Reducing energy use – some preliminary notes

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The level of energy use is determined by several factors, e.g., how efficiently energy is used, organizational issues that have an impact on energy use, population size, life styles and prevailing income levels. Here we will look at options to reduce energy use. The actual options vary, e.g., technologies to improve energy efficiency in cars are different from the technologies to reduce losses in electric engines. This text will focus on some general features.

Energy efficiency

Below, we will discuss energy efficiency from a technical perspective, and look at how energy is supplied, distributed, converted and used. In order to understand the discussion about the potential for improved energy efficiency it is important to distinguish between the theoretical, technical, and economic potential.

<u>Theoretical potential</u>

The *theoretical potential*is in many cases very large. It is even difficult to establish a lower limit for the energy supply that is required to perform a certain task. This means that the theoretical potential to improve energy efficiency is almost 100% in many cases, i.e., *in many cases the theoretical minimum amount of energy that is needed to provide a certain service is essentially zero*. For instance, the minimal energy supply required to maintain the indoor temperature in a house at a certain temperature (which is higher than the outdoor temperature) is equal to the losses. But the losses can be made however small you want them to be, by adding more and more insulation.

The same reasoning can be applied to the transportation sector. The theoretical minimum energy supply that is needed to move goods or a person from one place to another is the difference in potential energy (which is zero if the height above sea level is the same). In theory, energy is only needed to accelerate the goods or the person, but that acceleration energy can be recovered when braking. Energy is also needed to counteract friction losses (against the air and the road). However, since the speed could be arbitrarily low, it means that friction losses and acceleration energy could be made arbitrarily low.

Another example is chemical processes. Here energy (or exergy to be more specific) is needed to raise the chemical potential of certain materials, for instance, reduction of iron ores into metallic iron, or bauxite into metallic aluminum. In this case it is possible to establish a minimum theoretical energy requirement that is larger than zero, but in theory this amount of energy could be released again if the iron or the aluminum is re-oxidized. However, these reactions would have to be done in a reversible manner, and that would take an infinite amount of time. Thus, if the processes should occur at a certain speed, entropy production will occur, and exergy loss (dissipation of energy) is a fact. But, as was the case with the transportation sector, it means that it is not possible to establish a lower limit.

<u>Technical and economic potential</u>

The *technical potential* is of course more limited. Analysts are not always clear about the exact definition of this concept. Sometime reference is being made to what could be expected to be achieved at a certain point in time, sometimes focus is on best available technology at present. It is, however, not clear that the best technologies will ever be employed at a large scale since they may be much more costly or difficult to use than competing technologies. Well-insulated houses is a typical example. Here, the cost of additional insulation will be compared with the additional saving on energy, and if the cost of energy is low, then the demand for insulation will drop.

For this reason, the *economic potential* of various technologies is often discussed. The economic potential does not only depend on the cost of the technology, but also on the interest rate, and present and expected energy prices. If the cost of energy is expected to jump in the future, the economic potential for energy efficiency improvements will increase.

It has been shown that technologies that have the economic potential to be widely used nevertheless fail to be adopted on a large scale. This is often explained by the fact that incentives for energy efficiency sometimes are distorted (those who rent apartments are different from those who own them), the possibility that consumers have inconsistent requirements on pay back times, e.g., in certain studies consumers were found to require internal rates of returns of as much as 60% have been reported while the same consumers at the same time save money on bank accounts with interest rates less than a few percent, that consumers lack of information about more energy efficient products, by the existence of minor differences between the products that consumers paid more attention to than what was initially believed.

In some analysts views, these barriers can be removed at rather low costs. This would then imply that substantial carbon abatement could be achieved at low costs. Others claim that there are substantial costs associated with the removal of these barriers, and that that explains why several energy efficient technologies are not adopted by the market.

Historic and future trends in energy efficiency and energy intensity

Energy efficiency has generally increased over time. Typical examples can be found from electricity generation, i.e., the efficiency by which thermal energy is converted into electric energy, and process industries in general, e.g., steel and aluminum production. Electricity generating efficiency in the beginning of this century was as low as a few percent, whereas conversion efficiencies above 50% are common for natural gas, and new and advanced coal fired power plants almost reach that level. Further improvements can be expected. For steel making, a similar pattern applies. These improvements have been driven by attempts to increase profits: since energy inputs make up such a large share of the cost of the final product (electricity or steel) there are strong incentives to economize on the fuel use.

In cases where energy costs are minor (in relative terms) much less efforts have been put into improving energy efficiency. Overall energy efficiency in cooking increases when shifting from tree-stone ovens to gas ovens, but drops when shifting to electric ovens. Similarly, the fuel consumption of a typical car in the 30s was 6 litres of gasoline per 100 km, which is generally lower than present day cars. This does not mean that energy efficiency has dropped. Rather, engine energy efficiency improvements have been used to increase weight and performance characteristics.

Governmental and public perception about energy issues are also main drivers of the uptake of energy efficient technologies. During the oil crises of the 70s the adoption of energy efficient technologies was not only speeded by higher energy prices but also by the introduction of energy efficiency standards (for instance, for buildings and household appliances) and voluntary agreements between the government and industry.

This impact of higher energy prices and concerns about energy security and scarcity is clearly seen in the energy intensity records over the past century. There has been a consistent decline in energy intensity, i.e., energy use divided by GDP, over the past 100 years in most countries, but this decline was much faster following the oil crises 73 and 79. Since the collapse of the oil prices in 1986, energy intensity has continued to fall, albeit at a slower rate.

Observe that energy intensity is not a direct measure of energy efficiency, since the former measures aggregate changes in the economy. Structural changes in the economy, e.g., the emergence of a rapidly growing software industry, might trigger faster GDP growth rates without triggering energy use. In such a case, energy intensity would drop even if energy efficiency in all sectors might be constant.

The extent to which more energy efficient technologies will be adopted by the market, depends largely on the future price of energy, government policies to regulate energy efficiency, voluntary commitments by industries as well as consumers' preferences for energy efficient products. Incentives for private manufacturers to develop more energy efficient technologies in industry depend largely on the same factors as those mentioned above, as well as public R&D on energy efficiency.

Organizational changes and energy efficiency

Organizational changes to improve energy efficiency could involve a change in the transportation system towards trains and ferries. Public transportation systems could be improved so as to play a more important role for commuting and personal transportation. We could also reconsider the way cities are planned and where production facilities are located. This is particularly important in developing countries where new infrastructures are emerging. Basic infrastructure is very long lived, and making the right choices now could make these developing country societies less energy intensive for a long time to come. Using information technologies, we could work more at home and thereby reduce personal transportation, but it is far from certain that such an outcome will materialize. Information technology also makes it easier to get in touch with people far away, and this may contribute to more long-distance travelling. Other examples include increased recycling rates of steel and aluminum. This would save substantial amounts of energy.

One "organizational" change, which is as much a pure energy efficiency measure is co-generation, i.e., the simultaneous production of heat and power. All too often, electricity is produced in power plants with the waste heat emitted to the surroundings. However, this heat can in many cases cost efficiently be used to supply heat (for space heating) or process heat (for industrial applications). In this way, the overall energy efficiency, i.e., energy supplied (electricity + heat) divided by energy inputs could be as high as 90%. Co-generation is by many seen as a key technology for reducing CO_2 emissions in the near-term.

<u>Rebound effect</u>

Finally, if energy efficiency improves, there is a drop in the cost of energy services for consumers. There is a risk that this reduced cost leads to higher consumption levels of the energy service. For instance, as electricity production became more energy efficient over the past century, the price of electricity dropped. This has clearly lead to an increased use of electricity. As noted above, energy per GDP has dropped over time, but electricity per GDP has increase consistently over the last fifty years or so. Similarly, if cars suddenly were twice as energy efficient, the actual use would most likely increase since driving costs would decrease.

There is considerable debate about the magnitude of this so-called rebound effect. One of the reasons why it is difficult to establish its magnitude, is that it is difficult to isolate the impact of lower energy prices from other factors, such as the emergence of new household appliances and higher income levels. As a general rule of thumb though, it may be stated that the lower the relative energy cost the lower the rebound effect. For instance, electricity costs for using computers are small, and making them twice as energy efficient is not likely to increase the use of computers very much.

Population

Although policies that reduce population growth are rarely discussed in the context of climate change, it could be an important policy option. The global population just reached 6 billion. Near-term projections are rather robust and can only be marginally affected by family planning policies. But, over the next century, small changes in population growth may compound to differences in global population by almost a factor of two. For instance, some scenarios suggest that the global population by the year 2100 could end up at 7-8 billion whereas others suggest 15 billion people.

A world with 15 billion people is likely to have higher carbon emissions than a world with 8 billion people. But, carbon emissions are not likely to be twice as high since most of the population growth is expected to occur in developing countries where per capita use of energy and CO_2 emissions are much lower than in industrialized countries.

Further, concerns about climate change should not be the main driver for population policies. Rather, governments should work to improve maternal and infant health care, the status of women and the level of education, in particular amongst women. It has been experienced that such measures have led to reductions in fertility rates.

Sometimes, but not always, these advances have come about with higher income levels, but they have also been reached in regions where GDP per capita is very low, e.g., in the state of Kerala in the southwest of India. This points to the fact that income growth is not a necessary requirement for achieving a reduction in fertility and infant mortality rates.

Finally, lower population levels would, in turn, bring about many other positive effects: the pressure on the local environment in poor countries (e.g., water resources, forests and soils) may be relieved and the nutritional status may be improved if the number of small children drops. And it would also relieve, to some extent, pressure on global commons, such as the climate.

Income per capita and prevailing life styles

The main reason for the higher energy use and associated carbon emissions in USA, Europe and other OECD countries is the higher levels of income that prevail in these regions. Although policies aiming to reduce income as a means to obtain lower carbon emissions are not being discussed in the policy making community, there is a general acceptance that the main driver for the increasing carbon emissions in most, if not all, countries of the world is the continued economic growth. Thus, green political parties and environmental organizations have criticized the prevailing focus on economic growth.

Clearly, it is not economic growth as such but the content of the growth that determines whether economic growth will lead to higher energy use (and potentially growing carbon emissions). This has led to a growing discussion about the way we live our lives in developed countries. Calls for life style changes are being made, in favor of less resource consuming life styles, e.g., travelling less by car and airplanes, buying energy efficient products etc. If this takes place, one would be able to decouple energy use from GDP. It is particularly important to discourage the emergence of future new energy intensive activities, e.g., space travelling to take an extreme example, since this is easier than discouraging such activities once they have emerged.

Since it is the content of economic growth rather than the number as such that determines the environmental impact of continued growth, policies should be directed at those impacts that cause CO_2 emissions rather than GDP as such.

Finally, it is important to distinguish our standard of living from our material standard of living. Our strive for increased purchasing power has brought negative consequences such as increased stress and other illnesses. Some of these negative impacts could be reduced by changing life style, e.g., by travelling by bike instead of car to work. If so, the standard of living might improve despite a possible reduction in the material standard of living. In some cases, such decisions are difficult to make on an individual level, but they are more acceptable if there is a collective decision to move in same direction. For instance, France recently decided to reduce its normal work week to 35 hours rather than 40, despite the fact that this might lead to losses in economic output.

Reducing energy use — some concluding observations

It is clear that the potential to increase energy efficiency is high. For instance, comparisons between the best available products on the Swedish market and the average product, reveals that efficiency improvements on the order of 40-60% can be made for lightning, washing, storing food, and heating houses etc. Technological development is expected to increase the potential for energy efficiency improvements even further. Further reductions in our energy requirements could be obtained by focusing economic development in less energy intensive sectors, reducing population growth and changing life styles.

Still, even under the assumption that major improvements in energy efficiency (say around 50%) were obtained over the next fifty years, carbon emissions would still most likely be growing. Thus, changes in the supply of energy would also be needed.