Industrial energy conservation

Integrated conservation efforts could reduce industrial energy consumption by an estimated 20–25 percent.

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The recent drop in international petroleum prices is unlikely to diminish the fundamental challenge that both developed and developing countries face in adjusting to the high cost of energy. For oil importing developing countries, the challenge is all the more acute since even a modest growth of their economies will generate increased demand for energy.

In most developing countries, initial efforts to reduce the cost of imported energy have centered on increasing the domestic supply of energy. While most have increased the average level of energy prices and some have rationed energy supplies, other institutional and policy measures necessary to reduce energy demand have not yet received adequate attention. Yet for most developing countries, more efficient utilization offers substantial opportunities to improve their energy situation. Increasing domestic energy supplies normally takes several years to yield significant results, while many energy conservation and demand measures can produce more immediate results. The objective of energy conservation measures, however, is not merely to minimize the cost of energy relative to GDP but also to maximize the rate of GDP growth for given energy prices, subject to environmental and other constraints. For most purposes, though, minimizing the cost of energy relative to output is consistent with maximizing GDP.

While in most industrial countries the industrial, transportation, and household sectors are all major consumers of commercial energy, in many developing countries—due to their frequently mild climates and less intensive urban transportation needs—the main energy consuming sector is industry, accounting for an average of about 40 percent of total commercial energy consumption. Preliminary studies prepared in the World Bank indicate that as much as 20 to 25 percent of industrial energy consumption could be saved with adequate conservation measures. Through such measures, the additional energy supplies required for economic growth could also be reduced, thus alleviating, to some extent, the financing constraints in developing country economies.

The energy intensity of a country's industrial sector is affected by a number of factors, including the type of industry and the process used. Some industries, such as ammonia or aluminum production, consume large amounts of energy. The operation of petroleum refineries may, in itself, require 5 to 9 percent of the total crude processed. By contrast, other manufactures, such as electrical and mechanical equipment, have considerably lower energy intensity. Likewise, modern and efficient ammonia plants based on steam reforming of natural gas may require only 60 percent of the fuel that older processes had needed. Other factors affecting energy intensity are the type of energy used (for example, processes using coal normally require larger quantities, though at a lower unit cost, than oil and gas); the age of the plants (efficiency declines with age); the climatic conditions (more energy is used where space heating is required), and the general operating practices and skills of the plant operators (maintenance and losses due to inoperational plants).

With the exception of a few countries such as China and India that rely substantially on coal, most developing countries meet their industrial energy requirements primarily with petroleum products. Noncommercial fuels, such as bagasse and wood, also play an important role in some industries. In most countries, most plant design and equipment were developed prior to the energy price increases of the mid- and late 1970s and were designed to minimize capital investments and to take advantage of low energy costs. This has resulted in higher energy consumption and lower investment costs than today's costs and technological developments would justify. Many processes also involve massive conversion of petroleum raw materials with significant losses of energy during the transformation process. While some of these losses are unavoidable, much useful energy is wasted. With increasing energy prices, it is becoming economically attractive to recover much of this wasted energy through the installation of additional equipment.

Conservation potential and costs

There is, thus, considerable economic scope for additional investments in existing plants to improve the efficiency of energy utilization. Such investments would reduce total energy consumption and improve production capacity utilization.

The range of specific energy consumption measures can roughly be divided into two groups: short-term measures, which require small investments and consist mostly of better maintenance and process control, including, for example, insulation and steam system efficiency improvements; and medium-term measures, which require larger investments in retrofitting of existing plants and additions to facilities, including waste heat recovery, combined heat and power generation, increased use of waste fuels, improved process controls, and replacement of inefficient equipment.

in developing countries

Potential energy savings and investment in developing countries

Industry	Process or product	Range of energy savings (In millions of tons of oil equivalent a year) Short-term	Medium-term	Total	Range of investment required (In billions of 1982 U.S. dollars) Short-term	Medium-term	Total
Iron and steel	Steel	3.3 – 7.6	16.3 – 21.8	19.6 – 29.4	0.8 – 2.7	13.9–20.8	14.7 – 23.5
Electrometallurgy	Aluminum (from alumina)	0.3 – 0.5	1.3 – 2.0	1.6 – 2.5	0.1 – 0.2	0.6 – 1.1	0.7 – 1.3
Petroleum	Refining	3.8 – 6.5	8.1 – 13.5	11.9 – 20.0	0.7 – 1.5	3.2 – 6.1	3.9 – 7.6
Chemicals	Ammonia	0.4 – 0.9	3.8 – 4.1	4.2 – 5.0	0.1 – 0.2	1.9 – 2.5	2.0 – 2.7
Cement	Dry and wet	5.7 – 7.0	9.1 – 14.3	14.8 – 21.3	1.3 – 1.9	6.4–11.4	7.7 – 13.3
Pulp and paper	All grades	1.6 – 2.2	1.8 – 2.3	3.4 – 4.5	0.5 – 0.8	1.0 – 1.4	1.5 – 2.2
Food	Cane sugar	2.8 – 3.2	2.6 – 5.2	5.4 – 8.4	0.5 – 0.7	1.6 – 3.6	2.1 – 4.3
Textile	Finishing	0.5 – 0.6	0.6 – 0.7	1.1 – 1.3	0.1 – 0.2	0.3 – 0.4	0.4 – 0.6
Glass	All grades	1.5 – 1.7	2.2 – 2.9	3.7 – 4.6	0.4 – 0.5	1.0 – 2.0	1.4 – 2.5
Bricks	All grades	0.9 – 1.3	1.3 – 1.8	2.2 – 3.1	0.2 – 0.4	0.6 – 1.2	0.8 – 1.6
Other industries (estimated)		17.0–34.0	34.0 – 51.0	51.0 – 85.0	3.4–10.2	17.0–35.7	20.4 – 45.9
Total (estimated)		**37.8–65.5**	**81.1–119.6**	**118.9–185.1**	**8.1–19.3**	**47.5–86.2**	**55.6–105.5**

Source: World Bank, *Potential and Prospects for Industrial Energy Conservation in Developing Countries*, forthcoming.
Note: Details may not add up to total because of rounding.

Estimating potential industrial energy savings for all developing countries is a complex task. Using industry-specific data, a recent World Bank study has estimated that developing countries, as a group, could save 5 to 10 percent of total industrial energy consumption through short-term measures and 10 to 20 percent by medium-term measures (see table). The largest industrial energy conservation potential lies in steel, petroleum refining, cement, and chemical industries (including fertilizers).

While the potential for saving energy in industry is substantial, the investment required to achieve it is proportionately modest. For short-term measures, the average investment cost per ton of oil equivalent saved per annum is estimated to be between $175 and $350. For the medium-term measures, the average investment costs range from $400 to $550 in petroleum refining and chemicals and from $850 to $950 in the iron and steel industry.

At today's crude oil price of about $200 per ton, most short-term measures would recover their investments in 12 to 18 months. In many process industries where naphtha is used as a raw material, or in applications where gas oil is used as fuel, the capital costs would be recovered in less than 8 to 12 months. For the majority of the medium-term investments, this period is normally between two to five years when energy saved has the less expensive fuel oil equivalent value, and between nine months to three years when it is equivalent to the more expensive naptha/gas oil value. The economic rates of return range between 50–125 percent and 20–50 percent for the short- and medium-term measures, respectively. Total investment requirements of developing countries to achieve these potential savings are estimated at $8–$19 billion for short-term measures and an additional $47–$86 billion for medium-term measures, averaging less than three years in terms of payback period. Because of managerial, financial, and other constraints these measures cannot be implemented all at once. If developing countries pursue active energy conservation programs, the implementation of all possible short-term measures would require between three to seven years, and medium-term measures may take seven to ten years.

These investment estimates include only potential measures for energy conservation in existing plants and facilities. Interfuel substitution and the installation of new, more efficient plants require substantial additional investment. The experience of the World Bank in about a dozen industrial energy conservation projects in ten countries indicates that interfuel substitution measures are often as economical as purely energy-saving measures. Such interfuel substitution measures involve switching from more expensive, often imported, forms of energy (such as naphtha, gas oil,

or fuel oil) to less expensive and domestic energy supplies (coal, natural gas, or refinery gases). For example, in Turkey a fertilizer plant is being retrofitted to switch from naphtha to natural gas and refinery gases for ammonia production, and a number of cement plants in Portugal and Hungary are being converted from fuel oil to coal. Such interfuel substitution measures are important components of practically all of the Bank's energy efficiency projects in the fertilizer, cement, and petrochemical sectors. In many instances, the major energy conservation measures are implemented along with interfuel substitution investments.

Implementation

In a free market economy, the adjustment of energy prices to long-term opportunity cost levels should, in theory, provide sufficient incentive for consumers to adjust their energy consumption. Experience in developing countries, however, has indicated that industrial and other consumers are slow to invest in energy conservation measures, even where the potential economic and financial benefits of such investments are visible and excellent. This is due to four factors: (1) the lag, perhaps due to inertia, in responding to changes in input prices, particularly when existing facilities have operated well in the past and when energy represents a relatively low portion of operating costs; (2) the complexity of energy conservation investments, caution over the innovative nature of many of the proposed devices, and the risks involved in interrupting production flows; (3) the low visibility of these investments, which normally consist of a large number of separate items and facilities; and (4) the current economic climate, which has made it difficult to generate the substantial resources needed for new investments.

Technical, financial, and economic barriers may also intervene. At the plant level, lack of information about the appropriate technical options and the absence of expertise in energy management often hamper conservation, as does the nonavailability of specialized energy auditing capabilities and the lack of suitable equipment and instrumentation. Financial stumbling blocks include scarcity of capital, high interest rates, and lack of simple, accessible forms of medium-term financing for energy-saving equipment. Common economic obstacles are energy prices below opportunity costs, distortions in relative prices of different energy products, and cost-plus product pricing systems that reduce incentives for energy efficient use.

Many of these constraints are more serious in developing countries than in industrial countries. For example, in developing countries, the technical skills needed are not as readily available; sophisticated techniques to alert industrialists about economics of energy-saving investments are not common; and distortions in relative pricing are also generally more serious. To surmount these barriers, integrated energy savings programs must often be designed and implemented at the national level. Key elements in such programs include (1) appropriate energy and product pricing; (2) energy management and audit programs; (3) technical and financial assistance; and (4) institutional and regulatory measures.

Pricing; management and audit

Appropriate industrial energy pricing policies must take into account both the absolute and relative price levels of the various energy sources and, where relevant, the rate structure that will provide adequate incentives to improve energy efficiency through both conservation and fuel conversion. Although the pricing strategy will depend on individual country conditions, domestic energy prices for industrial energy normally need to reflect economic opportunity costs. Rate structures for power or gas are also important in that respect. Declining blockrate structures that unduly lower unit costs with increased energy consumption may, for example, reduce incentives for energy conservation. Some countries used quota systems for key energy products so that consumption above the quota carries a substantially higher price. Further, it is of utmost importance that the government's intention to rationalize energy pricing policy be announced in clear terms.

Experience suggests, however, that adequate energy pricing is a necessary, but generally not sufficient, condition for an effective conservation program. The overall product pricing policy for industry is also crucial. In countries where prices are administered and manufactured products are priced on a cost-plus basis to guarantee returns to the producers, there is often no real incentive to save energy.

A policy of high or increasing energy prices will have its full effect only to the extent that enterprises are adequately informed about the various energy savings measures that are technically and economically feasible; this is a particularly important problem in developing countries. Energy costs, of course, account for varying shares of total production costs depending on the industry concerned. Where energy costs are proportionally modest, enterprises might give higher priority to investments that improve their productivity or competitiveness through other means. Because of the complexity and variety of possible solutions, it is important to design an integrated energy conservation program that also includes an array of nonpricing measures and programs.

Energy audits of large- and medium-sized energy-intensive facilities constitute the core of any national program for industrial energy savings. Energy audits are necessary to estimate the potential for energy savings, to identify the individual measures implied and their cost, and the economic viability of the investments. The type of audit needed depends on process energy consumption intensity, the complexity of the in-plant energy distribution and utilization systems, and the objectives pursued.

In-depth audits require a detailed analysis of energy flows and balances for each major energy-using piece of equipment and may involve up to 30–50 man-months of technical input. They are recommended for large steel, chemical, fertilizer, cement, refinery, and paper plants. *General energy audits*, while also requiring the preparation of a plant's energy balance, involve less technical analysis of the individual facilities and may take up to 8–12 man-weeks of technical services. They are more appropriate for facilities with a simpler energy use pattern and are sufficient for most medium-sized facilities in food, textile, bricks, and similar industries. *Brief audits* collect essential data through basic energy accounting; that includes, for example, total fuel and electricity consumption by type for a given period (generally the previous year). They normally involve three-five

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days of consulting services. Such brief audits indicate relative performance in energy consumption and are usually adequate for most small-sized plants. They also furnish the basic data for national estimates of potential savings and benefits.

Energy audits may be either voluntary or mandatory, though in many countries they are generally mandatory for establishments exceeding a certain energy consumption threshold (for example, 1,000 tons per annum of fuel oil equivalent). Some countries also provide subsidies for energy audits or provide free brief audits or plant surveys. Crucial to the effective performance of an overall energy audit program is the development, through training, of domestic energy auditing capabilities, particularly with respect to general and brief audits. The training and appointment of energy coordinators or energy management teams in the major energy-consuming enterprises can assure follow-up on the audits and introduce better management practices.

Technical, financial assistance

Promotion and information campaigns, both at the national and plant levels, have been useful in creating an awareness among industrial managers, employees, and the public at large of the benefits of energy savings. Brochures, pamphlets, general or subsector seminars, and energy savings contests have proven effective educational devices. Training programs in conservation or auditing can be addressed to energy auditors, energy managers of enterprises, boiler operators, and maintenance engineers with significant results. For more complex needs, technical assistance can be provided in the form of free audits or audit assistance, technical advisory services, or referral services.

Most countries that have formulated national industrial energy savings programs have provided, at least initially, some financial assistance and incentives for conservation investments. In general, grants initially used for energy savings projects in industrial countries have been phased out and replaced over time by preferential interest rates, accelerated depreciation, and other tax-related incentives. Subsidies for energy audits have, however, been maintained in many countries. When energy prices are low, some form of financial assistance for capital investments might be needed during the transition period, provided its amount is reduced as energy prices are gradually increased to their opportunity cost. The desirability of such a subsidy should, however, be weighed against the merits and feasibility of a policy of faster energy price increases. Also important is the need to provide simplified access to medium-term financing for investments in energy savings, particularly for small- or medium-size enterprises that embark on relatively small energy conservation projects.

Finally, in most developing countries, technological possibilities for alternative energy sources and uses remain largely unexploited. It may be appropriate in the developing countries with more advanced technological infrastructure to undertake formal and institutionalized industrial research into alternative energy sources and uses.

Institutional, regulatory aspects

Institutional and regulatory mechanisms are often necessary to complement market signals and synchronize the various elements of integrated industrial energy conservation programs. Since 1973–74, most industrial countries have established energy conservation centers that coordinate information, training, and technical assistance on conservation matters, often in collaboration with training or technical assistance for other purposes, and sometimes with private sector participation (as in Japan and France). Only a few developing countries have established such centers. Some, however, are in the process of being set up, with Bank assistance, in Bangladesh, Hungary, Pakistan, Peru, Portugal, Thailand, and Turkey.

To have maximum impact, the energy conservation centers should be organized and staffed on the basis of an in-depth review of the industrial sector, the potential for energy savings, and the capabilities of the domestic technical specialists. All existing centers render information and promotion services, and most carry out energy audits and sponsor training programs—the training of plant energy managers and local energy auditors being of special importance. Only rarely are these centers directly involved in financial assistance (particularly in view of the trend away from grants for energy conservation to credit and tax incentives).

While the regulatory framework varies, most developed countries have enacted basic energy conservation laws of a very technical nature. These generally set energy consumption standards for boilers, furnaces and other combustion units, and sometimes for industrial lighting, space heating, and other items. Energy consumption standards by product are significantly more difficult to establish and administer. The usefulness of and the compliance with such standards varies considerably from country to country. Most such regulations also require the mandatory appointment of energy managers and the mandatory performance of energy audits in industrial establishments that exceed minimal energy consumption standards, and these are particularly applicable to most developing countries.

To be successful, energy conservation regulations need to be complemented with appropriate measures for promotion, incentives, and free technical assistance. The exact blend in this "carrot and stick" approach must, however, be determined by individual country circumstances and industry response.

World Bank role

During the last few years, the World Bank has assisted some 20 countries in developing programs primarily aimed at improving energy conservation in the industrial sector. Our experience shows that industry and governments in developing countries are increasingly aware of the large potential for energy savings in the industrial sector and the significant impact that this could have in reducing costs and improving balance of payments situations. The realization of this potential, however, could be a long and slow process unless governments carry out vigorous and comprehensive measures and campaigns to induce industries to initiate and implement required investments. International financial institutions such as the World Bank can play a catalytic and increasingly important role in assisting member countries in designing and implementing comprehensive energy conservation programs. F&D

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