Impact of Improved Technologies on Industrial Greenhouse-gas Emissions in Developing Countries

Phase 1

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Foreword

In response to a formal request by the Group of 77 and China, the United Nations Industrial Development Organization (UNIDO) initiated a study to identify opportunities to reduce the emissions of greenhouse gases from energy-intensive industries in developing countries. These sectors currently include iron & steel, petroleum refining, cement, paper & pulp and nitrogen fertilizers. The aim of this first phase was to describe

- how energy is used in the energy-intensive industries in developing countries today,
- what current trends indicate for the future,
- the potential contribution of improved technologies and practices to moving toward more sustainable industrial production in developing countries,

and to provide developing countries with an analytical tool for evaluating opportunities to limit industrial greenhouse-gas (GHG) emissions in their industrial sectors through the transfer of improved technologies and processes.

The immediate objectives of Phase 1 were twofold:

- to **provide information** to developing countries in the form of an inventory of energy-efficient, best-available technologies and processes that can be used to abate greenhouse-gas emissions in the most energy-intensive industrial sub-sectors as well as cross-cutting measures applicable in a range of sub-sectors, and
- to **provide an analytical methodology in** the form of **a software tool** that enables the user to evaluate and compare the costs, energy requirements, and greenhouse-gas emissions associated with scenarios of specific technology and process options.

To meet these objectives, the first phase of the study comprised:

- a Report entitled Industrial Greenhouse-gas Emissions from Developing Countries,
- a Software Package containing,
    - an Industrial Technology Inventory, and
    - an Analysis Tool, and
- Industry/country-specific Case Studies.

The **Report** describes current energy use and greenhouse-gas emissions in energy-intensive industries in developing countries, and similar industries exemplifying good current practice in industrialized countries. Both technologies and processes are addressed.

The **Technology Inventory** has been produced in spreadsheet form and contains a wide range of efficiency and fuel-switching measures (both technologies and processes) that represent good current practice in developed countries in the selected industrial sectors. Inputs from regional experts have been used to incorporate successful developing-country experiences.

The **Analysis Tool** provides an analytical framework that enables the user to estimate the potential to improve the energy efficiency and reduce the greenhouse-gas emissions of selected energy-intensive industries in a given country. The tool allows the user to input technical data, such as that identified in the Technology Inventory, and create scenarios through which energy-efficiency and fuel-switching options can be explored. It has been designed in layered spreadsheets using a four-level hierarchy through which the user can move to a specific industrial sector, a stage of production activity within that sector, and on to specific processes and technologies appropriate to that production stage.

Nine **Case Studies** provide energy-consumption profiles for specific energy-intensive industries in three countries in each of the three regions, thus describing a range of efficiencies in existing capital stock and fuels used in developing countries.[1] The case studies are printed in a separate report.

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[1] The nine case studies are for the following industry/country combinations: cement in Argentina and Egypt; iron & steel in Brazil and India; paper & pulp in China and South Africa; petrochemicals in Kuwait and Trinidad & Tobago; and chemical fertilizers in Zimbabwe.

Part One: Industrial Greenhouse-gas Emissions from Developing Countries

Overview

The use of energy in the industrial sectors of nations with developed economies has been, and will continue to be, a major source of greenhouse gas (GHG) emissions, particularly carbon dioxide. The patterns of industrial-sector energy use—energy provided primarily by the combustion of fossil fuels—have shifted both within and between countries in recent decades. Projections of future energy use and carbon-dioxide (CO_2) emissions suggest continued shifts in these patterns, as industrial production in developed countries stabilizes and declines, while industrial output in the developing world continues to expand. In all scenarios, Intergovernmental Panel on Climate Change (IPCC) projections indicate that non-Annex I countries' share of global CO_2 emissions will increase significantly by 2050 (IPCC, 1996a).

This expansion of industrial-sector activity and CO_2 emissions in developing countries presents both a *challenge* and an *opportunity*. The challenge is to reduce global GHG emissions without denying developing countries the benefits of economic development. The opportunity is to use the substantial potential for improvements in industrial energy efficiency, particularly in the developing world, as a vehicle (though certainly not the only one) to allow and even spur economic development while helping to mitigate the environmental impacts of industrial energy use. As the IPCC points out, the greatest opportunity for energy-efficiency improvements to reduce industrial CO_2 emissions by introducing new technologies and processes lies in Annex I countries with economies in transition and non-Annex I countries. Furthermore, "The greatest gains in efficiency for OECD Annex I countries have occurred in chemicals, steel, aluminum, paper and petroleum refining, suggesting that it should be relatively easy to achieve even larger gains in the industries in non-Annex I and transitional economies" (IPCC, 1996a).

In this report, we briefly illuminate the reasons behind changing patterns of industrial energy use, and explain both the challenges and the opportunities for energy efficiency that these changes portend. In so doing, we provide a thumbnail regional perspective on the growth of industrial production in developing countries, increases in energy use that come with growth in output, and the environmental impacts that can accompany increase in fuel consumption. In addition, we outline some of the opportunities for implementing energy-efficient technologies that will be created as industrial-sector activity grows in the developing world. As such, we set the backdrop for the analytical tools, databases, and case studies that have been carried out under Phase 1 of this project.

Regional Distribution of Industrial Energy Use

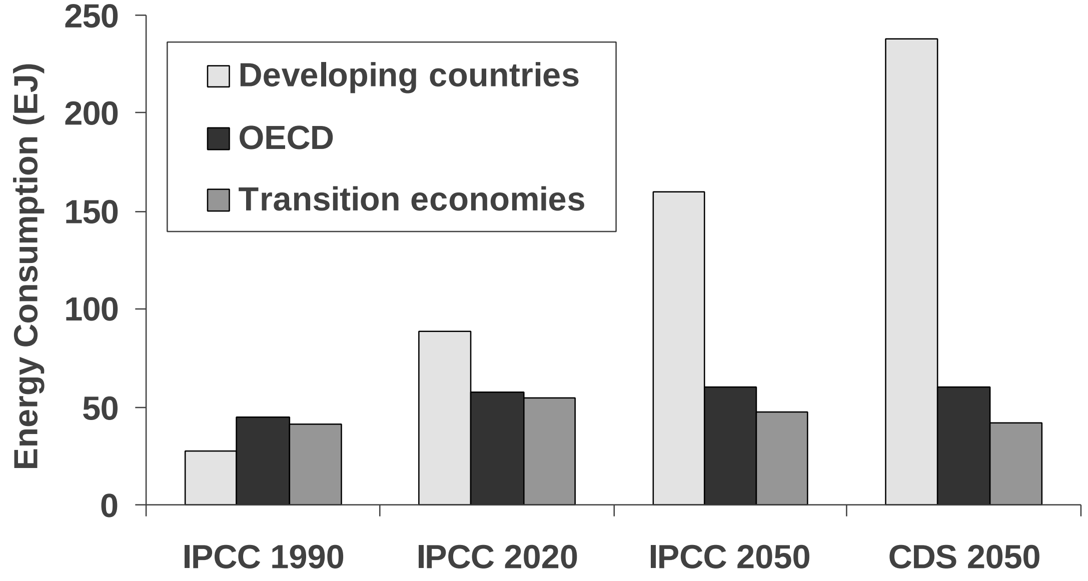
The activities of the industrial sector generate a large fraction of global gross domestic product (GDP). One of the costs of this industrial performance is the consumption of a large fraction of the world's energy supply, and the generation of a similarly large share of the global anthropogenic emissions of carbon dioxide and other greenhouse gases. As of 1990, the industrial sector accounted for approximately 35 percent of global economic activity (measured as GDP—SEI-B, 1995), roughly 44 percent of global primary energy demand (WEC, 1995), and a similar percentage of carbon-dioxide emissions.

On a regional basis, industrial energy consumption (and related greenhouse-gas emissions) has been undergoing a fundamental shift. Recent scenarios of future economic development and energy use show the waning importance of the industrial sector in the developed world, and the increasing dominance of those countries now undergoing economic development. Figure 1.1 underscores the changing pattern—given "business-as-usual" scenarios of future energy-sector development—of industrial energy use among three broad classes of countries:

- Countries with currently developing economies, including the countries of Latin America, Africa, and South and East Asia (excluding Japan);
- Countries with economies in transition, including the countries of Eastern Europe and the Commonwealth of Independent States (CIS);
- and the OECD countries, which includes most of the globe's currently "industrialized" nations.

It should be stressed that this grouping tends to mask the considerable variations in current energy use and growth rates among developing countries, especially between some countries of Latin America and Africa when compared with China and India. Variations also exist among OECD countries, with growth in energy use in some Mediterranean countries likely to continue as growth tapers off in other OECD countries. In addition, it should be noted that Figure 1.1 presents results from only two of a number of different sources, and any estimate of energy use to the year 2050 is subject to great uncertainty.

Figure 1.1: Current & Projected Industrial Sector Energy Use by Region, 1990-2050



Sources: IPCC, 1992 and SEI-B, 1995

In 1990, the OECD and the transitional economies accounted for about three-quarters of the world's industrial energy use. The scenarios of the Intergovernmental Panel on Climate Change (IPCC), as indicated in Figure 1.1, show that fraction changing markedly in the future, with developing nations responsible for over 40 percent of global industrial-sector energy demand by 2020, and about 60 percent by 2050. In the Conventional Development Scenario (CDS), assembled by Raskin and Margolis (SEI-B, 1995), the developing-country dominance of industrial-sector energy use is even more complete, reaching nearly 70 percent of global use by 2050.

A number of inter-related factors underlie these potential shifts in the structure of industrial energy use among regions. These factors include population growth, changes in per-capita consumption of industrial goods, changes in the importance of different economic sectors within countries, changes in industrial economic efficiency and energy intensity, and shifts in the distribution of production of industrial goods from the currently industrialized countries to developing countries.

Current Regional Distribution of Industrial Energy Use by Major Sub-sectors

Although energy is used in the industrial sector to produce and manufacture a vast array of materials and products, there are a few major sub-sectors that can be singled out as using sizable shares of the sector's overall energy demand at the global, regional, and, usually, national levels. The World Energy Council (WEC, 1995) lists five sub-sectors in particular—iron and steel, chemicals, petroleum refining, pulp and paper, and cement—as being the five most energy-intensive, accounting for about 45 percent of total world industrial primary energy use in 1990. Brief descriptions of these sub-sectors, and the ways in which energy is used in them, are provided below.[2]

- The **iron and steel** industry produces pig iron, crude steel, and various forms and grades of refined and finished steel products. Major processes used in the industry include concentrating and processing of iron ore, producing coke from coal or charcoal, adding coke to iron ore to make iron, steel making, casting raw steel, and rolling, finishing, and milling steel products. Energy, in the form of heat, is used in each of these steps, with additional energy (usually electricity) used to provide lighting and to drive motors and presses used to move and finish materials. The fuels used in providing heat for steel making vary considerably by country and region, with newer mills often using mostly natural gas or electricity. Older mills and mills in developing countries with indigenous coal resources (China, for example) primarily use coal to provide both heat and coke. Using scrap steel as a raw material greatly reduces overall energy use, as the iron- and steel-making processes are avoided.

- Producing **chemicals** involves a variety of different processes, depending on the type of commodity produced. Major categories of chemical products include petrochemicals, made from petroleum; inorganic chemicals including fertilizers, chlorine, soda ash, and silicon carbide; and other chemicals, most of which are made from petrochemical and/or inorganic chemical feedstocks. Major energy end uses in the chemical industry include electrolysis, process heating, cooling, distillation (separation of products), refrigeration, evaporation, and moving materials from place to place (for example, with pumps or moving belts). Fuels such as crude oil, natural gas (especially for ammonia fertilizer production) and sometimes coal are also used as the feedstocks out of which chemicals are made.

- **Petroleum refining** involves breaking down and fractionating the complex mixture of hydrocarbons in crude oils into standard fuel and non-fuel products, including gasoline, diesel oil, heavy fuel oil, liquefied petroleum gas (LPG), bitumens, and lubricants. Heat is used in the many distillation, conversion, reforming, and finishing (product purification) processes used in a refinery. Motive power to turn pumps and other equipment is typically provided by electricity, which is often generated on site. Refineries are typically fueled with crude oil or "waste" products from the conversion processes, but sometimes use coal or natural gas as a fuel as well, depending on local supplies.

- The **pulp and paper** sub-sector produces pulp from wood, wood wastes, scrap paper, and occasionally non-woody, high-cellulose crops or crop wastes. The pulp is used to produce paper and cardboard products of different types. Pulp and paper mills use energy for wood preparation (chipping, grinding), pulping, bleaching, chemical recovery, paper making, and drying. The amount of fuel used per unit output varies widely with the type of product produced, and with the input material used. Major end-uses in the sub-sector include process heat and motive power. A

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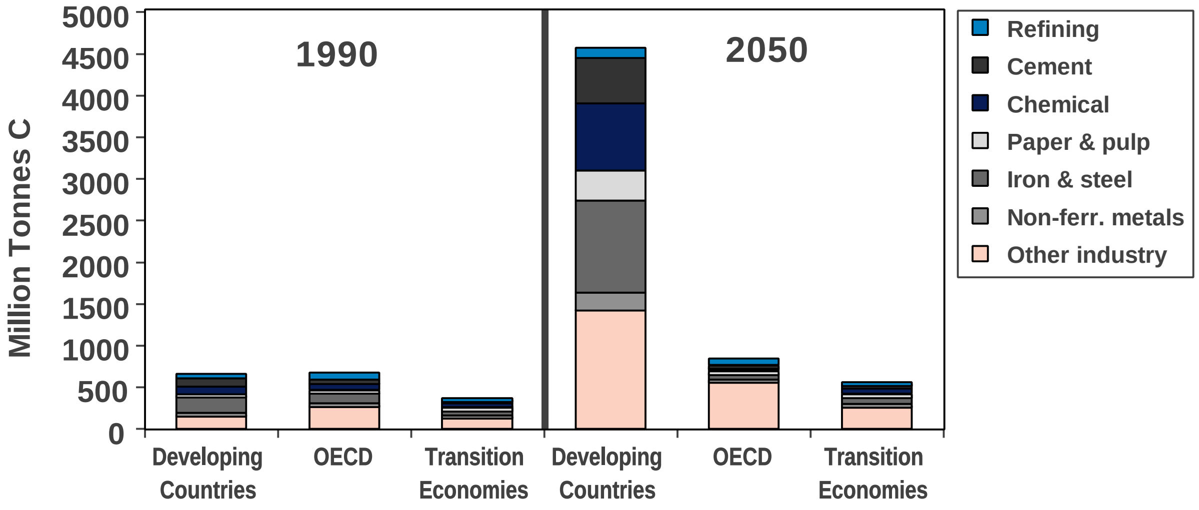
[2] For further detail on the processes used in these sub-sectors, the reader is urged to consult Chapter 2 of WEC, 1995.

variety of different fuels are used, from biomass wastes such as lumber mill wastes and "black liquor" (generated during pulping in some processes), to coal, natural gas, and electricity.

- **Cement** production involves treating limestone with heat to produce calcium oxide, or lime, and adding silicates to yield "clinker," a raw cement. Clinker is then ground to size and blended to yield various cement-type products. The major end-uses of energy in this sub-sector are process heat for producing clinker from limestone and other minerals, plus motive power (usually supplied by electric or diesel motors) for grinding, moving, and blending intermediate and final products. Cement-making is typically fueled with the least-expensive fuel readily available, often coal.

If current reliance on fossil fuels and non-energy-efficient technologies continues, increasing use of energy in the industrial sector of developing countries will result in vastly increased emissions of carbon dioxide. Figure 1.2 contrasts patterns of industrial-sector emissions in 1990 with the CDS projection of the same emissions for the year 2050. Industrial-sector CO_2 emissions for the developing nations increase to over three-fourths of the global total, with emissions from a single sub-sector—iron and steel—nearly equaling the total industrial CO_2 emissions from the OECD and transition economy nations combined. Figure 1.2 also indicates a shift of the most energy- and emissions-intensive industries (including iron and steel, cement, paper and pulp, chemicals manufacture, and oil refining) from the OECD to the currently developing world. In contrast, the industrial sub-sector in OECD countries that shows the greatest emissions in 2050 is "other industries," possibly reflecting the shift in industrial production in developed nations away from traditional "smokestack" industries and toward high-technology industries, such as electronics and biotechnology.

Figure 1.2: Current and Projected Industrial-sector CO_2 Emissions (Energy Use)



Source SEI-B, 1995

The reader is cautioned that the particular numbers shown in Figure 1.2 reflect the results of a single scenario from a single group of researchers, and that different "business as usual" ("BaU") scenarios assembled by other workers can and do show somewhat different results.[3] The scenario shown in Figure 1.2 assumes a global population of about 10 billion in 2050, with about 86 percent of the world's population in developing countries (up from 76 percent in 1990).[4] Thus developing-country

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[3] A full discussion of the parameters and assumptions that underlie these scenario results is unfortunately beyond the scope of this paper. The reader is urged to consult IPCC, 1992, and SEI-B, 1995, for details of how the scenarios shown in these figures were assembled.

[4] As with future energy use, future population growth varies considerably among developing countries and regions. The population growth rate in Africa, for example, is projected to be roughly twice that of Latin America or Asia (SEI-B, 1995; original figures are from the World Bank and the United Nations).

emissions in the 2050 scenario are less than half those of the industrialized world when compared on a per capita basis. The main point here, however, is that under BaU assumptions (without intervention), growth in industrial energy use, and the GHG emissions that result from industrial energy use, are likely to A) be very robust, and B) be centered almost entirely in developing nations. As a consequence, if future global greenhouse-gas emissions are to be significantly reduced, *opportunities* for increasing energy efficiency and the use of renewable fuels in the industrial sector of developing economies cannot be ignored.

Current and Recent Patterns of Industrial-sector Activity

Trends and patterns in industrial-sector activity within and between countries and regions result from complex interactions of a number of different processes. Some of the critical interacting processes—ongoing social, economic, and technical changes in and among countries—that affect industrial-sector activity, energy use, and emissions include:[5]

- Continuing population growth in developing regions, while populations in industrialized and transition economies remain relatively stable.
- Increasing per-capita consumption of industrial goods in developing countries, as households become more affluent. This increase in per-capita consumption has been found to be strongest as countries develop from the lower range of per-capita income towards middle-range income, and weaker as people continue to move toward the higher income range. Appendix 1A provides a brief discussion of this phenomenon, based on work by Williams, Larson, and Ross (1987).
- Stabilizing or declining per-capita consumption of industrial products in developed countries as the market for certain goods—such as large household appliances and automobiles—becomes “saturated."[6]
- Shifting of developed economies towards more service-oriented production, with an increasing proportion of energy-intensive manufacturing activities (including manufacturing of many energy-intensive goods and intermediate materials consumed in industrialized economies) carried out in developing nations.
- Improvements in the energy efficiency of industries in developed nations, driven in part by the need to enhance economic competitiveness, and in part by the need to meet environmental regulations (these factors are also relevant in many developing countries).[7]
- Changes in the fuel types used by industries, particularly in developed countries, in response to changing technologies, economic situations, or environmental regulations.

Recent Historical Trends in the Production of Key Industrial Goods

A review of recent historical trends in the production of key industrial goods underscores the importance of addressing the efficiency of industrial infrastructure in developing countries. Figure 1.3, for example, shows the changes between 1979 and 1992 in the production of two key commodities (crude steel and cement) by two major developing countries (China and India), two developed countries (Japan and the U.S.), and the Former Soviet Union (FSU).

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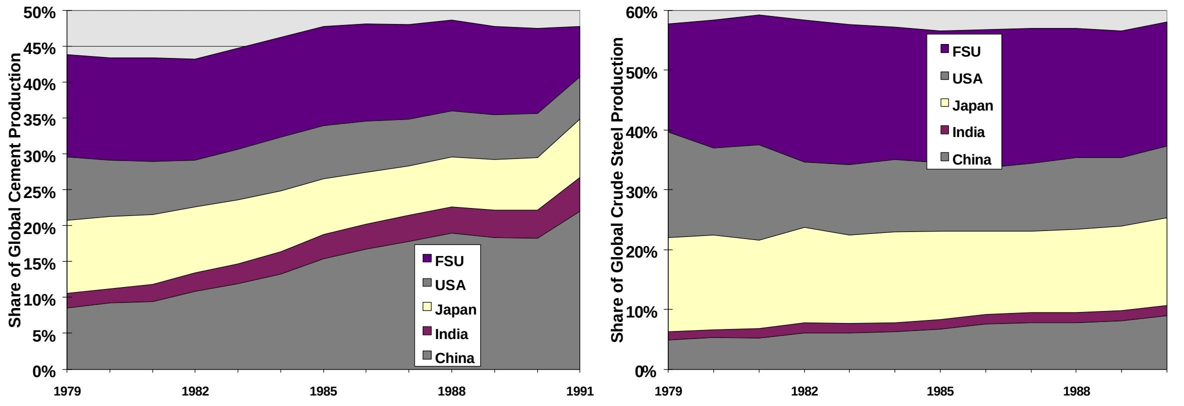
[5] A detailed discussion of these processes is beyond the scope of this report. An excellent overview is provided in Schipper et al, 1992.

[6] The term “saturated” is used to mean that virtually all households that wish to have the given good have already acquired it.

[7] Some of these improvements in developed countries may well flow to developing nations through the international market for energy- and industrial-sector goods and services, and as a result of investments in developing-country industrial infrastructure by developed-country firms.

Figure 1.3: Trends in Cement and Steel Production, 1979-1992, Selected Countries



Source: Sinton et al., 1996

During the 1980s, crude steel production nearly doubled in China and increased markedly in India as well. In contrast, annual steel production in Japan was stagnant during the decade, and production in the United States declined by about one quarter. The US decline in steel production reflected both the movement of steel making to other countries and a per-capita reduction in the consumption of steel (Sinton, 1996; and WEC, 1995).[8] In the United States, this reduction in steel production is the continuation of a trend—chronicled by Williams, Larson and Ross (1987)—that showed increasing steel production from 1880 through 1950, when the growth in production began to slow, and a reduction in production beginning around 1980.

A similar pattern of shifting production during the 1980s occurred in the cement industry. Cement production in China and India nearly tripled during the decade, almost doubling their share of global output, while production in Japan and the United States were primarily in modest decline, with the share of world production from those two countries falling by over 20 percent.

These examples of changing consumption of energy-intensive materials, when taken in aggregate, indicate a continuing trend, where the shares of global industrial output shift to the developing world.[9] This shift means that changes in industrial infrastructure in these sub-sectors—changes that represent opportunities for adopting high-efficiency technologies and practices—are concentrated in the developing world.

The regional patterns of energy use and carbon-dioxide emissions from industrial energy consumption, broken down by major sub-sectors, are shown in Figures 1.4 and 1.5, respectively (the Cement sub-sector actually denotes the entire "Stone, glass, and clay" sub-sector). In both developing and industrialized economies, current industrial energy use and greenhouse-gas emissions are concentrated in the major industrial sub-sectors. However, an important difference between developing and developed regions is evident when one considers the proportion of energy use and emissions contributed by the "other industry" sub-sectors. The "other industry" category contributes a much larger share to regional totals in North America—and to a lesser degree in other OECD countries—than it does in developing countries. This is further evidence of the opportunity and importance of boosting the efficiency of industrial energy use in the energy-intensive industries in developing regions.

CO_2 emissions from industrial energy use in the FSU and China currently equal or surpass those from North America. In China this holds even though total industrial energy use is significantly lower. China's higher emissions of CO_2 per unit of energy, relative to other regions, are due to the dominance

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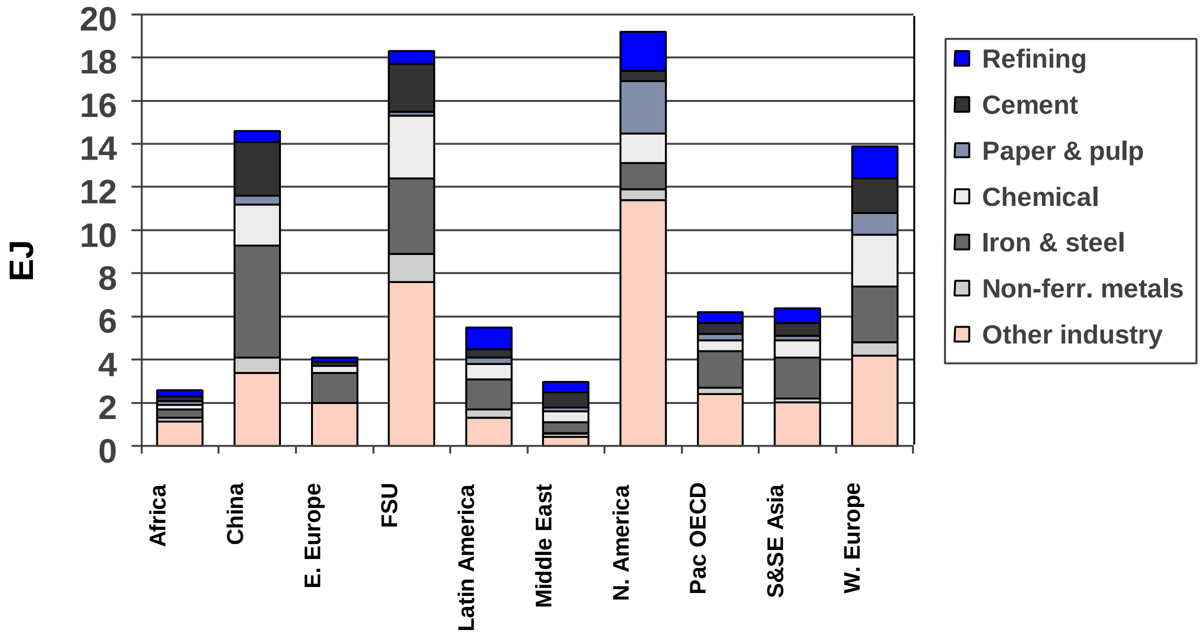
[8] Page 27.

[9] Although the shift in output is unlikely to be distributed evenly across developing countries, and may or may not persist in the long term.

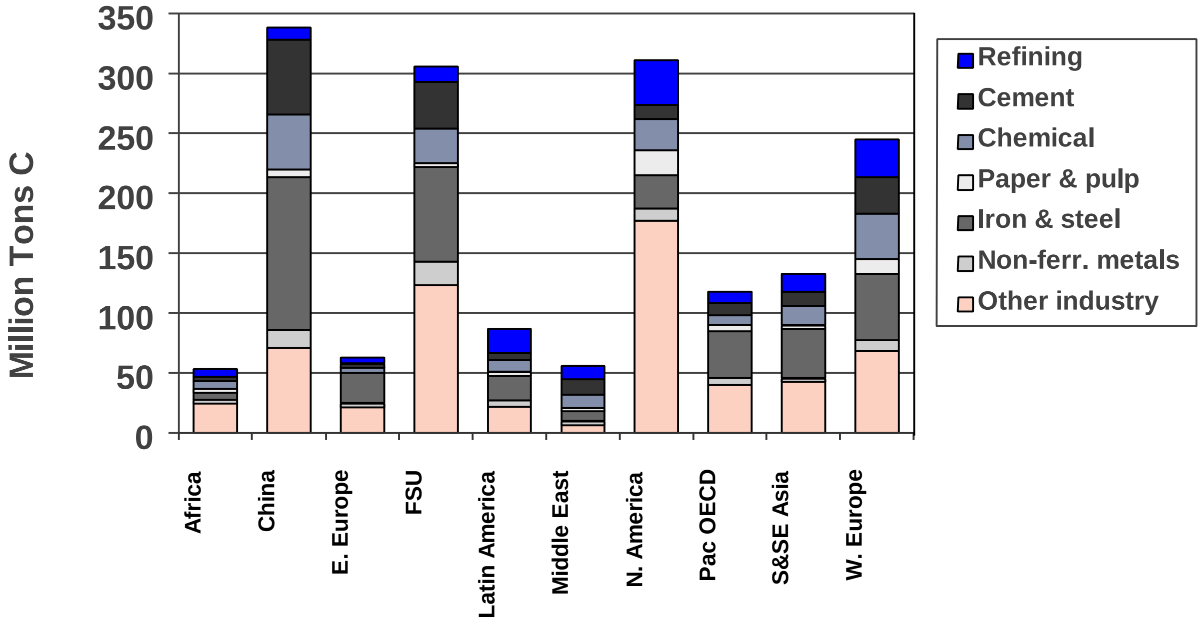
of domestic coal as an industrial fuel—a situation not representative of many developing countries and regions (Latin America and Africa, for example).[10]

Figure 1.4: Global Industrial Energy Consumption by Sub-sector, 1990



Source: IEA, 1994

Figure 1.5: Global industrial CO_2 Emissions by Sub-sector, 1990



Source: SEI-B, 1995

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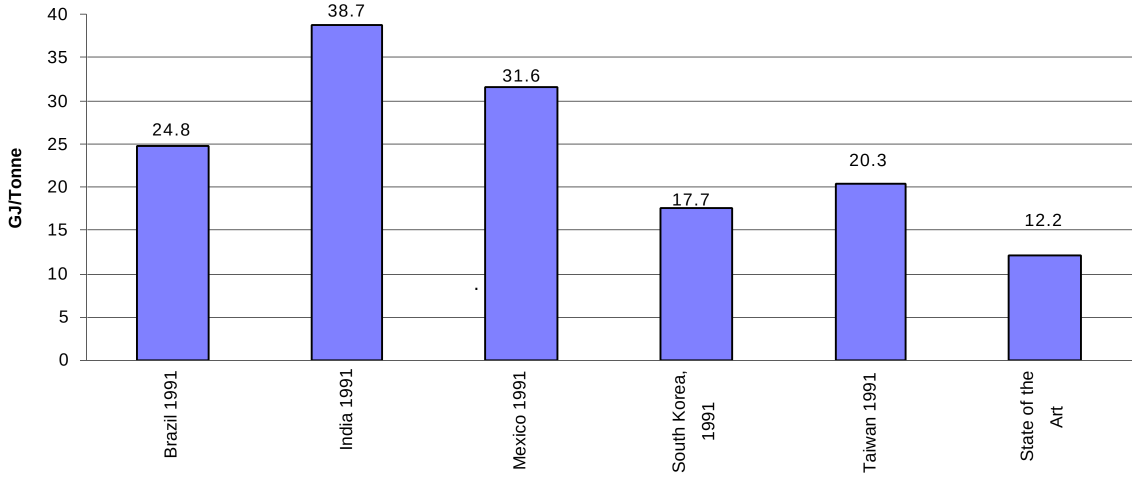
[10] Figure 2.6 also shows the very different industrial energy consumption in different developing regions. Industrial energy use in Latin America, for example, is only 40 percent of that in China. Differences in energy consumption between regions are due to a combination of different fuel use patterns, different patterns of industrial production, different industrial energy intensities, and different population bases.

Industrial Energy Intensity

The concept of industrial energy intensity denotes the amount of energy or fuel required to produce a unit of industrial output. Comparisons of energy intensities—among regions, countries, and individual facilities, or against a “best practices” benchmark—can indicate opportunities for improvements in energy and process efficiencies. Two basic approaches are used to express industrial energy intensity. The first is energy intensity per unit **physical** product. The second is energy intensity per unit of **economic** output.[11]

Examples of energy intensities denominated in physical units include tonnes of coal equivalent (tce[12]) per tonne of raw steel, kilowatt-hours per tonne of cement, or gigajoules per case of glass. Physical energy intensities specify the amount of energy—either all fuels or a specific fuel—used to make a specified unit of output. Properly specified physical energy intensities have the advantage that they allow easy comparison between countries. Some of the disadvantages of physical energy intensities are that they are only useful for certain sub-sectors, in particular, those with a single, relatively homogeneous product; that they must be carefully evaluated to make sure that the unit of production is comparable across sources (Is a “case” of glass the same in China and Japan? Is pulp counted at the same moisture content in the U.S. and Chile?); that it may be hard to find sufficient data on sub-sectoral output to allow specification of physical intensities in some instances; and that product quality or composition may vary across countries or plants.[13]

Figure 1.6: Process Energy Use for Steel Production, National Averages Compared to State Of The Art[14]



Source: Technology Inventory

Physical energy intensities (GJ per tonne) for the production of a fairly homogeneous product—steel—are shown in Figure 1.6 for several steel producers, and for the best current practice (“State of the Art”). This comparison demonstrates both the substantial variation in energy use per unit of output

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[11] Note that energy intensity, the amount of energy used per unit of product or energy service, is the inverse of energy efficiency, which is the amount of product or energy service produced per unit of fuel consumed.

[12] The tonne of coal equivalent (tce) is a standard energy unit equal to 29.3 gigajoules (GJ).

[13] For example, Worrell et. al. (1995) demonstrate how clinker/cement ratios range from 27% (Ireland) to 90%+ in several Latin American and OECD countries. Clinker production is the most energy intensive stage in the production of cement, and so “Portland” cements (with a high clinker content) tend to have high energy intensities. Similarly, high quality steels and reformulated gasoline are examples of commodities that, because of the specifications that must be met in their manufacture, have above-average energy intensities in comparison to their broad product class.

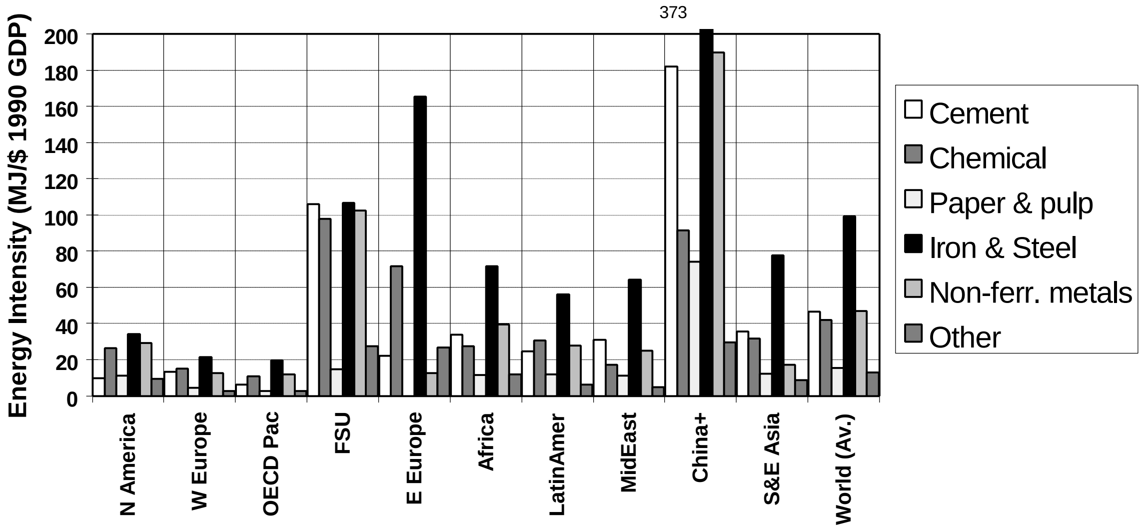
[14] Data shown in this figure are derived from the Technology Inventory produced as a part of this project.

between countries, and the considerable improvement (reduction) in energy intensity that that is possible using existing efficient technology. The energy used to produce a tonne of steel in India, for example, is more than 50 percent higher than that used in Brazil, and is more than twice the amount used in South Korea. Even the relatively new, efficient Korean plants, however, use an average of almost 50 percent more energy per unit of output than would a state of the art plant.

Energy intensity is also commonly described in energy units per unit of economic output. Examples of intensities specified in this way include tonnes of oil equivalent per dollar of value added in the chemical production sub-sector, or megacalories per dollar of domestic product in the non-ferrous metals sub-sector. Disadvantages of currency-denominated indices of industrial energy intensity include that they can A) be influenced by foreign exchange rates and the costs of production in each country[15]; B) be biased by non-market internal prices for commodities; and C) fail to reflect varying product types and material use in certain industries.[16]

Given these caveats, energy intensities for products from a number of major industries are presented in Figure 1.7. Some notable features of the comparisons shown in this figure are the extremely high intensities for almost all of the industries shown for the developing and transition economies (especially China) versus those shown in the OECD economies. Even taking into account variations in the quality of domestic fuels and in the profitability of the commodities produced by each sub-sector, this comparison shows that energy intensities in the developing (and transition) economies, while varying quite considerably across regions (the energy intensity in the Iron and Steel industry in Latin America, for example, is one-seventh that in China), appear to have substantial room for improvement.

Figure 1.7: Industrial Energy Intensity By Sub-sector, 1990



Source SEI-B, 1995

National Examples of Sectoral Patterns and Trends in Developing Regions

To provide a national example, the changing patterns of carbon-dioxide emissions from major industries (and other related sectors) in India are given in Table 1.1, below. Here, emissions from both

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[15] Adjusting the index to reflect purchasing power parity (PPP) can provide a more accurate comparison between countries (for example see Leach *et. al.*, 1986 and Ishiguro and Akiyama, 1995).

[16] For example, a country whose chemical industry produced a set of commodities that were higher in value and/or required less energy to produce than a second country whose chemical production comprised products of lower value and/or requiring more energy to manufacture, would show a lower sub-sectoral energy intensity per unit economic output, even if the energy efficiencies of the equipment used in the chemical industries of the two countries were comparable.

the steel and cement industries are shown to have nearly doubled in the eight years between 1986-87 and 1994-95, while emissions in the fertilizer industry increased by over 30 percent. Growth in emissions from power production have grown even more, although this reflects emissions from electricity produced for use in all sectors of the Indian economy. Of all of the Indian sub-sectors in Table 1.1, only railways show a decline in CO_2 emissions. This decline resulted from a substantial program of electrification of the Indian railways, and thus came at the expense, so to speak, of increased emissions in the power sector. Overall, the emissions pattern shown in Table 1.1 reinforces the message that emissions from the industrial sector of developing countries are undergoing rapid growth, and, as such, are important candidates for adopting energy-efficiency measures. Some of the potential for energy-efficiency and fuel-switching measures to contribute to emissions reduction can be seen by comparing the growth in CO_2 emissions from nitrogenous fertilizers industry with the actual production increase over the same period. The result that emerges (as shown in the last two columns of Table 1.1) is that the CO_2 emissions per unit of production has fallen for this industry. In the fertilizer industry, total CO_2 emissions fell in absolute terms even as production increased significantly between 1986/87 to 1988/89. This decline is attributable to both an increase in energy efficiency and to a shift to plants using natural gas as fuel.

Table 1.1: CO_2 Emissions and Emissions per unit Production by Selected Indian Industries

	CO_2 Emissions (million tonnes)		***CO_2 Emissions per Unit Production***		
Sub-sector	***1986-87***	***1989-90***	***Units***	***1986-87***	***1989-90***
Steel	39.31	56.91	t/t crude steel	3.37	4.52
Power	146.10	236.68	t/MWh (thermal)	0.946	1.085
Railway	17.09	13.68	t/thous. t-km	0.0783	0.0588
Cement	17.56	22.82	t/t cement	0.487	0.505
Fertilizer	9.16	11.30	t/t Nitrogen	1.882	1.679

Sources: TEDDY, 1995; UN, 1994

An example of the change in energy intensity in a specific industry over the last decade is provided in Table 1.2, which shows the changes in energy use and intensity ("specific energy consumption"—here energy use per tonne of output) for a petrochemical company in Brazil. Here, the trend is toward declining energy use per unit of output, as plants in the sub-sector were modernized. The energy intensity of production of three groups of products declined between 14 and 43 percent in the 1980s, allowing greatly expanded production of these products without a substantial increase in energy use or greenhouse-gas emissions.

Table 1.2: Development of Specific Energy Consumption at Petroquímica UNIAO

YEAR	FUEL USE (10^6 GJ)	CHEMICAL PRODUCTION			SPECIFIC FUEL USE PER UNIT OF PRODUCT (GJ/t)		
		GASOLINE (t)	ETHYLENE (t)	BASICS (1) (t)	GASOLINE	ETHYLENE	BASICS
1980	20.84	1301115	317990	767101	16.0	50.4	65.7
1981	20.50	1401388	338760	841410	14.6	43.2	51.3
1982	21.16	1494390	368766	895635	14.2	38.4	42.9
1983	20.88	1501642	359398	879926	13.9	38.7	44.0
1984	20.01	1484335	337339	879193	13.5	40.0	45.5
1985	20.80	1590367	361960	963518	13.1	36.1	37.5
1986	20.54	1495828	362325	910687	13.7	37.9	41.6
1987	21.81	1559955	383959	947871	14.0	36.4	38.4
1988	22.13	1557782	399929	961625	14.2	35.5	36.9
1989	19.97	1389564	356503	842661	14.4	40.3	47.9
1990	21.46	1552278	390380	938555	13.8	35.4	37.7

Source: Petroquímica Uniao.

Petrochemical Report from the "Energy-Intensive Industrial Sectors," EEC/Brazil Seminar, March 1992.
(1) Benzene, Toulene, Xylene, Ethylene, Propane and Butadiene.

Another example of the trends in industrial energy intensity, here in terms of energy use (tonnes of oil equivalent, or "toe") per unit physical output, in shown in Table 1.3. This table shows the decline in energy intensity in four major industrial sub-sectors in Brazil between 1978 and 1993. The increase in energy intensity shown for the chemicals sub-sector (and for the pulp and paper sub-sector between 1985 and 1993) may have been due to a shift in the types of products manufactured.

Table 1.3: Industrial Energy Intensity, Brazil (toe per thousand tonnes of output)

Sub-sector	**1978**	**1985**	**1993**
Cement	142	124	103
Iron and Steel	696	669	631
Non-ferrous Metals	7507	5807	5700
Paper and Pulp	665	599	616
Chemicals	545	654	729

Source: IEA, 1995, *World Energy Outlook*

Table 1.4 provides an additional example of changing energy intensities in Brazil, this time expressed in terms of energy use per unit of industrial output. Here, intensities in some sub-sectors increase substantially over the period shown, others decrease, and still others rise and fall over time. One should recall that energy intensity per unit of economic output combines trends in energy intensity per unit of physical output with trends (or variations) in the value (or market price) of the goods produced. Extra care must therefore be taken when interpreting energy-intensity trends expressed in economic terms, particularly when comparing results from different countries.

Table 1.4: Development of Energy Intensity in the Brazilian Industrial Sector (In TJ/Millions of 1980 CR$)

YEAR	CHEMICALS (3)	META-LURGY (1)	FOOD & BEVERAGES	TEXTILES (4)	PAPER & CELLULOSE	MINERAL EXTRACTION (2)	CEMENT & CERAMICS	ENERGY SECTORS (5)	OTHER (6)	TOTAL
1975	0.431	1.717	1.177	0.251	1.506	0.669	1.608	0.853	0.126	0.550
1976	0.542	1.679	1.151	0.255	1.510	0.712	1.567	0.841	0.136	0.550
1977	0.619	1.794	1.205	0.258	1.658	0.846	1.568	0.877	0.137	0.593
1978	0.651	1.808	1.175	0.249	1.637	0.913	1.585	0.965	0.155	0.607
1979	0.685	1.923	1.147	0.247	1.578	0.909	1.441	1.070	0.163	0.623
1980	0.692	1.817	1.166	0.241	1.651	0.912	1.422	1.002	0.152	0.607
1981	0.643	1.927	1.183	0.246	1.746	1.044	1.510	0.991	0.143	0.629
1982	0.586	2.074	1.192	0.247	1.674	0.984	1.560	1.073	0.159	0.656
1983	0.670	2.364	1.272	0.265	1.738	0.928	1.621	1.182	0.171	0.747
1984	0.696	2.572	1.309	0.279	1.690	0.876	1.543	1.173	0.184	0.784
1985	0.800	2.757	1.318	0.288	1.798	0.841	1.581	1.224	0.162	0.775
1986	0.783	2.694	1.289	0.280	1.658	0.868	1.514	1.159	0.154	0.731
1987	0.749	2.879	1.292	0.292	1.716	0.884	1.513	1.274	0.156	0.766
1988	0.784	3.144	1.208	0.314	1.752	0.822	1.514	1.197	0.170	0.806
1989	0.798	3.142	1.087	0.312	1.651	0.828	1.489	1.187	0.166	0.790

Source: *National Energy Balance (Brazil)*, Mining and Energy Ministry, miscellaneous issues.

Table taken from the Petrochemical Report from the "Energy-Intensive Industrial Sectors," EEC/Brazil Seminar, March 1992.

(1) Metallurgy: Pig iron and steel; ferro-alloys and non-ferrous products.

(2) Mineral extraction: Mining and pelletization, exclude petroleum extraction.

(3) Chemicals: Does not include petroleum refining, distillation of alcohol or coke production.

(4) Textiles: Also includes clothing, shoes and woven goods.

(5) Energy Sector: Extraction and refining of petroleum, distilling of alcohol, generation of electricity and production of coke.

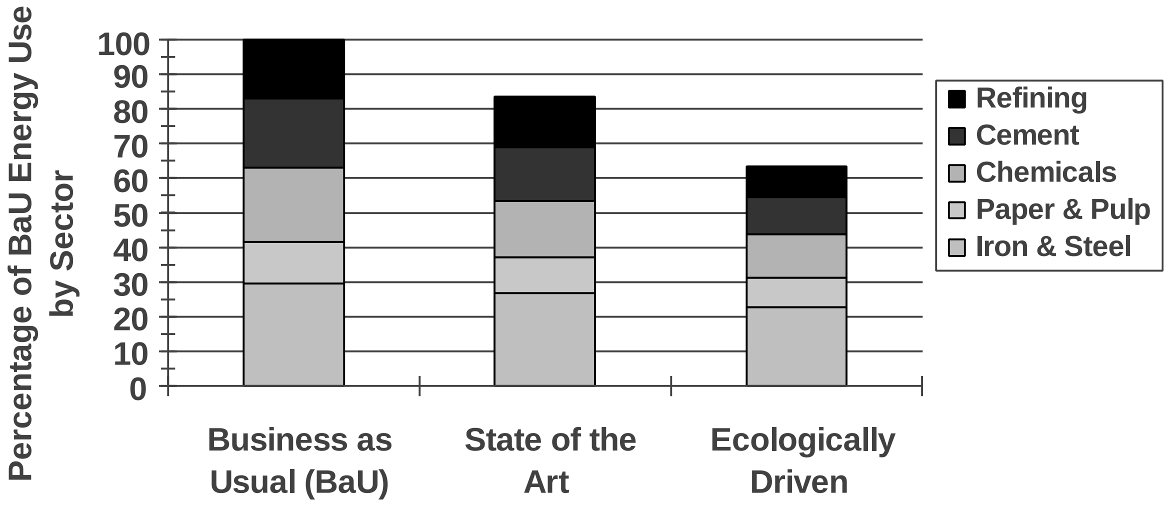
(6) Others: Mechanics, electrical materials, transport materials, furnishings, rubber, pharmaceuticals, soaps and candles, plastic, tobacco and construction.

Scenarios of Future Industrial Energy Use in Developing Countries

In scenarios of future industrial energy use in developing countries, different assumptions regarding future economic, technical, and social developments result in different estimates of international, regional, and national energy use in general, and of industrial energy use in particular. These, in turn, result in different conclusions regarding future emissions of greenhouse gases. Exploring some of the many scenarios that have been prepared can help to identify areas of the globe in which future industrial energy consumption shows marked growth, and thus where opportunities for high-efficiency industrial technologies may have the greatest impact. The following are a few examples of scenario studies which the reader may find interesting in this respect.

Figure 1.8 presents a comparison of three scenarios of energy use in the industrial sectors of the developing countries, as assembled by the World Energy Council (WEC 1993, 1995). In their "business-as-usual" scenario, the WEC assumes continued use of the current mix of fuels and industrial technologies. The "state-of-the-art" scenario, on the other hand, assumes replacement of the current industrial stock with the most efficient technologies available in the mid-1990s, and the "ecologically-driven" scenario assumes that efficient technologies under development but not yet commercialized (as of 1995) are also adopted. As shown, the state-of-the-art scenario saves about 16 percent of the energy use in the business-as-usual case, while the ecologically-driven scenario shows a reduction of approximately 35 percent relative to projected demand in the business-as-usual scenario. The potential savings in moving from the business-as-usual to ecologically-driven scenarios are strongest in the refining, cement, and chemicals sub-sectors.

Figure 1.8: Potential for Energy Savings in Developing Countries from Improved Industrial Technologies in the Year 2020



Source: WEC 1995

In a study entitled China: Issues and Options in Greenhouse Gas Emissions Control (World Bank, 1994), a joint study team of Chinese and international researchers prepared baseline and alternative ("High-Efficiency") scenarios for China. In the high-efficiency scenario, year 2020 energy intensities for steel, cement, ammonia (a key nitrogen fertilizer), caustic soda (a major chemical product), and ethylene (a chemical feedstock) ranged from 55 to 75 percent of their energy values in the baseline scenario.[17] Interestingly, none of these energy intensities (with the exception of that for ethylene) were lower than the per physical unit energy intensities in Japanese industry in 1980. This suggests that even in this high-efficiency scenario there is considerable room for additional improvement in industrial energy efficiencies.

At present, a number of greenhouse gas (GHG) mitigation studies are underway in nations around the world. These studies will yield additional detailed scenarios for energy-efficiency improvements, including those in the industrial sector. Two groups that are coordinating (and sometimes sponsoring) such studies are the UNEP Collaborating Center on Energy and Environment (see UCC, 1994, for example) and the U.S. Country Studies Program (Dixon et al, 1996).

In India, TERI (the Tata Energy Research Institute) is presently involved in a regional study titled "Asia Least Cost Green-house Gas Abatement Strategy," sponsored by the Asian Development Bank. The study will estimate CO_2 emissions under a base case scenario and identify a least cost abatement strategy to bring emissions to an acceptable level.

Key Issues in the Growth of Activity, Energy Use, and GHG Emissions

Both business-as-usual and alternative scenarios of development call for considerable growth in developing-country industrial output. This growth is necessary if the benefits of development are to be extended to (or start to be extended to) the substantial fraction of the globe's population that do and will live in what we now term the developing countries. The growth in industrial output means an increase in industrial capacity, which means that energy will be needed to power new facilities. Depending on the technologies adopted, there is a wide variation in the amount of energy that could be required to meet the needs for industrial output from such plants.

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[17] Values from Table 2.4 of World Bank, 1994.

As part of the trend toward integration of the global economy, there has been an ongoing trend toward locating industrial production facilities in developing countries, even when the goods produced by those facilities, particularly in the short-to-medium term, will be consumed largely in developed nations. Among the many reasons for this trend are: the attractiveness of less-expensive labor, raw materials, and energy in developing nations, the relative ease (in some cases) of siting and permitting major industrial facilities, and the desire to place production strategically for future global markets. The net result of this trend is that a great deal of productive capacity is likely to be built in the developing nations in the next two decades, and the energy efficiency of those plants will in large part determine the level of industrial-sector carbon emissions for many years to come. Since the least expensive time to influence the efficiency of an industrial facility is almost invariably *before* it is built (that is, during the design phase), this growth in productive capacity represents an excellent opportunity for mitigating future CO_2 emissions.

Some of the advantages provided by installing efficiency and GHG-reduction measures in new facilities include:

- A smaller incremental investment is usually needed when designing-in new technologies, as opposed to trying to retrofit newer technologies to existing installations.
- It becomes possible to design facilities "right" from the ground up, offering opportunities for minimizing energy and materials use, reducing the production of solid and liquid wastes and air-pollutant emissions, improving and better controlling product quality, improving working conditions, and reducing operating and maintenance expenses.
- New plants, if constructed to international state-of-the art specifications, can take advantage of the global marketplace for new technologies. State-of-the-art plants can also more easily meet the requirements of export product quality standards, making the output of the plants more valuable.

Opportunities for Improved Industrial Energy Efficiency in Developing Countries

A wide range of energy-efficiency technologies are available for application in industrial facilities in both developed and developing countries. Some examples of these technologies are listed Part Two of this report. Examples of the potential to apply industrial energy-efficiency options are presented in Table 1.5. Here, results of initial GHG mitigation analyses for a number of developing nations are reported (UCC, 1994). Some countries, such as Egypt and Venezuela, list technology-specific options, while others, such as Thailand and Senegal, attribute savings to generic industrial energy-efficiency improvements.

Table 1.5: Industrial Options Examined In UNEP/RISq GHG Abatement Studies (From UCCEE, 1994)

Country	Final Energy Avoided[1] (PJ)	CO_2 Emissions Avoided[2] (million tons)	CO_2 Abatement Options
BRAZIL	1134[3] (10%)	379 (47%)	– Efficiency improvements in lighting, electric heating, electric motors and general electricity savings. – Replacing fuel oil, metallurgical coal with fuelwood and charcoal from aforestation programs.
EGYPT	734 (64%)	59 (47%)	– Fuel switching (oil and coal to gas) – Cogeneration – General efficiency improvements – Waste heat recovery – Power factor increase – Efficient lighting – Solar energy penetration in thermal uses – Combustion control
INDIA	651 (7%)	68 (56%)	– Replacing coal with fuel oil for process heating. – Captive power generation by using pulverized coal-fired power generation technology.
SENEGAL	1 (7%)	(n.a.)	– Energy conservation measures
THAILAND	3.3 (0.2%)	0.8 (0.4%)	– Efficient electric motors
VENEZUELA	436 (20%)	15 (25%)	– Reducing energy intensities in furnaces (direct heat), motors, boilers (steam production) and specific uses of electricity (refrigeration, air conditioning, lighting)
ZIMBABWE	168 (68%)	17 (79%)	– Efficiency improvements in boilers, furnaces and electric motors. – General energy savings
TOTAL	3127.3 (12%)	538.8 (40)%	

Notes: 1. Figures in brackets refer to energy reduction as a percentage of industrial demand in the reference scenario.
2. Figures in brackets refer to percentages of the total amount of CO_2 reductions in the abatement scenario.
3. It refers to electricity savings. Energy demand in the sector increases due to the penetration of biomass (bagasse, fuelwood and charcoal) in industrial uses.

Although the information presented in this table represents only initial, incomplete surveys of industrial-sector CO_2 abatement options, it serves to underscore the importance of industrial-sector measures in helping to reduce (relative to standard practices) energy use and greenhouse-gas emissions. As shown by the percentage figures in parentheses, potential energy savings in the industrial sector could represent a substantial fraction of reference-case industrial energy use, and CO_2 emissions avoided by industrial efficiency improvements can represent a large fraction of the total emissions abatement available in a country.

In a separate study on energy efficiency opportunities in North Korea, Von Hippel and Hayes (1995) estimated that industrial boiler and furnace improvements *alone* could save about 12 percent of the nation's annual output of coal, compared to 1990 production levels, with a savings in carbon-dioxide emissions of about 15 millions tonnes per year.

Varying Needs and Opportunities for New Technologies Across and Within Regions and Countries

The future requirements of developing countries for energy-efficient industrial technologies, and the level of assistance that may be required from the international communities to help those countries optimize their use of those technologies, will vary from country to country. Some of the determinants of the need for these technologies include:

- The size, composition, incomes, and level of education of the population and of the work force, which will in part determine the internal market for industrial goods and the attractiveness of the country to external investors in industrial facilities
- The structure of economy,
- The age and condition of the existing stock of industrial facilities and related infrastructure (energy supply, transport), and
- The availability and quality of indigenous technologies and raw materials.

Different countries' situations will also pose different levels of opportunity for implementing industrial energy-efficiency measures. Some of the determinants of these opportunities could include:

- Political and economic stability, serving as a foundation for economic growth
- The efficiency of information dissemination within the country—specifically, the degree to which adoption of efficiency measures in a few demonstration plants are likely to catalyze adoption of similar measures in other industrial facilities
- The availability of internal and external capital for energy-efficiency investments in the sector, including the attractiveness to capital providers
- Relationships with trading partners that have energy-efficient technologies to offer (for example, the relationships of developing countries in Asia with Japan, South Korea, and other potential sources of highly-efficient equipment).

Differences in the applicability of energy-efficient industrial technologies can also arise from different national and regional circumstances. For example, depending on their resource endowment, countries may have different traditional feedstocks for specific industrial processes,[18] have labor-relations situations that make certain types of technologies difficult to use, or have political structures that have isolated them, in some respect, from access to industrialized-country technologies. Helping countries with these types of circumstances to catalyze changes in their industrial sectors may require extra effort by the international community.

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[18] A substantial fraction of North Korea's textile industry, for example, is based on fiber made from domestic coal. Although improvements in this substantially unique process are possible, they are not likely to be generalizable to other developing countries, and are thus less attractive to potential suppliers of financial and technical assistance.

Sample Analyses of Industrial Energy-efficiency Potential in Developing Countries

Industrial energy intensities in **India** are typically quite high, and there is significant scope for energy conservation. Energy intensities can be reduced not only in the long run (through the use of process modifications, high-efficiency equipment, and energy substitution), but also in the short run through better “house-keeping” measures. A survey of 304 industries revealed the savings potential shown in Table 1.6.

Table 1.6: Energy Saving Potential in Industries (% of total energy consumption)

Industry	Without significant investment (%)	With significant investment (%)	Total (%)
Foundries	15	10	25
Aluminum	8	2	10
Cement	4	4	8
Fertilizer	12	2	14
Paper	6	12	18
Glass	5	5	10
Textiles	10	5	15

Source: Proceedings of the conference on energy savings in industry organized by FICCI, Bombay, India (1988)

Table 1.6 indicates that in a number of very energy-intensive industries, including metal foundries and aluminum and fertilizer production, sizable energy savings can be achieved simply through better management practices and at no major cost. The problem therefore seems more to be one of low incentive to save energy and/or lack of awareness of methods of improving energy management, rather than a problem of poor technology (though the latter too is important).

According to the Tata Energy Research Institute (TERI), The primary barrier to industrial energy conservation in India lies in the lack of knowledge in industry about conservation potential. Government efforts to promote energy efficiency have been bureaucratic in nature, with little coordination with other organizations operating in the field. As a consequence, these efforts have been largely ineffective. Many of the major energy-intensive industries are dominated by public-sector enterprises that operate as monopolies and/or are subsidized by the government. Even in the private sector, the industrial licensing regime in force until very recently prevented domestic competition, while the threat of foreign competition was reduced by trade restrictions. As a consequence, industry in general had little incentive to try and reduce production costs, including energy costs. Recent attempts at energy pricing and economic reforms aimed at promoting competition, however, are likely to increase the pressure on industries to pursue energy conservation in order to maintain large market shares.

Where a conscious effort to improve energy efficiency has been made, results have been very encouraging. For example, in the 1980s the Steel Authority of India Ltd. (SAIL) was able to achieve a 15% reduction in its energy consumption in just five years.

In **Brazil**, the National Technological University conducted a program on “Optimization of the Rational Use of Energy” (RUE) in small and medium-sized industrial firms. According to the assessment made under this program, the total annual energy consumption in the 543 firms audited was 409 Mtoe/year. The technically-feasible savings identified was 49 Mtoe per year, or 12% of the total energy used. Table 1.7 shows the breakdown of potential savings by measure. Notably, this assessment found that 50 percent of the potential savings could be attained without any additional investment.

Table 1.7: Energy Savings Potential in Audited Small and Medium Size Brazilian Industrial Firms

ENERGY EFFICIENCY MEASURE	TOE/YEAR SAVINGS	PERCENTAGE OF TOTAL SAVING
Boiler combustion	22302	46
Furnace combustion	3753	8
Insulation	8084	17
Use of steam	3267	7
Use of condensates	2497	5
Energy recovery	5987	12
Process	356	1
Lighting	390	1
Electricity	623	1
Energy management	1375	3
Fuel substitution	166	0
TOTAL	**48945**	

The main obstacles, as identified by the assessment, to implementing a program of energy- saving measures in small and medium-sized industries include:

- Uncertainty regarding future energy prices,
- Insufficient numbers of engineers in the plants,
- Uncertainty regarding the benefits resulting from the application of energy-conservation measures,
- Lack of investment in research and development of new technologies and more efficient processes (This aspect restricts the long-term saving potential and makes the industries dependent on foreign suppliers of energy-efficient technologies.),
- Lack of funds to implement improvements in the plants,
- Obsolete equipment and facilities,
- Insufficient attention to the analysis of fluctuations in energy consumption,
- Little information on Governmental RUE measures,
- Low energy costs as a fraction of total costs,
- Unwillingness to invest in RUE with internal rates of return lower than alternative investments,
- Most of the small- and medium-sized firms do not keep records of energy consumption,
- High financial cost of energy-efficiency measures and the lack of availability of credit,
- Lack of fiscal and financial incentives for what may be perceived as “risky” irreversible investments, and
- Lack of regulatory standards and information enabling the user to compare and select equipment based on its energy efficiency.

Conclusions

The current and future patterns of energy use and GHG emissions in the industrial sector indicate both the need and opportunities for enhancing sustainable development through industrial energy efficiency and process improvements.

The need:

- "Business-as-usual" scenarios of future global industrial energy use show the share accounted for by developing economies increasing from roughly 25 percent in 1990 to 40 percent by 2020, and 60 to 70 percent in 2050.
- The developing-country share of carbon-dioxide emissions from the industrial sector is likely to be even higher than their share of energy use.
- The combination of population growth and economic expansion in many developing countries (particularly in Asia) during the 1990s has caused an increase, sometimes even a doubling or tripling, of the consumption and production of key energy-intensive industrial goods in those countries, while the consumption and production of those goods in developed and transitional economies has generally been stagnant or declining.

Opportunities:

- "Alternative" scenarios of industrial-sector development in developing nations indicate substantial opportunities for overall reduction of industrial-sector energy use.
- There is a vast array of technologies applicable for energy- and process-efficiency improvements in the industrial sectors of developing countries. The technologies and examples of applications described in this chapter present only a few of the options.
- Assuming that current patterns of growth in industrial infrastructure in the developing world continue, there will be opportunities to cost-effectively install energy-efficient technologies as new industrial facilities are built, yielding a reduction (relative to standard technologies) in energy use and greenhouse-gas emissions, as well as other environmental and economic benefits.

As many previous studies have pointed out, developing countries require access to specific information describing the technological options available for harnessing these opportunities as well as tools to allow for their evaluation and comparison. The World Resources Institute, for example, illuminated developing countries' need for impartial information on available energy-efficient technologies in the energy chapter of their 1992-93 annual publication (WRI, 1992). The IPCC elaborated on this theme in 1996, calling for "concerted efforts to disseminate information" on GHG abatement techniques and technologies (IPCC, 1996a). Development of IDENTIFY, including both a Technology Inventory and an Analysis Tool as described in Part Two of this document, represents a concrete effort on the part of UNIDO to contribute to addressing these requirements.

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Appendix 1A: Per-capita Income and the Consumption of Energy-intensive Industrial Goods.

Evidence suggests per capita consumption and production of energy-intensive materials tend to increase most rapidly in early stages of economic development. For example, Figure 1A-1, below, [19] shows the relationship between per-capita consumption—in this case, demand for ten energy intensive materials—and per-capita income.

Looking at the trends shown in Figure 1A-1, there is a clear increase in production and consumption of energy intensive materials as incomes rise, but there is also evidence of a tendency for the consumption and production to be most sensitive to changes in income at the lower income levels. For example, note how the points for the low and low/middle income countries (marked as Aa through Dd) on the graph are more widely spread than points for the industrial market economies (points hH through kK). This saturation of energy-intensive goods with rising incomes is observed in both periods 1969-1971 and 1979-1980, suggesting that it is an income effect, rather than a response to higher energy prices (caused by the “oil crises” of the 1970s) in the latter period. The type of relationship illustrated in Figure 1A-1, between per capita income and another economic, social or environmental variable, is often referred to as a Kuznets curve.[20]

Williams, Larson and Ross (1987) interpret these and other data as suggestive of a fundamental shift away from the consumption of energy-intensive materials in developed market economies. Market saturation for energy-intensive materials in higher income economies, combined with rapidly increasing per capita demand for energy intensive materials in developing countries, reinforces the importance of examining energy-intensive industries in developing countries when searching for attractive options for mitigating greenhouse-gas emissions at the global scale.

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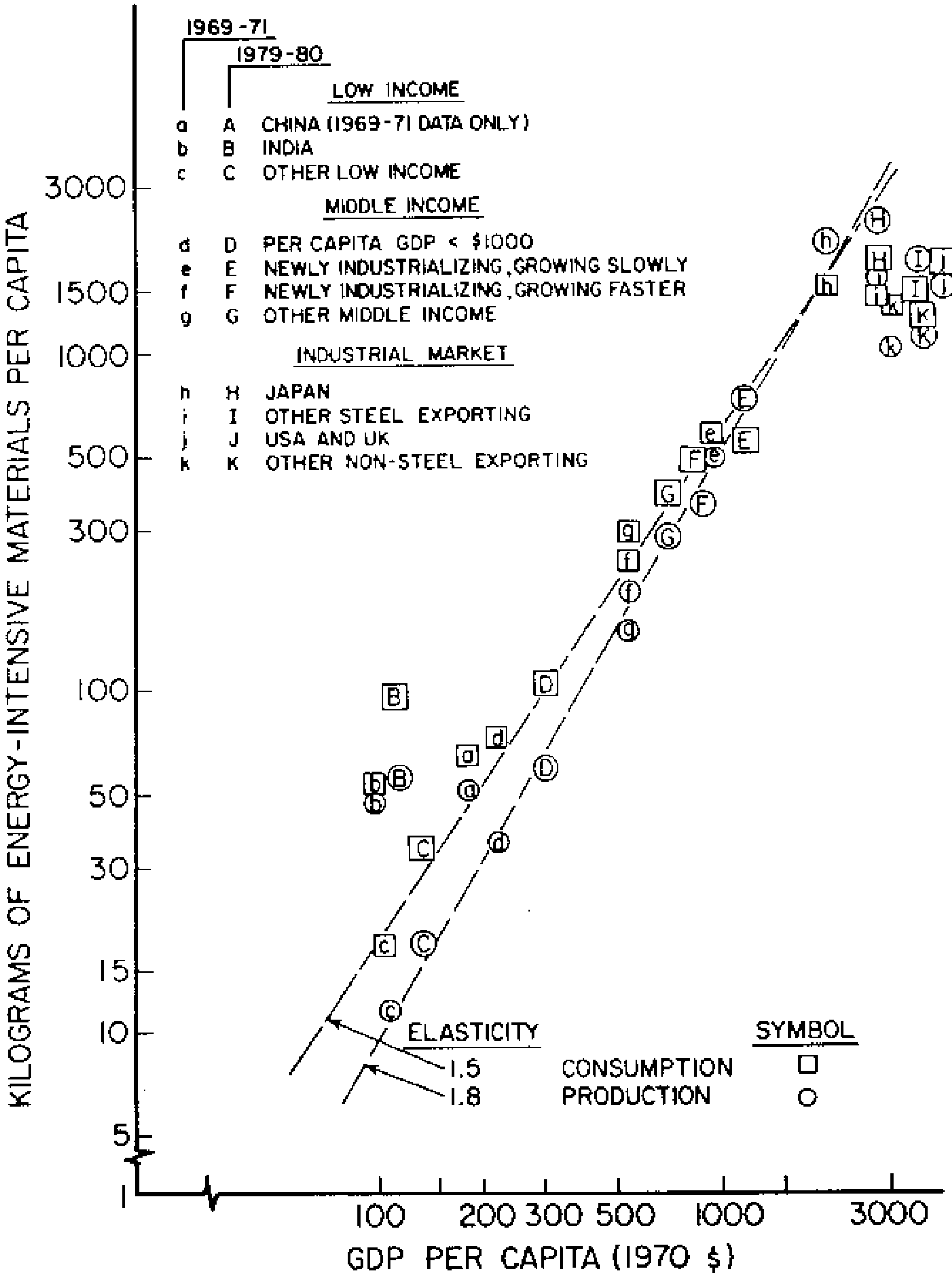
[19] Source: Williams, Larson and Ross (1987), citing original research conducted by Strout (1985) on per capita production and use of 10 energy intensive materials during two periods (1969-1971 and 1979-1980).

[20] See World Bank (1995) for a Kuznets-type curve, relating carbon emissions per unit of GNP to the log of per capita GNP. The curve is interpreted to suggest middle income countries emit the most carbon per $ of GNP.

Figure 1A-1: Relationship between per capita income and production/consumption of energy-intensive materials



Source: Williams, Larson, and Ross, <u>Annual Review of Energy</u>, 1987

Part Two: The UNIDO Industrial Development Energy Technology Investment Framework (IDENTIFY)

IDENTIFY is a software package designed to help users answer two key questions:

- To what extent can improved industrial technologies and practices reduce greenhouse-gas emissions in a given developing country?
- What other impacts such as costs and non-economic benefits would result from the introduction of these technologies?

IDENTIFY is intended to be used by analysts to assess energy-efficiency and fuel-switching measures that can reduce fossil-fuel consumption, thereby reducing greenhouse-gas emissions and, in many cases, providing overall economic benefits as well. The package is comprised of an **Analysis Tool** and an **Industrial Technology Inventory**, each designed to complement the other but be useable, if desired, on a stand-alone basis.

The Analysis Tool: An Overview

The Analysis Tool provides a means for assessing the costs and benefits of industrial greenhouse-gas mitigation strategies. The tool is intended to be used by anyone with an interest in analyzing industrial greenhouse-gas mitigation options: government planners, researchers, NGOs, consultants or industry managers. It walks the user through the steps needed to evaluate the greenhouse-gas emissions, energy-consumption patterns and costs of different industrial technologies (including both new plants and retrofits) by performing cost-benefit analyses of energy-efficiency and fuel-switching investments.

The tool is implemented as an Excel spreadsheet, making it easy to use but also flexible and simple to adapt to different user needs and data requirements. The user specifies information about the basic physical, cost and emissions characteristics of alternative industrial-sector mitigation options, and projects how costs might change over time. The tool includes specialized calculations for the emissions produced both by on-site fuel use and by off-site generation of electricity or production of steam.

Types of Analysis

Two types of analysis can be carried out with the spreadsheet tool: project analysis and comparative analysis.

- **Project Analysis:** Project or absolute analysis is concerned with the overall viability of an option. The benefits of the project, comprising the economic value of the products produced by an industrial facility (*e.g.* tonnes of cement or steel), are compared to the costs of building and operating the project.

- **Comparative Analysis:** Comparative analysis allows a user to compare any option to a baseline option. Benefits comprise the cost, energy and emission savings of an option relative to the baseline option. This kind of analysis can be particularly useful when examining retrofit options for reducing emissions from an existing plant. It is important to note that an option which appears favorable under a comparative analysis (for example when compared to a currently operating facility) will not necessarily appear favorable when analyzed using the absolute analysis described above.

The spreadsheet projects costs over a 30 year period in order to calculate a range of standard indicators such as the net present value, internal rate of return, and simple payback period for investments. It also calculates key mitigation analysis results including annual avoided carbon emissions, the costs of saved carbon (or benefits, in the case of "no regrets" options), and the cost of saved energy. The spreadsheet reports additional key indicators useful in determining local and global benefits, and identifying financing needs, where needed, to pay for incremental costs. In addition, it displays a range of more detailed reports and graphics including the types of fuels used by each option and the breakdown of costs (capital, operating and maintenance, fuel costs, administration, etc.) for each option. Carbon externality costs can be included optionally in the analysis by simply entering a cost per tonne of carbon emitted, and then clicking on a check box to include the cost in the calculations.

Examples of Energy-efficient Technologies and Process Improvements

The list below presents a sampling (only) of technological and process improvements that can be applied to the major energy consuming sub-sectors described earlier in this paper, plus a list of some of the more "generic" measures that can be applied in a variety of industrial settings. Most of these examples are derived from WEC (1995), except as noted. Additional information on energy efficiency in the industrial sector is provided in work by the U.S. Office of Technology Assessment (OTA, 1993).

Users of the analysis tool should use this list along with the data collected and presented in the technology inventory to help formulate the options being examined in their analyses.

Specific Options for the Iron and Steel Industry

- The continued replacement of open-hearth furnaces with basic oxygen furnaces (can save 1 to 3 GJ per tonne of steel—about 5 to 15 percent relative to current OECD practice)
- Increase the use of scrap steel
- Use of power recovery turbines on blast furnaces
- Use of continuous casting of steel products (as opposed to ingot casting, in which steel ingots must be re-melted to produce products in their final form, and rolling of steel before it has cooled

Specific Options for the Chemicals

- Use of improved catalysts for key types of chemical reaction
- Improvements in distillation equipment
- Improvements in gas turbine efficiency
- Expanded process integration to conserve heat generated during reactions
- Use of membrane technologies for separation of reactants

Specific Options for the Refining Industry

- Pre-heating of crude oil input
- Use of reflux-overhead vapor compression
- Use of mechanical vacuum pumps
- Integration of heat use between distillation units
- Improved catalysts

Specific Options for the Pulp and Paper Industry

- Continuous pulp digesters, alternative chemical and chemi-mechanical pulping processes, alcohol-based solvent pumping
- Oxygen or ozone bleaching and delignification
- Chemical recovery, including freeze concentration or gasification of black liquor
- Wet-pressing of paper products, high-consistency forming, impulse drying, and microwave drying

Specific Options for the Cement Industry

- Materials preparation efficiency measures including waste-heat drying, differential grinding of limestone and clay, fluidized-bed drying with low-grade fuels
- Kiln combustion system improvements and modifications to reduce heat loss, use of waste heat from product cooler, use of fluidized-bed kilns and all-electric or hybrid kilns
- Blending cements so as to reduce the energy required for production
- Modified product grinding equipment, including better control of particle size (for example, high-efficiency air classifiers; IPCC, 1996b)

Generic Options Important in Many (if not most) Industrial Sub-sectors

- The use of heat recovery (in many different sub-processes) for steam generation, pre-heating of combustion air, including the use of ceramic recuperators (IPCC, 1996b)
- Fuel-switching to natural gas (where available)
- Improved industrial boilers and furnaces, including improved fuel pre-treatment, computerized boiler control, and natural gas pulse-combustion boilers (IPCC, 1996b)
- Expanded use of cogeneration of heat and power
- High-efficiency electric motors and electronic adjustable-speed drive systems
- High-efficiency lighting systems
- Computerized process optimization, control, energy management, and environmental management (that is, pollution emission sensing and control) systems
- Good housekeeping and minimization of materials waste, including pre- and post-consumer recycling of raw materials

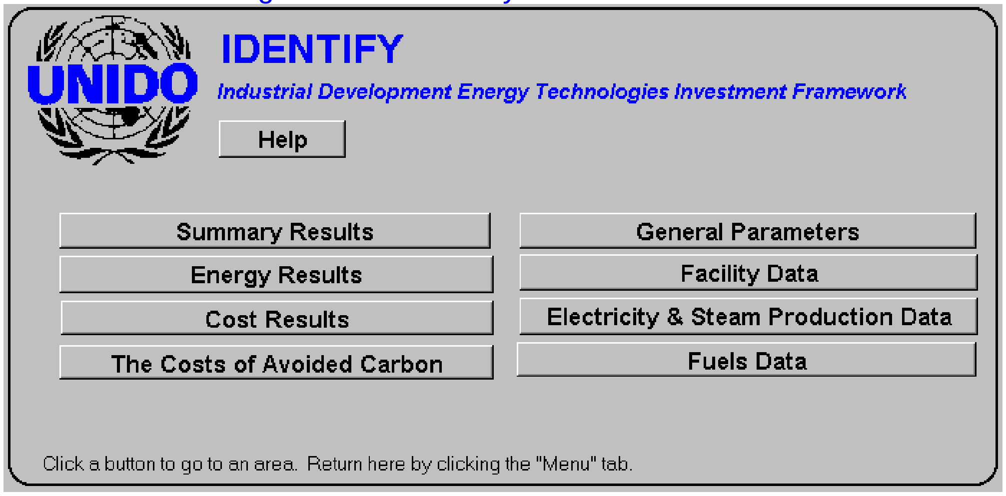
The Analysis Tool: User Instructions with Examples

The Identify Analysis Tool is implemented as Microsoft Excel spreadsheet. To use the tool, simply load the spreadsheet "IDENTIFY.XLS" into Excel. You will need to be using Microsoft Excel version 5.0 or higher.

The Main Menu

On first loading the spreadsheet, the main menu of the system will be displayed (see Figure 2.1). This contains two columns of buttons; the first directs you towards results, and the second lists areas where inputs are required.

Figure 2.1: The Analysis Tool Main Menu



Click a button to go to an area. Return here by clicking the "Menu" tab.

At any time, you can return to the Menu screen by clicking on the "Menu" tab at the bottom of the Excel Window. Tabs provide you with a second way of moving between the spreadsheets. *Within* a spreadsheet, you can move around by using the mouse, the arrow keys, the Page Up and Page Down keys, and the scrollbars. Moving *between* sheets, requires using the tabs on the screen or the buttons on the Menu screen.

The following sections describe the functionality of the analysis tool, and illustrate that functionality through the use of a simple example *(shown in italics)*, which you may care to follow. In our example, we examine mitigation options for a fictitious industrial facility "**ACME Widgets**" operating in the manufacturing sector. The process of making widgets is relatively energy intensive, using electricity for fans, pumping and lighting, and process heat for molding the widgets. ACME Widgets is considering building a new plant to produce a million widgets[21] a year, and has been asked by the government to examine the economic costs and climate change mitigation benefits of various construction and operation options. Two major alternatives are being considered:

1. **A Standard Plant:** with electricity purchased from the national grid (which in turn generates electricity from a mix of relatively inefficient coal, fuel oil, and diesel plants), and with all process heat produced in-house using conventional fuel-oil boilers.
2. **Cogeneration:** a more advanced plant using in-house natural gas fired cogeneration to generate all of the facility's electricity requirements and about 70% of its process heat needs. The remainder of the process heat requirements would be supplied from conventional fuel oil boilers.

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[21] A 'widget" is some unspecified product.

In addition, two further sub-options are being considered, and may be implemented at the same time as the construction of the more advanced plant.

3. **Efficient Process Heat:** Efficiency investments are being considered to reduce overall process heat requirements through heat recovery, improved insulation and other measures. These investments would be coupled with more efficient natural gas fired process heat boilers.
4. **Efficient Motors:** Demand side management investments are being considered that will lower the overall electricity requirements of the plant by about 5%. Note: this option could actually be investigated independently of options 2 and 3, but to simplify this example, we will consider it only after first examining options 2 and 3.

We will see how these four options can be investigated using the analysis tool. We will begin by entering basic data for the four options. We will then use the tool's project analysis features to examine the overall viability of the four plants. Finally we will examine the economic costs and benefits and greenhouse gas mitigation potential of options 2, 3, and 4 relative to the "baseline" standard plant.

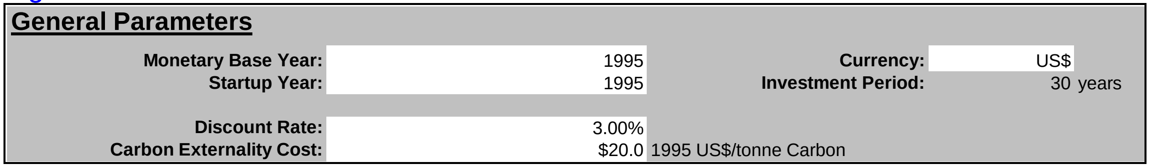
Entering Data

General Parameters

Using the main menu of the analysis tool, go to the General Parameters section of the spreadsheet. In general, all areas where you can enter data have a white background. Numbers with a gray background are the results of calculations in the spreadsheet and cannot be changed.

In this example, our analysis will be conducted in ***US dollars****, using a base year of* ***1995****. We will use a standard social discount rate of 3% and will assume an externality value of $20 per tonne of carbon emissions. Complete the General Parameters screen as follows:*

Figure 2.2: General Parameters Screen



General Parameters

Monetary Base Year:	1995		**Currency:**	US$
Startup Year:	1995		**Investment Period:**	30 years
Discount Rate:	3.00%			
Carbon Externality Cost:	$20.0	1995 US$/tonne Carbon		

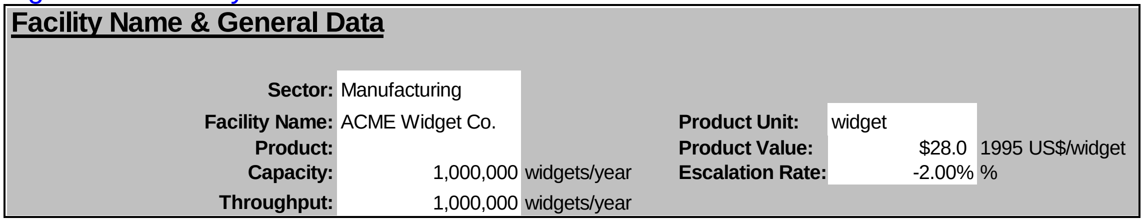
Facility Data

This sheet has four sections: Facility Name and General Data, Scenario Name, Cost Data, and Physical Data.

- **Facility Name and General Data:** Enter the sector, facility name, product and the product unit (e.g. tonnes of cement). You also need to enter the capacity and throughput of the plant, as well as the product value in terms of the monetary units specified under General Parameters. There is also a variable called escalation rate. This refers to the expected percent rise in the product value in real terms (i.e. not due to inflation).

  For our widget example, enter the following general data about ACME Widget Co.

Figure 2.3: Facility Name and General Data Screen



Facility Name & General Data

Sector:	Manufacturing				
Facility Name:	ACME Widget Co.		**Product Unit:**	widget	
Product:			**Product Value:**	$28.0	1995 US$/widget
Capacity:	1,000,000	widgets/year	**Escalation Rate:**	-2.00%	%
Throughput:	1,000,000	widgets/year			

Note that, in the base year (1995) each widget can be sold for $28, but that because of increasing competition in the sector, this value is expected to decrease by 2%/year in the foreseeable future in real terms (i.e. not including inflation). Note also, that in our example the capacity and throughput items are identical.

- **Scenario Names**: Here you enter a name for each option of the options to be examined. Note that you must enter a name in order to activate calculations for that option.

  For our widget example, enter the following four names:

Figure 2.4: Scenario Names Data Screen

Scenario Names	**Baseline**	**Option 1**	**Option 2**	**Option 3**
Enter a name to activate analysis...	Standard Facility	Cogeneration	Eff. Proc Heat	Eff. Motors

- **Cost Data**: Now enter cost information for each option. You can specify four types of costs: capital costs (which occur in the startup year of the facility), and three types of operation and maintenance (O&M) costs: fixed, variable, and administration. Cost units will depend on how you defined your general parameters earlier. Since O&M costs are incurred yearly, you may also enter a real escalation rate to describe for these costs will change over time. If you intend to carry out *project analyses* of all options then you will need to specify the full costs of all options. If you only intend to carry out *comparative analyses* of options, you need only specify how costs differ from the baseline option.

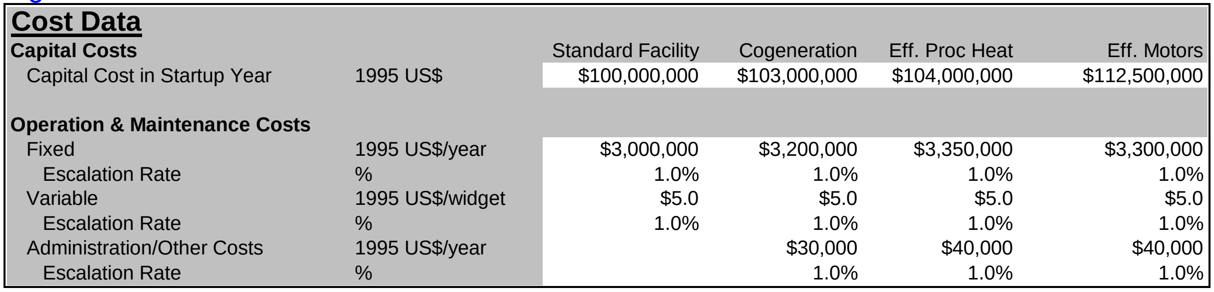
  For our widget example, start by specifying the costs of the standard facility. This has a capital cost of $100 million, fixed O&M costs of $3 million per year (expected to grow at 1% per year for the foreseeable future), and variable costs of $5 per widget (also expected to grow at 1% per year).

  The other three options differ as follows:

  1. ***Cogeneration:*** *capital costs are $3 million higher reflecting investment in the cogeneration system, which also raises fixed O&M costs by $200,000 per year, and adds administrative costs of $30,000 per year. These administrative costs are expected to increase by 1% per year for the foreseeable future.*
  2. ***Efficient Process Heat:*** *This option will incur additional capital costs of a million dollars (over and above those for the cogeneration option), plus additional O&M costs of $150,000 per year and additional administrative costs of $10,000 per year.*
  3. ***Efficient Motors:*** *This option will incur additional capital costs of $8.5 million (over and above those for the process heat and cogeneration options), but will lead to $50,000 per year savings in O&M costs (due to the lower maintenance requirements of the motors).*

  Overall, the costs data screen for the four options should be completed as follows:

Figure 2.5: Cost Data Screen



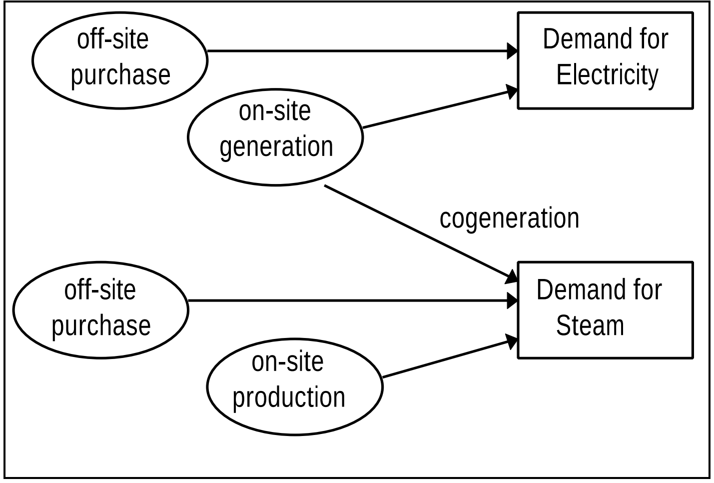
Cost Data

		Standard Facility	Cogeneration	Eff. Proc Heat	Eff. Motors
Capital Costs					
Capital Cost in Startup Year	1995 US$	$100,000,000	$103,000,000	$104,000,000	$112,500,000
Operation & Maintenance Costs					
Fixed	1995 US$/year	$3,000,000	$3,200,000	$3,350,000	$3,300,000
Escalation Rate	%	1.0%	1.0%	1.0%	1.0%
Variable	1995 US$/widget	$5.0	$5.0	$5.0	$5.0
Escalation Rate	%	1.0%	1.0%	1.0%	1.0%
Administration/Other Costs	1995 US$/year		$30,000	$40,000	$40,000
Escalation Rate	%		1.0%	1.0%	1.0%

- **Physical Data**: The physical data screen is used to specify fuel use in the plant. This section is properly considered in two parts. The first includes electricity and steam, fuels which are produced indirectly from other fuels. The second includes all other fuels used directly in the facility. Note that, if the fuels listed in this section do not correspond with those used in the facility you are studying, you can change the list by editing the Fuels Data screen.

When considering the consumption of electricity and steam, keep in mind that demand for these can be met from a variety of sources. As seen in Figure 2.6 below, demand for both electricity and steam can be met through on-site production or through outside purchases. Additionally, on-site production of electricity can be used to cogenerate steam to help meet process heat demands. In order to quantify the emissions associated with electricity and steam use, you will need to specify how each demand is met, i.e. what portion is produced on site, how much steam results from cogeneration, and how much remaining demand is met through purchases. It is then necessary to specify the fuels used for on-site generation and the mix of fuels used to generate purchased electricity or steam. NB: A separate worksheet is used to specify how purchased steam and electricity are produced (see below).

Figure 2.6: Schematic of Electricity & Steam Production.



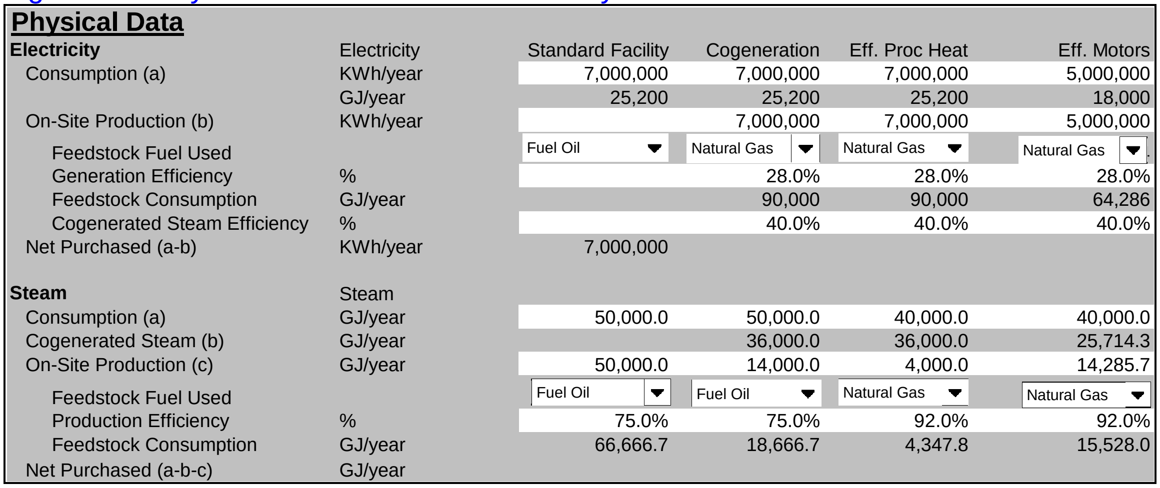
In the Physical Data section find the headings for Electricity and Steam. Under electricity, enter total consumption in kWh/year (row a). Next, enter the amount of electricity produced on-site in kWh/year (row b), and indicate the feedstock fuel used for its production. Feedstock fuel consumption will be calculated in GJ/year. Below this, enter the electricity generation efficiency and the cogenerated steam efficiency. Note that the sum of these two efficiencies must be less than 100% and typically will be no higher than about 80%. The amount of electricity purchased is calculated as (a-b).

Steam is calculated in a similar way. Enter total consumption (a), on-site production (c), the fuel used for on-site production, and the production efficiency. Cogenerated steam (b) is taken from the electricity calculations described above. The spreadsheet calculates the steam purchased by subtracting on-site production and cogenerated steam from total consumption (a- b-c).

In our widget example, the standard facility consumes 7 million kWh/year of electricity, all of which is purchased from the national grid. It also consumes 50,000 GJ/year of steam for process heat, which is produced on-site using standard fuel oil boilers that operate at an efficiency of

75%. The cogeneration option will produce all its electricity on-site using a natural gas fired system that operates at an electrical efficiency of 28% and a steam efficiency of 40%. This in turn reduces the need for on-site steam production to 14,000 GJ/year. The efficient process heat option reduces total process heat requirements to 40,000 GJ/year and uses more condensing efficient natural gas boilers that operate at 92% efficiency. The efficient motors option reduces overall electricity consumption to 6.7 million kWh/year. This in turn reduces overall cogenerated steam production, but also increases the need for on-site steam production. Enter this data under the Electricity and Steam option as shown below:

Figure 2.7: Physical Data Screen for Electricity and Steam



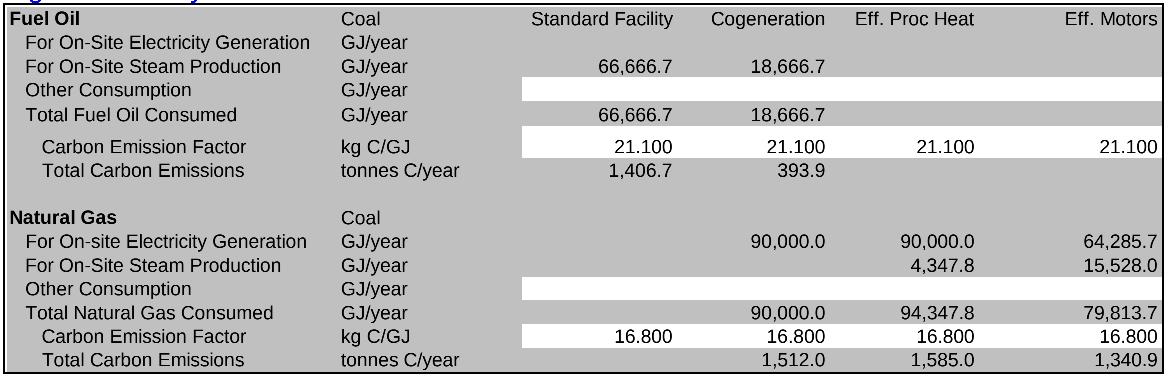
Physical Data

Electricity	Electricity	Standard Facility	Cogeneration	Eff. Proc Heat	Eff. Motors
Consumption (a)	KWh/year	7,000,000	7,000,000	7,000,000	5,000,000
	GJ/year	25,200	25,200	25,200	18,000
On-Site Production (b)	KWh/year		7,000,000	7,000,000	5,000,000
Feedstock Fuel Used		Fuel Oil ▼	Natural Gas ▼	Natural Gas ▼	Natural Gas ▼
Generation Efficiency	%		28.0%	28.0%	28.0%
Feedstock Consumption	GJ/year		90,000	90,000	64,286
Cogenerated Steam Efficiency	%		40.0%	40.0%	40.0%
Net Purchased (a-b)	KWh/year	7,000,000			
Steam	Steam				
Consumption (a)	GJ/year	50,000.0	50,000.0	40,000.0	40,000.0
Cogenerated Steam (b)	GJ/year		36,000.0	36,000.0	25,714.3
On-Site Production (c)	GJ/year	50,000.0	14,000.0	4,000.0	14,285.7
Feedstock Fuel Used		Fuel Oil ▼	Fuel Oil ▼	Natural Gas ▼	Natural Gas ▼
Production Efficiency	%	75.0%	75.0%	92.0%	92.0%
Feedstock Consumption	GJ/year	66,666.7	18,666.7	4,347.8	15,528.0
Net Purchased (a-b-c)	GJ/year				

Data entry for other fuels used in the plant are entered below electricity and steam. In each case the first two lines calculate the demand for that fuel for steam production and electricity production. After that there is a field into which you may enter any other consumption of that fuel. In this section, you should also specify the carbon emission factor associated with each fuel. By default, this value is taken from the Fuels Data sheet (see below), however, you may choose to override the data for specific technology options.

In our widget example, no further fuels are used and hence no additional data entry is required. Check the sections for natural gas and fuel oil to make sure they are similar to the following screen capture.

Figure 2.8: Physical Data Screen for Fuel Oil and Natural Gas



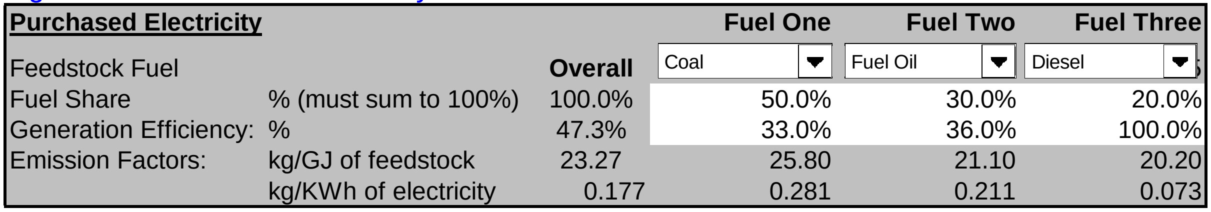
Fuel Oil	Coal	Standard Facility	Cogeneration	Eff. Proc Heat	Eff. Motors
For On-Site Electricity Generation	GJ/year				
For On-Site Steam Production	GJ/year	66,666.7	18,666.7		
Other Consumption	GJ/year				
Total Fuel Oil Consumed	GJ/year	66,666.7	18,666.7		
Carbon Emission Factor	kg C/GJ	21.100	21.100	21.100	21.100
Total Carbon Emissions	tonnes C/year	1,406.7	393.9		
Natural Gas	Coal				
For On-site Electricity Generation	GJ/year		90,000.0	90,000.0	64,285.7
For On-Site Steam Production	GJ/year			4,347.8	15,528.0
Other Consumption	GJ/year				
Total Natural Gas Consumed	GJ/year		90,000.0	94,347.8	79,813.7
Carbon Emission Factor	kg C/GJ	16.800	16.800	16.800	16.800
Total Carbon Emissions	tonnes C/year		1,512.0	1,585.0	1,340.9

Electricity and Steam Data

In addition to direct on-site fuel use, you will also need to account for the emissions resulting from purchased electricity and steam. This is done in the Electricity and Steam Data sheet. On this screen, use the pull down menus to select a mix of up to 5 fuels used to produce the electricity and steam products, and enter the percentage of generation from each fuel. Note that you can edit the overall list of fuels on the Fuels Data sheet. The spreadsheet checks that the percentages entered here sum to 100 percent and prints a warning note if they do not. Finally, enter the generation efficiency for each fuel. By convention, efficiencies for hydro, solar and other renewable forms of energy are often expressed as 100% (i.e. in electric equivalent units). However, you may wish to compare these resources to their thermal counterparts by entering a thermal equivalent efficiency of approximately 33%. Either approach may be used and both will yield the correct GHG mitigation factors.

In our widget example you need only specify data about purchased (grid) electricity since no outside steam is purchased by any configuration of our manufacturing facility. In the example, electricity is produced relatively inefficiently and from a carbon intensive mix of plants: coal, fuel oil and diesel. Complete the screen as follows:

Figure 2.9: Purchased Electricity Data Screen



Purchased Electricity			**Fuel One**	**Fuel Two**	**Fuel Three**
Feedstock Fuel		**Overall**	Coal	Fuel Oil	Diesel
Fuel Share	% (must sum to 100%)	100.0%	50.0%	30.0%	20.0%
Generation Efficiency:	%	47.3%	33.0%	36.0%	100.0%
Emission Factors:	kg/GJ of feedstock	23.27	25.80	21.10	20.20
	kg/KWh of electricity	0.177	0.281	0.211	0.073

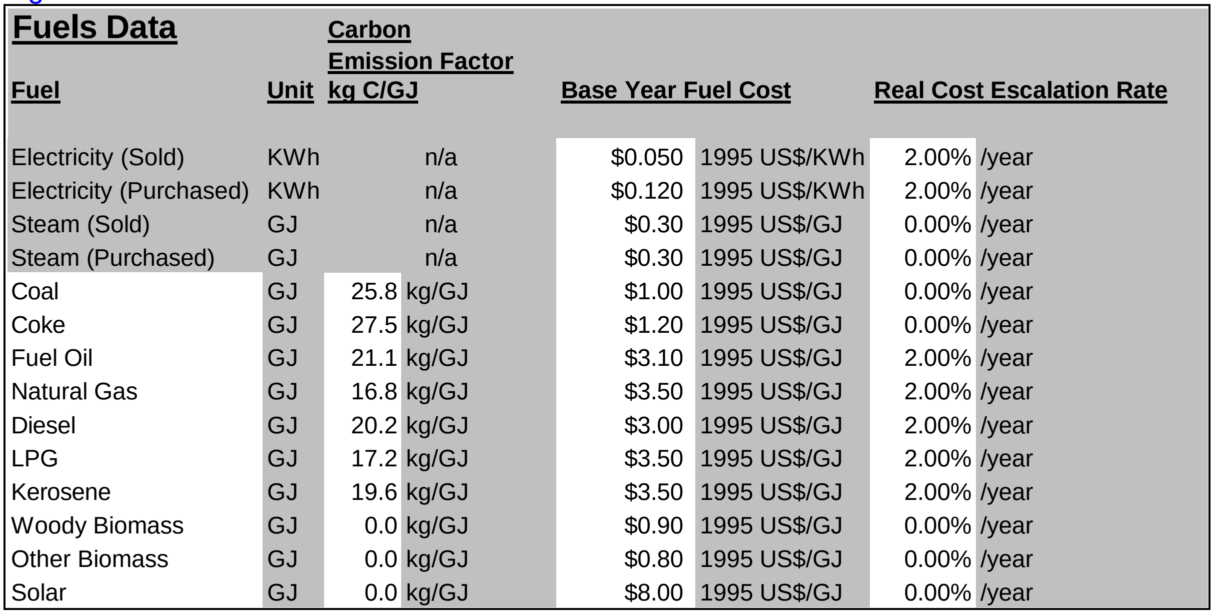
Fuels Data

The Fuels Data sheet is a database of information on the fuels used in your analysis. From here you can enter information on the carbon emission factor for each fuel (kilograms of carbon per GJ), fuel prices (monetary unit per kWh for electricity or per GJ for all other fuels), and the real price escalation rate for each fuel (the expected long-run growth in fuel prices over and above the general level of inflation – it can be negative if real prices are expected to decrease). By default the analysis tool includes default carbon emission factors compatible with factors recommended by the IPCC for greenhouse gas mitigation analysis, plus base year fuel costs taken from US government estimates of long-term fuel price changes. You can change these values to suit your own study requirements or build multiple fuel price data sets using Excel's built-in scenario manager. You may also adjust the list of fuels for your own study purposes. The list of fuels specified on this screen appears in the fuel selection pull-down menus in the Facility Data and Electricity and Steam Data sheets.

If you scroll to the right on this sheet, you will find time series data for fuel costs starting in the startup year and going for 30 years. These numbers result from calculations based on the growth rates described above. They may be overridden if you have more detailed time series data simply by typing numbers into the appropriate spaces.

For the widget example, you can use the default list of emission factors and supplied with the tool. You will also need to specify the costs of the fuels used in the various options: natural gas, fuel oil, (and for purchased electricity) coal and diesel. Complete the screen to match the one shown below:

Figure 2.10: Fuels Data Screen

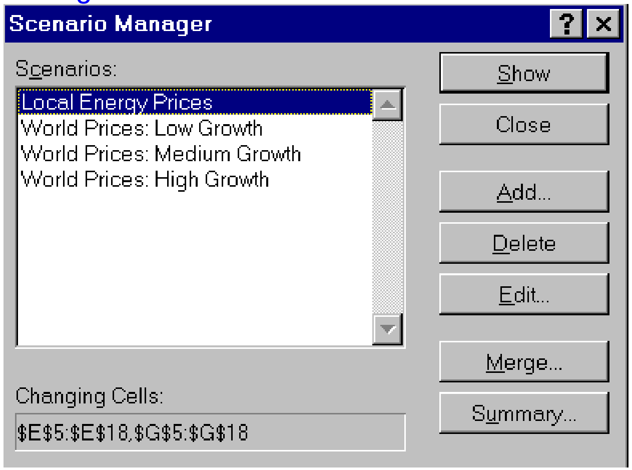


Fuels Data

Fuel	Unit	Carbon Emission Factor kg C/GJ		Base Year Fuel Cost		Real Cost Escalation Rate	
Electricity (Sold)	KWh	n/a		$0.050	1995 US$/KWh	2.00%	/year
Electricity (Purchased)	KWh	n/a		$0.120	1995 US$/KWh	2.00%	/year
Steam (Sold)	GJ	n/a		$0.30	1995 US$/GJ	0.00%	/year
Steam (Purchased)	GJ	n/a		$0.30	1995 US$/GJ	0.00%	/year
Coal	GJ	25.8	kg/GJ	$1.00	1995 US$/GJ	0.00%	/year
Coke	GJ	27.5	kg/GJ	$1.20	1995 US$/GJ	0.00%	/year
Fuel Oil	GJ	21.1	kg/GJ	$3.10	1995 US$/GJ	2.00%	/year
Natural Gas	GJ	16.8	kg/GJ	$3.50	1995 US$/GJ	2.00%	/year
Diesel	GJ	20.2	kg/GJ	$3.00	1995 US$/GJ	2.00%	/year
LPG	GJ	17.2	kg/GJ	$3.50	1995 US$/GJ	2.00%	/year
Kerosene	GJ	19.6	kg/GJ	$3.50	1995 US$/GJ	2.00%	/year
Woody Biomass	GJ	0.0	kg/GJ	$0.90	1995 US$/GJ	0.00%	/year
Other Biomass	GJ	0.0	kg/GJ	$0.80	1995 US$/GJ	0.00%	/year
Solar	GJ	0.0	kg/GJ	$8.00	1995 US$/GJ	0.00%	/year

Our widget example is based on fuel prices that reflect world market prices for most fuels. In you own studies you may want to examine the impact of fuel price subsidies on the economics of your envisaged options. To do this, you can use Excel's built-in ***scenario manager*** *to build two fuel price data sets: one representing local (subsidized or otherwise distorted) fuel prices, and another that is more consistent with world fuel prices or the removal of local subsidies.*

Figure 2.11: Using The Analysis Tool to Manage Fuel Cost Scenarios



Scenarios:
Local Energy Prices
World Prices: Low Growth
World Prices: Medium Growth
World Prices: High Growth

Changing Cells: $E$5:$E$18,$G$5:$G$18

This completes all of the data entry requirements for our simple widget example. You can now view the various results produced by the tool and use them to investigate both the absolute costs of the facilities and to compare the costs, benefits and mitigation potential of the three mitigation options against the baseline of the standard facility.

Viewing Results

From the Main Menu of the Analysis Tool you can access four different areas of results: summary results, energy results, cost results, and costs of avoided carbon.

Summary Results

Two types of analysis can be carried out with the spreadsheet tool: project analysis and comparative analysis. Summaries of results from each of these analyses are presented in the summary results section.

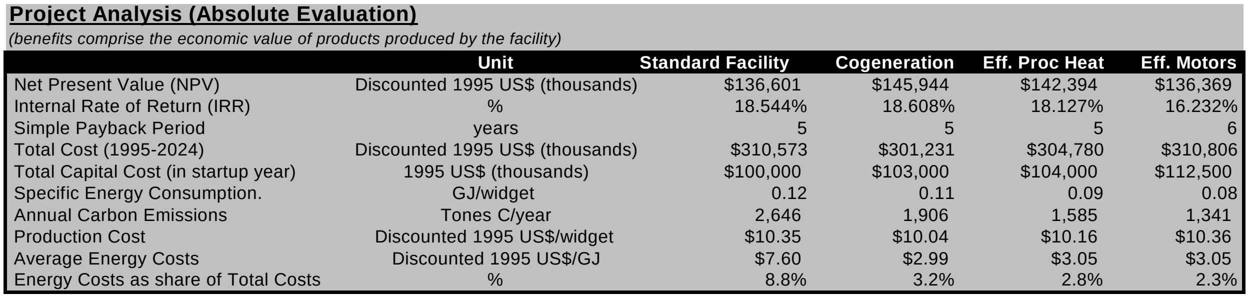
Project Analysis: Project or absolute analysis is concerned with the overall viability of an option. The benefits of the project comprise the economic value of the products produced by an industrial facility (e.g. tonnes of cement or steel). The Project Analysis Summary contains the following rows of information:

- **Net Present Value (NPV):** NPV is calculated as the value of the product produced by the facility (e.g. tonnes of cement) minus the costs of building and operating the plant (capital, O&M, fuel costs and, optionally, externality costs). Costs and benefits in years after the startup year are discounted back to the base year. Positive NPVs indicate the option is viable. Negative NPVs are shown in red in parentheses.
- **Internal Rate of Return (IRR):** IRR is defined as the discount rate that would result in a NPV of zero. Therefore, if the IRR for an option is greater than the discount rate, the option is considered viable.
- **Simple Payback Period:** The payback period refers to the number of years before the initial capital investment has been recouped from sales of the product, net of fuel, O&M, administrative, and (optionally) externality costs.
- **Total Cost***:* the sum of capital, fuel, O&M, and (optionally) externality costs over the 30-year analysis period, discounted to base year currency units.
- **Total Capital Cost:** the initial capital cost of each investment. All capital costs are assumed to be invested in the startup year of the analysis.
- **Specific Energy Consumption:** the total energy use (direct use of electricity and other fuels on-site) divided by the facility throughput.
- **Annual Carbon Emissions:** the total annual emissions of carbon from each option.
- **Production Cost:** the total discounted costs over the 30 year period divided by total facility throughput in the same period.
- **Average Energy Cost:** Total discounted costs over the 30 year period divided by the total on-site energy use (i.e. on-site fuel use the purchase electricity and steam). NB: energy use here and elsewhere is not measured in units of primary fuel equivalents. Instead, fuel use is measured in the units of measurement that are applicable to the industries themselves.
- **Energy Costs as Share of Total Costs:** a percentage indication of energy costs expressed as a fraction of total costs.

In our widget example, you should see a project analysis summary report like the one shown below. A number of interesting features stand-out from the report. First, and foremost, the economics of all four of the options look favorable under the project analysis. All of the options have high IRRs of between 16% and 19%, well above the discount rate we used of 3%. Similarly, the projects all yield strongly positive Net Present Values (NPVs) of over $135 million over the 30 year study lifetime, and all of the projects have a simple payback period of six years or less. The main reason for this effect is the large margin between the value of widget sales and costs (capital, O&M, and fuel costs). Nevertheless, fuel costs are a relatively high 8.8% of total costs in the standard facility, but decrease dramatically to around 3% of total costs in the 3 mitigation options (due primarily to fuel switching savings from cogeneration).

It is also interesting to note the relatively small effect that the inclusion or exclusion of carbon externality costs has on the evaluation. Even including a carbon externality value of $20 per tonne has little effect on the overall economics of the analysis You can try this yourself by checking the ***Include Externality Costs?*** *checkbox.*

Figure 2.12: Project Analysis Results Screen



Project Analysis (Absolute Evaluation)

(benefits comprise the economic value of products produced by the facility)

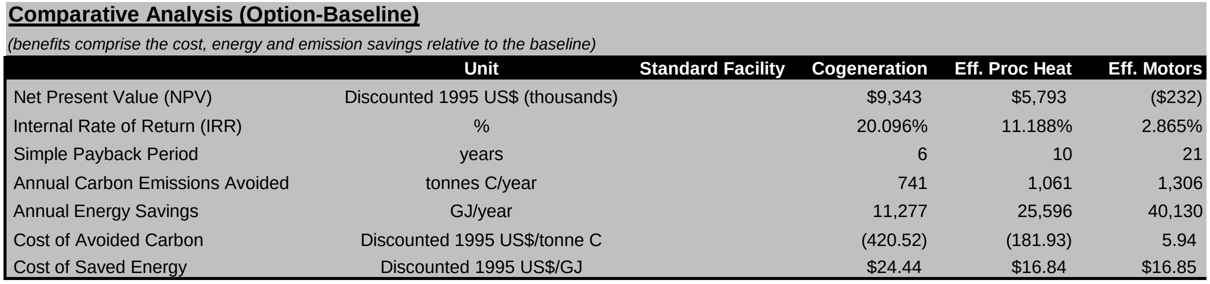
	Unit	Standard Facility	Cogeneration	Eff. Proc Heat	Eff. Motors
Net Present Value (NPV)	Discounted 1995 US$ (thousands)	$136,601	$145,944	$142,394	$136,369
Internal Rate of Return (IRR)	%	18.544%	18.608%	18.127%	16.232%
Simple Payback Period	years	5	5	5	6
Total Cost (1995-2024)	Discounted 1995 US$ (thousands)	$310,573	$301,231	$304,780	$310,806
Total Capital Cost (in startup year)	1995 US$ (thousands)	$100,000	$103,000	$104,000	$112,500
Specific Energy Consumption.	GJ/widget	0.12	0.11	0.09	0.08
Annual Carbon Emissions	Tones C/year	2,646	1,906	1,585	1,341
Production Cost	Discounted 1995 US$/widget	$10.35	$10.04	$10.16	$10.36
Average Energy Costs	Discounted 1995 US$/GJ	$7.60	$2.99	$3.05	$3.05
Energy Costs as share of Total Costs	%	8.8%	3.2%	2.8%	2.3%

Comparative Analysis: Comparative analysis compares the costs, benefits and greenhouse gas mitigation potential of options to a nominated baseline option. Benefits comprise the cost, energy and emission savings of an option relative to the baseline option. This kind of analysis can be particularly useful when examining retrofit options for reducing emissions from an existing plant. The Comparative Analysis summary contains the following information:

- **Net Present Value (NPV):** NPV reports the total cost of an option minus the total cost of the baseline option. Costs include capital, O&M, fuel and (optionally) externality costs. Costs in years after the startup year are discounted back to the base year. Positive NPVs indicate the option is less costly than the baseline. Negative NPVs (shown in red and in parentheses) indicate the option costs more than the baseline. Notice that a comparative analysis tells you nothing about the absolute viability of a plant. Even if an option has a positive NPV in a comparative analysis, it may still not be financially viable, indicated by a negative NPV value in the absolute analysis.
- **Internal Rate of Return (IRR):** IRR is defined as the discount rate that would result in an NPV of zero.
- **Simple Payback Period:** The payback period is the number of years before the option's capital investment (e.g. investment in energy-efficient technologies) has been recouped from savings in fuel, O&M costs, and (optionally) externality costs.
- **Annual Carbon Emissions Avoided:** the tons of carbon per year by which emissions would be reduced through this option as compared to the baseline.
- **Annual Energy Savings:** the amount of energy (in GJ) saved per year by this option compared to the baseline.
- **Cost of Avoided Carbon:** the total discounted costs (not including externality costs) divided by the total amount of carbon emissions avoided. This number is shown in red and in parentheses if the benefits exceed the costs ('no-regrets' options).
- **Cost of Saved Energy:** the total discounted non-fuel costs divided by the total final energy saved. This value can be compared to projected levelized fuel costs.

In our widget example, you should see a comparative analysis summary report like the one shown below. We will examine features of each of the three mitigation options in turn:

Figure 2.13: Comparative Analysis Results Screen



Comparative Analysis (Option-Baseline)

(benefits comprise the cost, energy and emission savings relative to the baseline)

	Unit	Standard Facility	Cogeneration	Eff. Proc Heat	Eff. Motors
Net Present Value (NPV)	Discounted 1995 US$ (thousands)		$9,343	$5,793	($232)
Internal Rate of Return (IRR)	%		20.096%	11.188%	2.865%
Simple Payback Period	years		6	10	21
Annual Carbon Emissions Avoided	tonnes C/year		741	1,061	1,306
Annual Energy Savings	GJ/year		11,277	25,596	40,130
Cost of Avoided Carbon	Discounted 1995 US$/tonne C		(420.52)	(181.93)	5.94
Cost of Saved Energy	Discounted 1995 US$/GJ		$24.44	$16.84	$16.85

- ***Cogeneration:*** *The economics of this option look very positive. Notice that the option has an IRR of almost 20% and a payback period of only 6 years. The option leads to 741 tonnes per year of avoided carbon emissions with a benefit of $420 per tonne of carbon. Thus, this option can be considered a "no regrets" option since it is economically viable under the current set of assumptions.*
- ***Efficient Process Heat:*** *This option, considered cumulatively after the introduction of the cogeneration option, provides further benefits with an IRR of 11.2% still well above the criteria discount rate of 3%. The two options combined avoid 1,061 tonnes per year of carbon emissions.*
- ***Efficient Motors:*** *Primarily because of its high additional capital costs this option has an IRR of only 2.9%. Since this is lower than criteria discount rate of 3%, the option yields a negative NPV of -$232,000. The poorer economics of the option can be confirmed by noting the longer payback period of 21 years. This is the only option that cannot be considered as a "no regrets" option, since it has a positive cost of avoided carbon. Note however, that the NPV is dependent on whether or not a carbon externality cost is included in the analysis. Including a carbon externality value of $20 per tonne is enough to yield a positive NPV (and an IRR of 3.17%). You can try this yourself by checking the* ***Include Externality Costs?*** *checkbox. Note also, that the value of the discount rate is crucial in determining the viability of this option. By entering a lower discount rate, you can cause the NPV of the project to become positive and the cost of Saved carbon to become negative.*

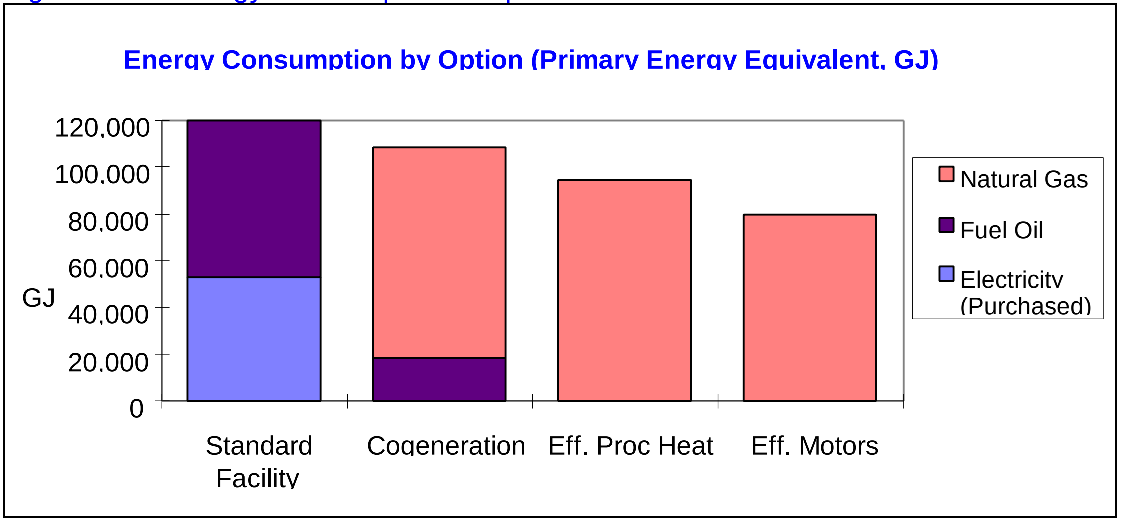
Hint: To test out the tool, you can try setting the discount rate to the same value as one of the IRR values. Once the spreadsheet recalculates you should see an NPV for that option of 0 (or close to it depending on rounding).

Energy Results

Energy results can be viewed in two ways: as **absolute** energy use in each facility or as **energy savings** for each option compared to the baseline. You choose which way you want the data presented through a pull-down menu just below the Energy Results title. The list of fuels in this section corresponds to the list in the Energy Data section, and the energy values are given in Gigajoules. Below the table of energy results you will find a graph presenting the same information (shown below).

The graph shown below illustrates the energy savings from our widget example. Notice how more carbon intensive purchased electricity and fuel oil in the standard facility are displaced by less carbon intensive, and more efficient use of natural gas in the three mitigation options, thus leading to greenhouse gas mitigation.

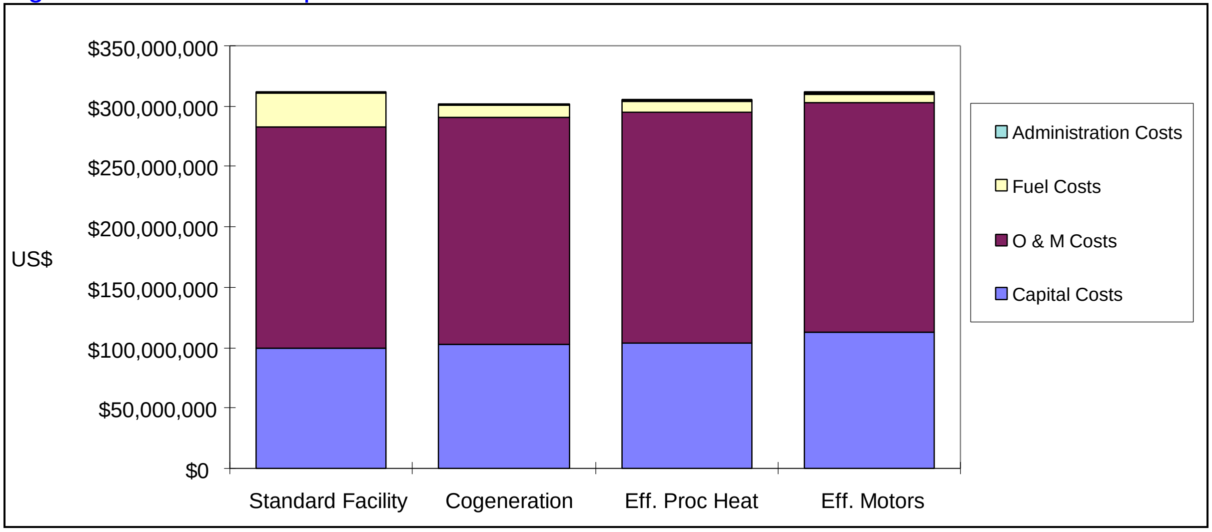
Figure 2.14: Energy Consumption Graph



Cost Results

The presentation of cost results is analogous to that of energy results. First you choose whether you want to view the data in absolute terms or relative to the baseline through a pull-down menu. Results are shown in both table and graph format, presented in five cost categories: capital, O&M, fuel, administration, and externality costs. *The graph shown below illustrates the costs of options in our widget example.*

Figure 2.15: Costs Graph



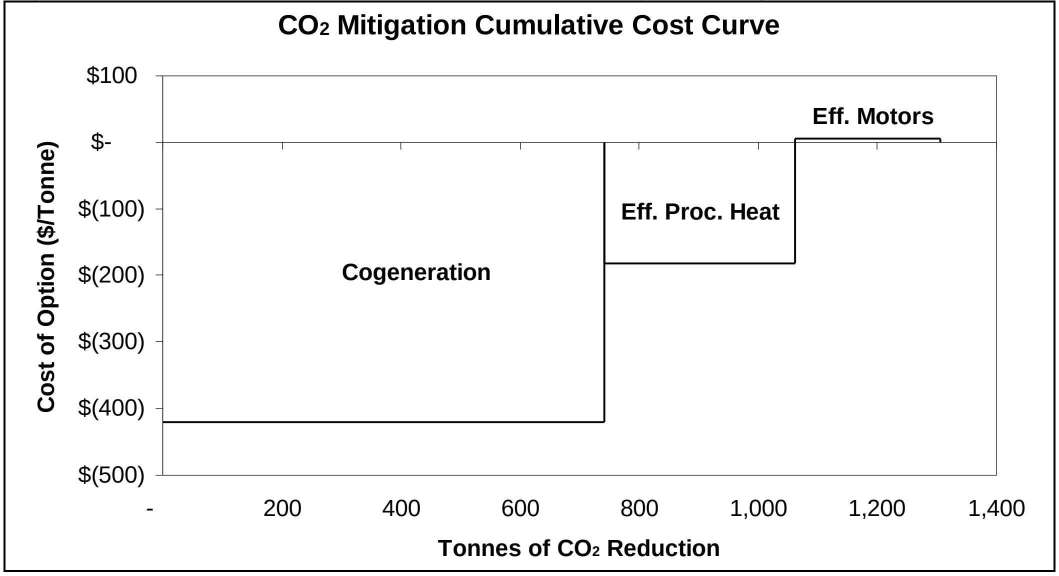
Costs of Avoided Carbon

The last option you can choose from the Main Menu for results concerns the costs of avoided carbon. Clicking this button takes you to a graph where the tonnes of carbon avoided annually by each option (tonnes C avoided) are plotted against the unit cost of avoiding those emissions (US$/tonne). You can use this graph to help identify and prioritize your mitigation options. Notice that, when plotted in ascending order of cost (and assuming that each option can be implemented cumulatively in addition to previously implemented options – i.e. no options are mutually exclusive), the area under the curve represents the total costs of all mitigation options.

Note: Take care when producing these cost curves. The current version of the Analysis Tool does not automatically order mitigation options in order of ascending costs, nor does it ensure that listed options are compatible with one another. Note also that when adding new options, you may need to manually alter the data series used by Excel when plotting this and other graphs.

The graph shown below shows the cumulative cost curve for the three mitigation options specified in the widgets example.

Figure 2.16: GHG Mitigation Cost Curve for Widget Example



Note that the first two options appear below the X axis, and so are classified as "no regrets" options. Final option appears above the X axis at a cost of approximately $6 per tonne. The cost curve assumes the options can be implemented cumulatively. Note that the sum of the area under the three blocks gives the total cost of all three options [Tonnes x $/Tonne].

The Technology Inventory: An Overview

The Industrial Technology Inventory within IDENTIFY is a spreadsheet-based database, intended to support users of the Analytical Tool. It provides quick and easy access to information about technological options for reducing greenhouse-gas emissions in the industrial sector.

Information on greenhouse-gas mitigation options for the industrial sector can be found in a wide array of sources. Considerable research effort is often needed to collect the books, reports, and other literature that can help to identify promising technologies, to determine where they have been used, and to show the benefits that can be achieved through their application. A primary goal of the Inventory is to enable access to the data available from many disparate sources and to present them in a cohesive, consistent manner.

The Inventory can be used to identify and compare industrial practices within a sector or across countries. For example, one can quickly access information about the iron and steel industries in China, Japan, Brazil, India, and the United States. At the same time, one can compare information on current practices in the U.S. iron and steel industry with projections to the year 2010 under both "state-of-the-art" and "advanced" scenarios.

Inventory Contents

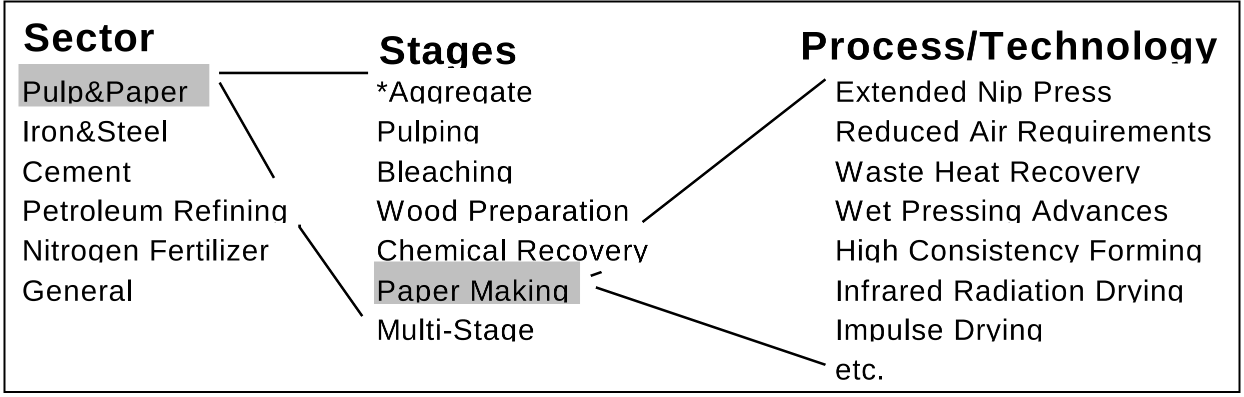
The Inventory contains data and reference information for a wide range of efficiency and fuel-switching measures. The Inventory covers both current and best practices in energy-intensive industries from a range of countries around the globe, including both developing and industrialized countries. As such, it provides a useful starting point for in-country data collection and option identification efforts. Inputs from regional experts have been used to incorporate additional developing-country data and experiences. As with most databases, the Inventory is limited in the extent of the information it provides. For this reason, and given the site-specific nature of many technology applications, the database contains references that direct the user towards important contacts and more detailed literature.

The Inventory contains four categories of information: energy data, cost data, non-energy impacts, and references. Energy data include process energy use and estimated energy savings per unit of output. Cost data include capital costs, operation and maintenance costs, cost of saved energy, and financial indicators, such as simple payback, net present value and internal rate of return. Non-energy impacts include changes in product quality, productivity, or work environment.

Inventory Structure

To allow for quick access to data sources, the Inventory has been structured in three hierarchical layers labeled: *Sector*, *Stage* and *Process/technology*. The Inventory currently spans five energy-intensive industries or "sectors" as shown Figure 2.17 below. An additional sector, "general," contains cross-cutting technologies applicable across a range of industrial processes and applications, as such motor drive systems, lighting, and fuel switching.

Figure 2.17 Technology Inventory Structure



The data for each sector is broken down by stages, which differ for each sector, as shown is Table 2.1 below. The "Aggregate" stage lists total energy consumption per unit of product. The "Multi-stage" classification lists technologies spanning more than one production stage, such as medium consistency processing in the pulp and paper industry.

Table 2.1: Inventory Sectors and Stages

Pulp & Paper	**Iron & Steel**	**Cement**	**Petroleum Refining**	**Nitrogen Fertilizer**	**Aluminum**	**General**
• Aggregate	• Aggregate	• Aggregate	• Aggregate	• Aggregate	• Aggregate	• Aggregate
• Wood Preparation	• Agglomerization	• Raw Material Preparation	• Separation	• Reforming	• Alumina Refining	• Fuel Switching
• Pulping	• Coke Making	• Clinker Production	• Conversion	• Synthesis	• Aluminum Smelting	• Cogeneration
• Bleaching	• Iron Making	• Finish Grinding	• Reforming	• CO2 Removal	• Holding, Casting, Melting	• Lighting
• Chemical Recovery	• Steel Making		• Finishing	• Multi -Stage		• Motor Drive
• Paper Making	• Secondary Refining					• Pumps & Fans
• Multi-Stage	• Casting					• Other
	• Forming & Finishing					

The final level in the hierarchy is labeled "Process/Technology." All data records in the Technology Inventory are specified at this level.

In some cases, the Inventory contains data about the specific processes within a particular stage of production. In other cases, the use of processes may not be applicable, so that data will only be available for the stage as a whole or for typical technologies (*e.g.* current, state-of-the-art, advanced, etc.). For example, some data sources may record the costs and energy use of specific machines in a steel plant, while others may simply record the total energy used in milling or other stages of production. For this reason, the Technology Inventory has been structured in a generalized fashion allowing data to be recorded either for a stage as a whole, or, if available, for more specific processes or technologies.

As an example, consider the pulping stage of the pulp and paper industry. Several processes separate and treat wood or recycled paper fibers when producing pulp. These include: Kraft (chemical), mechanical, thermo-mechanical, and biological. Processes may be further classified by technology. For example, batch and continuous digesters are used within the Kraft process.

Data Sources

A major part of the development of the Inventory has been the identification and review of useful sources of information. The Inventory references include examples from all major geographic regions, for both industrialized and developing economies. Currently, the Inventory contains data for five energy-intensive industries: iron and steel, pulp and paper, cement, refining, and nitrogen fertilizers. Together, these industries account for 50% to 75% of many countries' total industrial energy consumption. Data in the Inventory are most complete for three of these industries: iron and steel, pulp and paper, and cement.

Some of the principal data sources reflected in the current inventory include the World Energy Council (WEC), the U.S. Office of Technical Assistance (OTA), the World Bank, and the Centre for the Analysis and Dissemination of Demonstrated Energy Technology (CADDET). Table 2.2 provides a listing of some of the most important references incorporated in the current version of the Inventory.

Table 2.2 : Selected References From the Technology Inventory

Authors	Year	Title	Journal/Publisher
Geller, Howard S. and David Zylbersztajn	1991	"Energy-Intensity Trends in Brazil"	Annual Review of Energy and the Environment, Volume 16, pp. 179-204.
Gilbreath, Kenneth R. et al.	1995	Background Paper on Energy Efficiency and the Pulp and Paper Industry	ACEEE 1995 Summer Study on Energy Efficiency in Industry. Conference Proceedings, Volume 1, pp. 1-71.
Ishiguro, Masayasu and Takamasa Akiyama	1995	Energy Demand in Five Major Asian Developing Countries: Structures and Prospects	World Bank, Discussion Paper #277
Niefer, Mark J.	1995	"Technology, Energy Intensity and Productivity in the Cement Industry: A Plant Level Analysis"	ACEEE 1995 Summer Study on Energy Efficiency in Industry. Conference Proceedings, Volume 2, pp. 227-237.
Tresouthick, Stewart W. and Alex Mishulovich	1991	Energy and Environmental Considerations for the Cement Industry.	Energy and Environment in the 21st Century, MIT Press, Boston.
U.S. Congress, Office of Technology Assessment (OTA)	1992	Fueling Development: Energy Technologies for Developing Countries,	U.S. Government Printing Office, OTA-E-516, Washington, D.C.
U.S. Congress, Office of Technology Assessment (OTA)	1993	Industrial Energy Efficiency	U.S. Government Printing Office, OTA-E-560, Washington, D.C.
World Energy Council (WEC)	1995	Energy Efficiency Improvement Utilizing High Technology: An Assessment of Energy Use in Industry and Buildings	World Energy Council, London
Worrell, Ernst	1994	Potentials For Improved Use of Industrial Energy and Materials	Utrecht University, Netherlands

The Technology Inventory: User Instructions

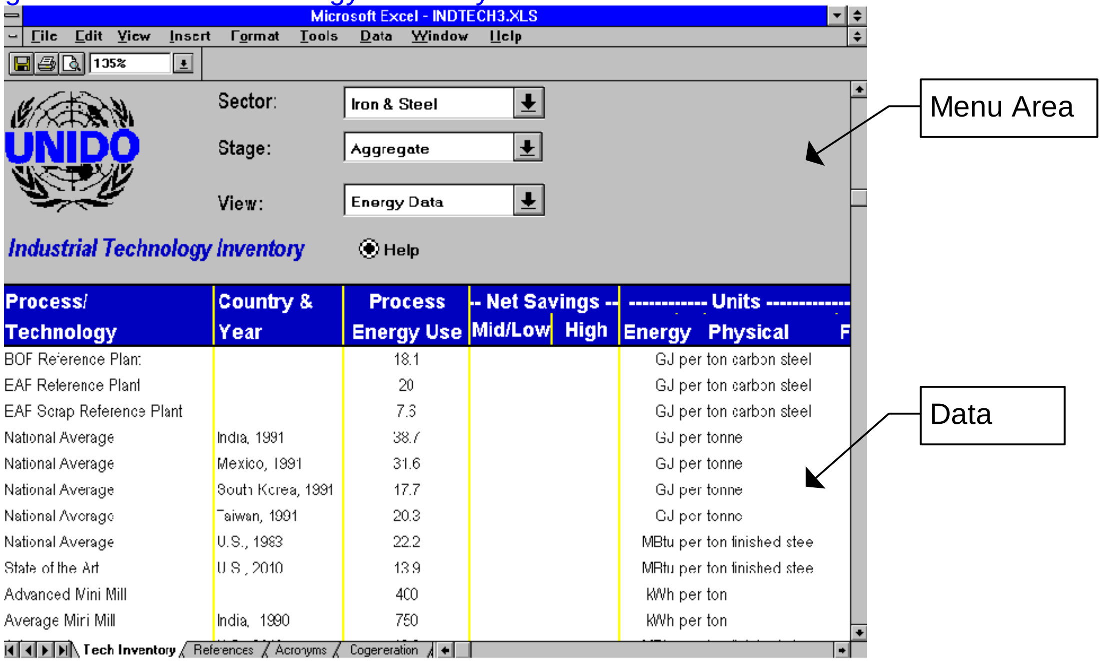
Getting Started

The Technical Inventory has been implemented as a Microsoft Excel Spreadsheet. To use the Inventory, simply load the spreadsheet "DBASE.XLS" into Excel. You will need to be using Microsoft Excel version 5.0 or higher. All functions of the Inventory are accessed from a single screen shown below.

Selecting Records

The Technology Inventory screen, shown below, is divided into two areas: the Menu Area and the Data Area:

Figure 2.18: The Technology Inventory Screen



Sector: Iron & Steel

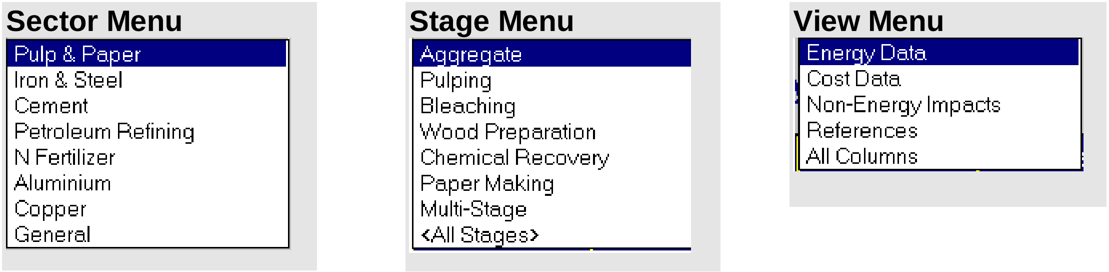
Stage: Aggregate

View: Energy Data

Process/ Technology	Country & Year	Process Energy Use	-- Net Savings -- Mid/Low	High	----------- Units ----------- Energy	Physical	F
BOF Reference Plant		18.1			GJ per ton carbon steel		
EAF Reference Plant		20			GJ per ton carbon steel		
EAF Scrap Reference Plant		7.3			GJ per ton carbon steel		
National Average	India, 1991	38.7			GJ per tonne		
National Average	Mexico, 1991	31.6			GJ per tonne		
National Average	South Korea, 1991	17.7			GJ per tonne		
National Average	Taiwan, 1991	20.3			GJ per tonne		
National Average	U.S., 1983	22.2			MBtu per ton finished stee		
State of the Art	U.S., 2010	13.9			MBtu per ton finished stee		
Advanced Mini Mill		400			kWh per ton		
Average Mini Mill	India, 1990	750			kWh per ton		

- **Menu Area:** In the Menu area, use the **Sector** and **Stage** pull-down menus to find the records of interest and the **View** Menu to choose which types of data will be displayed: energy data, cost data, non-energy impacts, references, all columns. There is also a "Help" button to provide you with on-line help.

Figure 2.19: Technology Inventory Menus



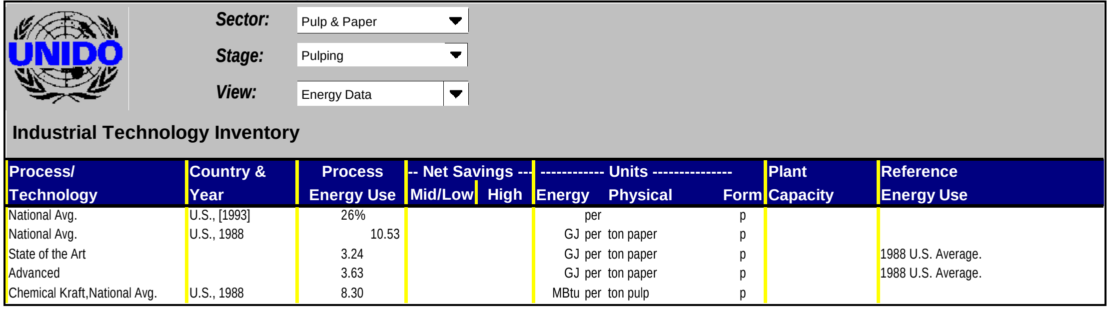
- **Data Area:** The lower part of the screen displays the results of the selections you made in the menu area. The column headings are shown in a blue field. It is possible that there will be more records than the View Area can display, and then it will be necessary for you to scroll down using the side bar.

Inventory Data Views

Use the View Menu to select the types of data to be displayed. Four types of data are available: energy data, cost data, non-energy impacts, and references. A fifth view allows you to display all columns simultaneously. In this mode, you will need to use the horizontal scroll bars to scroll through the various data columns. The data contained in these four views are described in more detail below:

- **Energy Data:** Energy data is recorded in one of two ways: (1) process energy use and (2) net savings relative to standard or reference technologies. Process energy use may be given as the absolute amount of energy used for a certain process or as a percentage of the aggregate energy use. Net savings may also be presented as an absolute energy saving or as a percent of energy used in the reference technology. When savings are presented, information on the reference technology is given in the column "Reference Energy Use." Saving estimates are often presented as a range, thus we have provided "high" and "low" estimated savings fields. In cases where the source provides only one savings estimate, the entry appears under the "low" savings estimate field.

Figure 2.20: The Energy Data Screen



Sector: Pulp & Paper
Stage: Pulping
View: Energy Data

Industrial Technology Inventory

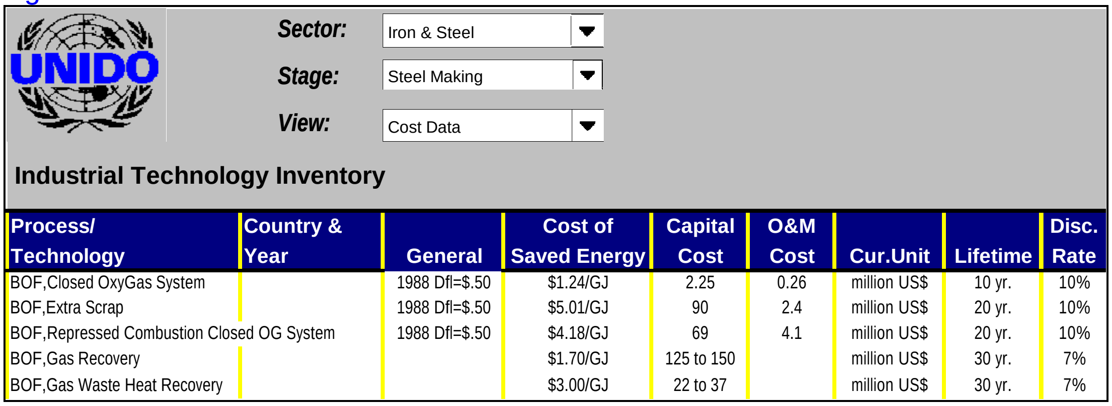
Process/ Technology	Country & Year	Process Energy Use	-- Net Savings --- Mid/Low	High	------------ Units --------------- Energy	Physical	Form	Plant Capacity	Reference Energy Use
National Avg.	U.S., [1993]	26%			per		p		
National Avg.	U.S., 1988	10.53			GJ per	ton paper	p		
State of the Art		3.24			GJ per	ton paper	p		1988 U.S. Average.
Advanced		3.63			GJ per	ton paper	p		1988 U.S. Average.
Chemical Kraft,National Avg.	U.S., 1988	8.30			MBtu per	ton pulp	p		

Absolute energy values are presented in their original energy units; these are given in the "Units" column. In this column you will find the energy units used (GJ, BTU, kWh, etc.), the physical units of interest (usually per tonne of intermediate or final product). and the form of energy (denoted as "e" for electricity, "f" for fuel, "h" for heat, or "p" for primary energy equivalent).

As an example, go to the Pulping stage of the Pulp & Paper sector. If you select Energy Data on the View menu (this is the default) you can see that in 1988, the US national average for the pulping process was 10.53 GJ per ton of paper.

- **Cost Data:** Cost data is presented in the format provided by the original reference. When the Cost Data option is chosen from the view menu, the following columns are shown: General, Cost of Saved Energy, Capital Costs, and O&M Costs. When available, additional information is given on currency units, lifetime of equipment, and discount rates. Note that energy savings are often presented in the literature without corresponding cost information, and so cost data will be absent for some records in the Inventory.

Figure 2.21: The Cost Data Screen



Sector: Iron & Steel

Stage: Steel Making

View: Cost Data

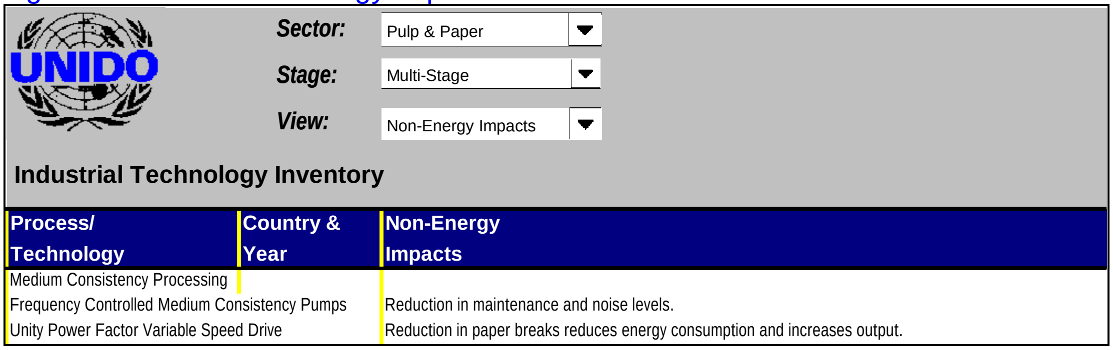
Industrial Technology Inventory

Process/ Technology	Country & Year	General	Cost of Saved Energy	Capital Cost	O&M Cost	Cur.Unit	Lifetime	Disc. Rate
BOF,Closed OxyGas System		1988 Dfl=$.50	$1.24/GJ	2.25	0.26	million US$	10 yr.	10%
BOF,Extra Scrap		1988 Dfl=$.50	$5.01/GJ	90	2.4	million US$	20 yr.	10%
BOF,Repressed Combustion Closed OG System		1988 Dfl=$.50	$4.18/GJ	69	4.1	million US$	20 yr.	10%
BOF,Gas Recovery			$1.70/GJ	125 to 150		million US$	30 yr.	7%
BOF,Gas Waste Heat Recovery			$3.00/GJ	22 to 37		million US$	30 yr.	7%

- **Non-Energy Impacts:** Adopting the energy saving technologies listed in the inventory often leads to impacts on levels of production or emissions. We have included this information when it was available in the literature.

  As an example, go to the Pulp & Paper sector and open "Multi-Stage" in the Stage menu, you will see an entry for frequency controlled, medium consistency pumps. Choose "Non-Energy Impacts" from the View menu, and you will see the comment that this technology can help reduce noise levels and maintenance.

Figure 2.22: The Non-Energy Impacts Screen



Sector: Pulp & Paper

Stage: Multi-Stage

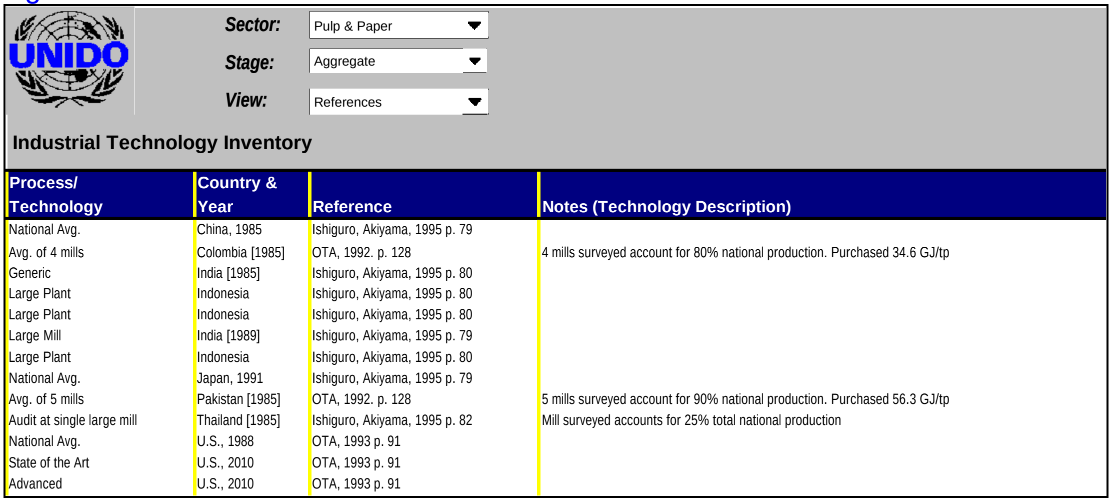
View: Non-Energy Impacts

Industrial Technology Inventory

Process/ Technology	Country & Year	Non-Energy Impacts
Medium Consistency Processing		
Frequency Controlled Medium Consistency Pumps		Reduction in maintenance and noise levels.
Unity Power Factor Variable Speed Drive		Reduction in paper breaks reduces energy consumption and increases output.

- **References:** To find the source of the data in a record, select "References" under the View menu. The inventory displays a brief citation of the author or publisher, the year, and where available a specific page reference. A full bibliographic citation can be found on a separate spreadsheet within the Inventory, titled "References." A full list of the references used in the Inventory is contained in Appendix 2A of this report.

Figure 2.23: The References Screen



Sector: Pulp & Paper

Stage: Aggregate

View: References

Industrial Technology Inventory

Process/ Technology	Country & Year	Reference	Notes (Technology Description)
National Avg.	China, 1985	Ishiguro, Akiyama, 1995 p. 79	
Avg. of 4 mills	Colombia [1985]	OTA, 1992. p. 128	4 mills surveyed account for 80% national production. Purchased 34.6 GJ/tp
Generic	India [1985]	Ishiguro, Akiyama, 1995 p. 80	
Large Plant	Indonesia	Ishiguro, Akiyama, 1995 p. 80	
Large Plant	Indonesia	Ishiguro, Akiyama, 1995 p. 80	
Large Mill	India [1989]	Ishiguro, Akiyama, 1995 p. 79	
Large Plant	Indonesia	Ishiguro, Akiyama, 1995 p. 80	
National Avg.	Japan, 1991	Ishiguro, Akiyama, 1995 p. 79	
Avg. of 5 mills	Pakistan [1985]	OTA, 1992. p. 128	5 mills surveyed account for 90% national production. Purchased 56.3 GJ/tp
Audit at single large mill	Thailand [1985]	Ishiguro, Akiyama, 1995 p. 82	Mill surveyed accounts for 25% total national production
National Avg.	U.S., 1988	OTA, 1993 p. 91	
State of the Art	U.S., 2010	OTA, 1993 p. 91	
Advanced	U.S., 2010	OTA, 1993 p. 91	

Future Developments: Phase 2

Greenhouse-gas mitigation analysis requires substantial institutional and human resource capabilities, which are often in short supply. Training, assistance, and simple transparent tools adapted to local conditions can play a vital role in building these capabilities. Under Phase 1 of this project UNIDO developed the Technology Inventory and Analytical Tool contained in IDENTIFY to address these needs.

Phase 2 will provide the tools, major categories of information, and training and support needed in developing countries to undertake assessments of industrial GHG emission-reduction opportunities and produce comparable and transparent industrial-sector analyses for their communications to the UNFCCC COP. By doing so, the outputs of Phase 2 will enable developing countries to take initial steps toward introducing an energy-efficient industrial capital stock that:

- reduces costs of energy inputs to industrial processes;
- reduces atmospheric emissions responsible for local, regional and global air pollution; and
- meets the requirements of national regulations and international agreements established to control emissions of atmospheric pollutants.

Moving Beyond Phase 1 Accomplishments

Although the Technology Inventory developed under Phase 1 currently includes over 300 specific measures, it is not comprehensive. At present, the data cover a limited range of measures for the iron & steel, pulp & paper and cement industries, as well as some measures for the fertilizer and refining industries. The Phase 1 Analytical Tool allows for rapid assessment of technological options at the specific plant level, but it requires the expertise of an energy analyst to run and does not provide functions for aggregating plant-level analysis to the sub-sectoral or national levels. The two existing tools offer transparency and flexibility in their use, but are not directly linked, and neither offer the kind of user-friendliness and assistance required to make them accessible to planners and decision-makers.

Phase 2 will build upon the inventory and analytical methodology developed under Phase 1, taking them beyond their current capabilities. The immediate objectives of Phase 2 are fourfold:

- to **advance development** of the Analysis Tool to allow for aggregation of plant-level results to the sub-sector and national levels,
- to **expand** the data available in the existing Technology Inventory, thereby creating a comprehensive source of information on energy-efficient industrial technologies,
- to **link and fully integrate** the Analysis Tool and the Industrial Technology Inventory into one software package which moves beyond the limitations of simple spreadsheets and provides on-line guidance, assisting the user in the analytical process, and
- to **provide training and support** in applying IDENTIFY in studies aimed at identifying and evaluating a range of industrial abatement options that meet the objectives of the FCCC.

As a major output of Phase 2, an advanced version of IDENTIFY will be produced to support preparations of communications to the UN FCCC. This software tool will enhance, link and integrate the Analytical Tool and Technology Inventory components of the Phase 1 version of IDENTIFY. The resulting full-fledged operational tool will be straight-forward, readily understandable, and flexible, making it useful to analysts and decision-makers with little computing experience, while powerful enough for more experienced planners, economists, and engineers to conduct comprehensive cost-benefit analyses. Further, the tool will be tested in developing countries and adapted to ensure that it meets their needs.

Linking the Analytical and Inventory Components of IDENTIFY

The new **advanced** version of the **Analytical Tool** will draw upon and provide direct links to the data contained in the Technology Inventory, allowing users to compare relevant technology options. The integrated tool will also allow the user to move beyond the project-level analysis currently available and work at the aggregate level.

Aggregate-level analysis capabilities will provide a broad picture of current and future potential to avoid greenhouse-gas emissions achievable throughout a specific industry or an entire nation’s industrial sector. Analyses performed at the project-level can be combined with end-use and economic data for industrial sub-sectors as well as other estimates of technology costs and achievable penetrations to generate scenarios of energy use and emissions in the industrial sector and the country as a whole. By providing an integrated framework and “big picture” for the industrial sector, the tool will provide assistance in developing national action plans for industrial-sector greenhouse-gas emissions abatement and for prioritizing investments across sub-sectors.

As with the current version, the **expanded Inventory** will contain information on the energy use, costs, and greenhouse-gas emissions associated with selected industrial-sector technologies and practices. The technologies and practices included will comprise state-of-the-art technologies as well as best practices as documented both industrialized and developing countries. Where possible, it will include information on technology transfer issues. The expanded inventory will focus on seven energy- and emissions-intensive industrial sub-sectors (iron & steel, building materials, non-ferrous metals, pulp & paper, refining, chemicals, and food processing & tobacco), as well as important cross-cutting end-uses and technologies such as lighting, combined heat and power and motor drives. Experts from each of these sub-sectors will be engaged to review and build upon data developed under earlier UNIDO projects, providing a comprehensive a dataset for the inventory.

The advanced version of IDENTIFY will move the Technology Inventory from the static to the dynamic by allowing for linkages to other databases as well as user-provided information. Doing so will allow users of the new software to capitalize on the results of two additional UNIDO projects: UNIDO’s data management and presentation tools for energy and environment information initiated as part of the in-house environmental information capacity-building exercise in 1990, and; the pilot-tested information strategy/methodology, resulting from the Energy and Environment Information System for networking and data dissemination for entrepreneurs.

Field Testing and Adaptation

The integrated tool will be field-tested and subsequently adapted, to ensure that it is useful to and meets the needs of developing-country parties to the FCCC. Appropriate national participants will be trained in the use of the tool and its application in the preparation of input to national greenhouse-gas mitigation strategies. Participants will be given the opportunity to use the model to perform national industrial abatement studies, or case studies, with direct technical support from the project. They will be asked to provide feedback on their experience in using the tool, including any comments or concerns, so that these can be taken into account through subsequent adaptation of the tool.

The final version of the tool and supporting documentation will be translated from English into French and Spanish and published. Offering the tool in these three languages will enable its use in the majority of developing countries. UNIDO is prepared to provide for broad dissemination of the tool throughout the G77 and China. The project will provide direct technical assistance to users on a full-time basis for a period of two years following the dissemination of the Tool. In these ways, the project will provide a significant contribution to increasing capacities to prepare National Communications to the COP.

Phase 2 Outputs

The project will provide an analytical "decision-support" tool in a single user-friendly software package: IDENTIFY. The analytical component will have been integrated with a comprehensive inventory of techno-economic information on available technologies and processes applicable in seven energy-intensive industrial sectors as well as cross-cutting measures applicable in a range of sub-sectors. IDENTIFY will be available in English, French, and Spanish, and designed and developed to allow additional language versions to be developed rapidly and at low cost.

Case-studies performed using a draft of the tool will have been prepared in nine developing countries. This field testing of the Tool will have provided analyses and descriptions of industrial abatement options as contributions to each country's communications to the Conference of the Parties (COP). More than 60 national representatives of developing countries will have been trained in the use and application of the Tool. IDENTIFY will have been made widely available to developing-country Parties to the UN FCCC, in order to increase their capacity to prepare national communications to the COP. Technical support in using the tool will be available through UNIDO for a period of two years.

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- Result 47: “Improved Design for Foundry Ladle Pre-heaters”
- Result 80: “Closed System Reduces Losses from an Oxygen-Steel Furnace”
- Result 94: “A Gas-Fired Immersion-Heated Furnace for Metal Melting and Holding”
- Result 113: “DSM Technology Benefits Steel Producer”
- Result 123: “Efficient Ignition of a Sintering Furnace for Crude Steel Production”
- Result 124: “Unity Power Factor Motor Drive System at a Paper and Board Mill”
- Result 130: “Recuperative Aluminum Recycling Plant”
- Result 139: “Computer-based Monitoring and Targeting on a Hot Rolling Mill”
- Result 163: “Speed Control of Pumps Saves Energy at a Pulp Mill”
- Result 165: “Advanced Process Management System for Thermo-mechanical Pulping Plant”
- Result 166: “Heat Recovery at a Nitric Acid Plant”
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