# Energy efficiency from the perspective of developing countries

*Jose Goldemberg*
Institute of Electrical Engineering and Energy, University of Sao Paulo, Sao Paulo, Brazil

*Thomas B. Johansson*
Department of Environmental and Energy Systems Analysis, University of Lund, Gerdagatan 13, 223 62 Lund, Sweden

*Amulya K.N. Reddy*
International Energy Initiative, 25/5, Borebank Road, Benson Town, Bangalore 560 046, India

*Robert H. Williams*
Center for Energy and Environmental Studies, Princeton University, Princeton, NJ 08544, USA

***Energy efficiency improvements are particularly important for developing countries. In most developing countries, the costs of reducing energy use by one kWh with more efficient technology are invariably much lower than the costs of increasing energy supply by one kWh through investments in new energy supply equipment. In fact, if the unit cost of energy supply increases is taken as the reference for comparison, then the relative costs of energy-efficient technologies can turn out to be*** **negative.** ***Thus, capital can be saved by investing in energy efficiency compared to investing in energy supply.***

***Energy needs in the South are different from those of the North because of differences in climate (e.g., space heating is not required in most of the South) and because satisfaction of basic human needs and infrastructure building must be given paramount attention in the South. Consequently, the innovations necessary are also different. For example, innovations in the processing of basic materials (e.g., steel, cement, glass, etc.) are needed in developing countries because these materials are needed for infrastructure-building. Yet innovations in the basic materials-processing industries will come only slowly from the industrialized countries because the infrastructure-building era is largely over there and the demand for basic materials is largely saturated. Because such industries are energy-intensive, innovations would result in less energy-intensive, less costly and cleaner technologies with beneficial implications for energy futures in developing countries. Such opportunities for technological leapfrogging should be identified and utilized. The technical and economic potential for energy saving is 20-50% in the case of efficiency improvements in existing installations and 50-90% in the case of new installations. The potential for further efficiency improvements through continued research and development is large because fundamental physical constraints on efficiency are remote.***

***The pursuit of energy efficiency improvement should be carried out in parallel with improvements in institutions, entrepreneurship management and human resource development.***

***A key policy is to bring more energy-efficient technologies to the market, and to focus market attention on energy efficiency performance. Several successful approaches have been tried. The incentive structures in the markets are fundamental, as illustrated by integrated resource planning and utility demand side management that took off in the US only after the regulations of the power industry were changed to make it possible for utilities to earn profits on demand side energy efficiency investments.***

***There is a need for an integrated view of the concept and role of energy efficiency revealing its structure and interconnections. Energy efficiency should be an integral characteristic of any product or activity. Emphasis on energy efficiency would liberate resources that can then be used for socio-economic development.***

## 1. Introduction

Energy was one of the areas of intensive debate at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in June 1992. In Agenda 21, Chapter 9, it was agreed that current patterns of production and utilization of energy cannot be sustained, and that one of the ways of promoting sustainable development is to reduce adverse effects on the atmosphere from the energy sector. Two directions for the energy system to evolve were identified: (1) more efficient production, transmission and distribution, and end-use of energy; and (2) greater reliance on environmentally sound energy systems, particularly new and renewable sources of energy.

Notwithstanding the fact that the need for energy efficiency is widely accepted today, there is still need for an integrated view of the concept and role of energy efficiency revealing its structure and interconnections. Hence this paper.

## 2. From sources to services

The objective of the energy system and its supply and utilization activities is to provide energy services, for instance, illumination, comfortable indoor climate, refrigerated storage, transportation, appropriate temperatures for cooking, etc.

The energy chain to deliver these services begins with the collection or extraction of primary energy which in one or several steps is converted into energy carriers suitable for the end-use(s). These energy carriers are used in energy end-use equipment to provide the desired energy services.

Thus far, it is the supply-side activities that have tended to attract most of the discussions of the energy *sector*. But, the energy system extends beyond what is conventionally considered the energy sector (Goldemberg et al., 1988) and unless the scope of the energy system is extended, energy efficiency will receive less importance than it deserves.

## 3. Reducing energy service levels in developing countries is not acceptable

This paper only addresses energy conservation measures that result in the use of less energy to provide the same energy service, or to achieve more energy services for the same energy. An illustrative example of this is the switch from kerosene wick-lamps to fluorescent tubelights in villages in developing countries. Experience from Pura village in South India shows that the household expenditure for lighting was cut in half despite the fact that illumination increased by a factor of about 19, and the energy input decreased to one-ninth compared to the kerosene originally used (Reddy, 1994). This stress on energy services is crucial in developing countries where the current levels of energy services are unacceptably low.

In contrast, energy use levels may also be reduced by diminishing the level of energy services, e.g., by reducing the indoor temperatures in space-heated areas to levels that require unreasonably warmer clothing. This approach to energy conservation based on a reduction of the level of energy services is not treated here. While a reduced level of energy services would also influence the total use of energy, it is associated, in developing countries, with the unreasonable request to reduce already unacceptably low levels of energy services, and, in industrialized countries, with the politically difficult task of asking affluent populations to decrease their affluence.

## 4. Classification of energy efficiency measures

The efficiency of energy conversion is one characteristic of each step of the energy chain. The energy efficiency of these conversions is quantified through the concept of *specific energy use* which is the energy used per unit of an energy service, for instance, in the case of refrigeration, $kWh_e$ per liter of refrigerated volume per year; or, when the service is a product, the energy used per unit quantity of product, for instance kWh per kg of steel. Energy efficiency can be improved in each of the steps of the energy chain. Energy efficient technologies lead therefore to a lowering of the specific energy use for an energy service.

There are different types of energy efficient measures that can be considered in formulating energy strategies:

i) more efficient extraction of primary energy and its conversion into energy carriers, for instance, in power plants and refineries;
ii) more efficient transmission and distribution of energy carriers;
iii) more efficient end-use of energy in existing installations through improved operation and maintenance, and efficiency retrofits through replacement of some components; and
iv) more efficient end-use of energy in new installations, equipment, etc., through systematic deployment of more energy efficient systems and technology; these systems and technologies may be introduced at the rate of capital turnover and expansion, for instance, at the rate of replacement and addition.

## 5. Technical and economic potential of energy efficiency measures

In the case of the extraction/conversion of primary energy and the transmission and distribution of energy carriers, the specific energy use can be reduced by about 10-40%[1] (with respect to the energy use levels of the present average stock of equipment in industrialized countries). The corresponding figure is 20-50% in the case of efficiency improvements in existing energy-using installations and 50-90% in the case of new installations. These reductions can be achieved by using the most efficient technologies that are available today and are cheaper than increasing supply[2]. In developing countries, the potential for demand reduction is often even larger. The potential for further efficiency improvements through continued research and development is large because fundamental physical constraints are remote.

The energy performance of alternative pieces of new equipment that provide the same energy service varies considerably. However, the life-cycle cost of providing an energy service, as a function of energy efficiency, after an initial decline, is typically relatively constant, over a considerable range before rising again (Von Hippel and Levi, 1983), so that societal interventions aimed at achieving high efficiencies can often be realized at no net extra cost to consumers.

Reduced expenditures on energy, resulting from energy efficiency improvements, will generate money savings that in turn, when spent, may create additional use of energy, thereby eliminating or reducing the overall impact of the energy efficiency improvement on the energy demand of a country. This is called the **take-back effect.** However, in general, the spending of saved money would be distributed on all kinds of expenditure, thereby reducing the amount of money spent on energy to a small fraction of what was saved in the first place. In the case of minimum impact on the overall energy use, the saved money would be used only to buy energy for other purposes, such as gasoline for more automobile driving. However, even in this case, an overall reduction of the energy use would result, as all activities (such as the automobile driving in this case) are also associated with non-fuel costs for capital and maintenance. The take-back effect should accordingly not be over-emphasized.

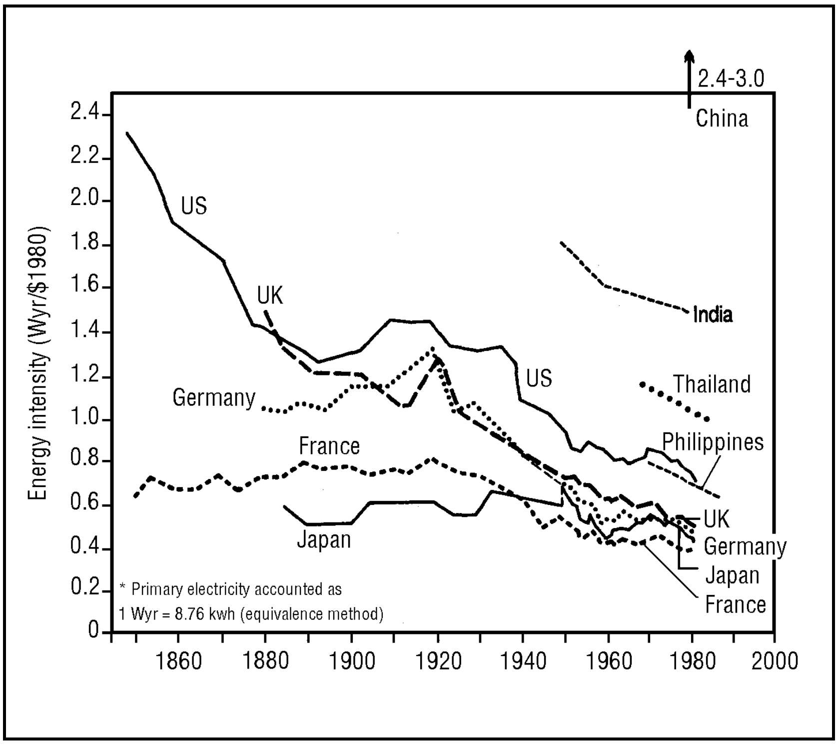


Fig 1. Primary energy* (including wood) per unit GDP

**6. Macro-economic impacts of energy efficiency measures**

One way of considering the aggregate impact of energy efficiency improvements on the economy is through the so-called energy-GDP (Gross Domestic Product) correlation which may be expressed thus. Every economy consists of a number of energy-utilizing activities each of which involves an *energy intensity,* $I^j$, and a contribution, $C^j = f^j \times \text{GDP}$, to the GDP, where $f^j$ is the fraction of GDP from activity j. Hence, the energy demand E is the sum of the energy demands, $E^j = C^j \times I^j$, of the various activities:

$$
\begin{aligned}
E &= \text{SUM } E^j \\
&= \text{SUM } [C^j \times I^j] \\
&= \text{SUM } [f^j \times \text{GDP} \times I^j] \\
&= \text{SUM } [f^j \times I^j] \times \text{GDP}
\end{aligned}
$$

from which we see that the energy demand is proportional to GDP *if and only if* the term SUM $[f^j \times I^j]$ is a constant. Thus, the *so-called energy-GDP correlation,* according to which a country's energy consumption is proportional to its gross domestic product, is valid only during periods when there is no change in the economy's (1) energy efficiency and (2) structure. If, however, there are changes in energy intensity due to efficiency improvements, process changes or product changes and/or there are changes of the contributions of different activities to the GDP (e.g., the share of basic materials manufacturing goes down and the share of less energy-intensive activities increases), the proportionality breaks down. A decrease of SUM $[f_j \times I_j]$ can offset an increase in GDP so that coupling between GDP and energy is reduced. There can even be a decoupling so that there is a decrease in the energy consumption associated with an increase in GDP.

The historical evidence for this reduction of coupling between energy and GDP may be obtained from the longitudinal and cross-sectional comparison of energy intensities, i.e., from a comparison of the energy/GDP ratios over time and between countries. These economy-wide energy intensities have varied dramatically in industrialized countries. For example, in the UK, the energy intensity has declined by about 1% per year since 1880 (Figure 1) (Reddy and Goldemberg, 1990).

Similar patterns have been followed by other industrialized countries (Figure 1). There are three factors responsible for this behavior of the energy intensities. The first factor is the improvement over time of the efficiency of production of energy carriers – e.g., the $kWh_e$ generated per tonne of coal burned has improved. The second factor is the improvement of energy end-use technologies – the specific energy use has decreased over time, i.e., the energy to perform an energy service (e.g., $kWh_e$ to achieve a certain illumination) or produce a product (e.g., $kWh_e$ per tonne of aluminum) has decreased over the years. The third factor involves the structural changes in the use of materials whereby economies become less materials-intensive at higher levels of economic activity, leading to a less energy-intensive economy as a whole. This arises as a result of both consumer preferences shifting to more valuable, less-materials-intensive products and production shifting to better performing materials (e.g., through replacement of conventional steels with modern high-strength steels in construction) (Williams et al., 1987).

### 7. The effect of energy efficiency improvements on power sector investments

The power sector in developing countries is suffering from a grave capital crisis. The essence of the capital crisis is that the financial requirements of the electricity system are several times more than what can be provided by the suppliers of capital. The "unbridgeable gap" between capital demand and supply was first highlighted at the level of the whole developing world by Churchill and Saunders (1989) and later expanded upon by Moore and Smith (1990) in World Bank publications. It was projected that installed capacity in developing countries would increase from 471 GW at the end of 1989 to 855 GW at the end of 1999 (an average growth rate of 6.1%/year). The total cost in constant 1989 dollars was estimated to be $760 billion for 10 years or $76 billion per year or $1,970 per kW of total capacity (of which $1,200 per kW is for the generation portion and the rest for transmission, distribution, etc.). Of this, only a small fraction would be available from the World Bank and other multilateral sources of capital, leaving a major fraction unfinanced.

The annual investment, I, required for expansion of installed capacity can be estimated with the following formula:

$$I = E(0) \times a \times g_{GDP} \times UCOP$$
$$= E(0) \times g_{CAP} \times UCOP$$

where E(0) is the installed capacity (in MW) in the base year, $g_{GDP}$, the growth rate of the GDP, $g_{CAP}$, the growth rate of installed capacity, and UCOP, the unit cost of installed capacity in $/kW.

The term a is the ratio of the growth rates of installed capacity and GDP (GDP is denoted U in the following) but from the relationship $E = \text{constant} \times G^a$ it is seen that $a = [(d\ln E)/(d\ln G)]$ is the GDP elasticity of electrical capacity. (In terms of the above formula, the World Bank estimate of an annual investment, I, of $76 billion required for expansion of installed capacity corresponds to an installed capacity in the base year 1989 of E(0) = 630 GW, a growth rate of installed capacity, $g_{CAP}$, of 6%, and a unit cost of installed capacity, UCOP, of $l,970/kW.) As long as the product [a × UCOP] is viewed as immutable, the $g_{CAP}$ is in a capital trap – it must fall if the required investments are not made.

To break out of the trap, the product [a × UCOP] must be reduced. One way of achieving this reduction is through a reduction of UCOP, for example, by shifting to gas turbines and combined cycles, a shift that is already happening. Another way – and one that is directly pertinent to this paper – is through energy efficiency improvements as follows. If c is the rate of efficiency improvement, then one can write

$$E(t) = \text{constant} \times G(0) \times (1 + g_{GDP})^{a(c=O)t}/(1 + c)^t$$
$$= \text{constant} \times G(0) \times (1 + g_{GDP})^{a(c)t}$$

from which it follows by taking the logarithms and representing the elasticity in the presence of efficiency improvements as $a(c) = (g_{CAP}/g_{GDP})_c$, and the elasticity in the absence of efficiency improvements as $a(c{=}0) = (g_{CAP}/g_{GDP})_{(c=0)}$ that

$$a(c) = a(c{=}0) - \{\ln(1{+}c)/\ln(1{+}g_{GDP})\}$$
$$a(c) \approx a(c{=}0) - (c/g_{GDP}).$$

Thus, if c, the rate of efficiency improvement, is greater than zero, the effective GDP elasticity or the elasticity in the presence of efficiency improvements, a(c), is less than the elasticity in the absence of efficiency improvements, a(c=0). Hence, c reduces the effective elasticity, and thereby the annual investments required to sustain a particular growth rate of GDP – energy efficiency enables a "greater GDP bang for a smaller energy buck".

In both industrialized countries and developing countries, cost-effective end-use efficiency improvements can take care of a considerable fraction of future electricity service requirements (Bodlund et al., 1989; Reddy et al., 1991). Energy efficiency, therefore, does not obviate the need for supply expansion, but the magnitude of supply expansion that is necessary decreases with the implementation of energy efficiency.

End-use efficiency improvement is even more relevant and crucial to small-scale decentralized systems than to centralized generation systems, because grid extension for small loads is expensive and, because the cost of power in small systems is invariably higher. Often the viability of these systems increases with decreases in scale, and such decreases hinge upon end-use efficiency improvements which lower energy consumption, and therefore, energy demand. Thus there is synergy between the decrease in demand brought about by end-use efficiency improvements and the increases of supply from decentralized systems. For example, photovoltaic power supplies and wind generators that may be uneconomical for grid-connected power generation can become viable when the demand of the end-use devices is reduced with efficiency improvements, so that a decentralized system becomes less expensive than the alternative of extending the grid.

### 8. Efficiency improvements are particularly important for developing countries

While energy consumption levels are indeed low in developing countries, the levels of energy services provided are much lower than the levels of services obtainable from the same amount of energy in industrialized countries, because efficiencies are much lower. Efficiencies are especially low for non-commercial biomass energy but they are low for commercial energy as well.

The quantitative potential for more efficient use of energy with already known technologies clearly indicates that there are large opportunities of energy efficiency improvements when making new investments. These are especially interesting for developing countries, because most investments in infrastructure and equipment aimed at economic growth are yet to be made.

In fact, analysis shows that by shifting to high-quality energy carriers and by exploiting cost-effective opportunities for more efficient use of energy, it would be possible to satisfy basic human needs and to provide considerable further improvements in living standards without significantly increasing per-capita energy use above the present level. For instance, the energy requirements for the West European standard of living of the 1970s could be as low as 1 kW/capita, which is only about 20% higher than the 1986 level in developing countries (Goldemberg et al., 1985). This is a remarkable result, which comes about because of the extremely inefficient use of energy today, especially traditional sources of energy, and because of the high energy efficiency obtainable with modern cost-effective energy end-use technologies available today. With a path of development that makes use of technologies with such energy performance, energy supply need not become a constraint on development.

Of course, total energy use would grow somewhat faster than population, and electricity demand would grow much faster than total energy. Primary energy use in developing countries increases from 1.11 kW per capita in 1980 to 1.24 kW per capita in the 1 kW per capita scenario, while at the same time electricity consumption increases from 39 W to 210 W per capita. In fact, it is this shift to electricity that is to a large degree responsible for the fact that primary energy use does not go up much (because of the better opportunities for efficiency improvement when electricity is the energy carrier).

Thus, for developing countries, there is an immense opportunity to promote measures that will permit them to avoid going through the now obsolete patterns of industrialization of the last 200 years, and instead pursue a development path that makes use of and builds on the technological know-how that now exists in the world. The use of technologies performing at least at the level of average sold technology in the North would seem a minimum requirement for technology to be transferred, or used in joint ventures. It is possible to make use of available highly efficient technologies that are applicable to the conditions of the South, for example, equipment for illumination and drives, and are less costly than the supply expansion alternative, taking into account all costs, including externalities. And, growing emphasis on free trade by governments around the world can facilitate this technology transfer.

In most developing countries, the costs of reducing energy use by a kWh with more efficient technology are invariably lower than the costs of increasing supply by a kWh through investments in new energy supply equipment. In fact, if the unit cost of supply increases is taken as the reference for comparison, then the relative costs of energy-efficient technologies can turn out to be *negative.* More capital can be saved by investing in energy efficiency compared to investing in energy supply.

**9. Technological leapfrogging**

Developing countries should seek to utilize the best energy-efficient technologies available on the world market, if such technologies are relevant to developing country needs and are cost-effective. But they should also seek specific innovative technologies and technological systems, when appropriate. The adoption of such innovative technologies is often referred to as "technological leapfrogging" (as in the children's game), whereby developing countries leap over the already industrialized countries.

Technical innovation is needed to sustain economic growth for the long term. Whereas some of the requisite advanced technologies can be obtained by the transfer of technologies developed for industrialized country markets, technologies are also needed that are better suited to developing country needs. Consider the relative prices of labour and capital. Because labour is expensive and capital relatively cheap in industrialized countries, many innovative technologies produced there are labour-saving and capital-intensive. Because labour is cheap and capital dear in developing countries, there is a need for more labour-intensive, capital-saving advanced technologies. And the scales of technologies available from industrialized countries are sometimes inappropriately large for the less-developed infrastructures of developing countries. A good example is the high-efficiency biomass power-generation technology that is to be commercially demonstrated in the northeast of Brazil (Elliott and Booth, 1993).

Developing countries also need innovations better suited to their natural resource endowments than what they can get from industrialized countries. For example, not only is the production of biomass labour-intensive, but also biomass is more readily available than fossil fuels in many developing countries. Hence, a major energy R&D priority for developing countries should be to find ways to improve the efficiency of using biomass for energy and transforming this resource from being "the poor man's oil" into electricity and fluid fuels that are deemed attractive in modern energy markets (Johansson et al., 1993). Many countries in the South also have access to low-cost hydropower resources.

Finally, energy needs in the South are different from those of the North, because of differences in climate (e.g., space heating is not required in most of the South), and because satisfaction of basic human needs and infrastructure building must be given paramount attention in the South. Consequently, the innovations necessary are also different. For example, innovations in the processing of basic materials (e.g., steel, cement, glass, etc.) are needed in developing countries because such materials are needed for infrastructure-building. Yet innovations in the basic materials-processing industries will come only slowly from the industrialized countries[3], because the infrastructure-building era is largely over there, and the demand for basic materials is largely saturated (Williams et al., 1987). Because such industries are energy-intensive, innovation will tend to be less energy-intensive, as well as less costly and cleaner (Goldemberg et al., 1988), and thus can have profound beneficial implications for future energy in developing countries.

There are historical examples of technological leapfrogging. For example, the world's first plants for producing iron by direct reduction (without smelting) were built in Mexico. This technology used in conjunction with electric arc furnaces for steelmaking is especially well-suited to many developing countries because favorable economics can be realized at scales of 100,000 tonnes of annual capacity or less, compared to capacities of 2.5 to 3.5 million tonnes per year needed for conventional blast furnaces plus oxygen-blown converters (Miller, 1976). Moreover, while most of the world's iron-making is based on the use of coke, coal-poor but biomass-rich Brazil has developed a modem charcoal-based process based on the efficient use of eucalyptus grown on plantations; this iron is processed into a high-quality steel that is competitive in world markets (Goldemberg et al., 1988).

The fundamental importance of technological leapfrogging is not widely appreciated – especially for energy. Faced with many pressing near-term crises, energy planners in developing countries are reluctant to assume the risks of innovative projects that offer only long-term payoffs. And many have been "burned" by past efforts to transfer advanced energy (e.g. nuclear) technology from industrialized countries. Moreover, the development assistance community has also not been supportive of innovations in the energy sector; the World Bank and other multilateral financing agencies finance only energy projects based on technologies with proven track records in the industrialized countries.

Because of the importance of technological innovation for development generally, and the major energy-saving benefits inherent in advanced energy conversion and utilization technologies in particular, energy strategies for developing countries should include technological leapfrogging as appropriate. Unfortunately, risks are inherent in innovation and so cannot be avoided. But foolish risks can be avoided by focusing on sets of technologies that are truly important in relation to development goals. And risks can be shared in various ways – for example, if innovative projects were pursued as joint ventures between industrialized and developing country companies, and if international, multilateral and bilateral development assistance organizations were to assume some of the risks of innovating. The latter should also help build the infrastructure needed to support a dynamic innovative process in developing countries. Unfortunately, these agencies can sometimes be the barrier by insisting that, in the transfer and development of energy-efficient technologies, "all technologies supplied should be well tried and proven" (UN, 1994).

Technical changes are being made all the time in developing countries by many actors, quite often at an extremely rapid pace. One has only to recall the explosive spread of color television in India or even more recently cable TV, cellular telephones and electronic mail. It appears that technological leapfrogging can be accelerated by simultaneous leapfrogging in entrepreneurship, institutions, management and human resource development involving capacity building.

The pursuit of energy efficiency improvement should be carried out in parallel with improvements in institutions, entrepreneurship management and human resource development. Unfortunately, the project-mode operation of aid agencies leads them to pay little or no attention to these institutional and human resource aspects in the name of achieving measurable benefits in the short term. When, however, due attention is paid to simultaneous capacity building, large opportunities would be created for making better and wiser use of capital, human, and natural resources that otherwise would be inefficiently spent on costly supply infrastructure. Emphasis on energy efficiency would liberate resources that can be used for socio-economic development and give it a better form.

### 10. Efficiency improvements require a favorable policy environment

How far different energy efficiency measures should be pursued must be evaluated from the standpoint of socio-economic development and protection of the environment. However, it is clear that energy efficiency must be the core of a genuine strategy for sustainable development.

In the first place, energy efficiency should be an integral characteristic of any product or activity. It is often referred to as something extra, almost like a flue gas scrubber, that is added on. But being an integral characteristic implies that energy efficiency should always be given attention when a design or investment is made. Policy formulation should start from this observation, and focus on making energy performance an intrinsic part of the continuous on-going investment process.

There are several reasons why most opportunities of more efficient use of energy are not routinely captured in the investment process, leading, therefore, to the belief that energy efficiency improvements are not possible. For instance, there exist a number of barriers facing actors in selecting and implementing the least-cost solution from a societal perspective (Reddy, 1991). Some barriers are associated with the fact that first-costs to capital-poor customers are prohibitively high[4], that energy prices are often much less than the full costs of energy, including external social costs, that some consumers pay little attention to energy because it is not a significant expense, and that the beneficiaries of efficiency improvements are not the same as the ones that incur the investments (e.g., the landlord/tenant problem).

With respect to efficiency improvements in energy supply, including transmission and distribution, there exists in most countries a reasonably functioning marketplace or other incentives for an economically efficient operation. In contrast, incentives are by and large weak or non-existent in the case of energy efficiency improvements at the demand side, especially the performance of new equipment. However, there are promising ways of improving the situation in some developing and industrialized countries (Williams, 1989).

A key policy is to bring more energy-efficient technologies to the market, and to focus market attention on these characteristics. Several successful approaches have been tried. In Sweden, for instance, the government used its convening power to bring together the major buyers on the market for some products, such as appliances, windows, etc., where significant market fractions are bought by large buyers. A consortium of these buyers organized a competition for better products that led not only to an improvement of the products but to the buyers having a feeling of ownership. The US Golden Carrot program has applied a similar idea.

The incentive structures in the markets are of course fundamental. Integrated resource planning with energy efficiency as a key element took off in the US only after the regulations of the power industry were changed to make it possible for utilities to earn profits through activities on the demand side, thereby making it possible for society to collect the benefits of efficiency improvements.

In many countries, considerable attention is given by utilities to demand side management as a mechanism of deferring costly investments in new energy supply. Also, industrialized countries are pursuing radical improvements in energy-using technologies – for example, the present US attempt at developing in a decade's time a new automobile that is three times as fuel efficient as today's cars of comparable performance.

Measures to improve energy efficiency must be considered in all areas where energy is used. These measures would include a rationalization of energy prices directed towards prices reflecting both internal and external costs, innovative financing[5], support of research and development with respect to more efficient energy end-use technologies, and the support of demonstrations and steps to create early markets for more efficient technologies. Government-organized procurement and utility-operated demand side management programs are good examples here.

The promotion of energy efficiency, at the point of energy end-use, and as built into society through the process of economic growth and investment, should be an integral part of national efforts to make energy systems compatible with sustainable development. The other element is renewable energy, where recent developments have improved the outlook for significant and cost-effective contributions to energy supply (Johansson et al., 1993). It is important to formulate and implement strategies, policies, programs and projects to reach environmentally sound development goals.

Fortunately, the international context is favorable for efficiency improvements. Industrialized countries which have hitherto turned a blind eye to energy efficiency issues in developing countries, are now threatened by the global environmental consequences of conventional energy strategies that ignore energy efficiency. Now, a historic shift is taking place – industrialized countries are finding it in their enlightened self-interest to support developing country energy strategies based on efficiency improvements. ■

**Acknowledgement: The authors would like to acknowledge constructive comments by the Editor.**

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**Notes**

1. The incremental heat rate for cogenerated power is 30-40% less than for power provided in central station power plants, and for central station power plants, the most energy-efficient technology now on the market is the ABB GT26, a 240 MW combined cycle involving an advanced reheat gas turbine. The heat rate of this combined cycle on natural gas is 6,180 kJ/kWh (58.5% efficient), LHV (lower heating value) basis or 6,840 kJ/kWh (52.7% efficient), HHV (higher heating value) basis. (ABB intends to sell these combined cycles for $500/kW. For comparison, the average heat rate for oil and gas-fired power plants in the US was 11,320 kJ/kWh (31.8% efficient), HHV basis. The introduction of fuel cells in distributed configurations will not only lead to high conversion efficiencies, but also to much larger markets for cogeneration.
2. The comparison of the costs of efficiency improvements with the cost of expanding energy supply does not take into account external costs (for example, environmental costs) associated with energy supply.
3. Innovation is taking place in the materials industries of the industrialized countries, but this has been mainly for making value-added-intensive specialty products, such as steels with special properties, pharmaceuticals, etc., rather than for basic iron and steel making, the production of basic chemicals, and the manufacture of other basic materials needed for infrastructure building.
4. But, the higher cost of the efficient device may be offset by the reduction in the system cost. It has been found in Sweden, for instance, that the more expensive insulation and better windows used in energy-efficient homes are now largely offset by the reduced costs for radiators under each window, and a much simpler heating system that can be installed when only small quantities of heat are required.
5. Based on the fact that to consumers, it is bills rather than tariffs (and unit costs of energy) that matter and therefore if ways are found of reducing bills through efficiency improvements and reduced energy consumption, there will be a positive response from consumers.