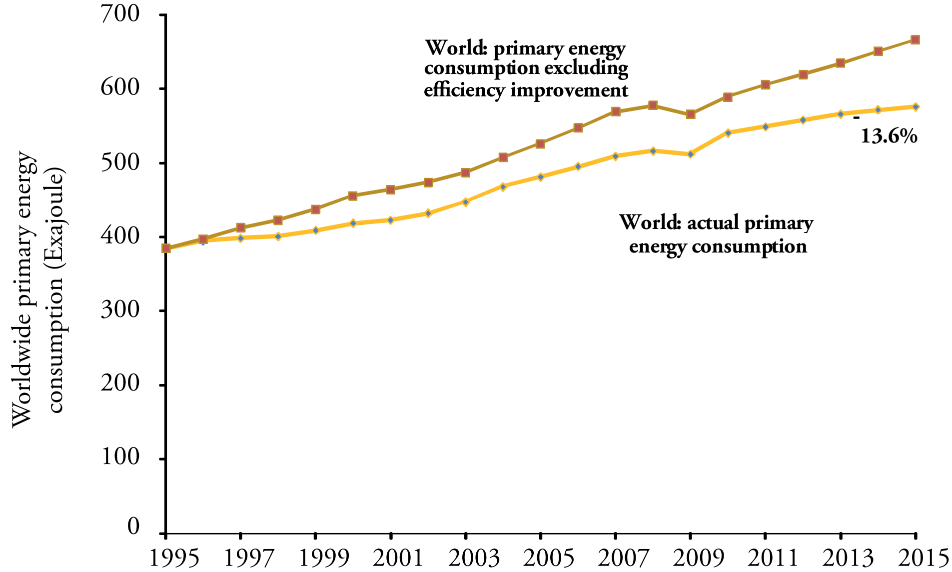
WHY –DESPITE INCREASING ENERGY EFFICIENCY– ENERGY CONSUMPTION IS STILL INCREASING WORLDWIDE?

Improving energy efficiency does not mean automatically that energy demand is decreasing. In many developing countries in an early stage, energy intensity may even have been increasing (not to talk about energy consumption), given the large need in an early stage to set up industries or provide first basic human needs. In more developed countries such as China, energy intensity is already considerably decreasing but not fast enough to curb energy demand. Finally, in the most developed countries such as the OECD countries, energy intensity is improving faster than activity levels are growing which implies falling energy demand. The IEA states that since 2007 the peak in energy consumption has been reached by OECD countries and that it is unlike to return to those levels in the future any more (IEA, 2016). This holds in particular for Europe who has reached its peak energy about that time also.

On a world-wide level, between 1995 and 2015, energy consumption has been increasing by 50% while GDP growth was 73% (Enerdata Global Stat, 2016). This shows that the main reason why energy consumption has not been growing even faster is due to energy efficiency. Without energy efficiency improvement, world energy consumption would have been by nearly 14% higher, as shown by the graph below.

Exhibit 1

Energy efficiency – the “first fuel”



Source: Own calculations based on data from ENERDATA Global Stat.

Despite this strong improvement in energy consumption by energy efficiency, it may nevertheless still increase further, mainly in developing countries driven by economic needs and lifestyle (see the following section). Population increase also plays a primary role. Though per capita income has greatly risen in large number of those countries, notably in China, the distance to the developed countries is still large. China alone produces presently in a quarter year 5 million cars and though it is unlikely that they will all be able to drive in the already now overcrowded cities, they may penetrate further the rural areas. OECD countries still use three times more energy per capita on average than developing countries (in 1995 this was still nearly five times more). It is unlikely that this level will remain as high as now in OECD countries, and it is also unlikely that developing and transition countries will reach the same level of consumption. If those human beings would need the same amount of energy as OECD countries, the world energy consumption would be two to three times larger than it is today. It follows from this, that in order to achieve targets on energy consumption and greenhouse gas emissions, technical energy efficiency improvement has to step up further but also that policies aiming at sufficiency strategies need to be stepped up.

Signs are increasingly showing nevertheless that countries like China are strongly stepping up their energy efficiency policies. China therefore may reach a peak in energy consumption soon (while some even think it has already reached the peak, given the less strong economic growth in recent times and given the weight put on energy efficiency in the national policy sphere).

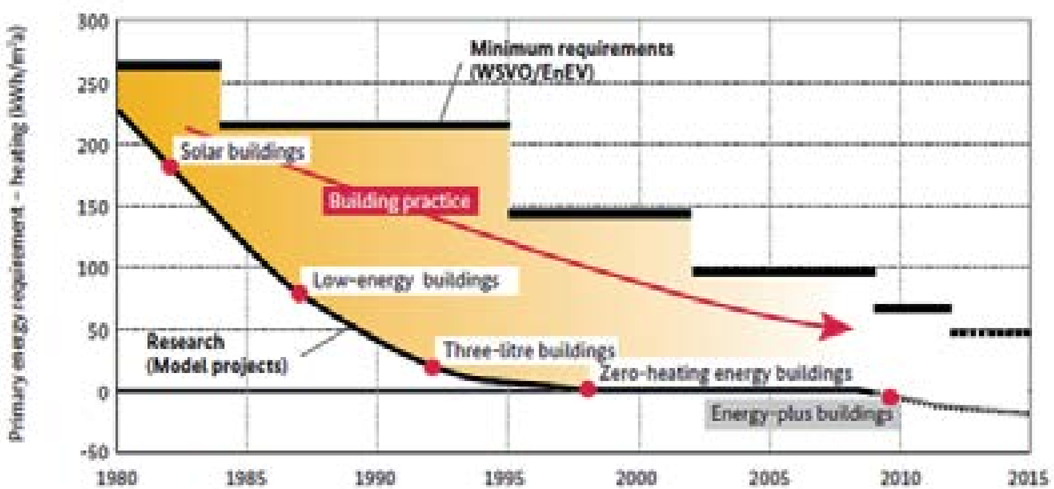
In the following section we illustrate the impact of lifestyle on energy consumption more in detail and argue why energy efficiency policies must also embrace sufficiency strategies more strongly.

ENERGY EFFICIENCY AND LIFESTYLES

In the past, though energy efficiency had been increasing in many areas, energy consumption was still increasing or has been hardly decreasing. Lifestyles are important contributors to this evolution. This is illustrated in this section more in detail with buildings. The following graph shows the improvements in building

Exhibit 2

Energy efficiency – the "first fuel"



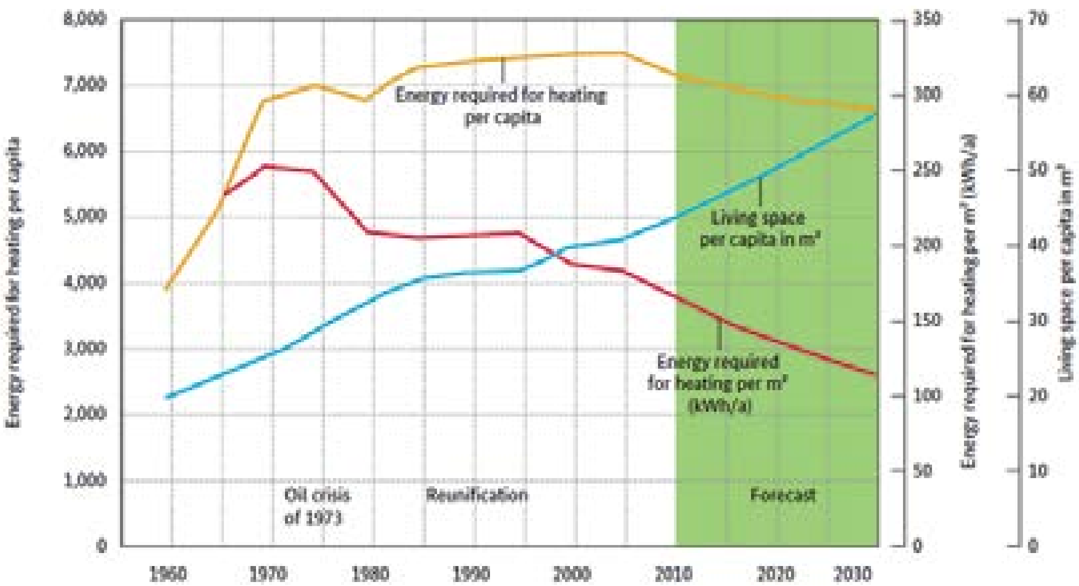
Source: Fraunhofer IPB, cited from the 6th Energy Research Programme of Germany.

regulation in Germany as compared to the average building of the sixties, which used more than 250 kWh energy per square meter and year to heat the building. Today, after many building regulations, standard buildings use only one fifth of that energy, and research pushes even more efficient regulation into buildings, up to Plus-Energy houses in the future, i.e. houses which produce more energy than they consume. Houses will become power generation centers on their own that could provide energy to other sectors such as the industrial sector.

Despite this amazing achievement in the energy consumption of new buildings, when it comes to the energy consumption of all our buildings we have hardly achieved any reduction per capita over the past forty years. How is this possible? The main reason are the increased surfaces available to each person in Germany. While the space heating need for the buildings has nearly halved per square meter, we have increased the space available to each person by more than a factor of two. In total, the overall consumption of buildings increased even slightly. A factor adding to this is that our room temperatures and heating periods have

Exhibit 3

Energy efficiency – the "first fuel"



Source: DETAIL Green Books, cited from the 6th Energy Research Programme of Germany.

been increasing over time: while in the sixties only a small number of rooms was heated, and only to 18°C and from mid-October to mid-March, today buildings are frequently heated in all rooms to 20-22°C with extended heating periods.

Only in the future it is expected that the technical improvements might outweigh the further expected increase in surfaces per person. In some more distant future, this may be enhanced by saturation effects (what is the benefit of living alone in a house of 200 square meters?) or by energy efficiency policies.

Another example of such negative impacts of our lifestyles are the size of cars (penetration of sports utility vehicles) and the distance driven, though the later tends to saturate, at least when driven by cars, due to the increased time used in transport. We tend to spend on average always roughly one hour in transport. By car we have a limited distance we can reach. Only high-speed trains may open up larger distances to users (and perhaps self-driving cars in the future which allow drivers to use the time more efficiently but then cost may be a limiting factor).

This shows that choices due to our comfort have extremely large impacts on energy consumption. Therefore limiting comfort factors (sufficiency strategies) may in the future need largely to contribute to climate mitigation policies and may form – in difference to today – an integral and accepted part of energy efficiency policies.

There are already a variety of policies today which impact on our lifestyles. They may be energy efficiency policies or policies from other fields. For example in Denmark when a car is purchased, it is taxed so heavily that the number of cars per 1000 inhabitants is considerably lower than in the rest of Europe. In France, a bonus-malus-scheme incites car buyers to buy cars with less CO_2 emissions and hence (frequently) less energy consumption. Taxation policies tax owners of large cars more strongly than other car owners, while persons who drive more pay more through higher fuel taxes. Owners of large buildings pay more that owners of smaller buildings or persons in rented buildings. This means that there are already a larger number of "sufficiency policies" which are accepted while others are not: Typically taxation policies are more accepted (though from time to time there are protests when taxation is felt as high) while regulation is felt as too interventionist (yet), and reserved to emergency cases. While during the oil price shocks in the seventies and eighties, regulation stipulated maximum room temperatures in buildings, this is hardly accepted or part of the energy efficiency policy portfolio today.

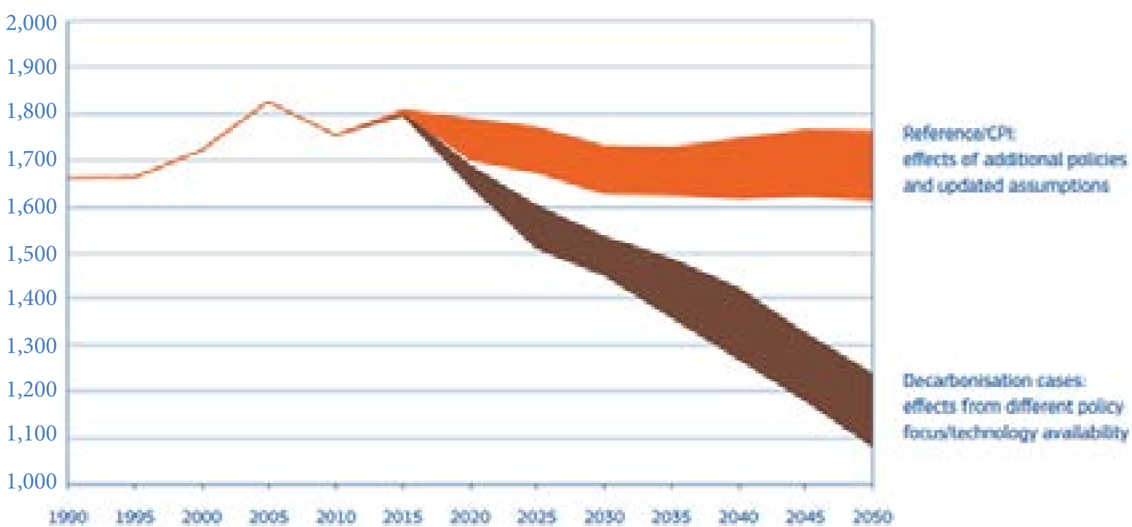
WHERE DO WE NEED TO HEAD TO FOR ENERGY EFFICIENCY? – A LOOK TO EUROPEAN ENERGY EFFICIENCY TARGETS

The exhibit below shows the trend where current energy efficiency policies bring us, which covers a range of stabilisation to -10% compared to present level. Though one has to doubt whether this reference reflects properly the efforts

Exhibit 4

EU Energy Roadmap 2050 – range in current trend (REF/CPI) and decarbonisation scenarios

(Million toe)



Source: EU Energy Roadmap to 2050.

already undertaken, as well as saturation effects in comfort factors and living styles, the necessity to reduce energy consumption by about 50% as compared to present levels by 2050 is without doubt. This is the range required to achieve overall a reduction of greenhouse gases by at least 80%, if not 95% as requested by the EU Carbon Roadmap 2050.

FURTHER RADICAL INNOVATION IN ENERGY EFFICIENCY POSSIBLE AND NECESSARY

The above has shown that it is necessary to step up energy efficient solutions to compensate for a large degree for lifestyle impacts in order to achieve the requested reduction of energy consumption. This forces engineers to find innovative and intelligent solutions that use much less energy.

There are many examples of this type which need to be enhanced and expanded:

For example, as mentioned previously, housing envelops have already reached the stage where the building may be a producer of energy rather than a consumer of energy. The main issue of research is here how to make those buildings cheaper, and the issue of energy efficiency policy is how to have those building penetrate faster. Nevertheless, much more radical changes in energy efficiency could occur further in buildings through materials whose properties can be dynamically adapted to the environment (outside temperatures, incident light).

Why does a pixel on a screen need power even if nothing changes?

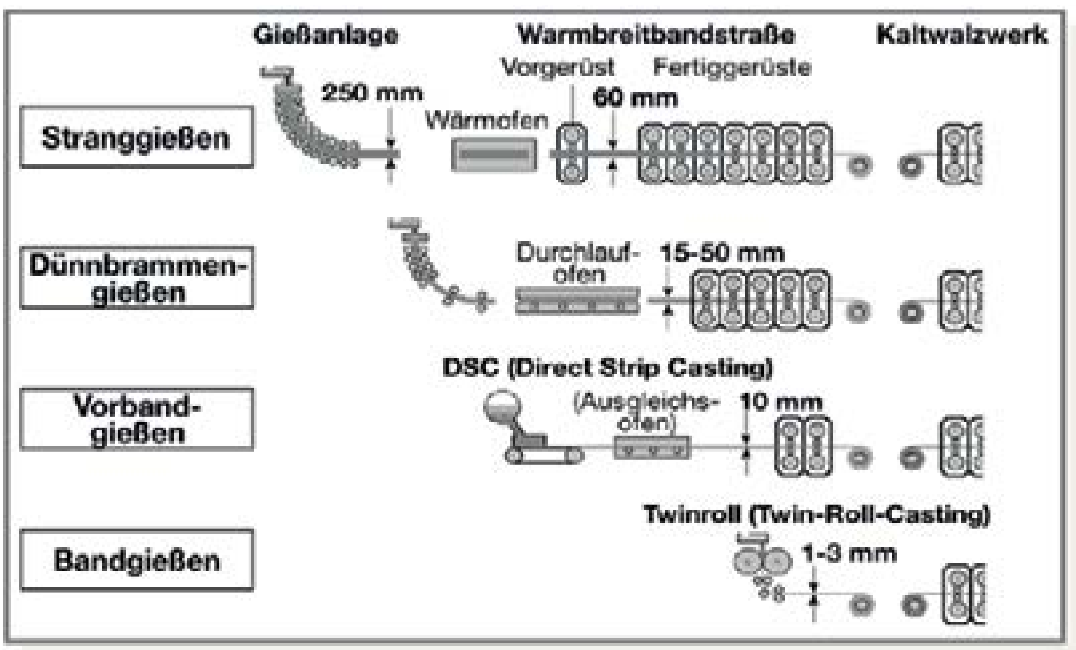
Today a television of computer screen uses electricity even if nothing changes on the picture. With electrophoresis displays the pixels can be maintained in a bistable state and rest there until they are changed again. This has the advantage that they only consume little electricity, as it is only need to change the state of the pixel. This is particularly relevant for battery driven displays.

New bi-stable LCD technology uses 99% LESS power than traditional LCDs: Traditional LCD requires 25-50mW of constant power to display even a static, unchanging image. Bi-stable LCDs can display the same information for over a year after power has been turned off with just a onetime 2-5second burst of 10mW of power.

In cement making new processes relying on a different chemistry and working at lower temperature may considerably lower energy consumption for the process. Cement represents 5% of worldwide CO_2 which is a larger contribution than air traffic. The Karlsruhe Institute of Technology KIT in cooperation with industry develops Celitement: a new hydraulic binder based on previously unknown calcium hydrosilicates that harden after gauging with the formation of calcium silicate hydrates (C-S-H phases). The material is produced in a two-stage process with maximum temperatures of around 200 °C (while the present processes burn clinker at 1400°C. This implies a sharp reduction in the consumption of lime

Exhibit 5

Shortening of process chains by more efficient rolling procedures



Source: Aichinger and Steffen (2006).

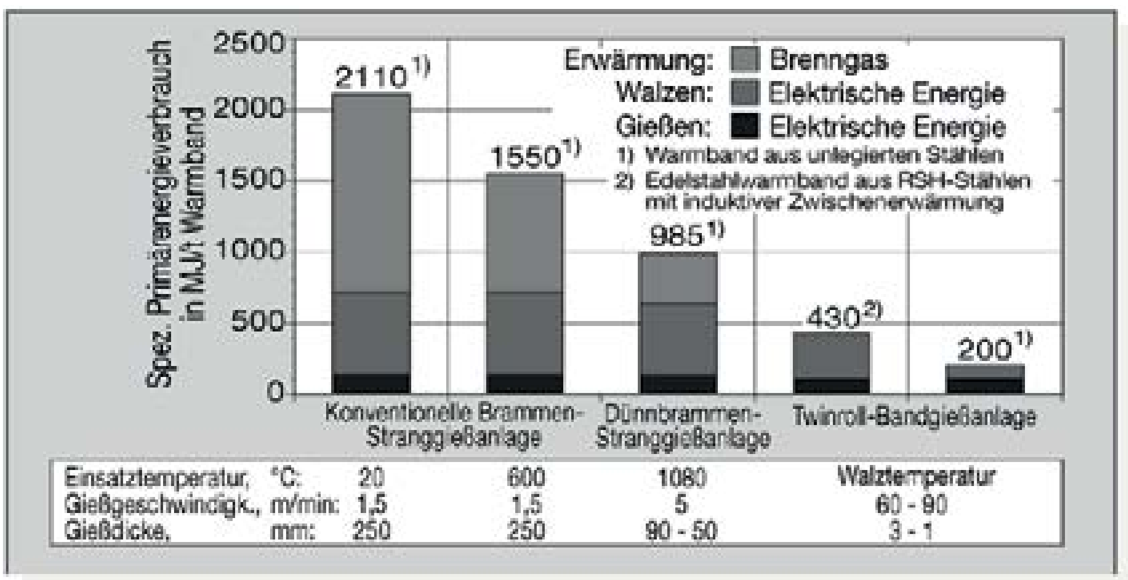
and energy, and saves up to 50% of the CO_2 emissions in production. However, the way to commercial application is still long.

In steel making near-end shape steel production can reduce today's energy consumption by up to 90% (as multiple heating up and cooling down of the materials is avoided); the electricity for the rolling can be reduced by two thirds (given the fact that the length of the rolling street can be reduced largely as illustrated by various steel rolling processes).

The path to such radical energy efficiency improvements is long: the larger the process, the longer. But many examples from practice show that, when energy efficiency is put in the focus. This is well illustrated by specific case studies from the industrial sector (taken from the annual dena energy efficiency awards to industry, see references) which illustrate on one hand the large potentials, and on the other hand the important role of the company management and how it is able to motivate the staff and integrate their enthusiasm.

Exhibit 6

Specific primary energy consumption for the process step from liquid steel to hot rolled steel for different process technologies



Source: Aichinger and Steffen (2006).

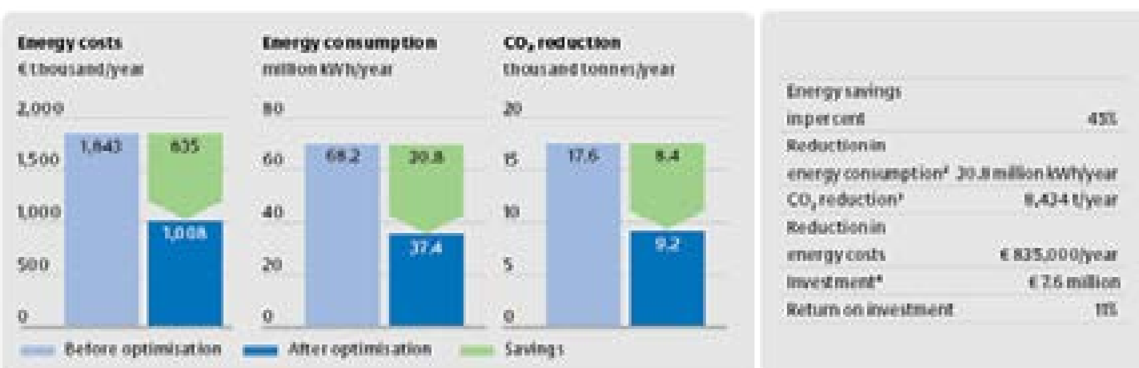
Example 1: Aluminium Norf GmbH – Process optimisation in the metal industry (dena energy efficiency award 2014)

Aluminium Norf GmbH pursued the goal of moving aluminium coils carrying the heat from the cold rolling process for further processing in furnaces without a loss in temperature. An approach contrary to the previous practice of cooling aluminium coils heated from the rolling process to below 60 degree Celsius and then, for safer process conditions, heating them up again to an annealing temperature of 480 degree Celsius. To achieve this goal, the company established a plant concept never previously applied in industry and realised the large-scale use of an energy-efficient annealing furnace plant with protective gas preheating and a primary control concept. The thermal state of each aluminium coil is computer controlled along with the energy-efficient operation of the furnaces with individual burner zones. A temperature measuring concept utilises the individual burner control with a simultaneously reduced number of burners.

Selected energy efficiency measures:

- Utilisation of the residual heat from the rolling process during annealing through the use of hot coils
- Protective gas preheating with the aid of exhaust gases
- Computerised control for each aluminium coil
- Equipping all fans and blowers with variable-speed drives

Exhibit 7



Source: German energy efficiency agency dena (energy efficiency award).

- Sealing and insulating the furnaces

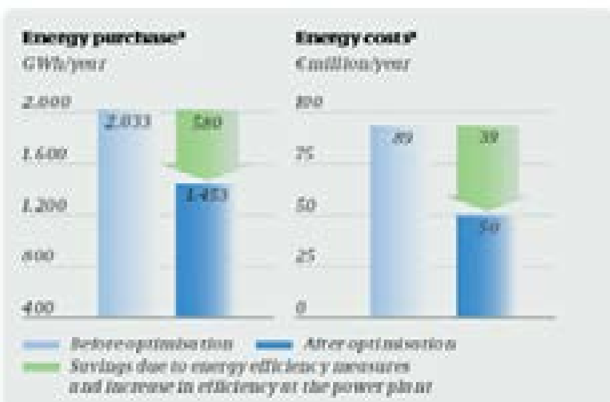
Example 2: SALZGITTER FLACHSTAHL GMBH, an international manufacturer of connection technology (dena energy efficiency award 2013)

Salzgitter Flachstahl GmbH produces at the site Salzgitter as the largest single entity of the Salzgitter AG flat steel products. About 4,800 employees produced 2012 around 4.5 million tons raw steel (turnover of 2.8 billion Euro). For a structured administration of all single measures a database was established in which all ideas and measures of the Project “EE EnergyEfficiency“ were included and described. By that the staff is continuously informed about the project progress and motivated for own ideas with respect to a lower energy consumption. By March 2013 in total 234 energy efficiency measures had been integrated in the database and 118 had been put into practice.

Selected energy efficiency measures:

- Use of pure oxygen to reduce the use of fuels in furnaces
- Renewal of the regulation for heating of the production facility cold flat products
- Use of recuperators in high temperature processes
- Modernisation of the blast furnace gas power plant

Exhibit 8



Saving	
- Energy efficiency measures and increase in efficiency at the power plant	580 GWh/year
- Additional blast furnace gas obtained due to increase in production	316 GWh/year
Total	**896 GWh/year**
Percentage saving	
Energy efficiency measures and increase in efficiency at the power plant	29%
CO_2 reduction	238,063 t/year
Reduction in energy costs	€28.8 m/year
Investment	€264.6 m
Return on investment	14% p.a.

Source: German energy efficiency agency dena (energy efficiency award).

- Optimisation of the switching off of plants while idle
- Running conveyer belts depending on the need
- Introduction of frequency converters to optimise motor use
- Optimisation of compressed air system and lighting of the production facilities

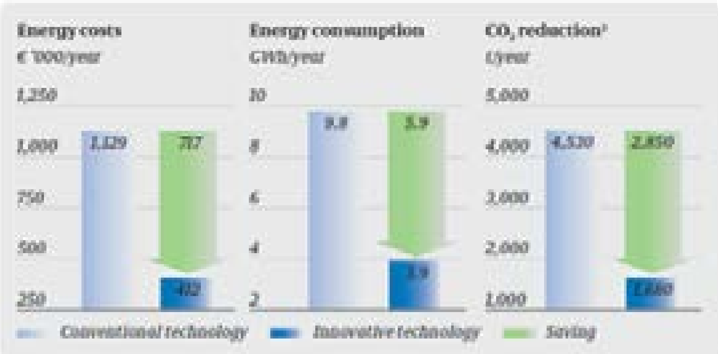
Example 3: SCA Hygiene Products, providers of measurement equipment (dena energy efficiency award 2012)

Endress+Hauser Conducta GmbH + Co. KG is one of the world's leading providers of measurement equipment and complete systems for liquid analysis. The company manufactures with more than 600 employees. The company's environmental management has been certified according to ISO 14001 since 2009; its energy management has been certified according to ISO 50001 since 2012.

Selected energy efficiency measures:

- Heating system with CHP station and gas-fired condensing boilers
- Ground collectors for generating ventilation heat and cooling
- Activated concrete core for heating and cooling
- Use of a free cooler for generating cooling
- Energy-efficient ballasts and light sources

Exhibit 9



Percentage saving	60%
Reduction in energy usage	5.9 GWh/year
CO_2 reduction	2,850 t/year
Reduction in energy costs	€ 717,000/year
Investment	€ 1.5 m
Return on investment	48%

Source: German energy efficiency agency dena (energy efficiency award).

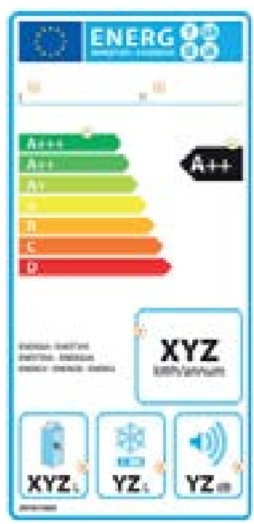
- Reduction in the number of printers and virtualisation of the servers
- Electric vehicles

WHERE ARE THE FUTURE LIMITS TO ENERGY EFFICIENCY?

The previous section has shown that enormous energy savings have been achieved in some energy uses. By the middle of this century 50% reduction in energy consumption is required. In many sectors the long-term potentials are there for a strong improvement in energy efficiency but they require important efforts to research and implement such improvements.

The whole *building sector* in Europe may at the end reach a nearly zero energy level. The European energy efficiency policy has this in focus for the middle of the century but the path to that moment is still very long. Many of the buildings that will be existing in 2050 are already around now and require substantial improvement. The thermal rehabilitation of buildings must be largely stepped up to reach such a level. At present in many countries in Europe it is less than 1% annually and must reach levels of the order of 2-3% annually.

Electric appliances have made enormous progress in the past 20 years, bringing the average device from a D level around 1995 to A++ or even A+++ on the European labeling scale. A+++-refrigerators today use 60% less energy than A-refrigerators, which in turn uses 50% less than the D-refrigerators of the nineties. Hence A+++-refrigerators consume only 30% of the electricity compared to some 20 years ago. Further progress is bound to more radical improvements *(e.g.* dry cleaning of clothes). IT appliances, in particular screens as illustrated above, have still a large potential for energy efficiency, well in excess of 50%. Stand-by consumption was largely reduced by the electricity efficiency standards under the Eco-design directive. Old appliances had stand-by consumption in the order of 7-10 W while present standards are more than ten times lower. Too bad nevertheless that such appliances were already available in the early nineties but did not make it to the consumer due to a lack in policy making in that field.



The *transport sector* sees on one end a strong drive towards electric vehicles which will bring energy consumption further down. Lightweight cars could reduce energy consumption to 1 liter per 100km. Trucks are more difficult to reduce energy consumption but presently new concepts in the form of overhead electricity cables for truck arise. Those could be able to open also for trucks the benefits of electric drives which is not possible with battery driven vehicles so far. Even more difficult is energy efficiency in air traffic: although the economic pressure on companies is very high to reduce energy consumption, given the international environment and the high share of energy cost in overall running costs, there is not radical change ahead but continuous progress. On a technical scale the Solar One flight around the world has shown the scope, but this is far from being realizable for large passenger aircrafts by the middle of the century. Reduced air friction has continuous scope of improvement. Scale effects (larger planes) have spurred larger improvements in the past. But in future this may be more limited as less routes offer large enough passenger potentials, nor are airports easily adapted. In total energy demand growth for air travel is still not yet compensated by energy efficiency improvements. Space craft tourism may offer further scope for energy demand though at present it is only open to smaller groups of the society.

SEVs* instead of SUVs….

- L1 (2009: diesel plug-in-hybrid 0.99 L/100 Km (238 mpg_{-us})
- 381 kg, twin-cylinder, common-rail turbodiesel, 10.5 kW E-motor, 800 cc
- 158 km/h (99 mph)
- lightweight materials 650 km using 6.5 l.

- XL1 (2011): diesel plug-in hybrid 0.9l/100 km (260 mpg-US)
- 795 kg, two-cylinder turbo-diesel 800 cc, 35 kW. Lightweight materials

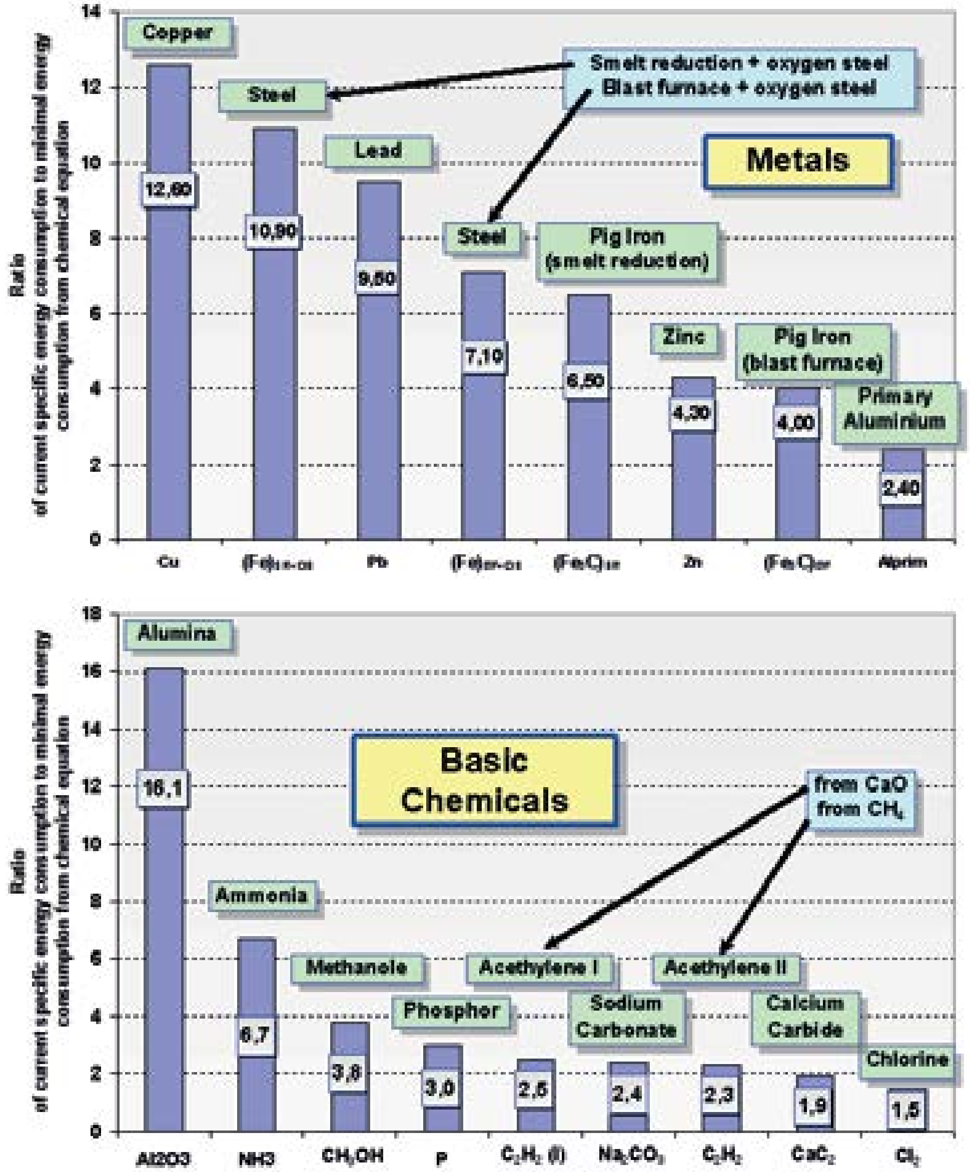
Note: *Super Efficient Vehicle.

Source: Wikipedia.

The industry sector is more difficult to tackle in terms of long-term potentials for energy efficiency. The limits of energy efficiency in industrial processes are large dominated by the chemistry of a given process. Present processes are still,

Exhibit 10

How much more are large industrial processes presently consuming than their theoretical minimum energy consumption



Source: Fraunhofer ISI.

nevertheless factors away from their theoretical limits: typical metals a factor 2 to 12, typical chemicals a factor 1.5 to 16, as illustrated with the following exhibits. This does not mean that these potentials are easily accessible given that they have been subject to much research already in the past. However it shows that there is a scope and individual processes, when radically thought new in one or the other manner, have brought about substantial energy efficiency improvements. This may involve combining processes which use energy and others that consume energy in the same reaction vessel (case of the QSL process for lead smelting), changing the chemistry for the process (this is the target of new cement making processes) or at the end move to other, less energy intensive materials. The time frame for developing such solutions and bringing them to a marketable product, however, should clearly not be underestimated.

Dramatic cuts in energy consumption by a factor of 2 have been shown possible by highly decorated industrial processes. For example, the 1st prize 2009 in the award for innovative climate and energy solutions iku in Germany organised by Fraunhofer for the German Industrial Head Organisation BDI and the German Ministry of the Environment goes to…...

A new furnace design for aluminium working: 50% less energy consumption by using superconductors for magnetic heating.

Source: Award for innovative climate and energy solutions iku (Germany), Zenergy Power.

A second way of saving energy is through material efficiency: Example from the Deutsche Mechatronics GmbH, Mechernich: Gluing metal sheets instead of using massive materials. In printing drums transport the freshly printed paper and the printing colour should not touch the drums. High precision is required.

Instead of producing the drum out of massive material the company produces the drums by gluing metal sheets. Material savings are 48%, additional energy savings through reduced weight for the rotating parts.

Source: German material efficiency agency demea.

However, improving energy efficiency in industry is not only a technical matter; it is also a matter of overcoming the barriers in companies. For that purpose so-called Learning Energy Efficiency Networks (LEEN) have been set up in Germany that shall overcome the transaction cost barrier in companies. Innovative companies take these networks as a chance to increase energy efficiency and, at the same time, improve their own competitive position. By learning from each other a multitude of companies cooperate in order to save energy in the most cost-effective way. The main starting points of the cooperation in the networks are efficiency improvements with respect to cross-cutting technologies *(e.g.* compressed air systems, combined heat and power systems, electrical drives).

Table 2

Examples from the LEEN Networks

Modernisation of a compressed-air system One-off investment: €70,000 Energy savings: 9 % p.a. Cost savings: €60,500 p.a. Payback: 1.2 years	*Modernisation of a heat exchanger* One-off investment: €42,000 Cost savings: €58,600 p.a. Payback: 0.9 years
Exchange of 250 lights in the production area One-off investment: €11,500 Energy savings: 48 % p.a. Cost savings: €7,100 p.a. Payback: 1.6 years	*Heat recovery concerning a compressed-air system* One-off investment: €45,500 Cost savings: €46,600 p.a. Payback: 1 year

Fuente: LEEN.

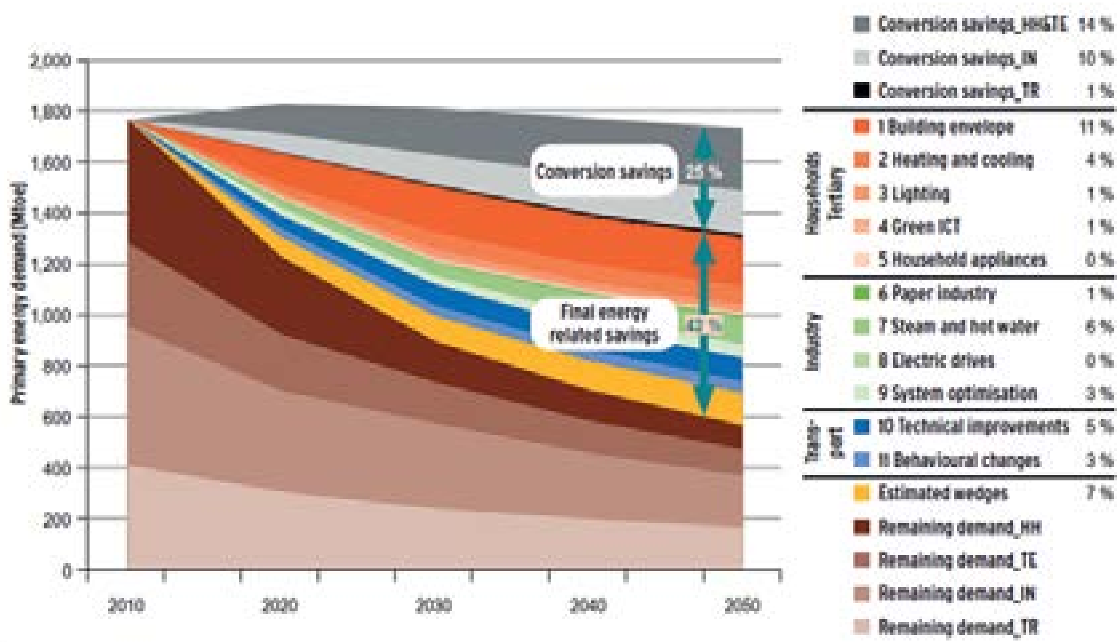
The scientific evaluation of 30 networks in Germany identified approximately 4,000 profitable measures (average internal rate of return, IRR: about 35%; average payback period: about 3 years). The evaluations showed that companies cooperating in networks increase their efficiency twice as fast as the German industrial average.

OVERALL – HOW MUCH POTENTIAL IS OUT THERE IN ENERGY EFFICIENCY IN EUROPE?

Based on the previous view on energy efficiency improvements possible at the long-term in all sectors, the question arises, how much potentials for energy efficiency exist compared to the target of 50% improvement in energy consumption by the middle of the century? The exhibit below shows the answers provided to this question by a detailed energy systems analysis looking in every sector to the potentials available for energy efficiency up to 2050.

Exhibit 11

Overall primary energy savings potentials by 2050 in the European Union



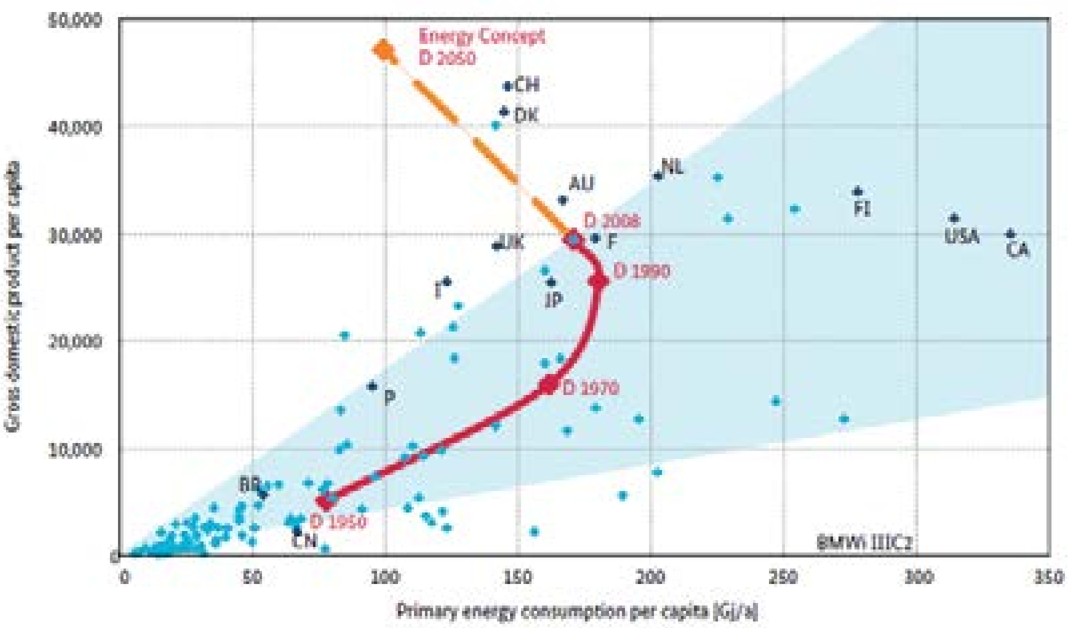
Source: Fraunhofer ISI (2014).

These potentials are realistic potentials, as they do in general respect that people will only invest in new technology after a reasonable lifetime of the products and processes. All in all, the analysis shows that taking energy efficiency potentials in the demand side (final energy related savings) and the supply side (conversion sector savings) together, including their interaction, savings of two thirds of present energy consumption are feasible. This is largely in excess of the required 50% reduction in Europe.

Another way of looking to the energy efficiency challenge is to compare the "energy efficiency path" of a country like Germany, in the past and required in the future up to 2050. It shows the radical change in path required for the 2050 target when comparing with countries that are consuming while having reached higher wealth levels.

Exhibit 12

Economic development and energy consumption in selected countries in 2008, plus the course plotted by Germany's energy sector from 1950 to 2050

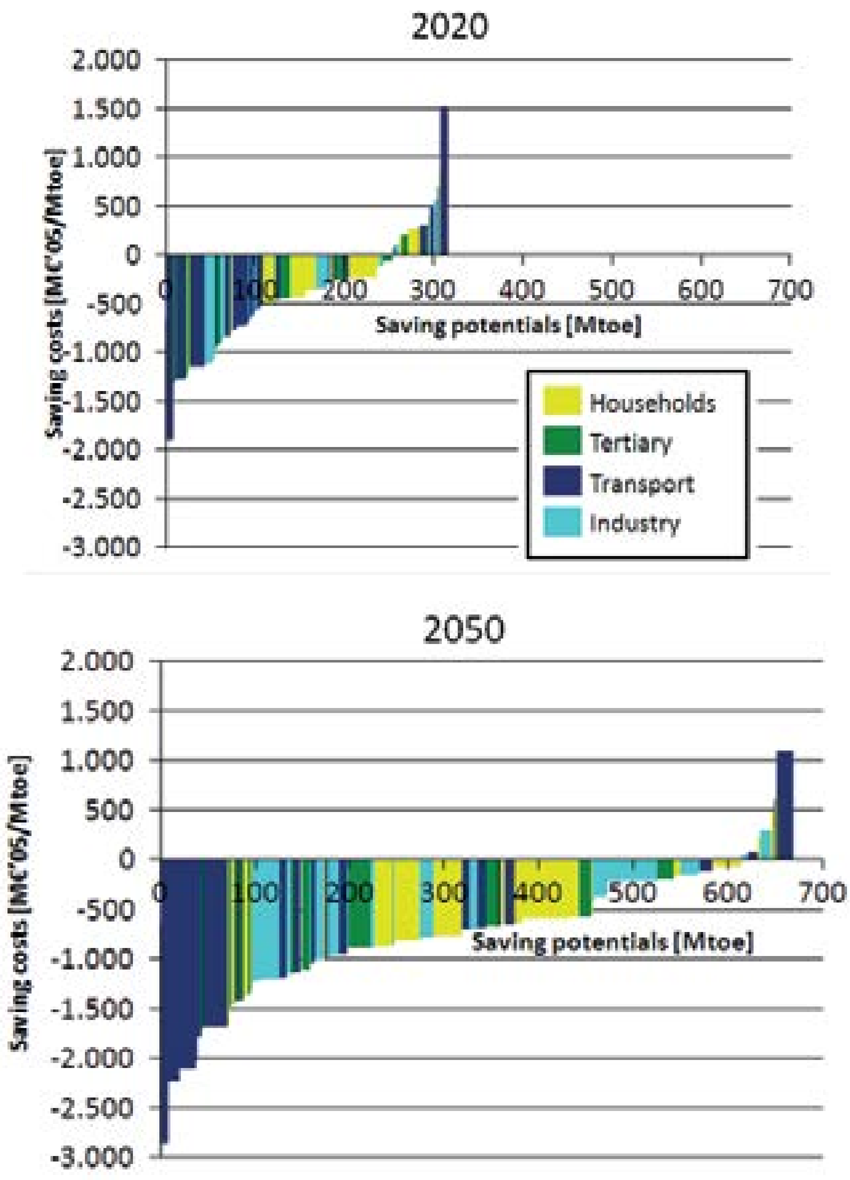


Source: 6th Energy Research Programme of Germany.

What is more, these saving are economic. This is illustrated with the following exhibits showing so-called cost-potential curves (they show which energy efficiency potentials are available at which cost). At some point in time potentials get more

Exhibit 13

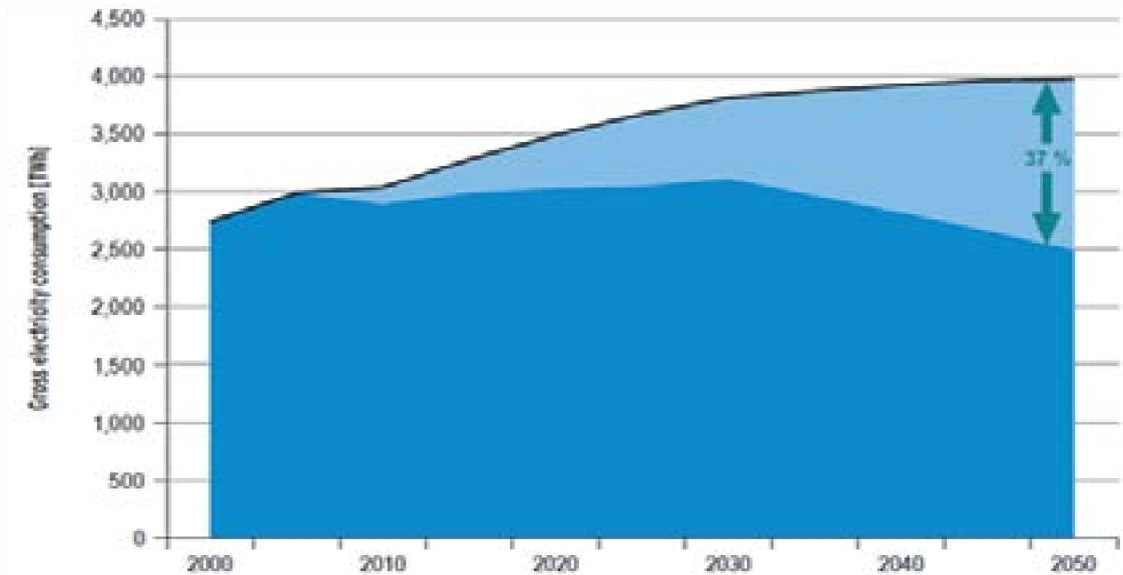
Cost-potential curves for the EU in 2020 and 2050



Source: Fraunhofer ISI (2014).

Exhibit 14

A stabilisation of the European electricity demand on today's level is feasible



Source: Fraunhofer ISI (2014).

expensive: The negative part of the curve illustrates energy efficiency options where monetary savings (from saved energy) exceed investment cost, which is true for the larger part of the two curves for 2020 and 2050. The comparison of the two curves show that energy potentials become larger with time (which is due to the fact that they need time to penetrate the market), second they become less expensive which is due to the fact that technologies which are produced in large amounts offer scale and learning effects. For example, today a double glazed window is not more expensive that a single glazed window used to be.

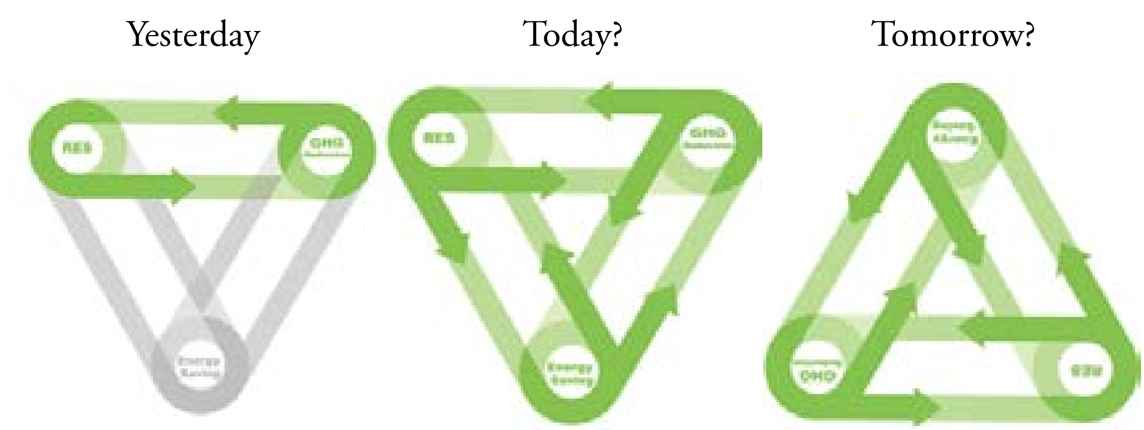
A particular effort is necessary to curb electricity consumption. Here a 50% cut is not feasible until the middle of the century, given the fact that large new users (electric cars, heat pumps) may enter the market. Nevertheless, even in that case a decrease in consumption is possible by energy efficiency policies by at least 10%.

EUROPEAN ENERGY EFFICIENCY POLICY IN THE FRAME OF EUROPEAN ENERGY AND CLIMATE POLICY – WE NEED TO PUT THINGS ON THE HEAD

How can the potentials for energy efficiency identified in the previous sections be realised? Some people (including the author) say "Energy efficiency policy" has been the step child of energy policy. This is less true with respect to individual instruments such as energy efficiency labeling and standards which have been one of the most successful policy examples in the energy field.

This is nevertheless true when it comes to the position of energy efficiency in the total architecture of energy and climate policy. European Energy and Climate policy was dominated by the target triad for 2020 (20% greenhouse gas GHG emission reduction, 20% renewables RES target, 20% energy efficiency EE target. However, while the targets for GHG and RES were binding, EE targets were indicative. Today, there is a reform of the EU Energy Efficiency Directive under discussion which might bring about a mandatory target for energy efficiency also. However, the true importance of energy efficiency including for RES and GHG has been uncovered with the recently developed "Energy Efficiency First"-Principle which has been laid down in the new EU Energy Governance scheme which shall shape future energy and climate policy. At the end this puts the target triad "head up", with energy efficiency at the top of the target pyramid.

Climate change architecture of European Energy and Climate policy…



It is too far reaching here to list all European energy efficiency policies in detail. The MURE database on energy efficiency policies (www.odyssee-mure.eu) is listing 2400 of them. A detailed analysis is provided in the recent report by the Odyssee-MURE project which gathers energy efficiency agencies in all EU Member States.

EFFICIENCY – AN INDISPENSABLE ELEMENT OF A SUCCESSFUL EUROPEAN POLICIES FOR CLIMATE PROTECTION, SUPPLY SECURITY AND COMPETITIVENESS

There are huge saving potentials available by the middle of the century (up to two thirds, if conversion sector efficiency is included), large enough to cover the 50% reduction target required for energy consumption in the light of greenhouse gas reduction requirements (as well as for the reduction of important dependence and for the enhancement of European competitiveness).

However, one saving option is not just like another: Some saving options trigger high demand reductions whereas others create particularly high monetary benefits: Overall cost savings of up to 500 billion €'05 annually by 2050 have been seen as possible.

They need specific energy policies to address the barriers the policies are facing. Exploiting the saving potential requires concrete political action addressing specific energy demand branches and considering concrete efficiency technologies.

Renewables and efficiency – together they are more effective than each alone. "Efficiency" also concerns the energy supply side which can have a large impact on primary energy savings (25% in 2050). This adds to the large saving potentials on energy demand side. Most profitable is to pursue a combined strategy of expanding renewable capacities as well as pushing efficiency measures.

Efficiency – yes this has been the stepchild of current energy policy and energy research: up to now the topic of efficiency has been underrepresented on the political agenda despite the cost-effectiveness of most of the technologies. The level of detail regarding efficiency has been much lower than for energy supply side.

This needs giving a higher priority on the political as well as the scientific agenda. Constructing a common target frame for EU energy and climate based on the "Energy Efficiency First" principle is the basis for energy efficiency to unfold.

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