Industrial Development Report 2011

Industrial energy efficiency for sustainable wealth creation

Capturing environmental, economic and social dividends

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INDUSTRIAL DEVELOPMENT ORGANIZATION

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Foreword

Since the Industrial Revolution and the introduction of steam power, industrialization has produced goods that have improved living standards around the world. The greater availability of a broader range of manufactured products has been based on a substantial expansion in the use of energy. Over the past 200 years, energy consumption per capita has increased, and overall energy consumption is unlikely to decline in the foreseeable future.

During the early stages of industrialization, energy seemed to be plentiful, without evident limits on its use. More recently, we have become aware that the fossil fuels that have powered industrial development are probably not as abundant as once thought. Even more important, their use has generated unintended and undesirable environmental impacts.

Technological change has helped to address the dual problems of growing resource scarcity and environmental degradation. New and emerging technologies that consume materials more efficiently, use waste heat or upgrade motor performance have spread within the manufacturing sectors, boosting the energy efficiency of existing equipment, production processes and plants. Large price changes in global energy markets as well as national and international policy responses to energy availability and environmental impact have also helped to shift attention towards industrial energy efficiency.

However, we are far from conquering the challenges posed by fossil fuel–based energy depletion and greenhouse gas emissions. As developing countries raise their standards of living, take on a growing share of manufacturing and engage in a wider range of industrial activity, energy use is likely to continue its upward trajectory. The question that arises is how to accommodate rising living standards in developing countries while moderating the pernicious effects of energy use.

UNIDO's *Industrial Development Report 2011 (IDR 2011)* shows that increased industrial energy efficiency is one of the most promising routes to sustainable industrial development worldwide, particularly in developing countries. Industry remains among the most energy-intensive sectors: its contribution to global GDP is lower than its global share of energy consumption. Industrial processes have an estimated technical efficiency potential of 25–30 percent. That means that adopting best available technologies and related business and engineering practices could eventually enable industry to lower emissions of greenhouse gases and combat climate change and also reduce other pollutants. The energy savings could be redirected to meeting social needs for access to energy, particularly acute in developing countries, and could help companies everywhere to improve their bottom line.

The report provides further evidence that improvements in industrial energy efficiency continue apace. During the past 20 years, developed countries, which are the largest energy users, have lowered their energy intensity. Large developing countries have also realized the importance of boosting efficiency early in their industrialization processes and have begun to adopt the technologies and other measures that have led to unprecedented gains in energy efficiency. Low- and middle-income developing countries, which are gradually taking over manufacturing production, are also contemplating ways of becoming more energy efficient.

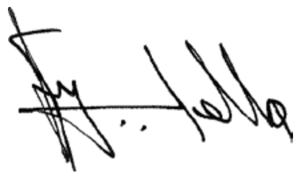
The report argues that the key to sustaining these gains continues to be industrial technological change and the related economic and policy incentive system. Yet markets do not always work as expected, nor are individual and corporate behaviour as rational as predicted by orthodox economic theory. Multiple barriers block the path to full energy-efficiency levels.

The report suggests that overcoming barriers to industrial energy efficiency will require public policy measures, including a sectorally coordinated energy strategy; formal and informal mechanisms, targets, benchmarks and standards; and policy designs grounded in the specific context at the country level. Policy interventions involve choosing the right policy mix, continuously assessing effectiveness and focusing on small and medium-size enterprises. Policy measures include official support for developing more efficient industrial technologies, disseminating best available technologies, introducing fiscal incentives for innovation and diffusion of industrial energy efficiency, and establishing financial mechanisms to fund improvements.

The report recommends decisive international collective action, including reducing industrial energy intensity by 3.4 percent a year through 2030. It calls for international collaborative research and development and the establishment of information clearinghouses and information exchanges to identify best practices and compare the performance of different technologies under varying conditions. Since the adoption of energy-efficient technologies involves the acquisition of increasingly sophisticated technological capabilities, the report points at ways in which the international community can assist in capacity development. It also discusses the need for a well developed framework for international financing of industrial energy efficiency.

I am pleased to note that the *IDR 2011* is a prelude to the UN Secretary General's Sustainable Energy for All initiative. The General Assembly has declared 2012 as the International Year of Sustainable Energy for All, and collaborations are planned with all relevant stakeholders in the public and private sectors to raise public awareness and the financial resources needed to combat energy poverty. The Sustainable Energy for All initiative will bring these stakeholders together in a global campaign to turn attention towards the importance of energy for development and poverty reduction. Energy is vital to almost every major challenge and opportunity that the world faces today. Be it jobs, security, climate change, food production or poverty reduction, sustainable energy for all is essential for strengthening economies, protecting ecosystems and achieving equity.

It also gives me great satisfaction to report that the *IDR 2011* has drawn on all of the knowledge resources of UNIDO, bringing together the organization's expertise and experience in analytical research, technical cooperation and policy advice. This has resulted in a comprehensive and multidisciplinary treatment of the critical issues covered in the report. Moreover, the *IDR 2011* has a unique focus on developing countries, backed by a set of statistics unavailable anywhere else. And as has become customary, the report includes sections on trends in manufacturing value added and manufactured exports and on UNIDO's Competitive Industrial Performance index, which ranks economies according to multiple indicators of industrial performance.



Kandeh K. Yumkella
Director-General, UNIDO

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Technical notes and abbreviations

References to dollars ($) are to US dollars, unless otherwise indicated.

In this report, *industry* refers to the manufacturing industry and *sectors* refers to specific manufacturing sectors.

This report defines *developed countries* or *developed economies* as the group identified as "high-income OECD countries" by the World Bank and *developing countries* or *developing economies* as all other economies. See Annex 13 for a complete list of economies by region, income level, least developed countries and largest developing economy in each region.

This report focuses on the energy consumed in industrial processes, so most of the analysis excludes feedstock use.

Components in tables may not sum precisely to totals shown because of rounding.

AGECC	Advisory Group on Energy and Climate Change
CIP	Competitive Industrial Performance
$CO_{2\text{-eq}}$	carbon dioxide equivalent
EJ	exajoules
GDP	gross domestic product
GEF	Global Environment Facility
GJ	gigajoules
Gt	gigatonnes
Gtoe	gigatonnes of oil equivalent
IDR	*Industrial Development Report*
IEA	International Energy Agency
ISIC	International Standard Industrial Classification
ISO	International Organization for Standardization
MVA	manufacturing value added
OECD	Organisation for Economic Co-operation and Development
R&D	research and development
SAR	Special Administrative Region of China (Hong Kong, Macao)
toe	tonnes of oil equivalent
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization

Glossary

Best available technology. The most energy-efficient way of producing goods and services that is commercially viable and in use.

Best practice technology. The top performing technologies and business practices for industrial energy efficiency among those in use by most plants within an industry.

Combined sector. A sector that combines some of the characteristics of discrete and process product sectors. (See also *discrete product sector* and *process sector*.)

Decoupling. Weakening or breaking the link between environmental effects and economic activity so that output increases with a less than commensurate increase (or with a decrease) in energy consumption (Von Weizsäcker 1989; Enevoldsen, Ryelund and Andersen 2007). ***Absolute decoupling*** in industry is when the decrease in material, energy and pollution intensity is greater than the growth rate in manufacturing (OECD 2002; Spangenberg, Omann and Hinterberger 2002). ***Relative decoupling*** is when the growth rate of manufacturing value added is higher than that of industrial energy consumption.

Discrete product sector. A sector that involves a variety of production processes because of the differentiated nature of the products and their constituent components, each also requiring its own production process. The equipment used depends on production volume and technical complexity; large-volume and low- to moderate-complexity output is largely automated. There are also sequential transformation stages – numerous in more complex products – often linked through an assembly line and requiring many parts. Throughput is transformed by temperature, force or chemical reaction; output is counted in units rather than in weight or volume. (See also *process sector*.)

Embodied energy. The cumulative amount of commercial energy (fossil, renewable, nuclear) invested to extract, process and manufacture a product and transport it to its point of use. This accounting concept sums the energy physically embodied in the materials (which can be released by reversing the process) and the energy invested in creating the processing conditions and bringing the materials together (including transport).

Energy. The ability to do work. In industry it commonly refers to the energy used to power manufacturing processes. This report measures energy in tonnes of oil equivalent to allow comparisons of energy from various sources. ***Primary energy sources*** include biomass-based fuels (trees, branches, crop residues), fossil fuels (coal, oil, natural gas) and renewable sources (sun, wind, water). ***Secondary energy sources*** are derived from other (usually primary) energy sources and have zero pollution at the point of use (electricity, for example).

Energy efficiency. The ratio of a system's energy inputs to its output. Since inputs and outputs can be measured in more than one way, *energy efficiency* has no single meaning. (See also *exergy*.) An engineer's definition will differ from an environmentalist's or an economist's – mainly reflecting differences in the level of aggregation.

The energy-efficiency ratio is commonly called thermal or first-law efficiency, based on the first law of thermodynamics. In any closed energy-conversion process, energy can be neither created nor destroyed; energy that goes in must come out or be accumulated in the system. But only a portion of the energy output will be in a useful form (for example, light) while the rest is waste, typically low-temperature heat. The thermal efficiency of a process is thus the ratio of useful energy outputs to total energy inputs.

In engineering, energy efficiency is interpreted as conversion efficiency – the proportion of the energy input that is available as a "useful" output. For example, only 5–10 percent of the electrical energy fed to an incandescent light bulb is converted to useful light energy; the remaining 90–95 percent is lost to the environment as "waste" energy (low-temperature heat). In developed countries, the average efficiency of conversion of heat energy from fuel to electric power delivered to consumers is 33–35 percent (Ayres, Turton and Casten 2006), so if this electricity is converted to light energy using an incandescent bulb, the overall energy efficiency is just 3 percent.

In economics, energy efficiency is the ratio of the value of output to the quantity or cost of energy inputs – the amount of economic activity produced from one unit of energy. (See also *energy intensity*.)

Energy intensity. The amount of energy used to produce one unit of economic activity. It is the inverse of energy efficiency: less energy intensity means more energy efficiency. This report measures energy input in physical terms (tonnes of oil equivalent) and economic activity in monetary terms (sectoral and manufacturing value added), so the energy intensity of a manufacturing process is the amount of energy used to produce a unit of value added – for example, tonnes of oil equivalent per $1,000 in manufacturing value added (in constant dollars).

Energy services. The physical services (light, torque or heat) delivered when energy is consumed. Some energy is used directly in manufacturing (for example, fuel for direct-fired kilns or ovens), but most is converted by utilities into an energy service that is then used in the manufacturing system, such as process heating and cooling liquids, compressed air, motion and lighting. The aim of process economies is to produce more products with less use of energy services – for example, more beer per tonne of steam use or more cups per unit of fuel consumption in the firing kiln.

Environmental impacts of industrial energy use. The environmental impacts of industrial energy use differ by energy source. ***Direct impacts*** arise during energy use in industrial processes, while ***indirect impacts*** result from production and supply of the energy source.

Exergy. The maximum work that can be performed as a subsystem approaches thermodynamic equilibrium with its surroundings – that is, the amount of energy actually used to achieve an intended or desired end result in an end-use application or total energy used minus estimated losses. It is known technically as "useful energy."

Unlike first-law energy efficiency, this concept takes into account qualitative differences between types of energy, particularly their ability to perform physical work (to move an object over a distance). For example, high temperature steam has a greater ability to perform physical work than low-temperature hot water. While first-law efficiency is easy to grasp (energy is conserved; all of it must be accounted for as useful output or waste). The problem is that the numerator (useful output) is not rigorously defined. For instance, it is easy to misinterpret a boiler's efficiency (say, 80 percent if 80 percent of combustion heat goes into the water tank and 20 percent goes up the flue) as the efficiency with which a house or bathwater is heated by the boiler. In fact, the ratio reveals nothing about how much energy would be required to heat the house by the best (most efficient) available technology.

A more precise definition is the ratio of the minimum amount of energy theoretically needed to perform a task (such as heating a house) to the amount of energy used in practice (the efficiency of the furnace-plus-boiler system in heating a house is likely to be around 5 percent, much less than the boiler's 80 percent efficiency). An equivalent way of expressing this idea is the ratio of the amount of thermodynamic work performed by a process (the numerator) to the maximum amount of work that could be performed in theory (exergy). This ratio is second-law efficiency because it takes into account the unavoidable losses owing to the second law of thermodynamics. While energy is conserved, exergy, the useful component of energy, is destroyed by every process or action, while the non-useful component of energy (anergy) increases. Eventually, all energy becomes anergy, because it can do no work. Only second-law efficiency can show how well machines and systems are doing and how much opportunity there is for improvement. The first-law definition has often been used to claim that an economic system, or a process within it, is much more efficient than it really is.

Feedstock. Energy used as a raw material to generate power. Most of the analysis in this report excludes feedstock.

Gross energy requirement. The amount of energy required to manufacture a product. Similar to *embodied energy* but product-specific.

Industrial energy efficiency. The ratio of the useful or desired output of a process to the energy input into a process; for a higher aggregated level (sector, economy or global), the ratio of the amount of economic activity produced from one unit of energy.

Industrial energy intensity. The amount of energy used to produce one unit of economic activity across all sectors of an economy; related to the inverse of energy efficiency but only at the sectoral, economy or global level.

Manufacturing value added. See *value added.*

Primary energy. The energy embodied in natural resources before they undergo any human-made conversions or transformations; examples are coal, crude oil, sunlight, wind, running water in rivers, vegetation and uranium.

Process sector. An industrial sector that uses coal, natural gas, metallic and non-metallic minerals or oil as raw material or feedstock; that involves a sequence of linked transformation stages with several supporting processes operating on site; that requires a series of containers, pipes, vessels, complex purpose-designed and fabricated plants and advanced control technologies; that employs high pressures, high temperature and chemical reactions to transform throughput; and that delivers output in bulk, generally in units of weight or volume, although the output may be presented or packaged differently depending on the customer. See also *discrete product sector.*

Sectoral value added. See *value added.*

Structural change. Changes in the long-term composition and distribution of economic activities. (See also *technological change.*)

Technological change. Improvements in technology. Technological change involves a series of stages with multiple actors, relationships and feedback loops – from invention, as a new technology is created and prototyped, to innovation, as it becomes commercially viable (Freeman and Soete 1997; IEA 2008a). In decomposition analysis, if data on manufacturing processes were available at the lowest level of aggregation, the measure of technical change would be actual physical efficiency and the rest would be structural change (Jenne and Cattell 1983). Industrial energy intensity can be lowered by improving technology (technological change) and producing more goods that require less energy (structural change).

Technological efficiency. The efficiency with which the economy converts raw materials into finished materials, or the ratio of actual work output to the theoretical maximum. It is the result of technological change, system change and product upgrading.

Technological intensity. The ratio of input use and service output across a specific manufacturing sector. It is the inverse of technological efficiency.

Technology. The application of knowledge to production. It comprises processes (organizational and management practices and production processes), knowledge (tacit and codified) and products and machines (physical equipment and artifacts). Processes and knowledge are sometimes referred to as "software" and products and machines as "hardware" (IPCC 1996).

Total final energy consumption. The sum of consumption in end-use sectors. For the most part, final consumption reflects deliveries to consumers (IEA 2010c).

Value added. A measure of output net of intermediate consumption, which includes the value of materials and supplies used in production, fuels and electricity consumed, the cost of industrial services such as payments for contract and commission work and repair and maintenance, compensation of employees, operating surplus and consumption of fixed capital. ***Manufacturing value added*** is the contribution of the entire manufacturing sector to GDP (manufacturing net output). ***Sectoral value added*** is the net output produced by individual sectors. The sum of value added from all manufacturing sectors should equal manufacturing value added, but limited coverage of activity units or data items in manufacturing surveys can result in discrepancies.

Overview

Part A

Industrial energy efficiency for sustainable wealth creation: capturing environmental, economic and social dividends

Key messages

- Improving industrial energy efficiency is a key route to sustainable industrial development worldwide – especially in developing countries. Investing in energy-efficient technologies, systems and processes can provide environmental, economic and social dividends to achieve green growth.
- In recent decades, industrial energy efficiency has been improving as industrial energy intensity has fallen (at an average of 1.7 percent a year), though absolute energy consumption rose 35 percent over 1990–2008. Energy consumption could grow even faster as developing countries reduce the income gap with developed countries and grapple with rising demand for manufactured products from growing populations.
- In both developed and developing countries, investing in industrial energy efficiency makes financial sense. Yet the potential for further investments remains high. Why are these investment opportunities not being realized? Because countries face numerous barriers to investment – barriers stemming from market and behavioural failures.
- Public policy interventions will be needed to overcome these barriers, drawing on regulatory and market-, knowledge- and information-based tools. A global consensus could be built to support such interventions through international collective action to reduce industrial energy intensity 3.4 percent a year, or 46 percent in total, through 2030.

The *Industrial Development Report 2011 (IDR)* addresses the role of industrial energy efficiency in sustainable industrial development. About a fifth of global income is generated directly by the manufacturing industry, and nearly half of household consumption relies on goods from industrial processes. People's needs for food, transportation, communication, housing, health and entertainment are met largely by manufacturing. Since the Industrial Revolution, waves of innovation have shaped how people work and live. During the 19th and 20th centuries, developed countries relied on manufacturing to reduce poverty and improve the quality of life of their growing populations. Today, developing countries are counting on industrialization to do the same for them.

Improvements in the standard of living made possible through industrialization have come at an environmental cost. Energy consumption per capita has increased nine-fold over the last 200 years (Cook 1971). Materials use per capita more than doubled over 1900–2005 (Krausmann et al. 2008). And though the fossil fuels that have fed industrial development are not as abundant as once thought, overall energy consumption is not likely to fall soon. Pollution, resource depletion and the waste of discarded products – each at an all-time high – are major causes of environmental degradation and climate change. Policy-makers must address them as they remap development paths.

Industrial development must become sustainable. Continued high resource consumption and reliance on carbon-intensive and polluting technologies will sap the potential for growth and development. Innovative solutions, national and global, are vital to making industrial activity more sustainable – to attuning it to environmental, economic and social needs. This "green industry" approach can provide the blueprint for sustained industrial development.

Industrial energy efficiency is a key foundation for greener industry worldwide. By building on past successes, countries can develop their industries and generate employment while tempering the impacts on resource depletion and climate change.

The *IDR 2011* focuses on industrial energy-efficiency challenges in developing countries, which

Industry is the largest energy user globally, and growth in industrial energy use would have been higher over 1990–2008 but for reductions in industrial energy intensity

are emerging as key actors in global industrial development. The report looks in depth at long-term trends in industrial energy intensity and related technological and structural change; examines the environmental, economic and social benefits of industrial energy efficiency; and identifies obstacles to its promotion and uptake and ways to overcome them.

Changing industrial energy trends

Final energy consumption worldwide increased from 6.0 gigatonnes of oil equivalent (Gtoe) in 1990 to 8.2 Gtoe in 2008, a 35 percent rise. Per capita, the increase was far less steep, from 1.2 tonnes of oil equivalent (toe) in 1990 to 1.3 toe in 2008, or just above 7 percent (Figure 1). Developed economies saw a steady increase in energy demand to 3.4 Gtoe in 2008, equivalent to 3.5 toe per capita. Energy demand by developing countries grew faster, reaching 4.7 Gtoe in 2008, or 0.9 toe per capita.

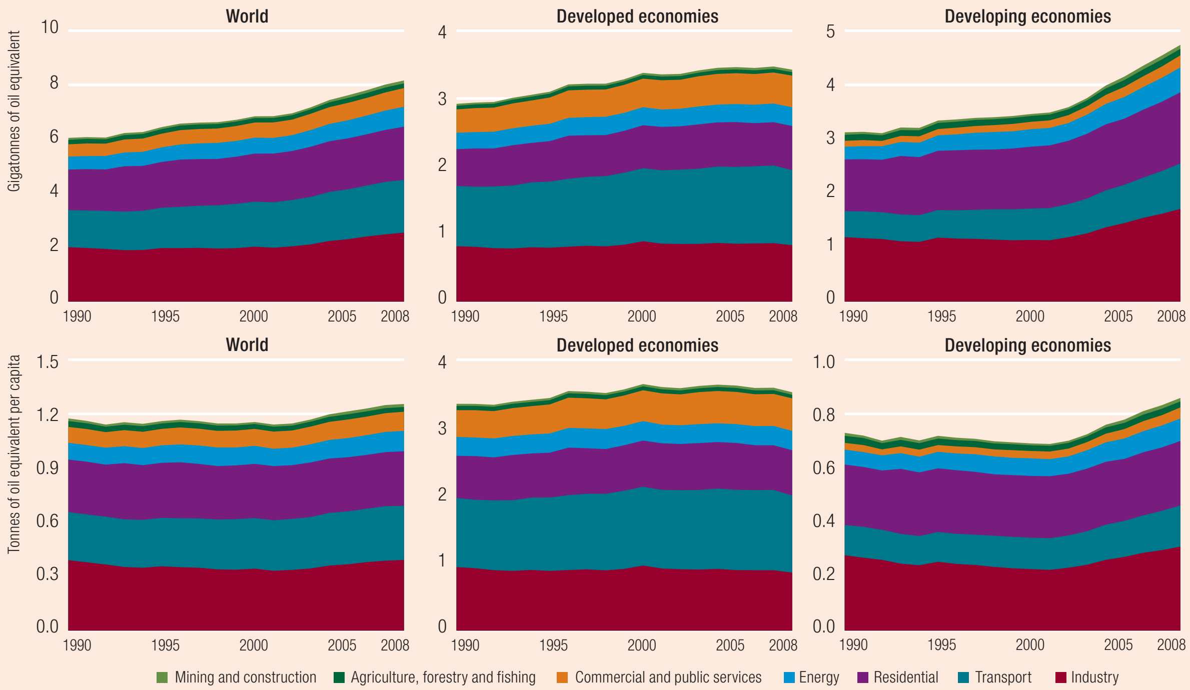
Industry is the largest energy user, accounting for around 31 percent of world energy consumption since the early 1990s. In developed economies, however, industry accounted for only 24 percent of energy consumption (0.8 Gtoe), lagging behind the transport sector (32 percent) and slightly ahead of the residential sector (19 percent). In developing economies, energy demand in industry rose much faster and remains the main user of energy (1.7 Gtoe).

Industrial energy intensity is falling

Growth in industrial energy use would have been higher over 1990–2008 but for reductions in industrial energy intensity – the ratio of the amount of energy used to produce a unit of output (conventionally measured as $1,000 in manufacturing value added [MVA]). Over the past 20 years, developed economies have been reducing industrial energy intensity. In addition, large developing economies such as China,

Figure 1
Growth in energy consumption and energy consumption per capita, 1990–2008

Industry is contributing to the rise in global energy consumption



Source: IEA 2010c.

“Over 1995–2004, technological change accounted for a slightly larger share of the decline in industrial energy intensity globally, but structural change has become increasingly important since 2005

India and Mexico and transition economies such as Azerbaijan and Ukraine began adopting technologies and measures that produced unprecedented cutbacks in industrial energy intensity. Among the trends:

- *Global industrial energy intensity dropped* some 25 percent over 1990–2000, but stabilized more recently at around 0.35 toe per $1,000 of MVA (in constant 2000 prices; Figure 2).
- *Industrial energy intensity has been inversely related to national income* since 1990 (Figure 3). On average over 1990–2008, developed economies had the lowest energy intensity (0.2 toe per $1,000), and low-income developing economies had the highest (2.2 toe per $1,000).

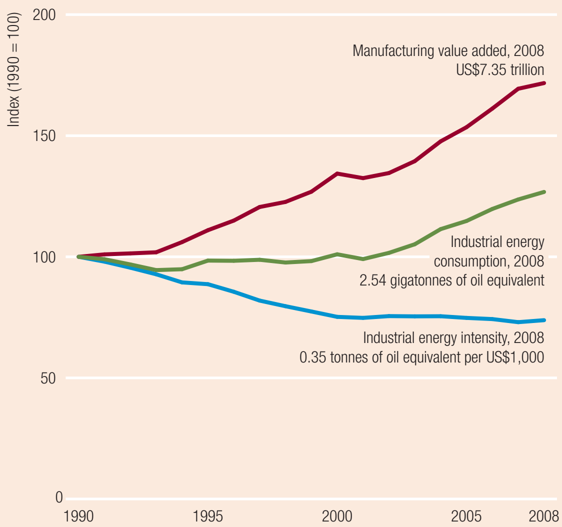
Closer analysis of industrial energy intensity trends over 1995–2008 for 62 economies meeting specific criteria for decomposition analysis shows a 22.3 percent decline, or an average annual reduction of 1.9 percent (Figure 4). Both technological and structural factors contributed. Technological change occurs through changes in the product mix of each manufacturing sector, adoption of more energy-efficient technologies, optimization of production systems and application of energy-efficient organizational practices. Structural change reflects changes in the contribution of each sector, including shifts from or towards energy-intensive industries. Over 1995–2004, technological change accounted for a slightly larger share of the decline in industrial energy intensity globally (see Figure 4), but structural change has become increasingly important since 2005. By 2008, structural change (12.5 percent) had a larger effect than technological change (9.8 percent).

Structural change was the main driver of falling energy intensity over 1995–2008

Reductions in energy intensity over 1995–2008 were larger in developing economies than in developed economies (Figure 5). Structural change was the driving force behind reductions in developed economies and in high-income developing economies as they shifted from energy-intensive industries towards

Figure 2
Global trends in manufacturing value added, industrial energy consumption and industrial energy intensity, 1990–2008

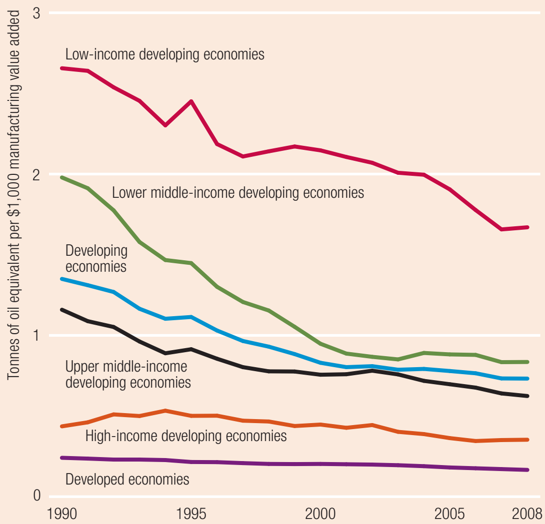
Industrial energy intensity fell markedly in 1990–2000 but stabilized more recently



Note: Industrial energy intensity in 2000 US dollars.
Source: UNIDO 2010e,f,g; IEA 2010c.

Figure 3
Industrial energy intensity, by income group, 1990–2008

The higher the development level, the lower the industrial energy intensity

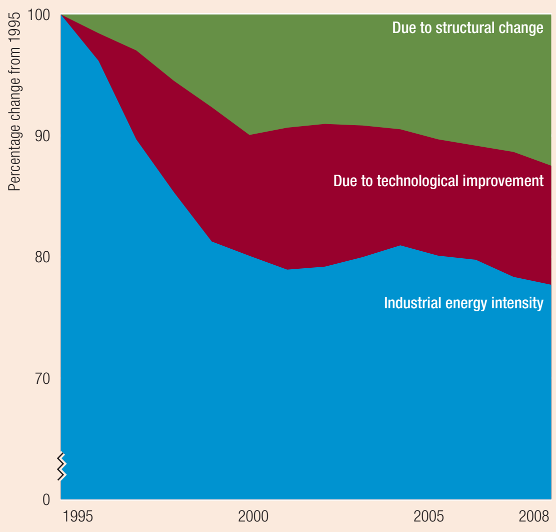


Note: See Annex 4 for economies in each group. Industrial energy intensity in 2000 US dollars.
Source: UNIDO 2010e,f,g; IEA 2010c.

Reductions in industrial energy intensity after 1995 were around 30 percent for high-income developing economies and for upper middle-income developing economies and around 40 percent for lower middle-income developing economies

Figure 4
Components of change in global industrial energy intensity, 1995–2008

Structural change is the main driver of falling global industrial energy intensity



Source: UNIDO 2010e,f; IEA 2010c.

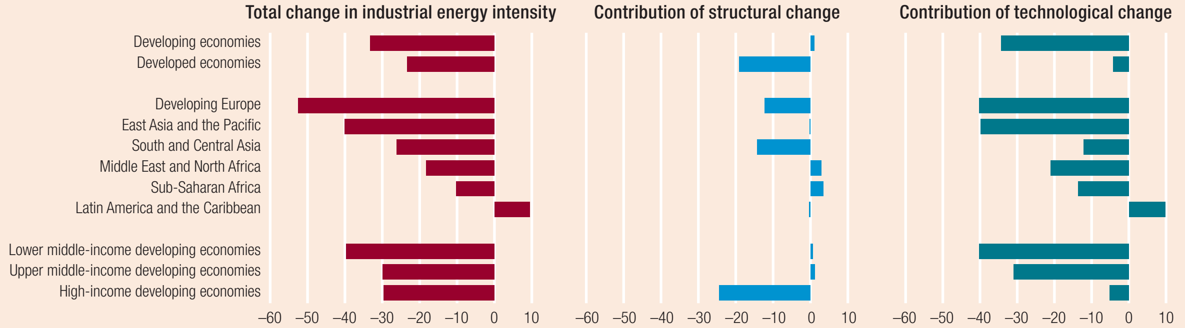
high-tech sectors. Technological change was apparent at all developing economy income levels, and the lower the income level, the higher the technical effect. Total reductions in industrial energy intensity after 1995 were around 30 percent for high-income developing economies and for upper middle-income developing economies and around 40 percent for lower middle-income developing economies. The respective contributions from technological change were 5 percent, 32 percent and 40 percent.

As industrialization progresses and incomes rise, the large gaps in energy intensity between developed and developing countries begin to close. Initial gains can be substantial as new vintages of energy-efficient capital goods are adopted, production processes are modernized and new resource-efficient products are offered. Concerns about energy efficiency also begin to kick in, both within industry and among policymakers. In China, India and the Russian Federation, technological change was responsible for 37–48 percent of reductions in energy intensity. A major exception among the upper middle-income countries is Brazil. Investing heavily in petrochemical and steel industries, it experienced rising energy intensity as the structural effects cancelled the technological effects.

As countries reach a more mature stage of industrial development, industrial energy intensity declines, largely as a result of structural shifts from energy-intensive industries as industries relocate elsewhere or move into higher value services. In high-income developing economies, the structural effect is already more significant than the technological effect. And in Japan, the Republic of Korea and the United States, structural change accounts for more than two-thirds of the decline in industrial energy intensity.

Figure 5
Components of change in industrial energy intensity, by region and income group, 1995–2008 (percent)

Technological change is the primary driver of lower industrial energy intensity in developing economies



Source: UNIDO 2010e,f,g; IEA 2010c.

"The *IDR 2011* presents diverse estimates suggesting that large savings in energy use continue to be possible from industrial energy efficiency

Large savings in energy use continue to be possible from energy efficiency

Can the world satisfy the mounting demand for industrial goods, particularly from developing countries, while keeping energy consumption growth in check? Can developing countries' legitimate demands for rising living standards and poverty reduction be made compatible with green industry?

In 2008, per capita industrial energy consumption in developing economies was 29 percent of that in developed economies. As per capita income in developing economies converges to that in developed economies, the gap in per capita industrial energy consumption is expected to narrow, with a potentially huge impact on global energy demand. In combination with population growth, this could accelerate resource depletion and environmental degradation and raise energy prices enough to impair economic growth. Hence, to be sustainable, long-term industrialization in developing countries needs to be accompanied by substantial improvements in industrial energy efficiency.

The *IDR 2011* presents diverse estimates suggesting that large savings in energy use continue to be possible from industrial energy efficiency. According to the International Energy Agency's (IEA) 2010 *World Energy Outlook,* a reduction in global energy intensity of 23 percent over 1980–2008 saved 32 percent in energy consumption (5.8 Gtoe; IEA 2010e). Looking forward, IEA (2010e) estimates several scenarios:

- *A current policies scenario,* which takes into account only policies already formally adopted and implemented, anticipates a 28 percent reduction in energy intensity by 2035, or savings of around 6.5 Gtoe in primary energy consumption (2 Gtoe from industry).
- *A new policies scenario,* which assumes implementation of announced policy commitments to reduce greenhouse gas emissions and phase out fossil energy subsidies, foresees a 34 percent reduction in energy intensity, equivalent to an additional 1.3 Gtoe in savings over the current policy scenario.
- *A 450 scenario,* limiting the average global increase in temperature to 2°C and the concentration of greenhouse gases in the atmosphere to around 450 parts per million of carbon dioxide equivalent, would add 3 Gtoe in savings to the current policies scenario.

McKinsey & Company (2007, 2008, 2009) also estimates that the growth in global energy demand could be reduced, from 2.3 percent a year in the mid-2000s to 0.7 percent a year by 2020 (from 3.4 percent to 1.4 percent in developing countries), by seizing emerging opportunities to reduce energy intensity.

Improving industrial energy efficiency can deliver many well documented environmental, economic and social benefits. The *IDR 2011* substantiates these dividends and then looks at how to overcome some of the obstacles to cashing in on them.

The three dividends: environmental, economic and social

Continuing efforts to improve industrial energy efficiency should contribute to the global effort to halt or reverse climate change while reducing other pollutants. At the same time, these efforts should help businesses improve their bottom line and optimize strained energy systems to better meet social and economic needs. These environmental, economic and social dividends are a win-win-win combination.

Environmental dividend

Industrial firms transform raw materials into final goods through integrated, sequential and supporting processes that require energy to fuel them. The energy required depends on the nature of the technology and on its efficiency in using raw and auxiliary materials.

Improving industrial energy efficiency can yield a large environmental dividend

The environmental impact of industrial energy use is direct, a result of energy demands for production processes, and indirect, a result of energy demands on energy suppliers. The environmental impact of energy use includes emissions (to air, water and land),

The profitability of energy-efficiency projects is well established in developed countries. The *IDR 2011* demonstrates that substantial economic dividends can be earned in developing countries as well

depletion of natural resources and alterations to landscape and biodiversity. Greenhouse gas emissions, particularly carbon dioxide, dominate the international discussion because of their impact on climate change. But the combustion of fossil fuels for industrial use also contributes to acid rain and to emissions of particulates, heavy metals and other pollutants. Resource depletion is of particular concern. Physical interventions to establish energy generation and distribution facilities also affect land and seascapes and local ecosystems, while nuclear radiation poses significant risks to human health.

Cutting-edge technologies for industrial energy efficiency can reduce the widespread environmental impact of industrial energy use. These include cross-cutting and industry-wide technologies (such as cogeneration, energy recovery and efficient motor and steam systems), inter-industry opportunities (such as reuse of waste heat or by-products by other industries), and process-specific technologies. Improving industrial energy efficiency can yield a large environmental dividend for two main reasons:

- *Industry accounts for about 25 percent of greenhouse gas emissions from all sources globally* (Bernstein et al. 2007). When indirect emissions from power generation are allocated by sector, manufacturing and construction contribute almost 37 percent globally to carbon dioxide emissions from fuel use and industrial processes and a startling 47 percent in developing countries (IEA 2010a). Industry causes further emissions of greenhouse gases in other sectors through transport of raw materials and finished manufactured goods and management of industrial waste. Industry's direct mitigation potential also includes options to reduce non-energy greenhouse gas emissions and implement production processes that economize on materials and water consumption.
- *Industry is a major user of natural resources and could contribute substantially to mitigating resource depletion.* Savings are possible in the use of fossil fuels, a non-renewable resource. Savings are also possible in the use of raw materials and water, which are intrinsically linked to manufacturing. Processing materials and water in manufacturing requires energy proportional to the throughput.

Economic dividend

Like any other investment, new technologies, processes and approaches for industrial energy efficiency need to be profitable. While some companies may be motivated by environmental and social concerns to invest in industrial energy efficiency, the primary rationale must be economic – green investments must be profitable.

The profitability of industrial energy-efficiency projects is well established in developed countries

The decision to allocate resources to improving industrial energy efficiency depends on the importance of energy costs to the firm and the risks and rewards of the investment. For firms in continuous process industries – such as basic metals, non-metallic minerals, petroleum refining and chemicals – energy constitutes a large share of total costs. Cost savings from improved energy efficiency could be substantial. But the wide variations in energy prices and subsidies across countries and industries affect potential cost savings.

Investments in energy efficiency must compete with alternative projects for financial and other resources. Relevant factors include the energy intensity of the firm or industry, the organizational and technological complexity of the project and the technological, external and business risks. Technological risks include uncertainties about the technology's performance and compatibility with existing processes. External risks include uncertainties about energy and product prices. And business risks include shifts in business strategies that may be required to adapt to the new technologies.

The profitability of energy-efficiency projects is well established in developed countries. The *IDR 2011* demonstrates that substantial economic dividends can be earned in developing countries as well, results

> **The data suggest that there is a wide range of profitable opportunities in improving energy efficiency and that firms in developing countries might not be aware of many of these opportunities**

that are in line with the findings of a recent United Nations Environment Programme report (UNEP 2011). Many energy-efficiency projects perform significantly better than the most lucrative financial investments, but their profitability varies widely and is sensitive to the time horizon of the investments. Of 119 industrial energy-efficiency projects that UNIDO assessed in developing countries, the average internal rate of return was slightly more than 40 percent for those with an expected lifetime of five years (Figure 6). Highly profitable projects often involve smaller investments, process reorganization and housekeeping measures, and minor changes to infrastructure. Projects that involve larger investments and require replacing machinery and equipment (mainly in process industries) are typically less profitable and take longer to mature. But they can still have considerable absolute impact on corporate profits.

Does this mean that all industrial energy-efficiency projects are profitable under normal investment criteria? Clearly not. Generally speaking, the data suggest that the more technologically and organizationally complex the project, the lower the profitability. Many energy-efficient technologies are likely to remain unprofitable for some time, at least until environmental damages are properly priced. But the data also suggest that there is a wide range of profitable opportunities in improving energy efficiency and that firms in developing countries might not be aware of many of these opportunities.

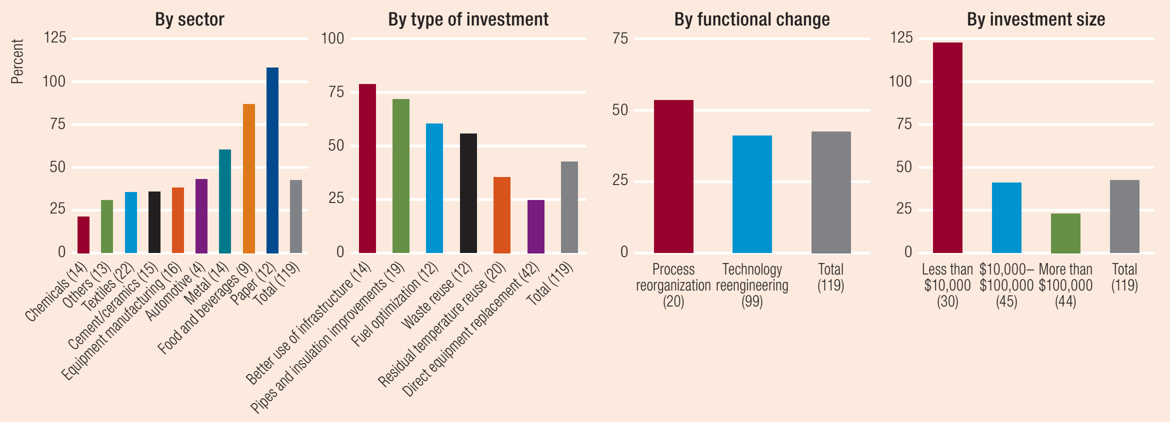
Social dividend

In many developing countries, inefficiencies in energy use by manufacturing firms result in high running costs, wasted energy and materials, underuse of industrial capacity and unnecessary investments in standby equipment. For these countries, improvements in industrial energy efficiency, promoted and implemented through appropriate policy reforms, could allow a better social use of energy resources. Energy could be redistributed towards the poorer segments of the population. Energy efficiency improvements could also free resources for investment in new machinery and further improvements in the production process – boosting competitiveness, productivity growth, employment and wages. The productivity improvements in developing countries could be especially large in small and medium-size industrial enterprises, which tend to be less energy efficient than larger firms.

Industrial energy-efficiency improvements can boost productivity and improve health outcomes

Industrial energy-efficiency improvements can also boost skill levels, raising overall productivity. Many training programmes to increase industrial energy

Figure 6
Internal rates of return of industrial energy-efficiency projects with an expected lifetime of five years



Note: Numbers in parentheses are number of projects.
Source: UNIDO 2010h.

> To overcome market and behavioural barriers, policy-makers need to formulate a coordinated energy strategy – including formal and informal mechanisms, targets, benchmarks and standards – and adapt policies to national and local contexts

efficiency enhance worker productivity across the board, as workers acquire knowledge applicable to multiple fields. Workers can also benefit from improved health as factory emissions decline. Lowering atmospheric emissions of pollutants such as sulphur oxides, nitrogen oxides, smoke and airborne suspended particulate matter reduces the incidence of acute and chronic respiratory illnesses and asthma attacks and increases the life expectancy of factory workers. And because many industries are clustered in the same areas, emissions reductions can have health benefits for local communities – especially poor communities, since pollution-intensive industries in developing countries tend to be located in low-wage areas.

Adopting industrial energy-efficiency technologies can improve the indoor environment as well, increasing comfort and safety (Mills and Rosenfeld 1996). Variable speed drives and air blowers and energy-efficient furnaces tend to be quieter than the equipment they replace. Exhaust heat recovery systems also improve ventilation. Glazed windows keep occupants of households and factories cooler in hot weather and reduce external noise. Efficient lighting technologies such as fluorescent lamps and light-emitting diodes increase the likelihood that warning signs will operate properly when needed, thus improving safety.

Overcoming obstacles to industrial energy efficiency

Despite the substantial environmental, economic and social benefits of investing in industrial energy efficiency, the *IDR 2011* finds numerous untapped opportunities. A study commissioned for the report estimates that manufacturing industry spends some $1 trillion a year on energy, 55 percent of it in developing countries (Saygin et al. 2010). It also shows that universal adoption of best practice technologies – the energy intensity of the top 10 percent of plants in the world – could yield annual savings in energy costs of $65 billion in developed economies and $165 billion in developing economies, corresponding to 23 percent of total energy costs and 2 percent of MVA. Investing in best available technologies – the most energy-efficient way of producing goods and services that is commercially viable and in use – could save an additional 5–15 percent in costs. The potential energy savings from the best available technologies total 32.7 exajoules a year (0.8 Gtoe), roughly 30 percent of today's global industrial energy consumption and 6 percent of total energy use worldwide (Table 1).

Why is so much improvement potential ignored?

Why are so many of these potentially profitable investment opportunities overlooked? Because markets depart from the textbook ideal, and individual and corporate behaviour is not always rational. While long known and understood, the obstacles to improving energy efficiency are difficult to remove. Too often, potential users are not aware of the advantages and opportunities from investments in energy-efficient technologies. And when they are, they cannot easily obtain the funding to acquire the new equipment or make the necessary plant modifications. Decision-makers in firms do not always benefit directly from their decisions, and it is difficult to estimate all the costs, benefits and risks of projects. Furthermore, government subsidies that lower energy prices can make these investments less attractive.

In developing countries, the barriers can be even greater because of institutional, economic and technical conditions. Where the supply of energy is irregular, efficiency typically takes a back seat to availability. Small and medium-size firms face the biggest obstacles to achieving energy-efficiency improvements.

What policy tools are available?

How can developing countries overcome these market and behavioural barriers? Policy-makers need to formulate a coordinated energy strategy – including formal and informal mechanisms, targets, benchmarks and standards – and adapt policies to national and local contexts. Measures should have a time horizon of a couple of decades, including realistic interim medium-term targets (typically 5–10 years), and be

"The potential energy savings from the best available technologies total roughly 30 percent of today's global industrial energy consumption and 6 percent of total energy use worldwide

Table 1

Technical and economic savings potential arising from industrial energy-efficiency improvements

Sector and product	Technical improvement potential (percent)		Total savings potential (exajoules per year)		Share of energy costs[a] (percent)		Carbon dioxide savings potential (tonnes of carbon dioxide a year)	Share of current emissions (percent)
	Developed countries	Developing countries	Developed countries	Developing countries	Developed countries	Developing countries		
Process sectors								
Petroleum refineries	10–15	70	0.7	4.6		50–60		
Chemical and petrochemical			0.5	1.8			300	20
Steam cracking (excluding feedstock)	20–25	25–30	0.4	0.3		50–85		
Ammonia	11	25	0.1	1.3				
Methanol	9	14	0	0.1				
Non-ferrous minerals			0.3	0.7				
Alumina production	35	50	0.1	0.5		30	45[b]	12[b]
Aluminium smelters	5–10	5	0.1	0.2	35–40	35–50		
Other aluminium	5–10	5	0.1	0.2	35–40	35–50		
Copper smelters		45–50	0	0.1				
Zinc	16	46	0	0.1				
Iron and steel	10	30	0.7	5.4	10–20	30	350	14
Non-metallic minerals			0.8	2.0				
Cement	20	25	0.4	1.8	25–30	50	450	23
Lime					40			
Glass	30–35	40	0.4	0.2		7–20		
Ceramics						30–50		
Combined sectors								
Pulp and paper	25	20	1.3	0.3		15–35	80	20
Textile						5–25		
Spinning	10	20	0.1	0.3				
Weaving					5–10	10–15		
Food and beverages	25	40	0.7	1.4		1–10		
Other sectors	10–15	25–30	2.5	8.7				
Total	15	30–35	7.6	25.1				
Excluding feedstock	15–20	30–35					12[c]	

Note: Potential savings based on universal application of best available technologies.

a. Share of total production costs (total fixed costs and variable costs, including depreciation).

b. All aluminium activities.

c. Includes only chemical and petrochemical, aluminium, iron and steel, and pulp and paper.

Source: Saygin et al. 2010; IEA (2009b) for emissions figures.

> **Key policy approaches include laws and regulations, negotiated agreements, information-based instruments, new technology and innovation support, market-based instruments and financial facilities**

sufficiently credible and stable to encourage firms to invest. Policy-makers need to continually assess policy effectiveness and benchmark policies against best international practice. They should also establish local, regional and national bodies for implementation and explore possibilities for international cooperation. (See Box 1 for examples of industrial energy-efficiency policies applied in some developing countries.)

There are many tools for overcoming barriers to improving industrial energy efficiency

There are many tools for tackling these barriers and considerable international experience with "what works." The first steps are establishing quantified and achievable efficiency targets, benchmarking the performance of different sectors and identifying opportunities to improve energy efficiency. Once realistic and measurable targets are set, legislation and negotiated

Box 1

Experiences of industrial energy-efficiency policies applied in selected developing countries

Brazil. The National Electrical Energy Conservation Programme (Procel) introduced the Industrial Energy Efficiency Programme in 2003, stressing awareness-raising and capacity-building, implementation of demonstration projects, regulatory and legislative actions and establishment of financing lines for project replication. Procel Industria originally focused on electric motor-driven systems, industrial processes, energy audits and industrial facilities' electricity losses. It used universities to provide training and develop analytical tools for manufacturers and provided financing for equipment and instrumentation to enable self–energy auditing and implementation by industry. Procel's industrial energy-efficiency programme was executed through the National Confederation of Industry (NCI) to strengthen NCI as a leader in industrial energy efficiency, to create a focus point instead of having specific agreements with all sectors and to build a common agenda. It included an international survey of industrial energy-efficiency programmes and projects, a national survey of industrial energy-efficiency projects results and mechanisms, and identification of barriers for energy-efficiency projects and of key success factors.

China. In 2004, China launched its Ten Key Projects initiative, a $1 billion programme to provide financial incentives for a range of industrial energy-saving projects. Funding is earmarked for 5 of the 10 key projects (coal industrial boilers and kilns, waste heat and power recovery, petrochemical conservation, electrical machinery, energy-saving systems and energy system optimization). Applicants must undergo a comprehensive energy audit, demonstrate adequate accounting and management systems and show that the project will save at least 7,000 tonnes of oil equivalent (toe). If independent reviewers conclude that a project is successful, applicants can also receive financial awards linked to energy savings. In 2007, Shanghai had 243 energy conservation projects with a total investment of $439 million and estimated savings of 600,000 toe. Weifang City in Shandong Province implemented 66 projects in 2007, with a total investment of $1.28 billion. By June 2008, 26 projects were completed with an energy-saving capacity of 121,000 toe per year.

India. The objective of the Bureau of Energy Efficiency is to reduce the energy intensity of the Indian economy. Within the overall framework of the 2001 Energy Conservation Act, the Bureau assists in developing policies and strategies that emphasize self-regulation and market principles. Among its initiatives are the National Energy Conservation Award for Industries (14 industrial sectors have set ambitious targets to cut energy use by up to 40 percent through conservation measures), an energy-efficiency labelling scheme, a model energy performance contract for energy services companies and organization of the National Certificate Examination for Energy Managers and Energy Auditors.

South Africa. Through the Energy Efficiency Accord signed with the Ministry for Energy and Minerals, the chief executive officers of 24 major energy users and seven industry associations voluntarily committed to work individually and collaboratively to meet government targets for energy savings, promote demand management contracts with energy suppliers, develop common reporting requirements for energy use from all sources, forecast industry-specific energy use based on business-as-usual growth expectations, develop a generic energy-auditing protocol that can be adapted by the sector and company signatories, and exploit opportunities to develop Clean Development Mechanism energy-efficiency projects under the Kyoto Protocol.

Source: UNIDO 2011.

As industrial activity shifts towards developing countries, information and knowledge exchanges and international coordination are needed to level the playing field

agreements can ensure their achievement. Some key policy approaches include:

- *Laws and regulations* that remove the least efficient equipment and practices from the market and cut greenhouse gas emissions. Energy efficiency laws generally establish government regulating, implementing and coordinating agencies – as well as promotional and support organizations – and cover energy standards, energy-savings plans, regular reporting of energy consumption, energy-auditing and energy-conservation training, and technical assistance. Laws can also stipulate priorities and provide tax incentives, subsidies and penalties. But legislation can have drawbacks. Targets may be unrealistic, and laws based on experiences from a developed country might not be adequately adjusted to developing country contexts, putting the targets at odds with other economic and social goals. There is also a risk of technological "lock-in" at inappropriate levels determined by regulations rather than by market conditions. Finally, inadequate funds are typically allocated to implement, monitor and enforce legislation.
- *Negotiated agreements* for energy efficiency are contracts between government and industry – typically including specific targets to meet within set time schedules. The understandings can engage stakeholders in developing a long-term plan for greater energy efficiency. Some successful agreements contain elements that can be applied in other countries and sectors. Agreements in Denmark, Finland and the Netherlands have been models for those in China. Such negotiated arrangements are seen as viable for meeting energy-saving targets while adhering to market-oriented policies. But the pressure of continuing economic growth on energy demand, the environment and competition may force some countries to develop a stronger, more strategic policy on energy efficiency.
- *Information-based instruments* – such as information and awareness campaigns, labelling schemes, offices to disseminate energy-efficiency information and public repositories for energy-efficiency and operational data – can raise awareness of the benefits of energy efficiency at all levels in industry. By making the lifetime costs of available technologies more transparent, these instruments make it easier for firms to choose energy-efficient options. The instruments have no direct impact on production costs or greenhouse gas emissions, but they can affect stakeholder perceptions and decisions. Although fairly easy to implement, they require public funding and institutions to organize and develop campaigns – again, a major obstacle for many developing countries.
- *New technology and innovation support* – government's role includes funding research and development (R&D) and supporting private sector research, encouraging adoption and diffusion of best available technologies, promoting demonstration projects and engaging international research partners. Best available technologies and innovation are key drivers of industrial energy efficiency, but they are beyond the means and capabilities of all but a few developing countries and can take a long time to yield returns. Most developing countries will continue to rely on foreign technologies, but even this requires building local absorptive capacity.
- *Market-based instruments* – such as carbon taxes, subsidies, accelerated depreciation of energy-efficient equipment and tradable energy-efficiency certificates – are often central measures in energy-efficiency policy. They reinforce prices, create the appropriate market for energy efficiency and drive consumer choices towards the most socially cost-effective solutions. One merit of market-based incentives is that they are more cost-effective than some non-market solutions. For instance, a carbon tax is in principle the least costly way to provide meaningful incentives for technology innovation and diffusion, cut greenhouse gas emissions and drive energy efficiency. Demand management can encourage less energy consumption by end-users (including industry), and energy service companies can promote energy efficiency for industries and firms.

> **Since 1990, industrial energy intensity has fallen globally at an average annual rate of 1.7 percent, just half the rate needed to keep energy consumption adequately in check. UNIDO proposes an annual target of 3.4 percent through 2030**

- *Financial facilities* – such as loans, guarantees, revolving funds and venture capital funds – increase the availability of capital and lower its cost, thus reducing risk. But there must first be sound public financial institutions and a reasonably developed commercial banking sector, likely a major obstacle in developing countries.

International collective action through information exchange and international coordination

In addition to national policy initiatives, there is a need for international collective action. Many changes in industrial energy efficiency arise from technical and structural shifts within and across industries, some being the result of international movements of goods and capital. As industrial activity shifts towards developing countries, information and knowledge exchanges and international coordination are needed to level the playing field. And because problems such as climate change are systemic and involve global externalities and public goods, only international action can provide the basis for solutions.

Five key areas for international collective action to improve industrial energy efficiency

There are five key areas for international collective action on industrial energy efficiency: setting global performance targets and standards, facilitating technological and structural changes, contributing to international technology transfer, promoting financial mechanisms to support those transfers, and establishing an international monitoring and coordination function for industrial energy efficiency.

Setting energy-intensity targets and standards

In 2010, the Advisory Group on Energy and Climate Change to the UN Secretary-General recommended that international cooperation to ensure universal access to modern energy services by 2030 give priority to boosting energy efficiency. It recommended reducing overall global energy intensity by 40 percent through 2030, or around 2.5 percent a year, but it set no goal for industrial energy intensity.

As a well established approach to achieving performance objectives, setting measurable targets clearly identifies priorities and direction, allows for comparison and benchmarking and acts as a focusing device for action. Targets are intended to improve performance and to challenge those for whom they are set. But they have to be realistic to maintain their motivating power. And for international collective action to combat climate change, targets must demand major improvements from current trends. Ambitious targets are justified not only on environmental grounds but also on financial grounds, because industrial energy-efficiency projects can yield significant financial gains.

Since 1990, industrial energy intensity has fallen globally at an average annual rate of 1.7 percent, just half the rate needed to keep energy consumption adequately in check. Against this background, UNIDO proposes an annual target of 3.4 percent through 2030, or a total of 46 percent. Because reaching a binding international agreement on such a target will be difficult, countries should make it part of their national development plans. And countries that have already reached the target should strive to reduce energy intensity even more.

To be effective, targets must be monitored. In developing countries, data are often limited, and consequently a first step is to collect and harmonize data on energy intensity. Country performance can then be assessed, and cross-country comparisons can identify where progress is and is not taking place. Processes can be set in motion to inform countries about their progress and examine reasons for deviations.

Setting international standards can also help in achieving targets. Standards can focus on harmonizing terminology and calculation methods for energy efficiency, managing energy, retrofitting and refurbishing standards and standardizing energy-efficiency activities for buildings. These types of standards help define, implement and monitor energy-efficiency policies at macro and micro levels. They also bring innovative energy-efficient technologies to the market faster. And they are objective metrics for regulations and

> **Since targets and transfers are unlikely to materialize without financing, a well developed institutional framework for international financing of industrial energy efficiency would be necessary**

policy incentives to encourage greater use of innovative energy-efficiency technologies.

Facilitating technological and structural change

Further reductions in energy use could be achieved and more resource depletion avoided by launching major international efforts aimed at technological and structural change for industrial energy efficiency.

Efforts should focus on R&D cooperation to share knowledge, coordinate R&D priorities and pool risk (Stern 2006). There has been some international R&D cooperation on adopting low-carbon technologies such as renewable energy sources and on the transfer and diffusion of clean energy technologies. But few international efforts focus exclusively on R&D for industrial energy-efficiency technologies. An international programme aimed at gradually phasing out energy-intensive products that have economically feasible alternatives could also be established. There is already significant international experience in phasing out chlorofluorocarbons worldwide and incandescent light bulbs in the European Union.

International collective action could ensure that the global restructuring of industry considers energy efficiency. An information clearinghouse and information exchanges can help countries and industries identify best available technologies and compare the performance of different technologies under different conditions before investing in them. International coordination could also help deploy industrial energy-efficiency technologies and practices, especially in collaboration with the private sector. Lead multinational firms in global and local value chains and production networks can speed the uptake of industrial energy efficiency in developing countries.

Contributing to international technology transfer

International energy-efficiency technology transfer would involve the movement of skills, knowledge, manufacturing methods, equipment and facilities across countries. A major difficulty developing countries face in adopting industrial energy-efficiency technologies is lack of access to international best available technology, because of lack of information or the large scale of the necessary investment. Host country governments could develop local absorptive capacity, facilitate local spillovers, acquire international licences and promote learning among industrial firms. Source country governments could increase technical and financial assistance and capacity-building to improve developing countries' ability to acquire and absorb foreign technologies. They could also disseminate technological knowledge and standards, promote joint research and establish grants for studying industrial energy-efficiency experiences in developed and developing countries.

International collective action could provide a coordinating mechanism to overcome problems in private technology markets and negotiate rules for international technology transfers. That would require making scientific and technological knowledge widely available, establishing channels for information on successful technology acquisition programmes, harmonizing processes for patents and standards and enforcing international law. Scaling up multilateral agreements such as the Clean Development Mechanism and the Global Environment Fund and establishing international information exchange networks could ensure access to basic science and technology for industrial energy efficiency.

Promoting international financing

Since targets and transfers are unlikely to materialize without financing, a well developed institutional framework for international financing of industrial energy efficiency would be necessary. Multilateral and bilateral sources of finance, direct or through implementing agencies or local financial institutions, could also provide financial assistance to industrial energy-efficiency projects in developing countries. Efforts could focus on assessing global financing requirements and expanding carbon-trading programmes, again through the Clean Development Mechanism and the Global Environment Fund. Current funds are inadequate for accomplishing the task (Stern 2006). Further measures could establish a global fund for

> **Global industrial production is shifting gradually from developed countries to developing countries**

industrial energy efficiency, introduce international guarantees, facilitate lending by private financial institutions and banks and create international energy service companies with a focus on developing countries.

Establishing an international monitoring and coordinating function for industrial energy efficiency

Achieving international synergies and "internalizing externalities" are complex tasks that require bringing national and international interests and objectives into a common understanding of the public good. Yet, only a few fragmented international initiatives are overturning the barriers to industrial energy efficiency. The *IDR 2011* thus argues for an industrial energy-efficiency function to help set and monitor international targets and standards; address data collection and benchmarking; provide technical and economic information; coordinate regulation, targets, standards, R&D, technology transfers and value chain operations; and devise innovative mechanisms to address the challenges of industrial energy-efficiency financing nationally and internationally.

Part B
Trends in manufacturing and manufactured exports, and benchmarking industrial performance

Key messages

- Over the last 20 years, manufacturing valued added (MVA) growth has remained at an average annual rate of 1.7 percent in developed countries, below their annual GDP growth rate, highlighting a waning reliance on manufacturing as a source of growth. Meanwhile, manufacturing has been buoyant in developing countries, with MVA expanding at an average annual rate of 5.6 percent.
- Developing countries' share of world manufactures trade has also been rising steadily to a 39 percent share in world manufactured exports, a trend that is likely to continue as developing countries increase their industrial production capacity and more manufacturing activities are relocated to these countries to reduce production costs.
- The financial crisis affected the manufacturing industry in developed countries more than in developing countries. In 2009, while developed countries faced an 8.1 percent reduction in MVA, developing country MVA grew 2.9 percent. The crisis abruptly halted the growth in manufactured exports, which fell 18.7 percent in developing countries and 23.2 percent in developed countries in 2009.
- UNIDO's 2009 Competitive Industrial Performance index, which assesses industrial performance using indicators of an economy's ability to produce and export manufactured goods competitively for 118 economies, revealed that Singapore, the United States, Japan, Germany and China were the overall leaders.

Global industrial production is shifting gradually from developed countries to developing countries as firms move to benefit from cheaper labour, quality infrastructure, lower social costs and large markets in some countries. Changes in world MVA reflect greater integration of national economies through trade liberalization, wider availability of financial resources and increased flows of foreign direct investment.

Trade expansion has been central to economic globalization, and manufactures make up the bulk of world trade, consistently accounting for more than 80 percent of exports since 1990. While developed countries have traditionally dominated world manufactures trade, developing countries' share has risen steadily – as has their exposure to trade shocks (Montalbano 2011). To benchmark national industrial performance, UNIDO has developed the Competitive Industrial Performance (CIP) index, which assesses industrial performance using indicators of an economy's ability to produce and export manufactured goods competitively (UNIDO 2003).

> **Developing economies' share in world manufactured exports climbed from 20.4 percent in 1992 to 39.0 percent in 2009**

Trends in manufacturing value added

Over 1990–2010, global MVA grew 2.8 percent annually, from $4,290 billion to $7,390 billion. MVA growth averaged just 1.7 percent a year in developed countries, below their annual GDP growth of 2 percent, highlighting a waning reliance on manufacturing as a source of growth and the increased role of services. In developing countries, by contrast, manufacturing was buoyant, registering a remarkable 5.6 percent annual growth rate in MVA over the period, even higher than their 4.8 percent annual increase in GDP.

Shares in manufacturing value added

The 15 largest developing economies accounted for 83.0 percent of developing economy MVA in 2010, up from 73.2 percent in 1990. The increase is attributable mainly to China, which has emerged as a factory to the world, more than tripling its share of developing economy MVA over 1990–2010 to 43.3 percent.

Both developed and developing economies increased their share of medium- and high-technology products over 1990–2009, as the global share of these products rose from 41.3 percent to 55.8 percent. Developing economies – particularly in East Asia and the Pacific – have become more integrated into global value chains and production networks, with their accelerated technology transfer and better market access. Moving on from an early focus on low-end, low value-added products, economies such as China, Malaysia and Taiwan Province of China have diversified their manufacturing production by moving into more technologically advanced products.

In 1995, the dominant manufacturing sectors worldwide were food and beverages (11.8 percent), chemicals and chemical products (10 percent) and machinery and equipment (8.5 percent). By 2000, radio, television and communication equipment had surpassed all three, at 13.9 percent, and by 2009 that share had soared to 20.7 percent, riding the surge in demand for electronic goods (computers, mobile phones and other electronic devices).

Global manufacturing employment has been shifting from developed to developing countries. This trend is expected to intensify as more manufacturing relocates to developing countries. There are sharp regional differences, however, with East Asia and the Pacific accounting for more than 60 percent of manufacturing employment in developing countries.

The 2008–2009 economic and financial crisis affected manufacturing more in developed countries than in developing countries

Global MVA grew an average 2.7 percent a year over 2000–2004 and 2.4 percent over 2005–2010, peaking at $7,350 billion in 2008 (Table 2). In 2009, however, the global recession led to a 4.5 percent drop in MVA over 2008, to $7,020 billion. The crisis affected developed countries more, with MVA falling 8.1 percent from 2008 to 2009. MVA growth in developing countries slowed to 2.9 percent in 2009, down from an annual average of 6.8 percent over the previous eight years.

The financial crisis affected developing regions differently through a region-specific mix of channels including trade, remittances, financial flows, foreign direct investment and development assistance. MVA grew 7.7 percent in East Asia and the Pacific and 4.8 percent in South and Central Asia but fell in other regions.

Europe was most affected, with MVA dropping 7.1 percent from 2008 to 2009. Latin America and the Caribbean's MVA fell 6 percent. In the Middle East and North Africa, MVA fell 0.5 percent between 2008 and 2009. Despite declining oil revenues, some oil-exporting countries used their substantial foreign exchange reserves for large investment programmes. Worryingly, sub-Saharan Africa's industrial base has been eroding, a process likely to be accelerated by the depletion of much needed resources for investments in productive capacity and infrastructure.

Despite the crisis, MVA in the least developed countries grew 6.3 percent between 2008 and 2009. This growth may conceal long-term adverse effects of the crisis on industrialization because of increased international competitive pressures and the countries' still fledgling manufacturing sectors and vulnerability to external shocks.

> **“In 2009, 54.8 percent of developing countries’ exports were medium- and high-technology products, up from 48.6 percent in 1995**

Table 2
Manufacturing value added levels and growth, by region, 2005–2010 (US$ billions unless otherwise indicated)

Region	2005	2006	2007	2008	2009	2010	Average annual growth rate (percent) 2001–2005	Average annual growth rate (percent) 2006–2010
World	6,570	6,900	7,260	7,350	7,020	7,390	2.7	2.4
Developed economies	4,710	4,880	5,040	5,010	4,600	4,760	1.4	0.2
Developing economies	1,870	2,020	2,220	2,340	2,410	2,630	6.2	7.1
Region								
East Asia and the Pacific	966	1,060	1,200	1,290	1,390	1,540	8.6	9.8
Excluding China	320	342	365	370	375	406	4.8	4.9
Europe	148	156	171	176	164	169	5.9	2.8
Excluding Russian Federation	81	91	101	105	101	105	6.3	5.3
Latin America and the Caribbean	373	392	411	423	397	423	1.9	2.5
Excluding Brazil	262	279	293	302	281	294	1.5	2.3
Middle East and North Africa	183	198	210	217	216	229	4.4	4.6
Excluding Turkey	116	125	134	140	143	150	4.4	5.2
South and Central Asia	149	166	179	185	194	210	7.4	7.0
Excluding India	58	64	69	72	75	79	8.6	6.2
Sub-Saharan Africa	47	49	51	53	52	54	3.2	3.0
Excluding South Africa	20	21	22	23	24	26	3.6	4.6
Least developed countries	24	26	28	30	32	34	6.6	7.1

Source: UNIDO 2010g.

Trends in world manufactured exports

World manufactured exports peaked at $12,095 billion in 2008 (Table 3), having grown faster than both MVA and GDP over 2005–2008. Trade liberalization, tumbling transportation costs and globalization of production contributed to the growth. Trade in primary products increased even faster, likely fuelled by strong demand from fast-growing developing countries. With growth rates higher than in developed countries, developing countries’ share in world manufactured exports climbed from 20.4 percent in 1992 to 39.0 percent in 2009. This trend is likely to continue as developing countries increase their industrial production capacity and more manufacturing activities are relocated to these countries to reduce production costs.

Shares in world exports

While developed economies account for more than 60 percent of medium- and high-technology exports, developing economies have also made some inroads, increasing the technological complexity of their exports and gaining market share. In 2009, 54.8 percent of developing economies’ exports were medium- and high-technology products, up from 48.6 percent in 1995; developing economies accounted for 35 percent of global exports of medium- and high-technology products.

Although developing economies’ share of world manufactures trade is rising, some economies contribute more than others. China, in particular, is changing the landscape of world manufactures exports. Its exports grew 14.6 percent annually over 1992–2001 and a staggering 27.9 percent a year over 2001–2008 after China joined the World Trade Organization. Ranked 13th in manufactured exports in 1992, China steadily improved its position, becoming the global leader in 2008, with a world market share of 11.3 percent and manufactured exports totalling $1,370 billion. The second largest importer in the world, China’s share of world imports was 8.7 percent

> **World manufactured exports growth of 9.6 percent annually over 2000–2004 continued into the second half of the decade, but the financial crisis slashed sales abroad, reducing annual growth over 2005–2009 to 5.2 percent**

in 2009, behind the United States and ahead of Germany, helping fuel global demand.

Trade between developing economies grew 14.9 percent annually over 2004–2009, reaching $2,247 billion in 2008 before dropping to $1,871 billion in 2009. This trade accounted for 51.8 percent of developing economies' total trade in 2009, up from 39.9 percent in 2000. The share is likely to continue to rise as production fragmentation expands, trade continues to develop and large countries such as Brazil, China and India grow and reinforce their trade ties with other developing economies.

The economic and financial crisis halted the growth in manufactured exports

World manufactured exports growth of 9.6 percent annually over 2000–2004 continued into the second half of the decade, but the financial crisis slashed sales abroad, reducing annual growth over 2005–2009 to 5.2 percent on average (Table 3). From 2005 to 2008, growth in manufactured exports in developing economies (17.3 percent) was far greater than in developed economies (11.0 percent). The 2008–2009 crisis abruptly halted the growth in manufactured exports, which fell 18.7 percent in developing economies and 23.2 percent in developed economies in 2009.

In 2009, manufactured exports from East Asia and the Pacific dropped 20.4 percent to the European Union and 14.5 percent to the United States. Declines were even sharper for Europe, Latin America and the Caribbean, and the Middle East and North Africa. Sub-Saharan Africa was hit hardest, with a 35.7 percent plunge in combined exports to the European Union and the United States. The decline in manufactured export revenues, along with falling commodity prices, has constrained imports of vital production inputs and the ability to mitigate the effects of the crisis.

Table 3
World manufactured export levels and growth, by region, 2004–2009 (US$ billions unless otherwise indicated)

Region	2004	2005	2006	2007	2008	2009	Average annual growth rate (percent) 2000–2004	Average annual growth rate (percent) 2005–2009
World	7,379	8,252	9,448	10,845	12,095	9,490	9.6	5.2
Developed economies	4,974	5,409	6,066	6,890	7,542	5,792	7.9	3.1
Developing economies	2,405	2,844	3,382	3,955	4,554	3,699	14.0	9.0
Region								
East Asia and the Pacific	1,468	1,736	2,081	2,446	2,732	2,308	13.7	9.5
Excluding China	910	1,013	1,159	1,278	1,362	1,153	8.9	4.9
Europe	252	306	366	455	575	402	20.4	9.7
Excluding Russian Federation	183	214	258	326	398	293	20.8	9.9
Latin America and the Caribbean	318	378	419	455	534	415	8.9	5.4
Excluding Brazil	250	292	320	344	401	318	7.8	4.9
Middle East and North Africa	218	240	299	359	432	335	17.0	9.0
Excluding Turkey	160	173	222	261	314	248	16.1	9.1
South and Central Asia	100	129	154	171	197	181	16.6	12.6
Excluding India	35	42	49	46	41	31	16.4	–1.8
Sub-Saharan Africa	48	56	64	69	83	58	14.4	3.8
Excluding South Africa	21	23	29	27	32	22	19.8	0.9
Least developed countries	19	19	22	21	15	–	45.7	–

– is not available; about half the least developed countries have yet to report 2009 data.
Source: UN 2011.

The *IDR 2011* adds two new indicators to the Competitive Industrial Performance index used to benchmark an economy's industrial performance

Despite a better than average showing for the least developed countries on manufactured imports from major importing countries, the collapse in export revenues is likely to hurt these countries in the long term, perhaps jeopardizing years of development progress, by affecting investments in productive capacity, infrastructure and social programmes.

Benchmarking industrial performance: the Competitive Industrial Performance index

UNIDO developed the Competitive Industrial Performance (CIP) index to benchmark an economy's industrial performance. The index assesses industrial performance using indicators of an economy's ability

Table 4
Rank on the revised Competitive Industrial Performance index, 2005 and 2009

Rank		Economy	CIP index	
2005	2009		2005	2009
3	1	Singapore	0.631	0.642
2	2	United States	0.660	0.634
1	3	Japan	0.661	0.628
4	4	Germany	0.598	0.597
6	5	China	0.461	0.557
7	6	Switzerland	0.455	0.513
9	7	Korea, Rep. of	0.438	0.480
5	8	Ireland	0.499	0.479
11	9	Finland	0.411	0.442
8	10	Belgium	0.439	0.442
12	11	Taiwan Province of China	0.401	0.437
10	12	Sweden	0.432	0.430
18	13	Austria	0.368	0.401
21	14	Slovakia	0.322	0.387
13	15	France	0.395	0.384
16	16	Netherlands	0.374	0.378
14	17	Hong Kong SAR China	0.385	0.375
17	18	Italy	0.370	0.361
15	19	United Kingdom	0.383	0.356
24	20	Czech Republic	0.310	0.352
26	21	Slovenia	0.306	0.345
30	22	Israel	0.286	0.332
25	23	Hungary	0.310	0.328
22	24	Luxembourg	0.316	0.323
27	25	Thailand	0.300	0.320
23	26	Denmark	0.311	0.320
20	27	Malaysia	0.330	0.320
19	28	Canada	0.349	0.309
28	29	Spain	0.293	0.291
29	30	Mexico	0.286	0.286
31	31	Malta	0.266	0.284
34	32	Poland	0.235	0.279
32	33	Philippines	0.262	0.272
38	34	Norway	0.209	0.248
33	35	Turkey	0.237	0.237
35	36	Estonia	0.220	0.234
36	37	Portugal	0.218	0.224
43	38	Iceland	0.187	0.218
47	39	Romania	0.178	0.218
41	40	Lithuania	0.196	0.216
39	41	Costa Rica	0.208	0.215
42	42	India	0.190	0.206
40	43	Indonesia	0.198	0.203
37	44	Brazil	0.212	0.202
51	45	Jordan	0.167	0.193
49	46	Argentina	0.168	0.192
46	47	Australia	0.180	0.188
62	48	Swaziland	0.152	0.186
45	49	South Africa	0.181	0.184
52	50	Greece	0.166	0.182
58	51	Georgia	0.155	0.179
61	52	Latvia	0.154	0.178
44	53	Cyprus	0.182	0.176
53	54	Bulgaria	0.165	0.176
54	55	Tunisia	0.157	0.175
50	56	El Salvador	0.168	0.175
55	57	Barbados	0.156	0.174
72	58	Viet Nam	0.137	0.171
59	59	Morocco	0.155	0.168
64	60	Qatar	0.150	0.168
48	61	New Zealand	0.172	0.161
73	62	Egypt	0.137	0.157

“The Competitive Industrial Performance index now comprises eight indicators classified in six dimensions

to produce and export manufactured goods competitively (UNIDO 2003).

The *IDR 2011* adds two new indicators to the CIP index – the share of an economy's MVA in world MVA (to measure impact in world manufacturing production) and the share of an economy's manufactured exports in world manufactured exports (to measure an economy's impact in manufactures international trade). The CIP index now comprises eight indicators classified in six dimensions:

- Industrial capacity, measured by MVA per capita.
- Manufactured export capacity, measured by manufactured exports per capita.
- Impact on world MVA, measured by an economy's share in world MVA.

Table 4 *(continued)*

Rank on the revised Competitive Industrial Performance index, 2005 and 2009

Rank		Economy	CIP index	
2005	2009		2005	2009
67	63	Pakistan	0.147	0.156
88	64	Kuwait	0.107	0.156
60	65	Bahamas	0.154	0.154
57	66	Russian Federation	0.155	0.154
63	67	Trinidad and Tobago	0.151	0.151
66	68	Macedonia, Former Yugoslav Rep. of	0.147	0.149
75	69	Bangladesh	0.135	0.145
56	70	Mauritius	0.156	0.144
65	71	Lebanon	0.149	0.144
78	72	Macao SAR China	0.130	0.142
76	73	Jamaica	0.132	0.141
69	74	Colombia	0.140	0.135
68	75	Senegal	0.142	0.134
77	76	Albania	0.132	0.133
71	77	Venezuela, Bolivarian Rep. of	0.138	0.131
79	78	Botswana	0.128	0.131
80	79	Uruguay	0.123	0.129
102	80	Syrian Arab Rep.	0.082	0.128
70	81	Chile	0.139	0.128
89	82	St. Lucia	0.106	0.127
82	83	Iran, Islamic Rep. of	0.114	0.126
87	84	Moldova, Rep. of	0.111	0.126
98	85	Gambia, The	0.087	0.124
83	86	Palestinian Territories	0.114	0.121
90	87	Rwanda	0.106	0.119
93	88	Cambodia	0.102	0.119
92	89	Honduras	0.103	0.118
74	90	Côte d'Ivoire	0.136	0.116
99	91	Oman	0.087	0.115
86	92	Sri Lanka	0.111	0.115
94	93	Fiji	0.101	0.110
91	94	Nepal	0.105	0.108
85	95	Niger	0.111	0.107
96	96	Peru	0.094	0.106
100	97	Madagascar	0.086	0.101
105	98	Uganda	0.075	0.100
84	99	Zimbabwe	0.114	0.100
97	100	Kenya	0.092	0.094
101	101	Kyrgyzstan	0.085	0.089
103	102	Cameroon	0.080	0.083
81	103	Nigeria	0.114	0.081
108	104	Ecuador	0.069	0.079
104	105	Paraguay	0.075	0.076
107	106	Eritrea	0.071	0.076
111	107	Bolivia, Plurinational State of	0.063	0.073
112	108	Mongolia	0.055	0.070
109	109	Ghana	0.069	0.069
114	110	Tanzania, United Rep. of	0.046	0.068
118	111	Ethiopia	0.017	0.068
110	112	Malawi	0.064	0.059
113	113	Panama	0.048	0.053
116	114	Yemen	0.036	0.044
115	115	Algeria	0.037	0.042
117	116	Gabon	0.034	0.038
106	117	Azerbaijan	0.072	0.036
95	118	Sudan	0.095	0.035

Source: UNIDO.

"In 2009, East Asia and the Pacific performed best on the index, followed by Europe, the Middle East and North Africa, Latin America and the Caribbean, South and Central Asia, and sub-Saharan Africa

- Impact on world manufactures trade, measured by an economy's share in world manufactured exports.
- Industrialization intensity, measured by the average of the share of MVA in GDP and of medium- and high-technology activities in MVA.
- Export quality, measured by the average of the share of manufactured exports in total exports and of medium- and high-technology products in manufactured exports.

Ranking economies using the Competitive Industrial Performance index, 2005 and 2009

The CIP index was computed for 2005 and 2009 for 118 economies with sufficient recent data. Singapore, the United States, Japan and Germany were the overall leaders (Table 4). China ranked fifth in 2009. At the bottom of the rankings were Mongolia in East Asia and the Pacific; Algeria, Azerbaijan and Yemen in the Middle East and North Africa; Panama in Latin America and the Caribbean; and Sudan and Gabon in sub-Saharan Africa.

At a regional level, in 2009 East Asia and the Pacific performed best on the index, followed by Europe, the Middle East and North Africa, Latin America and the Caribbean, South and Central Asia, and sub-Saharan Africa. The 2005 regional rankings were similar, except that the Middle East and North Africa was behind Latin America and the Caribbean.

Part A

Industrial energy efficiency for sustainable wealth creation: capturing environmental, economic and social dividends

Chapter 1

Trends in industrial energy efficiency

This 2011 *Industrial Development Report (IDR)* addresses industrial energy efficiency in sustainable development. Around a fifth of global income is generated directly by manufacturing industry, and nearly half of household consumption relies on goods from industrial processes. People's needs for food, transportation, communication, housing, health and entertainment are all met by industry. Since the Industrial Revolution, waves of innovation have shaped how people work and live. During the 19th and 20th centuries, developed countries relied on manufacturing to spur economic growth. Today, developing countries are counting on industrialization to reduce poverty and improve the quality of life of its growing populations.

But improvements in the standard of living made possible through industrialization have come at an environmental cost. Before the late 1960s, energy consumption per capita had increased nine-fold over the previous 200 years (Cook 1971, 1972). Since then, energy consumption per capita has increased by a further 25 percent (IEA 2010c). Materials use per capita more than doubled over 1900–2005 (Krausmann et al. 2008). And though the fossil fuels that have fed industrial development may not be as abundant as once thought, overall energy consumption is not likely to fall soon. Pollution, resource depletion and the waste of discarded products – each at an all-time high – are major causes of environmental degradation and climate change. Policy-makers must address them as they remap development paths.

Industrial development, therefore, must become sustainable. Continued high resource consumption and carbon-intensive and polluting technologies will sap the potential for growth and development. Innovative solutions, national and global, are vital to making industrial activity more sustainable – to attuning it to environmental and social needs. This "green industry" approach can provide the blueprint for sustained industrial development.

Increasing industrial energy efficiency is a key foundation for green industry worldwide. By building on past successes, countries can develop their industries while tempering the impacts on resource depletion and climate change. The *IDR 2011* emphasizes industrial energy efficiency in developing countries, which are emerging as key actors in global industrial development. The report takes an in-depth look at long-term trends in industrial energy intensity as well as related technical and structural change, examines the environmental and economic benefits of industrial energy efficiency and identifies ways of overcoming obstacles.

Decoupling industrial energy use and economic growth

Industrial energy consumption, still growing in developed countries, is soaring in developing countries. Developed countries remain the largest per capita users of both total energy and industrial energy, but developing countries are quickly catching up – satisfying domestic demands for improved living standards and import demands from developed countries – and becoming large energy consumers. Their need for energy is expected to continue to rise for the foreseeable future.

Although energy use has been rising, industrial energy intensity has been declining in all regions and in countries at all levels of development, implying a gradual decoupling of industrial energy use and economic growth, though with considerable variation across regions and industries. Part of the reduction in industrial energy intensity results from government policy. Another important part is an outcome of technological progress, industrial restructuring and changes in fuel mix and production-oriented initiatives. And while globally 1990–2000 saw an absolute decoupling of manufacturing value added (MVA) growth from industrial energy intensity (a decrease in industrial energy intensity greater than the increase

> **Developed countries are the largest energy consumers per capita, but developing countries are driving the global increase in final energy demand**

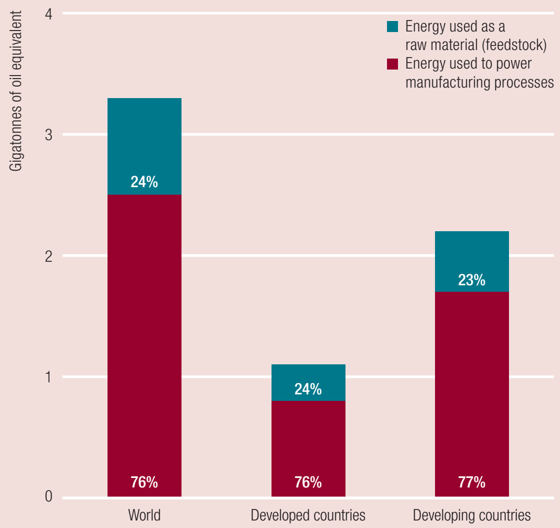
in MVA;OECD 2002; Spangenberg, Omann and Hintenberger 2002), industrial energy consumption still grew rapidly afterwards (see *Glossary* for definitions of key terms). With industry essential for economic growth and developing countries unrelentingly pursuing economic development, more effort is needed to understand the sources and drivers of decoupling and the policies that encourage it.

How is global industrial energy consumed?

A first step in evaluating global industrial energy intensity is to take stock of how energy is consumed. Industry uses fossil fuels in manufacturing processes and as a raw material (to generate power). In the 134 economies analysed for this report (see Annex 4), energy used to power manufacturing processes accounted on average for about 76 percent of industrial energy consumption over 1990–2008 in both developed and developing economies; feedstock accounted for the rest (Figure 1.1).

Figure 1.1
Split in industrial energy consumption between manufacturing processes and feedstock, 1990–2008

Energy's largest role in industry is powering manufacturing processes



Note: Data are for 134 economies; see Annex 4.
Source: IEA 2010c.

Total final energy consumption grew at an annual average of 0.1 percent in the early 1990s, 1.4 percent over the next decade, and an unprecedented 2.7 percent thereafter, resulting in a 1.7 percent average annual rise over the period (Figure 1.2).[1] Growth in energy consumption per capita was slower. Energy consumption per capita stagnated at around 1.2 tonnes of oil equivalent (toe) until 2002 and then increased gradually to 1.3 toe in 2008, an annual growth rate of 0.4 percent.

Industry, by far the largest energy consumer among the seven economic sectors studied, accounts for about 31 percent of global final energy consumption in 2008. Transport and residential uses follow, at about 24 percent each. Within industry, the metals sector uses the most energy, followed by chemicals and non-metallic minerals (Figure 1.3).

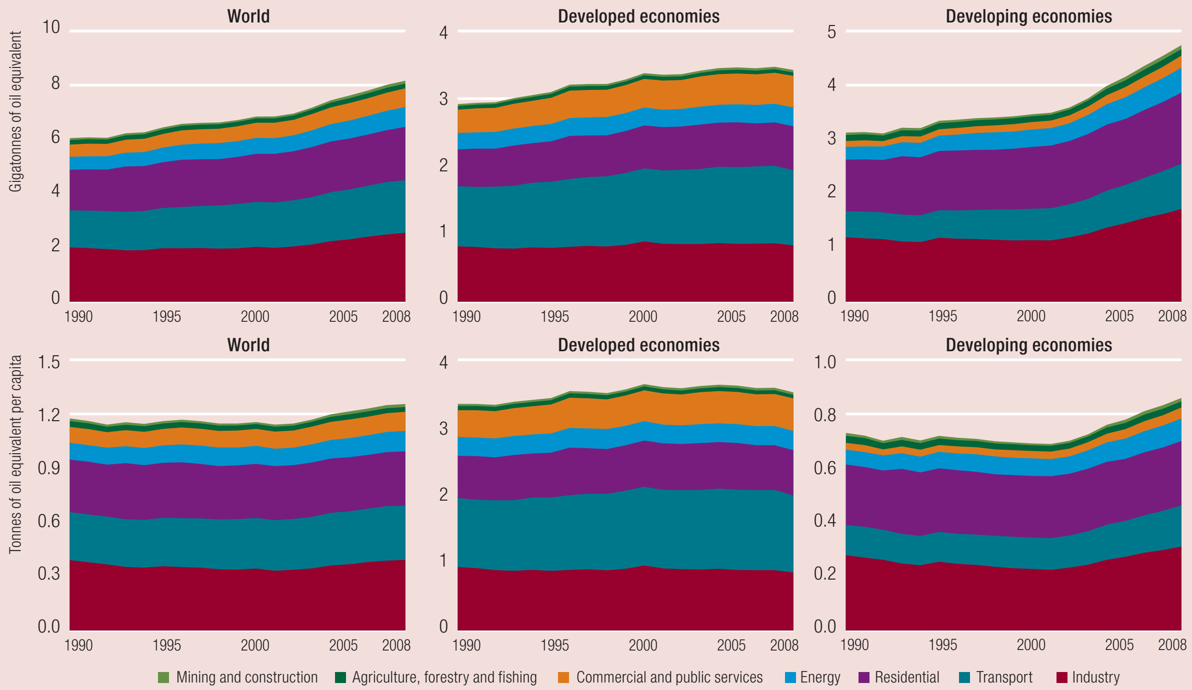
Developed economies, with just 15 percent of the world's population, are the largest energy consumers per capita, accounting for 42 percent of final energy consumption in 2008. Total energy consumption from the early 1990s to 2004 grew 1.3 percent. But demand has since stabilized – at 3.4 gigatonnes of oil equivalent (Gtoe) and 3.5 toe per capita. Transport consumes the most energy (32 percent), followed by industry (24 percent) and residential uses (19 percent). The three highest consuming industrial sectors are metals; chemicals and chemical products; and paper, pulp and printing. These figures exclude the energy used to manufacture and transport goods to importing countries. Developed economies are net importers of manufactured goods – and of the energy and carbon emissions embodied in those goods – and developing economies are net exporters. This import dependence of developed economies has grown over time and is proportionately greater for energy-intensive goods.

Developing economies are driving the global increase in final energy demand, with annual average growth of 0.7 percent in the early 1990s, 1.2 percent over 1994–2001, and a rapidly accelerating 4.5 percent since 2002 (see Figure 1.2). In 2008, industry accounted for the largest share of final energy consumption (36 percent), followed by residential (28 percent) and transport (18 percent). The three top consuming industrial sectors are metals, chemicals

“A first step in evaluating global industrial energy intensity is to take stock of how energy is consumed

Figure 1.2
Growth in energy consumption and energy consumption per capita, by economic sector, 1990–2008

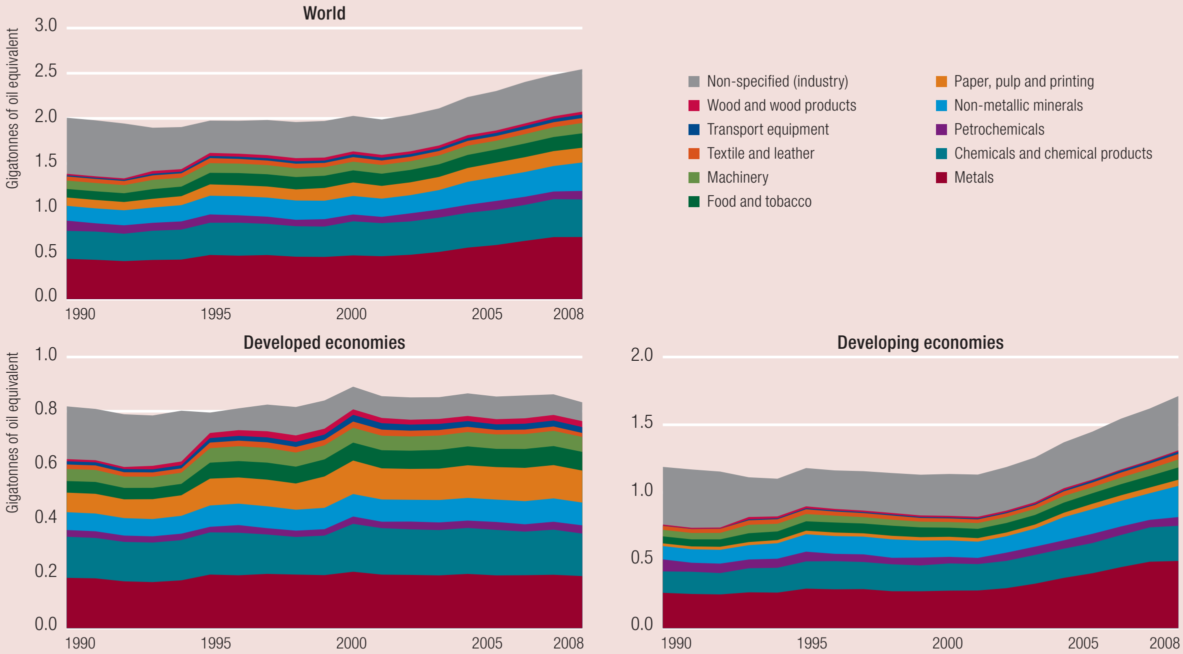
Industry is contributing to the rise in global energy consumption



Source: IEA 2010c.

Figure 1.3
Industrial energy consumption, by sector, 1990–2008

Within industry, metals, chemicals and non-metallic minerals consume the most energy



Source: IEA 2010c.

> **A striking trend is the annual 2.3 percent growth in developing economies' total energy consumption over 1990–2008, more than 2.5 times the 0.9 percent annual growth in developed economies**

and chemical products, and non-metallic minerals. Average annual energy consumption per capita fell 0.5 percent over 1990–2001 and then increased rapidly, as did industrial production relative to total output. In 2008, average annual energy consumption per capita stood at 0.9 toe – an annual increase of 3.2 percent since 2001. Even so – and despite ignoring the energy embodied in exported goods – this is less than a quarter of the average in developed economies.

A striking trend is the annual 2.3 percent growth in developing economies' total energy consumption over 1990–2008, more than 2.5 times the 0.9 percent annual growth in developed economies. And with emerging market economies poised to grow faster than the more advanced economies, energy demands in developing economies are poised to rise even more. A key driver of these differences in growth of energy consumption is the disparity between developing economies' 0.6 percent annual rise in industry's share of energy consumption and developed economies' 0.7 percent annual decline. Driving the increase in developing economies are population growth and a shift towards more energy-intensive activities – such as paper and plastics – and construction activities for infrastructure and housing. In addition, production capacity in many sectors is shifting from developed to developing economies, which are producing goods for export to developed economies.

Energy consumption trends

- From 1990 to 2008, especially since the early 2000s, energy consumption has risen in both developed and developing economies. Per capita, the overall consumption increase has been less striking, levelling off in developed economies and rising slightly in developing economies.
- Developed economies have traditionally been the largest energy consumers, but developing economies' share now surpasses that of developed economies, and emerging market economies are growing faster than more advanced economies.
- Industry consumes a higher proportion of energy per unit of output in developing economies than in developed economies.

Over 1990–2008, the final energy consumption of industry rose 11 percent (0.6 percent a year) in developing economies while remaining fairly stable in developed economies. As economies grow, the allocation of energy resources shifts – usually towards services and away from industry and energy (Enevoldsen, Ryelund and Andersen 2007). During periods of rapid economic expansion, additions to capital stock are high, resulting in a newer and more energy-efficient industrial infrastructure, a trend that can be strengthened with effective policy support.

What has happened to industrial energy intensity globally and regionally?

As energy consumption rises, what happens to energy intensity?[2] This section looks at changes in industrial energy intensity globally and regionally; the following section looks at sectoral patterns.

Global trends

Global industrial energy consumption fell 0.3 percent a year over 1990–1995, recovered over 1995–2002, and has been rising since at 3.8 percent a year (Figure 1.4). MVA had a sustained increase over the period, averaging 3.1 percent annual growth.[3] While average industrial energy intensity fell 26 percent over 1990–2008 – an average decline of 1.7 percent annually – two distinct phases are evident: a marked decline in 1990–2001, averaging 2.6 percent a year, and a levelling off at a 0.2 percent annual decline since.

Thus, MVA was decoupled from industrial energy use during 1990–2001. That means that industry produced considerably more value added from a relatively small increase in energy consumption. Since 2001, global industrial energy intensity has stabilized at around 0.35 toe per $1,000 of MVA.

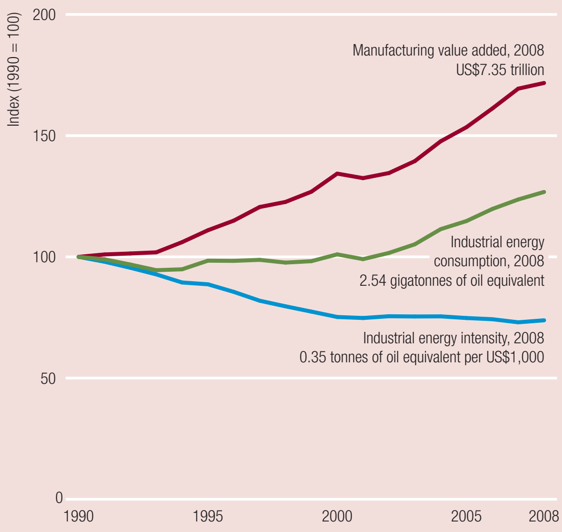
Trends by income group

Have all economies and regions, whatever their levels of development, seen their energy intensity fall? The pattern since 2000 is that industrial energy intensity

Developed economies have the lowest level of industrial energy intensity, followed by high-income and upper middle-income developing economies and – farther behind – by lower middle-income and low-income developing economies

Figure 1.4
Global trends in manufacturing value added, industrial energy consumption and industrial energy intensity, 1990–2008

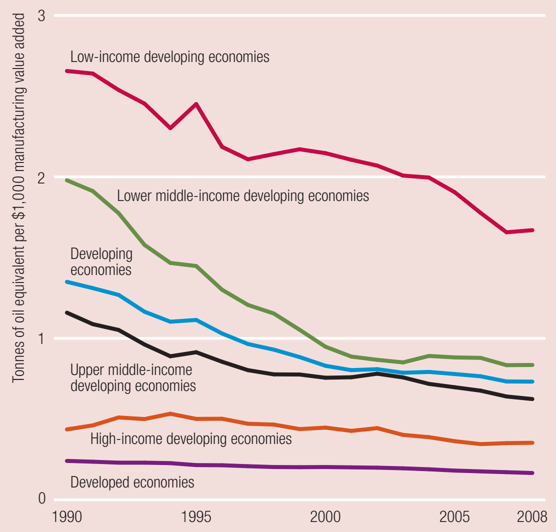
Industrial energy intensity fell markedly in 1990–2000 but stabilized more recently



Note: Industrial energy intensity in 2000 US dollars.
Source: UNIDO 2010e,f,g; IEA 2010c.

Figure 1.5
Industrial energy intensity, by income group, 1990–2008

The higher the development level, the lower the industrial energy intensity



Note: See Annex 4 for economies in each group. Industrial energy intensity in 2000 US dollars.
Source: UNIDO 2010e,f,g; IEA 2010c.

wanes as development waxes (Figure 1.5). On average over 1990–2008, developed economies have the lowest level of industrial energy intensity (0.2 toe per $1,000 MVA), followed closely by high-income (0.4) and upper middle-income developing economies (0.8) and – farther behind – by lower middle-income (1.2) and low-income developing economies (2.2). Part of the decline in energy intensity with rising development may be due to a shift from lower to higher quality energy sources, which has not been corrected for. UNIDO (1991) reported the same trends 20 years ago, indicating a long-term correlation between industrialization/income level and industrial energy intensity. While prior studies have found that the relationship between income and energy use is linear, this study suggests that it is closer to a U-shaped Kuznets curve (Cantore 2010).

Although average industrial energy intensity in developing economies is five times that in developed economies, it fell 46 percent over 1990–2008 in developing economies (an average annual decline of 3.4 percent), compared with 31 percent in developed economies (2.0 percent annually). Among developing economies, lower and upper middle-income economies reduced their energy intensity the most (58 percent and 46 percent). The biggest overall declines came during the 1990s, except in high-income developing economies. The oil price shock of 1990 and the subsequent recession likely played a role. Despite the overall decline, individual economies show considerable diversity.

Does the stage of industrialization shape energy use? Our study suggests the following patterns:

- Total industrial energy intensity tends to be high at early and intermediate stages of industrialization, when energy-intensive materials processing industries dominate, technical energy efficiency is poor and low-quality fuels (such as coal) predominate.
- Industrial energy intensity decreases at later stages of industrialization, as the structure of industry shifts from energy-intensive raw material

> **"Regional energy intensity trends have been affected by international shifts in the location of manufacturing activity from developed to developing economies**

processing to less energy-intensive processes – from "brown" process industries to greener industries – and technical energy efficiency and the quality of the fuel mix improve.

- Industrial energy intensity declines substantially at the most advanced stages of industrialization, with further technological improvements, structural change, production shifts towards more skill-intensive industries and increasing use of high-quality fuels (gas and electricity).

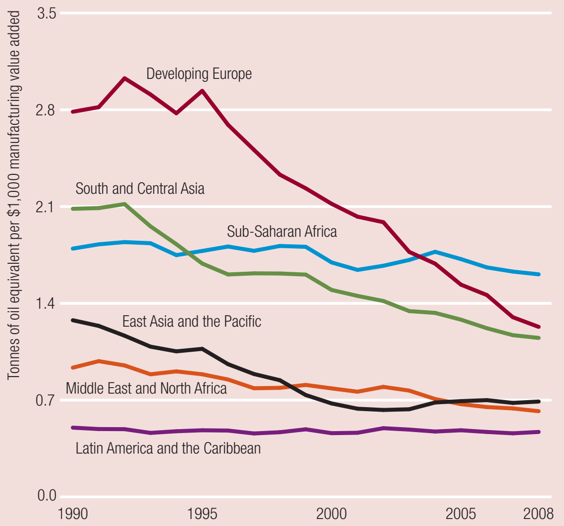
Developing economy regional trends

There is considerable regional variation, however. For example, industry uses on average 4.7 times more energy to produce a unit of MVA in developing Europe than in Latin America and the Caribbean (Figure 1.6). One reason is the vintage of industrial facilities. There have been continual improvements in nearly every aspect of industrial activities, so countries with newer industries tend to have newer, more efficient facilities. Many non–OECD European countries have inherited inefficient, coal-based, energy-intensive industries that operate at a small fraction of their output capacity. The most energy-intensive industrial region has been developing Europe (averaging 2.2 toe per $1,000 MVA over 1990–2008), followed by sub-Saharan Africa (1.8) and South and Central Asia (1.6). Industry in East Asia and the Pacific (0.9), the Middle East and North Africa (0.8) and Latin America and the Caribbean (0.5) has been considerably less energy intensive.

Industrial energy intensity fell substantially over 1990–2008 in developing Europe, East Asia and the Pacific, and South and Central Asia. Developing Europe registered a 56 percent decline – thanks largely to remarkable improvements across the board. That region was the only one to experience a drop in industrial energy consumption (51 percent) and an increase in MVA (11 percent). In East Asia and the Pacific, industrial energy intensity dropped 46 percent, as a 160 percent rise in industrial energy consumption accompanied a 381 percent jump in MVA. Industrial energy intensity fell slightly in Indonesia and Malaysia

Figure 1.6
Industrial energy intensity in developing economies, by region, 1990–2008

There have been large reductions in industrial energy intensity in some regions



Note: See Annex 4 for economies in each group. Manufacturing value added is in 2000 US dollars.
Source: UNIDO 2010e,f,g; IEA 2010c.

(less than 5 percent), while rising 273 percent in Hong Kong SAR China. And though South and Central Asia registered a 51 percent increase in industrial energy consumption, MVA grew rapidly (173 percent), reducing industrial energy intensity 45 percent. India and Kazakhstan contributed most to this success.

Reductions in industrial energy intensity were far lower (7–33 percent) in Latin America and the Caribbean, sub-Saharan Africa, and the Middle East and North Africa. In Latin America and the Caribbean and sub-Saharan Africa, MVA and industrial energy consumption followed the same growth path. In the Middle East and North Africa, however, industrial energy consumption and MVA were decoupled in the early 1990s.

Regional energy intensity trends have been affected by international shifts in the location of industrial activity. For example, the United States has seen much of its labour-intensive industrial sectors move to the Republic of Korea, Taiwan Province of China, Mexico and China. Increasingly, it has

Average values for industry as a whole mask wide variations in energy intensity among industrial sectors

> **Industrial energy-efficiency trends**
> - Global industrial energy intensity has been dropping since 1990 but has stabilized in recent years.
> - The more advanced the level of development, the lower the energy intensity.
> - Some convergence across regions has been occurring over the last decade.

been importing petroleum and petrochemicals from Saudi Arabia, Venezuela and Nigeria and cars from Germany, the Republic of Korea and Japan. Globally, energy-intensive aluminium smelting has moved to countries such as Brazil, Iceland and Mozambique, with their cheap hydroelectric power, or to the Middle East, with its cheap natural gas. Aluminium output in the United States has declined more than 80 percent since 1990.

While contributing to the decline in industrial energy intensity in the United States and other advanced industrial economies, these locational factors have slowed the rate of decline in exporting countries. Exporters, most of them developing countries, are engaging in energy-intensive industrial activities to produce commodities that are consumed in developed countries. These issues are explored in Chapter 2.

How has sectoral industrial energy intensity changed?

Average values for industry as a whole mask wide variations in energy intensity among industrial sectors. Of the 10 (or 11, if non-specified is included) sectors examined, 3 dominate global industrial energy consumption.[4]

Energy intensity differs by industrial sector

Industrial sectors generally fall into one of three groups.

Most energy intensive. Process sectors such as metals, non-metallic minerals, and chemicals and chemical products are the most industrial energy intensive globally and in all income groups considered (Figure 1.7). The global mean for 1995–2008 is 1.6 toe per $1,000 MVA for metals, 0.9 for non-metallic minerals and 0.6 for chemicals and chemical products, each above the global industry average of 0.35. These sectors also have the highest proportion of energy costs in total input costs (see Chapter 4). Technologically, these energy-intensive industries:

- Use coal, natural gas, metals and non-metallic minerals or oil as raw material or feedstock.
- Follow a sequence of linked transformation stages, with several supporting processes operating on site.
- Require containers, pipes, vessels, complex purpose-designed and -built plants, and advanced control technologies.
- Employ high pressures, temperature and chemical reactions to transform throughput.
- Deliver output in bulk, generally in units of weight or volume.

Two of these industrial energy-intensive sectors process extracted natural resources. The energy spent mining and extracting the raw materials has not been included in this assessment, implying that the energy consumed in producing refined primary materials from extracted natural resource is high compared to the value added they produce. With natural resources dwindling, deposits will be harder to extract and their quality poorer, requiring increased processing and thus more energy.

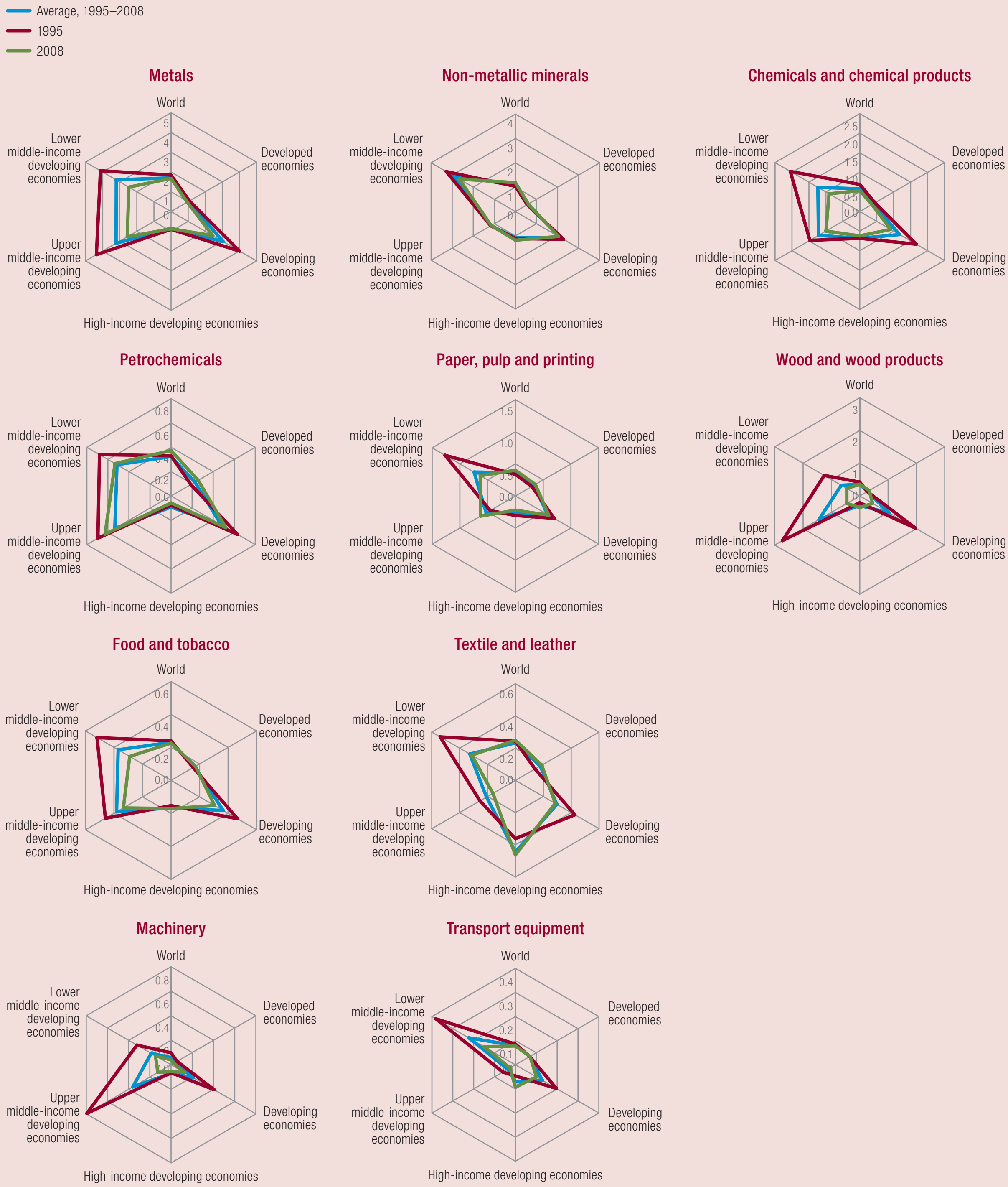
Least energy intensive. Discrete product sectors such as machinery and transport equipment are the least energy intensive, with global averages of 0.06 and 0.07 toe per $1,000 MVA (see Figure 1.7).[5] Energy constitutes a small share of input costs in these sectors. Technologically, discrete product manufacturing involves a variety of production processes because of the differentiated nature of the products and their constituent components, each also requiring its own production process. The equipment used depends on production volume and technical complexity; large-volume and low- to moderate-complexity output is largely automated. There are also sequential transformation stages – numerous in more complex products – often linked through an assembly line and requiring many parts. Throughput is transformed by

> **“Over the past 20 years, both developed and developing economies have increased industrial energy efficiency in response to rising and volatile energy prices, energy supply insecurities and environmental and social concerns**

Figure 1.7

Energy intensity, by industrial sector and income group, 1995–2008 (tonnes of oil equivalent per $1,000 manufacturing value added, in 2000 prices)

Process industries have the highest energy intensity and discrete product sectors the lowest



Source: UNIDO 2010e,f,g; IEA 2010c.

“While the same sectors are the most energy intensive in both developed and developing economies, developing economies use about three times more energy per unit of manufacturing value added

Energy intensity trends among industrial sectors

- At the global level, metals, non-metallic minerals, and chemicals and chemical products have the highest energy intensity.

temperature, force or chemical reaction; output is counted in units rather than in weight or volume.

Intermediate energy intensity. Somewhere between the high and low ends are the intermediate energy-intensive sectors of petrochemicals (0.3 toe per $1,000 MVA), paper, pulp and printing (0.3), wood and wood products (0.3), food and tobacco (0.2) and textile and leather (0.2; see Figure 1.7). Technologically and economically, they combine characteristics of process sectors (carbonated drinks and beer or paper pulp) and discrete product sectors (clothing, footwear and furniture). Some plants share continuous and discrete processes, some plants produce goods in bulk, while others convert or “package” bulk inputs into individual products.

Energy intensity of industrial sectors differs by income group

The energy intensity of industrial sectors varies considerably within economies (see Figure 1.7).[6] Thus, while the same sectors are the most energy intensive in both developed and developing economies (metals, non-metallic minerals, and chemicals and chemical products), the energy to produce a unit of MVA is generally higher in developing economies, which as a group use about three times as much energy to produce a unit of MVA as developed economies. For developed economies, metals was the most energy-intensive industrial sector (1.0 toe per $1,000 MVA), followed by non-metallic minerals (0.6) and chemicals and chemical products (0.4). For developing economies, industrial energy intensity for the three sectors was much higher (3.1, 2.1 and 1.2).

In high-income developing economies, non-metallic minerals was the most energy-intensive sector (1.1 toe per $1,000 MVA), with industrial energy intensity down just 6 percent since 1995. In upper and lower middle-income developing economies, metals was the most energy-intensive sector (3.2 toe per $1,000), but with a 41 percent decline in energy intensity since 1995.

*   *   *

Over the past 20 years, both developed and developing economies have increased industrial energy efficiency in response to rising and volatile energy prices, energy supply insecurities, and environmental and social concerns. But are these the only reasons? Is it possible for an economy to consume less energy with no loss in output? What accounts for the changes in energy intensity? This report now turns to the key drivers for improving industrial energy efficiency, focusing on developing countries, which have already entered or are about to enter the energy-intensive stage of industrial development.

Notes

1. Total final energy consumption is equal to the sum of the consumption in the end-use sectors. Final consumption reflects mainly deliveries to consumers (IEA 2010c).
2. This section examines trends in energy intensity using International Energy Agency (IEA) estimates. For details on the estimates, see Annexes 1, 3 and 5. Since the estimates relate to total energy consumption and do not distinguish among energy sources, they cannot identify changes in energy intensity that result from shifts from lower to higher quality energy sources (for example, from coal to gas). Data on MVA in real terms are derived from the Index of Industrial Production from UNIDO’s *International Yearbook of Industrial Statistics* (UNIDO 2010c). All value added figures and energy intensity figures are in 2000 US dollars.
3. See Chapter 8 for trends in MVA.
4. See Annex 3 for details of the manufacturing sectors.

5. Data for all 10 sectors examined were not available for all 100 economies. For example, no energy data were available for the chemicals sector for many Middle Eastern countries, and no value-added data were available for the petrochemical sector in Israel, even though those countries engaged in those activities.
6. Data availability was poor at a sectoral level for low-income developing countries, so this group is not included in the analysis.

Chapter 2

Technological and structural change for industrial energy efficiency

Chapter 1 showed that energy intensity (energy use per unit of manufacturing value added [MVA]) has been falling globally and in most countries. Average industrial energy intensity fell 26 percent over 1990–2008 – an average annual decline of 1.7 percent. Despite the improvement, rapidly rising industrial energy consumption in developing countries continues to push global energy consumption higher.

Can the world satisfy rising demand for industrial goods, particularly from developing countries, while keeping industrial energy consumption growth in check? Can the demand for better standards of living and reduced poverty in developing countries be made compatible with sustainable industrialization? In 2008, per capita industrial energy consumption in developing countries was only 24 percent of that in developed countries. But as per capita incomes converge, so too will per capita industrial energy consumption, potentially running up global energy demand and more than doubling it in industrial energy alone. Population growth would push energy demand even higher, so that the burden on the environment and the pressures on energy prices and supplies could impede further economic growth.

To address these challenges, we need to understand what drives changes in industrial energy intensity. This chapter looks at the two main drivers: technological change and structural change.[1] It shows that new and more energy-efficient technology has had a large role in lowering energy intensity globally and in many countries – especially developing countries. Lower energy intensity has resulted largely from incremental improvements in a range of technologies rather than from a single major breakthrough:

- Applying the findings of basic and applied research.
- Optimizing and integrating production systems.
- Improving air and heating systems.
- Introducing better motors, pumps and compressors.
- Applying good housekeeping principles.

Changes in the structure of industry have been even more instrumental in reducing industrial energy intensity, particularly in developed countries and in some upper middle- and lower middle-income developing countries. The growing demands from developing countries for a higher standard of living, the international relocation of productive activities to lower cost sites and the structural change in many of these countries towards energy-intensive industries seem to be exerting counter-pressures to the forces advancing the adoption of improved technologies, thus slowing the pace of improvements in industrial energy intensity.

This chapter examines:

- The process of innovation and technological change in industrial energy efficiency.
- The potential for improved energy efficiency.
- Trends in the composition of global MVA that would explain the observed structural effects.

What drives changes in industrial energy intensity?

Industrial energy intensity can be reduced through technological progress and system changes that improve technical energy efficiency – changes that increase output using the same amount of energy or that deliver the same output using less energy. These changes include replacing old technologies, adopting energy-saving technologies (preferably best available technologies), improving processes and optimizing systems, and employing energy management practices. They also include using more high-quality energy, such as gas and electricity; innovating product designs; and changing the output mix. These improvements, especially those related to new technologies and processes, vary in complexity – from simple add-ons to complex system change – and in the rewards, as discussed later in this report.

If data on fabrication processes were available at the lowest level of aggregation, the measure of technological change would be actual physical efficiency and the rest would be structural change (Jenne and Cattell

> New and more energy-efficient technology has had a large role in lowering industrial energy intensity globally and in many countries, but changes in the structure of industry have been even more instrumental

1983). But this level of disaggregation is not available for all sectors, so physical efficiency is estimated by subtracting structural effects (discussed below) from the change in energy intensity. Over time, technological energy efficiency can be a useful indicator of technological progress (Ayres 1998).

Industrial energy intensity can also be affected by structural changes in an economy – long-term changes in the composition of economic aggregates, including modifications in output shares across sectors (Chenery, Robinson and Syrquin 1986; Syrquin 2007). Structural change can have a strong effect on economic growth. Shifting from low-productivity, labour-intensive sectors to more value added–, capital-, skill-, and technology-intensive sectors can generate the financial and knowledge resources to expand economic activity even faster. A shift towards sectors with lower energy use per unit of MVA – brought about by changes in product demand, product specialization or relocation of production – can reduce industrial energy intensity. Shifting from "brown sectors" (with higher energy-intensive products and processes) to "green sectors" (with lower energy-intensive products and processes) can also have environmental benefits.

What role have structural and technological factors had in lowering industrial energy intensity?

How much of the changes in energy intensity have come from technological change and how much from structural change? We explore this question by decomposing energy intensity changes into its two components, focusing on 62 of the 134 economies (see Annex 4) studied in Chapter 1 because of stricter data requirements. (See Annex 2 for the methodology and Box 2.1 on decomposition analysis.) But while this smaller sample is more homogeneous (there are no low-income developing countries), it might not be fully representative of all developing countries. Nonetheless, to our knowledge, this is the first attempt to apply a decomposition technique to data covering such a wide selection of developing countries.

Trends in total industrial energy intensity reflect changes in technology, energy management, and output volume and composition. Total industrial energy

Box 2.1
Decomposition analysis

Decomposition analysis has been widely applied to historical trends in energy and material consumption. There have been numerous applications to manufacturing in Organisation for Economic Co-operation and Development (OECD) countries; most Eastern European countries, including the Russian Federation; and such large developing countries as Brazil, China, India, the Republic of Korea and Mexico. These studies have used various methods, time periods, data sources and levels of sectoral aggregation. Decomposition studies can focus on one country or involve cross-country comparisons.

The two main types of decomposition analysis are index decomposition analysis, which uses sectoral production and energy use data, and structural decomposition analysis, which uses energy input-output analysis. There is no consensus on which method is best. When selecting a method, researchers generally consider theoretical foundation, adaptability, ease of use and ease of understanding. This report uses index decomposition analysis.

The two main index decomposition analysis methods are the Laspeyres Index and the Arithmetic Mean Divisia Index (Ang and Zhang 2000). The Laspeyres Index measures the percentage change in some aspect of a group of items over time, using weights based on values in a base year. The impact of that aspect is computed by allowing it to change while holding all other factors at their base-year values. The Divisia Index is a weighted sum of logarithmic growth rates, where the weights are the components' shares in total value in the form of a line integral. Both indexes can be multiplicative or additive.

The decomposition method employed here is the Fisher Ideal Index, a multiplicative energy-intensity index. To ease the interpretation, the factoral contributions of the structural and technical effects were transformed into percentage points of the changing total industrial energy intensity, so the overall change in industrial energy intensity can be expressed as the sum of the percentage changes in structural and technical effects.

Technological change has reduced industrial energy intensity in a majority of economies, while structural change has reduced it in most developed economies

intensity is decomposed into a technological effect component and a structural effect component.

The technological effect measures the combined influence of improvements in technical energy efficiency due to technological change, changes in fuel mix, better energy management and factors unrelated to changes in the volume or composition of output at the level of sectoral aggregation examined. The structural effect measures the impact of changes in the share of output from different sectors of industry (Liu and Ang 2007). A decline in either indicates that it has helped reduce industrial energy intensity from the base-year level (an improvement in energy use).

Split between technological and structural effects at the global level

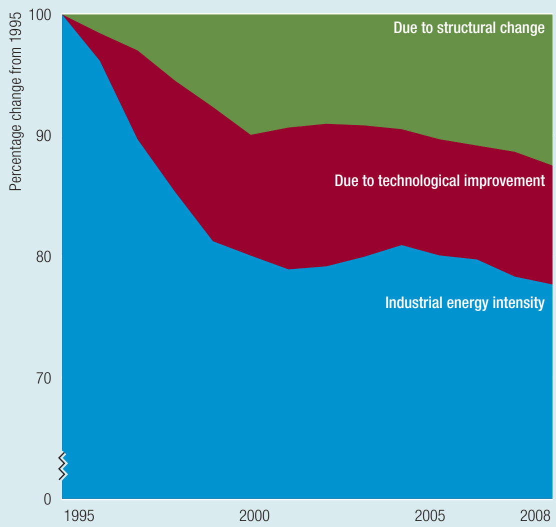
The estimated split between technological and structural effects depends on the level of sectoral aggregation. For this report, industry was disaggregated into 11 sectors: food and tobacco; textile and leather; wood and wood products; paper, pulp and printing; petrochemicals; chemicals and chemical products; non-metallic minerals; metals; machinery; transport equipment; and non-specified industry. (See Annex 3 for details on the composition of these sectors.) The study found wide variation in the contributions of technological and structural effects to energy intensity across countries and over time, confirming the results of an earlier UNIDO (1991) study.

Global industrial energy intensity for the 62 economies included in the decomposition analysis declined 22.3 percent over 1995–2008 (Figure 2.1), for an average annual reduction of 1.9 percent. Structural change (12.5 percent) had a slightly larger effect than technological change (9.8 percent).

Developed economies and, to a lesser extent, high-income developing economies are largely responsible for lowering global industrial energy intensity. With structural effects as the major contributor to lower energy intensity in these economies, it is not surprising that structural effects contribute so strongly to lower industrial energy intensity at the global level. Technological change has reduced industrial energy intensity in a majority of economies, while structural change has reduced it in most developed economies.

Figure 2.1
Components of change in global industrial energy intensity, 1995–2008

Structural change is the main driver of falling global industrial energy intensity



Source: UNIDO 2010e,f; IEA 2010c

Technological and structural effects by region and income group

Average industrial energy intensity fell in all income groups over 1995–2008 (Figure 2.2).[2] In developed economies, the structural effect was stronger in lowering energy intensity; in developing economies, structural change increased energy intensity marginally, an impact more than offset by the reduction in energy intensity from technological change. Technological improvements were thus the main driver of the drop in industrial energy intensity in developing economies, except among those with high incomes. These high-income developing economies, entering a more mature phase of industrialization and with an increasing share of skill- and technology-intensive output, are beginning to resemble developed economies in many respects.

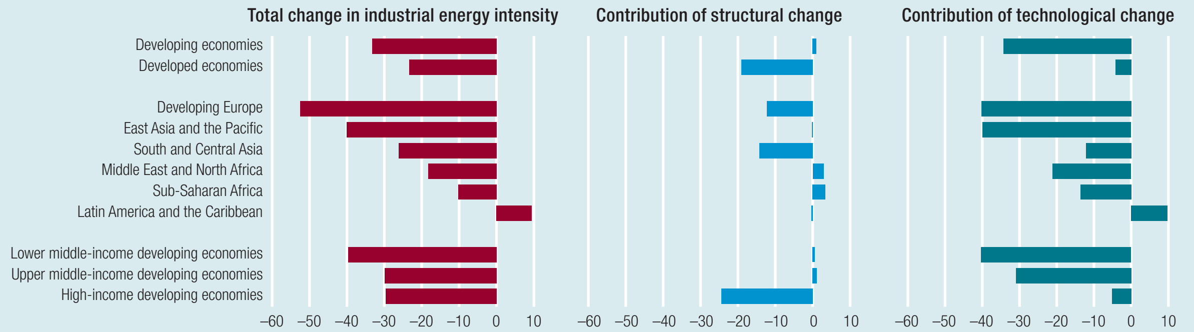
Latin America and the Caribbean was the only region with an overall increase in industrial energy

> **The average industrial energy intensity fell in all income groups over 1995–2008**

Figure 2.2

Components of change in industrial energy intensity, by region and income group, 1995–2008 (percent)

Technological change is the primary driver of lower industrial energy intensity in developing economies



Source: UNIDO 2010e,f,g; IEA 2010c.

intensity, due mostly to technological change. Industrial energy intensity declined in the other regions, with technological change being the major contributor except in South and Central Asia, where the structural effect was marginally stronger. Although the Middle East and North Africa and sub-Saharan Africa experienced a structural change in favour of more energy-intensive industries, technological changes offset this effect.

On a country or economy basis, several results stand out (Figure 2.3):

- Industrial energy intensity fell in 52 of the 62 economies.
- The technical effect contributed to declining industrial energy intensity in all economies but Armenia, Chile, Colombia, Moldova and the United States.
- For 34 economies, structural changes favoured less energy-intensive industries; for 28 economies, it favoured more energy-intensive industries.

In developed countries, the combined technological and structural effects lowered industrial energy intensity. In the Netherlands, New Zealand, Portugal and Switzerland detrimental structural effects were offset by technological effects. In the United States, detrimental technological changes were offset by strong structural changes towards less energy-intensive industries.

Among developing economies, energy intensity fell in China, India, the Russian Federation, South Africa, Tunisia, Turkey and Ukraine, among others. The technological effect was the main cause, but it was supported by the structural effect in China, the Russian Federation, Turkey and Ukraine. The structural effect was found to have a small increasing effect on energy intensity in India, South Africa and Tunisia but was easily offset by the technological effect.

Energy intensity increased in Argentina, Armenia, Brazil, Chile, Colombia, Côte d'Ivoire, Gabon and Kyrgyzstan. The technological improvements in Argentina, Brazil, Côte d'Ivoire, Gabon and Kyrgyzstan were not sufficient to offset a shift towards more energy-intensive industries. In Chile and Colombia, shifts towards less energy-intensive industries could not offset adverse technological effects.

Overall, developing economies shifted slightly towards energy-intensive industries due to rising demand from growing populations and the upsurge in manufacturing for export. The combination of this high export orientation, poor energy infrastructure, reliance on low-quality and carbon-intensive fuels, and less efficient industrial technology makes industrial activities in these economies carbon intensive as well as energy intensive.

While most developing countries are net exporters of energy and carbon (embodied in manufactured

“ In developed economies, the combined technical and structural effects lowered industrial energy intensity, while in developing economies there was a slight overall shift towards energy-intensive industries due to rising demand from growing populations and the upsurge in manufactured exports

Figure 2.3
Components of change in industrial energy intensity by economy, 1995–2008 (percent)

Technological change has lowered energy intensity for most economies, but structural change has a mixed record

a. Data for 1991–2008.
b. Data for 1998–2008.
c. Data for 2000–2008.
Source: UNIDO 2010e,f; IEA 2010b.

Innovation in industrial energy efficiency and in systems optimization and systems solutions are the key elements of technological change

Trends in industrial energy intensity

- Since 1995, technology has contributed most to reducing industrial energy intensity globally – especially in developing countries.
- Structural changes have reduced industrial energy intensity in developed countries but made little difference in developing countries.
- Industrial energy consumption in developing countries is likely to increase due to rising populations, per capita incomes and demand for manufactured exports, coupled with structural change oriented towards the more energy-intensive phase of industrialization.

goods), most OECD countries are net importers (Davis and Caldeira 2010).[3] As a result, developed countries' energy intensity is substantially lower than it would be if they manufactured their own goods. And if the carbon emitted by developing countries in the manufacture of goods imported by OECD countries were taken into account, most European countries' emissions would rise by a third and US emissions would rise 12 percent. For China, the situation is the reverse; its emissions fall by a quarter if exports are taken into account.

Thus, improving technology in developing countries might not suffice to curb growing industrial energy demand. With rising per capita incomes and domestic demand and an increasing orientation towards energy-intensive goods for export, industrial energy consumption seems likely to continue its upswing in most developing countries.

How much has technological change lowered energy intensity?

Capital renewal is the main factor permanently altering energy use across industries. Industries consist of different age cohort of capital (capital vintages), with each vintage distinguished by specific attributes in input and energy efficiency, output volume, rate of production capacity utilization and so on and with older vintages generally requiring more inputs per unit of output than newer vintages. Industries evolve by progressively adding new capital stock while retiring older capital and, through this process, change the attributes and age of the capital stock and thus its productivity (Davidsdottir and Ruth 2004, 2005, 2008; De Beer 1998; Doms and Dunne 1998; Lempert et al. 2002).

Adding to the capital stock requires investments to replace or retrofit machinery, equipment and buildings. The extent of energy savings depends on the capital intensity of an industry – because of lock-in effects, the attributes of new capital vintages, the life-cycle of individual pieces of equipment or a combination of these (Davidsdottir and Ruth 2005). Industries' capital intensities, vintage attributes and capital life-cycles arise from their underlying process and equipment technologies, and technological and financial considerations guide investment decisions. So, capital investment is a process of technological change.

Technological change involves multiple stages with multiple actors, relationships and feedback loops – from invention, as a new technology is created and prototyped, to innovation, as it becomes commercially viable (Freeman and Soete 1997; IEA 2008a). The more radical the innovation, the larger the gains to industrial energy efficiency and the environment (Eichhammer and Walz 2011; Fleiter, Eichhammer and Schleich 2011). Much contemporary innovation results from dedicated research and development (R&D). For energy projects, this includes investing in demonstration for the scientific community and potential users (Grubb 2004; Foxon et al. 2004). Innovation in industrial energy efficiency and in systems optimization and systems solutions are the key elements of technological change.

Innovation in industrial energy efficiency

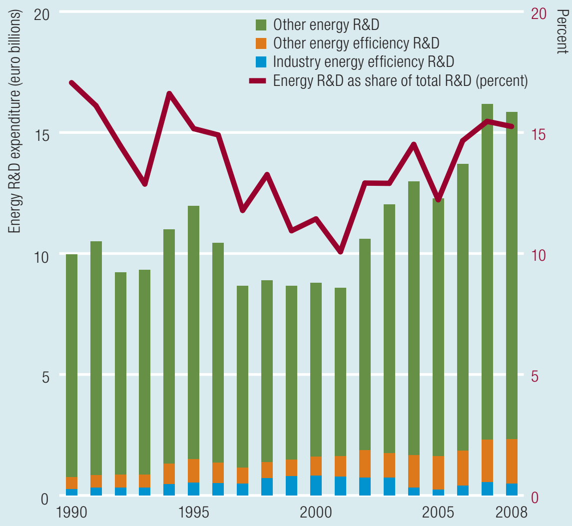
Public sector energy R&D expenditure increased from €10.0 billion in 1990 to €15.8 billion in 2008 – with a dip in the late 1990s and early 2000s – driven by expenditures on fuel cells, renewable energy sources and fossil fuels (IEA 2010d; Figure 2.4). As a share of total public R&D expenditure, however, energy R&D fell from around 17 percent to 15 percent. Public

"Major transitions in energy technologies can take decades and entail massive investments that are beyond the reach of most private investors

Figure 2.4

Public sector R&D expenditure on energy technologies in selected countries, 1990–2008

Public sector R&D has shot up since 2001



Note: Analysis includes Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Turkey and the United States.
Source: IEA 2010d.

Box 2.2

Industrial energy-efficiency R&D case study: decreasing the inlet velocity required for pneumatic and hydraulic conveying

Industrial energy-efficiency R&D is a hot topic among researchers, whether in academia or the private sector. One example is a series of research studies at the University of Nottingham on reducing the energy required for pneumatic or hydraulic conveying, one of the most common methods of transporting bulk solids.

The research has shown that a three-lobed helical pipe can induce swirl and increase local turbulence, useful for increasing the turbulent energy of the flow to lean-phase pneumatic and hydraulic conveying to reduce particle settlement and blockage. In early development, the pipe has reduced the need to pump the conveying fluid into the system at high velocity, lowering electricity use as much as 20 percent, depending on applications. The swirl pipe has other advantages over traditional swirl-generation devices: it is not intrusive to the flow or prone to blockages, and it contains no moving parts. Again, this saves on electricity use as obstructed pipelines require higher conveying fluid velocity. This application of the helical pipe has been patented by the university but is not yet on the market, as it is being refined before commercial demonstration.

Source: Fokeer, Lowndes and Kingman 2009.

sector R&D expenditure on energy efficiency has been growing steadily, reaching €2.3 billion in 2008. About a fifth of it was allocated to improving the energy efficiency of industrial processes and developing more efficient technologies for industrial application.

Grubb (2004) and Murphy and Edwards (2003) argue that public sector R&D in energy, with its potential for profitability and environmental benefits, is far lower than it should be. The commercial failure of earlier large-scale public sector expenditures on technologies, such as breeder reactors and synthetic fuels, has made governments wary of targeting R&D to particular energy technologies. But major transitions in energy technologies can take decades and entail massive investments in capital equipment and infrastructure that are beyond the reach of most private investors.

But while government R&D expenditure is important for reducing energy intensity, it is neither the only nor the largest such investment. Private sector R&D expenditure on energy efficiency is difficult to identify, but it is thought to be substantial (IEA 2010d). Equipment suppliers and large energy users conduct most industrial energy-efficiency R&D – working to improve product design, feedstock and process technology – because the energy efficiency of production processes strongly influences competitiveness. Because no single innovation – not even a handful – can improve energy efficiency dramatically, R&D often combines technologies from different suppliers. Improved energy efficiency in production processes is also frequently an unexpected by-product of investments in new process technologies aimed at increasing capacity, throughput or product quality (Box 2.2).

Diffusion of new technologies – best available and best practice technologies. Invention and innovation are followed by diffusion, as new technologies penetrate

“Faster uptake of best available technology would greatly reduce energy intensity

and improve markets, reduce costs through scale and learning economies and compete with other technologies until some dominate (Freeman and Soete 1997; Grubb 2004). The many sources and choices of technologies, the unexpected nature of many energy-efficiency gains and the ongoing evolution of technological diffusion mean that users have a wide range of technological options, each with different effects on industrial energy efficiency. The potential for industrial energy efficiency reflects these options.

Best available technology is the most energy-efficient way of producing goods and services that is commercially viable and in use. It refers to the most advanced usable technologies and methods of operation, the way installations that deploy them are built and operated, and the economic feasibility of the technologies. Best available technologies come from the best plant in an industry (Saygin et al. 2010). Normally the newest technologies in an industry, best available technologies are always changing due to continuous radical and incremental innovation.

Best practice technology, a related concept, focuses on the best performers among plants with widely diffused industrial energy-efficiency technologies and business practices. In some cases, best available technologies and best practice technologies are identical. But in most cases best practice technology differs in that it considers all the plants that have adopted energy-efficient technologies, at all times and under all conditions. Saygin et al. (2010) places the top 10 percent of energy-efficiency performers worldwide in this category.

By definition, the average energy efficiency of existing plants is always lower than the best available technology average. Current investments in new equipment and best available technology are generally more efficient than previous investments in old equipment. If annual efficiency gains from best available technology accelerate, or if equipment lifespans lengthen, the gap widens. Faster uptake of best available technology would greatly reduce energy intensity (Box 2.3).

Most industrial plants and much energy-intensive capital stock have long technical life spans, slowing the diffusion of best available technology. A plant built today could remain in service for decades, retrofitted and refurbished several times. In many developing countries, equipment stays in service even longer because capital costs are so much higher than energy costs. Continuously upgrading to best available technology entails retiring equipment earlier or retrofitting it sooner, although premature replacement might not be economical (Table 2.1). China, for example, closed energy-inefficient plants before the end of their "extended" technical life to meet ambitious targets for industrial energy efficiency.

There can be great differences, however, in technical performance across new and similar technologies. Equipment manufacturers often trade technical quality for price and availability (CERF/IIEC – Asia, 2002). For example, China has emerged as a major equipment supplier. In many sectors, the cost of Chinese equipment can be half that of its Western competitors. But in some cases, the energy efficiency is also lower, and the equipment tends to deteriorate faster because of lower quality materials. While a full cost assessment should be done to properly measure the return on investment, for many companies in developing countries, with limited access to capital, the upfront cost of equipment is generally the overriding investment criterion.

Technological evolution in selected industrial sectors. Over time, global average industrial energy efficiency and best available technology in specific sectors both improve, sometimes in parallel and sometimes converging, with typical energy reductions of 20–60 percent (Figure 2.5). This implies that innovation and best available technology uptake must go together. This section focuses on advances in the major industrial sectors.

In chemicals and petrochemicals, the main best available technologies are process integration, cogeneration (combined heat and power), recycling and heat recovery. Worldwide, potential savings from these measures are estimated at 235 million tonnes of oil equivalent a year in final energy and 290 million in

"The average energy efficiency of the motor stock lags substantially behind that of motor sales, implying an opportunity for policy intervention to expedite uptake of best available technology

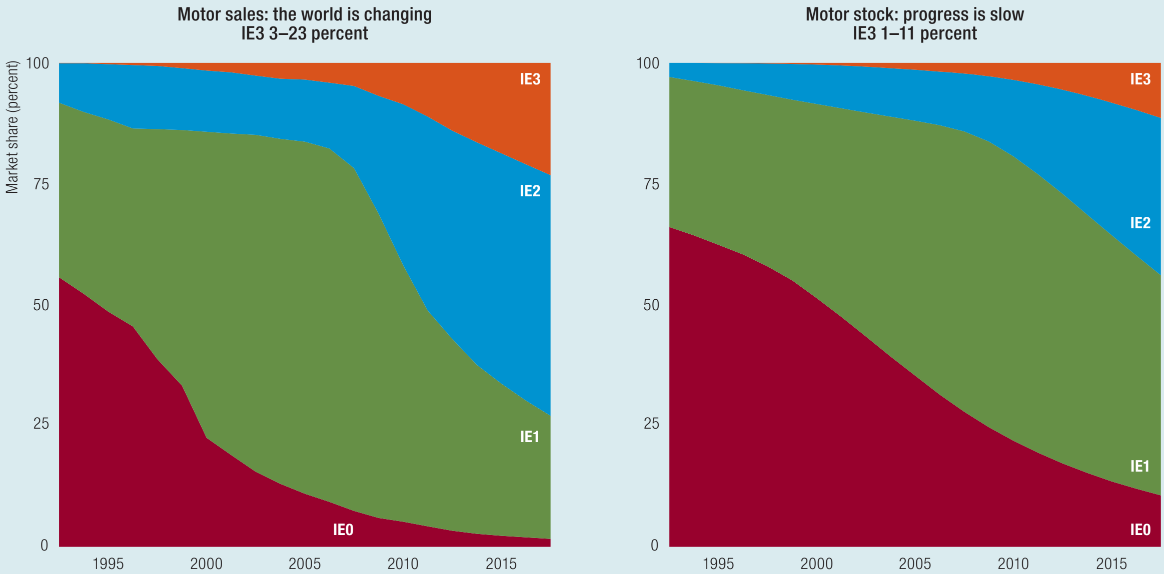
Box 2.3

Uptake of best available technology is generally slow: the case of energy-efficient motors

Energy-using capital stock generally has a long lifespan, increasing the time lag between the introduction of best available technology and improvements in the average efficiency of the capital stock. Consider electric motors (see figure). There are three international efficiency (IE) standards for motors: IE1 (standard), IE2 (high) and IE3 (premium). IE1 typically achieves 85–93 percent efficiency, depending on motor size. Moving from IE1 to IE2 yields a 2–3 percentage point efficiency gain, and moving from IE2 to IE3 yields another 2 percentage point gain. Gains are larger for smaller motors.

The more efficient motors are generally cost-effective where energy prices are high. Initial capital costs are typically 5–20 percent of lifecycle cost, and efficient motors cost only 15–30 percent more than less efficient motors. But the uptake has been slow, suggesting market failures. IE3 motors have been around since before 1995, but the market sales share in 2010 was still less than 20 percent. And the share in the overall motor stock is even smaller, with the average energy efficiency of motor stock lagging substantially behind that of motor sales. This implies an opportunity for policy intervention to expedite uptake of best available technology.

Average electric motor stock efficiency changes slowly



Note: IE3 is the highest international efficiency standard for electric motors.
Source: Brunner 2010.

primary energy – with the greatest potential savings in the United States (IEA 2010e).[4] In ammonia production, adopting the best available technology could halve energy use. The best practice technology energy requirement for the most efficient decile of ammonia producers is 32 gigajoules (GJ) per tonne of ammonia. Revamping less efficient plants could increase energy efficiency and reduce carbon dioxide emissions by some 10 percent (IFA 2009).[5] This calculation of savings based on the use of best practice technology does not apply, however, to the quarter of the world's ammonia production that originates in China, where production is coal-based and uses about a third more energy than best practice technology. As China develops natural gas fields in its western regions and pipelines to population centres in its east, the energy required for ammonia production is likely to fall.

In the metals sector, the potential energy savings for *iron and steel* from applying today's best available technology is about 20 percent (4.1 GJ per tonne of

> **Continuously upgrading to best available technology entails retiring equipment earlier or retrofitting it sooner**

Table 2.1
Examples of best available technology uptake in China: technology diffusion as a share of capacity, 2000 and 2006–2009 (percent)

Sector and technology	2000	2006	2007	2008	2009	Energy efficiency impact
Steel						
Continuous casting	83	99	99	99	99	Energy savings of 200 kg coal equivalent per tonne (ce/t) billets produced
Coke dry quenching	6	40	45	50	>70	Energy savings of 100 kg ce/t processed coke
Blast furnace top gas recovery turbine	50	95	96	99	100	Energy generation of 30 kilowatt hours per tonne (kWh/t) of pig iron
Coke						
Mechanical coke making	72	88	91	96	99	Reduced consumption of coking coal of 170 kg ce/t mechanical coke
Aluminium (electrolytic)						
Prebaked cell	52	82	83	86	90	9 percent savings (compared with Soderberg cell)
Chemicals						
Caustic soda production membrane process	25	31	38	50	55	Electricity savings of 123 kWh/t (compared with diaphragm process)
Cement						
Bulk processing	28	39	45	46	46	Net savings of 24 kg ce/t cement from 4.5 percent savings in reduced losses and 3.3 million cubic metres savings in timber use for paper bags (compared with bagged cement)
New suspension preheater dry process	12	50	55	63	73	Fuel savings of 40 percent (compared with mechanized vertical shaft kilns)
Glass plate						
Floating process	57	82	83	83	83	Energy savings of 16 percent
Construction						
Replacing clay bricks with new wall materials	28	46	48	50	52	Energy savings of 40 percent

Source: Wang 2008.

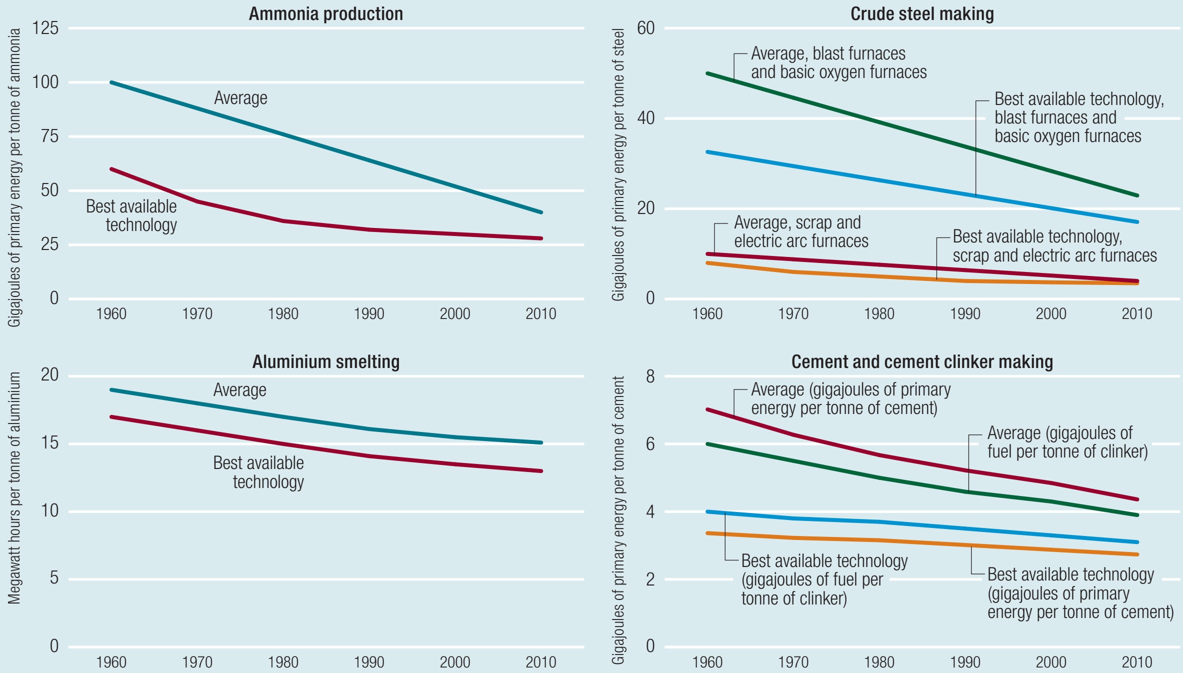
steel). Replacing small-scale blast furnaces promises the most savings, followed by recovering more residual gases and waste heat (Figure 2.6). Energy requirements per tonne of steel have fallen by half over the past 50 years for primary steel making from ore and for steel recycling in electric arc furnaces, reflecting large declines in energy use through best available technology. Energy efficiency in US electric arc furnaces increased 1.3 percent a year over 1990–2002, and similar savings have been achieved globally (IEA 2007a). Slightly more than half the improvement came from replacing old furnaces; the rest came from retrofitting, which is more cost-effective in the short run (Worrell and Biermans 2005). For furnaces using recycled scrap, the long-term potential energy savings is about 3.5 GJ per tonne.

For *aluminium,* the main opportunities for energy-efficiency improvements involve replacing old smelter technologies with modern prebake cells, developing process controls to optimize cell operating conditions, improving insulation to reduce heat losses and reducing electricity use in auxiliary equipment, such as compressors and fans. The production of primary aluminium is electricity intensive: aluminium smelters accounted for some 3.5 percent of total global electricity consumption in 2009. In recent years, smelter performance has improved considerably, but considerable scope for energy savings remains (about 15 percent). New world-class plants can achieve around 13.5 megawatt hours per tonne, a savings of 13 percent over the current world average. Aluminium recycling is extremely energy

“Over time, energy intensity falls, driven by advances in best available technology

Figure 2.5
Global average energy intensity and best available technology for ammonia, iron and steel, aluminium and cement, 1960–2010

Big drops in energy intensity, but still room for improvement



Source: UNIDO.

efficient, using less than 10 percent of the electricity required for primary smelting. As economies develop, the availability of aluminium scrap for recycling will likely also increase.

In the *non-metallic minerals* sector, total potential energy savings in the *cement* subsector is an estimated 2.5 exajoules (EJ) a year, about a quarter of current energy use. Potential fuel savings are greatest in cement clinker production. Average thermal energy consumption per tonne of clinker has fallen some 15 percent since 1990. And while the current global average thermal energy intensity is 3.9 GJ per tonne of clinker, actual thermal energy consumption depends on the type of kiln. Efficient dry kilns with preheaters use about 3.3 GJ per tonne of clinker, while a wet kiln can use 5.9 GJ–6.7 GJ per tonne (IEA 2009a). Vertical-shaft kilns, with even higher energy needs, are being phased out in China but are still widely used elsewhere.

In the *bricks and ceramics* subsector, coupled kilns and dryers, furnace upgrades and cogeneration technologies offer the greatest potential for improving energy efficiency. For *glass,* these strategies include developing and using advanced refractory materials in kilns and new technologies such as oxyfuel firing and electric boost that increase production capacity. The optimal electricity consumption using best available technology is about 2.32 GJ per tonne of molten glass. Actual consumption, however, is 30 percent higher because of inefficiencies in glass-melting furnaces, where 40 percent of the energy goes to heating the batch, 30 percent is lost through the furnace structure and 30 percent exits with stack gases (Worrell et al. 2008).

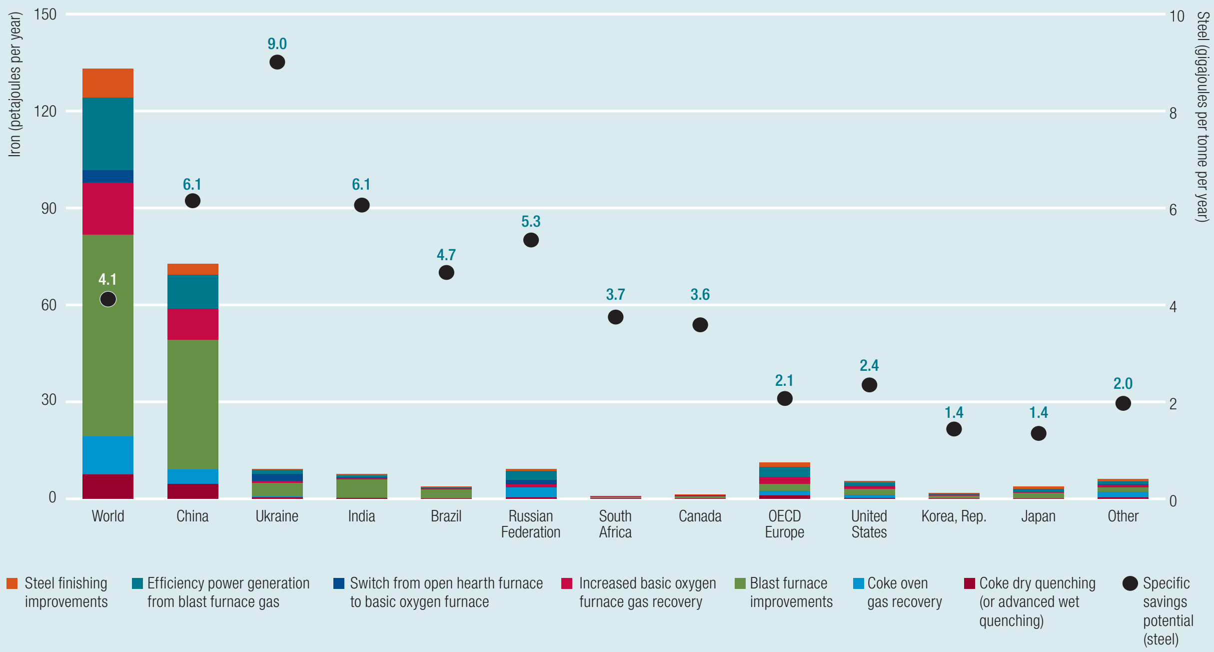
Systems improvements

A system is a set of connected unit operations or pieces of equipment that perform a service together. There is

> **There is growing evidence that systems optimization and systems upgrading hold the greatest potential for energy-efficiency gains and environmental benefits**

Figure 2.6
Energy savings potential in iron and steel making, 2006

Small-scale blast furnaces promise better energy efficiency



Source: IEA 2009a.

growing evidence that systems optimization and systems solutions (systems upgrading) hold the greatest potential for energy-efficiency gains and environmental benefits (see, for example, UNIDO 2010a).

Systems optimization. Energy-efficient components in industrial systems, while important, will not yield the expected energy savings if the entire system is not properly designed and operated. Experience shows that while efficient energy components, such as pump, steam and compressed air systems, can raise average efficiency 2–5 percent, system optimization measures can yield 20–30 percent gains – with a payback period of less than two years (see, for example, the survey of Tunisian manufacturing companies conducted for this study by Fokeer 2010). Further gains can be achieved if systems are optimized in tandem with production processes, for example, by reducing raw materials or other inputs.

An industrial facility may upgrade processes – change production volumes, schedules or type of product manufactured – many times during its useful life. The energy-using systems that support these production patterns might be relatively energy efficient under the initial production design conditions, but energy efficiency can regress as production patterns change. Thus, systems need to be optimized over time as well as across equipment components.

Globally, the energy-consuming systems with the highest potential energy savings are motors, compressors and steam systems.[6] *Motor-driven equipment* accounts for about 60 percent of manufacturing final electricity use and is ubiquitous worldwide. Motor systems, consisting of drives, pumps and fans, are a largely untapped, cost-effective source of industrial energy-efficiency savings that could be realized with existing technologies (see Box 2.3). Some 55 percent of the electricity used by motor systems (16 percent of total industrial energy consumption) is lost before the motor systems do any work. Losses can be reduced by using more efficient motors and variable speed drives, sizing motors appropriately and optimizing motor-driven systems, such as pumps and conveyors.

“ Motor systems are a largely untapped, cost-effective source of industrial energy-efficiency savings that could be realized with existing technologies

Compressed air systems – compressors, drives, air treatment, compressed gas network and the end-use devices driven by compressed air – account for 10 percent of industrial consumption of electricity. Compressors lose 80 percent of the mechanical work done by the motor, and leaks in the air distribution systems are rampant. Case studies show that savings of up to 50 percent are possible, but these are not being realized under current market and decision mechanisms (Fleiter, Eichhammer and Schleich 2011).

Steam systems account for 35 percent of global industrial energy consumption. These systems lose an average 45 percent of their input heat before reaching point of use. In many developing countries, the losses are substantially larger. For example, in the Russian Federation, most steam systems have no pipeline insulation. In China, many small-scale boilers operate with considerable excess air and incomplete coal combustion. Experience in well managed industrial facilities in OECD countries shows potential energy-efficiency gains of about 10 percent from system efficiency measures (Table 2.2).

Apart from plugging leaks, installing cogeneration systems may be the best way to reduce energy loss in steam generation. A traditional system produces heat and power separately, with a typical combined efficiency of 45–60 percent. In a cogeneration system – also known as a combined heat and power system – fuel technologies generate power at the point of use, allowing recovery of the heat normally lost in power generation. An attractive complementary measure once steam leaks have been stopped, cogeneration systems can operate with a first-law energy efficiency[7] of 75–90 percent and avoid electricity system distribution losses as well.

Cogeneration is widely applied in the paper, pulp and printing; chemicals and petrochemicals; oil refining; and food processing sectors, and its share is rising in others. The economics of cogeneration are sensitive to the heat to power ratio at the site and to the load factor of the plant; the most promising opportunities occur in non-stop operations (24 hours a day, seven days a week). Yet few countries generate more than 20 percent of their electricity from cogeneration. Installed capacity in OECD countries is 174 GW (6 percent of total electricity generation; UNIDO calculations from IEA data). The estimated global potential for new industrial cogeneration is around 160 GW

Table 2.2
Typical savings from efficiency measures for steam systems (percent unless otherwise indicated)

System efficiency measure	Typical investments (US$ per gigajoule of steam per year)	Typical savings	Use in OECD countries	Use in non–OECD countries
Steam traps	1	5	50	25
Insulated pipelines	1	5	75	25
Feedwater economizers	10	5	75	50
Reduced excess air	5	2	100	50
Heat transfer	–	–	75	50
Return condensate	10	10	75	50
Improved blowdown	20	2–5	25	10
Vapour recompression	30	0–20	10	0
Flash condensate	10	0–10	50	25
Vent condenser	40	1–5	25	10
Minimized short cycling	20	0–5	75	50
Insulated valves and fittings	5	1–3	50	25

– no data available.
Source: IEA 2006a.

> **Global experience suggests important energy-saving opportunities from cooperation and energy systems integration among firms**

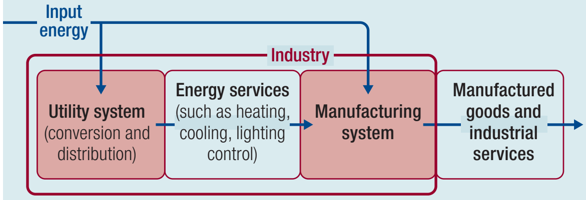
(IEA 2007d), enough to generate 500 terawatt hours (TWh) of electricity a year and to reduce primary energy consumption by 4.5 EJ. The potential for electricity generation is greatest in China (200 TWh), the United States (108 TWh) and the European Union (60 TWh).

Another type of technical improvement combines energy-efficiency measures such as cogeneration with electricity delivery to the grid, district heating networks, technologies using pinch analysis and heat cascading for large industrial sites.[8] Rapidly growing global experience suggests important energy-saving opportunities from cooperation and energy systems integration among firms. A notable example is the Kalundborg eco-industrial park in Denmark, which uses waste heat from a coal-fired power plant in surrounding industrial facilities and for district heating. Such opportunities need to be assessed case by case.

Energy use in industrial operations can be decomposed into the utility system and the manufacturing system (Figure 2.7). Enterprises acquire input energy mostly as fuels and electricity, but sometimes as other energy carriers, particularly steam and process heat, compressed air, and cooling or freezing liquid (liquid ammonia or nitrogen). Some energy is used directly in manufacturing (for example, fuel for direct-fired kilns or ovens), but most is converted by utilities into an energy service that is then used in manufacturing, such as process heating and cooling liquids, compressed air, motion and lighting.

For utility systems, the key performance factor is the efficiency of energy conversion – the ratio of useful energy in the output energy services (such as steam) per unit of useful energy input (such as fuel). For the manufacturing system, the determining performance factor is the economic use of energy in manufacturing operations. The aim of process economies is to produce more products with less use of energy services – for example, more beer per tonne of steam use or more plates per unit of fuel consumption in the firing kiln. Both utility efficiency and process economies are levers for improving overall energy efficiency (Table 2.3).

Figure 2.7
System model of industrial energy use



Source: UNIDO.

Systems solutions. A system's performance depends on the performance of each component and especially on overall system design and operation. Systems solutions thus consider technical improvements of individual energy-consuming components and systemic upgrades and improvements.

Losses can occur at each stage in the energy supply chain. Through an energy-efficiency "leverage" effect, energy savings at any stage can lead to compound gains by the end of the chain. For example, to deliver one unit of energy service in a pipe requires about 10 units of fuel at a power plant (Figure 2.8). Those 10-fold compounding losses can be reversed to yield 10-fold compounding savings of fuel for each unit of reduced friction in the pipe. Other examples include use of waste heat for cogeneration, pinch technology or heat cascading, and optimization of material flows through a facility, an industrial cluster or the economy to reduce energy needs for materials production, such as increased recycling of waste materials.

How much has structural change lowered energy intensity?

Structural change – changes in the economic structure of a sector, economy or the world – is both an economic and a social process. It involves changes in institutions, the size and distribution of economic activities, the political environment and consumer demand. For this report, which focuses on manufacturing activity, structural change is measured as the share of MVA, though it could also be measured as the change in each sector's contribution to total value added, employment or productivity.

> **Both utility efficiency and process economies are levers for improving overall energy efficiency**

Table 2.3
Resource-efficient and cleaner production approaches to improving industrial energy efficiency

Common improvement practices for industrial energy efficiency at the utility and manufacturing levels

Improvement practice	Example in industrial energy efficiency: Utility efficiency: utility system	Example in industrial energy efficiency: Process economies: manufacturing system
Good housekeeping	• Identify and repair leaks in utility systems, including compressed air and steam • Apply energy management systems • Conduct preventive maintenance and clean steam traps, cooling tower fans	• Identify and repair leaks and spills • Apply environmental management system • Plan production for extended batches and reduced start-ups/shutdowns • Reduce inventory
Substitute energy carriers	• Switch to lower carbon fuel (natural gas or biomass) • Switch to solar process heating	• Replace electric motor drives with medium- or low-pressure steam drives • Replace steam humidification with air cooling by ultrasonic humidifiers • Replace compressed air tools with direct driven tools
Better process control	• Monitor exhaust gas to improve efficiency of boilers and kilns • Control air intake for compressors	• Use timers and on-off controllers on equipment, lighting, air conditioning • Control and balance peak load
Equipment modification	• Install variable-speed drives for motor systems • Insulate hot utility systems • Rationalize utility reticulation systems, including steam and compressed air	• Remove bottlenecks in the production line to optimize use of ovens, furnaces and kilns • Optimize factory layout to reduce material transfer requirements • Use advanced tank and reactor design to eliminate stirring • Modify exhausts to reduce volume and increase temperature for heat recovery
Technology change	• Install energy-efficient energy equipment, including motors, boilers and furnaces	• Use process intensification • Apply green chemistry and engineering (catalysis, ambient temperature and pressure)
On-site reuse and recovery	• Recover waste heat recovery from boilers, furnaces, kilns and other hot equipment • Recover condensate as boiler feed • Remove moisture from wet raw materials entering kiln • Operate kilns on counter-current	• Recover solvents and other combustible process wastes and emissions as supplementary fuels
Production of useful by-products	• Use low-grade waste heat for building or district heating • Desalinate with low-grade waste heat • Store energy in ground reservoir, phase-change materials	• Switch to cogeneration or trigeneration systems
Product modification	• Not applicable	• Optimize dematerialization and product design to reduce breakage and cracks

Source: UNIDO.

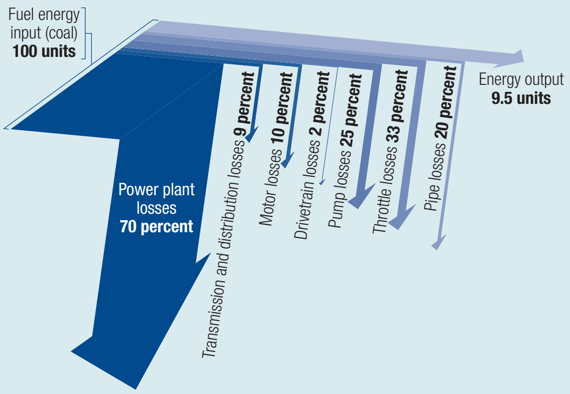
Of the 22.3 percent decline in global industrial energy intensity over 1995–2008, 56 percent was due to changes in industrial structure. There has been a major reduction in the share of energy-intensive process sectors in global MVA and a large increase in the share of the machinery sector (from plant equipment to consumer electronics and electrical appliances) – from around 29 percent in 1995 to 44 percent in 2008.

Changes in demand patterns as standards of living improve account for much of the shift in the structure of industry. Long-term studies show that as disposable income grows, so does the demand for certain products (Schäfer 2005). At lower incomes, demand is greatest for basic infrastructure – housing, roads and other services. This requires energy-intensive inputs like steel rods, aluminium castings, and

Of the 22.3 percent decline in global industrial energy intensity over 1995–2008, 56 percent was due to changes in industrial structure

Figure 2.8
Typical energy losses in energy conversion chains

Ten-fold compounding losses



Source: Lovins 2004.

copper and lead wires. As incomes grow, people want higher quality products, a wider choice of goods and new products that upgrade an existing service (say, an electronic reader in place of a book). Global per capita incomes rose more than 26 percent over 1995–2008, stimulating widespread adoption of new electronic products. These emerging global consumer preferences may account for the large increase in machinery's share in MVA and the shift to less energy-intensive sectors.

Developed countries. Structural change in developed countries follows the global trend, but with a more pronounced increase in machinery's share, which grew to more than half of total MVA by 2008, and larger declines in the shares of food and tobacco, textile and leather, and paper, pulp and printing (Figure 2.9). Lifestyle changes as incomes rise play a key role in developed countries, reflected in growing demands for environmentally friendlier products; a shift from manufacturing to services; rapidly expanding demand for health care, entertainment and leisure; and rising demand for transport, particularly by air. Once basic durable consumer goods saturate an economy, industrial energy consumption starts to taper off to around 40–60 percent of total final energy use, usually at a GDP per capita of roughly $5,000 (in 1985 prices; Schäfer 2005).

Structural change in developed country industries is also linked to product specialization and changes in international competitiveness arising from absolute and relative differences in the cost of labour, energy, physical assets and raw materials. Although the textile and leather sector is declining worldwide, the long-term decline has been more rapid in developed countries – as cheaper garments and shoes become available from developing countries – falling to around 2 percent of MVA by 2008 (see Figure 2.9).

Weber (2009) argues that the growing US trade imbalance in manufactured goods has contributed to structural change, as more and more goods consumed by Americans are imported from abroad. Many of these goods are produced by US firms that relocated production or started sourcing from abroad. He contends that the US economy saved 3 EJ in energy between 1997 and 2002 as energy use fell in both domestic low energy-intensive discrete product sectors and high energy-intensive process sectors, and rose in imported manufactured products.

Studies of energy use and structural shifts in industries in Canada, Norway, Sweden and the United Kingdom find that the energy-price response to the 1973 oil crisis was a major determinant of the share of energy-intensive process sectors in manufacturing (Schipper Howarth and Carlassare 1992; Östblom 1982; Gardner and Elkhafif 1998; Jenne and Cattell 1983).

Developing countries. Structural change in developing countries also seems to follow changes in income, but less than in developed countries because per capita incomes are lower. The machinery sector increased its share of MVA to 26 percent in 2008 (see Figure 2.9), while the share of textiles and leather and food and tobacco combined fell to 25 percent. Energy-intensive sectors such as chemicals and metals increased their share to 25 percent. The combined share in MVA of other process sectors, such as petrochemicals,

Structural change in developing countries also seems to follow changes in income, but less than in developed countries because per capita incomes are lower

Figure 2.9

Share of selected industrial sectors in global manufacturing value added, 1995–2008

Structural change in developed countries generally follows the global trend

Source: UNIDO 2010g.

“There is enormous potential for improving energy efficiency in all industrial sectors, both by adopting the best available technologies and by shifting the technological frontier

non-metallic minerals, and paper, pulp and printing, declined, but the share remains larger than in developed countries. Altogether, process sectors accounted for 41 percent of MVA in developing economies.

Structural changes in developing countries are heavily influenced by changes in middle-income and rapidly industrializing economies, as the emerging middle classes replicate the consumption patterns in developed countries. In Eastern Europe and the countries of the former Soviet Union, 30–40 percent of households owned an automobile by the mid-1990s, 80 percent a washing machine, and 90 percent a refrigerator (Schäfer 2005). In Brazil, shifts to a more affluent lifestyle and population growth over 1970–1996 contributed to the changing industrial structure and energy-use patterns (Wachsmann et al. 2009).

China's industrial structure, too, reflects a large and growing middle class demanding consumer products such as cars. It also reflects China's position as "factory to the world" and its immense infrastructure development. Exports and investment accounted for more than 70 percent of GDP in China in the early 2000s, and that investment alone accounted for a staggering 43 percent of GDP in 2006 (Kahrl and Roland-Holst 2009). Such investment influences the industrial structure as construction increases demand for cement and steel, and equipment purchases drive up the demand for chemicals and chemical products, petrochemicals, metals and machinery.

As income grows, structural shifts in the economies of developing countries will continue to affect industrial energy intensity, but not in the same ways. For example, regional climate differences will affect demand for cooling and heating equipment (Schäfer 2005). Countries well endowed with energy sources, such as the Russian Federation and some in Central Asia, will continue to emphasize energy- and material-intensive industries, while countries with limited space and large populations will develop mass transport industries. Low-income developing countries will likely face an initial stage of structural change dominated by energy-intensive process industries.

*   *   *

Can developing countries use technological change and focus on certain sectors to avoid the environmentally destructive paths taken by industrial countries as they developed? Yes, if countries can accelerate the technological processes already under way or can shift manufacturing sectors over to "greener pastures." As this chapter demonstrates, there is enormous potential for improving energy efficiency in all industrial sectors, both by adopting the best available technologies and by shifting the technological frontier. While it may always be necessary to have energy-intensive industries globally, individual countries may choose combinations of sectors with lower energy intensity.

The International Energy Agency's (IEA) 2010 *World Energy Outlook* estimates that a reduction in global energy intensity of 23 percent over 1980–2008 saved 32 percent in energy consumption (5.8 Gtoe; IEA 2010e). Looking forward, IEA (2010a) estimates several scenarios:

- *A current policies scenario,* which takes into account only policies already formally adopted and implemented, anticipates a 28 percent reduction in energy intensity by 2035, or savings of around 6.5 Gtoe in primary energy consumption (2 Gtoe from manufacturing).
- *A new policies scenario,* which assumes implementation of announced policy commitments to reduce greenhouse gas emissions and phase out fossil energy subsidies, foresees a 34 percent reduction in energy intensity, equivalent to an additional 1.3 Gtoe in savings over the current policies scenario.
- *A 450 scenario,* limiting the average global increase in temperature to 2°C and the concentration of greenhouse gases in the atmosphere to around 450 parts per million of carbon dioxide equivalent, would add 3 Gtoe in savings to the current policies scenario.

McKinsey & Company (2007, 2008, 2009) also estimates that the growth in global energy demand could be reduced, from 2.3 percent a year in the mid-2000s to 0.7 percent a year by 2020 (from 3.4 percent to 1.4 percent in developing countries), by seizing emerging opportunities to reduce energy intensity.

Improving industrial energy efficiency promises many well documented environmental, economic and social benefits. But can greater industrial energy efficiency deliver these benefits?

Is a development approach based on industrial energy efficiency sustainable – environmentally, economically and socially? Chapter 3 examines in detail how and to what extent industrial energy efficiency can mitigate environmental damage. Chapter 4 sheds light on the profitability of improvements in industrial energy efficiency and on their broader economic and social benefits.

Notes

1. Switching to higher quality fuel could be another driver, but because the analysis is based on aggregate measures of energy consumption, changes in energy intensity due to fuel substitution cannot be determined (for a discussion on energy quality see Cleveland, Kaufmann and Stern 2000).
2. Cross-country differences and long-term trends in industrial energy intensity are the net result of a complex mix of causal factors (technology level, product mix, comparative advantage in energy-intensive activities, resource endowment, population density and climate) that vary considerably by country. Similarly, more heavily industrial economies will show higher energy intensity than more service-oriented economies, so a lower intensity may reflect different types of economic activity rather than different levels of energy efficiency within a sector. These measurement problems make it difficult to assess the contribution of any one factor to the overall trend.
3. Davis and Caldeira (2010) explore this issue using multiregional input-output analysis to estimate the carbon embodied in imported and exported goods and services.
4. Primary energy is the energy embodied in natural resources before undergoing any human-made conversions or transformations; examples are coal, crude oil, sunlight, wind, running water in rivers, vegetation and uranium.
5. This percentage refers to member companies of the International Fertilizer Industry Association.
6. Irrespective of whether first law energy efficiency or exergy efficiency is used for the calculation.
7. First-law energy efficiency is based on the first law of thermodynamics, which states that in any closed energy conversion process, energy can be neither created nor destroyed – in other words, any energy that goes in must come out or be accumulated in the system (See *Glossary* for more details).
8. *Pinch analysis* reduces energy consumption in chemical processes by calculating thermodynamically feasible energy targets (or minimum energy consumption) and achieving them by optimizing heat recovery systems, energy supply methods and process operating conditions (Kemp 2007). *Heat cascading* is when heat is used repeatedly in different applications and its quality (temperature) and value decrease with successive uses.

Chapter 3

The environmental dividend from industrial energy efficiency

Industrial development has brought unprecedented improvements in standards of living – but at an environmental cost. Over the years, industrial development has overexploited natural resources, polluted the air and water, altered the climate and resulted in enormous accumulations of waste from industrial facilities and from products discarded at the end of their life or displaced by newer models.

Industry does not just contribute to these impacts. It is vulnerable to them as well. The increased frequency and intensity of extreme weather events mean that industry has little choice but to adapt. Mitigating emissions entails increasing energy efficiency, switching fuels and improving environmental management of energy equipment and processes. If industry continues using energy-intensive technologies and deriving its energy from carbon-intensive sources, the impacts on climate and the environment are likely to impede economic and industrial development.

Industrial energy use is a key lever for sustainable industrial development

Thus, industrial development must become sustainable. That requires innovative solutions – national and global – for minimizing energy consumption, particularly from carbon-intensive sources; using resources more efficiently; and improving productivity and competitiveness. In tandem with improving energy efficiency, industry needs to consider switching energy sources, so that every application uses the most appropriate energy source, which will reduce the environmental impacts of energy use. Options include switching to fuels or energy carriers with lower greenhouse gas intensities (including more use of renewables); expanding the use of heat recovery and recycling, perhaps by exploiting low-grade heat from energy and manufacturing processes that would otherwise be wasted (for example, by raising low-pressure steam to drive motor systems); and choosing the right energy equipment (for example, replacing compressed air tools and controls with direct drives and electronic controls).

Another complement to increased industrial energy efficiency is environmental management, because every energy source has environmental impacts. Minimizing the negative ones means advancing pollution control technologies to reduce or treat common emissions from fuel combustion (such as fly ash, sulphur dioxide and nitrogen oxides). Current technology assessments suggest that achieving deeper cuts in carbon dioxide emissions requires carbon capture and storage, which is currently implemented on an industrial scale in only a few oil fields. Carbon capture and storage works only for large-scale concentrated carbon dioxide streams such as certain chemical processes (refining and ammonia, cement, iron and chemical pulp-making). There will be trade-offs, however. Carbon capture and storage will increase energy use, especially electricity, and thus reduce overall industrial energy efficiency – indirectly limiting the net reductions in greenhouse gas.

Increasing industrial energy efficiency is thus one of the foundations for global green industrial development. By building on proven methods for raising industrial energy efficiency, countries begin dampening their environmental impact without slowing the growth of their industrial base – reducing air and water pollution, helping businesses improve their bottom line and optimizing strained energy systems so that they can continue to meet economic and social needs. These environmental, economic and social dividends are a "win-win-win" combination for policy-makers.

Chapter 4 reviews the economic and social dividends from making industry energy more efficient. This chapter examines the environmental dividend, looking first at reducing the environmental impacts of energy use and then at the impacts of materials and water use on energy efficiency. It also considers the need for better environmental management of energy

Efficient energy use has emerged as an effective and feasible way to reduce environmental impacts and put industrial development on a more sustainable trajectory

use. A three-part strategy for reducing the environmental impacts of industrial energy use and reaping the environmental dividends includes:

- Raising energy efficiency.
- Switching fuels.
- Improving environmental management of energy equipment and processes.

The data to be reviewed here provide compelling evidence that industrial energy use is a key leverage point for action on climate change. Industrial energy use is a major source of greenhouse gas emissions and other pollution, and while industry is vulnerable to the impacts of resource depletion and climate change, it also has enormous potential to mitigate these impacts:

- *Industry accounts for about 25 percent of all greenhouse gas emissions from all sources globally* (Bernstein et al. 2007). When indirect emissions from power generation are allocated by sector, manufacturing and construction contribute almost 37 percent globally to carbon dioxide emissions from fuel use and industrial processes and a startling 47 percent in developing countries (IEA 2010a). Industry causes further emissions of greenhouse gases in other sectors through transport of raw materials and finished manufactured goods and through management of industrial waste.
- *Industry is exposed to the impacts of climate change* in several ways. These include uncertainty in the supply of water and feedstocks (particularly from climate-sensitive farming, fisheries and forestry), interruptions to operations and logistics from more frequent and severe extreme weather events, and changes in demand as lifestyles and consumption patterns adjust to a warmer and less predictable climate and as prices rise for carbon-intensive energy, goods and services.
- *Industry has substantial mitigation potential,* mainly through improved energy efficiency. There are also options for reducing non-energy greenhouse gas emissions and for implementing resource-efficient and cleaner production methods (WBCSD 2000; van Berkel 2007a,b). If all industrial sectors used best available technologies (see Chapter 2), industry's direct carbon dioxide emissions would fall considerably, and the potential to reduce non-energy greenhouse gas emissions would increase as well. And industry can mitigate emissions in other sectors by designing and delivering low-carbon products and services; reducing, recycling and recovering waste from its own operations and those in its supply chains; and reducing associated transportation requirements.

Lessening the environmental impact of industrial energy use

Energy must power sustainable development – development that meets the needs of this generation without compromising the ability of future generations to meet their needs (UNCED 1987). In recognition of the Earth's limited carrying capacity, sustainable development integrates environmental protection, social advancement and economic development (Schmidheiny 1992; Elkington 1998; Spangenberg 2001; Holliday, Schmidheiny and Watts 2002; van Berkel 2007b).

Local and regional environmental impacts weigh heavily on many communities, especially in developing countries, but in recent decades global environmental challenges have seized the political spotlight (UNEP 1998, 2000, 2002a, 2007). With the growing reach and complexity of emissions and their impacts, energy efficiency has emerged as an effective and feasible way to reduce environmental impacts and put industrial development on a more sustainable trajectory.

Industrial enterprises use energy, along with water, chemicals, equipment and other materials, to process raw materials into products. Materials and water consumption are thus also determinants of energy use, so improving their efficiency is an important leverage point for industrial energy efficiency (discussed later in the chapter). Moreover, energy use degrades the environment and alters climate, limiting the availability of materials and water and thus the energy required to supply these to industry.

Environmental controls are often required for energy-using equipment such as boilers and furnaces,

> **Energy use affects the environment through emissions, depletion of natural resources, impacts on nature and landscape, and radiation**

though the additional energy to scrub, treat or convert pollutants reduces overall energy efficiency. Similarly, switching to cleaner fuels can decrease energy efficiency, so a systems perspective (a life-cycle assessment) is needed to fully consider the environmental impacts of energy use.

Energy use affects the environment through emissions (to air, water and land), depletion of natural resources, impacts on nature and landscape, and radiation.

Reducing greenhouse gas emissions

Greenhouse gas emissions[1] from human activities have grown enormously since the Industrial Revolution, rising 70 percent over 1970–2004 alone and 24 percent over 1990–2004 (IPCC 2007), with carbon dioxide contributing 77 percent of the total in 2004 (Figure 3.1; Barker et al. 2007).[2]

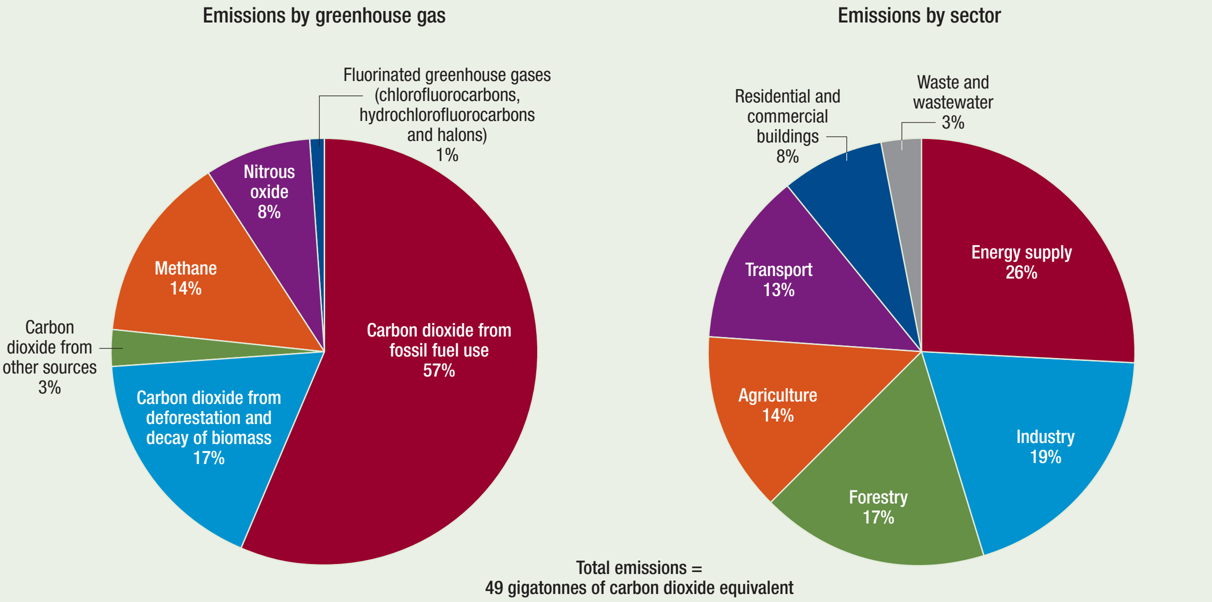
Energy supply is the largest direct source of greenhouse gas emissions (26 percent), followed by industry (19 percent), forestry (17 percent), agriculture (14 percent), transport (13 percent) and residential and commercial buildings (8 percent; see Figure 3.1). Per capita emissions vary widely across economies (Box 3.1).

The Intergovernmental Panel on Climate Change (IPCC) concluded, in its fourth and most recent assessment, that global climate change is unequivocal (IPCC 2007).[3] Rising air and ocean temperatures, melting snow and ice and mounting sea levels are just a few of the demonstrated impacts. The warming is a result of changes in atmospheric concentrations of greenhouse gases and aerosols, land cover and solar radiation that have altered the energy balance of climate systems (the enhanced greenhouse effect; UNEP 2008).

A rise in global mean temperature of more than 2°C above pre-industrial levels would sharply increase risks (IPCC 2007; Smith et al. 2009). Keeping global warming at less than 2°C entails stabilizing atmospheric greenhouse gas concentrations at around 450 parts per million of carbon dioxide equivalent ($CO_{2\text{-eq}}$).[4] Doing that requires at least halving global emissions from current levels by 2050.

Figure 3.1
Global greenhouse gas emissions, by greenhouse gas and sector, 2004

Carbon dioxide emissions account for the largest share of greenhouse gas emissions, and energy supply is the largest source of direct emissions



Source: Barker et al. 2007.

“Emissions have been rising in emerging market economies and falling in more advanced economies

Box 3.1
Trends in carbon dioxide emissions

In 2009, for the first time since 1992, there was no growth in global carbon dioxide emissions from fossil fuel use, cement production and chemicals production. The 2008 credit crunch drove many developed countries into recession and led to a 7 percent (800 million tonne) drop in their combined carbon dioxide emissions. This decline compensated for the continuing strong rise in emissions in developing countries, such as China (9 percent) and India (6 percent). The top six emitting economies in 2009, together accounting for some two-thirds of carbon dioxide emissions, were China, the United States, the EU-15, India, the Russian Federation and Japan.

The top 25 emitting economies accounted for more than 80 percent of total emissions, with large variations in per capita emissions and emissions per unit of GDP (see figure). Emissions have been rising in emerging market economies and falling in more advanced economies. Since 1990, per capita carbon dioxide emissions nearly tripled in China (from 2.2 tonnes to 6.1) but dropped 13 percent in the EU-15 (from 9.1 tonnes to 7.9) and 12 percent in the United States (from 19.5 tonnes to 17.2).

Carbon dioxide emissions in the top 25 emitting economies in 1990 and 2009

Source: Olivier and Peters 2010.

Extracting energy and processing it into fuel are major sources of emissions to land and water

This ambitious endeavour must begin now. Major shifts in lifestyles, massive investment in energy efficiency and low-carbon energy supply, and a transformation in how land and forests are managed are all on the agenda to avoid an increased risk of irreversible, catastrophic impacts. Industry will have to adapt to greater weather variability, more frequent and intense extreme weather events, and greater exposure to coastal storm surges.

Developing countries, more exposed to climate hazards and less resilient, would be hit hardest by the economic and social impacts of climate change. They are projected to bear some 75–80 percent of the costs of damages induced by climate change (Box 3.2; UNFCCC 2007a). Warming of 2°C could permanently reduce annual income per capita an estimated 4–5 percent in Africa and South Asia. The estimated losses for high-income countries are smaller, dropping the global annual average loss in income per capita to about 1 percent (World Bank 2010c).

Reducing other emissions

Fossil fuel combustion for industrial use and power generation emits other pollutants that do not contribute to climate change, including:

- Oxides of nitrogen and sulphur, which contribute to acid rain.
- Particulate matter or soot, which damages pulmonary and cardiovascular systems.
- Metals, including mercury, arsenic, beryllium, cadmium and nickel, which pose grave risk to the environment and human health.
- Unintended combustion products, including dioxins and furans, which are persistent organic pollutants.

Additional pollutants are emitted in processing, refining, cleaning, transporting and distributing liquid, solid and gaseous fuels, including volatile organic compounds (contributing to photochemical smog and ozone formation on the ground) and methane and carbon dioxide (greenhouse gases; see Box 3.3). Mining and processing fossil and nuclear fuels are

Box 3.2

Climate change affects regions differently

The impacts of climate change will differ markedly within and across regions. Asia, for example, will warm above the global mean except in the southeast. Precipitation is likely to decrease in Central Asia but increase elsewhere, with more frequent intense precipitation in South and East Asia; more frequent, longer and more intense hot spells in East Asia; and melting snow and ice in the Himalayas and the Tibetan Plateau, greatly reducing flows in major Asian rivers. The Small Island Developing States are expected to experience less warming than the global average but increasingly intense tropical cyclones, storm surges, coral bleaching and floods.

Many least developed countries are particularly vulnerable to the impacts of climate change, as evidenced by persistent unseasonal weather patterns in Africa.

In Ethiopia, climate variability is not new, but its effects have been exacerbated by human activities. The mean annual temperature has increased about 1.3°C since 1960, and the annual minimum temperature has risen about 2.0°C since 1951. As a result, rains are arriving late, with diminished volume during the main rainy season. More rain is falling during extreme weather events (heavy rains, storms, droughts), flooding and eroding fertile lands and threatening harvests, food security, jobs and income. Extreme weather events can wipe out whole crops and the infrastructure for harvesting, storage and processing.

In Cameroon, the mean annual temperature has risen 0.7°C since 1960, with even greater increases in the north. There are fewer cold nights, especially at higher altitudes, so mosquitoes thrive – as evidenced by malaria's recent rising prevalence, boosting medical costs and reducing productivity and quality of life. As temperatures rise, agricultural productivity and food security are projected to decline in already marginal areas. Depending on the climate scenario, agricultural production could decline \$5–\$20 billion annually by 2100. While mean annual precipitation is projected to remain stable, the share falling during extreme weather events is likely to rise. Already, a larger share of rain is falling in the traditionally dry season (December to March), affecting growing seasons.

Source: UNFCCC 2007a; UNDP 2008; World Bank 2007.

“ Energy supply and use are also major sources of emissions of trace metals to the atmosphere and to water and land

Box 3.3
Discriminating among primary energy sources

The environmental benefits from increased industrial energy efficiency go beyond the energy saved to a lessening of the detrimental environmental effects of industrial energy. The actual benefits depend on the type of primary energy that is displaced and the environmental controls applied.

Fossil fuels. From extraction to combustion, fossil fuels harm the environment. How much harm depends on the fuel type; the levels of ash, minerals and trace metals; and the technology used for extracting, refining and producing fuel and generating energy.

Coal has the highest greenhouse gas intensity of all fossil fuels when used for power generation, typically 0.85–0.95 tonne of carbon dioxide equivalent per megawatt hour ($CO_{2\text{-}eq}$ per MWh; see Figure 3.2 in text). Ash and sulphur and trace elements in mined coal determine other air emissions and generate waste and wastewater. Mining, particularly open-pit mining, destroys the land, and long-term disposal of coal tailings containing sulphur contaminates ground and surface water with acid and metals.

Oil used for power generation has a greenhouse gas intensity of around 0.75 tonne of $CO_{2\text{-}eq}$ per MWh. Nitrogen and sulphur oxides and many volatile organic compounds are emitted in refining and combustion, and transport and processing generate fugitive emissions. Refining also creates wastewater and solid waste. Accidental spills and leaks during exploration, production and transport pose even more risks.

Natural gas has the lowest greenhouse gas intensity of fossil fuels when used for power generation – well below 0.5 tonne of $CO_{2\text{-}eq}$ per MWh. However, methane, the main constituent of natural gas, is among the most potent greenhouse gases. Separating carbon dioxide from extracted gas, storing it (typically in old gas fields to increase gas recovery) and containing gas properly along the gas supply chain are necessary to net low greenhouse gas emissions from natural gas use.

The principal concern with *nuclear* power is protecting against radiation, primarily from the radioactive materials produced during power generation and contained in spent fuel rods. Nuclear power generation does not cause direct greenhouse gas emissions, but emissions occur from constructing, operating and decommissioning nuclear installations; from energy and materials used in mining, processing and transporting nuclear fuel; and from containing, transporting and storing long-lived radioactive waste (see, for example, Lenzen 2008). Because uranium ore is typically found in areas with high biodiversity and conservation value, open-pit mining of uranium can cause widespread environmental degradation.

Renewable energy. Renewable energy sources (solar, bioenergy, wind, hydropower and geothermal) do not emit greenhouse gases in final use, but their environmental impacts differ markedly at different stages. For example, solar systems do not harm the environment during use, but producing them, particularly photovoltaic cells, can be energy- and material-intensive. Wind energy can affect landscapes because of the large surface areas likely to be affected. Bioenergy's impacts depend on the type of biomass, its source and processing route.

major sources of emissions to land (large volume tailings and processing residues from coal and uranium mining) and water (wastewater from coal washing, oil refining, uranium processing and bioenergy production). Moreover, power generation leaves behind huge quantities of solid waste, such as fly and bottom ash from coal and spent fuel rods from nuclear power.

Fossil fuel combustion in industrial equipment (boilers, furnaces, kilns) and in power generation produces large-volume air pollutants, such as sulphur dioxide, nitrous oxides and particulate matter, all with harmful consequences to human health and the environment. Comparing life-cycle-based emission data for large-volume air pollutants from different types of power plants and power generation fuels shows substantial variations in emissions intensities (Figure 3.2; WEC 2004).

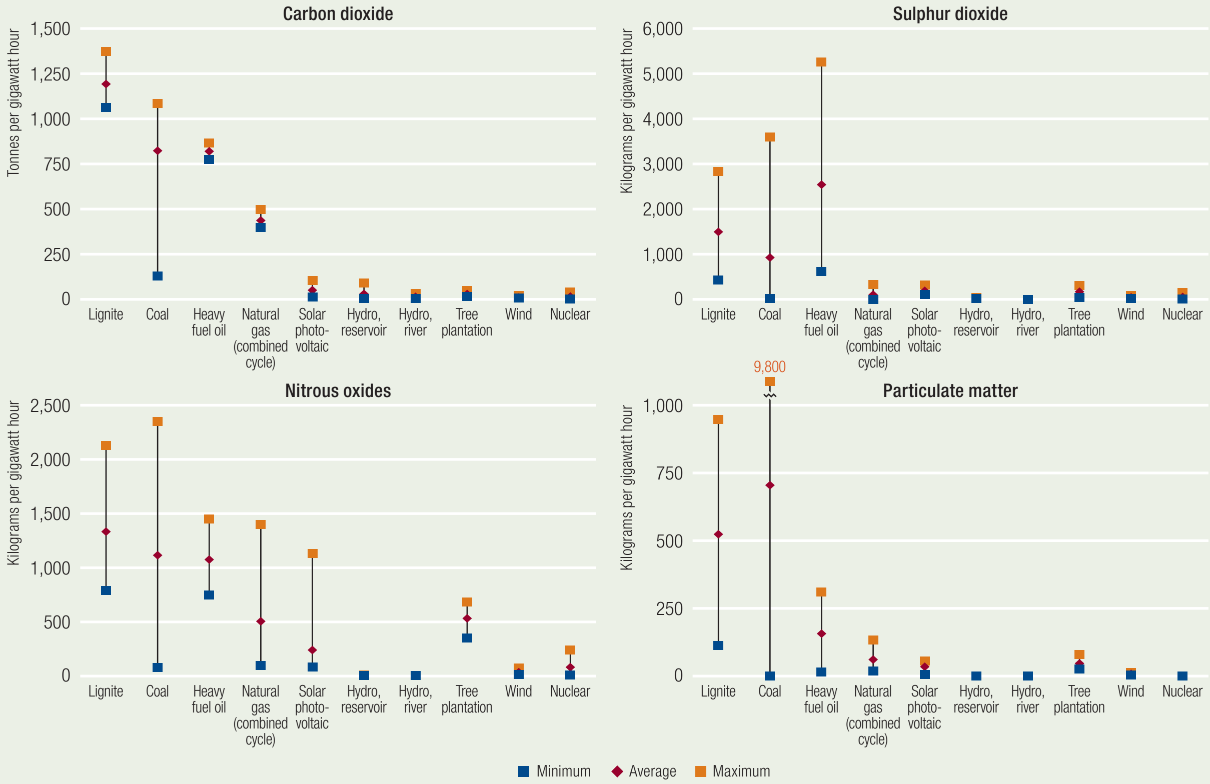
Of growing global concern is the dispersion and accumulation of small-volume emissions of toxic and persistent substances that also pose grave risks to human health and the environment. Energy supply and use are major sources of emissions of trace metals to the atmosphere and, less so, to water and land. Stationary fossil fuel combustion is the largest source of emissions of antimony, chromium, mercury, selenium, thallium and tin (coal), and nickel and vanadium (oil; Pacyna and Pacyna 2001). Moreover, depending on fuel mix technology and operation

> **Resource depletion is a particular concern for primary energy from non-renewable resources, both fossil and nuclear fuels**

Figure 3.2

Variability in life-cycle emissions of principal air pollutants from electricity generation, 2004

Life-cycle emissions of large-volume pollutants vary greatly across primary energy sources for electricity generation



Source: WEC 2004.

and maintenance conditions, combustion processes produce such persistent organic pollutants as dioxins and furans, which are associated with a wide range of harmful health effects.

Slowing down natural resources depletion

Sustainable development depends on safeguarding adequate supplies of natural resources for today and tomorrow. Fossil fuels, ores, food, fibres, water and other materials extracted or harvested for industry, agriculture and construction include ecosystem services (basic services provided by the natural environment that support human life). These services include a stable climate, fresh water and air, assimilation of waste and emissions, pollination and protection against diseases (Hawken, Lovins and Lovins 1999; MEA 2005).

Resource depletion is a particular concern for primary energy from non-renewable resources, both fossil and nuclear fuels (Ayres 2010). The ratio of reserves to production (proved reserves divided by current annual production),[5] though commonly interpreted as the number of years current production levels can be maintained from current proved reserves, can be used as a proxy indicator. At the end of 2010, reserves to production ratios were 46 for oil, 59 for natural gas and 118 for coal (BP 2011). With production expected to increase to meet soaring global energy demands, the ratios would decline. Eventually, production rates are expected to fall as reserves are depleted. But working in the opposite direction are improvements in energy efficiency, greater use of non-fossil energy and improved extraction technology. Discovery of new sources of fossil fuels would also delay resource depletion.

New fossil fuel reserves are often inferior to existing sources, with higher levels of contaminants

Numerous analysts forecast a peak followed by a decline in global oil production within the next decade – worrisome, because the world relies almost exclusively on oil as a transport fuel (Box 3.4). Oil and oil-derived products are already losing importance as an industrial energy source, a trend likely to accelerate.

As fossil fuel reserves in current production sites are exhausted, production will move to less favourable reserves. New oil fields are typically much smaller and located deeper in oceans, further from shore or in more ecologically vulnerable areas (such as sensitive arctic and maritime environments). An example is Petrobras's recent oil discovery in Brazil's Santos Basin, located 10 kilometres below the ocean surface under dense layers of salt. Extracting the oil will be technically challenging and economically and environmentally expensive, likely resulting in higher emissions than current industry averages (Ayres 2010). The 2010 Deepwater Horizon oil spill in the Gulf of Mexico is a stark reminder of the risks and challenges associated with developing production from reserves in more demanding environments.

New fossil fuel reserves are often of inferior quality to existing sources, with higher levels of contaminants. This is manifested in higher levels of carbon dioxide in gas fields (requiring co-development of carbon capture and storage), of sulphur in crude oil and of ash and trace elements in coal and non-conventional resources such as oil sands. Technology is available to produce and process high-quality fuels from such lower quality reserves, but doing so uses more energy and causes more pollution.

Energy use also depletes other natural resources. Power stations and energy-intensive industries depend on large volumes of water to discharge residual heat and maintain safe operating conditions. The heat-absorbing capacity of water bodies (rivers, lakes, coastal zones) is limited by the need to maintain temperatures that can sustain local ecosystems. Bioenergy depends on harvesting biomass, which needs to be sustainably cultivated to prevent overharvesting or declining soil fertility.

Lessening other environmental impacts

Energy supply and use also affect the environment through physical interventions, mainly large-scale alterations in landscapes or seascapes, to build energy facilities (mines, oil fields, refinery and processing

Box 3.4

Coping with the anticipated peak in oil production

With the easily recoverable oil reserves shrinking, the energy and costs of extracting and processing oil from other reserves are rising fast. The energy return on energy invested for oil discovered in the 1930s and 1940s was about 110 (110 units of energy produced for every unit of energy used to produce it). That value plunged to 23 for oil produced in the 1970s and to 8 for oil discovered in that decade. Fuel equivalent to 12.5 percent of the new oil had to be used to discover, drill, refine and distribute it. For deepwater oil and heavy oil, the energy return on energy investment is about 10.

The "end of oil" may not be just around the corner, but peak output may begin falling in as little as 5–15 years, entailing an unparalleled risk and financial management problems. As the peak approaches, liquid fuel prices and price volatility will increase, and without timely mitigation, the economic, social and political costs will be extensive, especially for developing countries. Higher oil prices transfer income from oil importers to oil exporters and slow economic growth. For oil importers, higher prices reduce national income because increased spending on oil reduces the funds available for other goods and services. Higher oil prices also lead to rising production costs for goods and services and can contribute to inflation and unemployment, reduce demand and lower capital investment – causing interest rates to rise as tax revenues fall and budget deficits increase. The larger the oil price hike and the longer it lasts, the harsher the impact.

Adapting to declining oil production and higher prices will be harder for developing countries, which have a limited ability to switch to alternative fuels. Higher oil prices can destabilize trade balances and increase inflation, especially in countries with underdeveloped financial institutions.

Source: Cleveland et al. 1984; Ayres 2010; Hirsh, Bezdeg and Wendling 2005.

> **Improved materials and water flows in manufacturing processes are key levers for raising industrial energy efficiency**

plants, wind or photovoltaic farms, and hydropower dams) and distribution infrastructure (pipelines and terminals). Once a local ecosystem is destroyed, it can seldom be returned to its previous state, though some progress has been made in restoring ecosystems after mining and in shutting down obsolete plants and infrastructure. And seldom does the harm stay local. Micro-climate and hydrology changes, ecosystem fragmentation and degradation, reduced food security and loss of aesthetic, cultural and heritage values all can extend far beyond immediately affected areas.

Nuclear and ionizing radiation – primarily from nuclear power plants with their fuel supply and waste-fuel disposal, but also on a smaller scale from fossil fuel combustion – pose considerable risks to human health and ecosystems. The risks of nuclear radiation include cell death, genetic damage, radiation burn, cancers and reproductive system disorders. Many radioactive nuclides result from nuclear reactions in power plants. Some nuclides are short-lived, but others remain unsafe for millennia. Additional nuclear radiation occurs through the release into the environment of naturally occurring radioactive materials from fossil fuel combustion. A related concern is ionizing radiation, which creates unstable atoms that harm living organisms.

Improving industrial energy efficiency by reducing materials and water use

Much of the environmental impact of materials and water use is determined by the energy required to transform materials into products; to extract, process and supply materials and water; and to manage the resultant waste streams. All inputs carry hidden flows of energy, materials and water in their production, a process captured in the concept of embodied energy, materials and water.

Improving materials and water flows

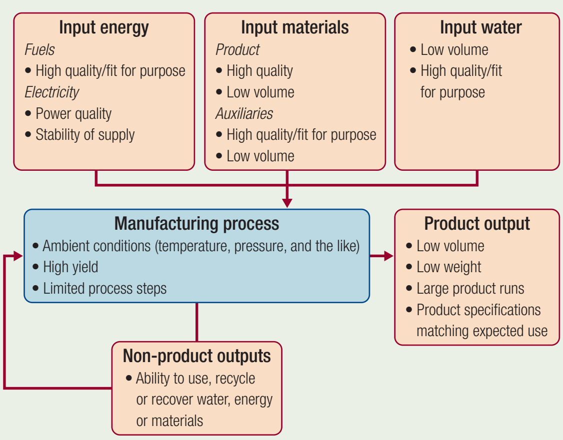
As a simplified physical input-output analysis shows, energy and materials and water use are interrelated in industry. Energy, materials and water carriers enter a plant, and (under laws of conservation of mass) equal amounts leave the plant as product or as waste, effluent or emission. Part of the input is incorporated in the product, part is consumed in delivering a function to the (intermediate) product or the process (such as cleaning) and the rest is dissipated (or wasted). Both the consumed and dissipated fractions exit as a non-product output or as emissions to land, water or air.

The correlations between process energy consumption and the quality and volume of material and water use, manufacturing efficiency and product specifications differ by industrial enterprise. But rules of thumb apply to positive or negative correlations. Figure 3.3 shows some common factors contributing to lower process energy requirements and so to improved industrial energy efficiency. For water, lower consumption and higher purity are associated with lower energy use, as less water has to be processed (pumped, heated, evaporated, cooled) and treated (such as filtered).

Improved materials and water flows in manufacturing processes are key levers for raising industrial energy efficiency. An example is the Colombian coil manufacturing company that changed its manufacturing processes to reduce water use and eliminate wastewater (Box 3.5). Ceramics is another example, with several leverage points. One is the quality of the clay

Figure 3.3
Factors generally contributing to lowering process energy requirements

Processes with low throughputs of fit-for-purpose inputs have better industrial energy efficiency



Source: UNIDO.

“By selecting and sourcing materials with lower embodied energy, industries improve the energy efficiency of their value chains

Box 3.5
How a Colombian metal working company saved energy by reducing wastewater and chemicals

Aceros Industriales, a medium-size metal working company in Medellin, Colombia, transforms steel bars into coils. A $640,000 investment led to $500,000 in annual savings from lower chemicals, water and energy use; increased productivity and improved product quality. Aceros switched from chemical pretreatment using hot caustic solutions to dry mechanical pretreatment, reducing water use by 8,000 cubic metres a year and thus reducing wastewater and sludge (previously 60 tonnes annually, disposed of as hazardous waste). The company was able to retire its boiler and stop using gas and fuel oil. While electricity consumption rose, the net energy and greenhouse gas emissions benefits remained substantial, at some 400 tonnes of carbon dioxide equivalent a year.

Source: CNPML 2005.

and its preparation; purer clay mixtures can be baked at much lower temperatures, reducing energy use by up to 40 percent. A second is product design: some potteries have trimmed material use by as much as 20 percent per item, with comparable savings in energy consumption. A third is the material handling system, which can be improved to reduce stress on products (less breakage) and maximize product throughput in the oven. Loading increases of 10 percent are typical, translating into similar savings in energy consumption per item. Taking advantage of all three leverage points could reduce energy use in ceramics production by up to 55 percent.

Reducing embodied energy, materials and water

Embodied energy is the cumulative amount of commercial energy (fossil, renewable, nuclear) invested to extract, process and manufacture the material or product and transport it to its point of use (gross energy requirement). This accounting concept sums the energy physically embodied in the materials (which can be released by reversing the process) and the energy invested in creating the processing conditions and bringing the materials together (including transport).

Thus, even before input resources reach their point of use, they have already had environmental impacts related to the energy used to extract, process and transport them. Embodied energy is thus a proxy for the total environmental impact in supplying the input to a company. It does not, however, account for the varying environmental impacts of different primary energy sources (such as fossil or renewable fuels; see Box 3.3). Improving downstream materials and water efficiency can lead to upstream energy savings and lower environmental impacts. For example, treating and transporting potable water can require from 2.88 megajoules of energy per cubic metre to 17.64, depending on treatment method (Vince et al. 2008). Embodied energy is approximately 35.30 megajoules per kilogram (MJ/kg) for steel and 218 MJ/kg for primary aluminium (Hammond and Jones 2008). Similarly, the packaging used in transporting materials also has energy use impacts (for example, polypropylene has an embodied energy of 95.4 MJ/kg).

By selecting and sourcing materials with lower embodied energy, industries improve the energy efficiency of their value chains. Recovering and recycling materials is typically less energy intensive than producing primary materials, especially for metals, so using recycled instead of primary materials can yield energy savings. For example, embodied energy is 28.8 MJ/kg for recycled aluminium and 218 for primary aluminium (Hammond and Jones 2008).

From a life-cycle perspective, using materials with higher embodied energy can make sense if that saves energy in other phases of the product life-cycle. Consider vehicle weight in the transport sector. Though light materials have higher embodied energy, using less energy during the use phase yields life-cycle energy savings. Life-cycle assessment shows that after a car has driven 200,000 kilometres, every kilogram of aluminium used in car parts in place of steel saves 190–210 MJ of primary energy and reduces greenhouse gas emissions by 15–16 kg $CO_{2\text{-eq}}$ (IAI 2008).

Embodied materials and water (gross material requirement and gross water requirement) are the total amounts of materials and water used, directly

“Slowing the increase in the harmful impacts of industrial production on the environment requires boosting industrial energy efficiency

and indirectly, to extract, process and manufacture an input (product, good, or water or energy flow) and transport it to its point of use. They include hidden flows without economic value, which can be assumed to have ended up as waste or wastewater upstream in the supply chain. Two indicators of material flows are materials intensity per service unit (total materials use relative to a functional unit of product service) and materials intensity (materials use relative to a physical unit of use of a material or energy carrier; Ritthoff, Rohn and Liedtke 2002).

Since materials and water consumption are proxies for environmental pressures for a range of impacts associated with materials and water use, embodied materials and water can be used as indirect proxies of the total environmental impact of the use of materials and energy. However, doing so ignores the large differences in environmental impacts across alternative materials and different water sources as well as the potential for recycling after use.

Awareness of embodied materials and water has spurred interest in dematerialization – getting more valuable product out of the same or fewer material resources (Geiser 2001; ADB and IGES 2008). Focused initially on reducing the direct and indirect (embodied) materials weight of products, dematerialization offers wider benefits through lowering embodied energy and greenhouse gas emissions. Approaches include redeveloping or redesigning production processes and products through light-weighting, reducing waste in production, leasing and sharing goods and equipment, introducing take-back systems and recovering end-of-life goods.

Making industry more energy efficient

Slowing the increase in the harmful impacts of industrial production on the environment requires boosting industrial energy efficiency. How much of a boost is needed to make industry sustainable (both in total environmental impact and per capita or per unit of economic activity), however, remains uncertain. With the stakes so high, it would be wise to err on the side of caution. The global community must do as much as possible to reduce environmental pressures. Otherwise, the rapid manifestation of the impacts of climate change (IPCC 2007), the alarming decline in ecosystem services (MEA 2005) and the ongoing deposition of heavy metals and other toxic materials in the environment will only worsen, while fossil fuel production might soon peak, starting with oil.

There are several entry points for reducing industrial energy intensity and total energy requirements (see Chapter 2). One is by using more energy-efficient equipment, process designs and systems. Another is by improving energy management systems. In addition, optimizing and minimizing materials and water flows can have spin-off benefits for energy efficiency and overall productivity.

The spotlight is on industrial energy efficiency in developing countries. In 2008, energy-related greenhouse gas emissions in developing countries for the first time exceeded those in developed (Annex I) countries (IEA 2010a), a result of a 2 percent decline in developed countries and a 6 percent increase in developing countries.

Taking a life-cycle perspective

The environmental impacts of industrial energy use differ across energy sources (see Box 3.3). Direct impacts arise during energy use in industrial processes, while indirect impacts result from the production and supply of the energy used by industry (such as at power stations in the case of industrial electricity consumption). Life-cycle assessment extends the traditional focus on production sites and manufacturing processes to the entire life-cycle of a product to account for all environmental, social and economic impacts (Box 3.6).

Reducing greenhouse gas emissions

The climate effects of greenhouse gas emissions will persist for centuries (Archer and Brovkin 2008). Industry and construction globally contribute almost 37 percent of total greenhouse gas emissions from fossil fuel use and industrial processes, directly from

" Each process in industrial energy use has environmental, economic and social impacts that depend on the type of energy and technology used

Box 3.6

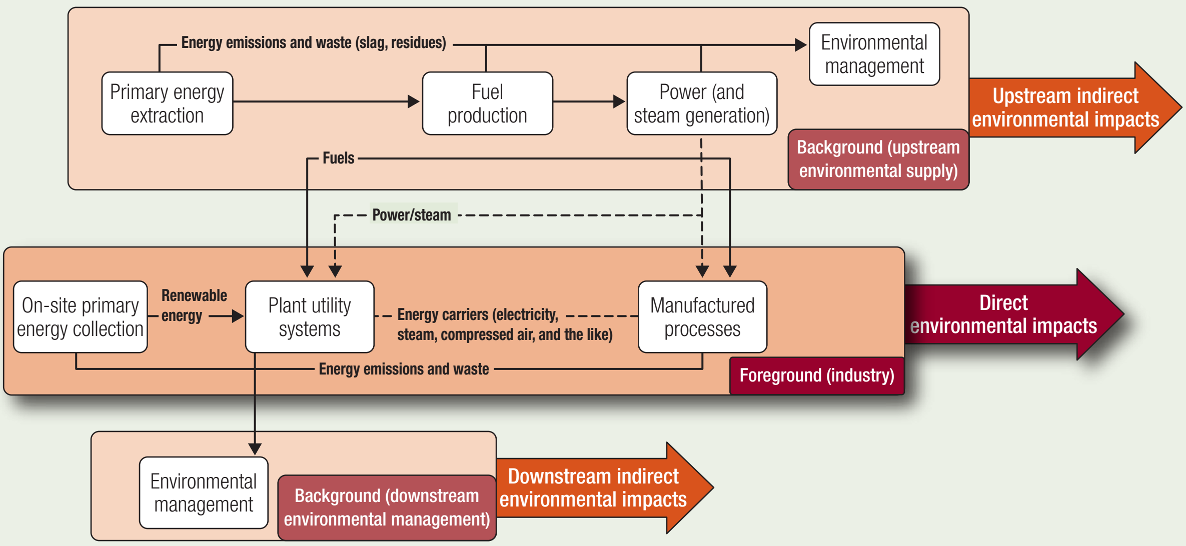
Life-cycle assessment and carbon footprinting

Life-cycle assessment quantifies the use of materials and energy and the generation of waste and emissions in each stage of a product's life-cycle, applying the same methods used for materials and energy flow analysis and balances at the unit operation level. Materials and energy use and waste and emissions are summed and linked to their environmental impact categories following established international standards (ISO 14041–14043). This results in cumulative environmental impact estimates for each category (such as resource depletion, global warming and ecotoxicity) that can in principle be further weighted and calculated as aggregate environmental indices.

The following figure applies life-cycle assessment to industrial energy use. Industrial energy use is in the foreground, indicating that the design, operation and performance of industrial processes are under a company's direct control and have direct environmental impacts. These processes require fuels and energy carriers (electricity, steam, compressed air), which are provided by utility systems at the plant (such as compressors and boilers) or are sourced from energy suppliers. The fuels to run these utility systems come from energy suppliers or from primary energy collected on site (such as solar heating or cooling and wind power generation).

The energy supply system forms the background. Its operation and performance are outside the immediate control of any particular manufacturing firm and have indirect upstream environmental impacts. The system covers primary energy extraction, production of commercial fuels (petroleum refining, gas processing, coal washing) and energy conversion to power and steam. It also includes environmental controls for treating wastes and emissions. Additional indirect downstream environmental impacts may arise from treating or disposing of the emissions and waste from energy use. Each process in industrial energy use has environmental, economic and social impacts that depend on the type of primary energy used, the required final energy service, the technology available and the associated operation, management and planning.

Life-cycle of industrial energy use



Carbon footprinting, a specialized application of life-cycle assessment focusing exclusively on carbon emissions, is gaining recognition as a means of quantifying direct and indirect greenhouse gas emissions. It can be applied to companies, products (including energy supply options) and consumption patterns. The World Resources Institute, in collaboration with the World Business Council for Sustainable Development, has developed protocols, methods and sector-specific calculators to estimate enterprise-level carbon emissions (www.ghgprotocol.org). Complementing the effort is the International Organization for Standardization's product-level carbon footprint standard (ISO 14067).

Source: Guinée et al. 2002; UNEP 2005; ISO 1997a,b, 1999a,b.

> **In 2004, emissions of all greenhouse gases from the industrial sector accounted for nearly 25 percent of global greenhouse gas emissions**

on-site fuel use and processes and indirectly through emissions from power generation for industry and construction (IEA 2010a).

In 2004, emissions of all greenhouse gases from the industrial sector accounted for an estimated 12 gigatonnes (Gt) $CO_{2\text{-eq}}$, nearly 25 percent of global greenhouse gas emissions (Bernstein et al. 2007; Figure 3.4). Some 9.9 $GtCO_{2\text{-eq}}$ (83 percent) of total industrial greenhouse gas emissions originated from energy use, up from 6 $GtCO_{2\text{-eq}}$ in 1971. Direct emissions totalled 5.1 $GtCO_{2\text{-eq}}$, and indirect emissions associated with the generation of electricity and heat and steam by the power sector but used by industry accounted for the rest of industrial energy-related emissions in 2004 (Bernstein et al. 2007).

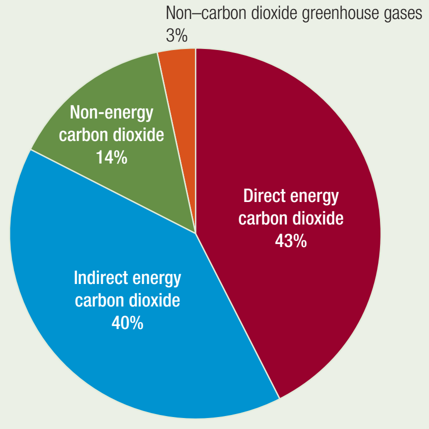
Industry also emits carbon dioxide from nonenergy sources (from chemical and metallurgical processes), mainly from cement and lime production. These non-energy carbon dioxide emissions were estimated at 1.7 $GtCO_{2\text{-eq}}$ for 2004 (Bernstein et al. 2007).

Industry emits other greenhouse gases too, including fluoroform from the manufacture of refrigerant (HCFC-22); perfluoro compounds from aluminium smelting and semiconductor processing; sulphur hexafluoride from the manufacture of flat panel screens (liquid crystal displays) and semiconductors, magnesium die casting, electric equipment and aluminium melting; and methane and nitrous oxide from chemical industry sources and food industry waste. Emissions from these sources were estimated at 0.4 $GtCO_{2\text{-eq}}$ in 2004 (Bernstein et al. 2007).

In addition to energy supply and use, industry influences greenhouse gas emissions by using services from other greenhouse gas–emitting sectors. In 2004, transport accounted for emissions of 6.3 $GtCO_{2\text{-eq}}$ (13.1 percent of total global emissions; Ribeiro et al. 2007). As in 2000, freight transport accounted for an estimated 43 percent of the total energy use and greenhouse gas emissions from transport (WBCSD 2001). Industry's contribution to emissions from transport and waste management (Bogner et al. 2007) can be estimated at 2–3 $GtCO_{2\text{-eq}}$ a year, raising industry's contribution to global greenhouse gas emissions to 14–15 $GtCO_{2\text{-eq}}$ a year, or around 30 percent of global emissions.

Figure 3.4
Breakdown of all greenhouse gas emissions from the industrial sector, 2004

Energy use caused some 83 percent of industrial greenhouse gas emissions in 2004



Source: Bernstein et al. 2007.

In 2004, seven sectors accounted for 76 percent of global industrial greenhouse gas emissions (Baumert, Herzog and Pershing 2005): chemicals and petrochemical (23 percent), cement (18 percent), iron and steel (15 percent), non-ferrous metals (7 percent), machinery (5 percent), food and tobacco (5 percent), and paper, pulp and printing (5 percent). Fossil fuel combustion (direct emissions) contributed 49 percent; electricity and heat consumption (indirect emissions), 35 percent; process carbon dioxide emissions, 10 percent; and high–global warming potential gases, 6 percent. Many sectors emit greenhouse gases from both energy and process sources. New process technologies have been applied in some sectors to conserve energy and minimize process-related greenhouse gas emissions; the chemical sector in India is an example (Box 3.7).

Based on world energy data and production data in key sectors, the International Energy Agency

“In developing countries, manufacturing and construction contribute nearly half of carbon dioxide emissions from direct fuel combustion and imports of electricity and heat

Box 3.7

Integrated clean technology solutions in India

Ankleshwar Industrial Estate in Gujarat State, one of India's chemical clusters, houses more than 500 small and medium-size chemical producers supplying the pharmaceutical, veterinary, fertilizer, pesticide and dyestuff sectors. UNIDO supported the chemical industries association and the Gujarat Cleaner Production Centre in identifying, transferring and adapting cleaner technologies appropriate for the scale and type of chemical processes. Three examples:

- About a dozen industries manufacture benzoic acid derivatives by oxidizing toluene derivatives. The process releases 281 tonnes of nitrous oxide annually, or 77,500 tonnes of carbon dioxide equivalent ($CO_{2\text{-eq}}$) a year. A new process technology that eliminates nitrous oxide emissions has been developed, based on catalytic oxidation. It promises to reduce emissions nearly 98 percent, to 1,762 tonnes $CO_{2\text{-eq}}$ a year. Moreover, the new process is less energy intensive, avoiding further energy-related carbon dioxide emissions, so that the net greenhouse gas reduction amounts to 88,498 tonnes $CO_{2\text{-eq}}$ a year.
- Some 40 target industries manufacture dyes, drugs, pigments, intermediates and other chemicals – for which they use about 400 tonnes of sulphuric acid a day – and produce around 2,000 tonnes a day of diluted, spent sulphuric acid. This acid, neutralized with hydrated lime or limestone, produces 53,950 tonnes a year of $CO_{2\text{-eq}}$ and almost 85,000 tonnes a year of solid waste contaminated with organics, heavy metals and chlorides. A new process recovers sulphuric acid for reuse by industries and avoids the need for disposal in landfills. This new process would reduce net greenhouse gas emissions 41 percent, to roughly 22,108 tonnes $CO_{2\text{-eq}}$ a year, and the chemical recovery is a net energy producer, providing 1,500 kilowatt hours a day in surplus power.
- Hazardous waste generated in the Ankleshwar Industrial Estate is incinerated, emitting sulphur dioxide, nitrogen oxide and trace amounts of nitrous oxide and potentially such persistent organic pollutants as dioxins and furans. Fly and bottom ash are also produced and require treatment and landfill disposal. A new waste treatment based on plasma technology generates no persistent organic pollutants, reduces flue gases and generates no secondary solid waste. Surplus electricity and steam can be transferred to neighbouring industries or the grid.

Source: UNIDO 2010b.

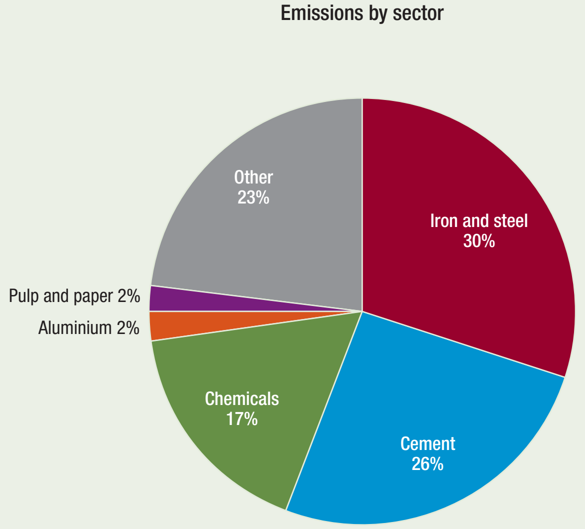
(IEA 2009c) estimated industry's direct contribution to global carbon dioxide emissions through fossil fuel use and process emissions at 7.2 Gt in 2006, up from 6.8 in 2004 (Bernstein et al. 2007 based on IPCC data). According to the same IEA study, industry also caused indirect emissions of 3.4 Gt of carbon dioxide in 2006 through electricity supply, lower than the more comprehensive IPCC estimate of 4.8 Gt in 2004. In 2006, iron and steel, cement and chemicals caused nearly three-quarters of industry's direct carbon dioxide emissions (Figure 3.5). The group of OECD countries and China each contributed 34 percent to the direct carbon dioxide emissions from industry.

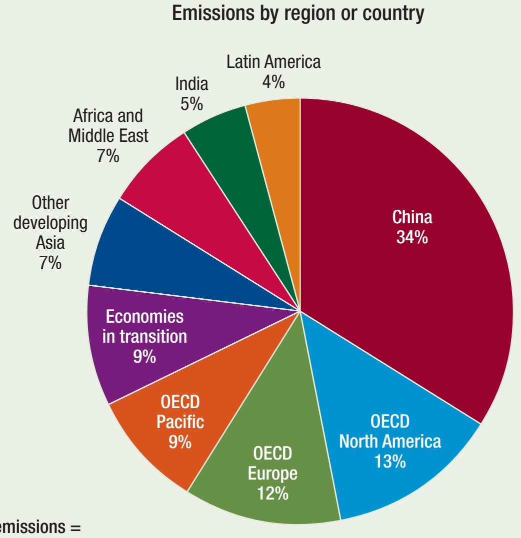
The IEA estimated carbon dioxide emissions from fossil fuel consumption at 29.4 Gt in 2008 (IEA 2010a). OECD countries contributed 12.6 Gt (43 percent) and non-OECD countries 15.7 Gt (53 percent); the remainder came from international marine and aviation bunkers. By economic sector, electricity and heat generation is the largest emitter, contributing 41 percent of global emissions (40 percent for OECD countries and 45 percent for non-OECD countries; Figure 3.6). Transport is the second largest contributor globally (22 percent) and for OECD countries (27 percent), while industry and construction is the second largest in non-OECD countries (26 percent). Globally, industry and construction is the third largest contributor (20 percent). However, when emissions from electricity and heat generation are allocated to end users, the emission contributions of industry and construction rise to 37 percent globally (27 percent for OECD countries and 47 percent for non-OECD countries; IEA 2010a). In developing countries, industry and construction thus contribute nearly half of carbon dioxide emissions from direct fuel combustion and imports of electricity and heat.

> **The largest carbon dioxide emitters are iron and steel and chemicals by sector, and electricity and heat generation by economic activity**

Figure 3.5
Share of direct industrial carbon dioxide emissions from fossil fuel use and industrial processes, by sector and region or country, 2006

Three sectors generate more than 70 percent of industrial carbon dioxide emissions, and China and OECD countries are now on par in industrial emissions



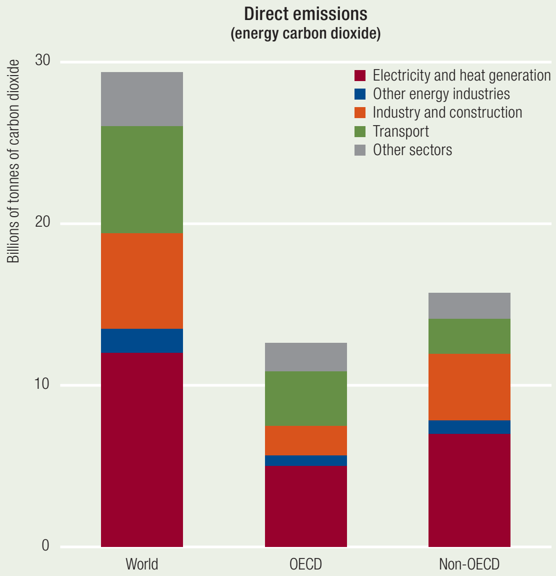


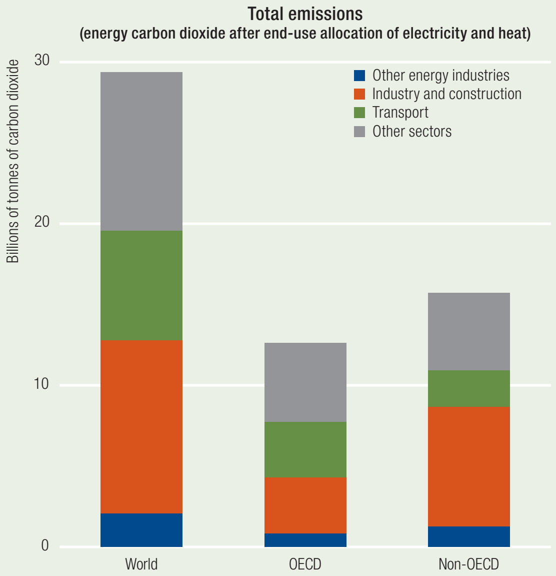
Total emissions = 7.2 gigatonnes of carbon dioxide equivalent

Source: IEA 2009c.

Figure 3.6
Contributions to carbon dioxide emissions from fossil fuel combustion, by economic sector, 2008

Electricity and heat generation and industry and construction are major emitters of carbon dioxide from fossil fuel consumption





Source: IEA 2010a.

"Industry can switch to cleaner production processes that use less material and water. And savings are possible in transport and waste management

The mitigation potential is substantial

Cross-cutting and industry-wide technologies (such as efficient motor and steam systems, cogeneration and energy recovery); inter-industry opportunities (such as reuse of waste heat or by-products by other industries); process-specific technologies; and materials and products with lower embodied energy can yield major environmental dividends. Large energy savings are also possible by using fewer raw materials and less water. Efforts to boost industrial energy efficiency are closely associated with the quantity and quality of raw materials and water used in plants because the energy used in manufacturing is proportional to the quantity of these inputs. Industry can switch to cleaner production processes that use less material and water. And savings are possible in transport and waste management. Industry emits some 25 percent of greenhouse gases worldwide and is a major user of natural resources, so the mitigation potential is substantial.

* * *

This chapter explored how and to what extent industrial energy efficiency can mitigate environmental damage. Chapter 4 considers the profitability of improvements in industrial energy efficiency and their broader economic and social benefits.

Notes

1. The United Nations Framework Convention on Climate Change covers six direct greenhouse gases: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.
2. This chapter uses estimates from different sources for different periods. Estimates differ because of uncertainties, different base years and different methods. Energy statistics (especially on the environmental impacts) are an evolving science.
3. As public debate over the science, impacts and costs of climate change have intensified, the IPCC has come under heightened scrutiny about its impartiality regarding climate policy and the accuracy and balance of its reports. An independent review of the 2007 fourth assessment report (*Climate Change 2007*) found reason for concerns about the accuracy and interpretation of some data, but it concluded that the overall assessment was well supported by the uncontested evidence available (IAC 2010).
4. Greenhouse gas emissions, weighted by their 100-year global warming potential, are expressed in carbon dioxide equivalents ($CO_{2\text{-eq}}$).
5. Proved reserves are those that geological and engineering information show have a high (typically more than 90 percent) probability of being produced. Data on the global production and proved reserves of fossil fuels are available from several sources, including the *BP Statistical Review of World Energy* (BP 2011).

Chapter 4

The economic and social dividends from industrial energy efficiency

Improving industrial energy efficiency is essential for helping supply-constrained developing and emerging market economies meet rising demand and for decoupling economic growth and environmental degradation. While firms may not be driven exclusively by profit motives, the market demands that investments achieve competitive rates of return.

Investment involves risk and therefore the expectation of returns that will minimally compensate for the probability of loss. The higher the anticipated return, the more attractive the investment. Investment can yield other returns as well, not just economic. Greater industrial energy efficiency can provide benefits to companies and societies in the form of new employment, higher income, and better health, working conditions and quality of life.

This chapter examines the underlying economics of industrial energy-efficiency investments from a micro-economic perspective, starting with energy costs at the industry and firm levels. It explores the risks associated with such investments, the financier's take on these risks compared with those of other investments, and evidence on the profitability and other economic and social benefits of the investment. Finally, it explores the technical potential for further improvements in industrial energy efficiency and notes that many profitable green investment opportunities go unrealized.

The importance of energy costs to businesses

Business profits depend on the difference between sales revenues and input costs. Sales revenues can be increased in the short run by raising output or price and in the long run by installing new and more productive capacity. The ability to modify output and boost prices depends on the industry's structure and competitive characteristics. In competitive markets, firms tend to be price takers. Costs include capital, labour and intermediate inputs (materials and energy). Costs can be reduced in the short run by optimizing production methods, using cheaper inputs and improving materials and energy use efficiency and in the long run by introducing new equipment.

While all costs need to be minimized, managers have limited time and so focus on expenses that make up the largest proportion of total costs.[1] Thus, managers are more likely to invest in industrial energy efficiency when energy constitutes a large share of costs. A firm's energy costs depend on the energy intensity of the production process, the prices of different energy carriers and the efficiency with which energy is used in production and auxiliary operations such as buildings and warehouses.

Investments in energy-efficient technologies entail estimating the size and timing of a project's income and outlays and choosing among investment options. Estimates need to factor in technical, environmental, economic and political considerations that vary over time and that are uncertain and difficult to measure. In many developing countries, investment decisions are constrained by structural deficiencies, limited infrastructure, volatile operating conditions and shortages of physical, human and institutional resources.

How energy costs vary

Industrial energy costs vary considerably by level of industrialization, sector and firm. Energy costs include the energy used to power production processes and to generate heat, light and power. In principle, energy costs exclude the outlays for fossil fuels used as raw materials in the production process, such as oil and coke feedstock in the petrochemical and steel industries, but many countries do not report these separately.

Which sectors have the highest proportion of energy costs in total input costs (Table 4.1)? Topping the list are *process sectors* such as refined petroleum (fuels, lubricants, chemical feedstock) and nuclear

“Greater industrial energy efficiency can provide benefits to companies and societies in the form of new employment, higher income, and better health, working conditions and quality of life

Table 4.1
Share of energy costs in total industry input costs, by sector, latest available year (percent)

Sector	All countries	Developed countries	Developing countries	Group of large developing countries[a]
Process sectors				
Refined petroleum and nuclear fuel[b]	61.6	59.4	70.6	68.4
Non-metallic minerals	11.8	7.2	12.7	6.5
Basic metals	7.3	5.8	8.3	9.9
Chemicals and chemical products	3.9	4.9	3.5	10.0
Discrete product sectors				
Other transport equipment	3.2	1.3	5.6	2.4
Fabricated metal products	2.4	2.5	2.4	5.1
Machinery and equipment	2.0	1.4	2.7	4.0
Medical and optical instruments	1.8	1.3	3.0	1.7
Electrical machinery and apparatus	1.5	1.7	1.4	2.2
Radio and television	1.4	1.2	1.6	1.3
Motor vehicles	1.1	1.0	1.6	1.2
Office and computing machinery	0.7	0.6	2.0	0.9
Combined sectors				
Rubber and plastic products	5.3	3.4	6.8	7.8
Paper, pulp and printing	3.2	3.6	2.9	4.0
Wood products	3.0	2.4	3.5	4.2
Textile and leather	3.0	2.3	3.3	2.5
Food and tobacco	2.3	1.7	2.5	1.9
Non-specified industry	2.0	1.3	2.8	3.2
Total	12.3	6.1	17.5	8.9
Excluding refined petroleum	3.6	2.5	4.3	4.8

Note: Includes energy costs for 50 countries. For methodological details, see Upadhyaya (2010).
a. Brazil, China, India, the Russian Federation and South Africa.
b. For most countries, includes total energy costs, including energy used for raw materials. Including these costs distorts the energy cost ratios for this sector. All developed countries in the sample use this method of accounting for energy costs, but few developing countries do. To make comparisons meaningful, the values for developing countries were recalculated to reflect the energy cost of raw materials.
Source: UNIDO 2010e,f.

fuel, non-metallic minerals (ceramics, cement, glass), basic metals (aluminium, copper, iron, steel), and chemicals and chemical products (fertilizers, plastics). Refined petroleum and nuclear fuel’s 61.6 percent share is way ahead of the others, largely because the industry practice is to include raw materials in energy costs. Ratios in other process sectors average 3.9–11.8 percent. These sectors share several economic characteristics. They are capital- and skill-intensive and pay above-average wages because of the large investments in equipment. Economies of scale and capacity use are the main determinants of profitability, with plants normally running continuously, 24 hours a day, 365 days a year. Inputs account for the largest proportion of production costs. And output tends to be homogeneous.

By contrast, average energy cost ratios are lower, at 0.7–3.2 percent, for *discrete product sectors* such as office and computing machinery (computers and peripherals, communication equipment), machinery and equipment (power and machine tools, general and special purpose, agriculture and industrial equipment), electrical machinery (motors, electrical equipment, and appliances), radio and television (consumer

> **Topping the list of sectors with the highest share of energy costs in total input costs are process sectors such as refined petroleum, non-metallic minerals, basic metals and chemicals**

electronics) and motor vehicles (passenger and commercial vehicles, parts, accessories). (However, some subsectors, such as foundry operations, have high energy intensity.) These sectors produce high-volume output and frequently use automated, multistage production processes. They are capital- and skill-intensive, equipment accounts for the largest share of production costs and scale economies are important for profitability.

Between the two are *combined sectors,* which share the technological and economic characteristics of process and discrete product sectors. These sectors have average energy cost ratios of 2.0–5.3 percent. They include rubber and plastic products (tyres, building material, consumption plastics), paper, pulp and printing (cardboard, newspapers and books), wood products (plywood, construction goods and furniture), textile and leather (textiles, shoes and clothing) and food and tobacco (processed meat and vegetables, dairy products and beverages).

The group of large developing countries (Brazil, China, India, the Russian Federation and South Africa) spends the largest share of input costs on energy (4.8 percent), more than all developing countries as a whole (4.3 percent). Developed countries spend the least (2.5 percent). The share of energy costs in total costs averages 65 percent higher in developing countries than in developed countries. Such comparisons also need to consider technological and production differences within a sector. For example, Mexico's steel sector is based on direct reduction of iron ore, whereas the United States increasingly uses electric furnaces to melt scrap (Ayres 2010). Also, developed countries produce more finished goods than do developing countries, so the value added is higher. Comparisons also need to consider differences in labour costs.

How energy prices vary

Though not as influential as technological and economic processes in determining the volume of energy inputs, energy's share in total costs is also determined by the price of energy and other inputs. Coal and oil, the main fuel sources, are traded internationally, and power generation technologies are fairly standard, so the price of energy should not vary widely across countries. Yet it does.

Take natural gas. Although prices in the Gulf countries are quite similar, prices in Qatar are more than double those in Saudi Arabia. The price of gas in Trinidad and Tobago, a major producer and exporter of liquefied natural gas, is nearly 7 times that in Saudi Arabia – Japan and the Republic of Korea pay more than 10 times as much.

Or consider electricity. The price of electricity supplied to industries in Europe varies greatly: in 2005, Italy paid 14 eurocents per kilowatt hour while Germany paid 7 (Eurostat n.d.). Although electricity prices have tracked rapidly rising fuel costs, large differences persist across countries, even for firms of similar size (Figure 4.1). In the United States in 2008, there were differences in the price of electricity of up to 50 percent in the pulp and paper industry and of up to 40 percent between the paper and pulp sector and the aluminium industry (Koc and Kaplan 2007; IEA 2009c).

Moreover, energy prices differ across sectors even within the same country. In Germany in 2000, the implicit energy price was 2.5 times greater in the machinery sector than in the food and tobacco sector (Figure 4.2).[2] In Thailand in 2006, the equivalent ratio was 10 times higher. In general, in most countries, energy-intensive sectors pay less per unit of energy consumption.

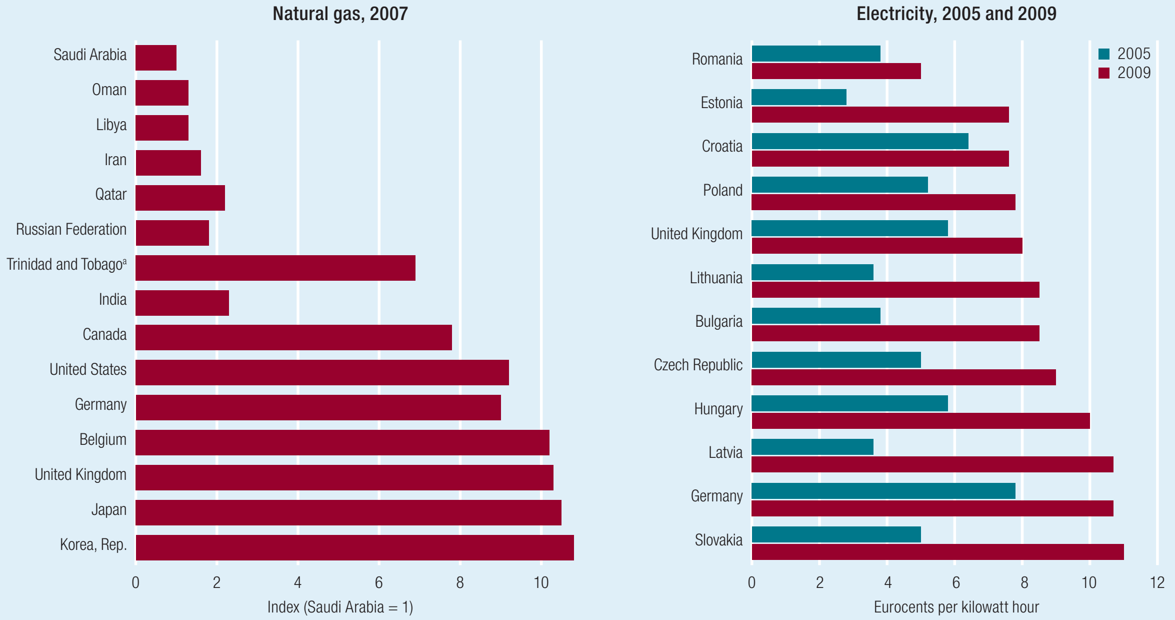
What accounts for energy price variation?

Both economic and policy factors account for these variations in energy prices. The economic factors relate to energy supply and demand. Price, for instance, is influenced by the share of different energy sources used. It also depends on the load factor of the power generator. Energy tariffs fluctuate with the cost of the fuels used in the energy mix and other costs associated with energy production and distribution. The timing of electricity purchase agreements also affects price, since energy tariffs for large users are usually governed by long-term electricity contracts.

"Both economic and policy factors account for the wide variations in energy prices

Figure 4.1
Price differentials in natural gas and electricity

Big differences in what countries charge for natural gas and electricity

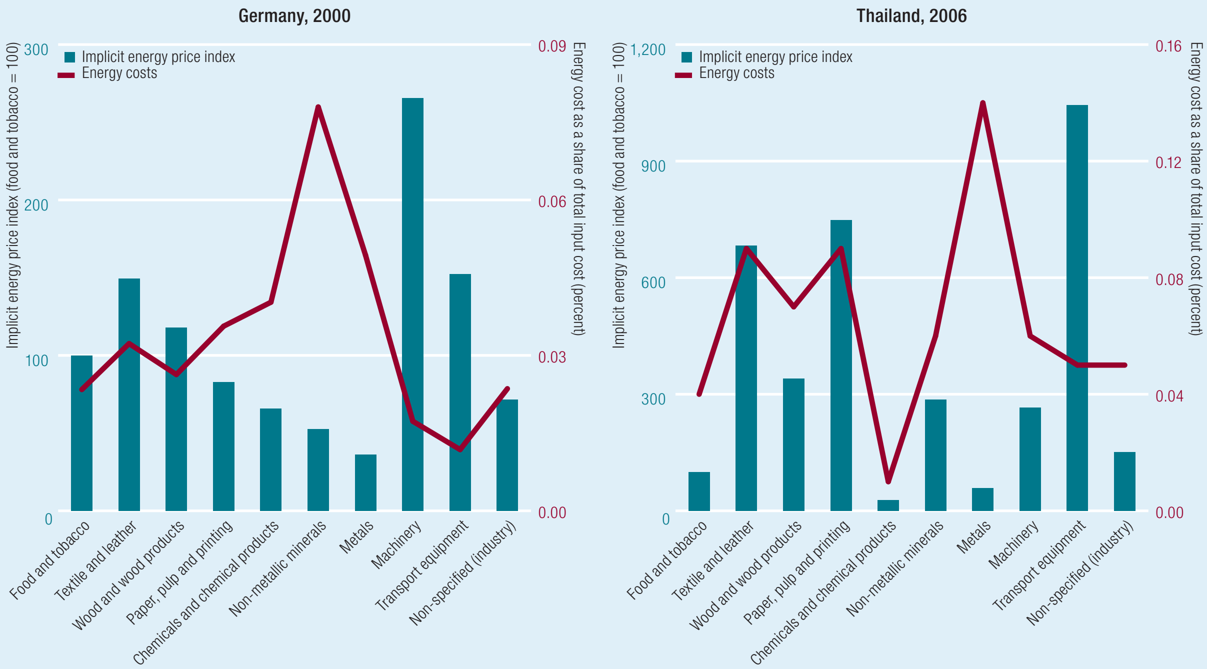


a. Liquefied natural gas.
Note: Price in selected gas-producing countries.
Source: Saygin et al. 2009.

Note: Includes non-manufacturing firms.
Source: Eurostat.

Figure 4.2
Implicit energy prices and energy costs in Germany and Thailand, by sector, 2000 and 2006

Some sectors pay more for energy than others



Source: Adapted from Upadhyaya (2010).

> **Investments in new plants and production technologies generally result in major savings in energy consumption and costs as well as gains in production efficiency and product quality**

Policy factors affecting energy prices include subsidies, taxes and regulations. In many developing countries energy markets are still heavily controlled if not directly in government hands. Governments often use energy taxes to enhance revenue. In 1987, the Chinese government raised electricity tariffs by two cents per kilowatt hour (the "two-cent policy") for all non-residential uses except for some electricity-intensive industries (Hang and Tu 2007; Wang, Qiu and Kuang 2009). The extra revenue went to finance power plant construction.

Risks and rewards of investing in industrial energy efficiency

Many industrial energy-efficient improvements are a by-product of investments undertaken for other reasons and that improve overall productivity. Investments in new plants and production technologies generally result in major savings in energy consumption and costs as well as gains in production efficiency and product quality. The extent of energy savings from such investments may be difficult to gauge, though there is reason to believe that they can be substantial.

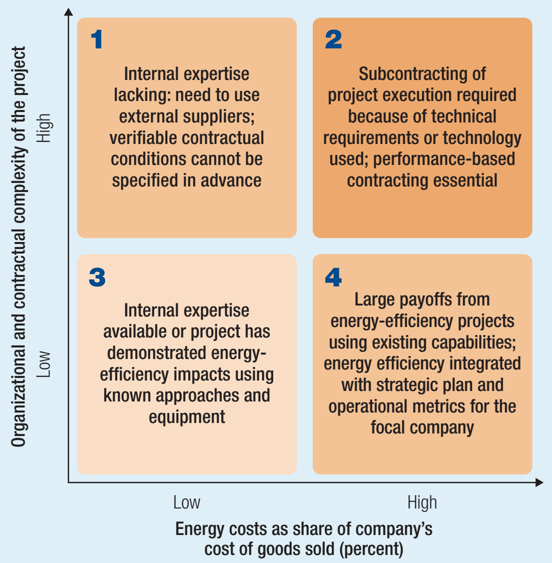
But how do managers decide whether to invest in dedicated energy-efficiency projects – investments with the primary purpose of improving energy efficiency (and hence for which only energy savings are relevant)? The company's energy cost and the complexity of the project are major determining factors.

Figure 4.3 classifies investment projects on two dimensions: importance of energy costs and project complexity (Kleindorfer 2011). The greater the company's relative energy costs (measured as the ratio of energy costs to the total cost of goods sold), the larger the potential payoffs and the greater the attention management is likely to give to saving energy. Project complexity includes operational, technical, organizational and contractual complexity. The larger the number of external parties (for example, if unique expertise or equipment is required and is available only from specialist companies), the more difficult the coordination and the higher the transaction costs.[3] For high energy-cost industries, critical projects are likely to be more directly aligned with company operations, so the company will already have project-relevant expertise to oversee or implement the project.

Quadrant 1 projects are low energy-cost and high-complexity and are rarely implemented because the high transaction costs usually exceed the modest energy savings. An exception could be the bundling by an outside partner of many small projects of similar technology or exceptionally attractive rates of return.

Quadrant 2 projects are high energy-cost and high-complexity in energy-intensive companies. The projects generally require multiple organizational providers and sophisticated contracting and finance guarantees. Examples include investments in new kiln technologies in cement companies and fuel-switching projects in pulp and paper plants. Unlike new infrastructure projects and power plants, whose rate of return may be guaranteed by the government or by major private operators (for example, through build, own, operate and transfer contracts), these large industrial energy-efficiency projects require separate measuring of project benefits in advance. Contracting against these benefits can raise the cost of capital (Box 4.1).

Figure 4.3
Criteria for making energy-efficiency project decisions



Source: Kleindorfer 2011.

“Energy-efficiency projects need to be subjected to both financial and risk analysis

Quadrant 3 projects are low energy-cost and low-complexity and are generally simple and straightforward with proven technologies and low cost, such as efficient lighting. Implemented by the company or by a local utility as part of a demand-side management programme, such projects would include no- and low-cost operations and maintenance measures that could be implemented internally. Examples are installing better meters, fixing leaking steam pipes and reducing use of compressed air. Companies can task their engineering and facility maintenance divisions to develop portfolios of energy-efficiency projects to help meet company cost and energy targets. The central impediment is generally not risk but energy cost savings too small to appeal to management.

Quadrant 4 products are high energy-cost and low-complexity and may include projects in energy-intensive sectors using internal capabilities to implement proven technologies, such as using new fuel sources in cement or electric power. When these projects are for specific modular purposes, use existing technology and are provided by suppliers with a good track record, they are low in complexity and risk. Projects would typically be one-on-one deals, with major suppliers selling demonstrated solutions and with built-in risk mitigation and financial guarantees (Box 4.2).

Economic feasibility – evaluating a project’s financial worth

Any investment decision also has financial considerations. Energy might be a large cost, but all profitable possibilities for reducing it might already have been explored or transaction costs might be too high. Conversely, energy costs might be small, but there could be promising investment opportunities for improving

Box 4.1

Weighing a high-complexity–high energy-cost project in South Africa

The Highveld Corporation’s Transalloys manganese alloy smelter energy-efficiency project in Mpumalanga Province, South Africa, illustrates a high-complexity project in a high energy-intensive company. The project was to retrofit Transalloys’ five furnaces with new electric arc furnaces, including related control and peripheral systems. The project was expected to reduce electricity consumption per tonne of alloy produced, with savings from lower electricity consumption and lower carbon dioxide emissions. (Most of South Africa’s electric power comes from coal-fired plants.)

A combination of subsidized energy prices, foreign exchange risk and production-yield uncertainty, together with energy’s centrality in manganese alloy production, made the project a high-intensity, high-complexity – and high-risk – project:

- *Low electricity prices.* Steady increases in subsidized electricity prices created uncertainty over whether prices would continue to rise. Prices were projected to remain low, reducing the incentives for saving electric power.
- *High investment cost.* Total initial investment cost for retrofitting all five furnaces was around $17.5 million. Annual savings in electricity and operations and maintenance costs were projected at $2.4 million. Even if such savings in energy and maintenance costs continued, the project was not considered financially attractive.
- *Uncertainty in market prices and exchange rates.* Whether the project increases output depends on the market price for the silicomanganese alloy, which was sold into global markets at dollar-based prices. This was an unsettling prospect, given the large upfront investment cost.
- *Uncertainty on yields, technical conditions and maintenance costs.* Furnaces are central to Transalloy’s production process, adding uncertainties in retrofitting to other equipment, as fit is not always guaranteed.

Highveld received additional funding through the Kyoto Protocol’s Clean Development Mechanism (which allows high-income countries to invest in emission reductions in developing countries to meet their own emission reduction targets), and the project was launched. A project evaluation conservatively estimated savings of more than 500,000 tonnes of carbon dioxide over the lifetime of the project (approximately 50,000 tonnes a year over 10 years). Valued at the low end of expected carbon dioxide prices in the EU market (around €15 per carbon credit), annual carbon revenues would amount to another $0.6–$1.0 million a year, enough to drive the project solidly into the black.

Source: Kleindorfer 2011.

> **Investment risks may vary with the country, sector, business and technology and over time**

Box 4.2
Weighing a low-complexity–high energy-cost project in China

The Dongying Shengdong Energy Management Company (DSEMC) in China installs power generators for industrial clients, such as Chinese steel plants and coal mines, using waste gas from these operations (that would otherwise be flared or released to the atmosphere) to operate electric power generators. The power generated helps meet the electricity demand of the company providing the waste gas, while selling excess electric power into the grid generates additional revenues. These are low-complexity and high energy-intensity projects.

They are low complexity because purchasing companies enjoy one-stop shopping. DSEMC installs the generator, negotiates contracts with the local electricity supplier and operates the generator. It then sells the electric power generated with the waste gas back to the company at marked-down prices, selling any excess to the grid. What makes this a win-win industrial energy-efficiency project for energy-intensive companies is the conversion of otherwise wasted energy into a valued energy stream.

Source: Kleindorfer 2011.

energy efficiency. Thus, energy-efficiency projects need to be subjected to both financial and risk analysis.

Standard financial procedures are used to evaluate the economic feasibility of energy-efficiency projects by estimating the net monetary effects of a project's costs and benefits over its useful life. The costs include capital outlays, operating and maintenance expenditures and costs associated with downtime. The primary benefit is lower energy costs, but there may be additional savings on materials and other inputs, with co-benefits such as improved reliability. Three common evaluation techniques are simple payback, return on investment and net present value.

Simple payback is the time in years for cumulative cash flow (net benefits) to equal the project's capital cost. This method measures the time it takes a project to pay for itself. For example, for South Africa's Highveld Corporation's $17.5 million investment that returns $2.4 million a year (see Box 4.1), payback is 7.5 years. Often, small projects are evaluated solely on their initial capital outlays and cost savings. Short payback periods make projects attractive investments, and many firms are reluctant to invest in projects with paybacks longer than two or three years. However, this cut-off varies widely by company and project size (Brealey, Myers and Allen 2008).

The more elaborate evaluation methods, return on investment and net present value, take the time value of money into account. They compare a project's worth with that of other investments (including no-risk financial instruments). Return on investment is the discount rate that equates the value of estimated future cash flows (net benefits) arising from an investment with the initial capital outlay. Net present value is the value of the future cash flows (discounted at a set rate) minus the initial capital outlay. High return on investment or net present value makes investment projects attractive. Depending on the company and the investment size and risk, industrial projects are commonly required to have returns on investment of 15–30 percent to be considered attractive. Highveld Corporation's internal rate of return was only 10 percent (see Box 4.1), making the project only marginally attractive (Brealey, Myers and Allen 2008).

The risk factor in industrial energy-efficiency investment decisions

High discount rates for energy-efficiency investments and the rejection of particular energy-efficient technologies may be rational responses to risk. Stringent investment criteria are appropriate when there are doubts about whether a business will survive in coming years. Risk may arise from overall economic trends (inflation and interest rates), potential changes in government policy, trends in input and output markets (for example, fuel and electricity prices), financing risk (such as the anticipated reaction of capital markets to increases in borrowing) and technical risks associated with individual technologies (for example, unreliability; Sorrell et al. 2004). These risks might vary by country, sector, business and technology and over time. Kleindorfer (2011) identifies three main risk categories: technical, external and business.

> **While some companies might also be driven by environmental and social responsibility concerns, they still need to find a solid economic rationale for energy-efficient investments**

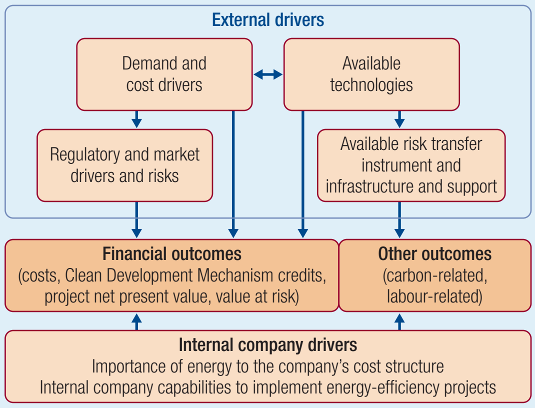
Technical risk is associated with technology and its relation to the industrial process. Most companies want to avoid any interruption of the core production process, unless it can be aligned with a scheduled shutdown. Two dimensions underlie these uncertainties: the perceived uncertainty of the technology itself and the compatibility of the new technology with the production process. If the new technology is perceived to be unreliable, the risk of breakdowns and disruptions might outweigh any potential benefits from reduced energy costs. Such risks are associated with new and unfamiliar technologies, which is why government-funded demonstration programmes aim to increase confidence and disseminate information and awareness of these technologies. Technical risk is usually higher in developing countries (especially least developed countries) than in developed countries because there is less technical support for new technologies.

External risk is associated with multiple uncertainties about economic trends, government policy, and energy and other prices – all factors that individual companies cannot influence. Consider a metal working company in Colombia, which switched its furnaces from electric power to natural gas in 2001, when gas prices were low (De Simone 2010). This change later became a source of concern as the price of natural gas was expected to increase about 30 percent by 2011.

Although uncertainty about future energy prices is often perceived as a barrier to energy-efficiency investments, it can also be an incentive. When prices do not increase as much as expected (or even decrease), investment earnings fall short. But when energy prices rise, so do costs savings.

Business risk is related to the uncertainties associated with shifting course. Companies tend to be risk-averse and avoid switching to a new strategy that is fraught with uncertainty (Bremmer et al. 2007). When a company is doing well, investments may be attractive, but bad results can make a company cut back on investments, particularly non-core investments such as energy efficiency. Upper management might see the potential for substantial cost reductions but still give such investments a low priority when sales volumes fall.

Figure 4.4
Valuation and risk drivers for energy-efficiency projects



Source: Kleindorfer 2011.

The standard approach to energy project valuation encompasses energy demand estimates, regulatory and market scenarios, trends in components contributing to capital costs, operating costs and carbon offset revenues, when applicable (Figure 4.4). The objective is to understand and value financial returns and to compare project returns and risks relative to a well defined benchmark case (typically the status quo) over several years.

Does investment in industrial energy efficiency pay?

Investments need to be profitable. While some companies might also be driven by environmental and social responsibility concerns, they still need to find a solid economic rationale for energy-efficiency investments. Investing in energy efficiency needs to be at least as profitable as, if not more profitable than, other options.

Strong evidence from developed countries

A vast literature on energy-efficiency measures shows enormous potential for cost savings, but most of the savings go unrealized, even in developed countries.

> A vast literature on energy-efficiency measures shows enormous potential for cost savings, but most of the savings go unrealized, even in developed countries

Start with the United States. Early studies by the US Department of Energy found that the adoption of industrial energy-efficient technologies and related managerial practices promoted by their programmes had a payback period of one month to two years (USDOE 2010). Another early study, reported in Nelson (1989) and Nelson and Rosenberg (1993), on industrial energy-efficiency projects in Dow Chemicals over 1981–1993 showed that 575 audited projects costing less than $200,000 had payback times of less than one year and yielded an average return on investment of 204 percent and savings of $100 million a year. Although the number of funded projects increased each year, there was no evidence of saturation. Numerous opportunities were still available with payback times of less than a year. In other words, the low-hanging fruit was picked, but it grew back. Tonn and Peretz (2007) provide more recent evidence, reporting that standard awareness- and capacity-building industrial programmes in the United States promoting energy efficiency typically identify up to 30 percent energy savings in plants. Such programmes are found to be quite profitable for the firms, for job creation and for tax revenues.

The European experience confirms the US findings. Jochem and Gruber (2007) report that around 1,000 large Swiss firms involved in energy-saving learning networks were pocketing around €110,000 in net annual profits per company. In Germany's Baden-Württemberg region, such networks had combined net earnings of €450,000 in 2004. A study of energy-efficiency investments by 70 industrial firms in six OECD countries (including in food manufacturing, building materials, steel manufacturing, paper manufacturing, chemicals manufacturing and textile manufacturing companies) found an average economic payback of 4.2 years and combined net savings of around $28.5 million (Worrell et al. 2001). Payback fell to 1.9 years once the non-energy benefits of the investment were included.

Energy efficiency is also profitable in developing countries

A few studies find that energy efficiency is also profitable in developing countries. Taylor et al. (2008) found that more than 80 percent of 455 World Bank–financed projects in 11 developing countries recovered their capital cost in 30 months or less. The average energy cost savings was $11 per barrel of oil-equivalent (boe; the discounted present value of the savings, based on an assumed 10-year investment life) on an average global price of $60 per barrel for crude oil in 2007. Savings varied from less than $3 per boe for modifications of steam thermal systems and $6 per boe for industrial energy recovery to $15 per boe for better insulation and windows, $19 per boe for district heating upgrades and $23 per boe for better lighting systems (the most expensive category).

UNIDO conducted an email survey of 357 industrial firms in 25 developing economies, based on a convenience sample, aimed at obtaining a basic understanding of the rationale behind investing in industrial energy efficiency and at illustrating the key energy-efficiency issues confronted by firms.[4] Of these firms, 261 were followed up by email or telephone to explore their responses in more depth. Face-to-face interviews were conducted with representatives of 96 firms in China, Colombia, Nigeria, Peru, Tunisia and Viet Nam to probe into the rationale for their decisions (UNIDO 2010h). Firms were included in the survey if they had invested in at least one project whose aim was to reduce energy use or costs; they were also queried about energy-efficiency projects they had decided not to take on. Investments in energy-efficiency projects totalled $613.7 million, and individual investments ranged from $100 to $73 million.

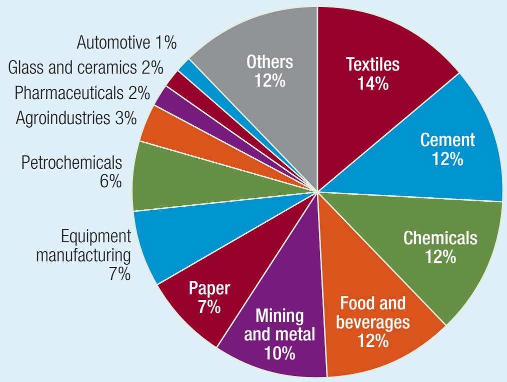
Projects were classified by sector (Figure 4.5), investment type, functional change and size. Six types of investment were identified:

- Direct equipment replacement (36 percent) related to switching energy sources (ovens, engines, boilers).
- Waste reuse (14 percent) arising from the production process, such as biomass, as a source of energy. May require some small-scale equipment purchase.
- Residual temperature reuse (14 percent) involves using hot or cold air or water from the production process to provide additional plant cooling or

A study of 455 World Bank–financed projects in 11 developing countries found that more than 80 percent recovered their capital costs in 30 months or less

Figure 4.5
Sectoral composition of UNIDO sample of industrial firms investing in energy efficiency, 2010

The UNIDO survey of firms investing in energy-efficiency projects covered a wide range of sectors



Source: UNIDO 2010h.

Box 4.3
Case study: PT. Pindo Deli Pulp & Paper repairs steam leaks

PT. Pindo Deli Pulp & Paper, an Indonesian company with a production capacity of 1,465,000 tonnes per year, produces photocopy paper, specialty paper and tissue paper. The project, supported by the United Nations Environment Programme, focused on machinery that produces mainly photocopy paper with a production capacity of 240,000 tonnes per year.

The project found many steam leaks, steam-trap leaks and uninsulated or poorly lagged steam pipes. The company conducted a survey to locate all the steam losses not accounted for and followed up with a repair campaign.

Steam losses dropped from 10,199 tonnes per month in 2003 to 8,165 in 2004. With an investment cost of $200,000 and annual cost savings of $366,192, the payback period was just six months. The company reduced natural gas consumption by 46,000 tonnes a year and carbon dioxide emissions by 311,000 tonnes a year.

Source: UNEP 2006.

heating. May require some small-scale equipment purchase.

- Pipes and insulation improvements (13 percent) aimed at reducing temperature or pressure loss from steam and other pipes (Box 4.3). May require some small-scale equipment purchase.
- Better use of infrastructure (12 percent) through changes in shift schedules, use of daylight and natural ventilation and similar changes.
- Fuel optimization (11 percent) by reducing the size of coal chips to raise oven temperatures or by modifying steam turbine pressure. The change originates with the fuel, not the equipment.

Projects were also distributed according to functional change into two broad types: technological reengineering (74 percent of projects) and process reorganization (26 percent); and according to size into three groups: less than $10,000 (27 percent), more than $100,000 (35 percent), and in between (35 percent).

In line with practice in developed economies, the survey found that more than 90 percent of surveyed firms in developing economies used simple payback rules to assess the financial viability of energy-efficiency projects.[5] Firms approved projects only if they had a simple payback of 2–3 years. The mean payback period for 119 projects with data was 23 months (Figure 4.6). Internal rate of return assessments were reserved for larger projects.

As mentioned, however, the payback approach has drawbacks (Brealey, Myers and Allen 2008; Lefley 1996; Remer and Nieto 1995). It neglects both the income generated after the payback period has expired and the time value of money. And though it may be a simple way to assess the profitability of individual investments, it is not an accurate means of comparing investment alternatives. Doing that requires net present value or internal rate of return calculations.

Using assumptions for the useful life of projects of 3, 4, 5 and 10 years, it is possible to determine different internal rates of return from the reported payback periods and compare them across projects by sector, type of investment, functional change and size (Gordon 1955; Holland and Watson 1976; Lefley 1996; Newnan 1969; Sarnat and Levy 1969; Figure 4.7).

For projects with a three-year lifespan and no resale value, the estimated mean internal rate of return

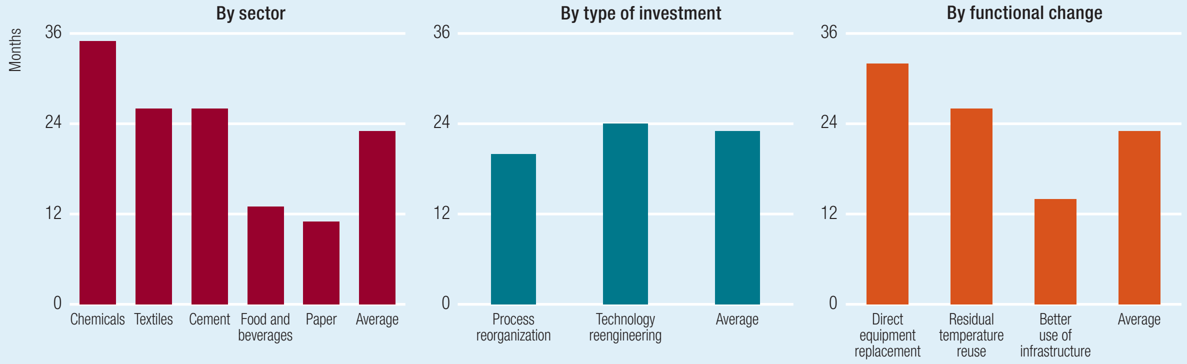
The data collected by UNIDO suggest a wide range of profitable opportunities to improve energy efficiency in all industrial sectors

4

Figure 4.6

Payback period of UNIDO sample of industrial firms investing in energy efficiency

Payback periods averaged 23 months in the UNIDO survey of industrial firms investing in energy-efficiency projects



Source: UNIDO 2010h.

was 25 percent, but the rate rose with each additional year of life, to 37 percent for 4 years, 43 percent for 5 years and 50 percent for 10 years. These higher rates compare favourably with average returns in capital markets, which are typically lower over comparable timeframes. Countries with high interest rates tend to have higher inflation, wiping out some of the gains of financial investments. And while some stock markets provided attractive returns in some years (2003–2004 and 2009, for example), energy-efficiency investments were far more profitable over longer periods.

Internal rates of return varied considerably across sectors and type of investment in the sample. Rates of return were lower in projects in process sectors, such as chemicals and cement, than in discrete product sectors, such as equipment manufacturing and automotive. Making better use of infrastructure, sealing pipes and improving insulation were extremely profitable; direct equipment replacement was less so. Projects involving process reorganization, especially when they cost less than $10,000, were highly attractive, with rates of return of up to 125 percent for projects that would last 10 years. Even for a more realistic project lifetime of three years, rates of return exceeded 100 percent. Paper, food and beverages, and textile firms had many projects of this type. By contrast, technological modifications costing more than $100,000 had far lower rates of return. Many of these projects needed to operate for more than five years to justify the investment.

The picture that emerges from this survey is that investing in industrial energy efficiency is profitable, but how profitable depends on the project and time horizon. More profitable projects commonly require small investments, involve process reorganization and housekeeping measures, use existing infrastructure better or improve pipes. These would fit in the low-low quadrant 3 projects in Figure 4.3: they are not organizationally, technically or contractually complex, and they have a relatively small impact on energy costs and company profits. Projects that involve larger investments and require changing machinery and equipment (mainly in process sectors) are less profitable and require longer periods to mature, though they will probably have a larger impact on corporate profits. These projects would fit in the high-high quadrant 2 and high-low quadrant 4.

Does this mean that all energy-efficiency projects are profitable under normal investment criteria? Clearly not. Generally speaking, the more organizationally and technologically complex a project becomes, the lower its profitability. Many energy-efficient technologies are likely to remain unprofitable for some time, at least until environmental damages are properly priced. But the data do suggest a wide range of profitable opportunities to improve energy efficiency in all industrial

> **“ For projects with a three-year lifespan and no resale value, the estimated mean internal rate of return was 25 percent, but rose with each additional year of life**

Figure 4.7
Internal rates of return of industrial energy-efficiency projects, by expected lifetimes

Internal rates of return of energy-efficiency projects rise with expected lifetimes

Note: Numbers in parentheses are number of projects.
Source: UNIDO 2010h.

> **“While investments in industrial energy efficiency are aimed primarily at profitability, they generally yield other economic benefits as well**

sectors. It seems likely that firms in developing countries are unaware of many of these opportunities.

The evidence presented above focuses on the insights from a few case studies. Does the relationship between investment in energy efficiency and profitability also hold for a wider, representative sample of firms? To find out, UNIDO conducted a study using the World Bank enterprise surveys database, which contains detailed information on energy efficiency and profits (Cantore 2011a; Cantore and Cali 2011).[6] The study investigated the relationship between profitability and energy intensity (ratio of energy consumed to total sales) using a large sample of firms from 29 developing countries. After controlling for firm characteristics such as age and size, the analysis found an inverse relationship in 27 countries between energy intensity and profitability, which was significant at the 0.05 level in 13 of them.[7] It also found an inverse relationship that was significant in 9 of the 15 manufacturing sectors for which data were available.

Are there other economic benefits from investments in industrial energy efficiency?

While investments in industrial energy efficiency are aimed primarily at profitability, they generally yield other economic benefits. Cleaner, more efficient technologies can improve output quality and reduce throughput and waste streams of energy, water, materials and by-products. For example, switching from vertical shaft kilns in the Chinese cement industry not only reduced energy intensity but also improved product quality, thus boosting sales. Companies that adopt energy-efficient technologies early may also benefit from enhanced competitiveness and first-mover advantage (Eichhammer and Walz 2011).

Because improvements in energy efficiency typically require higher skilled workers and managers, firms also invest in training, which imparts technical skills, raises awareness of the benefits of efficiency and best practices and increases worker involvement. These and other non-energy benefits, such as lower maintenance costs and increased output, often boost overall productivity. Worrell et al. (2003) find that more than two-thirds of industrial energy-efficient technologies not only save energy but also yield productivity gains through reduced capital costs or increased throughput compared with state-of-the-art technology.

Examinations of the relationship between total factor productivity and energy intensity using World Bank enterprise survey data for 24 developing countries found a strong inverse relationship between energy intensity and total factor productivity in 23 of the countries, suggesting that energy efficiency is accompanied by innovation and efficient management of other inputs (Cantore 2011a,b; Cantore and te Velde 2011). Another study of 77 energy-efficiency projects in six OECD countries in a range of industrial sectors (including food, building materials, steel, paper, chemicals and textiles) found 224 non-energy benefits through reduced material and water use, less wear and tear, lower labour costs, improved morale and lower noise levels (Worrell et al. 2003). The study also found that in 52 of the 77 industrial energy-efficiency investment projects with relevant data, the average payback improved from 4.2 years to 1.9 years after monetizing the co-benefits.

There are also important environmental co-benefits (see Chapter 3), as the example of a Chinese iron and steel company's efforts to recover heat and reuse steam illustrates (Box 4.4). Understanding the full benefits of investing in industrial energy efficiency is vital because incorporating them into cost analyses can result in a more favourable evaluation.

The social dividend

It is well established that economic growth is driven by improvements in productivity arising from sustained technological change. Productivity gains are converted into higher profits that can be redistributed as increased wages; invested to expand output, benefiting input-providing and output-using sectors; used for developing newer technologies and products; passed on to consumers in lower prices or translated into higher demand for existing goods. Whatever the transmission mechanism, output and demand

“By reducing resource use, cost-effective energy-efficiency improvements increase firm and industry productivity, which leads to an expansion in employment

Box 4.4
Chinese company secures environmental co-benefits

Dragon Iron & Steel Co., Ltd. is a Chinese state-owned integrated steel plant in Shijiazhuang, the capital of Hebei Province. It produces 2 million tonnes of carbon structural round steel annually. The company uses waste heat from two converter furnaces to generate steam. An energy assessment noticed that the operating pressure was much lower than the design pressure and that the resulting low-pressure steam could not be used and was vented. The problem was caused by steam leaks in the pipes and furnace hoods. The company invested $720,000 to replace four gas hoods to recover heat and reuse steam. Annual savings are $900,000, and the payback period was about 10 months. Steam recovery of 14,800 tonnes a year also reduced carbon dioxide emissions, an environmental benefit.

Source: Zeng and Rong 2010.

reinforce each other through multiplier effects in a virtuous cycle of higher growth, employment generation and rising living standards, which is the essence of development.

Productivity and employment gains

Industrial energy-efficiency gains lead to a similar virtuous circle. By reducing resource use, cost-effective energy-efficiency improvements increase firm and industry productivity, which leads to an expansion in employment. The employment impact takes place directly through the price elasticity of demand, which may result in higher demand for the goods produced. This higher demand affects both firms investing in industrial energy efficiency and manufacturers of energy-efficient equipment, which benefit from more orders.[8] However, there may also be short-term employment losses until the impact of renewed demand kicks in, as a recent United Nations Environment Programme report on the green economy suggests (UNEP 2011).

Evidence on the impact of energy efficiency on employment generation is still limited, especially for industrial energy efficiency. A recent study in the US state of Missouri on the impact of policies to promote energy-efficiency investments, including some in the manufacturing industry, estimated an impact of 8,500 net jobs by 2025 over and above the business-as-usual scenario (ACEEE 2011). A similar study for South Africa, but focusing on industrial energy efficiency (improvements in speed drives, motors, lighting heat and ventilation), estimated 4,000–60,000 new jobs over 2005–2020 in an efficiency scenario compared with the base scenario (Howells, House and Laitner 2005).

While the overall impact of industrial energy-efficiency improvements on employment is difficult to assess and might not be large overall, it might be larger among micro- and small enterprises in developing countries. Micro-, small and medium-size manufacturing firms frequently account for most industrial employment in developing countries and play a leading role in creating jobs, promoting growth and reducing poverty. But these firms also tend to be less energy efficient and more polluting (per unit of production) than larger firms, and they lack the in-house capacity to resolve their technical problems (Rath 2011). Thus, energy-efficiency options might offer them greater potential for closing their efficiency and productivity gaps and engaging in rapid growth.

Greater job security is another social co-benefit (Kanbur and Squire 1999). In India, highly polluting and energy-inefficient practices in energy-intensive sectors have threatened many firms with closure for violating pollution standards. Workers would suffer job and income losses from plant closure. Energy-efficient technologies could reduce the risk of lost income while contributing to higher returns, greater competitiveness and reduced business risk. Switching to energy-efficient technologies could also reduce the risk of competitive slippage in domestic and export markets as environmental standards become more stringent (Rath 2011).

Better access to energy

Industrial energy efficiency also has a key role in improving access to energy. Today, some 2–3 billion people are excluded from modern energy services and rely on traditional biomass for cooking and heating;

> “In many developing countries, energy shortages, unreliable and poor quality supply and inefficiencies in use have high economic costs in materials waste, capacity utilization and inefficient investment in standby equipment

about 1.5 billion people have no access to electricity (AGECC 2010). Access to modern energy services, particularly for women and girls in low- and middle-income countries, could help sustain industrialization by making possible income-generating activities, thus also lifting many out of poverty. Furthermore, in many developing countries, energy shortages, unreliable and poor quality supply and inefficiencies in use have high economic costs in materials waste, low capacity utilization and inefficient investment in standby equipment. Cost-effective improvements in industrial energy efficiency could help control growth in energy use and waste, redeploy expenditure into energy infrastructure, enable adequate provision of energy services at affordable cost and fund better energy access.

Improved health outcomes

There are also health advantages of greater energy efficiency, as shown in the impacts of the change to high-efficiency technologies in the brick industry in the Xuan Quan commune in Hung Yen Province of Viet Nam (Box 4.5) As highlighted in Chapter 3, greater energy efficiency reduces the atmospheric emission of damaging substances such as sulphur oxides, nitrogen oxides, smoke and airborne suspended particulate matter. Emissions from burning fossil fuels for industry, transportation and power generation are the largest sources of urban air pollution, with harmful effects on health (Rath 2011). Ardestani and Shafie-Pour (2009) estimated the health damage from air pollution in Iran at 8.4 percent of GDP. Introducing energy-efficient technologies and conservation practices can improve the health and life expectancy of factory workers, particularly by reducing upper respiratory tract illnesses and asthma attacks. The poor stand to gain the most, because pollution-intensive industries tend to locate in low-wage areas (Dasgupta, Lucas and Wheeler 1998).

Mills and Rosenfeld (1996) detail a range of health co-benefits from energy-efficient technologies. Energy-efficient high-frequency electronic ballast, which prevents flickering in fluorescent bulbs, causes fewer headaches and less eyestrain among office workers than does standard magnetic ballast. Several forms of anxiety have been found to diminish after a shift to high-frequency lighting. Mills and Rosenfeld add that exposure to daylight also has positive health impacts since an absence of windows is correlated with an increase in transient psychosis and absenteeism by factory workers. Light also affects melatonin levels, which are related to psychological depression affecting about 5 percent of the population.

High energy-efficient technologies can also improve the indoor environment, comfort and safety (Mills and Rosenfeld 1996). Variable-speed drives and air blowers and energy-efficient furnaces tend to be

Box 4.5

Increasing productivity and securing environmental and social co-benefits in Viet Nam

Brick-making is one of the most important industries in Viet Nam. However, brick kilns tend to be highly inefficient and to use low-quality, high-sulphur coal, making brick production one of the most environmentally damaging activities in the construction sector. Brick-making leads to high levels of local air pollution and greenhouse gas emissions.

In response to government demands to phase out inefficient kilns, the Xuan Quan commune in Hung Yen Province, where family-scale brick production is common, introduced several Chinese coal- and energy-saving (45–50 percent reduction) vertical shaft brick kilns and adapted them to local conditions. Adding coal to the clay cut the breakage rate almost in half (from 7 percent to 4 percent).

In addition to cost reductions and quality improvements, the project resulted in several co-benefits:

- Reduced greenhouse gas emissions from more efficient use of coal in the kilns.
- Reduced local air pollution from burning less coal.
- Anticipated drop in respiratory illnesses from lower air pollution.
- Higher incomes for family brick-making firms.

The project has been replicated in other areas.

Source: GEF 2011.

“Investing between 2007 and 2030 to achieve current levels of best practice technology would improve energy efficiency 1.2 percent a year and save $365 billion in costs by 2030, excluding investment costs

quieter than the equipment they replace. Glazed windows keep household and factory occupants cooler in hot weather and reduce external noise; double-glazed windows can protect buildings against fire. Efficient lighting technologies such as fluorescent lamps and light-emitting diodes (LEDs) increase the reliability of warning signs, thus improving safety. Exhaust-heat recovery systems provide better ventilation than systems without heat recovery.

Is there still room for profitable industrial energy-efficiency investments?

Should companies actively seek industrial energy-efficiency investments? Studies suggest the answer is yes, in both developed and developing countries. In Sweden, research on energy-management practices in the pulp and paper and steel industries suggests that even among these energy-intensive industries, energy investments do not seem to be a high priority: only 40 percent of the mills and 25 percent of the foundries were trying to improve energy efficiency (Thollander and Ottosson 2010). A similar study by Worrell et al. (2001) in 11 developing countries shows that on average, companies implement only 56 percent of the recommendations from energy audits. That suggests that there is plenty of room for cost-effective improvements.

UNIDO estimates that industry currently spends around $1 trillion a year on energy, 55 percent of it in developing countries (Saygin et al. 2010; Saygin and Patel 2010). Energy cost savings from adopting best practice technologies (energy intensity in the top 10 percent of plants) in industrial energy-efficiency projects could reach $65 billion in developed countries and $165 billion in developing countries – 23 percent of total energy costs and 2 percent of MVA. Investing in best available technology (energy intensity in the most energy-efficient plant in the world) instead could yield savings of around 30 exajoules (EJ) a year, some 27 percent of global energy use by industry (60 percent of it in developing countries) and 6 percent of global energy use. Investing between 2007 and 2030 to achieve current levels of best available technology would improve energy efficiency 1.2 percent a year and save $365 billion in costs by 2030, excluding investment costs.

For best available technology, the largest technical improvement potential is in process sectors such as petroleum refining, iron and steel, non-ferrous metals, non-metallic minerals (mostly cement), chemical and petrochemicals, and pulp and paper (Table 4.2; Saygin et al. 2010). In some energy-intensive processes, such as steam crackers and aluminium, investment could reduce energy use 10–20 percent. Energy savings of some 16.3 EJ a year could be achieved in these sectors, the largest share of it in developing economies. In sectors such as aluminium smelting, pulp and paper, and cement production, developing economies have invested in modern energy-efficient technologies or are using alternative fuels. But small plants equipped with old technologies are the norm in most process sectors.

There is also considerable potential for investment in discrete product and combined sectors (Saygin et al. 2010). Although absolute energy savings tend to be lower than in process sectors, the savings over baseline consumption are substantial. Savings of up to 2.5 EJ a year could be achieved in the textile and food and beverages sectors and of up to 11.2 EJ a year in machinery, transport equipment, wood and other sectors, mostly in developing countries (Saygin et al. 2010).

The environmental benefits of best available investments are also substantial. Achieving best available technology would reduce carbon dioxide emissions 12–23 percent, or by as much as 1.3 gigatonnes (Gt) of carbon dioxide, a reduction of 12 percent in total industry emissions and 4 percent in global emissions from 2006 levels (IEA 2009b).

A reference point for long-term emission reductions is the IEA's blue scenario, which aims to halve global industrial energy-related carbon dioxide emissions by 2050 (IEA 2009b). Total direct and indirect industrial emissions in 2050 would be 42 percent below their 2006 level of 10.6 Gt. The baseline scenario, reflecting energy and climate policies that are already implemented or planned, contemplates

> **The largest technical improvement potential is in process industries**

Table 4.2

Technical and economic savings potential arising from industrial energy-efficiency improvements

Sector and product	Technical improvement potential (percent)		Total savings potential (exajoules per year)		Share of energy costs[a] (percent)		Carbon dioxide savings potential (tonnes of carbon dioxide a year)	Share of current emissions (percent)
	Developed countries	Developing countries	Developed countries	Developing countries	Developed countries	Developing countries		
Process sectors								
Petroleum refineries	10–15	70	0.7	4.6		50–60		
Chemicals and petrochemicals			0.5	1.8			300	20
Steam cracking (excluding feedstock)	20–25	25–30	0.4	0.3		50–85		
Ammonia	11	25	0.1	1.3				
Methanol	9	14	0	0.1				
Non-ferrous minerals			0.3	0.7				
Alumina production	35	50	0.1	0.5		30	45[b]	12[b]
Aluminium smelters	5–10	5	0.1	0.2	35–40	35–50		
Other aluminium	5–10	5	0.1	0.2	35–40	35–50		
Copper smelters		45–50	0	0.1				
Zinc	16	46	0	0.1				
Iron and steel	10	30	0.7	5.4	10–20	30	350	14
Non-metallic minerals			0.8	2.0				
Cement	20	25	0.4	1.8	25–30	50	450	23
Lime					40			
Glass	30–35	40	0.4	0.2		7–20		
Ceramics						30–50		
Combined sectors								
Pulp and paper	25	20	1.3	0.3		15–35	80	20
Textile						5–25		
Spinning	10	20	0.1	0.3				
Weaving					5–10	10–15		
Food and beverages	25	40	0.7	1.4		1–10		
Other sectors	10–15	25–30	2.5	8.7				
Total	15	30–35	7.6	25.1				
Excluding feedstock	15–20	30–35					12[c]	

Note: Potential savings based on universal application of best available technologies.

a. Share of total production costs (total fixed costs and variable costs, including depreciation).

b. All aluminium activities.

c. Includes only chemical and petrochemical, aluminium, iron and steel, and pulp and paper.

Source: Saygin et al 2010; IEA (2009b) for emissions figures.

Many options for improving industrial energy efficiency in developing countries appear to be highly profitable, even when compared with the most optimistic returns on financial investments. Yet few of the opportunities are being seized

a doubling of total industrial emissions by 2050. In the blue scenario, direct industrial carbon dioxide emissions would fall 21 percent (from 7.2 Gt to 5.7 Gt). Improved energy efficiency could contribute an estimated 40 percent of the direct emission reductions required from industry by 2050, compared with 30 percent through carbon capture and storage, 21 percent through fuel switching and 9 percent through recycling and energy recovery. In addition, indirect emissions would fall from 3.4 Gt in 2006 to 0.4 Gt in 2050, with the nearly complete decarbonization of the power sector under the blue scenario.

It can be done

There are many options for improving industrial energy efficiency in developing countries. Many appear to be highly profitable, even when compared with the most optimistic returns on financial investments. The options cut across all sectors, investment types and time preferences for returns. There are also many co-benefits that increase the financial attractiveness of energy-efficiency projects. The case studies suggest that, by and large, investing in energy efficiency pays. Improving industrial energy efficiency, by boosting profitability, contributes to economic sustainability.

Thus, investing in green industry seems to be profitable in both developed and developing countries. Particularly in developing countries, the potential for improvement remains considerable, even without putting a price on carbon emissions. Yet few of the opportunities are being seized. What is happening? Why are firms in developing countries not cashing in on the dividends of green industry and reduced energy use? Some blame market failure, while others blame organizational decision-making. These and other possible reasons are the focus of Chapter 5.

Notes

1. The ability to make decisions is constrained by cognitive and time limitations (Williamson 1985).
2. The implicit energy price is the total energy cost per sector (in 2006 US dollars) divided by the sector's total energy use (measured in kilotonnes of oil equivalent).
3. Transaction costs – information, consulting, negotiating, insurance, conflict resolution and legal costs (Sorrell 2007; Williamson 1985) – will be incurred whether the project is carried out in-house or through external contractors.
4. Bangladesh, Bolivia, Brazil, Chile, China, Colombia, Ecuador, Ghana, Guatemala, India, Indonesia, Lebanon, Mexico, Mongolia, Nigeria, Panama, Peru, Philippines, South Africa, Sri Lanka, Taiwan Province of China, Thailand, Tunisia, Uruguay and Viet Nam.
5. In a survey of project evaluation techniques used by 33 Fortune 500 industrial companies in the United States in 1991, 64 percent used the payback period to determine the feasibility and profitability of an energy-efficiency project (Remer, Stokdyk and van Driel 1993).
6. World Bank enterprise surveys are conducted regularly in a large number of developing countries. Details of the database are available at www.enterprisesurveys.org/.
7. This analysis included some 41,000 observations for more than 34,000 firms in 15 manufacturing sectors over 2000–2005. Control variables included age, number of workers, value of investment in equipment, ownership (foreign or domestic) and whether the company exported or had ISO90000 certification for good management practices (Cantore 2010; Cantore and te Velde 2011).
8. Parallel to the expansion of employment and output, there may also be increases in demand for energy, which may wipe out initial energy-efficiency gains. This is referred to as the rebound effect (van den Bergh 2010, 2011; Sorrell and Dimitropoulos 2007). See Box 5.6 for a discussion of the rebound effect.

Chapter 5

Barriers to industrial energy efficiency

If investments in improved industrial energy efficiency yield environmental, economic and social benefits, what is impeding firms from seizing these opportunities? Economists, assuming that unobserved costs, risks and inconveniences explain why potential gains are not being realized, are generally sceptical about the existence of large unexploited potential for profitable investments in industrial energy efficiency. Physicists and engineers, however, often see substantial opportunities (Jaccard 2009).

Aversion to investment seems to stem from a combination of failures in the markets for energy-efficient goods and services and departures from the rational behaviour of orthodox economic theory. These forces overlap to create barriers to improving energy efficiency, including:

- Lack of awareness of efficiency opportunities.
- Difficulty borrowing money for energy-efficiency investments.
- Inadequate technical know-how.
- Disconnection between those responsible for investing and those operating the equipment.

This chapter examines potential barriers to industrial energy-efficiency investments from both private and social perspectives based on a review of 160 recent studies and 96 UNIDO case studies (UNIDO 2010h). It looks at how barriers to energy efficiency arise and how they operate. Summarizing some of the evidence on how the importance of these barriers differs across contexts, the chapter concludes that these barriers persist despite having been known for years – because information is lacking, decision-makers neither make informed decisions nor benefit from their choices, energy prices are far below their production and opportunity costs, financing is unavailable and many hidden costs are prevalent.

Barriers, failures and hidden costs

Sorrell, Mallett and Nye (2011, p. 27) define a barrier to industrial energy-efficiency investment as a "mechanism that inhibits a decision or behaviour that appears to be both energy and economically efficient." Some barriers arise from failures in the technology and energy services markets, when private markets do not provide goods or services at a level that maximizes economic welfare. Most economic theory posits that organizations are rational and invest based on cost-benefit analysis (for example, selecting equipment that maximizes profits or utility based on initial price, productivity, reliability, running expenses and other costs). But rational agents do not always consider broader social benefits and costs (for example, how carbon emissions harm the environment and human health), thus often overlooking industrial energy-efficiency technologies that would be socially desirable (Arrow and Debreu 1954; Bator 1958; Greenwald and Stiglitz 1987).

How can we understand the failure to make seemingly rational economic decisions? One way is through transaction cost economics, which assumes that individuals make satisfactory rather than optimal decisions and rely heavily on routines and rules of thumb (Furubotn and Richter 1997; Simon 1959; Williamson 1985). Behavioural economics goes further, arguing that human decision-making is not just boundedly rational but systematically biased and erroneous (Kahneman and Tversky 2000; Piattelli-Palmarini 1994). For example, a loss aversion or a status quo bias can discourage individuals from taking on highly cost-effective investments (Samuelson and Zeckhauser 1988; Swalm 1966; Thaler 1991). A large body of experimental evidence demonstrates that such biases are universal, predictable and largely unaffected by monetary incentives or learning (Kahneman and Tversky 2000).

To explore economic, organizational and behavioural barriers to improving energy efficiency, the following sections consider market failures, limitations of human decision-making (bounded rationality) and various hidden costs.

Many profitable industrial energy-efficiency investments go unrealized because the decision-maker is unaware of the costs and benefits or is unable to get the information needed to invest with confidence

Market failures

Four types of market failures inhibit improvements in energy efficiency:

- Insufficient information.
- Split incentives.
- Energy prices and unreliability of supply.
- Limited access to capital.

Insufficient information

Many profitable industrial energy-efficiency investments go unrealized because the decision-maker is unaware of the costs and benefits or is unable to get the information needed to invest with confidence.

Insufficient information. Obtaining information on the energy performance of various technologies may be expensive, especially if the equipment is an "experience good" (energy savings can be determined only after purchase) or "credence good" (performance is not immediately evident even after initial consumption). Energy-efficient equipment will be undervalued if consumers cannot accurately assess the costs and benefits before purchase.

Most new industrial energy-efficiency technologies have yet to introduce good labelling schemes, so the cost of searching for information may be much greater than for established technologies. And because industrial energy-efficiency investments depend on context, energy and cost savings can sometimes be assessed only after installation. Assessment is at times difficult even after installation because of metering difficulties. Without submetering, for example, the performance of control systems, motors and variable-speed drives is difficult to monitor and evaluate. The net result may be organizational decision-making that is systematically biased against industrial energy efficiency.

Evaluating energy-saving opportunities requires information on the levels and patterns of energy consumption and how they compare with benchmarks, on specific energy-saving opportunities (such as thermal insulation retrofitting) and on the energy consumption of new and refurbished buildings, process plants and purchased equipment – and all three are often lacking to some degree. Without knowing where and how energy is used, companies cannot know where to look for savings and how to achieve them, so there is limited incentive to invest in industrial energy efficiency. These problems, common in all sectors and countries, are particularly acute in developing countries, which often lack the infrastructure necessary to become informed about the technological options (UNDP 2000; Box 5.1).

Box 5.1
Determining energy needs

Bennett Industries, a small Nigerian company, fabricates and assembles light fittings, fixtures and accessories. Its main source of energy is electricity, 95 percent of it supplied by its own generator. According to Bennett, its average energy costs are around 30 percent of production costs, well above the global average of 5–10 percent.

The company wants to invest in a cogeneration plant, using the waste heat from the on-site generation plant within the industrial processes. A manager interviewed for this report stated that Bennett, despite considerable effort, could not find a local expert to determine the optimum generator size and energy-efficiency possibilities.

Like Bennett Industries, many Nigerian companies know little about the technical options available or even what electricity capacity they need. One consequence is the oversizing of self-generation and other plants, resulting in inefficient operation on part load. Thus, there appears to be great potential for correcting generator dimensions to needed capacity.

Source: Masselink 2009.

Information dissemination and awareness. Despite research and experience identifying profitable energy-saving technologies with fairly short payback periods, industry may discount energy-efficiency measures because of a lack of awareness and organizational capacity (Morris, Barnes and Morris 2011). Limited public capacity for information dissemination makes it more difficult for firms in developing countries to get the information they need (Sorrell, Mallett and Nye 2011). A Nigerian manager interviewed for this study stated that "awareness about energy use, energy

> **Limited access to modern technology, engineering skills and related services further constrains developing countries' capacity to improve industrial energy efficiency**

reduction and energy efficiency is key. For example, at our company we make all personnel aware of energy consumption . . . At the plant, we have posters that show how much energy we used in the last months and what we planned to use" (Masselink 2010, p. 5). However, he also suggested that this practice is rare and that there is nowhere to seek support. Many developing countries lack public and private institutions that provide information on energy use, processes and technologies. As a result, companies remain unaware of cost-effective energy-efficiency opportunities (Schleich 2011).

Limited access to modern technology, engineering skills and related services further constrains developing countries' capacity to improve industrial energy efficiency. For example, management at a Tunisian textile company was aware of the potential benefits of energy-efficiency audits and projects but lacked the skills to take them on (Fokeer 2010). Colombian firms complain that they can sometimes get information on energy-efficient US equipment but not on European alternatives (De Simone 2010). Wison (Nanjing) Chemical Co., Ltd., a new company, had few simple options left to improve energy efficiency. Further improvements would require adopting cutting-edge energy-efficient technologies and industrial processes, but these are hard for the company to identify and adopt (Zeng and Rong 2010). Many of the required technologies must be imported, making technology adoption even more difficult, costly and time consuming.

Many equipment producers in developing countries know little about industrial energy-efficiency opportunities and have limited access to efficient technologies. A study of motor systems in China found that design engineers were "specialized in certain specific subjects . . . , tend to use existing or old products and equipment and are not aware of the latest energy-efficient products" (EEPC India 2006 quoted by Sorrell, Mallett and Nye 2011, p. 53). In such cases, the information deficits in production and demand reinforce each other.

A study of small and medium-size enterprises in India found that an industrial energy-efficiency technology can be developed and demonstrated in a group of firms and its benefits revealed (improved product quality, fuel savings, and environmental performance; Sethi and Ghosh 2008). But for the technology to be adopted on a wide scale, local fabricators must have the information and skills to produce the equipment according to strict quality standards, and local technicians must have the expertise to maintain and repair the technology – a difficult combination in developing countries (Box 5.2).

Another impediment is the lack of credible, third-party verification of claims made for a product or service. A recent study on energy-management practices in Indian small and medium-size enterprises

Box 5.2
The Firozabad experience with adopting new industrial energy-efficiency technology

Almost the entire small-scale glass industry in India is located in a single enterprise cluster in Firozabad, near Agra. Until the mid-1990s, these firms used traditional, high energy-intensity technologies and operating practices. The Energy and Resources Institute (TERI) in New Delhi, supported by the Swiss Agency for Development Cooperation, developed and promoted industrial energy-efficiency technologies for this sector, focusing on the coal-fired pot furnace. The project took on new urgency when the firms were pressured to switch from coal to natural gas.

In 2001, TERI introduced a gas-based recuperative pot furnace that reduced energy use by half over the traditional coal-fired pot furnace and 30–35 percent over the conventional gas-fired pot furnace developed by local entrepreneurs just a few years before (and adopted by most coal-fired pot furnace firms, which had no alternative). Next, TERI strengthened the capacities of cluster-level service providers through awareness campaigns and hands-on training, so that entrepreneurs could sustain the new technology without depending on external agencies. Nearly 60 of the 100-odd operating pot furnace firms in Firozabad have switched to the new recuperative furnace, and the waste-heat recovery technology has inspired innovation among entrepreneurs across the cluster. Other pot furnace firms have set up locally designed heat-recovery systems to improve the energy efficiency of their conventional furnaces.

Source: Sethi and Ghosh 2008.

“When an investment reduces energy costs, it is profitable for the company as a whole but that might not be clear to individual departments, so the investment may be overlooked

revealed that a third of the 14 percent that engaged consultants to study energy use did not implement the recommendations (Ghosh 2011). Respondents from non-implementing firms questioned the consultants' credibility and impartiality, believing that they did not know enough about how the firms operate. Respondents believed that consultants were tied to certain equipment manufacturers and promoted that equipment under the guise of professional advice.

The study of small and medium-size enterprises in India reveals several misconceptions about energy audits. Only 5 percent of surveyed firms had engaged an accredited energy auditor to conduct a formal audit (Ghosh 2011). Most firms know little about how an audit could identify energy-saving measures. Many smaller firms assumed that an energy audit involved government officials and worried about external interference. Others feared legal sanctions. Indian energy auditors corroborated these findings (Ghosh 2011).

Split incentives

When departments or companies cannot appropriate all the benefits of an investment, they are less likely to invest. In larger organizations, departmental accountability for energy costs may be important. For example, if departments are accountable for their own energy costs, they benefit directly from any savings from investment projects or housekeeping measures. But if cost savings go to the company as a whole, the departmental incentive is diluted (split incentives). When an investment reduces energy costs, it is profitable for the company as a whole, but that might not be clear to individual departments, so the investment may be overlooked. In such cases, employees might be making rational decisions given the incentives they are aware of, but the outcome of their collective actions might be suboptimal for the firm as a whole (Golove and Eto 1996; IEA 2007c; Masselink 2008; Sorrell et al. 2000). The split incentives problem worsens when no single department has explicit responsibility for managing energy costs – when no one department has all the information needed to manage resource and energy consumption effectively (Masselink 2009).

Submetering can strengthen incentives to reduce energy costs. A recent study of energy management practices in Thai cement and textile industries found that changing operational practices was an important enabler of industrial energy-efficiency measures (Hasanbeigi, Menke and du Pont 2010). Submetering and billing individual cost centres for energy use is one way to motivate change. Whether submetering makes sense depends on the balance of energy costs, the potential for energy saving, and the investment, staff and operational costs required to set up the submeters (Box 5.3).

Split incentives also influence equipment purchase (Sorrell et al. 2004). Responsibility for capital costs might not match responsibility for operating costs, and the transaction costs of reducing operating costs might outweigh the potential savings (Sorrell, Mallett and Nye 2011). A study of energy-efficient motor systems in China noted that the purchasers of electric motors within a company are generally not the end-users (Yang 2007). Often, people without the knowledge, information and incentives to minimize operating costs are responsible for procuring equipment, and energy management staff might not have the time to check their decisions. Maintenance staff, too, might have incentives unrelated to running costs, including energy consumption, focusing instead on minimizing capital costs or repairing failed equipment. Consider the Indonesian pulp and paper

Box 5.3
Carrots and sticks for energy efficiency

A Chinese company providing coal mining support and research and development for machinery links employees' year-end bonuses to their energy conservation performance. Efficiency experts suggested that the company also link its personnel policy (promotions, salaries) to energy conservation. Many Chinese enterprises have such policies. Employees in Hubei Huazhong Pharmaceutical Co., Ltd. are eligible for a reward of up to 28 percent of energy expenses below a baseline; they are penalized up to 28 percent of energy expenses above the baseline.

Source: Zeng and Rong 2010.

> **Firms' decisions on how much energy to consume and whether to invest in industrial energy efficiency are heavily influenced by energy prices, which rarely reflect the environmental costs of energy consumption, particularly the costs associated with greenhouse gas emissions**

company that contracted out its compressed air supply to a third party, relying on the contractor to provide energy consumption data, identify options and monitor savings. But because the contractor's fee was not determined by how much the company reduced its energy consumption, the contractor had no incentive to accurately document savings opportunities (Punte, Repinski and Gabrielsson 2007).

Energy prices and unreliability of supply

Firms' decisions on how much energy to consume and whether to invest in industrial energy efficiency are heavily influenced by energy prices. While temporary energy-price hikes could encourage some energy conservation, the savings will be limited by the long lifespans and slow turnover of energy-using equipment. However, longer term energy price increases are more likely to influence industrial energy-efficiency investments, as firms have more time to develop new products and processes (Gillingham, Newell and Palmer 2009).

Consider utilities. In some developing countries, electric utility companies charge far more than marginal costs, reaping monopoly profits, because of imperfect competition. In other countries, regulators may require utility companies to set prices that preclude excessive profits – sometimes to the extent that prices do not cover the cost of energy supply. In both cases, electricity pricing affects whether companies invest in industrial energy efficiency. Energy prices rarely reflect the environmental costs of energy consumption, particularly the costs associated with greenhouse gas emissions. If these negative environmental externalities were factored into the price, the number of profitable industrial energy-efficiency projects would likely soar.

Energy prices also influence the rate of innovation and diffusion of energy-efficient technologies (Anderson and Newell 2004; Hassett and Metcalf 1995; Jaffe, Stavins and Newell 1995). Higher energy prices are associated with significantly higher rates of adoption of industrial energy-efficient equipment (Anderson and Newell 2004; Hassett and Metcalf 1995; Jaffe, Stavins and Newell 1995). Empirical estimates show that adoption and innovation of energy-efficient technology respond strongly to energy price changes (Popp, Newell and Jaffe 2009).

Thus, subsidizing energy by keeping prices artificially low can inflate energy consumption, something users recognize. For example, a Nigerian producer of electronic parts said that he makes no effort to become more energy-efficient because prices are so low (Masselink 2009). A subsidy that lowers fuel prices to end-users leads to higher demand, encourages waste, promotes inefficient resource use and increases energy consumption (UNEP 2008). Developing countries account for the bulk of global energy subsidies (Box 5.4).

Many respondents in an industrial energy-efficiency study in Asia viewed energy subsidies as a major barrier to energy-efficiency improvements (UNEP 2006c). Energy costs were not a large enough share of total expenditures for companies to place a high priority on improving energy efficiency. When energy prices are artificially low, energy-efficiency investments are less profitable than they would be at true cost (Jaccard 2009). Energy theft and payment

Box 5.4
Developing countries are the biggest energy subsidizers

The International Energy Agency estimates that global subsidies for fossil fuels totalled $312 billion in 2009, with oil products accounting for 40 percent, natural gas for 27 percent and coal for 2 percent. In economic value, Iran leads with $66 billion a year in energy subsidies, followed by Saudi Arabia with $35 billion, the Russian Federation with $34 billion and India with $21 billion. The next six – China, Egypt, Venezuela, Indonesia, the United Arab Emirates and Uzbekistan – have subsidies of more than $10 billion each a year.

Under-pricing is largest for natural gas. Consumers in non-OECD countries pay less than 50 percent of its true economic value. Iran has an 82 percent subsidy on gasoline; Venezuela has a 96 percent subsidy on diesel fuel.

Source: IEA 2006b, 2010e.

“Industrial energy-efficiency measures are frequently ignored because any savings that could be realized would not compensate for the enormous losses caused by power supply deficiencies

evasion often further reduce the incentive to conserve (Mallett 2010).

Prudent and well planned removal of subsidies will improve productivity, spur economic growth and boost conservation. Progressively phasing out fossil fuel subsidies could cut global primary energy demand an estimated 5 percent by 2020 – equivalent to the current consumption of Japan, the Republic of Korea and New Zealand combined (IEA 2010e). Phasing them out immediately could reduce global energy demand 5.8 percent by 2020.

Another key barrier to improving industrial energy efficiency in developing countries is unreliable energy supply, caused in part by inadequate investment as a result of distorted energy prices. Unreliable energy supplies encourage firms to invest in expensive and inefficient standby power systems, thus raising energy costs. Moreover, the poor quality of power supply from the grid (network surges, frequent interruptions) may prevent use of the advanced electronic controls that come with many imported technologies.

In Nigeria, some industries receive as little as 4.5 hours of power a day, and the highest daily level in any region is 12.5 hours (Okafor 2008). Companies’ own energy generation accounts for up to 20 percent of installed capacity in Nigeria and 6 percent across sub-Saharan Africa (Steinbuks and Foster 2010). Private generating facilities are costly to establish, operate and maintain, and they drain capital that could go to more productive investments (Okafor 2008; Steinbuks and Foster 2010).

Many developing country governments view energy conservation as a luxury and have shown little interest (Reddy 1991). At the firm level, the focus tends to be more on the supply of power than on the cost of energy. Industrial energy-efficiency measures are frequently ignored as a means of reducing production costs. Any savings that could be realized through industrial energy-efficiency projects would not compensate for the enormous losses caused by power supply deficiencies.

Unreliable power supply impedes the adoption of industrial energy-efficiency measures because in countries plagued by erratic power supply, firms tend to be less concerned about energy efficiency than about access to energy. There is a correlation between economy-wide industrial energy-efficiency rates and blackouts. Industrial energy efficiency is generally lower in countries with more power outages than in countries with a reliable power supply (Figure 5.1). For example, Uruguay, with a high level of industrial energy efficiency, averages only 0.29 power outage a month; Nepal, with a low level, averages 52.

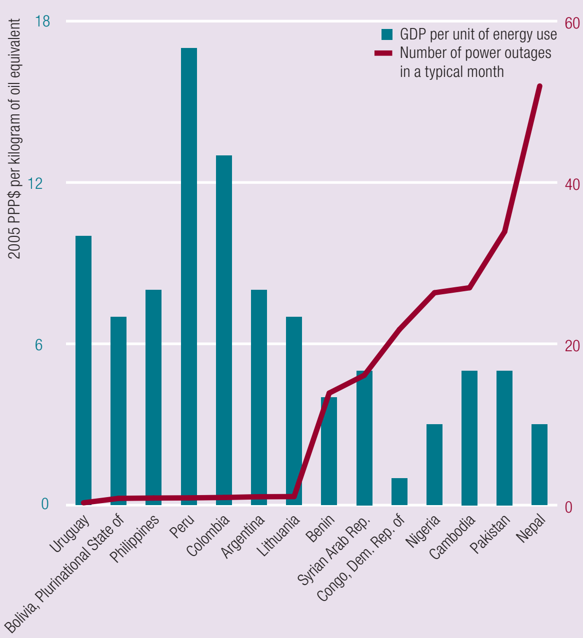
Limited access to capital

To invest in an industrial energy-efficiency project, a firm needs funding either from retained profits or equity or from a commercial bank or specialized financial institution. Several factors related to capital market failures make getting a loan for industrial energy efficiency difficult in developing countries.

One issue is shortfalls in technical capacity in financial institutions. Missing or incomplete financial

Figure 5.1
Energy efficiency and power supply reliability in selected countries, most recent year available

The higher the energy efficiency, the fewer the blackouts



Note: PPP$ is purchasing power parity in international dollars.
Source: World Bank 2010a,b.

Missing or incomplete financial and risk insurance markets create high barriers to industrial energy-efficiency investments in developing countries

and risk insurance markets create high barriers to industrial energy-efficiency investments in developing countries (Taylor et. al. 2008). Enterprise studies stress not only the importance of access to capital to implement industrial energy-efficiency projects but also the difficulties (Sorrell, Mallett and Nye 2011).

The main problem is that local financial institutions lack the technical capacity and experience to assess the credit-worthiness of firms and the risks and opportunities of the investments (De Simone 2010). According to India's Energy and Resources Institute (TERI), many Indian bankers lack the means and knowledge to evaluate industrial energy-efficiency technologies for financing. In many cases, new technologies are perceived as unproven and thus especially risky, despite the absence of any scientific evidence of such risk. The underlying project risks are thus often overestimated (Sethi and Ghosh 2008). Furthermore, domestic funders often have limited financial alternatives to offer, and that frequently precludes lending for industrial energy efficiency.

Another barrier is access to external capital. Lending for investment is an underdeveloped part of the financial sector in many developing countries. Often, firms can borrow only for working capital (running current operations) but not for investing in energy-efficient capital goods. Procedures for estimating and managing risks and dealing with defaults, including collecting collateral, are not well established. As a result, banks charge interest, set collateral requirements and expect repayment at rates that cannot reasonably be met and that make capital too expensive.

Small firms have the most difficulty getting capital because of higher risks of ensuring repayment, costs to the lender of establishing credit-worthiness, small size of industrial energy-efficiency projects, lack of adequate security for loans and limited experience in the domestic financial sector with assessing loan requests for industrial energy-efficiency projects (Arquit Niederberger and Spalding-Fecher 2006). Small Bolivian breweries could not switch from inefficient wood-fired production processes to more efficient natural-gas-fuelled processes because financial institutions, unable to understand the projects, would not fund them (ESMAP 2007). Government constraints on investment financing are an additional hurdle, as typified by China (Box 5.5).

Box 5.5

China: policy impediments to finance for investments in industrial energy efficiency

A study of industrial energy-efficiency financing in China found that the government had barred lending to steel and cement companies to check the expansion of heavy industry, blocking a path for energy-efficiency finance. The study also found that numerous rules discouraged lending for energy efficiency. Domestic banks were not permitted to lend at interest rates of more than about 8 percent, encouraging them to be risk-averse and automatically excluding long-gestation industrial energy-efficiency projects. Limits on the annual growth of loans undermined the effectiveness of longer term green loan programmes for industrial energy-efficiency improvements. Another study found that because only two banks were allowed to have branches in rural areas, Chinese village enterprises had limited access to capital.

Source: Worrell et al. 2001; Chandler and Gwin 2008; Yanjiaa and Chandler 2009.

Energy price volatility can make it even harder to obtain industrial energy efficiency–related loans. According to a respondent in the Colombian metal-working sector, energy price fluctuations make it harder to obtain external finance for energy-efficiency projects. These fluctuations introduce additional uncertainties about the rates of return, increasing project risk and making banks less likely to lend (De Simone 2010).

Behavioural and institutional failures: bounded rationality

Another set of barriers results from limitations of human decision-making, or bounded rationality.

Imprecise evaluation methods

Because of constraints on time, attention, resources and capacities, optimized analyses give way to imprecise routines – rules of thumb that result in

Imprecise evaluation methods help explain why companies sometimes decide against profitable energy-efficiency investments and for non-profitable production investments

decisions that stray far from the theoretical ideal. In organizations, this could mean focusing on core activities, such as the primary production process, rather than on subordinate concerns, such as energy use (DeCanio 1993; Sandstad and Howarth 1994; Sorrell, Mallett and Nye 2011; Stern 1986). Often, stringent internal limits are imposed on capital investment, even not financially optimal. Even with sophisticated energy-management practices, good information and appropriate incentives, time-constrained managers typically focus only on large projects, overlooking more modest industrial energy-efficiency options.

Imprecise evaluation methods help explain why companies sometimes decide against profitable energy-efficiency investments and for less-profitable production investments. Empirical studies find that investment analysis is frequently conducted late in decision-making and often to validate decisions already made. What determines whether an investment goes ahead is its contribution to the firm's objectives – including how much it would contribute to competitive advantage (Sorrell, Mallett and Nye 2011). A review of the use of formal capital budgeting tools for investment decision-making found that even when financial calculations were properly undertaken, they were not fully used (Cooremans 2009). Formal capital budgeting, which would green-light investments with the highest net present value, typically played only a partial role.

Internal capital budgeting rules

Internal capital budgeting procedures also discriminate against industrial energy-efficiency projects (Schleich 2011).[1] As Chapter 4 details, the rule of thumb for industrial energy-efficiency projects is a payback period of around two years. Other types of investment do not seem to be subject to similar demands, and there is no obvious rationale for a two-year period. Two years leaves little time to recover capital costs in industrial projects, which frequently take much longer to yield results. This applies as much to small Peruvian textile companies as to large Colombian metal producers (De Simone 2010). In addition, using a simple payback rule neglects the time-value of money and the expected positive cash flow from energy cost savings in the longer run. Finally, the non-energy benefits of industrial energy efficiency are often overlooked. More efficient furnaces, for example, are more reliable and reduce down time, improving productivity (Worrell et al. 2003).

Concerns about disrupting production

Fear of complexity and disruption also influences borrowing for industrial energy-efficiency investments. In many developing countries, corruption, political instability and high inflation rates increase investment risks, while national trade and investment policies often limit inflows of foreign capital and technology. Both fluctuating energy prices and high inflation rates discourage investments that pay back over a long period. According to a Colombian auto-parts producer, energy price fluctuations cloud calculations of payback periods, making industrial energy-efficiency investments harder to finance externally (De Simone 2010). Companies deal with these uncertainties by requiring higher rates of return. While this may appear to be a rational response (Sorrell et al. 2004), overestimating the risks seriously impedes industrial energy-efficiency projects.

Fear of disrupting production and reducing product quality and sales was the biggest barrier for two Vietnamese textile manufacturers considering a switch to modern productivity and industrial energy efficiency–enhancing machinery (Le 2010). Fear of such risk often means forgoing energy-efficiency projects that external experts would consider cost effective but that firms see as too complicated or too disruptive. These risk perceptions reinforce the bias towards purchasing technologies with the lowest capital cost even though running costs are higher – encouraging, for example, the purchase of inefficient, second-hand equipment (Worrell et al. 2001). Economically, the better approach would be to factor the costs or production interruption into the financial analysis.

At any given time, a technology survey can find unexploited energy-efficiency opportunities, even though the opportunities would naturally be exploited as equipment and structures are renewed

Top-down decision-making

Hierarchical management structures can also impede investments in energy efficiency, discouraging staff from suggesting improvements, even if there are formal procedures for doing so (Masselink 2009). In an Asian paper company, for instance, when consultants identified simple good housekeeping options that would reduce costs and save resources, the staff did not report the suggestions to management because they feared negative repercussions (Punte, Repinski and Gabrielsson 2007). This finding lines up with survey results showing that small and medium-size firms in India made decisions on industrial energy-efficiency projects primarily through a top-down process (Ghosh 2011). Projects were much more likely to be implemented if the firms' owner favoured them.

Hidden costs

Economists sometimes argue that when engineers calculate the gains of implementing industrial energy-efficiency technologies, they fail to account for hidden costs – costs hidden from the analyst but not from the organization – and so overstate the gains (Sorrell 2009; Sorrell, Mallett and Nye 2011; Table 5.1). Many economists argue that hidden costs explain much of the "efficiency gap" so often noted (Jaccard 2009). In principle, such costs can be quantified and included as production, management and transaction costs in the techno-economic feasibility analysis, though in practice this is not straightforward.

Hidden production costs

Most hidden costs could be lumped in with production costs, which should be taken into account when appraising investment opportunities (Sorrell, Mallett and Nye 2011). But many production costs are site-specific and difficult to estimate, so they are easily overlooked. Examples include design fees for large plant items and civil engineering costs associated with installing a cogeneration unit. When production has to be shut down to install new energy-efficient equipment, costs can include forgone sales income.

Another group of production costs concern the weaker performance of industrial energy-efficiency technologies along dimensions other than energy consumption. An energy-efficiency production process might be noisier than the equipment it replaces. Insulating a cavity wall in an old building could result in moisture build-up, or installing a variable-speed drive might require extra maintenance or new skills and tools.

Search costs

Hidden costs are also associated with obtaining, verifying and assessing information on energy-efficiency opportunities, such as the cost of identifying suppliers and obtaining information on price, quality and terms of trade. These search costs are strongly influenced by the characteristics of energy service markets and by the nature of energy efficiency as a good. Search costs are determined in part by factors outside a firm's control, such as the existence (or not) of standardized labelling schemes and by internal factors, such as company procedures for gathering information and specifying, purchasing and procuring the new equipment or process. Developing country firms may find it more costly to improve energy efficiency, because an array of economic and political factors often boost their search costs (Sorrell, Mallett and Nye 2011).

Transaction costs

Overhead costs of energy management are hidden as well, including for employing specialists and conducting energy audits (Sorrell, Mallett and Nye 2011). Low labour costs relative to energy costs (unless energy use is heavily subsidized) in developing countries might suggest that the energy-management overhead would be less of a barrier than in developed countries. This argument would not hold, however, for tasks requiring higher skill levels, typically the case for complex industrial technologies (Schleich 2011).

Other transaction costs that might be a greater barrier in developing countries include the costs for identifying opportunities, investigating options, appraising the investment and obtaining financing

“In enterprise surveys for this report, the top-ranked barrier to energy-efficiency investments was accessing capital

Table 5.1
Hidden costs associated with investments in industrial energy efficiency

Cost	Example
General overhead costs of energy management	• Specialists (such as an energy manager). • Energy information systems (including gathering energy consumption data, maintaining submetering systems, analysing data and correcting for influencing factors, and identifying faults). • Energy audits.
Costs involved in individual technology decisions	• Project identification, detailed investigation and design and formal investment appraisal. • Formal procedures for approving capital expenditures. • Specification and tendering for capital works to manufacturers and contractors. • Additional staff costs for maintenance. • Staff replacement, early retirement or retraining. • Disruptions and inconvenience.
Loss of utility associated with energy-efficient choices	• Problems with safety, noise, working conditions and service quality (such as lighting levels). • Extra maintenance and lower reliability.

Source: Sorrell, Mallett and Nye 2011.

(Sorrell, Mallett and Nye 2011). A study of small glass firms in India found that they ruled out debt finance for industrial energy-efficiency projects because of their inability to comply with the numerous formalities required for a bank loan (see Box 5.2).

Premature equipment retirement

Another hidden cost is the early retirement of capital equipment. The efficiency of equipment and structures typically increases over time, and as capital stocks are renewed, firms tend to acquire more efficient equipment. This means that at any given time, a technology survey can find unexploited energy-efficiency opportunities, even though the opportunities would naturally be exploited as equipment and structures are renewed in coming years (Jaccard 2009).

The costs of accelerating this “natural” rate of renewal include not only the incremental capital cost of more efficient equipment but also some of the full costs of the old equipment, which likely still had years of good service. If a firm decides to replace a piece of equipment at the age of, say, 7 years, even though it could have lasted 12, the overall cost would include not only the money spent on the more efficient equipment but also the return over five years that the firm could have earned with the old equipment. If the lost value from premature equipment retirement is greater than the net profits from acquiring the more efficient device, the firm is financially worse off (Jaccard 2009). This consideration is especially important in developing countries, where the average age of capital equipment is typically much higher.

Rebound effect

Although not precisely a barrier to the adoption of industrial energy-efficiency improvements, the “rebound effect” is a related behavioural issue that can affect such investments (Box 5.6). Improvements in energy efficiency can lead to increased demand for energy and energy services, lowering the initial gains from energy-efficiency investments. The rebound effect is related to the price elasticity of demand. As the cost (price) of energy falls as a result of higher energy efficiency, demand rises. In some cases (as in the case of iron and steel early in the 19th century, or computers and semi-conductors in modern times), the higher demand could even cancel out any energy savings from efficiency gains (Ayres 2010).

How the importance of barriers varies

All these barriers do not affect firms the same way. Some firms might be more sensitive to some types of barriers than to others.

In enterprise surveys for this report, 96 firms in developing countries (two-thirds large firms

Small firms face severe liquidity constraints, and their capital base is usually not strong enough to finance energy-efficiency investments. Large firms have greater capacity to improve energy efficiency – and stronger incentives

Box 5.6

The rebound effect

Some anticipated behaviours may keep energy consumption from falling by as much as would be expected from adopting industrial energy-efficiency improvements. One is commonly known as the rebound effect.

While improving energy efficiency can reduce absolute energy consumption, it can also drive a rebound in demand for energy and energy services, resulting in more modest gains in energy efficiency or even in greater energy consumption. An example is the driver who replaces a car with a more fuel-efficient model, only to take advantage of its cheaper running costs to drive further and more often. Rebound effects have long been neglected, but their consequences could be profound.

Since energy-efficiency improvements reduce the marginal cost of energy services such as travel, the consumption of those services may be expected to increase. Indeed, improved industrial energy efficiency causes behavioural and economic responses – such as more intense use of more efficient equipment, re-spending of money saved, and diffusion of more efficient and therefore attractive technologies – that offset some of the predicted reduction in energy consumption. The energy rebound can be direct, such as in taking advantage of cheaper marginal costs of energy services and then using more energy overall, or indirect, such as through savings from improved energy efficiency that lead to increased consumption of other goods and services.

Rebound effects apply equally to the production side of the economy, where the potential for large effects may be greater. For example, lower cost energy services will substitute for capital and labour, offsetting some of the anticipated reduction in energy consumption. Producers may also use cost savings from energy-efficiency improvements to expand output, increasing consumption of energy inputs as well as capital, labour and materials, which also require more energy. If the energy-efficiency improvements are sector-wide, they can lead to lower product prices, increased consumption of the relevant products and further increases in energy consumption. All these improvements will increase the economy's productivity – encouraging economic growth, increased consumption of goods and services and increased energy consumption.

Rebound effects may be mitigated by gradually increasing carbon and energy taxes or imposing increasingly stringent cap and trade schemes. Emission reductions will not be achieved by efficiency efforts alone but will require greater emphasis on all the other levers to attain climate mitigation goals.

More fundamentally, both analysts and policy-makers need to recognize the importance of such effects and of taking them into account in policy appraisals. In developing countries, especially, it can be argued that a marginal increase in income will be used for goods and services that are more energy intensive than the economy's average. If so, the rebound effect must be taken seriously and additional policy instruments might be needed to compensate for it.

Source: Van den Bergh 2010, 2011; Sorrell and Dimitropoulos 2007; Jenkins and Saunders 2011.

and one-third small) were asked to rank barriers in order of importance (UNIDO 2010h). Though not a representative sample, the responses shed light on the perceived importance of different barriers in different sectors. The top-ranked barrier to energy-efficiency investments was accessing capital. Also high on the list was investment risk – whether arising from uncertainty about the duration of the payback period, technical performance, future energy prices or some other source – combined with limited company savings. Overall, the findings were consistent with those of a study on barriers to the adoption of environmentally friendly technologies in the pulp and paper, textiles, leather, and iron and steel industries in developing countries (Luken and Van Rompaey 2008).

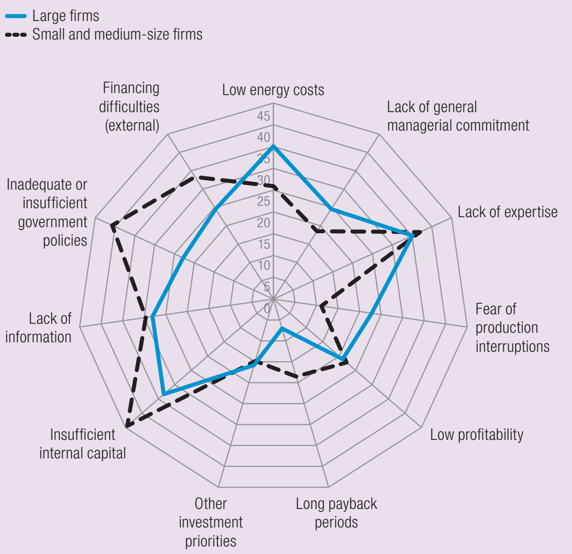
Firm size

Small and medium-size enterprises report more barriers to improving industrial energy efficiency than do larger firms (Figure 5.2). Operating closer to the edge and unable to afford a capital loss, smaller firms invest more carefully. Small firms face severe liquidity constraints, and their capital base is usually not strong enough to finance energy-efficiency investments (Worrell and Price 2000). In addition, small firms are less likely than large firms to have information about investment opportunities or the skills or

> **In continuous process sectors, which typically have high energy intensity, the risk of interrupting production constitutes a major barrier to process-related investment**

Figure 5.2
Percentage of firms mentioning specific barriers to energy efficiency as most significant, 2010

Key barriers for small and medium-size firms are insufficient internal capital and inadequate or insufficient government policies



Source: UNIDO 2010h.

policies to implement them. Smaller firms appear to face higher relative costs in obtaining energy consumption data and in comparing their performance with sector benchmarks (Sorrell, Mallett and Nye 2011).

Large firms have greater capacity to improve energy efficiency – and stronger incentives. The barriers they face differ from those of smaller firms (Sorrell, Mallett and Nye 2011). Fear of production interruptions was much more of a concern for larger firms, and low energy prices were a greater impediment to energy-efficiency investments than for smaller firms.

Although large firms considered corporate investment priorities a greater barrier than did smaller firms, the difference was marginal. This finding became more nuanced during the interviews, as large firms noted that the importance of the barrier depends on the scale of the project. An energy-saving improvement may require small investments (such as operational and housekeeping improvements, incremental technological changes and retrofitting) or a large investment (replacement equipment and processes). Large investments are generally assessed more stringently and less favourably than smaller ones. To make the improvements more attractive financially and more acceptable, companies often fold them into an existing programme to upgrade equipment and processes. Therefore, the willingness to pursue these investments may depend more on other projects in the pipeline than on estimated returns (Sorrell, Mallett and Nye 2011).

Energy intensity of production process

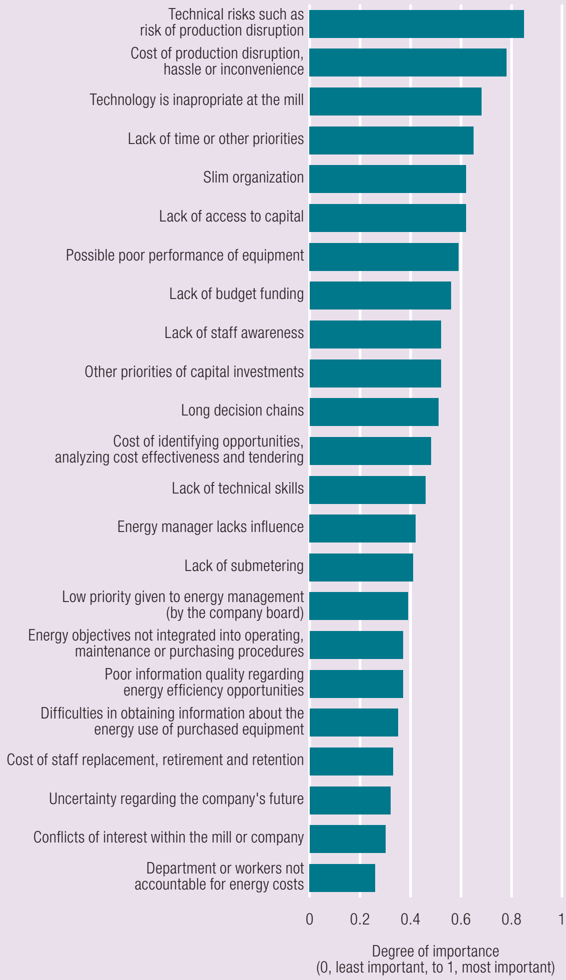
In determining the importance of a particular barrier, the nature and related energy intensity of a firm's production process appears to be as relevant as its size – if not more. While production interruptions might be more important in capital- and energy-intensive sectors such as cement and pulp and paper, staff time constraints and financial concerns are often greater barriers in discrete product sectors. Also, because energy consumption typically accounts for a large share of operations costs in continuous process production, such firms usually already have substantially reduced energy use (AHAG 2008). Since additional reductions are more costly, behavioural barriers and government policies often become more influential in determining investment decisions.

In discrete product and combined industry sectors, both large and small firms pay much less attention to energy efficiency than do firms in process industries. Interviews found that when energy costs account for a small share of a company's total costs, management has little interest in investments to reduce energy consumption. The hassle of upgrading technology or modifying established operations was considered to offset the potential cost savings. But it is important to distinguish between relative and absolute savings. For example, a Colombian coffee producer was spending more than $3 million a year on energy – only 1.4 percent of production costs but clearly a substantial absolute sum – and potential cost savings were large relative to the profit margin. (De Simone 2010).

The hidden costs of energy management are an important barrier to energy-efficiency improvements for a majority of firms

Figure 5.3
Ranking barriers to industrial energy efficiency in the Swedish pulp and paper sector

Technical risks are a big concern in the Swedish pulp and paper sector



Source: Thollander and Ottosson 2008.

In continuous process sectors, which typically have high energy intensity, the risk of interrupting production constitutes a major barrier to process-related investment. A survey of US cement customers found that the reliability and continuous operation of the plant are their highest priorities (Coito et al. 2005). Shutting down a plant to install new equipment can jeopardize the integrity of the kilns. A study of the Swedish pulp and paper sector found the same thing (Thollander and Ottoson 2008; Figure 5.3).

Perceptions about barriers

Barriers in access to information – such as details on the firm's energy performance or opportunities for improved efficiency – are considered much less important in continuous process industries (Sorrell, Mallett and Nye 2011). A majority of energy-intensive firms surveyed by UNIDO regularly monitored energy use at both the plant and the individual process levels, and both managers and engineers considered themselves well informed about energy-efficiency opportunities (UNIDO 2010h). The culture of energy monitoring and submetering in energy-intensive firms also lessened the incidence of split incentives. With energy consumption closely monitored, associated costs can be more easily assigned to the appropriate departments. The Swedish pulp and paper industry found lack of accountability for energy costs to be the least important barrier to energy efficiency, largely because of technically competent staff and the use of submetering to allocate energy costs to departments (Thollander and Ottosson 2008).

Economic trends also affect perceptions about barriers. Like pulp and paper, the foundry industry in Sweden is energy-intensive. It is also more electricity-intensive than other European foundries because of tight environmental controls that motivated a switch to electric furnaces – enabled by the low electricity prices before the market was liberalized. A recent survey found that limited access to capital is considered the greatest barrier today (Rohdin, Thollander and Solding 2007) – which is not the case for large firms in other energy-intensive industries (Thollander and Ottosson 2008; Hasanbeigi, Menke and du Pont 2010). More than two-thirds of the Swedish foundry sample had been in the red the previous three years, and they were reluctant to consider third-party financing. In this case, dynamic economic conditions seem to have altered the relative importance of the barriers.

In a principal-component analysis of the perceived barriers to adoption of industrial energy-efficiency technologies in 450 manufacturing firms in Moldova, the Philippines, Singapore and Viet Nam, Cantore (2011a) and Cantore and Cali (2011) regressed the

"Experience with industrial energy-efficiency technology investments increases the probability of implementing another energy-efficiency change

results against the firms' adoption of industrial energy-efficiency technologies. Identified barriers included insufficient commitment by top management, lack of expertise in energy efficiency, risk of production interruptions, lack of capital, insufficient information on costs and benefits, low market valuation of industrial energy-efficiency investments, inadequate government policies promoting energy efficiency and lack of external drivers, such as mandatory carbon dioxide emission targets. Adoption was defined as the probability of investing in industrial energy efficiency within the next five years. Three primary conclusions emerged:

- For explaining technology adoption, microeconomic conditions, such as possible production interruption, top management commitment and lack of internal finance, were more important than macroeconomic factors, such as insufficient public information, low market valuation or inadequate policies.
- Among microeconomic barriers, lack of commitment by upper management is a top concern. This aligns with findings from the study on barriers in Thailand's textile sector (Hasanbeigi, Menke and du Pont 2010).
- Experience with industrial energy-efficiency technology investments increases the probability of implementing another energy-efficiency change.

To summarize, the hidden costs of energy management appear to be an important barrier to energy-efficiency improvements for a majority of firms, while the risk of production disruptions is more important for energy-intensive firms and difficulties accessing capital for smaller firms. Barriers often overlap or reinforce one another, and they are strongly influenced by context, such as capital market operations and government promotion of energy efficiency .

* * *

All too often, firms are unaware of the advantages and opportunities from investing in energy-efficient technologies, especially in developing countries, where information barriers are pervasive. When firms do want to invest, they cannot easily obtain the funding needed to buy the new equipment or modify the plant. Decision-makers do not always benefit directly from energy-efficiency investments, and estimating the costs, benefits and risks of those investments is difficult. Energy subsidies, common in developing countries, further undermine the attractiveness of investing in energy efficiency, as do broader institutional, economic and technical conditions. Where energy supply is unreliable, firms are more concerned with availability than with efficiency. Similarly, small and medium-size industrial firms find it much harder to get a loan than do larger firms. And while the barriers to energy efficiency are also present in developed countries, they are more formidable in developing countries.

What can be done about these barriers, and who should do it? What are the appropriate roles of the public and private sectors? How are developing countries dealing with the barriers? These topics are the focus of Chapter 6.

Note

1. Internal capital availability also reflects priority-setting in companies, which is the terminology used in various empirical studies, including Schleich and Gruber (2008), Thollander and Ottosson (2008) and Schleich (2009).

Chapter 6

Overcoming barriers to industrial energy efficiency through regulation and other government policies

Chapter 5 identified barriers inhibiting industrial firms from investing in cost-effective and socially desirable improvements in industrial energy efficiency. So the crucial questions, particularly for developing countries, are: How to shrink or overcome the barriers? How to reduce the hidden costs associated with energy-efficiency investments? Which policies and actions are the most effective, economically efficient, administratively feasible and politically acceptable to resolve these problems?

Countries that have improved industrial energy efficiency have achieved this by creating an enabling governance framework through coordination and cooperation among stakeholders and through regulatory mandates. Behavioural changes require policies with strong implementation mechanisms and regular evaluation.

This chapter reviews the national policy framework for industrial energy efficiency and explores the advantages and disadvantages of different instruments for overcoming barriers to greater energy efficiency in developing countries. The first two sections address the legal and governance structure and the setting for introducing policy measures. The next four focus on information policy, innovation and technology support, and market-based and financial policy instruments for improving industrial energy efficiency. The last section examines policy design and implementation considerations that are important in developing countries.

Establishing the legal and governance structure for industrial energy-efficiency policy

Developed and developing countries often support industrial energy efficiency through legal measures. A 2006 review of policies in Asia found energy conservation laws in China, India, Japan, Thailand and Viet Nam (UNEP 2006c). In 2009, Indonesia introduced energy conservation legislation, while the Russian Federation adopted a new federal law on increasing energy conservation and efficiency (APERC 2010a). Many Latin American countries link industrial energy-efficiency legislation to electric power promotion laws (ECLAC 2010).

At the sector level, energy-efficiency initiatives can be mandated through legislation or encouraged through negotiated agreements. Laws typically cover energy standards, energy-savings plans, regular reporting of energy consumption and energy auditing, energy managers for energy-intensive industries, and energy conservation training and technical assistance. Laws also generally stipulate priorities and include tax incentives and subsidies, as well as penalties for non-compliance (Box 6.1).

Energy-efficiency legislation generally establishes government regulatory, implementing and coordination agencies as well as promotional and support organizations. Central responsibility for public management of energy policy often lies with a dedicated government body, such as the ministry of energy or a national energy-efficiency agency (Box 6.2). These agencies need a well defined mandate, strong technical skills and a secure source of funding. A specialized division is often created to encourage energy efficiency by disseminating information, implementing technical and policy measures, coordinating engagement of industry players in policy formulation and implementation, and serving as a focal point for industry (Clark 2000). Increasingly recognizing the importance of such agencies for fostering energy policies, more developing countries are establishing national energy-efficiency agencies (WEC 2010).

Of the 37 developing countries whose policies were reviewed for this study, 29 have established such administrative and regulatory bodies (UNIDO 2011).[1] They operate a variety of energy-efficiency plans and programmes addressing specific technologies, such as lighting and motor systems, or specific energy-efficiency functions, such as information provision and financing. In Brazil, for example, the Ministry of Mines and Energy and its Secretariat

One of the main policy goals should be to decouple industrial energy and resource consumption and negative environmental impacts from economic growth

Box 6.1

Energy conservation laws in India and Japan

India's Energy Conservation Act established the Bureau of Energy Efficiency to implement the law. Industry mandates include:

- Committing to national energy conservation and efficiency efforts and programmes.
- Adhering to energy standards and equipment labels.
- Appointing energy managers and carrying out mandatory energy audits in facilities operating above the energy consumption threshold.

India's Bureau of Energy Efficiency reports that many measures are still difficult to implement, such as gathering data from businesses on the performance and energy consumption of energy users, on the number of energy audits performed or on the energy savings achieved. The Bureau estimates that just applying the mandatory energy-efficiency standards and labels for industrial machinery and commercial appliances has saved 11,689 million kilowatt hours a year over five years.

Japan's Energy Conservation Law of 1979 stipulates that energy-intensive industries must:

- Submit periodic reports on energy use.
- Prepare and submit medium- and long-term plans for achieving energy conservation targets.
- Appoint energy conservation managers.
- Use products with mandatory energy-efficiency labelling.
- Monitor progress through regular factory inspections.

In 2005, the law was extended to 13,000 large and medium-size industrial firms and energy-intensive transportation businesses and buildings. Energy-efficiency and conservation guidelines were also added for fuel burning, heating, cooling and heat conduction, recovery and reuse of waste heat, conversion of heat to power, prevention of energy loss through radiation, and conversion of electricity to power and heat. The law encourages businesses to cooperate on large-scale energy conservation investments at industrial complexes.

The law has resulted in reductions of 2,166 tonnes of carbon dioxide emissions (from 52,673 in 1997 to 50,507 in 2005) and reductions in energy consumption of 832 kilolitres of crude oil equivalent (from 17,844 to 17,012).

Source: Adapted from UNEP (2006d).

Box 6.2

Tunisia's National Energy Conservation Agency

Tunisia established a National Energy Conservation Agency (ANME) to support its policy of energy security and independence and to reduce the national energy bill. ANME has made it a priority to sensitize companies to the importance of energy efficiency. It also:

- Requires companies with annual energy consumptions of more than 800 tonnes of oil equivalent (toe) to conduct energy-efficiency audits.
- Distributes subsidies for industrial energy-efficiency projects.
- Works with the Société Tunisienne de Gestion de l'Energie and the Société Tunisienne d'Electricité & Gaz to manage credit funds for industrial energy-efficiency projects.
- Identifies industrial energy-efficiency incentives.
- Runs training courses for energy managers.

ANME tracks companies that consume more than 800 toe a year and reminds them when their energy audits are due. ANME has designated energy-auditing firms, which prepare applications for industrial energy-efficiency subsidies and loans.

Industrial energy-efficiency projects are financed either entirely by ANME or through a 40–60 split between ANME and banks. There are three types of government subsidies:

- For energy audits: 70 percent of the cost, up to 30,000 dinars.
- For intangible investment (such as training): 70 percent of the cost, up to 70,000 dinars.
- For tangible investment (such as equipment): 20 percent of the cost, up to 500,000 dinars.

ANME claims a cumulative energy saving of 676 kilotonnes of oil equivalent (ktoe) solely from industrial energy-efficiency projects over 2004–2008. It assesses the potential for energy savings for 2008–2011 at 400 ktoe.

Source: UNIDO 2011.

Targets can be powerful instruments for increasing industrial energy efficiency

of Energy and Development Planning oversee the planning, promotion and evaluation of energy-efficiency activities. There are two national implementing programmes: the National Electrical Energy Conservation Programme (Procel), coordinated by the national electricity company (Electrobras), and the National Programme for Rationalizing the Use of Oil and Natural Gas (Conpet), which includes private initiatives and draws on the resources of Petrobras, the state oil company (ECLAC 2010).

Beyond the central government, developing countries have set up specialized local and regional government bodies to provide more targeted measures and to collaborate with industry, academia and intermediary institutions, such as energy information centres. Support institutions have also been set up, including industry associations, energy conservation centres, national and regional cleaner production centres, energy research and development (R&D) laboratories, energy technology and information centres, cluster development institutions, and metrology, standards, testing and quality control centres (UNIDO 2011).

The experiences of countries as diverse as Costa Rica and the Russian Federation suggest that several capabilities are critical to successful implementation of energy-efficiency legislation (UNIDO 2011; WEC 2008):

- Estimating the savings and impact of energy-efficiency projects.
- Applying the right mix of policy instruments in each sector (specificity is critical to success).
- Developing the institutional and organizational knowledge and skills for designing and implementing policies consistently.
- Rigorously monitoring and enforcing legislation.

One concern, particularly in large developing countries, is the weak coordination among energy-efficiency agencies, with agencies often working independently and towards different goals (UNIDO 2011).

Shaping the industrial energy-efficiency policy setting

To be successful, industrial energy-efficiency policy must have clearly specified and measurable goals and an effective framework for implementing them. One of the main policy goals should be to decouple industrial energy and resource consumption and negative environmental impacts from economic growth. Action areas need to be defined, including measurable and realistic targets, legislation on standards and labelling, systems of market-based incentives, knowledge and information programmes and a conducive institutional environment. Effective policymaking requires effective mechanisms for regular evaluations to determine whether targets and policies need to be revised (Mallett, Nye and Sorrell 2011; Verbeken 2009).

Setting national targets

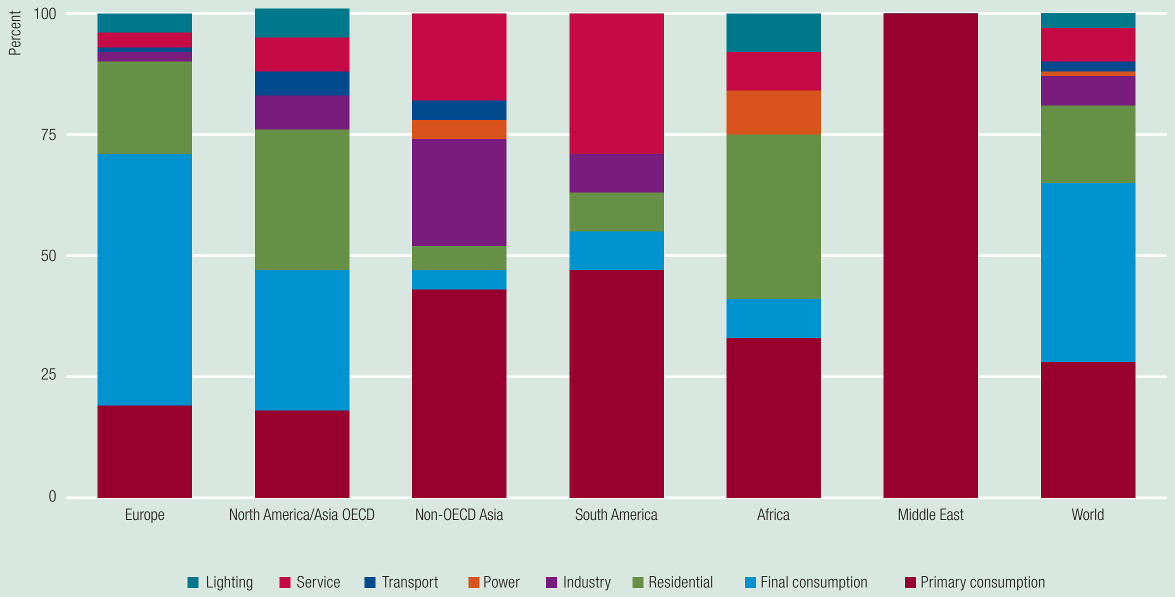
Many countries in Asia, Europe and Latin America have recently incorporated quantitative targets in their national energy laws and programmes (Figure 6.1). Targets can be powerful instruments for increasing industrial energy efficiency. Targets have been expressed in various ways – for example, as a specified annual rate of energy-efficiency improvement, as a percentage improvement over time, as energy savings in gigawatt hours or millions of tonnes of oil equivalent or as a reduction in energy intensity to some target value. Most countries target energy-efficiency improvements (WEC 2010).[2]

Brazil's National Energy Plan 2030 aims to reduce electricity use by 4.5–15.5 gigawatt hours by accelerating technical progress and industrial energy-saving initiatives (ECLAC 2010). China's 11th Five-Year Plan stipulated economy-wide improvements in energy intensity of 20 percent over 2006–2010, with targets and monitoring set at provincial and industry levels. When the target was grossly undershot in the first few years because of industry reluctance to comply, the government required all companies and local and provincial governments to submit detailed compliance plans beyond 2007. The Five-Year Plan linked institutional and individual staff performance assessments to target achievement. And in 2008, energy intensity declined 4.2 percent (UNIDO 2011).

Voluntary energy-efficiency agreements can increase awareness of industrial energy efficiency and engage stakeholders

Figure 6.1
Breakdown of energy-efficiency targets incorporated in laws or programmes, by region, 2009

Many countries in Asia, Europe and Latin America have established national quantitative energy-efficiency targets



Source: WEC 2010.

Setting sectoral targets

Industrial energy-efficiency targets can be set through mandatory measures or voluntary agreements with governments. Voluntary agreements include targets to meet specific energy-efficiency goals (generally over 5–10 years) so that investments can be planned and implemented (Worrell and Bernstein 2009; Price, Wang and Yun 2010).

Voluntary agreements have been implemented in developed countries since the 1990s (Price, Wang and Yun 2010).[3] Successful implementation is typically rewarded with financial gains or exemption from mandatory measures. They tend to receive greater support from industry and are more flexible and faster to implement than mandatory measures. However, if compliance is low, agreements may be replaced by mandatory alternatives (Price 2005 cited in Worrell and Bernstein 2009; McKinsey & Company 2009).

Setting targets under negotiated agreements involves assessing the energy-efficiency potential of each industry and identifying economically feasible measures for improvement. This assessment can be made by an independent third party and used as a basis for the negotiation. Rewards and sanctions, such as auditing, benchmarking, monitoring, disseminating information and offering financial incentives, can motivate participation.

These agreements can increase awareness of industrial energy efficiency and engage stakeholders. Several successfully negotiated agreements include elements that could work in other countries and sectors. China used negotiated agreements in Denmark, Finland and the Netherlands as models (Box 6.3).

A few developing countries use voluntary energy-efficiency agreements, notably Chile, China, India, Indonesia, Malaysia, Romania, South Africa and Thailand. Chile has a wide range of agreements covering mining, metals, chemicals and printing (UNIDO 2011). Romania is establishing long-term agreements in glass, cement and machinery (UNIDO 2011). China initiated the Top-1,000 Energy-Consuming Enterprises programme, a major voluntary agreement to achieve its Five-Year Plan (2006–2010) targets to reduce energy consumption per unit of gross domestic product (Box 6.4).

> **A natural starting point in setting targets and formulating policies is to benchmark the industrial energy efficiency of each sector and to identify its drivers**

Box 6.3
Voluntary agreements on long-term energy-efficiency targets in the Netherlands

In 1989, the Dutch Government and industrial sectors negotiated voluntary agreements involving 90 percent of national industrial energy consumption. They agreed on long-term energy-efficiency targets, with participating sectors committing to achieve the national target of 20 percent efficiency improvement by 2000. The sectors exceeded their targets, achieving an average improvement of 22.3 percent.

The programme's success was due to its ability to focus management on low-cost efficiency investment options, pre-empt future energy regulation, prepare legally binding contracts and provide supporting policies (such as tax rebates, subsidies and audits). Following the success of this first programme, which focused on process efficiency, a second one was launched for 2001–2012, broadening the focus to energy management outside the production process, including sustainable energy and energy-efficient product development. Thus far, more than 900 companies in 31 sectors have signed on, and improvements in energy efficiency have averaged 2 percent a year. A third programme is under development, to run until 2020.

Source: UNIDO 2008a; Nuijen 1998; Kerssemeeckers 2002; Korevaar et al. 1997; Rietbergen, Farla and Blok 1998; Price and Worrell 2002; SenterNovem 2008.

The Indian and Indonesian experiences suggest that voluntary agreements require substantial commitments by firms. The agreements can be difficult to implement, especially for small and medium-size firms, unless targets are realistic, guidelines are clear and information from experience is sufficient (UNIDO 2011). An assessment in Nanjing, Xian and Kelamanyi in China concluded that voluntary agreements can be effective instruments for implementing national policies (Eichhorst and Bongardt 2009). With greater firm ownership of the programmes, it became easier to adopt energy action plans and establish energy action teams.

Benchmarking

A natural starting point in setting targets and formulating policies is to benchmark the industrial energy efficiency of each sector and to identify its drivers by examining such variables as access to capital, skills, technical performance and management practices.

Benchmarking requires comparing the energy performance of a plant, process, system or industry with that of similar facilities producing similar products or to national or international best practice energy use. The results can be shown in benchmark curves that plot energy use from most to least efficient. These curves contain valuable information about best practice technologies for use in assessing global energy-saving potentials (see Chapter 2).

By identifying industrial energy-efficiency opportunities and capabilities that need to be developed, benchmarking allows realistic targets to be set and policies and programmes to be designed and implemented. But benchmarking is not easy. There are many difficulties with collecting accurate energy data.

Governments can initiate capacity-building for energy statistics by setting up entities for energy benchmarking and ensuring the accuracy of data collection and auditing. National statistics offices can train company staff to improve measurement and provide information on the potential for industrial energy-efficiency savings.

The Malaysian Government's National Productivity Corporation hosts an e-benchmarking database on energy efficiency, supported by the Department of Statistics and prepared in collaboration with industrial associations (UNIDO 2011). The database covers all manufacturing sectors and includes audited energy data for more than 5,300 registered firms in 2003. The database provides plant-level energy-efficiency data and has led to the identification of potential energy-efficiency savings of 40–45 percent in the cement and rubber industries, some of it requiring little investment. While the energy database has helped many firms improve their energy productivity through voluntary action, its usefulness will depend on its continuing refinement – to provide more disaggregated, user-friendly and reliable data.

Governments can also support intermediate energy organizations that are vital in enabling benchmarking practices by industrial firms. Industry associations and international organizations can also develop and apply

Many firms in developed countries have pursued their own industrial energy-efficiency targets, which are often supported by governments

Box 6.4
China's Top-1,000 Energy Consuming Enterprises programme

The enterprises participating in China's Top-1,000 Energy Consuming Enterprises programme are in nine energy-intensive industrial sectors (iron and steel, non-ferrous metals, chemicals, petroleum and petrochemicals, power generation, construction materials, coal mining, pulp and paper, and textiles), which together accounted for 33 percent of national energy consumption and 47 percent of industrial energy consumption in 2004.

The programme seeks to:

- Reduce greenhouse gas emissions in the top-1,000 energy-consuming enterprises through an increase in energy efficiency of 260 million tonnes of carbon dioxide equivalent ($CO_{2\text{-eq}}$).
- Benchmark against domestic best practice for all major products and international best practice for some.
- Achieve energy savings of 100 million tonnes of coal equivalent over 2006–2010.

The programme involves several national government departments: the Department of Natural Resources and Environmental Protection; National Bureau of Statistics; Office of National Energy Leading Group; General Administration of Quality Supervision, Inspection and Quarantine; and State-owned Assets Supervision and Administration Commission. Provincial, district and urban energy-saving authorities and local authorities were charged with overseeing energy management and reporting within enterprises.

Based on analyses of industrial energy-saving potential and the location of the enterprises, the Department of Natural Resources and Environmental Protection assigned the 100 million tonnes of coal equivalent energy savings to individual provinces. In 2006, targets per enterprise were discussed and published. Target-setting was generally a top-down process, though there were regular information exchanges. A two-tier contract system was established between the central government and provincial governments and between provincial governments and companies.

The programme, modelled on international experience with voluntary agreements, achieved its targets. But there were some shortcomings:

- Target-setting was rushed to meet the time constraints of the 11th Five-Year Plan and thus failed to adequately engage industry.
- Targets were not sufficiently ambitious; greater detail in assessing energy saving potential for specific industries could have resulted in higher targets for energy savings and efficiency.
- Supporting policies were slow to come online, and regulatory responsibilities were unclear.
- No systematic information and dissemination method was formed.
- Monitoring and evaluation were handicapped by lack of transparency, lack of external auditing and the use of aggregate data.

Source: Price, Wang and Yun 2008, 2010; Worrell 2011.

standardized methodologies for energy management and efficiency and help countries collect better energy data and develop benchmarking tools and methodologies. These collaborative efforts must be extended to small and medium-size enterprises, which often have the most potential for improvement.

Supporting private initiatives

Many firms in developed countries have pursued their own industrial energy-efficiency targets, setting up energy management programmes, often with ambitious targets, and hiring energy managers. These programmes are often supported by governments.

The key stages in a corporate energy-efficiency programme include benchmarking, auditing, energy action plans, progress monitoring and evaluation (Box 6.5). Energy managers decide which measures are implemented, such as improving monitoring, control and operating practices; signalling the need for timely repair and regular maintenance; and estimating costs for these requirements. Effective energy management in firms typically includes multi-year planning, plant-level performance goals and tracking, designated energy managers, energy management systems, energy auditing and capital allocation.

The US Government's Energy Star programme offers industrial firms energy management guidelines and supporting tools. The guidelines include assessment, benchmarking, energy management planning and progress evaluation. In 2007, around

The four elements of a regulatory framework for industrial energy efficiency are mandatory energy auditing, energy labelling, minimum efficiency standards and energy management systems standards

Box 6.5

Key stages in target-setting at the firm level

Setting firm-level industrial energy-efficiency targets has long been a central part of the promotion mechanism for many governments. Target-setting has several stages:

Benchmarking. Benchmarking enables measuring the energy performance of a plant or sector against best-practice performance in the sector.

Auditing. Auditing involves collecting data on all major energy-consuming processes and plant equipment; documenting technologies used in production, operation and maintenance practices and management systems; and identifying energy-efficiency opportunities throughout the plant. Audits can identify major energy-consuming areas and indicate possible energy-saving measures, look at improving specific systems, target high-energy areas and cover total energy consumption.

Energy action plan. The energy action plan outlines a company's plan for improving its energy efficiency through targets and related timelines and measures to reach the targets. The plan, required for compliance with an energy-management standard, is a working document for improving internal industrial energy efficiency.

Monitoring progress. Regular review and annual monitoring and reporting of progress towards the target are essential. Programmes are more likely to be effective if they are backed up by the threat of greater government regulation or taxes if the targets are not achieved.

Programme evaluation. Firms evaluate programmes periodically to investigate how a programme is progressing and why – and at its end, to determine if it has met its goals. Evaluation guidelines need to be set early. There are three types of evaluations: impact, which determines how well a programme did over a set time or at the end of the programme; process, which assesses how efficiently a programme was implemented compared with its stated objectives; and market effect, which estimates how a programme will affect the market in the future.

Source: Price, Worrell and Sinton 2003; Price, Wang and Yun 2008; Price et al. 2005; Vine and Sathaye 1997; MOTIVA, IFE and CRES 2000; Schiller 2007.

500 manufacturing firms made the commitment to follow the Energy Star guidelines.[4]

Creating an industrial energy-efficiency regulatory framework

The four elements of a regulatory framework especially important for industrial energy efficiency are mandatory energy auditing, energy labelling schemes, minimum efficiency standards and energy management systems standards. Standards and product labelling are used widely in developing countries – 21 of 37 reviewed countries have them. Mandatory audits are used less frequently; only 13 countries have introduced them (UNIDO 2011).

Conducting energy audits

Energy audits help firms determine their energy consumption and identify opportunities for energy saving. The audit typically involves analysing utility and building data; surveying, costing and evaluating energy-saving measures; and estimating energy saving potential (Krarti 2000). Energy audits include benchmarking analyses; walk-through audits to identify opportunities for improving industrial energy efficiency; detailed energy audits involving comprehensive surveys of energy use; and investment-grade audits that focus on more capital-intensive industrial energy-efficiency opportunities (ASHRAE 1997).

Mandatory industrial energy audits are key to improving industrial energy efficiency in some countries. They are used more in Asia than in Europe (WEC 2010). China, the Philippines and Viet Nam require energy audits for large-scale, high energy-intensive industries (UNIDO 2011). The knowledge gained through an energy audit helps firms improve the efficiency of their industrial processes. However, mandating audits does not always increase the use of industrial energy-efficiency technologies – for example, if the audits are weak and shallow because there is no unified standard, if auditing entities do not have enough qualified personnel or are not accredited and if audits have not been piloted or the financial means for more detailed auditing are lacking (Price, Wang and Yun 2010; UNIDO 2011). Some 25–30 Indian industrial small and medium-size firms, despite having been thoroughly audited, could not be convinced

Energy-efficiency labels are one of the easiest and cheapest policy tools and can lead to large energy savings

of the importance of energy-efficiency improvements, according to a study by the State Bank of India (Painuly 2009).

Improving auditing quality requires supporting measures, such as subsidies for audits and training for auditors and company personnel. Implementation of audit recommendations may require the government to process data and provide feedback. Experience shows that governments committed to industrial energy efficiency can introduce mechanisms that make energy audits an effective part of their energy strategies (as in Tunisia; see Box 6.2).

Using energy-efficiency labels

Energy-efficiency labels are one of the easiest and cheapest policy tools and can lead to large energy savings. Labels describe the energy performance of equipment in terms of average energy efficiency for consumption or costs, thus enabling consumers to make an informed purchasing decision. Labels help overcome information barriers and encourage the adoption of more efficient equipment (Wiel and McMahon 2005). They include endorsement labels, which certify that a product meets preapproved criteria; information labels, which inform consumers of a product's performance; and comparative labels, which allow consumers to compare the performance of similar products (Wiel and McMahon 2005; CLASP 2009).

Labelling often precedes standards by encouraging manufacturers to compete based on energy efficiency and preparing consumers and producers for new or stricter standards (Nadal 2002). Mandatory labels can lower the transaction costs associated with assessing energy performance, such as for electric motors (Schleich 2011). If clearly designed and accompanied by information campaigns, mandatory labels can encourage manufacturers to design more energy-efficient machines and processes (CLASP 2009).

Many countries have adopted labelling schemes, frequently in tandem with minimum energy performance standards. For example, the EU Energy Labelling Directive requires labels on all energy-using products (WEC 2010). Experience with labelling in developing countries has been positive, and in some countries, equipment failing to meet claimed efficiency ratings has been stripped of its labels, but there is room for progress (UNIDO 2011). Labelling schemes in India, Thailand and Malaysia are voluntary and do not perform as well as mandatory programmes, which give users full comparable information. Ghana's labelling efforts would be more credible with better testing facilities and equipment. A common problem with lighting and air-conditioning equipment in many developing countries is that nearly all products receive top ratings. South Africa needs to standardize label information updates to include product and equipment technology changes.

Overall, improvements are needed in energy-efficiency metrics, product categorization, certification and labelling regulation. Countries with weak border protection face the added task of dealing with unlabelled foreign products and equipment.

Establishing minimum efficiency performance standards

While labels help transform the market for high-efficiency equipment, minimum efficiency performance standards aim to reduce the market share of the least efficient models (Fleiter, Eichhammer and Schleich 2011; Nadal 2002). They can be an important source of gains in energy efficiency, as in the case of electric motors, which account for 60–70 percent of industrial electricity consumption (Fleiter, Eichhammer and Schleich 2011).

Standards are usually imposed by energy authorities, often through technical regulations that typically prohibit manufacturing, selling and importing non-conforming equipment and appliances. Setting standards for equipment such as boilers, motors, lighting and space conditioning can boost demand for energy-efficient equipment and eliminate the least efficient models from the market. Standards can also reduce other inefficiencies and losses indirectly related to energy, resulting in a cascade effect that drastically cuts energy intensity (de Almeida, Ferreira and Both 2005). These standards, used widely in many countries

> **While labels help transform the market for high-efficiency equipment, minimum efficiency performance standards aim to reduce the market share of the least efficient models**

and regions, can also spur competition among manufacturers to improve the efficiency of their equipment (Table 6.1).

Brazil's experience with standards is unique in that mandatory standards emerged from a voluntary agreement. Minimum efficiency performance standards were introduced less as an efficiency measure than as a mechanism for combating electricity shortages. The first product subject to standards was the squirrel cage three-phase induction electric motor, which used around 32 percent of Brazil's electricity supply. Government energy and standards regulatory agencies and Brazilian manufacturers entered into a voluntary agreement to sequentially introduce more stringent efficiency targets for both standard and high-efficiency motor classes. Implementing the standards not only saved energy but also benefited Brazilian motor manufacturers, since the standards eliminated competition from less technically and economically efficient foreign firms, and made it easier to introduce mandatory standards for induction motors (ECLAC 2010; Garcia et al. 2007).

Although minimum efficiency performance standards are considered cost-effective, they are not without problems. First, mandates that are not regularly updated can force firms to make production process decisions that they might not otherwise make (*New York Times* 2011). Second, the benefits need to be weighed against the challenges of implementing a new standard, such as engineering costs, slower deployment of new technologies and long lifespans of existing equipment. Standards can be especially difficult to impose on specialized process equipment and are probably not cost effective for low-volume equipment (McKinsey & Company 2009).

If regulatory policy forces the early retirement of capital goods, firms might be worse off financially if the profits associated with the more efficient replacement equipment do not offset losses from retiring capital goods early (Jaccard 2009). Regulatory policy needs to overcome this disincentive to upgrading equipment (Stern 2006). Conversely, firms could try merely to meet the mandated minimum standards, even as the standards get outdated, thus discouraging innovation. To prevent this, standards need regular review and updating to keep up with technological progress (IEA 2007b; Saidur 2010). Standards should encourage industry to continually improve energy

Table 6.1
Use of minimum efficiency performance standards in selected economies

Economy	Phase[a]	Pump	Fan	Chiller	R values[b]
Australia	✔				
Brazil	✔				
Canada	✔				
China	✔	✔	✔	✔	✔
Costa Rica	✔				
European Union	✔				
Israel	✔	✔	✔		
Mexico	✔	✔			
New Zealand	✔				
Republic of Korea	✔				
Taiwan Province of China	✔			✔	
United States	✔				
Total	12	3	2	2	1

a. Three-phase electric power systems.
b. A measure of insulation's ability to resist heat transfer.
Source: Adapted from Brunner (2007).

> **Much industrial energy efficiency is achieved by changing how energy is managed rather than by installing new technologies**

efficiency. For instance, Australia and China specify two performance levels: the real minimum (which must be adhered to) and a likely future minimum (what industry should expect and prepare for).

Developing energy management systems standards

Much industrial energy efficiency is achieved by changing how energy is managed rather than by installing new technologies. Energy-efficiency components in industrial systems will not achieve the projected energy savings if the system is not properly designed and operated (Lovins 2007). Evidence from national and international programmes shows that while efficient components might yield minor gains, systems optimization can yield much larger gains (20–30 percent), with payback periods of less than two years (ECLAC 2010; Garcia et al. 2007).[5] Energy management systems, by taking into account the entire industrial system, are more effective in optimizing industrial systems and monitoring system efficiency (EEEP 2010).[6]

Energy management systems include the technical systems, management programmes and trained staff needed to conduct energy audits, gather energy data, maintain submetering systems, analyse and compare consumption data to trends and benchmarks, correct for influencing factors, identify faults and so on (Sorrell et al. 2004). Energy management systems can help firms develop an energy use baseline, actively manage energy costs and document savings for internal and external use (such as greenhouse gas emission credits). A good energy management system is vital for identifying opportunities for sustainable energy savings (Worrell 2011).

An energy management system is typically part of a company-wide energy policy, supported by upper management and energy management staff (Sorrell 2009). A successful energy management system starts with a strong organizational commitment. A study of Turkey's textile sector suggests that implementing an energy management system company-wide is the best approach (Ozturk 2005). An approach that has worked in Malaysia is setting up an energy management committee and engaging the company head in energy-efficiency efforts (EIB n.d.). Energy management systems involve costs in wages, consultancy and other fees, so their cost effectiveness varies with the firm's size and energy intensity.

Governments can encourage companies to establish an energy management system by providing information on best practices, issuing standards, providing training in compliance and recognizing or certifying firms that meet the standards. International guidelines on standards are available through the recently established ISO 50001 Energy Management Systems and are also available through ISO 14 000 Environmental Management Systems, which includes suggestions for continuous improvement in energy efficiency. Developed countries with energy management system standards include Australia, Canada, Denmark, Germany, Ireland, Republic of Korea, the Netherlands, Sweden, the United Kingdom and the United States. Regional standards have also been established, such as the European Energy Management Standard (EN 16001), introduced in 2009.

Energy management systems are less common in developing countries. Countries that use them include Belarus, China, Ghana, Malaysia, Romania, the Russian Federation, South Africa and Thailand. Malaysia requires that installations consuming 3 million or more kilowatt hours of electricity over six months hire an energy supply manager. Experience with energy management systems in developing countries, though sparse, suggests that government measures should focus on the plant level, empower plant personnel at all levels and involve them in decision-making, encourage individual or team champions of energy management programmes and provide some financial support (UNIDO 2011).

Developing an information policy

Regulatory efforts can also work with public information, awareness and training programmes. Information and awareness-raising programmes are repeatedly

Public awareness and education campaigns can boost industry capability and willingness to adopt what has been considered high-cost and -risk technologies

identified as public policy priorities (Schleich 2011). Encouragement through recognition programmes has also proven effective in helping firms adopt industrial energy-efficiency practices and technologies. Developing countries are employing a wide range of these tools (Table 6.2).

Lack of awareness of energy-efficiency opportunities may stem from inadequate metering and insufficient information on energy performance, reinforced by weak skills and training. Language barriers and limited Internet access may exacerbate these problems in developing countries. Limited knowledge means that quick-fix options are often preferred to those that address root causes (te Velde 2010).

Raising knowledge and awareness

Public awareness and education campaigns can boost industry capability and willingness to adopt what has been considered high-cost and -risk technologies. To be effective, the campaigns must target management and technical personnel, other stakeholders (such as industry associations and government departments), the financial sector (on topics such as the profitability of industrial energy-efficiency investment projects) and the community at large – all at the same time.

Table 6.2
Information and technology policies applied in developing countries, 2010

Policy tool	Number of countries
Awareness and education campaigns	15
Training for firm personnel	8
Enhancement of local absorptive capacity	10
Recognition programmes	5
Industrial energy-efficiency networks	3
Support for energy-efficiency research and development	6
Support for deployment of energy-efficiency technologies	2
Technical assistance programmes for industrial energy efficiency	9
Energy-efficiency demonstration projects	6
International industrial energy-efficiency programmes	12

Note: Includes 37 developing countries in Africa, Asia, Eastern Europe and Latin America.
Source: UNIDO 2011.

Information campaigns can include workshops, training and seminars, best practice publications and mass media (te Velde 2010). Brazil's experience suggests the value of training trainer's programmes because of multiplier effects across firms and the potential damage inflicted by poorly informed teachers (UNIDO 2011).

An assessment of United Nations Environment Programme (UNEP) activities to encourage cleaner production technologies in five developing countries (Guatemala, Nicaragua, Tanzania, Viet Nam and Zimbabwe) highlights the importance of raising awareness and educating key players (Ciccozzi, Checkenya and Rodriguez 2003). It notes the importance of educating the financial sector about the profitability of industrial energy-efficiency investments. The study acknowledges the need for hard data and examples of successes to persuade stakeholders to adopt energy-efficient technologies.

Engaging key players is critical for successful awareness and education campaigns (UNIDO 2011). Chile actively involves the private sector in its campaigns, to encourage participation. Jordan tries especially to engage top management (Arburas 1989). Costa Rica, Honduras, South Africa and Thailand focus on local communities and youth, while Egypt uses non-governmental organizations and targeted media campaigns. India's Bureau of Energy Efficiency concentrates on small and medium-size enterprises and clusters because of their more limited access to information and technology.

Training firm personnel and increasing absorptive capacity

Several developing countries have national programmes to train managers, technical staff and workers in areas such as energy management, energy monitoring and process control systems, energy auditing, and certification, identification, appraisal and implementation of industrial energy-efficiency projects. The programmes are fairly standard. For instance,

> **Recognition programmes that reward firms implementing energy-savings solutions can promote positive perceptions of industrial energy efficiency**

in Chile, 19 universities and two engineering associations provide industrial energy-efficiency training (APERC 2010a). In China, such training is especially important for township and village enterprises, which typically rely on low-grade, non-standard technologies. Historically commune-based and non-specialist, these enterprises and their staffs are often underqualified to operate and maintain new energy-efficient equipment (Worrell et al. 2001).

A firm's absorptive capacity – its ability to use the information that comes from interacting with other firms, users and knowledge providers (Cohen and Levinthal 1990; Giuliani and Bell 2005) – determines its ability to benefit from the technological knowledge available in global and local networks. Absorptive capacity is generally low in firms in developing countries, but it can be expanded through training and information programmes (Box 6.6). Equipment suppliers provide training for their equipment, sometimes along with other, generic information. The Japanese gas supplier, Gasunie, for example, provides technical assistance by supporting process-integration analyses, audits and feasibility studies (Galitsky, Price and Worrell 2004). Governments can complement these efforts and provide training to enterprises or energy consultancy companies, but as with awareness campaigns, engaging top management is crucial to achieving positive outcomes (UNIDO 2011). In Indonesia and Viet Nam, national programmes have provided technical assistance and trained corporate energy consultants on the engineering and financial aspects of industrial energy-efficiency investment projects (USAID 2008; GEF 2004).

Offering recognition and reward programmes

Recognition programmes (contests, awards, media exposure, recognition certificates) reward firms that implement industrial energy-efficiency or other energy-savings solutions. These programmes can be effective motivators and promote positive perceptions of industrial energy efficiency by highlighting potential benefits and publicizing successful outcomes.

Box 6.6
Capacity-building for absorptive capacity

The China Motor Systems Energy Conservation Programme, introduced to assist the government in controlling greenhouse gas emissions, promotes improvements in motor-system efficiency in factories throughout the country.

Electric motor systems, used widely in Chinese industry to power fans, pumps, air compressors, refrigeration compressors, conveyers and other equipment, account for more than half of China's electricity use. Thus, they offer large opportunities for efficiency gains and energy savings (20 percent or more in many applications).

As a pilot, the programme focused on Jiangsu and Shanghai Provinces, demonstrating a methodology for establishing and training a network of motor-system optimization experts and identifying suitable business models for scaling up to the national level.

The programme has built a strong foundation for national scale-up. It trained 22 engineers in motor-system optimization techniques. And within two years of completing training, these local experts had trained more than 1,000 factory personnel, conducted 38 industrial plant assessments and saved nearly 40 million kilowatt hours of energy.

Source: UNIDO (www.unido.org/index.php?id=1000786).

Pursuing rewards for competitive advantage can embed pursuit of energy efficiency in an organization's culture (Mallett, Nye and Sorrell 2011). Energy awards provide a channel for companies to audit their energy use, identify possible energy savings and increase profitability.

Recognition programmes can be implemented in a range of contexts. In India, the Ministry of Power launched the annual National Energy Conservation Awards programme, which recognizes industrial firms that reduce energy consumption while maintaining production. Companies submit reports on completed energy conservation projects, which are reviewed by government officials. The number of participating firms expanded from 123 in 1999 to 558 in 2009 and over that period saved 12,113 million kilowatt hours of energy (11.3 million rupees; NECA 2009). Sri Lanka established a National Energy Efficiency Award

Governments can facilitate network building on industrial energy efficiency among firms, sector specialists, academia, industry associations, non-profits and other affected groups

in 2010, and Kenya's Energy Management awards are a popular annual event (Sri Lanka SEA 2011[7]; Kenya Association of Manufacturers n.d.).

Recognition programmes are an attractive policy option because the awards are performance-based; the investment necessary is low; and the potential for stimulating future energy savings is high. Recognition programmes can inform policy-makers of successful national and regional options, lessons that are frequently integrated into policy (McKane, Scheihing and Williams 2008).

Publicizing the successes of recognition programmes can motivate companies to comply with industrial energy-efficiency policies and programmes. For example, Japan's Top Runner Programme relies heavily on the strong cultural influence of saving face. Even if standards are voluntary, the incentive to comply is strong because an enterprise's failure to do so will be made public.

Building networks

Governments can facilitate network building on industrial energy efficiency among firms, sector specialists, academia, industry associations, non-profits and other affected groups. Such networks can be especially important in developing countries, where industrial energy efficiency is a low priority among senior managers (Ozturk 2005; Worrell and Price 2001). Studies show that projects strongly supported by leaders are more likely to succeed (Etzkowitz and Carvalho de Mello 2004).

Studies of China's iron and steel sector suggest that firms in developed and developing countries need to work together to share the risk of adopting advanced industrial energy-efficiency technologies (Worrell 1995). A Global Environment Facility project in India found that more communication was needed among private sector players (steel re-rolling mills, domestic equipment manufacturers, trade and industry associations and others) for uptake of industrial energy-efficiency technologies (Verbeken 2009). Similarly, stakeholder alliances were found to be an asset of UNIDO–UNEP clean-production projects (Ciccozzi, Checkenya and Rodriguez 2003). Agreements were established with local institutions hosting the project training courses, which could then offer the courses beyond the project's lifespan.

A project run by the Energy Research Institute at the University of Cape Town, South Africa, facilitated networking between firms and organizations with industry expertise in Organisation for Economic Co-operation and Development (OECD) countries and large South African firms (breweries, pulp and paper companies and mining companies). The networks helped participating South African firms identify more than 5 million rand in energy-efficiency investments, with a payback of less than a year (Spalding-Fecher 2003).

Promoting new technology and innovation

Countries can also adopt measures to promote industrial energy-efficiency innovation based on their economic structure and growth strategies. Some measures are more suitable for emerging market economies, which have the potential to develop an indigenous technology base, and other measures are more suitable for countries relying primarily on technology transfer. It probably does not make economic sense for smaller, less advanced economies to develop their own technology supply chain. (See Table 6.2 and Annex 14 for some of the main technology and innovation policy measures used by developing countries.)

Innovation encompasses several stages: R&D, practical demonstration, initial commercial application and diffusion of the new technology or process through market forces. New technologies are the result of a complex process of scientific advances, learning by doing, and directed and spillover efforts in the private and the public sectors (IPIECA 2006).

Industrial energy-efficiency innovation differs from other types of innovation. Dominant energy users and equipment suppliers jointly determine the development of new technology. And transitions in major energy technologies often take decades, requiring massive infrastructure investments, even for superior technologies.

“ Industrial energy-efficiency innovation differs from other types of innovation: energy users and equipment suppliers jointly determine the development of new technology, and transitions in major technologies often take decades

Encouraging research and development

How can governments promote R&D that accelerates reductions in industrial energy intensity? Policymakers who value technological innovation may develop and strengthen national and multinational strategic R&D programmes. Governments may focus on demand pull (achieving improvements through efficiency standards and regulations), technology push (encouraging improvements through R&D funding and technology transfer) or, most often, a combination.

For supply (technology push), public policy options to foster innovation include:

- *Government-funded research.* Publicly funded research centres, including training; public research institutions focused on energy efficiency; and jointly funded industry-government research.
- *Subsidized private sector research.* Private firms can have better information than the government about the commercial feasibility of energy-efficiency technologies. Subsidies can take the form of tax credits or matching funds for research projects, complemented by subsidies for training scientists and engineers.
- *Regulations.* Regulations, including legislation on intellectual property rights, can create incentives to invest in generating new knowledge.

Several large developing countries have implemented some of these measures to generate local capacity in industrial energy efficiency. Nigeria's severe shortage of energy prompted the government to establish the University of Lagos National Centre for Energy Efficiency and Conservation in 2008, which is responsible for R&D in energy-efficiency and -conservation options and technologies. Following the 2010 enactment of the Russian Federation's energy-efficiency legislation, the country has intensified efforts to create an R&D capacity in energy efficiency. The Russian Federation recognizes the role of a growing number of organizations engaged in research on improving energy efficiency, such as the Centre for Energy Efficiency, the Sustainable Energy Development Centre and the Institute of Energy Strategy. Under the 11th Five-Year Plan (2006–2010), China's government invested more than $10 billion to support hundreds of research projects in energy conservation, new energy, recycling, clean production, pollution control, climate change technology, demonstration and extension (APERC 2006).

Boosting adoption and diffusion of energy-efficiency technology

Encouraging adoption and diffusion of best available technologies requires considering domestic market conditions and the technical, managerial and financial capacities of domestic industries to take up the technologies. Government actions to encourage technology adoption and diffusion include:

- Supporting energy data collection and dissemination.
- Training scientists and engineers.
- Introducing regulations to remove inefficient producers from the market. Standards for industrial equipment and system optimization can make it easier for firms to trade off capital and energy costs, but they can also impose limits on product choice and undesirable costs for adopters.
- Procuring industrial energy-efficient equipment.
- Reducing the effective purchase price of new equipment that meets specified criteria. (A drawback is that these subsidies and tax credits can require large public expenditures per unit of impact.)
- Facilitating local production or import of high-efficiency equipment.
- Supporting public-private partnerships to promote technology centres.
- Establishing technical assistance programmes to inform enterprises of the opportunities and potential for energy savings, improved access to technical skills and reduced uncertainty about the appropriateness of certain technologies.

Analysing the costs and benefits of these polices is important but challenging, even in developed countries. Technology policy successes are difficult to measure because outputs are often intangible, expected benefits of technologies change with conditions, and evaluations of these polices make sense only

> **Demonstration projects inspire companies to implement new technologies and create the confidence to replicate them, facilitate staff training and stimulate ideas for further innovation**

after a long time (Jaffe, Newell and Stavins 2004). The effects, if they can be identified at all, are evident only after several years, a major barrier to increased R&D and technology diffusion. Evidence suggests that such expenditures are cost-effective for society as a whole, but successful developments could be copied by countries or firms that have not shared the upfront costs (UNIDO 2008b).

Two highly effective technical assistance programmes that eventually became commercial activities are Argentina's Energy Study Groups and Ghana's Energy Van Service (ECLAC 2010; Energy Foundation n.d.). Energy Study Groups, which emerged from an agreement between the National Technology University and the Secretariat of Energy in 1985, consist of a professor with extensive experience in energy issues (the director) and two or three engineering professionals who visit industrial firms, provide energy assessments and help implement solutions. The services were free at first, but in 1990 the groups began to charge a fee. By 2010, more than 2,000 companies assisted by the groups had improved steam production and distribution systems, ovens and drying systems, electrical motors, air compressors, refrigeration facilities, air conditioning and ventilation equipment, and other equipment and systems.

Under Ghana's Energy Van Service, provided by the Energy Foundation since 2004, a van stocked with energy diagnostic and measuring instruments such as motor testers, power and combustion efficiency gas analysers and ultrasonic leak detectors visits businesses regularly to identify and estimate energy-saving opportunities. The services were originally provided at no charge, but several companies have requested permanent on-site services, which are now available for lease to energy service companies.

Promoting demonstration projects

New technologies, especially if capital intensive, frequently require public investment in demonstration projects. Typically, a first-of-a-kind plant is several times as expensive per unit of capacity as adding a plant after the technology has been piloted elsewhere. These initial high costs can present a substantial barrier, especially if the technology is lumpy (it cannot be acquired in small increments but must be purchased in large, discrete units) and billions of dollars are involved. Egypt and Malaysia have used demonstration projects extensively in industries such as pulp and paper, glass, food, steel, palm oil and textiles to promote energy-efficient technologies (UNIDO 2011).

Demonstrating technology applications can show that new technologies need not be prohibitively expensive and can generate substantial benefits, thus encouraging adoption by similar companies. Demonstration projects inspire companies to implement new technologies and create the confidence to replicate them, facilitate staff training and stimulate ideas for further innovation. Thus, effectively promoted, such projects have a large multiplier effect (Hamed and Mahgary 2004).

Taking advantage of international cooperation

International cooperation can be a major source of new energy-efficiency knowledge and technology for developing countries. By participating in international research groups or taking advantage of foreign technical assistance and technology transfer in specialized energy-efficiency fields, countries have tapped state-of-the-art advances.

The Russian Federation recently sought public and private international cooperation (Soloviev 2009). It signed agreements with the German and Finnish Governments and with Siemens AG, a major German power equipment manufacturer. The German Energy Agency is advising its local counterpart on the design and implementation of innovative and promising approaches for energy efficiency, while the Finnish authorities provide expertise in technologies for cold climates. Siemens AG is helping develop a programme for enhancing energy efficiency in Yekaterinburg.

Experience shows that local partners can reap substantial benefits from international cooperation linked to local policy measures when there has been substantial

Accurate carbon pricing is a precondition for creating market incentives to change consumer behaviour and promote industrial energy efficiency

preparatory activity, when technology is adapted to local conditions, when cooperation at the working level is sustained and when public-private partnerships are given high priority (UNIDO 2011). Egypt's experience with international cooperation suggests that programmes that support the entire value chain, from product conception through final sales to consumers, yield better energy-efficiency results by enabling systemic gains than do piecemeal projects (UNIDO 2011).

Using market-based policy instruments

Market-based policy instruments capture the spillover effects of an economic agent's action by internalizing externalities. Instruments include corrective taxes for negative externalities (such as carbon taxes) and subsidies for positive ones (such as carbon emission trading schemes). International schemes of this type were established by the Kyoto Protocol and have since been replicated regionally and nationally.

Introducing carbon pricing

Industrial firms' decisions on investing in industrial energy efficiency are distorted when market forces fail to account for greenhouse gas emissions from carbon-intensive energy sources (market failure) or when carbon-intensive energy is subsidized and thus underpriced. Accurate carbon pricing is a precondition for creating market incentives to change consumer behaviour and promote industrial energy efficiency.[8]

Carbon taxes curb demand for carbon-intensive energy by increasing its price. In principle, the taxes should create an incentive for technical innovation (dynamic efficiency) – and also reduce greenhouse gas emissions to the point where the marginal cost of additional abatement equals the tax, thus minimizing the cost of reducing emissions (static efficiency).[9] Carbon taxes provide more choices in the level and method of cutting greenhouse gas emissions than do technical regulations and product bans. In addition, less administrative work is required to manage taxes than to establish and enforce regulations, thus saving taxpayer money (Jaffe, Newell and Stavins 2004; Kosonen and Nicodème 2009).

Taxes on products and services directly or indirectly linked to greenhouse gas emissions generate revenue that can go to the government budget or finance industrial energy-efficiency investment at a lower cost than commercial bank loans (Gillingham, Newell and Palmer 2006). Tax revenues can also finance information and auditing programmes, lower taxes for industries that meet negotiated energy-efficiency targets and fund research on energy-efficiency technologies. These funds can be administered through private organizations, government agencies or international organizations. An example is Sri Lanka's Pollution Control and Abatement Fund, established by the government in 1995 ($5 million) to help industrial firms improve energy efficiency and adopt pollution-reducing measures (Thiruchelvam, Kumar and Visvanathan 2003). The programmes included technical assistance and credit.

Energy and carbon taxes are often complemented by other instruments, such as energy-efficiency subsidies (see section below on tailoring subsidies), information campaigns and labelling. Taxes alone may not suffice to address environmental problems, since the tax rate is an imperfect proxy for the externality and is constrained by concerns about impact on income distribution and industrial competitiveness (Kosonen and Nicodème 2009). Taxes do not address other common market failures either, such as imperfect information.

Removing direct and indirect subsidies on carbon-intensive energy (such as lower value added taxes) is a first step towards pricing that reflects the true cost of energy use. Removing subsidies will increase the price of carbon-intensive fuels and strongly influence adoption of industrial energy-efficiency measures because of the long lifetimes and slow turnover of energy-intensive appliances and capital equipment. Energy-producing countries with subsidized fuel prices would also benefit from removing subsidies: carbon-intensive energy sources could be sold at much higher prices on international markets, with positive impacts on government budgets and export earnings, especially in an environment of rising energy prices. Whenever

> **Removing direct and indirect subsidies on carbon-intensive energy is a first step towards pricing that reflects the true cost of energy use**

subsidies are removed, the social implications must be taken carefully into account, with compensating mechanisms introduced as necessary to protect poor and disadvantaged groups.

China, Egypt, India, Indonesia, Malaysia, Romania and the Russian Federation were among the 37 developing countries reviewed that have begun removing subsidies on carbon-intensive energy and are moving towards carbon pricing (UNIDO 2011). The approach has for the most part been gradual, and some evidence in Egypt and Indonesia suggests that energy-intensive firms have adjusted to new pricing structures without major production disruptions. Taking guidance from international energy prices and using differential pricing to induce energy-efficient behaviour seem to be effective in reducing energy consumption and intensity in China. Enterprises are charged increasingly higher rates for additional units of electricity to phase out inefficient enterprises and reduce emissions (Moskovitz et al. 2007). In 2007, the policy was adjusted to allow provincial authorities to retain the revenue collected from the differential pricing, providing stronger enforcement incentives.

Designing an effective way to remove energy subsidies is a major policy challenge. Eliminating the subsidies can have negative effects where, for example, they promote affordable energy for smaller firms.[10] Eliminating or reducing energy subsidies to encourage industrial energy efficiency should be combined with other measures to help vulnerable firms and households (Ayres and Warr 2009). Strategically redirecting subsidies (leveraging the free-rider effect of energy subsidies for firms that would have made energy-efficiency improvements anyway) can release money for new programmes to support more successful energy-efficiency investments and reduce budget outlays.[11]

Launching emissions trading schemes

Emissions trading schemes are generally a more complex market-based approach to industrial energy efficiency and are unlikely to be a key policy initially for most developing countries. There is potential, however, for the schemes to be part of the policy framework of some larger developing economies.

The EU Emissions Trading System, a multi-country, multisector climate change mitigation policy, aims for cost-effective emission reductions. It sets targets for large greenhouse gas emission sources (including the energy-intensive manufacturing industry) and allows trading for emissions below the targets. It covers more than 10,000 installations in industrial electricity-generating sectors that are collectively responsible for nearly half of EU carbon dioxide emissions. But the system has faced several challenges. Notably, compliance has been difficult with the price of emission allowances so volatile (Wara and Victor 2008). Also, as a new scheme, there are complexities in measurement, reporting and verification, requiring a large, well trained staff and robust legislative procedures. There have also been concerns about international competitiveness and "carbon leakage," but only a few sectors have experienced large cost increases, and most appear to have benefited. The impact of the scheme on industrial energy efficiency is difficult to gauge, since the scheme began just a few years ago and is focused on carbon reduction, not efficiency directly.

Promoting energy saving certificates

A more direct industrial energy-efficiency policy, and one meant to complement the EU Emissions Trading System, is the UK Carbon Reduction Commitment, launched in 2010. This mandatory scheme aims to improve energy efficiency and cut emissions in large public and private sector organizations, which together account for some 10 percent of UK emissions. The scheme ranks participants annually on their energy-efficiency performance. The Energy Savings Scheme of New South Wales, Australia, requires electricity retailers, licensed suppliers and electricity purchasers to meet energy-savings targets through performance or the purchase of certificates (NSW Government 2010; see Chapter 5).

India has also taken this performance-based approach to industrial energy efficiency. In 2010, the

Subsidies and tax allowances, by lowering the costs of investing in industrial energy efficiency, are designed to mobilize investment, prepare for new regulations or promote energy-efficient technologies

National Mission for Enhanced Energy-Efficiency announced the Perform, Achieve and Trade scheme for large energy-intensive industries. Coupled with harsh penalties for non-compliance, the scheme aims to strengthen incentives for saving energy. It provides opportunities for energy-intensive industries to trade efficiency achievements above set targets through Energy Saving Certificates. Energy savings are certified, and credits are awarded for reaching benchmarks. The credits can be traded to industries that fail to meet technical regulations. Launched in April 2011, the scheme is too new to evaluate. The mechanism intends to cover about 600 enterprises initially. Baseline energy auditing for these industrial firms has already begun (Box 6.7).

Tailoring subsidies and allowing accelerated depreciation

Subsidies and tax allowances, by lowering the costs of investing in industrial energy efficiency, are designed to mobilize investment, prepare for new regulations or promote energy-efficient technologies by expanding markets. Subsidies can be paid directly from public funds to firms investing in energy-efficient technology or related services, such as audits, or they can be provided as tax credits and allowances or reductions in value added taxes.

Several countries subsidize energy-efficient equipment to accelerate uptake. Chile reimburses firms for the cost of hiring energy auditors, covering up to 70 percent of consulting fees, with a cap of $10,000 (ECLAC 2009). China has earmarked roughly $2 billion for subsidies for 5 of their 10 identified key industrial energy-efficiency projects (coal industrial boilers or kilns, waste heat recovery/waste power recovery, petrochemical conservation or substitution, electrical machinery energy-saving system and energy system optimization).

Malaysia has integrated subsidies into a targeted tax scheme for improving industrial energy efficiency. Companies that provide energy-efficiency services are eligible for a 100 percent corporate income tax exemption for 10 years or a 100 percent investment tax allowance on qualifying capital expenditures incurred over five years. Companies that make capital expenditures to reduce their energy consumption are eligible for a 100 percent investment tax allowance on the qualifying expenditure over five years. The package also features import duty and sales tax exemptions (APERC 2010a).

Thailand has allocated some $4.5 million to subsidizing energy-conservation programmes (APERC 2010a). A cost-based tax incentive offers a 125 percent tax break on investments improving energy efficiency. A performance-based incentive allows companies to deduct 30 percent of the energy savings from their taxes up to a ceiling of $60,000. Together, these incentives have led to estimated savings of $10–$30 million a year (Sinsukprasert 2009). A government evaluation found higher payback in energy saved per dollar invested from cost-based solutions than from performance-based ones. Tunisia has had similar success with cost-based subsidy measures when

Box 6.7
Energy saving certificates in India

India's total annual energy consumption is about 450 million tonnes of oil equivalent (toe). In April 2011, the Indian Bureau of Energy-Efficiency released targets for 580 industrial units in eight energy-intensive sectors (thermal power stations, steel, fertilizer, cement, aluminium, chloralkali, paper and textiles). Together, these units consume about 200 million toe a year. The overall targets would lead to sector wide savings of around 5 percent of current energy use, equivalent to 10 million toe.

Target-setting will eventually lead to a market-based mechanism allowing businesses that cannot reach their targets to buy energy certificates from businesses using less energy than their target.

Firms failing to comply will be assessed a penalty equal to the price of the shortfall. Penalties will accrue to state treasuries, with each state having a designated enforcement agency.

According to the Bureau of Energy Efficiency, operational guidelines have been prepared based on discussions with the targeted industries, and any concerns have been allayed.

Source: Economic Times 2011.

> **Access to finance remains a considerable barrier in developing countries, despite the flow of financial aid to energy-efficiency projects from multilateral financial institutions – and the financial profitability of many projects**

targeting energy audits and energy-efficiency projects (ANME n.d.; Georgy and Soliman 2007).

Boosting demand

Utility companies are in a unique position to influence industrial energy efficiency because of their financial, organizational and technical capacity and their connection to virtually all energy users (UNECE 2010). Many utility companies are motivated to manage demand because they face load-capacity limitations, blackouts and unreliable supply. Demand-side management programmes aim to reduce industrial energy consumption through rebates, loans, subsidized audits, free installation of equipment and energy awareness programmes (Gillingham, Newell and Palmer 2006). The changes are implemented through specialized firms. Thus, while demand-side management can reduce energy consumption and increase energy efficiency, regulatory mechanisms and government support are required to create mandates or incentives for utilities and supporting firms (Violette, 2006; Gillingham, Newell and Palmer 2006; World Bank 2005).

Demand-side management programmes, popular in developing countries, are used mainly to ease the shift from incandescent bulbs to fluorescent lamps and other forms of energy-efficient lighting. Some developing countries, including China, Colombia, Indonesia, the Philippines, South Africa and Thailand have gone further and integrated demand-side management programmes into broader national energy saving policies (Thiruchelvam, Kumar and Visvanathan 2003; UNIDO 2011).

The success of industrial demand-side management depends on the ownership and structure of energy markets and the systems for monitoring and verifying energy savings. Experience in South Africa, Thailand and Viet Nam reveals several potential obstacles (World Bank 2002, 2004, 2005). Problems have included inadequate information about efficiency opportunities for end-users, equipment manufacturers and service providers; insufficient incentives for utilities; unfair competition between private sector companies implementing the programmes; lack of transparency; inconsistent management support; frequent staffing changes; high project development costs arising from audit and technical studies require requirements; and lack of affordable financing. An assessment of demand-side management programmes in Thailand notes the greater success of programmes aimed at households than of programmes encouraging firms to adopt more energy-efficient equipment, largely because of a lack of investment financing.

Launching financial instruments

Both the public and private sectors have crafted financing mechanisms to address investment barriers at each stage of technology development: innovation (research and development), demonstration, deployment and diffusion (Makinson 2006). The gaps are concentrated between the demonstration and the deployment stages (MacLean et al. 2008; Figure 6.2), so the bulk of public finance and technical cooperation addresses the lack of capital and capacity before the technology reaches the diffusion stage.[12]

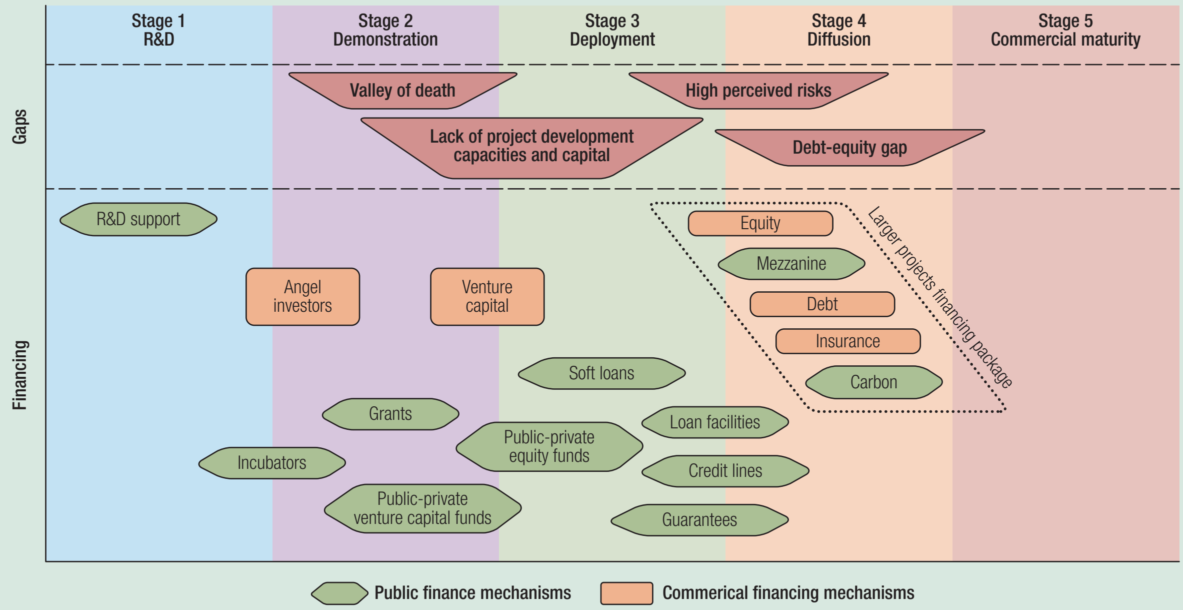
Ensuring access

Access to finance remains a considerable barrier in developing countries, despite the flow of financial aid to energy-efficiency projects from multilateral financial institutions – and the financial profitability of many projects (Sorrell, Mallett and Nye 2011; Worrell 2011; te Velde 2010; Schleich 2011). Soft loans, often as special-purpose energy-efficiency funds, are the most common form of finance (Box 6.8). Other mechanisms include credit lines, revolving funds, publicly backed guarantees and project loan facilities. Most of these financial instruments are backed by multilateral financial institutions; some include technical assistance.

Of the 37 developing countries in the UNIDO policy review, 21 have established an industrial energy-efficiency financing mechanism (UNIDO 2011). The Chinese Government set up a loan programme for energy conservation in 1980. The largest energy-efficiency investment programme ever undertaken

Of the 37 developing countries in the UNIDO policy review, 21 have established an industrial energy-efficiency financing mechanism

Figure 6.2
Technology innovation path and financing gaps



Source: MacLean et al. 2008.

Box 6.8
Tools for addressing liquidity constraints and risk in developing countries

There are several tools for addressing liquidity constraints and risk that impede investment in industrial energy-efficiency investments in developing countries.

Credit lines can be offered at concessional rates where market rates are high. Guarantees or other risk-sharing structures between the development finance institution and local commercial banks can reduce a project's credit risk.

Soft loans are loans at subsidized interest rates for industries that invest in energy-efficiency technologies and equipment. Some soft loans include interest-free grace periods until revenues from the energy savings start to flow. Most national and multinational development finance institutions set up loan programmes to fill the financing gaps in immature financial markets. Creating debt financing mechanisms is important for developing new markets, especially small energy-efficiency ventures. Concessional financing in the form of interest rate subsidies or fees paid to partner banks can be appropriate in markets without commercial financing of energy-efficiency projects and where bank liquidity is a barrier.

Closely related to soft loans are *revolving funds,* which use repayment of previous loans to finance new loans for energy-efficiency projects. Revolving funds can be publicly funded (fully or partially) and may be established in cooperation with commercial banks. Energy-efficiency projects seeking funding do not need to compete against more traditional investments for bank funding. The public funds are provided to commercial banks with no interest or well below market rates, enabling the banks to offer below-market rates. In return for receiving public funds, banks may be asked to assume some or all of the risk of repayment associated with the loans.

Publicly backed guarantees are three-party contracts in which a public institution guarantees to compensate a lender if the borrower defaults. These instruments mitigate the financing risks associated with medium- to long-term loans. Related schemes are partial credit and partial risk guarantees. Guarantee schemes in both developed and developing countries have mobilized private resources and facilitated access to capital.

Project loan facilities fill the financing gaps in markets where commercial institutions are unable or unwilling to provide financing. Created by governments and development financial institutions, these facilities can be effective finance mechanisms if carefully designed.

Source: Mostert, Johnson and MacLean 2010; Makinson 2006; MacLean et al. 2008.

Public finance can leverage and stimulate commercial finance, but financial institutions also need to be educated about industrial energy-efficiency financing

by a developing country, it commits 7–8 percent of total energy investment to energy efficiency, primarily in heavy industry. The programme not only funded projects that had an average cost of conserved energy well below the cost of new supply, but it also stimulated adoption of efficient technologies well beyond the small pool of project fund recipients (Levine and Liu 1990; Liu et al 1994). Of the apparent 25 percent drop in industrial energy intensity in the 1980s, about 10 percent can be attributed directly to the efficiency investment programme (Sinton and Levine 1994) and a larger amount to unsubsidized efficiency investments, efficiency improvements incidental to other investments and housekeeping measures (Worrell et al. 2001).

African governments have also begun to introduce concessional project finance for energy-efficiency investments (UNIDO 2011). The Egyptian Government set up the Environmental Compliance Office at the Federation of Egyptian Industries to provide environmental services to small and medium-size enterprises, including access to soft loans for industrial energy-efficiency investments (FEI n.d.). Tunisia established a National Fund for Energy Conservation in 2005. In South Africa, the public electricity utility, ESKOM, provides concessionary funding for capital expenditure and implementation costs for industrial energy-efficiency projects.

Public finance can leverage and stimulate commercial finance, but for industrial energy-efficiency projects, care is needed to ensure that public finance does not deflect businesses from seeking commercial finance. Commercial finance has to be the main source of energy-efficiency financing. To be effective, public financing mechanisms must address both supply and demand constraints, ensure that projects are technically viable and financially profitable and leave room for local financial institutions to offer accessible and affordable financing (Gielen 2009). The transaction costs of industrial energy-efficiency projects are high because many are small and technically complex. Financing mechanisms should accompany technical assistance programmes for financiers and project developers and implementers. Many financing mechanisms for small to medium-scale projects require financial intermediaries (Makinson 2006).

Financial institutions also need to be educated about industrial energy-efficiency financing (Ghosh 2011; UNIDO 2011). Poor communication and advertising prevent Indian enterprises from learning about the financial facilities available for industrial energy-efficiency projects. Bankers in India often regard energy-efficiency technologies as unproven and therefore risky because they lack the knowledge or resources to appraise them. And developing country banks need to avoid overburdening local firms with red tape. Loan applications often require so many clearances and certifications from multiple institutions (land offices, registration authorities, municipal water and waste disposal authorities, electricity departments, pollution control authorities, district industry centres, credit rating agencies and so on) that enterprises are deterred from applying.

Promoting energy service companies

Energy service companies (ESCOs), which provide energy-management services and creative financing tools to industrial firms (Vine 2005), are more a private initiative than a government policy instrument. They are discussed here because UNIDO's 2011 policy review found that 11 developing countries are promoting and supporting them as industrial energy-efficiency tools. Through energy performance contracts, ESCOs and firms set the terms for risk-sharing and co-financing industrial energy-efficiency projects. ESCOs design and provide or arrange financing for the project (and receive payment based on energy services provided by the project), sometimes assume the project performance risk (by guaranteeing a minimum level of energy savings) or the credit risk, and install and maintain the equipment (MacLean et al. 2008). For industrial firms, this approach is an innovative way to finance large industrial energy-efficiency projects without paying cash up front.

Traditional project financing rules may not apply to energy performance contracts, which can be treated

> **Many policy instruments in developed countries are suitable benchmarks for developing countries, though design may need to change to meet national and local conditions**

as either on- or off-balance sheet transactions. ESCO payments are linked to a firm's energy performance: no energy savings means no payment (Satchwell et al. 2010). Payments are not to exceed savings, and industrial firms do not make capital investments or capital commitments to the project. Monthly payments to ESCOs are treated as utility expenses and recorded as debt. The payments may vary with the savings, or the savings can be shared between the ESCO and the firm. Since project financing is considered an off–balance sheet transaction, no assets accrue to ESCOs, and the firm owns the equipment.

While there have been great expectations for ESCOs, experience in both OECD and developing countries shows that the impact of ESCOs in promoting and financing industrial energy efficiency has often been limited (Vine 2003; Painuly et al. 2003). Despite exceptional overall growth in the United States, ESCO's success has been confined largely to the public sector and much less to commercial and industrial activities (Goldman et al. 2002; Satchwell et al. 2010). Many developing countries lack the legal and financial framework to enforce the complex contractual models required for ESCOs (Sarkar and Singh 2010). International ESCOs, while initially eager to operate in developing countries, acknowledge that many prospective customers require more time and capacity-building to adequately understand and accept such models, and customer credit-worthiness and local credit are not assured (Sarkar and Singh 2010).

Policy design and implementation considerations for developing countries

Policy replication, local governance capacity and policy evaluation are all issues that developing countries should consider in policy design and implementation.

Policy replication

The literature on the impacts of industrial energy-efficiency policies shows that developed countries rely too much on policy tools from developed countries (Sarkar and Singh 2010). Policies (and policy evaluations) should reflect developing country market and technological conditions.

Still, many policy instruments in developed countries are suitable benchmarks for developing countries, though design may need to change to meet national and local conditions. Developing country policymakers seeking to replicate policies from other countries should consider several factors:

- National patterns of industrial specialization (dominant industrial sectors and their energy intensities).
- Characteristics of individual sectors, such as energy use, international and domestic energy performance, main sources of energy losses, potential for energy-efficiency improvements, domestic technological capabilities and technical, managerial and financial capabilities to implement energy-efficiency opportunities.
- Alignment of policy instruments with socioeconomic features (laissez-faire or command-and-control systems) and cultural norms; some countries may need more strict regulatory regimes with formal sanctions while others can rely on normative pressures (WEC 2010).
- Suitability of existing policy frameworks and policy-making records (achievement of policy objectives, including economic effectiveness and budgetary impacts).
- Ability of public administration to assess country-specific aspects and to implement policy measures.

Local governance capacity

Some instruments require sophisticated institutions and a capable public administration, so countries may need to improve administrative capabilities and establish new regulatory institutions. Preparing information and building the institutions needed to formulate, institutionalize and implement industrial energy-efficiency policies and programmes all have costs, something not always considered in policy measure discussions (UNEP 2006a; WEC 2008). Including these transaction costs is especially important in developing countries, where markets and institutions are less

“Some instruments require sophisticated institutions and a capable public administration, so costs for policy capacity-building in benchmarking and developing indicators need to be factored in

mature than in developed countries. Any costs for policy capacity-building in benchmarking and developing indicators to measure the effects of energy-efficiency policies, such as industrial plant energy auditing and monitoring, reporting, verification and evaluation, also need to be factored in.

International organizations can help to collect and disseminate information for domestic and international policy benchmarking. The UNIDO (2011) industrial energy-efficiency policy database developed for this report documents 21 industrial energy-efficiency policy mechanisms in 37 developing economies (see Annex 14). The International Energy Agency's (IEA) Energy-efficiency Database details some 170 policies and measures introduced locally, regionally and nationally in 32 countries and the European Union (IEA 2008c). The IEA's World Energy Outlook Policy Database includes 530 entries for industrial policies and programmes, drawn from other IEA databases (Climate Change Mitigation Database, Energy-efficiency Database, Global Renewable Energy Policies and Measures Database), the European Conference of Ministers of Transport and contacts in industry and government (IEA 2008a). Lessons from implementing these policies could accelerate industrial energy-efficiency uptake if applied across developed and developing countries.

Policy evaluation

There are numerous approaches to assessing barriers to industrial energy efficiency and identifying policies to overcome them, including orthodox, transaction cost and behavioural economics and organizational theory (Montalvo 2008; Sorrell, Mallett and Nye 2011). And there is a range of objectives against which to assess policy impact, including energy use and greenhouse gas emissions, social and developmental objectives and their economic costs. Instruments such as taxes, fees and penalties can generate revenue, while others such as subsidies, grants and information and awareness programmes have costs. Studies rigorously evaluating policy effectiveness in developing countries are still lacking.

Many options

As developing countries continue to industrialize to meet the needs of growing populations, industrial energy efficiency seems to be a relatively uncontroversial area for policy intervention to ensure sustainable development. It is hard to argue with the success of measures that resonate in both concept (doing more with the same or the same with less) and practice (increasing industrial energy efficiency to yield tangible benefits for most, if not all, stakeholders).

Developing countries have an array of policy options, but selecting the right mix is not easy. Most of the options come with uncertainties or downsides. Rules and regulations can cut greenhouse gas emissions substantially, but targets can be unrealistic and legislation too inflexible to adapt to rapidly evolving technological change. A governance structure is indispensable, yet it can also become a source of red tape and corruption. Information and training are crucial for dealing with market failures and apprising entrepreneurs of hidden costs, yet the costs of providing them and of identifying who to provide them for are often overlooked. Technology and innovation are key drivers of industrial energy efficiency, but they are beyond the means and capabilities of all but a few developing countries and can take a long time to yield returns. Most developing countries will continue to rely on foreign technologies, but even that requires building local absorptive capacity. Market-based policies can induce desired behaviour cost-effectively, yet they involve acute intertemporal trade-offs and can sometimes be unpopular. Financial instruments can overcome some problems of access to capital and lower perceived risk, but they require a sophisticated financial sector.

Despite the array of policy options to choose among, several things seem clear. International policy benchmarking is necessary, as are local adaptation of policy measures, solid local policy design and implementation capacity, and continuous evaluation of policy initiatives.

Promising areas for advancing developing country policies are voluntary and negotiated approaches and direct private sector involvement in implementation.

Despite the array of policy options, several things seem clear: international policy benchmarking is necessary, as are local adaptation of policy measures, local policy design and implementation capacity, and continuous evaluation of policy initiatives

China is one of the few developing countries using negotiated agreements, based on Danish, Dutch and Finnish models. Involving top management of high energy-intensity firms in corporate decision-making has led to successful information and technological policies on industrial energy efficiency.

Small and medium-size enterprises and the financial sector warrant special attention. Such firms have a vital role in accelerating industrial growth in developing countries, yet they are considerably less energy efficient than their developed country counterparts. Tailored policy packages and incentives could help transform small and medium-size enterprises into energy-efficient engines of growth. The domestic financial sector, despite making more funds available for investment in industrial energy-efficiency projects, has yet to establish the procedures needed to facilitate energy-efficiency lending. Governments need to provide the framework and support to enable these changes. Chapter 7 looks at the role of international collective action in encouraging industrial energy efficiency.

Notes

1. To accompany this report, UNIDO compiled a database of industrial energy-efficiency policies drawn from official documents and webpages, databases of various international organizations and the academic literature. The database is available at http://ieep.unido.org. A list of policies is in Annex 14.
2. The World Energy Council (WEC 2010) reports that as of 2009, 70 countries (or two-thirds of surveyed countries) had adopted national energy programmes with national and sectoral quantitative targets for energy-efficiency improvements, twice as many as in 2006. In Europe, some 90 percent of countries had adopted targets, up from 55 percent in 2007. Around 60–80 percent of surveyed countries prefer to use targets for energy-efficiency improvements or energy savings.
3. The rationale behind voluntary agreements can also be ethics-governed behaviour or hedging against imposition of mandatory obligations (UNEP 2006c). The US Department of Energy keeps a national database of voluntary reductions in greenhouse gas emissions and a national inventory of emissions enabling any company to "make public commitments to future reductions, set goals, and thereby improve its public image" (Gillingham, Newell and Palmer 2006).
4. Energy Star and the US Department of Energy's industrial technology programme Save Energy Now reduced energy intensity 25 percent over 10 years (McKinsey & Company 2009).
5. Studies based on empirical observation of positive impacts following adoption of formal energy management systems include Helgerud and Sandbakk (2009); Motegi and Watson (2005); and Thollander and Ottosson (2008).
6. Industrial systems such as steam- and motor-driven systems account for more than 50 percent of final manufacturing energy use. Energy-savings potential from cost-effective energy-efficient optimization of these systems is estimated at 10–12 exajoules of primary energy (Williams 2008).
7. Sri Lanka Sustainable Energy Authority (www.energy.gov.lk/sub_pgs/events_past.html).
8. Higher carbon prices can also result in lower output of desired products, higher costs for superior energy-efficient equipment and loss of competitiveness.
9. Energy savings from such an emissions price policy can be assessed by examining the price elasticity of energy demand using a computable general equilibrium model. These modelling exercises point out that energy-efficiency gains, energy conservation and alternative energy sources can generate deep cost-effective emissions cuts (Clarke et al. 2006; Weyant, de la Chesnaye and Blanford 2006).
10. The World Bank (2000) has called subsidies for energy access "a first priority of energy policies aimed at alleviating poverty." Well targeted subsidies can create a more inclusive electricity network by helping marginal populations and small firms overcome barriers to energy access and may

help reduce poverty and enhance rural development (Urban, Benders and Moll 2007).

11. Often, subsidies are captured by firms and households to help pay for efficiency improvements they were going to make anyway as part of the natural rate of efficiency gain.

12. MacLean et al. (2008) reviewed mechanisms to promote energy-efficiency investments in the early stages of technology development. The discussion here focuses on the public and commercial financing mechanisms that facilitate demand pull rather than technology push.

Chapter 7

International collective action for industrial energy efficiency

Policy initiatives for industrial energy efficiency, to be effective nationally, must be complemented by actions internationally. Systemic challenges such as climate change involve global externalities and public goods, so international collective action must go hand in hand with domestic action. And as industrial activity shifts towards developing countries, they must become part of international industrial energy-efficiency initiatives and coordination to ensure that emerging industrialization processes are sustainable.

In the absence of a global government, binding and voluntary country agreements have been the international collective response to environmental challenges. The international governance framework for industrial energy efficiency consists of soft legislation and non-binding rules, norms and action plans to coordinate strategies, policies and programmes. International agreements on specific actions and global coordination of domestic policies should benefit countries in two ways – providing domestic initiatives with the stability that comes with international legitimacy, and enabling countries to learn from each other's successes and failures in designing institutions and implementing practices (Sugiyama and Ohshita 2006).

This chapter briefly addresses mechanisms of international collective action that support industrial energy efficiency design and implementation in developing countries. After discussing the rationale for international collective action, it examines four areas for intervention:

- Setting international performance targets and standards.
- Facilitating technological and structural change.
- Contributing to international technology transfers.
- Procuring international financing.

The rationale for international collective action

This report contends that industrial energy efficiency has yielded economic, social and environmental dividends but that failures in the markets for energy-efficient goods and services and departures from the rational behaviour of orthodox economics have limited further gains. Reducing the risks of climate change (a product of perhaps the worst market failure ever) is the purest example of a public good – greenhouse gas emissions from any one country affect the atmosphere in the same way as those from any other (Stern 2006). Markets also fail to supply information to evaluate energy-saving opportunities. And with international trade in equipment and technology proceeding apace, learning about those opportunities also becomes a global challenge. Gathering trustworthy international information can be costly and time consuming – especially for developing countries and their small and medium-size industrial enterprises – and linking action to energy legislation can be difficult.

Global market failures call for worldwide cooperation. International collective action is the only viable solution for establishing governance mechanisms for some global common resources and addressing the failures. Even when collective action results in only soft commitments, it can establish important principles, incentives and norms – and increase monitoring and information flows (UNEP 2011).

Countries' motivation to participate in international collective action, especially for climate change, combines mutual self-interest and responsible, ethical behaviour (Stern 2006). Collective action decisions should be reciprocal, as parties expect equal treatment and can retaliate with equal force. But custom also often plays a role through understandings and agreements that are not formally binding. Respect for international obligations is increasingly based on views of conscientious and collaborative behaviour that is in line with domestic public opinion support.

Research on international collective action shows that it can succeed where there is:

- Sufficient mutual self-interest (Sandler 2004; Stern 2006).

Countries will see direct and indirect economic benefits from participating in international collective initiatives for industrial energy efficiency

- A common understanding of the problem and a recognized shared threat (Stern 2006; Sandler 2004).
- No free-riding on the efforts of others (Stern 2006).
- Agreement by all countries that action cannot succeed without their participation (Stern 2006).
- Leadership by a dominant country (Grasso 2004; Sandler 2004).
- An international institution that provides information and facilitates cooperation (Harris 2007; Keohane 1984).
- Flexibility for renegotiating rules and changing the structure of incentives (Barrett 2005).
- Frequent contact and transparency in negotiations (Stern 2006).
- Compensation mechanisms to promote wide participation and penalties to deter non-compliance (Barrett 2005).
- Selective mechanisms to deal with special groups (Myatt 2006).

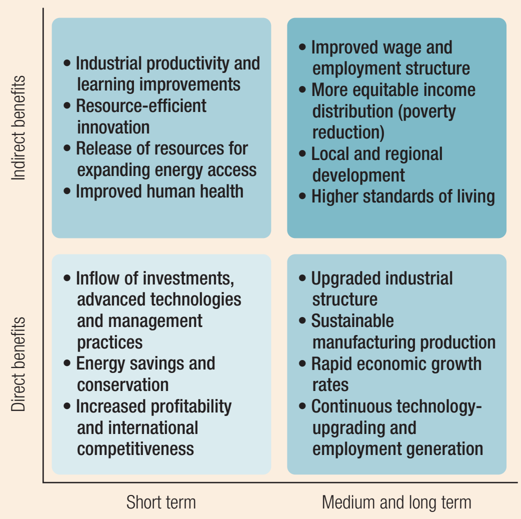
International collective action might face fewer complications in addressing the barriers to industrial energy efficiency than in addressing those for climate change or other environmental concerns. Climate change negotiations are likely to have winners and losers, at least in the short run, and those expecting to win may have incentives different from those expecting to lose (Cole 2008). So, while emission caps tend to divide countries, the need to promote energy efficiency is based on common interests and consensus in most countries (Sugiyama and Ohshita 2006). Industrial energy efficiency involves a wider range of economic, social and environmental benefits and more possible combinations – in the short, medium and long terms – increasing the number of win-win opportunities and thus the potential for international agreements.

Countries will see direct and indirect economic benefits from participating in international collective initiatives for industrial energy efficiency (Figure 7.1). In the short run, international cooperation could save more energy, and in the long run it could reduce poverty and spur economic growth. Making international agreements compatible with country benefits will ensure compliance and generate a credible, lasting framework (Stern 2006).

One initiative widely perceived as successful is the Montreal Protocol, which phases out chlorofluorocarbons and hydrochlorofluorocarbons worldwide (Harris 2007; UNEP 2011; see Box 7.1). It provides pointers for possible international collective action on industrial energy efficiency. The Montreal Protocol's success is built on three factors (Sunstein 2007):

- Skillful drafting, which allowed for flexible solutions and provisions for common but differentiated responsibilities.
- A multilateral fund, which helped developing countries comply with the protocol's control measures, particularly with the incremental costs of implementation.
- A focus on a narrow range of products for which substitutes could be developed, providing large benefits to politically influential players at low costs.

Figure 7.1
Economic benefits from participating in international collective action in industrial energy efficiency



Source: Adapted from Stern (2006, p 461).

International collective action for industrial energy efficiency should be mobilized in two closely related areas: establishing targets and standards and monitoring and assessing indicators and progress towards goals

Box 7.1
UNIDO and the Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer is an international treaty, opened for signature in 1987, aimed at protecting the ozone layer by phasing out the manufacture of several substances found to contribute to ozone depletion. These include several groups of halogenated hydrocarbons containing either chlorine or bromine that are used as solvents or refrigerating agents. The Montreal Protocol, which supplements the 1985 Vienna Convention for the Protection of the Ozone Layer, had been ratified by 196 countries by 2011.

UNIDO is one of the four implementing agencies of the Montreal Protocol and today tops the list of implementing agencies. By the end of 2010, the organization had completed 1,142 projects (worth $533 million in disbursements) phasing out 70,106 tonnes of potential ozone depleting substances. Another 199 projects are being implemented. A major challenge ahead both for UNIDO and the Montreal Protocol is the implementation of national or sectoral Hydrochlorofluorocarbon Phase-out Management Plans (HPMPs), which approach the development of elimination plans holistically.

Source: UNIDO.

Setting international targets and standards

The difficulties reaching international binding agreements on industrial energy efficiency limit international collective action for target-setting and benchmarking. So firm goals and legally binding targets might more appropriately fall to national energy programmes. But a wide variety of international actors can encourage those at the national level to set and meet such targets. International collective action for industrial energy efficiency should be mobilized in two closely related areas:

- Establishing targets and standards: international institutions can set global or regional goals and global standards for each industry.
- Monitoring and assessing indicators and progress towards goals: international institutions have a key role in measuring and monitoring progress.

Setting measurable targets

A well established approach to achieving performance objectives, setting measurable targets can determine priorities and direction, allow comparisons and benchmarking and sharpen the focus for action. Often, targets are used to improve performance, transparency and accountability and to challenge those for whom they are set. Yet, they must be realistic and reachable to stay motivating. To combat climate change with international collective action on energy efficiency, targets must involve a large element of additionality over past performance.

Many international actors recognize that committing to global performance targets is critical for international collective action on energy efficiency. The United Nations Advisory Group on Energy and Climate Change (AGECC) comprises representatives from business, the UN system, the World Bank and various research institutions, with broad geographic representation. Recognizing the need for sustainable development in line with environmental needs, the advisory group has called for international commitments to reduce global energy intensity 40 percent by 2030 (AGECC 2010). Meeting this goal entails cutting global energy intensity about 2.5 percent a year, or about twice the historical rate. Such a reduction would be necessary for ensuring universal access to modern energy services by the target date.

Energy efficiency is also pursued through regional integration initiatives, some of which set targets. For instance, the Sydney Declaration of September 2007 of the Asia-Pacific Economic Cooperation (APEC) asks members to increase region-wide energy efficiency at least 25 percent by 2030, using 2005 as the base year. APEC does not prescribe individual action plans or targets; instead, each member designs its own targets and initiatives appropriate for its economy. Some members have simply adopted the goal of a 25 percent improvement (such as Brunei, Hong Kong SAR China, Thailand and the United States). Others, especially in East Asia, have committed to energy-efficiency goals well beyond the 25 percent benchmark (such as Japan, the Republic of Korea, Singapore and

> **Many countries have used standards successfully as part of regulatory efforts to make their industries more energy efficient**

Taiwan Province of China). Still others have framed their goals in ways not directly comparable to the APEC goal – by using different target years or base years or by measuring their energy savings in petajoules (such as Canada, Chile, New Zealand and Peru; APERC 2010b). And some members, such as the Russian Federation, made pledges contingent on emission cuts by other countries or on financial support.

APEC has probably the most ambitious energy-efficiency goal among regional economic communities, but other communities also have set goals. In July 2010, the Association of Southeast Asian Nations set a goal of reducing energy intensity in the region 8 percent by 2015, using 2005 as the base year (ASEAN 2010). The Economic Community of West African States recommends that its members' domestic energy-efficiency programmes define energy-efficiency standards as a first step towards regional and international harmonization (ECOWAS 2003). In 2008, the Southern African Development Community released its Protocol on Energy (SADC 2008), which introduced guidelines for national energy-efficiency efforts and encouraged members to define achievable and quantifiable reduction targets in commercial and industrial energy intensity.

Designing standards

Closely related to energy-efficiency goals and targets are international standards. Standards, if properly designed, can help in meeting targets.

Many countries have used standards successfully as part of regulatory efforts to make their industries more energy efficient. For goods and services heavily traded internationally, coordinating the design and application of standards with related norms is cost effective. Stern (2006) points out that such international standards – by defining a set of similar conditions within larger markets – encourage innovation and competition among firms. They increase transparency for consumers and producers as comparable information is provided across borders. They reduce design and production costs related to differentiated compliance. And they help remove trade barriers by harmonizing test protocols or increasing their compatibility.

Standards and labelling schemes can drive environmental objectives and energy efficiency. But they can also create barriers to market access in developed countries for small and developing country producers, especially those that lack the technical or financial capacity to comply. As major impediments to their economic development, the barriers could discourage these producers from engaging in international collective action. Multilateral dialogue and negotiations, whenever possible, can ensure environmental protection while safeguarding market access (UNEP 2011).

One important venue for addressing these concerns is the International Organization for Standardization (ISO). A network of national standards institutes from 160 countries, the ISO is the largest developer and publisher of international standards. To reach a consensus and ensure that its standards are widely adhered to, the ISO offers public access to drafts of standards and uses voting and appeals systems. All ISO standards are voluntary agreements, meaning that compliance depends on broad agreement.

For energy efficiency, the ISO focuses on harmonizing terminology and calculation methods for energy efficiency, energy management standards, biofuels standards, retrofitting and refurbishing standards, and standardized energy-efficiency activities for buildings. For instance, the ISO 50001 energy management standard establishes a framework for industrial plants, commercial facilities and entire organizations to manage energy more efficiently. These types of standards help define, implement and monitor energy-efficiency policies at macro and micro levels. They also bring innovative energy-efficiency technologies to the market faster. And they are objective metrics for regulations and policy incentives to encourage greater use of innovative technologies.

Monitoring and assessing progress

Effective targets require monitoring progress. This is also true for standards, which risk becoming obsolete if they fail to keep up with technological progress and more general energy-efficiency trends. A challenge in

"To keep increases in industrial energy consumption to the minimum required to satisfy development needs, future efficiency efforts must be ambitious: they must double today's pace

monitoring and assessing progress is that data availability is often limited in developing countries. A first step in addressing this concern is initiating and harmonizing efforts to obtain energy-intensity data. Once data are collected, country energy performance can be assessed and explained, and cross-country comparisons made – to know where progress is considerable and where it is not. Processes could then be set for informing countries on their progress and examining reasons for deviations, positive or negative.

Several international actors have begun monitoring progress in regional and global energy efficiency:

- The United Nations Environment Programme (UNEP) engages in some target monitoring for industrial energy efficiency. For instance, in Eastern and Central Europe, the Energy Management and Performance-Related Energy Savings Scheme has established energy service companies, which set energy targets and monitor progress for industrial and commercial clients (UNEP 2004). Under the Cleaner Production Framework, UNEP, often together with UNIDO, identifies energy-efficiency opportunities and carries out the associated improvements to reduce greenhouse gas emissions from industrial enterprises in Asia and Eastern Europe (UNEP 2002b).
- The International Energy Agency (IEA), the most prominent non-UN agency in the field, works to enhance policy implementation for energy efficiency by analysing the potential in Organisation for Economic Co-operation and Development (OECD) countries, identifying and addressing emerging policy challenges and enhancing international cooperation (IEA 2011).
- The World Energy Council also monitors progress towards energy-efficiency targets. Its network of 94 national committees represents more than 3,000 member organizations – including governments, industries and expert institutions – with a mission to promote sustainable energy (WEC 2010).
- The International Partnership for Energy Efficiency Cooperation also monitors and assesses energy use activities through its Improving Policies through Energy Efficiency Indicators. It seeks to develop and implement new methodologies to establish indicators for measuring and reporting energy efficiency and to critique and update methodologies that have shortcomings (IPEEC 2011)

Several regional economic integration communities also commit to monitoring and evaluating energy-efficiency indicators and progress. The Economic Community of West African States Executive Secretariat reviews and facilitates the implementation of energy-efficiency provisions and sets energy-efficiency reporting requirements for its member states. The Southern African Development Community asks members to identify and minimize constraints to energy efficiency. And the Association of Southeast Asian Nations has recently agreed to review its 8 percent energy reduction target so it can construct plans to better meet the target and monitor the region's progress.

Moving forward

So, a start has been made in establishing international collective action in setting energy-efficiency goals and standards and in measuring energy-efficiency indicators to monitor progress towards meeting them (and perhaps readjusting them). But for industrial energy efficiency, much remains to be done. Even the AGECC has called only for a general energy-efficiency goal rather than one specifically for industry. Given industry's substantial contribution to global energy intensity, credible specific industrial energy-efficiency targets must be formulated.

Since 1990, global industrial energy intensity has fallen at a cumulative 1.7 percent a year, with most of the gains achieved during the 1990s (see Chapter 1). But to keep increases in industrial energy consumption to the minimum required to satisfy development needs, future efficiency efforts must be ambitious. They must double today's pace and reach energy intensity reduction rates similar to those in the 1990s. Doubling the industrial energy-intensity reduction rate is consistent with a similar exhortation made at the global level in the AGECC (2010) report.

> The *IDR 2011* recommends an annual target for industrial energy-intensity improvement of 3.4 percent, or 46 percent overall through 2030

The *IDR 2011* thus recommends an annual target for industrial energy-intensity improvement of 3.4 percent, or 46 percent overall through 2030. Of the 134 countries for which data were available for 1990–2008, 98 are reducing energy intensity below those rates or are even increasing energy intensity. Indeed, in 35 countries energy intensity grew at an average cumulative rate of 3.1 percent over the period. There is considerable scope for raising industrial energy efficiency in these countries, which stand to benefit from such efforts. Only 33 countries are above the historical level but below the desired rate.

Countries that have already reached the target should seek a 50 percent reduction in energy intensity beyond their 1990–2008 rate. During that period, these countries reduced their industrial energy intensity an average of 6.5 percent a year. It will be difficult to sustain such a rapid pace for an extended period, so a more modest, though still substantial, effort may be warranted. Ultimately, binding industrial energy-intensity targets must be set nationally, and regional and international actors can introduce the goals and international standards.

Many actors, such as IEA and the Latin American Energy Organization, collect industrial energy-efficiency country data and monitor progress. And though their expertise is important, an international monitoring and coordination function is needed to reap the potential complementarities of disparate actors, limit duplication and eliminate oversight and data gaps. Such a function could be mandated to one agency or several that could be responsible for informing countries and industries on their progress towards industrial energy-efficiency goals.

Facilitating technological and structural change

As Chapters 1 and 2 showed, energy-intensity reductions arise from technical and structural change within and across industries – changes that result from technological improvements and domestic and international movements of capital. The major driver of technological improvement is innovation, and while innovation within firms and countries is considerable, so is the room for international collective action. There is also scope for providing information and raising awareness of the energy-intensity and energy-consumption implications of international and sectoral shifts in investment patterns. That would allow developing countries to plan for their future energy demand and pay closer attention to the environmental implications of their economies' structural changes. This will be most important for low- and middle-income countries, which need to address industrial energy efficiency upfront in their industrialization processes.

International cooperation for innovation in industrial energy efficiency

International collective action helps address the inadequate breadth and depth of knowledge, which are acute for new technologies. Breadth is the range of knowledge required for innovation. A broad knowledge base involves familiarity with several knowledge domains, allowing exploration of more areas and solutions (Zhang, Baden-Fuller and Mangenatin 2007). Because industrial energy-efficiency innovation involves contributions from multiple suppliers and large users, breadth is particularly important (see Chapter 2). Depth is analytical sophistication in a specific subject (Wang and von Tunzelmann 2000). Deep knowledge involves profound understanding of causalities, complexities and relations. Breadth and depth, always matters of degree, are thus pooled in different proportions – but the harder the task, the more both are needed and the less they are available locally. Put simply, larger and more complex innovations require a larger and wider, gradually more international and interacting, research community.

International cooperation on research and development (R&D) can support sharing knowledge, coordinating R&D priorities and pooling risk (Stern 2006). Sharing knowledge helps link understanding of the issues with the individuals and teams involved in research, thus accelerating innovation – for example, by adopting a multilateral treaty that offers access to basic science and technology for industrial energy

> **International collective action can help ensure that the global restructuring of industry considers energy efficiency**

efficiency. Coordinating R&D priorities is necessary because national R&D aims to develop technologies for local demand, giving competitive and first-mover advantages to national economies and local firms. This might encourage countries to narrow their focus to local industry – to avoid sharing knowledge that might be useful to other countries – and to develop technologies difficult to imitate. None of that helps identify global solutions or creates the associated technological and market scales. Risk and reward must be pooled for major R&D investments because the scale of some technologies to be developed is too large for any one country to take on.

Energy-efficiency innovation and R&D are often perceived as the domains of OECD countries. But large developing countries have been contributing more, so involving their scientists and engineers can benefit everyone (Stern 2006). International cooperation does not have to be strictly developed–developing country interactions. R&D cooperation in clean and energy-efficient technologies is emerging between developing countries too. Brazil, India and South Africa signed a scientific cooperation agreement in 2010 for commercial use of solar energy (Xinhua News Agency 2010). Large developing countries may be especially well poised to adapt advanced technologies to developing country skills, labour markets and natural resource endowments.

There has been some international R&D cooperation in such low-carbon technologies as renewables and in the transfer and diffusion of clean energy technologies. But few international efforts focus exclusively on R&D for industrial energy-efficiency technologies. Perhaps the only exception, which focuses on the full range of energy technologies, is the IEA's technology cooperation programme, bringing together member and non-member countries in joint technology development projects. The idea is to link energy R&D networks and to ensure that policy-makers and other stakeholders (in finance, business, research and so on) are part of the collaboration. By 2010, the IEA had implemented 42 agreements and more than 1,000 projects in R&D for energy technologies (IEA 2010b).

International cooperation for structural change

Industrial structures evolve from change in the equipment, machinery and the buildings that house them. Output volumes and structures, input volumes and mixes and the resulting waste flows are driven by adding new capital and retiring old capital. Capital turnover is critical in altering energy use across industries (Davidsdottir 2005). But capital is also internationally mobile: as capital stock becomes obsolete or unprofitable, it is not necessarily replaced in the same place. Factories often close down in one location and reopen in another, with newer vintages of technology following changing business opportunities and emerging demand.

International collective action can help ensure that the global restructuring of industry considers energy efficiency. An information clearinghouse and information exchanges can help countries and industries identify best available technologies and compare the performances of technologies under varying conditions. International activities would showcase recent advances and communicate and benchmark experiences for developing countries to extract lessons and make informed choices.

International coordination can also help deploy industrial energy-efficiency technologies and practices, especially in collaboration with the private sector. Lead multinational firms in global and local value chains and production networks can speed the uptake of industrial energy efficiency in developing countries. Through their subsidiaries and buying power in value chains, they can work with local suppliers (particularly small and medium-size enterprises) to set up incentives and recognition programmes for pursuing energy management standards, transfer technical skills, prescribe new technologies and provide financing options. The impact could be large.

IBM's supply chain is among the world's largest, with more than 30,000 suppliers across the globe. IBM audits and checks its suppliers' environmental performance for compliance with its energy-efficiency principles. It has also helped develop the electronic industry's supply chain sustainability practices, codified by

> **The key mechanisms for industrial energy-efficiency technology transfers include international agreements, multilateral and bilateral agreements, and information exchange partnerships**

the Electronics Industry Citizenship Coalition. In collaboration with other companies, IBM develops and adheres to the Coalition's Code of Conduct, of which one concern is industrial energy efficiency.

Wal-Mart uses energy-sustainability indicators when selecting its products and service providers. It has announced that by collaborating with suppliers it would make its most energy-intensive products 25 percent more energy efficient in three years. It also has declared that it will reduce its supply chain's greenhouse gas emissions by 20 million tonnes of carbon dioxide equivalent. Outside the United States, Wal-Mart's goals for improving the energy efficiency of its international supply chain through manufacturing extension partnerships have been less ambitious. In 2008, it declared the goal of helping its top 200 Chinese suppliers become 20 percent more energy efficient by 2012. And starting January 2009, it required Chinese suppliers to conform to Chinese environmental laws, previously often ignored. In addition, Wal-Mart's audits of its Chinese suppliers began to focus more on environmental criteria, including greenhouse gas emissions. Wal-Mart is introducing similar requirements for its suppliers in other countries in 2011 (Wal-Mart 2008, 2010).

International collective action can organize and replicate these experiences across countries and industries, raising awareness of their potential. It can address possible concerns of local firms and governments. It can expand and adapt programmes to different sectors and countries. It can replicate programmes in countries where lead multinationals are absent, identifying actors to fill these roles. It can build capacity – preparing teaching materials, organizing training and facilitating the necessary expertise. And it can involve other multinational corporations in improving industrial energy efficiency through their value chains while ensuring that they follow corporate social responsibility principles transparently.

Contributing to international technology transfers

Technology transfers are critical for enhanced industrial energy efficiency and in the global response to the challenges of climate change. Industrial energy-efficiency technologies need to be transferred to developing countries, where energy use is growing faster and innovation is generally slower. Many of these countries lag in their capacity to obtain, develop and deploy innovative climate change and energy-efficient technologies (UNIDO 2010b). Adopting industrial energy-efficiency technologies is sometimes hampered by countries' lack of access to international best available technologies, because of lack of information or too small an investment.

For a host country, technology transfers in industrial energy efficiency require acquiring international licences, investing in modern equipment, facilitating local spillovers and promoting learning among industrial firms. Source countries can increase technical and financial assistance to improve developing countries' ability to acquire and absorb foreign technologies. Source countries can also disseminate technological knowledge and standards, help solve problems and establish grants for conducting industrial energy-efficiency analyses in developed and developing countries. International collective action could provide a forum for negotiating rules for international technology transfers between source and host countries.

The key mechanisms for industrial energy-efficiency technology transfers include international agreements, multilateral and bilateral agreements providing official development assistance, and information exchange partnerships. Transfers through these mechanisms focus on sharing knowledge and coordination; R&D, capacity-building and awareness programmes; hardware, such as machinery and equipment; and aid financing.

International environmental treaties

International environmental treaties generally have a complex, multidisciplinary and integrated set of solutions involving the environment, society, the economy, technology and finance – together with goals and targets and a plan and process to achieve them. Given the role of energy efficiency in addressing the challenges of climate change, industrial energy efficiency–related

“The Clean Development Mechanism has been useful for technology transfers to developing countries, allowing them to leverage investment for acquiring advanced environmentally friendly and energy-efficient industrial technologies

technology transfer arrangements have tended to arise in the context of existing international agreements for cooperation on climate change.

Chapter 34 of Agenda 21 of the United Nations Conference on Environment and Development, adopted in Rio de Janeiro in 1992, outlined an international agreement pertaining to the “transfer of environmentally sound technology, cooperation, and capacity-building.” Its objectives included facilitating access to technological information, promoting and financing appropriate technologies, supporting endogenous capacity-building and promoting long-term technological partnerships (IPCC 1996, 2000). National, regional and international information networks, collaborative networks of research centres, assessments of relevant technologies, and collaborative arrangements and partnerships are just a few of the activities the agreement proposed to achieve these ends.

The international environmental protocols, particularly the Kyoto Protocol, go further – providing tools for easing technology transfers for emission abatement. The Kyoto Protocol created mechanisms to allow developed countries to use credits from investments in emission reductions in other developed countries, through joint implementation, or in developing countries, through the Clean Development Mechanism (CDM), to offset their own emission reduction commitments (Gupta, Tirpak and Burger 2007). CDM projects involve all three elements of technology transfer (soft, hard and financing) and have the advantage of substantial local private or public participation, as the projects require domestic co-financing.

The CDM has been useful for technology transfers to developing countries, allowing them to leverage investment for acquiring advanced environmentally friendly and energy-efficient industrial technologies that they otherwise would not have available. The transfers seem, however, to have been limited to fairly established technologies, to a few industrial gas projects in large enterprises in a few advanced developing countries (Barías et al. 2005; Gupta, Tirpak and Burger 2007; Stern 2006).

Multilateral and bilateral agreements including energy-efficiency provisions

Multilateral and bilateral agreements for industrial energy-efficiency technology transfers can precede or follow international treaties. Generally, they ensure that parties are abiding by pacts, that there is continuity in activities and that action is coordinated, particularly where there is no legally binding commitment. Multilateral organizations, with well established organizational practices and procedures and substantial resources, can support large projects. Bilateral agreements can react quickly to changing circumstances (Ohshita, Wiel and Heggelund 2006).

Among the most important multilateral organizations in transferring energy-efficient technology is the Global Environment Facility (GEF). A funding mechanism, the GEF seeks new opportunities for technology transfers. In 2008, it started the Poznan Strategic Program to scale up investments in technology transfers and to help developing countries acquire clean, energy-efficient technologies. The programme conducts technology needs assessments, demonstrates new technologies, pilots technology projects and disseminates GEF experience worldwide. The GEF is involved with several successes as a facilitator of energy-efficient technology transfers (Box 7.2).

Other multilateral and bilateral technology transfer programmes include:

- The UNIDO and UNEP National Cleaner Production Centres, which promote cleaner production and energy-efficiency technologies in developing country industry through in-plant demonstrations, training, information dissemination and policy advice (Box 7.3).
- The US Agency for International Development’s Energy Efficiency and Renewable Energy programme, which in 2010 launched an Increasing Energy Efficiency programme focused on developing countries.
- The European Commission’s Global Energy Efficiency and Renewable Energy Fund, established as a public-private partnership aimed at

“Technology transfers under multilateral and bilateral agreements have helped reduce energy intensity, but challenges remain

Box 7.2
The Global Environment Facility's technology transfer projects in selected countries

The Global Environment Facility (GEF) has developed an energy-efficiency programme for Tunisia's industrial sector, fostering a sustainable industrial energy-efficiency market. The programme has approved an average of 60 projects a year, has saved nearly 40,000 tonnes of oil equivalent in energy since 2005 and has established six fully operational energy service companies. And it has exceeded its targets: the resultant $150 million investment in energy efficiency is six times the initial goal ($25 million), reducing carbon dioxide emissions by 130,000 tonnes a year.

In Armenia, the GEF has launched a district heating project to reduce greenhouse gas emissions from heat and hot water supplies. The project aims to strengthen the collective organization and management of heat and hot water in buildings, restructure and build the capacity of district companies to improve their energy efficiency, support new decentralized service providers to promote the use of alternative energy-efficiency technologies, and take stock of lessons from these activities to advance the sustainable development of heat and hot water services in Armenia. A tangible outcome of the project has been legislation dealing with preferential cogeneration feed-in tariffs, increasing private sector interest in power and heat supply projects.

In Central America, the GEF has introduced a programme on electrical energy efficiency in the industrial and commercial sectors. The goals include removing barriers to implementing energy-efficiency measures by establishing a regulatory base for market transformation, developing capacities to implement energy efficiency in small and medium-size enterprises, strengthening the technical knowledge of stakeholders and disseminating lessons and other information. The project has helped trigger energy-efficiency markets in the region by endorsing energy-efficiency standards and labels and promoting energy-efficient equipment imports.

Source: GEF 2010.

Box 7.3
National Cleaner Production Centres

Following the United Nations Conference on Environment and Development at Rio in 1992, UNIDO and the United Nations Environment Programme (UNEP) launched the National Cleaner Production Centres. The centres were set up to deliver services to business, government and other stakeholders and to assist them with adopting cleaner production methods, practices, policies and technologies. UNIDO and UNEP incorporated the lessons from the centres in their joint Resource Efficient and Cleaner Production programme, which supports decoupling economic development from further environmental degradation and resource depletion. The programme aims to improve the resource productivity and environmental performance of businesses and other organizations in developing countries. The centres promote and facilitate industrial energy efficiency in tandem with pollution prevention, water and materials reduction, and environmentally sound and safe management of chemicals and their waste. There now are Cleaner Production Centres or similar programmes in nearly 50 countries.

In 2007, an independent evaluation team found that the programme had been highly effective and sustainable, putting cleaner production on business and government agendas, training professional cleaner production auditors, implementing low- and intermediate-cost technology options in assisted companies and transferring technology and changing policy in several countries. The programme has improved businesses' resource productivity and environmental performance. And it has the potential to reduce energy and pollution intensity per unit of output in developing country industries – reducing ecological footprints and improving productivity and competitiveness.

Source: UNIDO 2010d.

leveraging public funds for technology transfer to developing countries and economies in transition.

- Japan's Ministry of Economy, Trade and Industry Green Aid Plan, which promotes the introduction and dissemination of cleaner energy technologies in the industrial sectors of Asian developing countries, targeting energy-efficient technologies and clean coal technologies.

The technology transfers under multilateral and bilateral agreements have helped reduce energy

"International independent information networks share information, exchange experts, build capacity, provide technical assistance and give advice and solve problems related to specific technologies and processes

intensity, but challenges remain. Stern (2006) contends that multilateral organizations such as the GEF would have to scale up further to deploy more advanced technologies effectively, but this would require significant institutional changes. Ohshita, Wiel and Heggelund (2006) argue that bilateral technology transfers are shaped by the relations between the countries involved, while multilateral transfers need to become faster and more flexible. Ohshita (2006) maintains that some bilateral and multilateral technology transfer programmes in Asia have not been sustainable because of donors pushing technologies into countries before local conditions were conducive, limited assessment of recipients' needs and preferences, emphasis on hard programmes over soft ones, foreign technology supplier concern about weak intellectual property protection, and ambiguous recipient-country technical specifications.

Information exchange partnerships

An emerging form of international technology transfer, sometimes part of multilateral agreements and sometimes arising from personal and institutional interactions, is the international independent information network. Organizations or individuals acquire knowledge by creating networks across countries and organizations, including governments, industries, financial institutions, research institutions and nonprofit organizations (Ohshita, Wiel and Heggelund 2006). Networks share information, exchange experts, build capacity, provide technical assistance and give advice and solve problems related to specific technologies and processes.[1] Independent networks can also interact with bilateral, multilateral and regional organizations to build on each other's strengths, work around political sensitivities (since they are not representing governments), use dedicated experts who have more flexibility than those in government institutions, operate with relatively small budgets and thus accomplish more (Ohshita 2006).

The United Nations Framework Convention on Climate Change and the GEF have established international partnerships among their constituencies and stakeholders. Other international networks include:

- The International Partnership for Energy Efficiency Cooperation, formed in 2008 as an international forum of developed and developing countries, which aims to promote global cooperation in industrial energy efficiency and to establish policies for meeting global energy-efficiency challenges.[2]
- The Asia-Pacific Partnership on Clean Development and Climate, which creates a voluntary, non–legally binding framework for cooperation to develop and transfer cost-effective energy-efficient technologies, promotes an enabling environment to assist technology transfers and facilitates national pollution reduction, energy security and climate change objectives.
- The Collaborative Labelling and Appliance Standards Program, founded in 1999, which brought together the Lawrence Berkeley National Laboratory, the Alliance to Save Energy and the International Institute for Energy Conservation. It has evolved into a global network of standards and labelling experts, an information clearinghouse and an aid to donor organizations.

Procuring international financing

Multilateral and bilateral financing help get developing country projects in industrial energy efficiency off the ground and leverage private funds, which constitute the bulk of financing for private industrial projects (Hansen, Langlois and Bertoldi 2009). Multilateral and official financing, direct or through implementing agencies or local financial institutions, also usually provides technical assistance in financial evaluation to assess industrial energy-efficiency projects more accurately and without bias (UNIDO 2011).

The World Bank and other multilateral development banks are often commissioned to become trustees of funds set up for environmental and sustainable development issues, energy efficiency and industrial energy efficiency among them. The banks manage, administer and disburse funds for industrial energy-efficiency

UNIDO's review of international financing policies suggests that developing countries see them as providing funding that they would not otherwise have and that they have helped reduce energy intensity

projects and programmes, using traditional grants, concessional credits, loans, guarantees and carbon financing as well as non-conventional sources such as venture capital, credit lines and risk-mitigating mechanisms (Nakhooda and Ballesteros 2010).[3]

The GEF has a strong record in financing programmes for energy efficiency (Box 7.4). The funding framework works through implementing agencies with a range of multilateral and bilateral donors. The GEF has financed the diffusion of industrial energy-efficiency technologies supported by wider investment in demonstration projects, local capacity-building and institutional development. Projects to increase the efficiency of boilers and lighting have delivered substantial energy savings and reduced greenhouse gas emissions (Stern 2006).

Regional banks have initiatives for industrial energy efficiency too. The Asian Development Bank launched the Energy Efficiency Initiative in 2005 as part of its climate change mitigation efforts. The Inter-American Development Bank has provided funding to the agribusiness and heavy industry sectors. Both banks have raised substantial private co-funding for industrial energy efficiency. The European Bank for Reconstruction and Development launched the Sustainable Energy Initiative to invest up to €1.5 billion in greenhouse gas emissions–reduction projects promoting industrial energy efficiency.

Box 7.4
UNIDO and the Global Environment Facility

UNIDO, an implementing agency for the Global Environment Facility (GEF), has had direct access to GEF funds since 2006. By 2009, GEF-funded UNIDO projects amounted to $257 million. Typical projects include policy support (providing fiscal incentives for industrial energy efficiency, setting up benchmarking and best-practice dissemination programmes, ensuring energy management standards); building capacity (energy management systems training, training industry managers and engineers); implementing pilot industrial energy-efficiency projects; and financing (supporting schemes with relevant financing institutions).

Source: UNIDO.

Other international financing-related initiatives include:

- The Energy Sector Management Assistance Programme was established by UNEP and the World Bank to provide technical assistance in developing financial intermediation mechanisms for energy-efficiency projects in Brazil, China and India. The Three-Country Energy Efficiency Project introduced new approaches to domestic and international energy-efficiency financing in these countries, including loan financing schemes, energy service company or third-party financing and demand-side management programmes (World Bank 2008).
- Led by the Indian government, the Assessment of Energy Efficiency Finance Mechanisms project identifies successful financing mechanisms for energy-efficiency initiatives (such as utility financing and energy performance savings contracts) and shares them with developing countries in need of better financing solutions. The project seeks to determine how industrial energy-efficiency initiatives can best exploit financing opportunities from domestic commercial banks and international financing institutions.

UNIDO's (2011) review of international financing policies and mechanisms suggests that developing countries see them as providing funding that they would not otherwise have access to and that they have helped reduce energy intensity. But in a few countries, banks and borrowers seem confused about industrial energy-efficiency financing procedures. Multiple donors and funding agencies have different approaches for the same type of lending, which makes it difficult for local firms to access the monies and calls for harmonizing procedures. And improving lending procedures also requires trained technical personnel and dedicated industrial energy-efficiency teams or units. Assistance with preparing feasibility studies and with monitoring and auditing would also help lending reach more firms.

Overall, current funds are insufficient for the task (Stern 2006). The GEF, for example, would require large increases in current financing to ensure sustained

“Investing in industrial energy efficiency provides more win-win opportunities and potentially more scope for building consensus than does investing in emerging non-carbon energy or other technological alternatives

market penetration of energy-efficient technologies over the next 10 years. “Whether it is through GEF or other institutional mechanisms, an expansion in the scale of funding is required if the deployment of low-carbon technologies is to be supported, and strong legal and regulatory environments and local partnerships are important in determining success” (Stern 2006, p. 13).

Establishing an international monitoring and coordinating function for industrial energy efficiency

International collective action and national policies for industrial energy efficiency are two sides of the same coin. National efforts can be legitimized internationally, while international agreements will succeed only if implemented wholeheartedly by national governments and local stakeholders. Complementarities are exploited to their fullest when international and national actors collaborate and when countries can benchmark themselves against others using internationally harmonized rules, targets, standards and practices. But achieving synergies and internalizing externalities are complex tasks that require bringing national and international interests and objectives into a common understanding of the public good.

Establishing an international monitoring and coordinating function for industrial energy efficiency would be an important step in that direction. Manufacturing is specialized and requires unique expertise and knowledge. A fast-growing economic activity, particularly in developing countries, it has great potential to reap energy-efficiency gains and reduce greenhouse gas emissions. And investing in industrial energy efficiency provides, at least for now, more win-win opportunities and potentially more scope for building consensus than does investing in emerging non-carbon energy or other technological alternatives. Industrial energy efficiency may not be exciting in the fight against climate change, but it can be effective. Yet, only a few fragmented international initiatives are knocking over the barriers to industrial energy efficiency.

Successes and failures in international collective action can inform the design and implementation of an international monitoring and coordinating function for industrial energy efficiency. To be effective, the function must be focused, agile, flexible, well informed and able to work closely with governments and the international private sector, including their representative associations. Cooperating with multinational corporations and international small and medium-size enterprises, including those from developing countries, will be critical. Cooperation could include generating data and comparable metrics, achieving energy-efficiency targets, enforcing industrial energy-efficiency targets and standards through international value chains, conducting joint R&D, building capacity, disseminating industrial energy-efficiency technologies and facilitating access to international finance. Cooperation would have to take place under the highest canons of ethics and corporate social responsibility to be credible, legitimate and effective.

An international industrial energy efficiency monitoring and coordination function can be envisaged as having five major roles:

- *Providing leadership and technical support in setting up and monitoring international targets and standards.* This would involve working not only on the scientific basis of targets and monitoring criteria but also with governments and the private sector to ensure that targets and standards are realistic and achievable.
- *Supporting data collection and benchmarking.* Energy data are available mainly in developed countries, and even in these countries they are not as detailed as needed for proper industrial energy-efficiency analysis and policy design. Benchmarking is required as much at the technology and process levels as at the policy level. The long distance to best practice is a major incentive for governments and firms to do better.
- *Disseminating information.* Freely available databases providing comparable technical and economic information – and specifying where and

how to find the desired technologies – would go far in addressing information gaps in the developing world. Information and knowledge exchange networks would suggest what to feed into those databases and advise governments and firms on possibilities for industrial energy efficiency.

- Coordinating regulation, targets, standards, R&D, technology transfers and value chain operations internationally.
- Devising innovative mechanisms to address the challenges of industrial energy-efficiency finance nationally and internationally.

Notes

1. Ohshita (2006) argues that knowledge networks are not only technical but also increasingly operating in policy-making. Policy development cooperation is perceived as an effective use of limited funds in that, by promoting policy action, it can achieve widespread investments in energy efficiency and large energy-efficiency improvements with a fairly small investment of public funds.
2. The forum includes Australia, Brazil, Canada, China, the European Union, France, Germany, India, Italy, the Republic of Korea, Mexico, the Russian Federation, the United Kingdom and the United States.
3. The World Bank Group International Finance Corporation's Cleantech Investment Programme provides venture capital and private equity finance for innovative energy-efficiency company projects in developing countries.

Part B

Trends in manufacturing and manufactured exports, and benchmarking industrial performance

Chapter 8

Trends in manufacturing – before and after the global financial and economic crisis

Global manufacturing production is shifting gradually from developed countries to developing countries, as firms move to benefit from cheaper labour, quality infrastructure, lower social costs and large markets in countries like China and India. These changes reflect greater integration of national economies through trade liberalization, wider availability of financial resources and increased flows of foreign direct investment. World manufacturing value added (MVA) peaked at $7,390 billion in 2010 (18.2 percent of global GDP) after a sharp drop in 2009 during the global economic and financial crisis (Figure 8.1).[1] MVA's share in GDP declined from 17.7 percent in 1990 to 16.6 percent in 2010 in developed countries and rose from 18.4 percent to 21.5 percent in developing countries.

Globalization of production opens doors for developing countries, but it also comes with threats. It has made developing countries more vulnerable to global shocks, such as the 2008 financial crisis that spread from the United States and resulted in steep declines in global employment, demand and trade. Global manufacturing production fell 4.1 percent in 2009, reacting to reduced consumer spending and business investment and primarily affecting developed countries, but developing countries have also not been immune.

This chapter analyses long-term trends in global MVA, the effects of the global crisis on manufacturing activity and changes in the structure of global manufacturing employment. The focus is on developing countries.

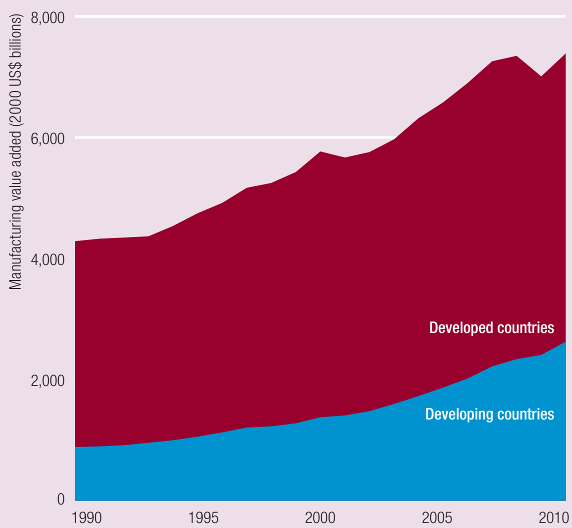
Manufacturing in developing countries

Over 1990–2010, global MVA grew 2.8 percent annually, from $4,290 billion to $7,390 billion (Table 8.1). Developed countries recorded 1.7 percent MVA growth but 2 percent GDP growth, highlighting their waning reliance on manufacturing as a source of growth and the increased role of services such as finance, insurance and real estate. In contrast, the manufacturing sector in developing countries has been buoyant, with a remarkable 5.6 percent annual growth rate in MVA over 1990–2010, slightly higher than the 4.8 percent GDP growth rate.

In 1990, developing countries were producing about 20 percent of world GDP (Figure 8.2). By 2010, this share had risen to 30 percent. This "rise of the rest" may be the defining economic trend of this century (Amsden 2001). Global manufacturing has been shifting from developed to developing economies even faster, with economies such as China, India and Taiwan Province of China building strong manufacturing sectors. In 1990, developed countries accounted for 79.3 percent of global MVA (see Table 8.1). Their share fell 0.4 percent annually to 76.1 percent in 2000 and then 1.2 percent annually to 71.6 percent in 2005. Since 2005, the decline in their share has accelerated to 2.1 percent annually,

Figure 8.1
Manufacturing value added, 1990–2010

Manufacturing value added is shifting from developed to developing countries



Source: UNIDO 2010g.

> **The manufacturing sector in developing countries has been buoyant, with a remarkable 5.6 percent annual growth rate in MVA over 1990–2010, slightly higher than the 4.8 percent GDP growth rate**

Table 8.1
Level and share of world manufacturing value added, by region and income group, 1990, 2000 and 2010

Group	Manufacturing value added (2000 US$ billions)			Share of manufacturing value added (percent)		
	1990	2000	2010	1990	2000	2010
World	4,290	5,770	7,390	100	100	100
Developed economies	3,400	4,390	4,760	79.3	76.1	64.4
Developing economies	888	1,380	2,630	20.7	23.9	35.6
Region						
East Asia and the Pacific	270	639	1,540	6.3	11.1	20.9
Excluding China	154	254	406	3.6	4.4	5.5
Europe	159	111	169	3.7	1.9	2.3
Excluding the Russian Federation	60	60	105	1.4	1.0	1.4
Latin America and the Caribbean	260	339	423	6.1	5.9	5.7
Excluding Brazil	176	243	294	4.1	4.2	4.0
Middle East and North Africa	99	147	229	2.3	2.6	3.1
Excluding Turkey	64	94	150	1.5	1.6	2.0
South and Central Asia	66	104	210	1.5	1.8	2.8
Excluding India	28	39	79	0.7	0.7	1.1
Sub-Saharan Africa	34	40	54	0.8	0.7	0.7
Excluding South Africa	14	17	26	0.3	0.3	0.3
Income						
High income	123	175	270	2.9	3.0	3.7
Upper middle income	464	540	717	10.8	9.4	9.7
Lower middle income	279	637	1,590	6.5	11.1	21.5
Low income	22	28	56	0.5	0.5	0.8
Least developed countries	12	17	34	0.3	0.3	0.5

Source: UNIDO 2010g.

falling to 64.4 percent in 2010. The financial crisis exacerbated the MVA decline in developed countries, which lost 3.7 percent of MVA share to developing countries in 2009 – the biggest one-year loss in almost two decades – but MVA continued to grow in developing countries.

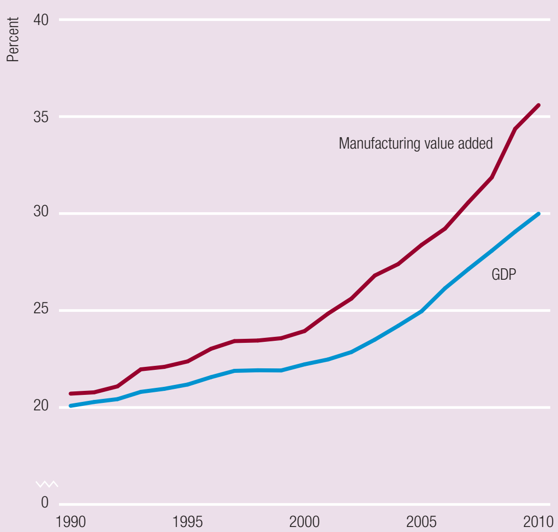
There are sharp variations in manufacturing performance among developing economies and regions. China, India and Taiwan Province of China lead the list, recording the largest surge in their global MVA shares. China increased its share from 6.7 percent in 2000 to 15.4 percent in 2010, becoming the second largest manufacturer after the United States. India, with an economy focused more on services, has also fared well – moving from 14th place to 9th – with a global MVA share of 1.8 percent in 2010.

Accounting for more than half of developing country MVA, East Asia and the Pacific remains the largest manufacturing region by far, with an MVA of $1,540 billion in 2010.[2] Almost 75 percent of the region's production originates in China. Next are Latin America and the Caribbean ($423 billion) and the Middle East and North Africa ($229 billion). Sub-Saharan Africa's MVA remains the smallest, at $54 billion in 2010, accounting for less than 1 percent of developing country MVA. All developing regions saw their global MVA share increase over 2000–2010, except Latin America and the Caribbean, where it declined, and sub-Saharan Africa, where it stagnated. The least developed countries, led by Bangladesh, Cambodia and Myanmar, have consistently gained share in global MVA since 1995.

> **Most of the largest developing economy manufacturers saw their share in developing economy MVA fall between 2000 and 2010**

Figure 8.2
Developing economies' share in world manufacturing value added and GDP, 1990–2010

Developing economies' share in world manufacturing value added rose from 20 percent in 1990 to 30 percent in 2010



Source: UNIDO 2010g.

Largest developing economy manufacturers

Manufacturing in developing economies is highly concentrated, with the 15 leading economies accounting for 83 percent of total production in 2010, up from 73.2 percent in 1990. The increase is attributable mainly to China, which has emerged as a factory to the world – more than tripling its share of developing countries' MVA over 1990–2010, to 43.3 percent (Figure 8.3). China also enjoyed faster average growth of MVA than other large developing economy manufacturers during that period.

Most of the largest developing economy manufacturers – except China and India – saw their share in developing economy MVA fall between 2000 and 2010. Brazil lost 2.1 percentage points and Mexico 3.8. India overtook Mexico and Brazil to become the second leading manufacturer among developing economies. Having experienced less of a decline in market share, Taiwan Province of China remained the fourth largest manufacturer among developing economies.

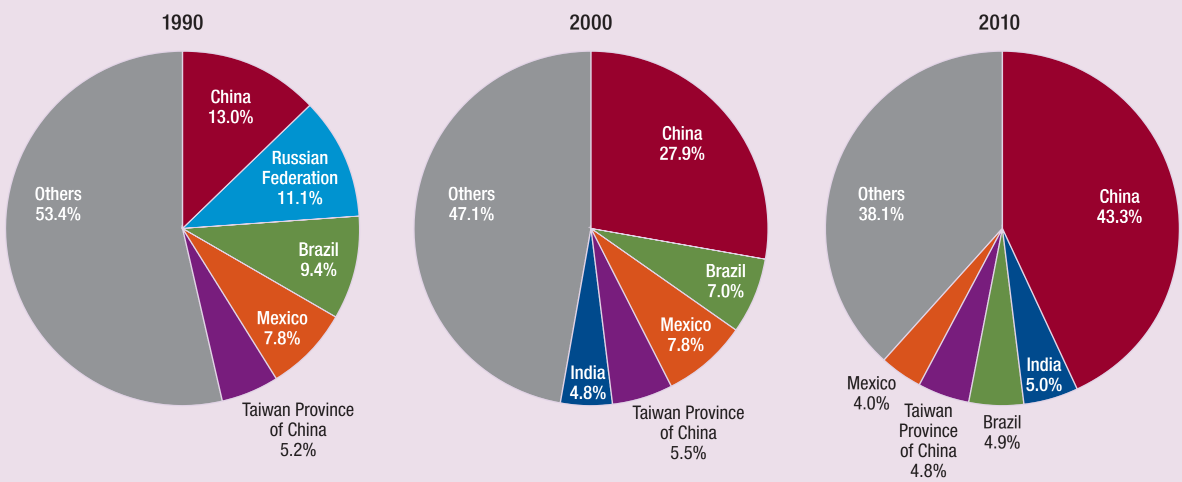
Manufacturing value added by technological category

Both developed and developing economies increased their share of medium- and high-technology products over 1995–2009, with the global share of these products rising from 41.3 percent to 55.8 percent (Table 8.2).[3]

Regionally, East Asia and the Pacific had 46 percent of its manufacturing production in medium- and

Figure 8.3
Share of large manufacturers in developing economy manufacturing value added, 1990, 2000 and 2010

China's share of developing economy value added has nearly tripled since 1990



Source: UNIDO 2010g.

Both developed and developing economies increased their share of medium- and high-technology products over 1995–2009, with the global share of these products rising from 41.3 percent to 55.8 percent

high-technology activities in 2009, slightly less than that of South and Central Asia, at 47.3 percent. Sub-Saharan Africa has the highest share of low-technology and medium-low technology activities in manufacturing, consistently at 75 percent over 1995–2009. When South Africa is excluded, the share of low-technology and medium-low technology activities rises to about 85 percent.

With globalization, developing economies – particularly in East Asia – have become more integrated into global value chains and production networks, with accelerated technology transfer and better market access. Having started with low-end, low value-added products, economies such as China, Malaysia and Taiwan Province of China have diversified their manufacturing production with more technologically advanced products. They also engage in more production activities – from design to manufacturing, distribution and marketing – and invest heavily in education, research and development, and infrastructure to catch up with developed countries.

The share of medium- and high-technology activities in manufacturing in least developed countries fell from 19.6 percent in 1995 to 16.7 percent in 2009. Although these countries are at the initial stage of industrialization, they need to maintain and develop manufacturing capacity in more technologically advanced products, which are more conducive to

Table 8.2
Technology composition of manufacturing value added, by region and income group, 1995–2009 (percent)

	1995			2000			2005			2009		
Group	**LT**	**MLT**	**MHT**	**LT**	**MLT**	**MHT**	**LT**	**MLT**	**MHT**	**LT**	**MLT**	**MHT**
World	34.5	24.2	41.3	29.2	21.4	49.4	26.0	20.9	53.1	24.2	20.0	55.8
Developed economies	33.3	22.8	43.9	27.2	19.6	53.2	23.3	17.7	59.0	20.7	15.8	63.6
Developing economies	38.3	28.6	33.1	35.6	27.4	37.1	32.0	28.2	39.8	30.1	26.9	43.0
Region												
East Asia and the Pacific	35.2	27.8	37.0	32.3	25.5	42.2	29.1	27.6	43.3	27.7	26.2	46.0
Excluding China	39.3	24.9	35.8	33.7	25.2	41.2	31.0	26.0	43.0	28.6	20.9	50.5
Europe	37.0	29.7	33.2	37.2	29.3	33.5	35.4	28.5	36.1	35.1	28.5	36.5
Excluding Russian Federation	44.4	25.3	30.3	44.3	25.9	29.8	41.0	25.9	33.1	37.8	26.4	35.9
Latin America and the Caribbean	42.7	27.6	29.7	40.3	27.8	32.0	39.4	27.6	33.0	39.4	27.2	33.3
Excluding Brazil	48.3	25.2	26.5	44.7	25.5	29.8	45.0	26.7	28.3	47.7	25.2	27.1
Middle East and North Africa	37.2	37.0	25.8	35.6	34.6	29.8	31.0	36.4	32.5	29.1	35.3	35.6
Excluding Turkey	35.7	38.8	25.5	34.4	36.7	28.9	31.0	39.3	29.6	28.6	38.4	33.0
South and Central Asia	37.4	26.1	36.5	33.6	26.3	40.1	31.2	25.5	43.4	27.7	25.0	47.3
Excluding India	53.5	24.1	22.4	49.5	25.2	25.3	46.5	26.0	27.5	44.5	26.5	29.0
Sub-Saharan Africa	48.8	27.2	24.1	47.2	28.6	24.2	46.0	28.5	25.5	47.6	28.2	24.2
Excluding South Africa	65.7	20.0	14.3	66.0	20.6	13.4	63.2	22.4	14.4	61.7	23.4	14.9
Income												
High income	26.1	34.2	39.7	22.4	31.9	45.7	19.8	34.1	46.1	17.0	27.3	55.8
Upper middle income	40.4	28.8	30.9	38.1	28.6	33.2	36.3	28.7	35.0	36.2	28.5	35.3
Lower middle income	39.1	27.2	33.7	36.0	25.4	38.5	31.0	27.3	41.6	28.9	26.6	44.5
Low income	63.4	17.2	19.4	64.2	16.9	18.9	62.5	16.8	20.7	61.7	17.6	20.7
Least developed countries	67.7	12.7	19.6	69.0	13.1	17.9	69.0	12.8	18.2	71.2	12.1	16.7

Note: Manufacturing value added in 2000 US dollars. LT is low-technology products; MLT is medium-low technology products; MHT is medium- and high-technology products.
Source: UNIDO 2010f.

"Radio, television and communication equipment's share in manufacturing rose to 20.7 percent in 2009 as a result of the surge in demand for electronic goods

long-term growth, less vulnerable to competition and more adaptable to technological and market trends (Lall 1998).

Value added by industry sector

In 1995, the dominant manufacturing sectors worldwide were food and beverages (11.8 percent share), chemicals and chemical products (10 percent) and machinery and equipment (8.5 percent; Table 8.3). By 2000, radio, television and communication equipment had surpassed all three, at 13.9 percent. Its share rose to 20.7 percent in 2009 as a result of the surge in demand for electronic goods (computers, mobile phones and other electronic devices).

Table 8.3
Industry sector share of manufacturing value added for developing and developed countries, selected years, 1995–2009 (percent)

International Standard Industrial Classification	World				Developing countries				Developed countries			
	1995	2000	2005	2009	1995	2000	2005	2009	1995	2000	2005	2009
Food and beverages	11.8	10.3	9.9	9.7	15.4	14.4	12.9	12.2	10.8	9.0	8.5	8.1
Tobacco products	1.2	1.1	1.1	1.2	2.8	2.8	2.6	2.4	0.7	0.5	0.4	0.4
Textiles	3.2	2.6	2.3	2.2	5.8	5.3	4.7	4.4	2.4	1.8	1.3	0.9
Wearing apparel and fur	2.8	1.9	1.5	1.4	3.5	3.2	2.9	2.7	2.5	1.5	0.8	0.7
Leather, leather products and footwear	0.9	0.7	0.6	0.6	1.6	1.4	1.2	1.2	0.7	0.5	0.3	0.2
Wood products (excluding furniture)	2.3	2.0	1.7	1.3	1.8	1.6	1.3	1.1	2.4	2.1	1.9	1.4
Paper and paper products	3.4	2.9	2.6	2.3	2.4	2.5	2.2	2.1	3.7	3.1	2.8	2.4
Printing and publishing	5.1	4.4	3.6	2.9	2.3	2.1	1.7	1.4	6.0	5.2	4.4	3.9
Coke, refined petroleum products, nuclear fuel	4.2	3.7	3.6	3.3	7.7	7.0	6.1	5.0	3.1	2.6	2.5	2.2
Chemicals and chemical products	10.0	9.6	9.9	9.7	10.1	10.9	10.9	11.0	10.0	9.3	9.4	8.8
Rubber and plastics products	3.3	3.1	3.0	2.8	3.4	3.6	3.6	3.5	3.2	3.0	2.7	2.4
Non-metallic mineral products	4.5	3.8	3.6	3.4	6.2	5.4	5.1	4.9	4.0	3.3	2.9	2.5
Basic metals	5.7	5.1	5.8	6.1	7.0	7.1	9.5	10.1	5.3	4.5	4.1	3.6
Fabricated metal products	6.5	5.8	5.0	4.5	4.4	4.3	3.9	3.5	7.2	6.2	5.5	5.0
Machinery and equipment	8.5	7.4	6.9	6.6	5.5	4.9	5.4	5.3	9.5	8.1	7.6	7.4
Office, accounting and computing machinery	1.7	3.0	3.1	3.5	1.6	1.7	2.0	2.0	1.8	3.4	3.6	4.4
Electrical machinery and apparatus	4.0	4.1	4.0	4.6	3.3	3.9	4.6	5.7	4.2	4.2	3.8	4.0
Radio, television and communication equipment	5.6	13.9	17.7	20.7	4.7	7.2	7.8	10.2	5.9	15.9	22.1	27.1
Medical, precision and optical instruments	2.2	2.1	2.2	2.2	1.1	1.2	1.5	1.3	2.5	2.4	2.5	2.7
Motor vehicles, trailers and semitrailers	7.0	7.0	6.9	5.9	4.7	5.1	5.3	4.8	7.7	7.6	7.6	6.6
Other transport equipment	2.3	2.3	2.3	2.6	2.0	2.1	2.4	2.7	2.5	2.3	2.3	2.5
Furniture; manufacturing not elsewhere classified	3.7	3.2	2.7	2.7	2.7	2.3	2.4	2.4	4.1	3.5	2.9	2.8
Total	100	100	100	100	100	100	100	100	100	100	100	100

Note: Value added in 2000 US dollars.
Source: UNIDO 2010f.

The positive growth in developing countries over 2008–2009 masks sharp disparities. The economic and financial crisis affected each developing region differently

In developing countries, the leading sectors in 2009 were food and beverages (12.2 percent); chemicals and chemical products (11 percent); radio, television and communication equipment (10.2 percent); and basic metals (10.1 percent). The increase in the share of radio, television and communication equipment (up from 4.7 percent in 1995) reflects a shift towards more sophisticated products. Even so, developing countries account for a substantial part of worldwide manufacturing of medium-low technology products in labour-intensive sectors such as textiles (74.7 percent), wearing apparel and fur (71.6 percent) and leather, leather products and footwear (77.2 percent; Table 8.4), with China leading in all three and accounting for roughly 60 percent of the total. India (5.7 percent) and Brazil (3.1 percent) followed in textiles, Thailand (6 percent) and Brazil (2.8 percent) in wearing apparel and fur and Argentina (7.1 percent) and Brazil (3.2 percent) in leather, leather products and footwear.

In contrast, developed countries account for 70 percent or more of manufacturing activities in medium- and high-technology products – such as machinery and equipment; motor vehicles, trailers and semitrailers; and medical, precision and optical instruments. Developed countries therefore appear to retain most high value-added or technologically

Table 8.4
Developing and developed countries' share of global manufacturing value added by industry sector, selected years, 1995–2009 (percent)

International Standard Industrial Classification	Developing countries				Developed countries			
	1995	2000	2005	2009	1995	2000	2005	2009
Food and beverages	30.6	33.2	40.4	47.9	69.4	66.8	59.6	52.1
Tobacco products	55.2	61.9	72.2	80.1	44.8	38.1	27.8	19.9
Textiles	43.1	48.1	62.9	74.7	56.9	51.9	37.1	25.3
Wearing apparel and fur	29.7	39.8	60.5	71.6	70.3	60.2	39.5	28.4
Leather, leather products and footwear	40.5	47.4	66.3	77.2	59.5	52.6	33.7	22.8
Wood products (excluding furniture)	18.8	19.1	23.9	33.7	81.2	80.9	76.1	66.3
Paper and paper products	16.6	19.9	26.4	34.6	83.4	80.1	73.6	65.4
Printing and publishing	10.5	11.2	14.9	17.9	89.5	88.8	85.1	82.1
Coke, refined petroleum products, nuclear fuel	42.9	45.2	52.4	57.9	57.1	54.8	47.6	42.1
Chemicals and chemical products	23.9	26.8	34.1	43.0	76.1	73.2	65.9	57.0
Rubber and plastics products	24.6	27.6	37.0	46.7	75.4	72.4	63.0	53.3
Non-metallic mineral products	32.1	33.7	43.9	53.7	67.9	66.3	56.1	46.3
Basic metals	29.0	33.0	50.9	63.2	71.0	67.0	49.1	36.8
Fabricated metal products	15.9	17.7	24.0	29.8	84.1	82.3	76.0	70.2
Machinery and equipment	15.3	15.8	24.0	30.3	84.7	84.2	76.0	69.7
Office, accounting and computing machinery	21.8	13.8	19.9	21.7	78.2	86.2	80.1	78.3
Electrical machinery and apparatus	19.6	22.4	35.5	46.6	80.4	77.6	64.5	53.4
Radio, television and communication equipment	19.9	12.4	13.6	18.5	80.1	87.6	86.4	81.5
Medical, precision and optical instruments	11.8	13.3	21.1	23.1	88.2	86.7	78.9	76.9
Motor vehicles, trailers and semitrailers	15.9	17.4	23.8	30.5	84.1	82.6	76.2	69.5
Other transport equipment	19.8	22.0	31.8	39.9	80.2	78.0	68.2	60.1
Furniture; manufacturing not elsewhere classified	16.8	17.1	27.1	34.6	83.2	82.9	72.9	65.4
Total	22.7	24.3	28.7	37.5	77.3	75.7	71.3	62.5

Note: Value added in 2000 US dollars.
Source: UNIDO 2010f.

“Developing countries account for a substantial part of worldwide manufacturing of medium-low technology products in labour-intensive sectors such as textiles, wearing apparel and leather products and footwear

complex activities, while outsourcing labour-intensive and simple activities – as exemplified by a small note on the back of the iPhone™: “Designed by Apple in California/Assembled in China.”

The five fastest growing sectors over 2005–2009 were office, accounting and computing machinery; radio, television and communication equipment; electrical machinery and apparatus; other transport equipment; and basic metals (Table 8.5). All are medium- and high-technology activities except for basic metals, whose growth is likely explained by demand from emerging economies such as China and India. In 2009, the leading producers in those sectors were the United States, China, Japan, Germany and the Republic of Korea. China was the first or second leading manufacturer in the world in 21 of 22 industrial sectors (International Standard Industrial Classification Revision 3). Other developing economy leaders in global manufacturing include Taiwan Province of China, Brazil and India.

Among developing economies, China has become the uncontested leader in all 22 industrial sectors, accounting for more than 50 percent of developing economies’ total MVA in 15 of them. When China is excluded, Brazil, Taiwan Province of China, India and Thailand lead in at least one of the five fastest growing sectors. In most of these sectors MVA remains concentrated, with the leading economy’s share at least twice that of the following economy. For example, in office, accounting and computing machinery, Thailand’s share is more than six times that of Brazil, in second place. Brazil, Taiwan Province of China and Mexico are among the five leading manufacturers in four of the five fastest growing industrial sectors.

The impact of the 2008–2009 economic and financial crisis on manufacturing

Global MVA grew an average 3.1 percent a year over 2000–2008, reaching $7,350 billion (Table 8.6). But in 2009, the global recession led to a 4.6 percent drop, to $7,020 billion. The crisis affected developed countries more, with MVA falling 8.1 percent from 2008 to 2009. Economic growth in developing countries slowed to 2.9 percent in 2009, down from an average of 6.8 percent a year over the previous eight years.

The positive growth in developing countries over 2008–2009 masks sharp disparities. The economic and financial crisis affected each developing region differently, through a region-specific mix of channels such as trade, remittances, financial flows, foreign direct investment and development assistance.

Europe was the most affected, with MVA dropping 7.1 percent, despite growth in five countries, including Bosnia and Herzegovina (5.4 percent) and Croatia (3.5 percent). The Russian Federation’s economy contracted sharply (12 percent) as the crisis depressed oil prices and reversed capital flows.

Latin America and the Caribbean’s MVA fell 6 percent from 2008 to 2009, the largest decline after Europe’s. MVA contracted at different rates in Argentina (1 percent), Brazil (3.7 percent) and Mexico (more than 10 percent) because of lower export demand and capital flight. Mexico’s close commercial links with the United States, the centre of the crisis, also contributed to the dramatic drop.

In East Asia and the Pacific, MVA grew 7.7 percent during the global downturn. Over 2008–2009, some of the highest growth rates were recorded in Cambodia (12.8 percent), China (10.2 percent) and Viet Nam (9.3 percent). By contrast, MVA fell in Malaysia (5.6 percent) and Thailand (1.5 percent) following several years of growth. The region’s ratio of exports to GDP was around 50 percent in 2008, the highest among developing regions. As a result, East Asian countries were affected by the crisis primarily through the collapse of world trade, which led to a scaling down of manufacturing and mass layoffs in labour-intensive sectors such as garments and electronics. Several countries, such as China, Indonesia and Malaysia, adopted stimulus packages combining tax cuts and government spending on housing, infrastructure, transportation and industry. These fiscal measures totalled 4.8 percent of GDP in China. East Asia and the Pacific is now leading the global recovery, with rapid growth foreseen for the coming years (IMF 2010).

The five fastest growing sectors over 2005–2009 were office, accounting and computing machinery; radio, television and communication equipment; electrical machinery and apparatus; other transport equipment; and basic metals

Table 8.5
Leading producers in the five fastest growing industry sectors, 2000 and 2009 (percent)

Industry sector	Average annual growth rate	World leading economy (share in world MVA)				Leading developing economies[a] (share in developing economy MVA[a])			
		Economy	2000	Economy	2009	Economy	2000	Economy	2009
Office, accounting and computing machinery (ISIC 30)	9.8	United States	53	United States	53	Thailand	21	Thailand	60
		Japan	15	China	11	Mexico	21	Brazil	9
		United Kingdom	6	Japan	9	Brazil	17	Mexico	8
		China	4	Germany	7	Malaysia	13	Philippines	5
		Germany	4	Republic of Korea	6	Philippines	8	Saudi Arabia	4
Radio, television and communication equipment (ISIC 32)	9.4	United States	61	United States	62	Taiwan Province of China	45	Taiwan Province of China	64
		Japan	15	China	12	Malaysia	14	Malaysia	7
		China	5	Japan	10	Brazil	7	Turkey	6
		Taiwan Province of China	3	Republic of Korea	5	Mexico	7	Philippines	5
		Republic of Korea	3	Taiwan Province of China	4	Philippines	6	Thailand	4
Electrical machinery and apparatus (ISIC 31)	7.9	Japan	23	China	33	Brazil	19	India	44
		United States	21	Japan	20	India	17	Brazil	15
		Germany	13	Germany	10	Mexico	15	Mexico	7
		China	8	United States	10	Taiwan Province of China	12	Taiwan Province of China	5
		Italy	4	India	5	Turkey	5	Iran, Islamic Rep.	4
Other transport equipment (ISIC 35)	7.3	United States	31	United States	22	Brazil	44	Brazil	63
		Japan	9	China	15	India	19	India	18
		United Kingdom	8	Brazil	14	Taiwan Province of China	8	Taiwan Province of China	3
		Brazil	6	Japan	7	Mexico	7	Viet Nam	3
		France	5	Republic of Korea	6	United Arab Emirates	3	Mexico	2
Basic metals (ISIC 27)	5.7	Japan	23	China	48	India	15	India	25
		United States	14	Japan	14	Mexico	14	Brazil	12
		China	12	United States	5	Taiwan Province of China	13	Mexico	9
		Germany	6	Germany	4	Brazil	12	Taiwan Province of China	8
		Republic of Korea	4	India	3	Turkey	7	Turkey	7

a. Excluding China.
Note: Value added in 2000 US dollars. ISIC is International Standard Industrial Classification.
Source: UNIDO 2010f.

Global manufacturing value added grew an average 3.1 percent a year over 2000–2008, reaching $7,350 billion, but economic growth in developing countries slowed to 2.9 percent in 2009

Table 8.6
Manufacturing value added levels and growth, by region and income group, 2005–2010 (US$ billions unless otherwise indicated)

Group	2005	2006	2007	2008	2009	2010	Average annual growth rate (percent) 2001–2005	Average annual growth rate (percent) 2006–2010
World	6,570	6,900	7,260	7,350	7,020	7,390	2.7	2.4
Developed countries	4,710	4,880	5,040	5,010	4,600	4,760	1.4	0.2
Developing countries	1,870	2,020	2,220	2,340	2,410	2,630	6.2	7.1
Region								
East Asia and the Pacific	966	1,060	1,200	1,290	1,390	1,540	8.6	9.8
Excluding China	320	342	365	370	375	406	4.8	4.9
Europe	148	156	171	176	164	169	5.9	2.8
Excluding Russian Federation	81	91	101	105	101	105	6.3	5.3
Latin America and the Caribbean	373	392	411	423	397	423	1.9	2.5
Excluding Brazil	262	279	293	302	281	294	1.5	2.3
Middle East and North Africa	183	198	210	217	216	229	4.4	4.6
Excluding Turkey	116	125	134	140	143	150	4.4	5.2
South and Central Asia	149	166	179	185	194	210	7.4	7.0
Excluding India	58	64	69	72	75	79	8.6	6.2
Sub-Saharan Africa	47	49	51	53	52	54	3.2	3.0
Excluding South Africa	20	21	22	23	24	26	3.6	4.6
Income								
High income	214	232	251	251	253	270	4.1	4.8
Upper middle income	628	661	700	718	677	717	3.1	2.7
Lower middle income	985	1,080	1,220	1,330	1,430	1,590	9.1	10.0
Low income	39	42	46	49	52	56	6.7	7.7
Least developed countries	24	26	28	30	32	34	6.6	7.1

Source: UNIDO 2010g.

South and Central Asia withstood the global recession with an average MVA growth rate of 4.8 percent – thanks mainly to India, which benefited from strong domestic demand and a relatively closed capital account, which buffered it from the financial aspects of the crisis. Over 2008–2009, MVA grew in Bangladesh (7.6 percent), India (5.4 percent) and Pakistan (2.5 percent). It declined in Turkmenistan (1.8 percent) and Kyrgyzstan (1 percent), likely because of their close links with the Russian Federation, which was strongly affected.

In the Middle East and North Africa, MVA declined 0.5 percent over 2008–2009. MVA in Turkey, the largest manufacturer in the region, declined 5.5 percent, in contrast to its average 7.1 percent annual gain since 2003. Saudi Arabia's (4.8 percent) and Qatar's (6.7 percent) also grew over 2008–2009. And though oil revenues declined, these oil exporters used their substantial reserves for large investment programmes. Similarly, MVA rose in Egypt (5.9 percent), Tunisia (4.5 percent) and Morocco (3.1 percent), despite the downturn, thanks to strong domestic demand.

In sub-Saharan Africa, Congo (12.5 percent), Uganda (9.1 percent) and Mozambique (8.8 percent) had the highest growth rate, though a few countries recorded large drops, including Liberia, Madagascar and Swaziland. Sub-Saharan Africa, the least industrialized region, had an MVA of 10.6 percent of GDP in 2010, down from 12.7 percent in 1990. Excluding

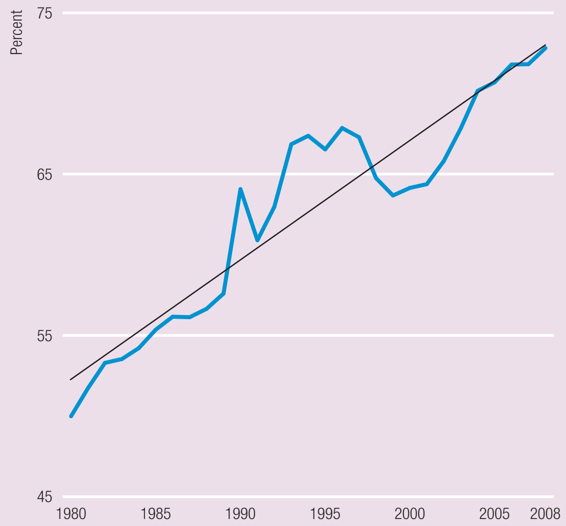
“Despite the crisis, manufacturing value added in the least developed countries grew 6.3 percent over 2008–2009

South Africa, the share drops to 7.8 percent. With countries in the region at an early stage of development, when shares would be expected to rise, this is a disturbing trend. It suggests that the region’s industrial base is eroding, a process likely accelerated by the depletion of much needed resources for investments in productive capacity and infrastructure as a result of the financial crisis. Sub-Saharan Africa is also likely to be severely affected through other channels, such as lower remittances, exports revenues and commodities prices.

Despite the crisis, MVA in the least developed countries grew 6.3 percent over 2008–2009. Three countries in Asia – Timor-Leste (13.8 percent), Afghanistan (13.6 percent) and Cambodia (12.3 percent) – had double-digit growth. In Bangladesh, the largest manufacturer among the least developed countries, with an MVA share of more than 40 percent of the group total, MVA grew 7.6 percent in 2009. Several countries in sub-Saharan Africa, such as Ethiopia, Togo and Zambia, also enjoyed MVA growth. However, this growth could conceal long-term adverse effects of the crisis on industrialization, due to their fledgling manufacturing sectors, increased international competitive pressures (for example, from China in low-technology labour-intensive sectors such as textiles) and vulnerability to external shocks.

Figure 8.4
Developing countries’ share in world manufacturing employment, 1980–2008

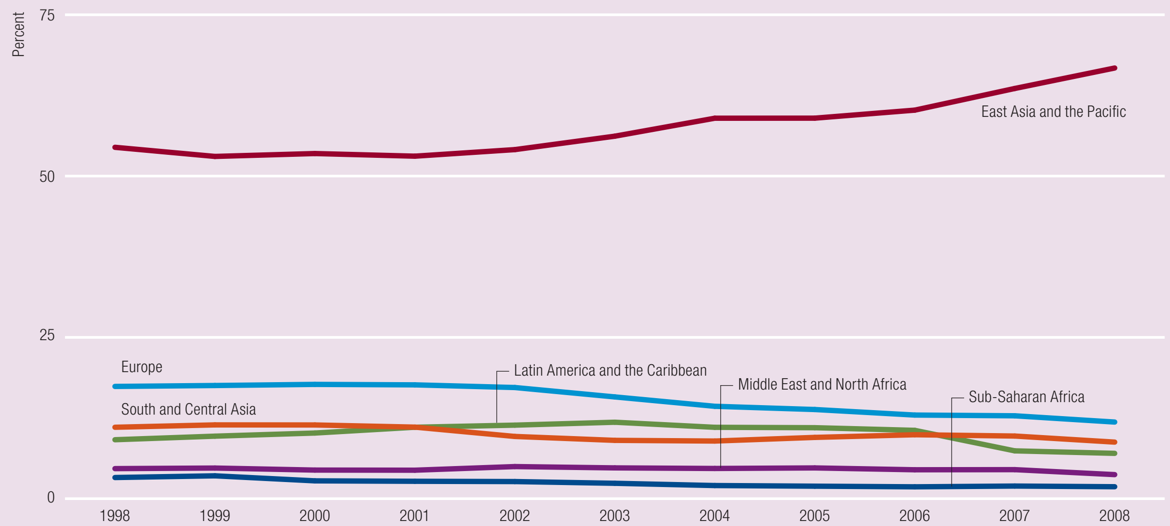
Global manufacturing employment has been shifting from developed to developing countries



Source: UNIDO 2010f.

Figure 8.5
Share of manufacturing employment in developing countries, by region, 1998–2008

There are sharp regional differences in the evolution of manufacturing employment in developing countries



Source: UNIDO 2010f.

Global manufacturing employment has been shifting from developed to developing countries

Table 8.7
Share of manufacturing employment for developing and developed countries, by industry sector, selected periods over 1993–2008 (percent)

International Standard Industrial Classification	World		Developing countries		Developed countries	
	1993–2000	2001–2008	1993–2000	2001–2008	1993–2000	2001–2008
Food and beverages	11.8	12.1	12.1	12.0	11.0	12.5
Tobacco products	0.8	0.7	1.1	1.0	0.2	0.1
Textiles	8.6	7.4	10.7	9.4	4.5	3.2
Wearing apparel and fur	6.0	6.4	7.1	8.2	3.9	2.4
Leather, leather products and footwear	0.9	5	0.8	3.2	1.2	0.9
Wood products (excluding furniture)	2.5	2.7	2.3	2.5	2.9	3.1
Paper and paper products	2.4	2.6	2.2	2.5	2.8	2.7
Printing and publishing	3.3	3.0	1.8	1.8	6.0	5.6
Coke, refined petroleum products, nuclear fuel	1.0	0.9	1.2	1.0	0.5	0.5
Chemicals and chemical products	7.3	7.0	8.2	7.2	5.6	5.7
Rubber and plastics products	4.3	4.7	3.8	4.2	5.3	5.8
Non-metallic mineral products	7.3	5.8	8.9	6.6	4.1	4.1
Basic metals	5.8	5.5	6.9	6.4	3.9	3.6
Fabricated metal products	5.9	6.8	4.1	5.1	9.2	10.7
Machinery and equipment	10.7	9.1	10.6	8.2	10.9	10.8
Office, accounting and computing machinery	0.5	0.9	0.2	1.0	1.0	0.8
Electrical machinery and apparatus	5.8	4.6	5.9	4.6	5.7	4.8
Radio, television and communication equipment	1.7	3.6	0.5	3.4	3.8	4.0
Medical, precision and optical instruments	2.0	2.1	1.4	1.5	3.2	3.5
Motor vehicles, trailers, semi-trailers	6.5	5.0	6.1	3.9	7.3	7.4
Other transport equipment	1.1	2.3	0.4	2.0	2.4	3.0
Furniture; manufacturing not elsewhere classified	4.0	4.5	3.6	4.4	4.6	4.8
Recycling	0.1	0.2	0.0[a]	0.2	0.1	0.2
Total	100	100	100	100	100	100

a. Less than 0.1.
Source: UNIDO 2010f.

World manufacturing activity declined in most sectors. Declines were high in basic metals; motor vehicles, trailers and semitrailers; machinery and equipment; fabricated metal products; and electrical machinery and apparatus. Consumer durable sectors – particularly the automotive sector – were hit hard by shrinking demand as consumers postponed major purchases because of the bleak economic outlook. Basic and fabricated metal industries suffered because of the slowdown in metal-intensive industries such as construction and motor vehicles, while export-oriented and labour-intensive industries such as textiles, leather and footwear, and electronics suffered from depressed global demand. By contrast, income-inelastic consumer non-durable industries, such as food and beverages, continued to grow.

Structure of global manufacturing employment

Global manufacturing employment has been shifting from developed to developing countries (Figure 8.4).[4] This trend is expected to intensify as more manufacturing relocates to developing countries.

“In developing countries, the largest manufacturing employers were food and beverages; textiles; machinery and equipment; wearing apparel and fur; and chemicals and chemical products

There are sharp regional differences, however, among developing countries (Figure 8.5). Growth in manufacturing employment in East Asia and the Pacific was negative over 1998–2001 but then picked up again, and the region now accounts for nearly two-thirds of manufacturing employment in developing countries. Europe’s share has been declining since 2000, following the ruble crisis, which substantially lowered manufacturing employment in the Russian Federation. Latin America and the Caribbean’s share has also declined, while the share remained stable in South and Central Asia, the Middle East and North Africa and sub-Saharan Africa – at generally less than 10 percent.

By industry, the top five manufacturing employers in developed countries over 2001–2008 (employing 47.2 percent of the developed country total) were food and beverages; machinery and equipment; fabricated metal products; motor vehicles, trailers and semitrailers; and rubber and plastics products (Table 8.7). In developing countries, the largest manufacturing employers (45.0 percent of the developing country total) were food and beverages; textiles; machinery and equipment; wearing apparel and fur; and chemicals and chemical products.

Notes

1. Data for 2010 were obtained using “nowcasting” (see Boudt, Todorov and Upadhyaya 2009).
2. For the regional classification of countries, see Annex 13.
3. Manufactured products can be classified by technological complexity as low-technology, medium-low-technology and medium- and high-technology (see Annex 7 for details). Low- and medium-low-technology products are sometimes called simple products, while medium- and high-technology products are also complex products. There is a high level of aggregation in classifying activities using physical complexity, which may result in combining products from the same industrial category but with different technological content (see Lall, Weiss and Zhang 2006 for a discussion).
4. In this section, 2007 data on the number of employees was estimated using a second-order autoregressive model.

Chapter 9

Manufactured exports trade

Trade expansion has been central to economic globalization. Exports have grown 5.9 percent annually since 2004, reaching close to $15,000 billion in 2008, before dropping in 2009 (Table 9.1). Manufactures make up the bulk of world trade, consistently accounting for more than 80 percent of exports since 1990.

While developed countries have traditionally dominated world manufactures trade, developing countries' share has risen steadily – as has their exposure to trade shocks (Montalbano 2011).[1] Although initially sheltered from the direct effects of the 2008–2009 financial and economic crisis, the trade channel has worked mainly by reducing developing country exports to developed countries hit hard by the crisis. Developing countries were later affected through other channels, including remittances, foreign direct investment and development assistance.

This chapter analyses trends in world manufactured exports since 1990, the changing roles of developing countries and the effects of the recent financial and economic crisis on their manufactured exports.

Trends in world manufactured exports

In 2008, world manufactured exports peaked at $12,095 billion (see Table 9.1), growing faster than both manufacturing value added and GDP during 2005–2009. Trade liberalization, falling transportation costs and increased globalization of production contributed to the growth (UNCTAD 2008). Exports of primary products grew even faster over the same period, likely fuelled by strong demand from fast-growing developing countries.

Developed countries' manufactured exports grew 11.0 percent over 2005–2008, reaching $7,542 billion before dropping to $5,792 billion in 2009 because of the crisis (Table 9.2; see also Table 9.4 later in the chapter). In developing countries, manufactured exports grew 17.3 percent over the same period, to a peak of $4,554 billion in 2008, and dropped to $3,699 billion in 2009.

With growth rates higher than those of developed countries, developing countries' share in world manufactured exports rose from 20.4 percent in 1992 to 29.4 percent in 2000 and 39 percent in 2009 (Figure 9.1). And the trend will likely continue, as developing countries increase their manufacturing production capacity and more manufacturing activities relocate to these countries to reduce production costs.

World manufactured exports are dominated by medium- and high-technology products such as telecommunications equipment, passenger vehicles, office machines and medicines. Since 1992, the share of medium- and high-technology products in world manufactured exports has remained above 60 percent, with a peak of 64.3 percent in 2000 (Figure 9.2).[2] The share has declined since 2000, due mainly

Table 9.1
World exports, by product category, 2004–2009 (US$ billions unless otherwise indicated)

Product category	2004	2005	2006	2007	2008	2009	Average annual growth, 2004–2009 (percent)
Manufactures	7,382	8,252	9,448	10,845	12,095	9,490	5.2
Primary	1,180	1,449	1,837	1,984	2,653	1,843	9.3
Other	107	114	149	167	217	207	14.1
Total trade	8,669	9,815	11,434	12,997	14,966	11,540	5.9

Source: UN 2011.

> **In developing countries, manufactured exports grew 17.3 percent over 2005–2008, to a peak of $4,554 billion in 2008, and dropped to $3,699 billion in 2009**

Table 9.2

World manufactured exports, by region and income group, selected years, 1995–2009 (US$ billions)

Country group	1995	2000	2005	2009
World	4,072	5,149	8,252	9,490
Developed countries	3,086	3,634	5,409	5,792
Developing countries	985	1,514	2,844	3,699
Region				
East Asia and the Pacific	667	937	1,736	2,308
Excluding China	534	708	1,013	1,153
Developing Europe	46	125	306	402
Excluding Russian Federation	45	84	214	293
Latin America and the Caribbean	143	246	378	415
Excluding Brazil	108	204	292	318
Middle East and North Africa	68	120	240	335
Excluding Turkey	51	96	173	248
South and Central Asia	38	55	129	181
Excluding India	12	18	42	31
Sub-Saharan Africa	23	32	56	58
Excluding South Africa	6	12	23	22
Income				
High-income	438	566	851	983
Upper middle-income	274	475	845	1,005
Lower middle-income	267	456	1,112	1,663
Low-income	7	18	36	48
Least developed countries[a]	5	11	19	–

– is not available because about half the least developed countries have yet to report 2009 data.
Source: UN 2011.

to the 2.4 percent annual drop in the share of high-technology exports over 2001–2008. The share of resource-based exports grew 2.9 percent annually over the period, while the share of low-technology products remained fairly stable.

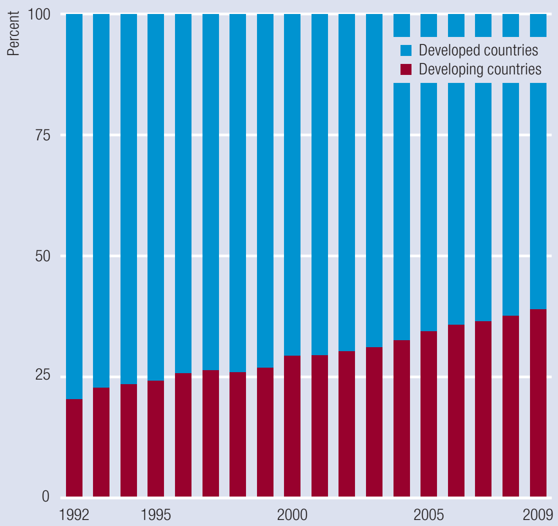
In 2009, developing countries accounted for 35 percent of world exports of medium- and high-technology products.[3] Although developed countries still account for more than 60 percent of medium- and high-technology exports, developing countries have made inroads, raising the technological complexity of their exports and gaining market share (Figure 9.3). In 2009, 54.8 percent of developing country exports were medium- and high-technology products, up from 48.6 percent in 1995.

Of the 20 most dynamic manufactured products[4] (products with the highest annual average growth rates) over 2005–2009, 12 were resource-based or low-technology products (Table 9.3).[5] Exports of the top three products (precious metals, iron ores and office machines) grew more than 25 percent a year on average. The dynamism of resource-based products, such as iron, steel, copper and other metallic and non-metallic minerals, can be explained by the high demand from countries such as China and India to feed metal-intensive construction and motor vehicle industries. This trend opens doors for low- and middle-income resource-rich countries that might be able to exploit the upward pressure on these commodities' prices. Developing countries' share in dynamic

> **Developing countries' share in world manufactured exports rose from 20.4 percent in 1992 to 29.4 percent in 2000 and 39 percent in 2009, and the trend will likely continue**

Figure 9.1
Developed and developing countries' share of world manufactured exports, 1992–2009

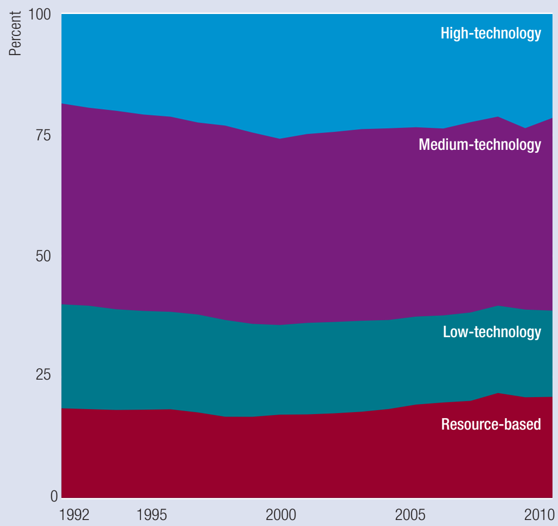
Developing countries' share in world manufactured exports rose from 20.4 percent in 1992 to 39.0 percent in 2009



Source: UN 2011.

Figure 9.2
Technology composition of manufactured exports, 1992–2009

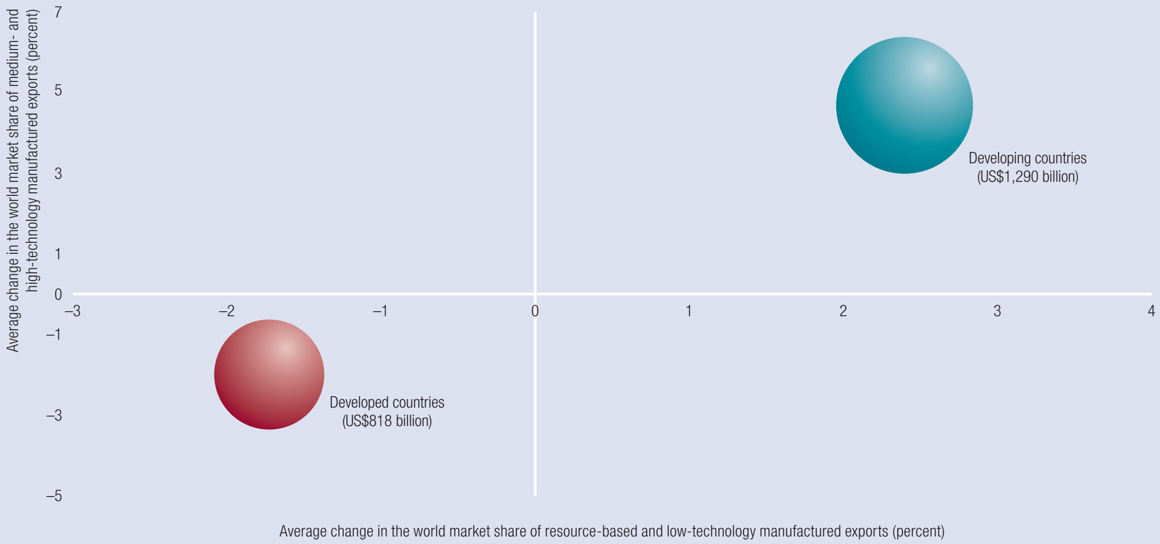
Since 1992, the share of medium- and high-technology products in world manufactured exports has remained above 60 percent



Source: UN 2011.

Figure 9.3
Change in world market share of manufactured exports by technological level, 2004–2009

Although developed countries still account for more than 60 percent of medium- and high-technology exports, developing countries have made inroads



Note: Bubble size indicates the change in the value of manufactured exports (in parentheses) between 2004 and 2009.
Source: UN 2011.

> **Exports of the top three products (precious metal ores, iron ores and office machines) grew more than 20 percent a year on average**

Table 9.3
Top 20 dynamic manufactured exports, 2005–2009

SITC Rev. 3[a]	Technology category	Product	Average annual growth, 2005–2009 (percent)	2009 value (US$ billions)
289	Resource-based	Precious metals, concentrates	29.0	22.6
281	Resource-based	Iron ore, concentrates	27.4	110.2
751	High-technology	Office machines	26.9	83.8
793	Medium-technology	Ship, boat, floating structures	17.8	283.4
871	High-technology	Optical instruments	17.3	144.6
283	Resource-based	Copper ores, concentrates	16.9	56.9
691	Low-technology	Metallic structures	16.4	95.8
422	Resource-based	Fixed vegetable fat, oils, other	16.0	54.7
541	High-technology	Medicines, excluding group 542	15.5	246.2
525	High-technology	Radioactive materials	15.3	25.2
562	Medium-technology	Fertilizer, except group 272	15.3	77.6
334	Resource-based	Petroleum products	13.9	985.8
61	Resource-based	Sugars, molasses, honey	13.0	51.9
897	Low-technology	Gold, silverware, jewellery	12.9	131.0
288	Resource-based	Nonferrous waste, scrap	12.7	46.6
718	High-technology	Other power generating machinery	11.9	34.0
761	Medium-technology	Television receivers, other	11.8	170.4
17	Resource-based	Meat, offal, prepared, preserved	11.7	31.0
679	Low-technology	Tubes, pipes, iron, steel	11.3	141.1
335	Resource-based	Residual petroleum products	11.3	51.4

a. Standard Industrial Trade Classification – Revision 3.
Source: UN 2011.

product exports averaged 47.3 percent over 2005–2009, up from 41.7 percent over 2000–2004. By total export value, one resource-based product (petroleum products, $986 billion) tops the list in 2009, followed by one medium-technology product (ships, $283 billion) and one high-technology product (medicines, $246 billion).

Developing countries' role in world manufactured exports

Although developing countries' overall share of world manufactured exports is rising, some countries have a greater influence than others. China, especially, is changing the world manufactured exports landscape. Its exports grew an average of 14.6 percent a year over 1992–2001 and 27.9 percent over 2002–2008, after it joined the World Trade Organization.

At 13th place in 1992, China has steadily risen in rank – becoming the global leader in manufactured exports in 2008, with exports of $1,370 billion and a world market share of 11.3 percent. It is also the top exporter to the European Union, the United States and Japan. Increasingly, China is exporting medium- and high-technology manufactured products; their share rose from 28.4 percent in 1992 to 45.5 percent in 2000 and 59.8 percent in 2009. And as the second largest importer in the world (with a share of 8.7 percent in 2009) – behind the United States (13.1 percent) and ahead of Germany (7.4 percent) – China is helping fuel global demand.

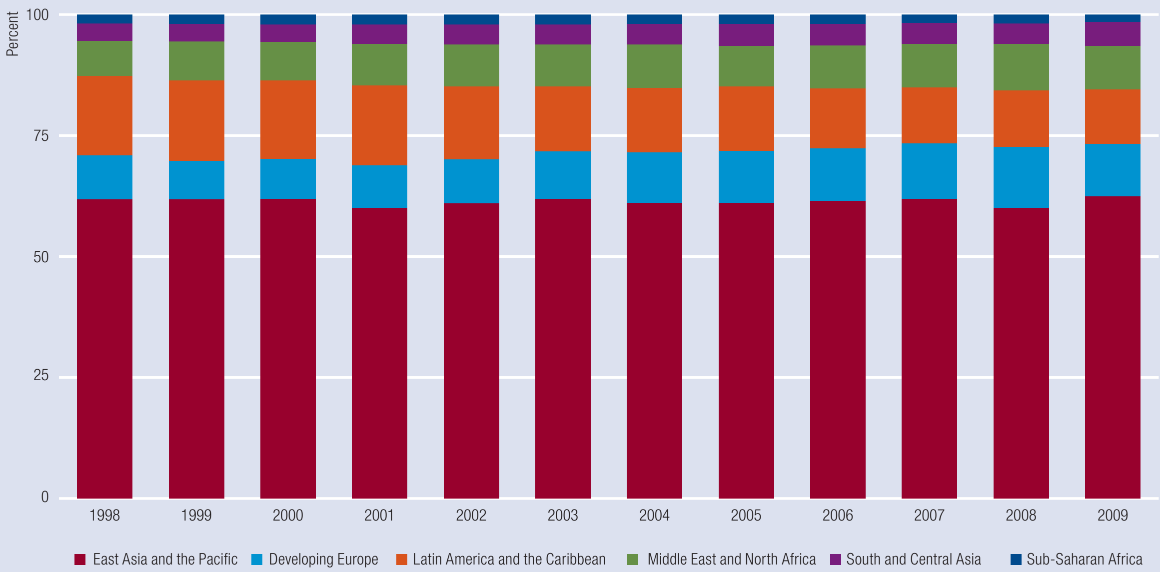
East Asia and the Pacific, led by China, accounts for the largest regional share of manufactured exports from developing countries, hovering around 60 percent since 1998 (Figure 9.4). Europe's share

> **East Asia and the Pacific, led by China, accounts for the largest regional share of manufactured exports from developing countries, hovering around 60 percent since 1998**

Figure 9.4

Share of developing country manufactured exports, by region, 1998–2009

East Asia and the Pacific, led by China, has the largest regional share of manufactured exports from developing countries



Source: UN 2011.

of manufactured exports has been on the rise, while that of Latin America and the Caribbean has fallen, from 16.6 percent in 1999 to 11.2 percent in 2009. Shares of developing country manufactured exports for the Middle East and North Africa, South and Central Asia and sub-Saharan Africa have yet to reach 10 percent.

The dynamism and sophistication of a region's exports show in the evolution of its world market shares by technological level (Figure 9.5). East Asia and the Pacific, Developing Europe, the Middle East and North Africa, and South and Central Asia increased their market shares of world resource-based and low-technology products over 2004–2009; their shares of medium- and high-technology products rose even more. Latin America and the Caribbean's share of resource-based and low-technology products increased slightly (2 percent a year on average), but its share of medium- and high-technology products stagnated. Sub-Saharan Africa's share in the world market for resource-based and low-technology products fell 2.8 percent annually over 2004–2009, but its share of medium- and high-technology products rose 1.6 percent per year.

Trends in manufactures trade between developing countries

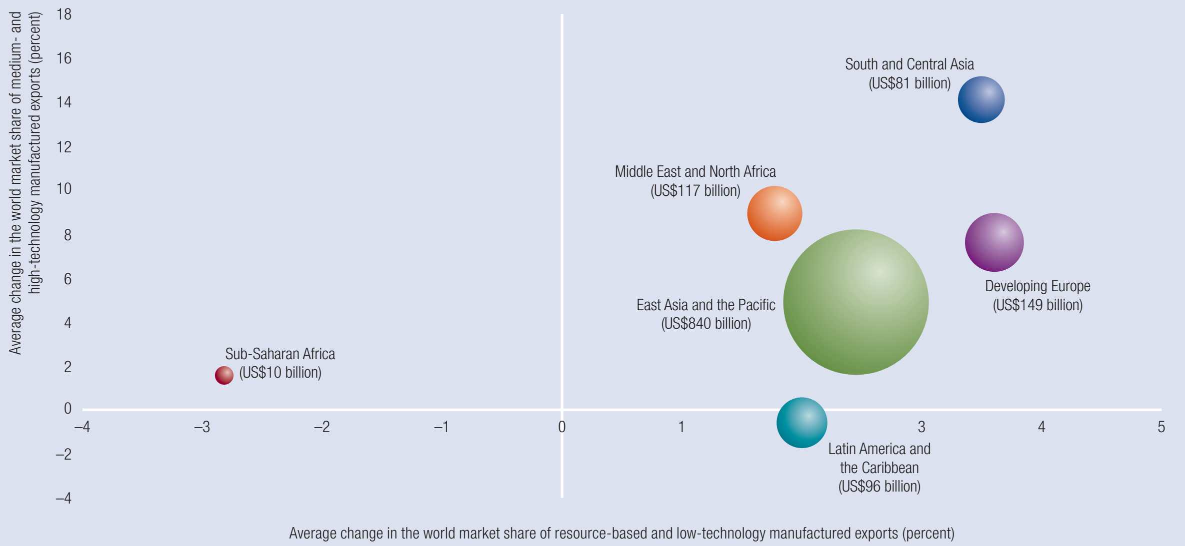
Trade between developed countries still accounts for the largest share of world manufactured exports, but the share fell 8.5 percentage points over 2004–2009, to 40.3 percent. By contrast, manufactured exports from developing to developed countries rose 8.8 percent a year on average over 2004–2009, and those from developed to developing countries rose 10.0 percent a year (Figure 9.6). Exports between developing countries grew even faster over the period, at 14.9 percent a year, reaching $2,247 billion in 2008 before dropping to $1,871 billion in 2009. They accounted for 51.8 percent of developing countries' manufactured exports in 2009, up from 39.9 percent in 2000. The share is likely to increase further as production fragmentation eases, as trade continues to develop and as large countries such as Brazil, China and India grow and reinforce their trade ties with other developing

> **Manufactured exports from developing to developed countries rose 8.8 percent a year on average over 2004–2009, and those from developed to developing countries rose 10 percent a year**

Figure 9.5

Change in regional share of world manufactured exports by technological level, 2004–2009

Export dynamism and sophistication show in the evolution of regions' shares of world manufactured exports by technology level

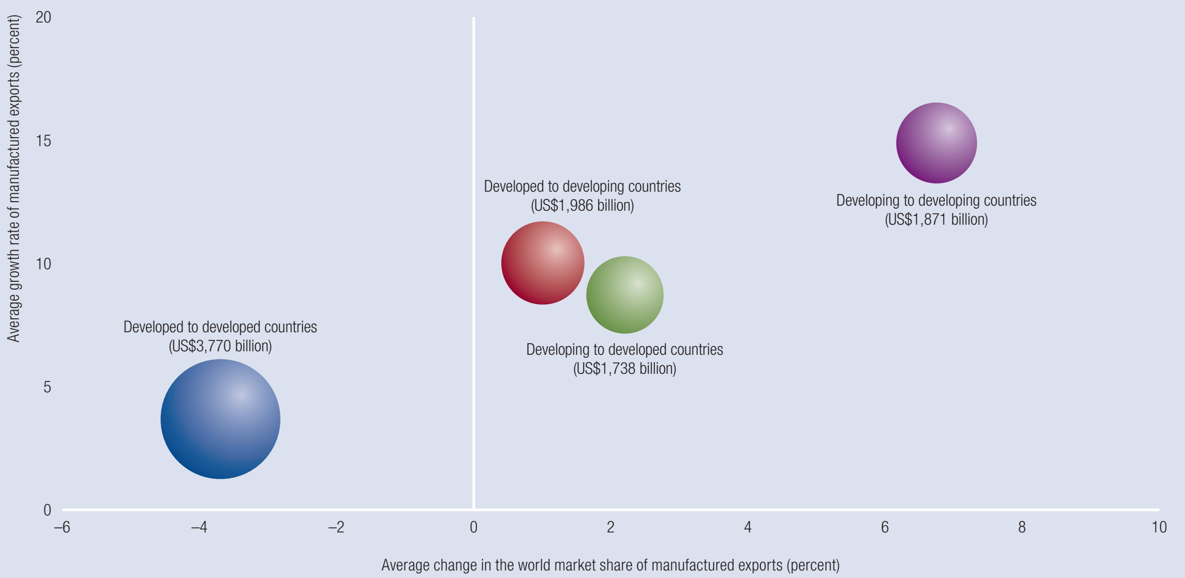


Note: Bubble size indicates the change in the value of manufactured exports (in parentheses) between 2004 and 2009.
Source: UN 2011.

Figure 9.6

Trade patterns between developed and developing countries, 2004–2009

Exports between developing countries grew 14.9 percent a year over 2004–2009



Note: Bubble size indicates the value of manufactures exports in 2009 (in parentheses).
Source: UN 2011.

“In all regions, developed countries remain the top trade partners, but their share is declining. Countries in the same region are the second largest trade partner group in all but South and Central Asia

countries. Actively promoting trade with other developing countries might be an attractive strategy for developing countries. One study found that removing barriers to trade between developing countries has the potential to generate annual gains 40 percent larger than those that would be generated by opening up developed countries' markets (Fugazza and Vanzetti 2008).

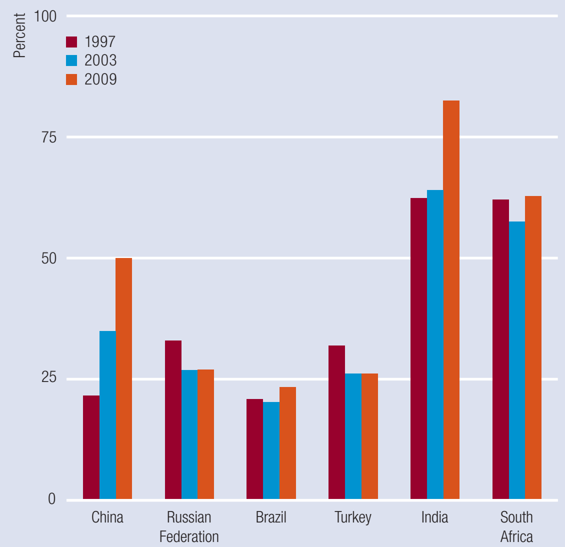
In all regions, developed countries remain the top trade partners, but their share is declining (Figure 9.7). Countries in the same region are the second largest trade partner group in all but South and Central Asia, where trade with East Asia and the Pacific and the Middle East and North Africa is more important.

Together, the manufactured exports of the largest country in each region – Brazil, China, India, the Russian Federation, South Africa and Turkey – accounted for 44.2 percent of the developing country total in 2009, up from 33.1 percent in 2003. China, with 50 percent of East Asia and the Pacific's

Figure 9.8

Largest country share in region's manufactured exports, 1997, 2003 and 2009

Together, the largest countries in each region accounted for 44.2 percent of total developing country manufactured exports in 2009

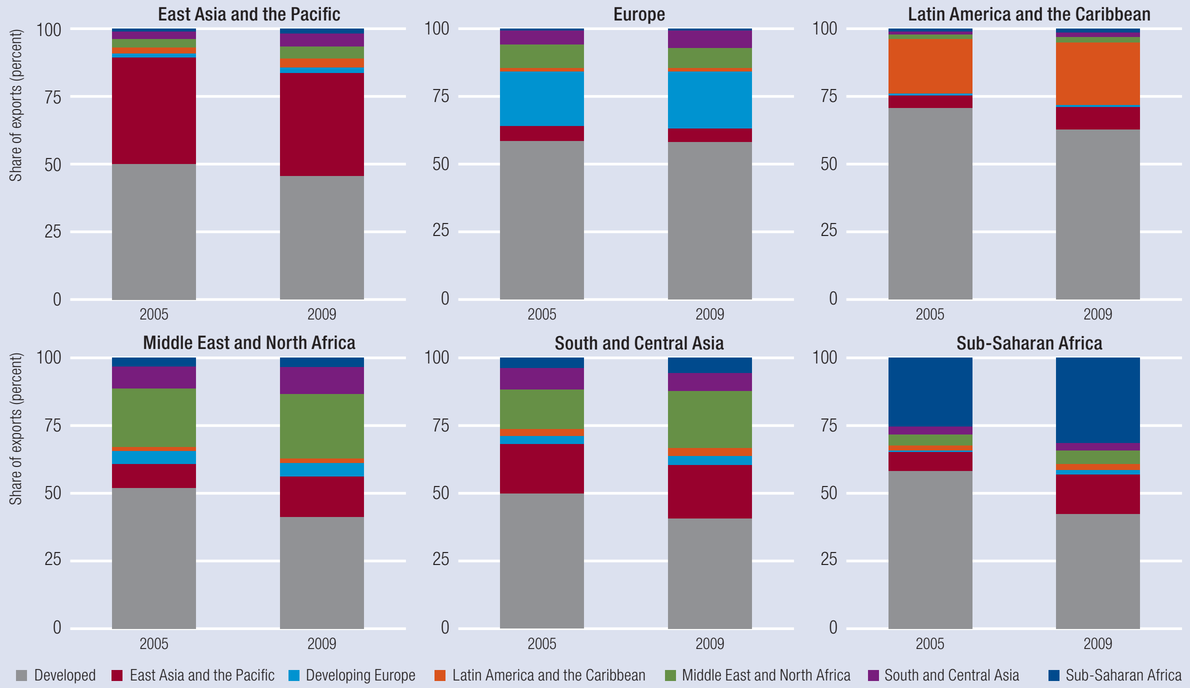


Source: UN 2011.

Figure 9.7

Manufactured exports markets, by region, 2005 and 2009

In all regions, developed countries remain the top trade partners, but their share is declining



Source: UN 2011.

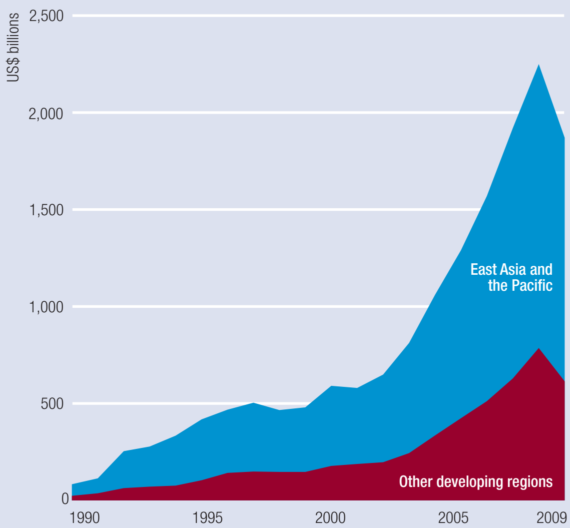
> **Benefiting from dynamic intraregional trade, East Asia and the Pacific accounted for almost 70 percent of manufactured exports between developing countries over 2000–2009**

manufactured exports in 2009, more than doubled its share since 1997 (Figure 9.8). Manufactured exports were even more concentrated in sub-Saharan Africa, where South Africa accounted for 62.8 percent of the region's total, and in South and Central Asia, where India exported 82.5 of the region's manufactures in 2009.

Benefiting from dynamic intraregional trade, East Asia and the Pacific accounted for almost 70 percent of manufactured exports between developing countries over 2000–2009 (Figure 9.9). The region has specialized in products with high value to weight ratios (such as semiconductors and textiles), which are more prone to fragmentation (Lall, Albaladejo and Zhang 2004); their parts and components are therefore easier to produce in other countries before final assembly. Trade in parts and components is proportionately much larger in East Asia and the Pacific than elsewhere, with China the premier centre of final assembly (Athukorala 2010). Sharing production has also allowed some latecomers such as Cambodia and Lao PDR to integrate into production networks and reach international markets. However, sharing production may mask the fact that little value is added to manufactured products. While developing countries' share in world exports of office, accounting and computing machinery was about 62 percent in 2008, their share in world manufacturing value added of those products was only 18 percent, suggesting that low value-added activities are outsourced to developing countries.

Figure 9.9
Manufactured exports between developing countries, 1990–2009

East Asia and the Pacific accounted for almost 70 percent of manufactured exports between developing countries



Source: UN 2011.

The impact of the economic and financial crisis

World manufactured exports grew 13.2 percent annually over 2005–2008, reaching $12,095 billion (Table 9.4), with the growth rate in developing countries (17.3 percent) far greater than that in developed countries (11.0 percent). For manufactured exports, the fastest growing developing regions were Europe, led by the Russian Federation, and the Middle East and North Africa, led by Turkey. The largest developing countries did especially well (Figure 9.10). Over 2005–2008, manufactured exports grew 27.6 percent a year in the Russian Federation, 24.6 percent in China, 24.3 percent in India, 20.2 percent in Turkey, 19.3 percent in Brazil and 16.4 percent in South Africa.

Weakly integrated in world financial markets, developing countries were somewhat sheltered from the financial effects of the 2008–2009 crisis, but they did not escape the subsequent blows to trade. Developing countries were hit hard, abruptly halting the growth in manufactured exports, which dropped 18.7 percent, compared with a 23.2 percent drop in developed countries.

Developed country imports dropped sharply as a result of the crisis. US imports from developing countries fell 18.1 percent in 2009, and EU imports fell 22.0 percent. Developing country exports to the three largest EU markets fell (21.5 percent to the United Kingdom, 16.9 percent to Germany and 16.0 percent to France), with harsh effects in developing countries, especially in sub-Saharan Africa.

Manufactured exports from East Asia and the Pacific in 2009 dropped 20.4 percent to the European

“World manufacturing exports reached $12,095 billion in 2008, with the growth rate over 2005–2008 in developing countries far greater than that in developed countries

Table 9.4
World manufactured export levels and growth, by region and income group, 2004–2009 (US$ billions unless otherwise indicated)

Group	2004	2005	2006	2007	2008	2009	Average annual growth rate (percent) 2000–2004	Average annual growth rate (percent) 2005–2009
World	7,379	8,252	9,448	10,845	12,095	9,490	9.6	5.2
Developed countries	4,974	5,409	6,066	6,890	7,542	5,792	7.9	3.1
Developing countries	2,405	2,844	3,382	3,955	4,554	3,699	14.0	9.0
Region								
East Asia and the Pacific	1,468	1,736	2,081	2,446	2,732	2,308	13.7	9.5
Excluding China	910	1,013	1,159	1,278	1,362	1,153	8.9	4.9
Developing Europe	252	306	366	455	575	402	20.4	9.7
Excluding Russian Federation	183	214	258	326	398	293	20.8	9.9
Latin America and the Caribbean	318	378	419	455	534	415	8.9	5.4
Excluding Brazil	250	292	320	344	401	318	7.8	4.9
Middle East and North Africa	218	240	299	359	432	335	17.0	9.0
Excluding Turkey	160	173	222	261	314	248	16.1	9.1
South and Central Asia	100	129	154	171	197	181	16.6	12.6
Excluding India	35	42	49	46	41	31	16.4	–1.8
Sub-Saharan Africa	48	56	64	69	83	58	14.4	3.8
Excluding South Africa	21	23	29	27	32	22	19.8	0.9
Income								
High-income	767	851	992	1,102	1,198	983	10.2	5.1
Upper middle-income	715	845	966	1,112	1,318	1,005	12.5	7.1
Lower middle-income	890	1,112	1,380	1,686	1,981	1,663	19.2	13.3
Low-income	32	36	44	55	57	48	25.0	8.1
Least developed countries[a]	19	19	22	21	15	–	45.7	–

– is not available; about half the least developed countries have yet to report 2009 data.
Source: UN 2011.

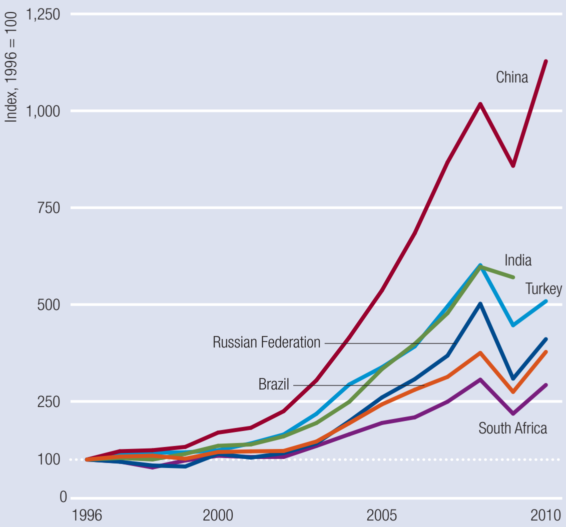
Union and 14.5 percent to the United States. Declines were even sharper for Europe, Latin America and the Caribbean, and the Middle East and North Africa. Sub-Saharan Africa was hit hardest, with a 35.7 percent plunge in combined exports to the European Union and the United States. Combined with falling commodity prices, the decline in manufactured export revenues has constrained the ability to import vital production inputs and to mitigate the effects of the crisis. The largest developing countries also suffered from the turmoil, but to varying degrees. Indian exports declined the least by far (4.9 percent), followed by China (16.0 percent). Manufactured exports dropped more than 20 percent in Brazil, the Russian Federation, South Africa and Turkey. However, these countries are quickly bouncing back, with China’s 2010 exports rebounding to their 2008 peaks.

The least developed countries were less affected by the drop in EU and US imports.[6] After expanding 10.3 percent annually since 2004 to $9 billion in 2008, US imports from these countries shrank 12.9 percent in 2009, less than the developing country average decline of 18.1 percent. Bangladesh, the largest country in the group, saw their imports by the European Union and the United States fall just 1.7 percent. Others, including Benin, the Democratic Republic of the Congo and

“Over 2005–2008, manufactured exports grew 27.6 percent a year in the Russian Federation, 24.6 percent in China, 24.3 percent in India, 20.2 percent in Turkey, 19.3 percent in Brazil and 16.4 percent in South Africa

Figure 9.10
Growth of manufactured exports in selected large developing countries, 1996–2010

The largest developing countries in each region did especially well in manufactured exports growth



Source: UN 2011.

Sudan, suffered sharp declines. EU imports from the least developed countries dropped 7 percent (to $14.6 billion), again less than the 22 percent overall decline for developing countries.

Overall, large developing countries, whose imports from least developed countries grew an average of 46.5 percent a year over 2004–2008, offer important trade opportunities. However, the crisis forced large developing countries to cut imports from least developed countries 26.9 percent in 2009. Despite the higher than average imports by major importing countries, the least developed countries are more vulnerable to economic shocks because they rely heavily on primary product exports (Malik and Temple 2009). While world manufactures trade dropped 21.5 percent in 2009, primary products trade dropped 30.5 percent. The accompanying collapse in export revenues is likely to hurt the least developed countries in the long run, perhaps jeopardizing years of development progress by affecting investments in productive capacity, infrastructure and social programmes.

Notes

1. The share of exports in GDP in developing countries rose from 20.4 percent in 1995 to 33.9 percent in 2008.
2. Manufactured exports can be classified by technological complexity as natural resource–based, low-technology and medium- and high-technology (see Annex 8 for details).
3. These figures may conceal the fact that complex activities such as design and marketing are still performed in developed countries, while assembly and production activities are carried out in developing countries.
4. By concentrating exports on “dynamic” activities, a country could limit the risk of export market saturation from an increased number of competitors and exploit the potential for long-term productivity growth associated with an export-oriented industrialization strategy (Mayer et al. 2003).
5. Geometric means are used to compute the average growth rates. The rates are lower than for 2004–2008 because the consequences of the crisis were felt mainly in 2009.
6. Because of data constraints, analysis of the effects of the financial crisis on the least developed countries looks only at imports from countries or groups of countries, such as the United States and the European Union.

Chapter 10

Benchmarking industrial performance

UNIDO developed the Competitive Industrial Performance (CIP) index to benchmark national industrial performance. Selecting appropriate indicators is challenging, and it builds on the notion that national competitiveness is an economy's ability to create welfare (Aiginger 2006).[1] This selection can be based on domestic production or international trade (Hughes 1993; Gough 1996). The CIP index assesses industrial performance using indicators of an economy's ability to produce and export manufactured goods competitively (UNIDO 2003).

The new Competitive Industrial Performance index

This report expands the CIP index from six indicators to eight. The two new indicators are the share of an economy's manufacturing value added (MVA) in world MVA (to measure impact on world manufacturing production) and the share of an economy's manufactured exports in world manufactured exports (to measure an economy's impact on international trade).[2]

The previous CIP index assumed that an economy's industrial performance depended entirely on endogenous factors – its own industrial capabilities to produce and export manufactures competitively. However, new studies find that in a global economy, exogenous factors, like third-country competition, strongly affect the international industrial scene.

The large Asian economies, particularly China and India, are commonly cited to show that external competitive pressures may be affecting other developing countries' export performance. Studies have focused mainly on China's impact on South and East Asia (Bhattacharya, Ghosh and Jansen 2001; Lall and Albaladejo 2004), Latin America (Lall and Weiss 2005; Blázquez-Lidoy, Rodríguez and Santiso 2006; Devlin, Estevadeordal and Rodriguez-Clare 2006; Gallagher, Moreno Brid and Porzecanski 2008) and sub-Saharan Africa (Kaplinsky, McCormick and Morris 2006, 2010). To assess the impact, these studies use world market share analysis. For instance, Bhattacharya, Ghosh and Jansen (2001, p. 217) conclude that "increases in world market shares of China are statistically correlated with declines in world market shares for some Asian countries since 1994, but not before 1994." Kaplinsky, McCormick and Morris (2010) also use world market shares analysis (together with global prices for African exports) to assess the trade impact of China on sub-Saharan Africa.

The previous CIP index did not consider economies' industrial and trade strengths in global markets.[3] The index was influenced only by national factors. Indeed, dynamics leading to international complementarity and competition were overlooked (Kaplinsky, McCormick and Morris 2010). The two new indicators in the index now partially capture these elements. Though imperfect measures, shares in world manufactures trade and in world MVA are widely used in the literature.

Dimensions, indicators and calculation of the Competitive Industrial Performance index

The CIP index has six main dimensions:

- *Industrial capacity. MVA per capita* is the primary indicator of an economy's industrialization adjusted for population. It shows an economy's capacity to add value in manufacturing. MVA is sometimes shielded from international competition by inward policies and trade barriers. MVA analysis can distort results for economies with a long history of protectionism and import substitution. But adding export orientation to the analysis places industrial competitiveness in a global context.
- *Manufactured export capacity.* In a global economy, the capacity to export is a key to economic growth and competitiveness. *Manufactured exports per capita,* a basic indicator of trade competitiveness, shows an economy's capacity to meet global demand for manufactures in an increasingly competitive environment. Manufactured exports

> **The previous CIP index assumed that industrial performance depended entirely on endogenous factors – industrial capabilities to produce and export manufactures competitively – however, new studies find that in a global economy, exogenous factors, like third-country competition, strongly affect the international industrial scene**

show whether national MVA is competitive internationally. Trade analysis on its own can distort results for countries that have low domestic capabilities and are used as export platforms by multinational corporations. MVA also adds to trade analysis by showing the value that domestic companies add to exports.

- *Impact on world MVA.* The impact of an economy on world MVA is measured by its *share in world MVA,* which indicates an economy's relative performance and impact in manufacturing.
- *Impact on world manufactures trade.* An economy's impact on world manufactured exports is measured by its *share in world manufactured exports,* which shows an economy's competitive position relative to others in international markets. Gains in world market share reflect more competitiveness; losses signal deterioration.
- *Industrialization intensity.* An economy's industrialization intensity is measured by the arithmetic average of the *share of MVA in GDP* and the *share of medium- and high-technology activities in MVA.* The share of MVA in GDP captures manufacturing's weight in the economy. The share of medium- and high-technology activities in MVA shows the technological complexity of manufacturing. This variable gives a positive weight to medium- and high-technology activities since a more complex structure denotes industrial maturity, flexibility and the ability to move into faster growing activities. However, the measure captures shifts across activities but not upgrades within them, so it misses an important aspect of technological improvement. As an aggregate measure, it does not capture fine technological differences within the categories (some low-technology activities can include some high-technology activities – and vice versa). These deficiencies reflect the nature of the data, but the broad findings appear to be sound.
- *Export quality.* Export quality is measured by the simple arithmetic average of the *share of manufactured exports in total exports* and the *share of medium- and high-technology products in manufactured exports.* The reasoning is similar to that for industrialization intensity. The share of manufactures in total exports captures the importance of manufacturing in export activity. The share of medium- and high-technology products in manufactured exports captures the technological complexity of exports, along with the ability to make more advanced products and move into more dynamic areas of exports.

All indicators are normalized as follows:

$$I_{ij} = \frac{X_{ij} - Min(X_{ij})}{Max(X_{ij}) - Min(X_{ij})}$$

where I_{ij} is the index value i for economy j, X_{ij} is the indicator value i for economy j, Min is the smallest value in the sample and Max is the largest. The top economy in the sample gets the value 1, while the worst performer gets the value 0. The CIP index is calculated as the arithmetic mean of the normalized values of the indicators. All six dimensions of the index have equal weight. Each combined indicator in industrialization intensity and export quality also gets equal weight .

The CIP index relies on a limited number of quantitative indicators. The indicators are computed from MVA and population data from UNIDO's statistical database and trade data from the United Nations Commodity Trade Statistics Database (Comtrade). Most indicators are easy to compute, but the share of medium- and high-technology activities in MVA is not, because recent MVA data are not available at the International Standard Industrial Classification (ISIC) two-digit level of aggregation. Censuses and surveys are the primary sources of UNIDO's industrial statistics. The sources generate statistics with a typical lag of two or three years. The most recent available data are used for this indicator, under the assumption that economic structure changes slowly. See Annexes 9–13 for more information.

The CIP index focuses on industrial performance, not industrial potential.[4] Performance involves a country's actual wealth creation. Potential refers to factors that may ease or impede it, such as the quantity and quality of input factors (labour, capital and

> **The four overall leaders in the Competitive Industrial Performance index in 2005 and 2009 were Singapore, the United States, Japan and Germany, with China ranking fifth in 2009**

land), institutions (property rights, financial markets), domestic market size and government policies. Both performance and potential are important for policy-making. The CIP index should be considered a preliminary measure of industrial progress because it excludes industrial potential (UNIDO 2003).

Ranking economies on the Competitive Industrial Performance index, 2005 and 2009

The CIP index was computed for 2005 and 2009 for the 118 economies with sufficient recent data. In both years, the four overall leaders were Singapore, the United States, Japan and Germany, with Singapore and Japan trading third and first in 2009. China was fifth in 2009; Ireland was fifth in 2005 (Table 10.1).

The four overall leaders generally are at the top of the individual indicators as well. For example, in 2009, Singapore led in exports per capita and was third in the share of manufactured exports in total exports, MVA per capita and industrialization intensity. Japan led in MVA per capita and export quality and was second in the share of world MVA. Germany was among the top 10 in five of the six dimensions.

Among the top 20 economies in 2009, three improved their rankings the most over 2005 – Czech Republic (+4), Austria (+5) and Slovakia (+7) – thanks largely to growth in MVA per capita and manufactured exports per capita (Table 10.2). The United Kingdom dropped four positions, from 15th to 19th, reflecting a decline on most indicators.

Table 10.1
Rankings on the Competitive Industrial Performance index, 2005 and 2009

Rank 2005	Rank 2009	Economy	CIP index 2005	CIP index 2009	Rank 2005	Rank 2009	Economy	CIP index 2005	CIP index 2009
3	1	Singapore	0.631	0.642	30	22	Israel	0.286	0.332
2	2	United States	0.660	0.634	25	23	Hungary	0.310	0.328
1	3	Japan	0.661	0.628	22	24	Luxembourg	0.316	0.323
4	4	Germany	0.598	0.597	27	25	Thailand	0.300	0.320
6	5	China	0.461	0.557	23	26	Denmark	0.311	0.320
7	6	Switzerland	0.455	0.513	20	27	Malaysia	0.330	0.320
9	7	Korea, Rep. of	0.438	0.480	19	28	Canada	0.349	0.309
5	8	Ireland	0.499	0.479	28	29	Spain	0.293	0.291
11	9	Finland	0.411	0.442	29	30	Mexico	0.286	0.286
8	10	Belgium	0.439	0.442	31	31	Malta	0.266	0.284
12	11	Taiwan Province of China	0.401	0.437	34	32	Poland	0.235	0.279
10	12	Sweden	0.432	0.430	32	33	Philippines	0.262	0.272
18	13	Austria	0.368	0.401	38	34	Norway	0.209	0.248
21	14	Slovakia	0.322	0.387	33	35	Turkey	0.237	0.237
13	15	France	0.395	0.384	35	36	Estonia	0.220	0.234
16	16	Netherlands	0.374	0.378	36	37	Portugal	0.218	0.224
14	17	Hong Kong SAR China	0.385	0.375	43	38	Iceland	0.187	0.218
17	18	Italy	0.370	0.361	47	39	Romania	0.178	0.218
15	19	United Kingdom	0.383	0.356	41	40	Lithuania	0.196	0.216
24	20	Czech Republic	0.310	0.352	39	41	Costa Rica	0.208	0.215
26	21	Slovenia	0.306	0.345	42	42	India	0.190	0.206

(continued)

10

BENCHMARKING INDUSTRIAL PERFORMANCE

"Among the top 20 economies in 2009, three improved their rankings the most over 2005 – Czech Republic, Austria and Slovakia – thanks largely to growth in MVA per capita and manufactured exports per capita

Table 10.1 *(continued)*
Rank on the revised Competitive Industrial Performance index, 2005 and 2009

Rank 2005	Rank 2009	Economy	CIP index 2005	CIP index 2009
40	43	Indonesia	0.198	0.203
37	44	Brazil	0.212	0.202
51	45	Jordan	0.167	0.193
49	46	Argentina	0.168	0.192
46	47	Australia	0.180	0.188
62	48	Swaziland	0.152	0.186
45	49	South Africa	0.181	0.184
52	50	Greece	0.166	0.182
58	51	Georgia	0.155	0.179
61	52	Latvia	0.154	0.178
44	53	Cyprus	0.182	0.176
53	54	Bulgaria	0.165	0.176
54	55	Tunisia	0.157	0.175
50	56	El Salvador	0.168	0.175
55	57	Barbados	0.156	0.174
72	58	Viet Nam	0.137	0.171
59	59	Morocco	0.155	0.168
64	60	Qatar	0.150	0.168
48	61	New Zealand	0.172	0.161
73	62	Egypt	0.137	0.157
67	63	Pakistan	0.147	0.156
88	64	Kuwait	0.107	0.156
60	65	Bahamas	0.154	0.154
57	66	Russian Federation	0.155	0.154
63	67	Trinidad and Tobago	0.151	0.151
66	68	Macedonia, Former Yugoslav Rep. of	0.147	0.149
75	69	Bangladesh	0.135	0.145
56	70	Mauritius	0.156	0.144
65	71	Lebanon	0.149	0.144
78	72	Macao SAR China	0.130	0.142
76	73	Jamaica	0.132	0.141
69	74	Colombia	0.140	0.135
68	75	Senegal	0.142	0.134
77	76	Albania	0.132	0.133
71	77	Venezuela, Bol. Rep. of	0.138	0.131
79	78	Botswana	0.128	0.131
80	79	Uruguay	0.123	0.129
102	80	Syrian Arab Rep.	0.082	0.128
70	81	Chile	0.139	0.128
89	82	St. Lucia	0.106	0.127
82	83	Iran, Islamic Rep. of	0.114	0.126
87	84	Moldova, Rep. of	0.111	0.126
98	85	Gambia, The	0.087	0.124
83	86	Palestinian Territories	0.114	0.121
90	87	Rwanda	0.106	0.119
93	88	Cambodia	0.102	0.119
92	89	Honduras	0.103	0.118
74	90	Côte d'Ivoire	0.136	0.116
99	91	Oman	0.087	0.115
86	92	Sri Lanka	0.111	0.115
94	93	Fiji	0.101	0.110
91	94	Nepal	0.105	0.108
85	95	Niger	0.111	0.107
96	96	Peru	0.094	0.106
100	97	Madagascar	0.086	0.101
105	98	Uganda	0.075	0.100
84	99	Zimbabwe	0.114	0.100
97	100	Kenya	0.092	0.094
101	101	Kyrgyzstan	0.085	0.089
103	102	Cameroon	0.080	0.083
81	103	Nigeria	0.114	0.081
108	104	Ecuador	0.069	0.079
104	105	Paraguay	0.075	0.076
107	106	Eritrea	0.071	0.076
111	107	Bolivia, Plurinational State of	0.063	0.073
112	108	Mongolia	0.055	0.070
109	109	Ghana	0.069	0.069
114	110	Tanzania, United Rep. of	0.046	0.068
118	111	Ethiopia	0.017	0.068
110	112	Malawi	0.064	0.059
113	113	Panama	0.048	0.053
116	114	Yemen	0.036	0.044
115	115	Algeria	0.037	0.042
117	116	Gabon	0.034	0.038
106	117	Azerbaijan	0.072	0.036
95	118	Sudan	0.095	0.035

Source: UNIDO.

“ Several economies slipped in their Competitive Industrial Performance index ranking, including the Russian Federation, Brazil and South Africa

Table 10.2
Change in rank on the Competitive Industrial Performance index between 2005 and 2009

Economy	Change in rank
Kuwait	24
Syrian Arab Republic	22
Swaziland	14
Viet Nam	14
Gambia, The	13
Egypt	11
Latvia	9
Israel	8
Romania	8
Oman	8
Slovakia	7
Georgia	7
St. Lucia	7
Uganda	7
Ethiopia	7
Jordan	6
Bangladesh	6
Macao SAR China	6
Austria	5
Slovenia	5
Iceland	5
Cambodia	5
Czech Republic	4
Norway	4
Qatar	4
Pakistan	4
Ecuador	4
Bolivia, Plurinational State of	4
Mongolia	4
Tanzania, United Rep. of	4
Argentina	3
Jamaica	3
Moldova, Rep. of	3
Rwanda	3
Honduras	3
Madagascar	3
Singapore	2
Korea, Rep. of	2
Finland	2
Hungary	2
Thailand	2
Poland	2
Greece	2
Yemen	2
China	1
Switzerland	1
Taiwan Province of China	1
Lithuania	1
Albania	1
Botswana	1
Uruguay	1
Fiji	1
Cameroon	1
Eritrea	1
Gabon	1
United States	0
Germany	0
Netherlands	0
Malta	0
India	0
Morocco	0
Peru	0
Kyrgyzstan	0
Ghana	0
Panama	0
Algeria	0
Italy	–1
Spain	–1
Mexico	–1
Philippines	–1
Estonia	–1
Portugal	–1
Australia	–1
Bulgaria	–1
Tunisia	–1
Iran, Islamic Rep. of	–1
Paraguay	–1
Japan	–2
Belgium	–2
Sweden	–2
France	–2
Luxembourg	–2
Turkey	–2
Costa Rica	–2
Barbados	–2
Macedonia, Former Yugoslav Rep. of	–2
Malawi	–2
Ireland	–3
Hong Kong SAR China	–3
Denmark	–3
Indonesia	–3
Palestinian Territories	–3
Nepal	–3
Kenya	–3
United Kingdom	–4
South Africa	–4
Trinidad and Tobago	–4
Bahamas	–5
Colombia	–5
El Salvador	–6
Lebanon	–6
Venezuela, Bol. Rep. of	–6
Sri Lanka	–6
Malaysia	–7
Brazil	–7
Senegal	–7
Canada	–9
Cyprus	–9
Russian Federation	–9
Niger	–10
Chile	–11
Azerbaijan	–11
New Zealand	–13
Mauritius	–14
Zimbabwe	–15
Côte d’Ivoire	–16
Nigeria	–22
Sudan	–23

Source: UNIDO.

“East Asia and the Pacific is the most industrialized region, with manufacturing value added at 31 percent of GDP in 2009

Several economies slipped too, including the Russian Federation (–9), Brazil (–7) and South Africa (–4). India (42) maintained its position.

Developing economies had the largest variations between 2005 and 2009. Gaining were Kuwait (+24), the Syrian Arab Republic (+22), Swaziland (+14), Viet Nam (+14), The Gambia (+13) and Egypt (+11). Tumbling were New Zealand (–13) and, affected by conflict and political instability, Côte d'Ivoire (–16), Nigeria (–22) and Sudan (–23).

At the bottom of the rankings are Mongolia in East Asia and the Pacific; Algeria, Azerbaijan and Yemen in the Middle East and North Africa; Panama in Latin America and the Caribbean; and Sudan and Gabon in sub-Saharan Africa.

Industrial performance of developing economies by region

The regional measure of industrial performance is the average CIP index of developing economies in each region. At a regional level in 2009, East Asia and the Pacific performed best on the index, followed by Europe, the Middle East and North Africa, Latin America and the Caribbean, South and Central Asia, and sub-Saharan Africa. The 2005 regional rankings were similar, except that the Middle East and North Africa was behind Latin America and the Caribbean.

East Asia and the Pacific

East Asia and the Pacific is the most industrialized region, with MVA at 31 percent of GDP in 2009. Gains in MVA per capita have been impressive: from $476 in 2004 to $678 in 2008 and $724 in 2009, despite the global economic crisis. Led by China, the region accounted for 20 percent of world MVA in 2009. Export performance is especially remarkable, with manufactured exports up 18 percent over 2005–2008 and constituting more than 90 percent of the region's exports.

The region's only change in rank was Thailand's rise from sixth to fifth in the region in 2009, ahead of Malaysia, placing it 25th in the world (Table 10.3). Its exports per capita grew 52 percent over 2005–2008, owing to such vibrant industrial sectors as electric appliances, computer parts and motor vehicles. Despite rising 14 spots in the world ranking, Viet Nam could not displace Indonesia, which dropped 3 spots.

Developing Europe

Developing Europe has the third highest MVA per capita, after Latin America and the Caribbean and East Asia and the Pacific, but moves to the top when the Russian Federation is excluded. The contribution of manufacturing to its GDP is about 18 percent. Thanks to greater integration with the European Union and low labour costs, manufactured exports grew 25 percent over 2004–2008, surpassing all other regions. Developing Europe's strong competitive and export capacities have propelled it to the top of manufactured exports per capita.

The small economies of Slovenia, Malta and Estonia typically lead the CIP index rankings for the region, mostly through increases in per capita indicators (see Table 10.3). For example, Slovenia increased its MVA per capita 20 percent and manufactured exports per capita 62 percent over 2005–2008, with trade oriented towards other EU countries, such as Austria, France, Germany and Italy. The Russian Federation maintained its regional position but dropped nine spots globally.

Latin America and the Caribbean

Latin America and the Caribbean had the highest regional MVA per capita in 2008, at $779, but it dropped to second place in 2009 because of the global economic and financial crisis. Manufacturing's contribution to GDP dropped from 16.6 percent in 2000 to 14.8 percent in 2009. The region's 14 percent annual growth in manufactured exports over 2005–2008 was slower than that of Europe (22.8 percent) and East Asia and the Pacific (16.8 percent).

Mexico, Costa Rica and Brazil were the top three performers in the region in 2005 and 2009, ranking 30th, 41st and 44th globally on the 2009 CIP index (see Table 10.3). Mexican exports are developing rapidly, with a strong contribution from the automotive

Israel was the top performer in the Middle East and North Africa, followed by Turkey; India remains the most industrialized economy in South and Central Asia; and Swaziland was the most industrialized economy in sub-Saharan Africa

sector, which produces technologically complex components. Overall, 76 percent of exports in 2008 were medium- and high-technology products. A large share of Mexico's trade is with its two northern partners in the North American Free Trade Agreement, Canada and the United States, increasing its sensitivity to shocks in these countries. Exports of medium- and high-technology products from Brazil, the largest economy in Latin America and the Caribbean, are rising swiftly in aircraft, electrical equipment and automobiles.

Several economies have slipped in the global rankings, such as the Bahamas (–5), Colombia (–5), El Salvador (–6) and Venezuela (–6). Others, such as Ecuador, Paraguay, Bolivia and Panama, are still among the least competitive countries.

Middle East and North Africa

Israel was the top performer in the Middle East and North Africa, followed by Turkey (see Table 10.3). Taking advantage of a 1995 customs union agreement with the European Union, Turkey increased its industrial production for export and also benefited from EU foreign investment. By 2008, Turkish manufactured exports were \$118.2 billion, and manufactures exports per capita had grown 71 percent since 2005.

Tunisia, the top industrial performer in North Africa, ranks 55th in the world, with considerable manufacturing activity in clothing and footwear, car parts and electric machinery. Manufactured exports to the European Union grew 17 percent a year over 2004–2008. In 2008, Tunisia completed dismantling tariffs on industrial products and entered a free-trade agreement with the European Union. Egypt improved its global industrial performance by 11 places, while Morocco maintained its position and Sudan lost 23 places.

South and Central Asia

India remains the most industrialized economy in South and Central Asia, followed by Pakistan (see Table 10.3). Bangladesh, the third most industrialized, gained six positions globally, moving from 75th in 2005 to 69th in 2009. More than 90 percent of Bangladesh's exports are manufactures, with garments being the high earner. Pakistan's position in the global CIP index also improved, while the other economies in the region either maintained their positions or lost them.

Sub-Saharan Africa

Sub-Saharan Africa has been slow to industrialize. In 2008, its MVA per capita (excluding South Africa) was \$34, or one-thirteenth the developing economy average. Economies in the region appear to be de-industrializing, as the region's share of MVA in GDP dropped from 13.9 percent in 2000 to 11.4 percent in 2009. Its share in world MVA is also falling, a sign that economies are unable to withstand increasing international competition. Its share of manufactured exports in total exports remains the lowest, with economies still relying on natural resource exports.

Swaziland gained 14 places in 2009, becoming the most industrialized economy in the region, ahead of South Africa and Mauritius (see Table 10.3). Swaziland recorded good growth in MVA per capita. Mauritius remains third despite losing 14 positions globally. Both Swaziland and Mauritius have boosted their manufactured exports through preferential access to the US textiles and apparel market (under the African Growth and Opportunity Act) and the EU sugar market. Although the ending of such trade preferences has threatened the vigour of the export sector, these economies have introduced reforms to boost growth.

Nigeria, West Africa's largest economy, lost 22 positions globally between 2005 and 2009 and also slid back within sub-Saharan Africa. Several other economies also slipped, including Niger (–10) and Zimbabwe (–15). By contrast, Ethiopia and Uganda moved up seven positions globally, thanks to strong export performance.

The Competitive Industrial Performance index and energy intensity

The recent focus on energy intensity has been driven by environmental concerns – air pollution, acid rain, fossil fuel depletion, global warming and climate

"East Asia and the Pacific performed best on the CIP Index in 2009, followed by Europe, the Middle East and North Africa, Latin America and the Caribbean, South and Central Asia, and sub-Saharan Africa

Table 10.3
Rank of developing economies on the Competitive Industrial Performance index, by region, 2005 and 2009

Region and economy	2005	2009
East Asia and the Pacific		
Singapore	1	1
China	2	2
Taiwan Province of China	3	3
Hong Kong SAR China	4	4
Thailand	6	5
Malaysia	5	6
Philippines	7	7
Indonesia	8	8
Viet Nam	9	9
Macao SAR China	10	10
Cambodia	11	11
Fiji	12	12
Mongolia	13	13
Developing Europe		
Slovenia	1	1
Malta	2	2
Poland	3	3
Estonia	4	4
Romania	6	5
Lithuania	5	6
Latvia	9	7
Bulgaria	7	8
Russian Federation	8	9
Macedonia, Former Yugoslav Rep. of	10	10
Albania	11	11
Moldova, Rep. of	12	12
Latin America and the Caribbean		
Mexico	1	1
Costa Rica	3	2
Brazil	2	3
Argentina	4	4
El Salvador	5	5
Barbados	6	6
Bahamas	7	7
Trinidad and Tobago	8	8
Jamaica	12	9
Colombia	9	10
Venezuela, Bolivarian Rep. of	11	11
Uruguay	13	12
Chile	10	13

Region and economy	2005	2009
St. Lucia	14	14
Honduras	15	15
Peru	16	16
Ecuador	18	17
Paraguay	17	18
Bolivia, Plurinational State of	19	19
Panama	20	20
Middle East and North Africa		
Israel	1	1
Turkey	2	2
Jordan	4	3
Georgia	6	4
Cyprus	3	5
Tunisia	5	6
Morocco	7	7
Qatar	8	8
Egypt	10	9
Kuwait	12	10
Lebanon	9	11
Syrian Arab Republic	15	12
Palestinian Territories	11	13
Oman	14	14
Yemen	18	15
Algeria	17	16
Azerbaijan	16	17
Sudan	13	18
South and Central Asia		
India	1	1
Pakistan	2	2
Bangladesh	3	3
Iran, Islamic Rep. of	4	4
Sri Lanka	5	5
Nepal	6	6
Kyrgyzstan	7	7
Sub-Saharan Africa		
Swaziland	3	1
South Africa	1	2
Mauritius	2	3
Senegal	4	4
Botswana	6	5
Gambia, The	12	6

“ Economies with low energy intensity, such as Germany, Japan and the United States, are also the best industrial performers

Table 10.3 *(continued)*
Rank of developing economies on the Competitive Industrial Performance index, by region, 2005 and 2009

Region and economy	2005	2009
Rwanda	10	7
Côte d’Ivoire	5	8
Niger	9	9
Madagascar	13	10
Uganda	15	11
Zimbabwe	8	12
Kenya	11	13
Cameroon	14	14
Nigeria	7	15
Eritrea	16	16
Ghana	17	17
Tanzania, United Rep. of	19	18
Ethiopia	21	19
Malawi	18	20
Gabon	20	21

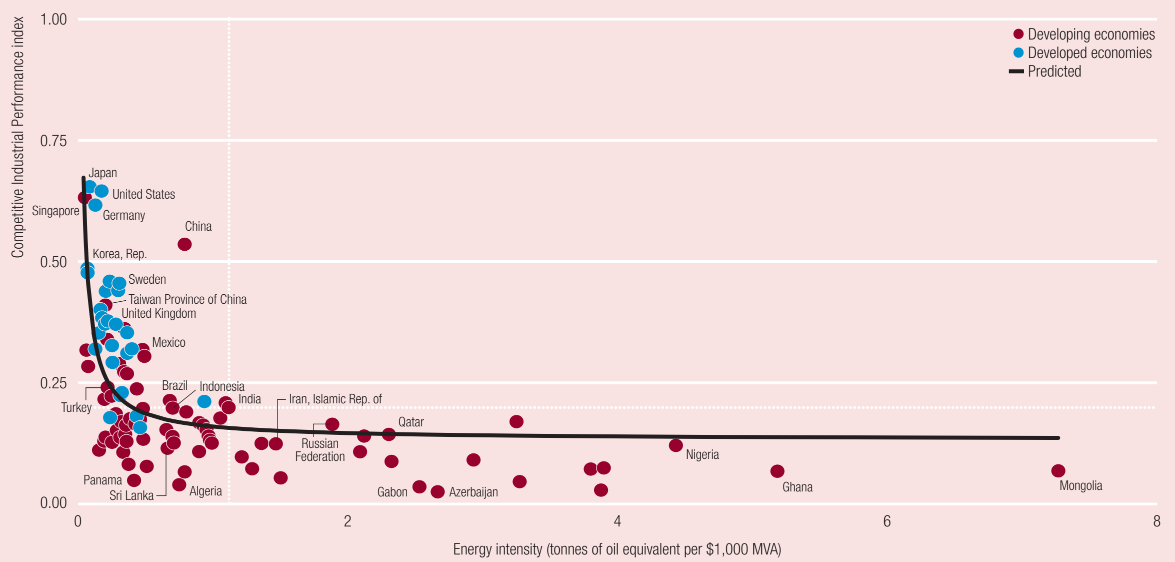
Source: UNIDO.

change. Increased competitive pressure, high and unstable energy prices and tightening environmental regulations also make energy intensity a key issue for industrial competitiveness.

To explore the relationship between industrial performance and energy intensity, the CIP index was regressed on manufacturing energy intensity for 104 economies in 2008.[5] The results suggest that energy intensity is inversely correlated with industrial performance (Figure 10.1).[6]

Economies with low energy intensity, such as Germany, Japan and the United States, are also the best industrial performers. Energy costs as well as energy-conserving technologies may explain energy efficiency in these economies. Japan, the best industrial performer in 2005, leads in energy-saving technologies in steel, cement and refineries, thus softening the impact on production of low energy-resource endowments and price volatility of imported energy sources. Japan plans to increase energy efficiency

Figure 10.1
Linking the Competitive Industrial Performance index with manufacturing energy intensity, 2008



Source: UNIDO; IEA 2010d.

There are large variations in industrial performance and energy intensity, with economies such as China and Singapore having relatively high industrial performance and low energy intensity, and others such as Ghana, Mongolia and Nigeria having relatively low industrial performance and high energy intensity

30 percent by 2030 and is investing heavily in innovative technologies to maintain its lead in this field.

There are large variations in industrial performance and energy intensity, with economies such as China and Singapore having relatively high industrial performance and low energy intensity, and others such as Ghana, Mongolia and Nigeria having relatively low industrial performance and high energy intensity. Developing economies generally fall into one of three groups, with India (CIP index of 0.20 and energy intensity of 1.12) as a "threshold" in Figure 10.1. Indeed, the vertical (1.12) and horizontal (0.2) lines through India's coordinates in the figure divide the graph area into four zones; there are no economies in the upper right quadrant of the graph.

Economies such as Gabon and Nigeria, with energy intensity higher than India's, typically have lower industrial performance. Their relatively low levels of industrialization leave considerable room for energy-efficiency improvements as they develop their industrial sector. In addition, economies in the bottom right quadrant of the graph such as Iran and Qatar are oil-producing economies that subsidize oil. Since energy price is a key determinant of energy intensity, subsidies may provide strong disincentives for energy savings.

Several economies with energy intensity lower than India's have higher industrial performance, including Indonesia, Mexico and Turkey (upper left quadrant in Figure 10.1). In this second group, economies such as Singapore and Taiwan Province of China have energy intensity and industrial performance comparable to those of developed economies. Finally, a third group, which includes Algeria, Panama and Sri Lanka, has low energy intensity and low industrial performance (bottom left quadrant), suggesting that other factors may also play a role in explaining industrial performance (although not investigated here).

Large developing economies such as Brazil, China and India rank in the top half in industrial performance (6th, 40th and 43rd, respectively) and energy intensity.[7] The Russian Federation is in the bottom half in industrial performance and the top half in energy intensity. In 2008, those four economies were among the top six energy consumers in the world, likely due to increased production of energy-intensive products (such as iron, cement and steel) to cope with rapid infrastructure growth – in housing and in metal-intensive industries such as motor vehicles. However, these economies are also improving their energy efficiency.

An interesting question is whether the causal relationship runs from industrial performance to energy efficiency, the other way around or in both directions. Most developed economies cluster at the top for industrial performance and the bottom for energy intensity, indicating greater energy-efficiency maturity than developing economies. The average energy intensity of developed economies in the sample is 0.26 tonne of oil equivalent per $1,000 MVA, less than a quarter the average for developing economies (1.17 tonnes of oil equivalent). By economy, Ireland and Switzerland have the lowest energy intensity, at 0.07 tonne of oil equivalent per $1,000 MVA; Iceland, the highest (0.94 tonne of oil equivalent). As noted in Chapter 2, total industrial energy intensity tends to be high at early stages of industrialization but decreases at later stages of industrialization due to technological improvements in the use of energy, structural changes away from energy-intensive sectors, production shifts towards more skill-intensive industries and increasing use of high-quality fuels. This view suggests that a higher industrialization stage and performance precedes lower energy intensity. But this may be explained by the fact that most developed economies industrialized without the current environmental concerns and constraints, before moving from "brown" to "green" industries.

The current situation is different. Economies might have to choose deliberate policies to lower energy intensity in order to promote industrial performance. At the firm level, lower energy intensity, resulting from reduced use of a costly input (energy), might save money and increase productivity, and

Some actions to decrease energy intensity will typically lead to better industrial performance relative, in particular, to technology and system improvements

as illustrated in Chapter 4, investments in energy efficiency can be profitable in both developed and developing economies. Furthermore, as mandatory minimum standards and voluntary agreements on energy performance become more widespread, energy intensity is likely to affect sales and trade directly by restricting the market for non-compliant firms. Finally, at the national level, benefits from lower industrial energy intensity might also lead to greater competitiveness, energy security and environmental protection (Mills and Rosenfeld 1996).[8] This line of reasoning suggests that lowering energy intensity might be a strategy for boosting industrial performance.

Finally, some actions to decrease energy intensity will typically lead to better industrial performance relative, in particular, to technology and system improvements. These include replacing old technology, adopting energy-saving technologies, improving processes and optimizing systems, employing energy management practices and using more high-quality energy (see Chapter 2). These technology and system improvements result in both lower energy intensity and higher industrial performance. This suggests that the posited relationship between industrial performance and energy intensity may be spurious.

In sum, more research and evidence might be warranted to provide a more complete answer on the relationship between industrial performance and energy intensity.

Notes

1. Competitiveness is a widely used concept but difficult to define. While there is some consensus about defining competitiveness at the firm level, debate continues at the country level.
2. For more details on the effects of including these two additional indicators, see Annex 6.
3. Capacity and structure indicators cannot assess those aspects.
4. See, for example, UNIDO (2003) and Aiginger (2006) for such a dichotomic approach. Related indexes such as the Global Competitiveness Index and the World Competitiveness Scoreboard mix both dimensions of competitiveness.
5. The most recent year in IEA (2010d) is 2008.
6. Energy intensity is measured here in tonnes of oil equivalent per $1,000 MVA (in 2000 prices); the lower a country's energy intensity, the higher its energy efficiency. The results of the regressions are suggestive at best, since some factors important for determining energy intensity were not considered. The estimated equation is as follows, with standard errors between brackets:

$$\text{CIP Index} = -0.13\,[0.015] + \frac{0.03}{\textit{Energy efficiency}}\,[0.003].$$

7. The ranking is based on the 104 economies in the sample for 2008.
8. As explained in Chapters 1–4, energy efficiency also brings additional benefits relating to, for example, the environment and poverty reduction.

Annexes

Annex 1

Energy intensity data and methodology

The data span 1990–2008 and cover as many economies as possible, subject to data availability, for industry as a whole and are disaggregated by manufacturing sector (International Standard Industry Classification [ISIC] 15–37). The economies were classified by UNIDO region and income.

Real-value manufacturing value added data were obtained from UNIDO's *International Yearbook of Industrial Statistics 2010* and presented in 2000 US dollars. INDSTAT 2 ISIC Revision 3 was the primary source of value added data. The Index of Industrial Production was also obtained from Revision 3 and was used to convert the nominal value-added data into real values in 2000 US dollars for any year *X,* as follows:

$$VA_{\text{yrX}} = VA_{2000} \times \frac{IIP_{\text{yrX}}}{IIP2000}$$

where VA_{2000} and IIP_{2000} are the 2000 (base year) value added and Index of Industrial Production. For any other year, the value added and Index of Industrial Production are referred to by VA_{yrX} and IIP_{yrX}.

Industrial energy consumption data for both aggregated and disaggregated levels came from the IEA databases of extended energy balances for OECD and non-OECD countries (IEA 2010c).

While UNIDO's manufacturing value added data are reported according to ISIC Revision 3, IEA's energy data are reported according to a classification closer to Revision 2. Annex 3 matches sector data for energy and manufacturing value added to enable cross-database comparisons. Three problem areas were identified:

- Manufacturing sector coke, refined petroleum products and nuclear fuel (ISIC code 23) was not listed under the industry sector classification of IEA data. It was listed under "transformation and energy." The difference between the two is that the energy sector reports energy used as fuel to power the manufacturing process, while the transformation sector reports fossil fuels used as raw material input to a manufacturing process. According to the definition of energy intensity used in this report (the unit of energy consumed [as fuel] per unit of value added produced), only energy sector and final consumption need to be included. Fossil fuel use as raw material input and feedstock use in the petrochemical sector were thus not included in the energy consumption figures.
- Blast furnace in the energy sector has been allocated to the iron and steel sector. Coke ovens from the energy sector were allocated half and half to iron and steel (ISIC code 27) and to coke, refined petroleum products and nuclear fuel (ISIC code 23).
- The IEA data treat recycling as part of the manufacturing sector and include energy consumption by the recycling sector under "non-specified." However, no value added data were available for the recycling sector in INDSTAT 2.

Annex 2

Decomposition data and methodology

The INDSTAT 2 ISIC Revision 3 dataset for 2010 is used for value added (UNIDO 2010f) and the International Energy Agency (IEA) Extended World Energy Balances for 2009 is used for energy consumption (IEA 2010c). Of the initial 64 economies 62 were investigated by Cantore and Fokeer (2010). To be selected, economies had to:

- Be covered by IEA and INDSTAT data.
- Have at least five years of data available in the IEA and INDSTAT datasets.
- Have data for at least 5 of 11 IEA sectors. As the analysis includes structural composition, countries for which this component is relevant were chosen.

The data were then cleaned by eliminating from the dataset sectors of economies with inconsistencies (for example, a sector with 0 for value added and a positive value for energy consumption) and outliers. Sectors with temporally inconsistent data were also excluded (for example, 0 value for the periods 0 . . . t–1 and a positive value at time t).

The first step was to calculate energy intensity for each economy as a ratio of energy consumption (in tonnes of oil equivalent, toe) to value added. Energy intensity is expressed as toe per $1,000 manufacturing value added (in 2000 international dollars).

Next, the Fisher Ideal Index technique was applied, based on the Laspeyres and Paasche Indices. The Laspeyres Index is expressed as follows:

$$L_{str} = \frac{\sum_i S_{i,t} I_{i,0}}{\sum_i S_{i,0} I_{i,0}} \quad \text{and} \quad L_{eff} = \frac{\sum_i S_{i,0} I_{i,t}}{\sum_i S_{i,0} I_{i,0}}$$

where L_{str} is the Laspeyres structural effect, L_{eff} is the Laspeyres energy efficiency, S is the share of sector i in total value added in time t and I is energy intensity of sector I in time t. The Paasche Index is expressed as follows:

$$P_{str} = \frac{\sum_i S_{i,t} I_{i,t}}{\sum_i S_{i,0} I_{i,t}} \quad \text{and} \quad P_{eff} = \frac{\sum_i S_{i,t} I_{i,t}}{\sum_i S_{i,t} I_{i,0}}$$

where P_{str} is the Paasche structural effect and P_{eff} is the Paasche energy-efficiency component.

The overall Fisher Ideal Index is calculated as follows:

$$FII = (L_{str} \times P_{str})^{½} \times (L_{eff} \times P_{eff})^{½}$$

where the Fisher structural effect, STR, is $(L_{str} \times P_{str})^{½}$, and the Fisher technical energy-efficiency effect, TEC, is $(L_{eff} \times P_{eff})^{½}$.

To express the total change in energy intensity as the sum of the structural effect and the Fisher energy-efficiency effect (instead of a product), log mean Divisia Index was applied as follows:

$$\Delta FII = \left\{ \left[\ln\left(\frac{STR_t}{STR_0}\right) \Big/ \ln\left(\frac{FII_t}{FII_0}\right) \right] + \left[\ln\left(\frac{TEC_t}{TEC_0}\right) \Big/ \ln\left(\frac{FII_t}{FII_0}\right) \right] \right\}.$$

Annex 3

Energy and manufacturing value added sector data

Table A3.1
Correspondence between energy data and manufacturing value added data by sector

Sector used for analysis	Energy data	Manufacturing value added data (International Standard Industrial Classification Revision 3)
Food and tobacco	Food and tobacco (FOODPRO)	15 (food and beverages) 16 (tobacco)
Textile and leather	Textile and leather (TEXTILES)	17 (textiles); 18 (wearing apparel; dressing and dyeing of fur); 19 (dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear)
Wood and wood products	Wood and wood products (WOODPRO)	20 (wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials)
Paper, pulp and printing	Paper, pulp and printing (PAPERPRO)	21 (paper and paper products); 22 (publishing, printing and reproduction of recorded media)
Petrochemicals	Petroleum refineries (EREFINER) Nuclear industry (ENUC) 50-percent coke ovens (ECOKEOVS)	23 (coke, refined petroleum products, nuclear)
Chemicals and chemical products	Chemical and petrochemical from industry sector (CHEMICAL) Patent fuel plants (EPATFUEL) Charcoal production plants (ECHARCOAL)	24 (chemicals and chemical products)
Non-metallic minerals	Non-metallic minerals (NONMET)	26 (other non-metallic mineral products)
Metals	Non-ferrous metals (NONFERR) Iron and steel (IRONSTL) Blast furnaces (EBLASTFUR) 50-percent coke ovens (ECOKEOVS)	27 (basic metals)
Machinery	Machinery (MACHINE)	28 (fabricated metal products, except machinery and equipment); 29 (machinery and equipment n.e.c.); 30 (office, accounting and computing machinery); 31 (electrical machinery and apparatus n.e.c.); 32 (radio, television and communication equipment and apparatus)
Transport equipment	Transport equipment (TRANSEQ)	34 (motor vehicles, trailers and semi-trailers); 35 (other transport equipment)
Non-specified industry	Non-specified industry (INONSPEC)	25 (rubber and plastics products); 33 (medical, precision and optical instruments, watches and clocks); 36 (furniture; manufacturing n.e.c.).

Source: UNIDO.

Annex 4

Economies included in the energy-intensity analysis

Table A4.1
All economies, by income group

Developed economies	Developing economies: High income	Developing economies: Upper middle income	Developing economies: Lower middle income	Developing economies: Low income
Australia*	Bahrain	Algeria	Albania	Bangladesh
Austria*	Brunei Darussalam	Argentina*	Angola	Benin
Belgium*	Croatia*	Belarus	Armenia*	Cambodia
Canada*	Cyprus*	Bosnia and Herzegovina	Azerbaijan*	Congo, Dem. Rep. of
Czech Republic*	Estonia*	Botswana	Bolivia, Plurinational State of	Ethiopia
Denmark*	Hong Kong SAR China	Brazil*	Cameroon	Eritrea
Finland*	Israel*	Bulgaria*	China*	Ghana
France*	Kuwait	Chile*	Congo	Haiti
Germany*	Malta	Colombia*	Côte d'Ivoire*	Kenya
Greece*	Oman	Costa Rica*	Ecuador	Korea, Dem. People's Rep. of
Hungary*	Qatar	Cuba	Egypt	Kyrgyzstan*
Iceland	Saudi Arabia	Dominican Rep.	El Salvador	Mozambique
Ireland*	Singapore	Gabon*	Georgia	Myanmar
Italy*	Slovenia*	Jamaica	Guatemala	Nepal
Japan*	Taiwan Province of China*	Kazakhstan*	Honduras	Senegal
Korea, Rep. of*	Trinidad and Tobago	Lebanon	India*	Tajikistan
Luxembourg	United Arab Emirates	Latvia*	Indonesia*	Tanzania, United Rep. of
Netherlands*		Libyan Arab Jamahiriya	Iran, Islamic Rep. of	Togo
New Zealand*		Lithuania*	Jordan	Uzbekistan
Norway*		Macedonia, Former Yugoslav Rep. of*	Moldova, Rep. of*	Viet Nam
Portugal*		Malaysia	Mongolia	Yemen
Slovakia*		Mexico*	Morocco*	Zambia
Spain*		Namibia	Nicaragua	Zimbabwe
Sweden*		Panama	Nigeria	
Switzerland*		Peru	Pakistan	
United Kingdom*		Poland*	Paraguay	
United States*		Romania*	Philippines*	
		Russian Federation*	Sri Lanka	
		Serbia	Sudan	
		South Africa*	Syrian Arab Rep.	
		Turkey*	Thailand*	
		Uruguay	Tunisia*	
		Venezuela, Bol. Rep. of*	Turkmenistan	
			Ukraine*	

* Meets the criteria for decomposition analysis.
Source: UNIDO.

Table A4.2
Developing economies, by region

East Asia and the Pacific	Developing Europe	Latin America and the Caribbean	Middle East and North Africa	South and Central Asia	Sub-Saharan Africa
Brunei Darussalam	Albania	Argentina*	Algeria	Azerbaijan*	Angola
Cambodia	Bosnia and Herzegovina	Bolivia, Plurinational State of	Armenia*	Bangladesh	Benin
China*	Bulgaria*	Brazil*	Bahrain	India*	Botswana
Hong Kong SAR China	Belarus	Chile*	Cyprus*	Kazakhstan*	Cameroon
Taiwan Province of China*	Croatia*	Colombia*	Egypt	Kyrgyzstan*	Congo
Indonesia*	Estonia*	Costa Rica*	Georgia	Nepal	Congo, Dem. Rep. of
Korea, Dem. People's Rep. of	Latvia*	Cuba	Iran, Islamic Rep. of	Pakistan	Côte d'Ivoire*
Malaysia	Lithuania*	Dominican Rep.	Israel*	Sri Lanka	Eritrea
Mongolia	Macedonia, Former Yugoslav Rep. of*	Ecuador	Jordan	Tajikistan	Ethiopia
Myanmar	Malta	El Salvador	Kuwait	Turkmenistan	Gabon*
Philippines*	Moldova, Rep. of*	Guatemala	Lebanon	Uzbekistan	Ghana
Singapore	Poland*	Haiti	Libyan Arab Jamahiriya		Kenya
Thailand*	Romania*	Honduras	Morocco*		Mozambique
Viet Nam	Russian Federation*	Jamaica	Oman		Namibia
	Serbia	Mexico*	Qatar		Nigeria
	Slovenia*	Nicaragua	Saudi Arabia		Senegal
	Ukraine*	Panama	Sudan		South Africa*
		Paraguay	Syrian Arab Rep.		Tanzania, United Rep. of
		Peru	United Arab Emirates		Togo
		Trinidad and Tobago	Tunisia*		Zambia
		Uruguay	Turkey*		Zimbabwe
		Venezuela, Bol. Rep. of*			

* Meets the criteria for decomposition analysis.
Source: UNIDO.

Annex 5

Industrial energy intensity

Table A5.1

Industrial energy intensity by economy, 1990, 2000 and 2008 (tonnes of oil equivalent per US$1,000 of manufacturing value added)

Economy	1990	2000	2008
Albania	1.202	0.556	0.204
Algeria	0.473	0.535	0.750
Angola	6.906	8.457	2.629
Argentina	0.295	0.333	0.281
Armenia	2.327	0.900	1.440
Australia	0.521	0.494	0.435
Austria	0.214	0.190	0.167
Azerbaijan	5.082	8.046	2.667
Bahrain	3.315	1.601	1.484
Bangladesh	0.287	0.281	0.350
Belarus	2.788	1.564	0.771
Belgium	0.384	0.376	0.298
Benin	2.143	1.675	1.776
Bolivia, Plurinational State of	0.723	0.957	0.791
Bosnia and Herzegovina	7.184	1.191	0.833
Botswana	0.962	0.089	0.194
Brazil	0.580	0.658	0.680
Brunei Darussalam	0.127	0.117	0.962
Bulgaria	1.863	1.913	1.055
Cambodia	0.515[a]	0.266	0.156
Cameroon	0.651	0.663	0.375
Canada	0.484	0.367	0.365
Chile	0.261	0.402	0.360
China	2.218	0.801	0.791
Colombia	0.412	0.577	0.484
Congo	1.217	1.938	1.347
Congo, Dem. Rep. of	4.758	19.049	17.736
Costa Rica	0.300	0.155	0.196
Côte d'Ivoire	0.997	0.896	2.091
Croatia	0.389	0.395	0.313
Cuba	1.647	0.861	0.844
Cyprus	0.350	0.570	0.425
Czech Republic	1.433	0.726	0.364
Denmark	0.140	0.125	0.129
Dominican Republic	0.405	0.288	0.211
Ecuador	0.558	0.856	0.510

Economy	1990	2000	2008
Egypt	1.215	0.712	0.655
El Salvador	0.256	0.240	0.239
Eritrea	6.441[b]	1.852	3.898
Estonia	2.934	0.612	0.436
Ethiopia	1.989	2.238	3.275
Finland	0.565	0.426	0.306
France	0.230	0.193	0.179
Gabon	1.731	1.936	2.532
Georgia	2.075	0.945	0.386
Germany	0.197	0.149	0.129
Ghana	4.975	5.096	5.185
Greece	0.341	0.365	0.238
Guatemala	0.365	0.436	0.247
Haiti	0.614	1.620	1.947
Honduras	0.890	0.590	0.313
Hong Kong SAR China	0.084	0.229	0.403
Hungary	1.051	0.381	0.252
Iceland	0.463	0.596	0.937
India	2.022	1.474	1.117
Indonesia	0.787	0.699	0.702
Iran, Islamic Rep. of	2.124	1.694	1.467
Ireland	0.143	0.087	0.071
Israel	0.163	0.109	0.062
Italy	0.226	0.199	0.200
Jamaica	0.309	0.703	0.978
Japan	0.123	0.110	0.087
Jordan	0.829	0.806	0.481
Kazakhstan	4.760	4.291	3.378
Kenya	2.932	3.172	2.932
Korea, Dem. People's Rep. of	5.930	6.131	4.419
Korea, Rep. of	0.436	0.341	0.235
Kuwait	1.410	1.961	0.701
Kyrgyzstan	4.921	1.872	2.324
Latvia	0.829	0.570	0.460
Lebanon	0.065	0.465	0.288
Libya	1.039	1.668	1.387

(continued)

A5

Table A5.1 *(continued)*

Industrial energy intensity by economy, 1990, 2000 and 2008 (tonnes of oil equivalent per $1,000 of manufacturing value added)

Economy	1990	2000	2008
Lithuania	1.416	0.377	0.248
Luxembourg	1.241	0.459	0.399
Macedonia, Former Yugoslav Rep. of	0.685	0.916	0.899
Malaysia	0.537	0.478	0.492
Malta	0.038[c]	0.057	0.075
Mexico	0.416	0.242	0.304
Moldova, Rep. of	1.945	1.492	1.361
Mongolia	13.167	10.692	7.268
Morocco	0.416	0.384	0.356
Mozambique	8.191	4.822	3.177
Myanmar	4.589	2.182	1.245
Namibia[d]	0.045[a]	0.035	0.010
Nepal	0.560	0.799	0.898
Netherlands	0.297	0.281	0.221
New Zealand	0.456	0.367	0.461
Nicaragua	0.884	0.595	0.517
Nigeria	6.366	6.636	4.433
Norway	0.403	0.430	0.325
Oman	1.691	1.136	1.214
Pakistan	1.309	1.224	0.953
Panama	0.176	0.541	0.416
Paraguay	1.066	1.246	1.291
Peru	0.375	0.439	0.335
Philippines	0.400	0.407	0.363
Poland	2.747	0.709	0.342
Portugal	0.374	0.364	0.313
Qatar	1.735	2.333	2.305
Romania	4.439	1.895	1.095
Russian Federation	2.607	2.798	1.885
Saudi Arabia	0.787	0.867	0.660
Senegal	0.985	1.019	0.968
Serbia	1.152	1.119	1.551
Singapore	0.089	0.076	0.051
Slovakia	0.986	0.763	0.281
Slovenia	0.326	0.296	0.216
South Africa	1.198	0.964	0.803
Spain	0.288	0.270	0.256
Sri Lanka	0.785	0.719	0.664
Sudan	10.600	6.312	3.878
Sweden	0.452	0.304	0.206
Switzerland	0.081	0.080	0.070
Syrian Arab Rep.	1.179	3.169	0.992
Taiwan Province of China	0.289	0.291	0.193
Tajikistan	1.597	1.523	1.041
Tanzania, United Rep. of	3.541	4.074	3.801
Thailand	0.688	0.524	0.478
Togo	4.691	7.976	6.302
Trinidad and Tobago	3.881	3.135	3.251
Tunisia	0.791	0.510	0.320
Turkey	0.360	0.378	0.219
Turkmenistan	8.036	0.745	0.639
Ukraine	6.926	8.688	3.280
United Arab Emirates	3.375	1.773	1.134
United Kingdom	0.172	0.170	0.152
United States	0.302	0.225	0.175
Uruguay	0.160	0.236	0.253
Uzbekistan	1.295	7.365	6.272
Venezuela, Bol. Rep. of	0.970	0.777	0.710
Viet Nam	1.118	0.937	0.928
Yemen	1.442	1.344	1.503
Zambia	7.335	6.972	5.177
Zimbabwe	1.491	1.222	2.121

a. Data are for 1995.
b. Data are for 1992.
c. Data are for 1991.
d. Data are for non-specified industry only.
Source: UNIDO 2010e,f; IEA 2010c.

Annex 6

How Competitive Industrial Performance index rankings change when new indicators are added

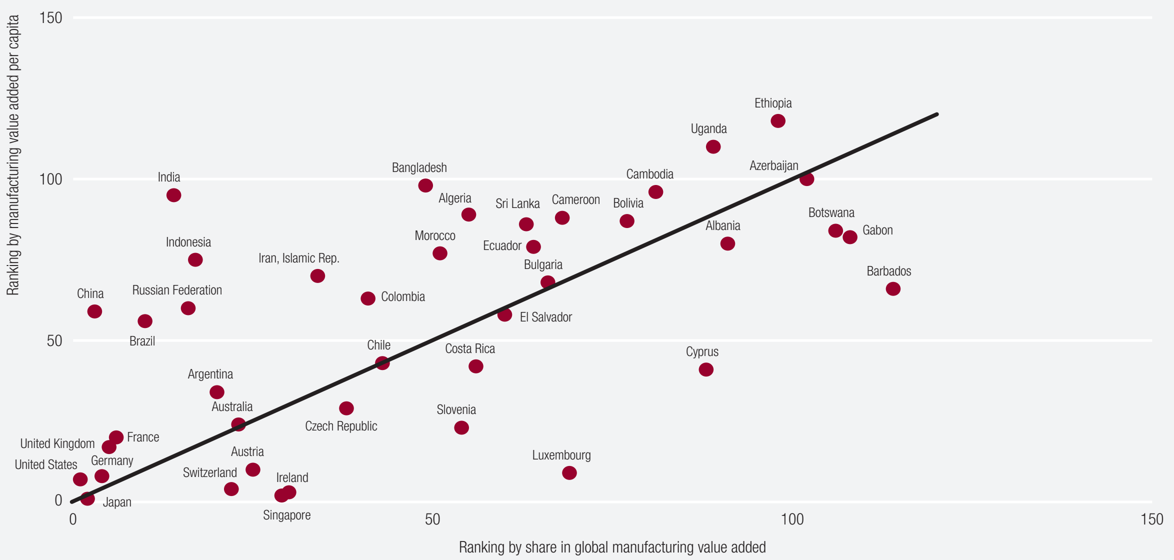
Two additional indicators were added to the Competitive Industrial Performance index: the share of an economy's manufacturing value added in world manufacturing value added, which measures the impact of an economy in world manufacturing production, and the share of an economy's manufactured exports in world manufactured exports, which measures an economy's ability to capture more from international trade.

With the addition of the new indicators, China rose 23 positions (from 29th to 6th) compared with its position using the old methodology, followed by the Russian Federation (19 positions, from 76th to 57th), the United States (9 positions, from 11th to 2nd), India (8 positions) and Italy (8 positions). The main losers were Slovenia (–7), Luxembourg (–6), Austria (–6) and Slovakia (–6).

Small economies are favoured when only per capita indicators are used, while large economies are favoured when world market shares are used (Figures A6.1 and A6.2). Including these indicators penalized small export-oriented economies such as Slovenia, Austria and Slovakia and favoured large economies such as China, India, Brazil, the United States and the Russian Federation (Table A6.1).

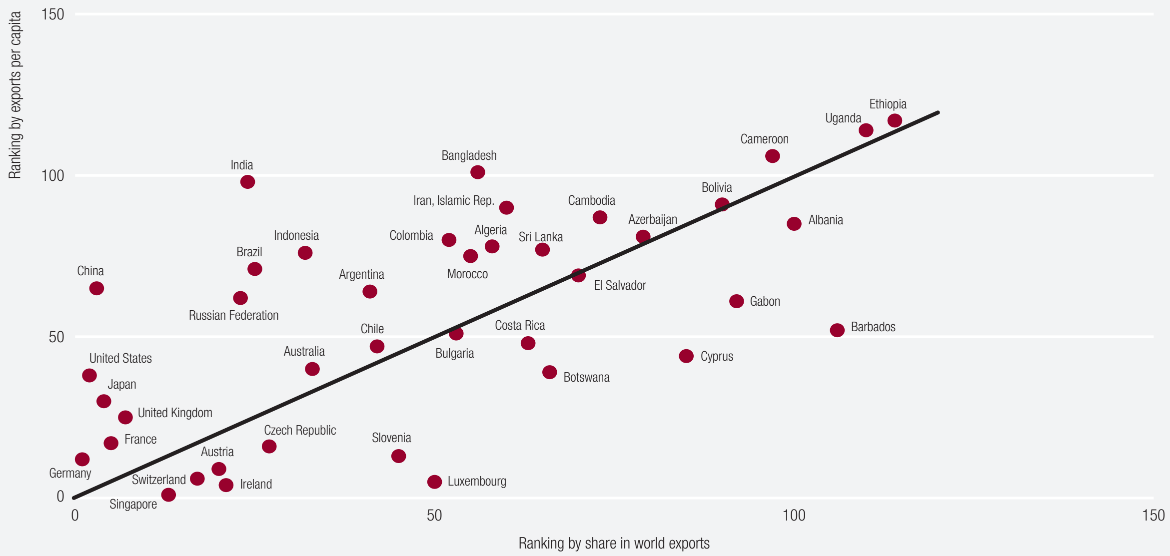
Overall, a third of the economies have no change in ranking, while almost three-fourths moved two positions or fewer. There is almost no change at the bottom, and the lowest 25 economies moved at most one position.

Figure A6.1
Small and large economy bias, manufacturing value added, 2005



Source: UNIDO.

Figure A6.2
Small and large economy bias, manufactured exports, 2005



Source: UNIDO.

Table A6.1
Impact of changes in the Competitive Industrial Performance index methodology on the rankings, 2005

Economy	Old	Revised	Difference
China	29	6	23
Russian Federation	76	57	19
United States	11	2	9
Italy	25	17	8
India	50	42	8
France	18	13	5
United Kingdom	20	15	5
Canada	24	19	5
Brazil	41	37	4
Argentina	53	49	4
Venezuela, Bol. Rep. of	75	71	4
Germany	7	4	3
Spain	31	28	3
Mexico	32	29	3
Tunisia	57	54	3
Iran, Islamic Rep. of	85	82	3
Kuwait	91	88	3
Japan	3	1	2
Indonesia	42	40	2
Australia	48	46	2
Turkey	34	33	1
Poland	35	34	1
Morocco	60	59	1
Chile	71	70	1
Nigeria	82	81	1
Sri Lanka	87	86	1
Oman	100	99	1
Algeria	116	115	1
Belgium	8	8	0
Korea, Rep. of	9	9	0
Thailand	27	27	0
Portugal	36	36	0
Norway	38	38	0
Greece	52	52	0
Trinidad and Tobago	63	63	0
Viet Nam	72	72	0
Albania	77	77	0
Macao SAR China	78	78	0
Botswana	79	79	0
Uruguay	80	80	0

Table A6.1 *(continued)*

Impact of changes in the Competitive Industrial Performance index methodology on the rankings, 2005

Economy	Old	Revised	Difference
Honduras	92	92	0
Cambodia	93	93	0
Fiji	94	94	0
Sudan	95	95	0
Peru	96	96	0
Kenya	97	97	0
Gambia, The	98	98	0
Kyrgyzstan	101	101	0
Syrian Arab Rep.	102	102	0
Cameroon	103	103	0
Paraguay	104	104	0
Uganda	105	105	0
Azerbaijan	106	106	0
Eritrea	107	107	0
Ecuador	108	108	0
Ghana	109	109	0
Malawi	110	110	0
Bolivia, Plurinational State of	111	111	0
Mongolia	112	112	0
Panama	113	113	0
Tanzania, United Rep. of	114	114	0
Gabon	117	117	0
Ethiopia	118	118	0
Hong Kong SAR China	13	14	–1
Denmark	22	23	–1
Czech Republic	23	24	–1
Cyprus	43	44	–1
South Africa	44	45	–1
Barbados	54	55	–1
Mauritius	55	56	–1
Swaziland	61	62	–1
Lebanon	64	65	–1
Macedonia, Former Yugoslav Rep. of	65	66	–1
Pakistan	66	67	–1
Senegal	67	68	–1
Colombia	68	69	–1
Zimbabwe	83	84	–1
Niger	84	85	–1
Moldova, Rep. of	86	87	–1
St. Lucia	88	89	–1
Rwanda	89	90	–1
Nepal	90	91	–1
Madagascar	99	100	–1
Yemen	115	116	–1
Singapore	1	3	–2
Taiwan Province of China	10	12	–2
Netherlands	14	16	–2
Philippines	30	32	–2
Estonia	33	35	–2
Costa Rica	37	39	–2
Lithuania	39	41	–2
Romania	45	47	–2
New Zealand	46	48	–2
Jordan	49	51	–2
Bulgaria	51	53	–2
Georgia	56	58	–2
Bahamas	58	60	–2
Latvia	59	61	–2
Qatar	62	64	–2
Bangladesh	73	75	–2
Jamaica	74	76	–2
Palestinian Territories	81	83	–2
Ireland	2	5	–3
Switzerland	4	7	–3
Malaysia	17	20	–3
Malta	28	31	–3
Iceland	40	43	–3
El Salvador	47	50	–3
Egypt	70	73	–3
Hungary	21	25	–4
Israel	26	30	–4
Sweden	5	10	–5
Finland	6	11	–5
Côte d'Ivoire	69	74	–5
Austria	12	18	–6
Slovakia	15	21	–6
Luxembourg	16	22	–6
Slovenia	19	26	–7

Source: UNIDO.

Annex 7

Technological classification of manufacturing value added data

To compute the share of medium- and high-technology activities in manufacturing value added, the OECD International Standard Industrial Classification (ISIC) was used (Table A7.1).

For Niger and Zimbabwe, the classification in Table A7.2 was used because data were available only in ISIC Revision 2.

For this classification, medium- and high-technology activities were combined. The sector shares of value added were then calculated in relation to the total for manufacturing subsectors.

Table A7.1

Technology classification of manufacturing value added, ISIC Revision 3

Type of activity	ISIC division, major group or group
Low technology	15, 16, 17, 18, 19, 20, 21, 22, 36, 37
Medium-low technology manufacturing	23, 25, 26, 27, 28, 351
Medium- and high-technology manufacturing	24, 29, 30, 31, 32, 33, 34, 35 (excluding 351)

Source: United Nations Statistics Division (http://unstats.un.org/unsd/cr/registry/regcst.asp?cl=2).

Table A7.2

Technology classification of manufacturing value added, ISIC Revision 2

Type of manufacturing	ISIC division, major groups or groups
Resource-based	31, 331, 341, 353, 354, 355, 362, 369
Low technology	32, 332, 361, 381, 390
Medium and high technology	342, 351, 352, 356, 37, 38 (excluding 381), 3522, 3852, 3832, 3845, 3849, 385

Source: United Nations Statistics Division (http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=8&Lg=1).

Annex 8

Technological classification of international trade data

The technological classification of trade is based on the Standard International Trade Classification (SITC), Revision 3.

Table A8.1
Technology classification of exports, SITC Revision 3

Type of export	SITC sections
Resource-based	016, 017, 023, 024, 035, 037, 046, 047, 048, 056, 058, 059, 061, 062, 073, 098, 111, 112, 122, 232, 247, 248, 251, 264, 265, 281, 282, 283, 284, 285, 286, 287, 288, 289, 322, 334, 335, 342, 344, 345, 411, 421, 422, 431, 511, 514, 515, 516, 522, 523, 524, 531, 532, 551, 592, 621, 625, 629, 633, 634, 635, 641, 661, 662, 663, 664, 667, 689
Low technology	611, 612, 613, 642, 651, 652, 654, 655, 656, 657, 658, 659, 665, 666, 673, 674, 675, 676, 677, 679, 691, 692, 693, 694, 695, 696, 697, 699, 821, 831, 841, 842, 843, 844, 845, 846, 848, 851, 893, 894, 895, 897, 898, 899
Medium technology	266, 267, 512, 513, 533, 553, 554, 562, 571, 572, 573, 574, 575, 579, 581, 582, 583, 591, 593, 597, 598, 653, 671, 672, 678, 711, 712, 713, 714, 721, 722, 723, 724, 725, 726, 727, 728, 731, 733, 735, 737, 741, 742, 743, 744, 745, 746, 747, 748, 749, 761, 762, 763, 772, 773, 775, 778, 781, 782, 783, 784, 785, 786, 791, 793, 811, 812, 813, 872, 873, 882, 884, 885
High technology	525, 541, 542, 716, 718, 751, 752, 759, 764, 771, 774, 776, 792, 871, 874, 881, 891

Source: UN 2011.

Annex 9

Data clarifications for the Competitive Industrial Performance index, by indicator

Table A9.1

Data years used for computing the Competitive Industrial Performance index

2005

Indicator and economy	Year used
Share of medium- and high-technology activities in manufacturing value added	
Algeria	1996
Argentina	2002
Bahamas	1998
Bangladesh	1998
Barbados	1997
Bolivia, Plurinational State of	2001
Botswana	1997
Cambodia	2000
Cameroon	2002
Côte d'Ivoire	1997
El Salvador	1998
Fiji	2004
Gabon	1995
Gambia, The	1995
Ghana	2003
Honduras	1996
Jamaica	1996
Kuwait	2001
Lebanon	1998
Malawi	2001
Nepal	2002
Niger	2002
Nigeria	1996
Pakistan	2001
Panama	2001
Paraguay	2002
Rwanda	1999
Senegal	2002
Sri Lanka	2001
St. Lucia	1997
Sudan	2001
Swaziland	1995
Switzerland	2003
Syrian Arab Rep.	1995
Taiwan Province of China	1996
Thailand	2002
Uganda	2000
Venezuela, Bol. Rep. of	1998
Viet Nam	2000
Zimbabwe	1995
Exports per capita	
Cambodia	2004
Eritrea	2003
Kuwait	2004
Nepal	2003
Nigeria	2003
Share of manufactured exports in total exports	
Cambodia	2004
Eritrea	2003
Kuwait	2004
Nepal	2003
Nigeria	2003
Share of medium- and high-technology activities in manufactured exports	
Cambodia	2004
Eritrea	2003
Kuwait	2004
Nepal	2003
Nigeria	2003
Share in world manufactured exports	
Cambodia	2004
Eritrea	2003
Kuwait	2004
Nepal	2003
Nigeria	2003

Table A9.1 *(continued)*
Data years used for computing the Competitive Industrial Performance index

2009

Indicator and economy	Year used
Manufacturing value added per capita	
Macao SAR China	2008
Share of manufacturing value added in GDP	
Macao SAR China	2008
Share in world manufacturing value added	
Macao SAR China	2008
Share of medium- and high-technology activities in manufacturing value added	
Albania	2008
Algeria	1996
Argentina	2002
Australia	2006
Austria	2007
Azerbaijan	2008
Bahamas	1998
Bangladesh	1998
Barbados	1997
Belgium	2007
Botswana	1997
Brazil	2007
Bulgaria	2008
Cambodia	2000
Cameroon	2002
Canada	2007
Chile	2006
China	2007
Colombia	2005
Costa Rica	2008
Côte d'Ivoire	1997
Cyprus	2008
Czech Republic	2007
Denmark	2007
Ecuador	2007
Egypt	2006
El Salvador	1998
Eritrea	2008
Estonia	2008
Ethiopia	2008
Fiji	2004

Indicator and economy	Year used
Finland	2007
France	2007
Gabon	1995
Gambia, The	1995
Georgia	2008
Germany	2007
Ghana	2003
Greece	2007
Honduras	1996
Hong Kong SAR China	2008
Hungary	2007
Iceland	2005
India	2007
Indonesia	2007
Iran, Islamic Rep. of	2005
Ireland	2007
Israel	2006
Italy	2007
Jamaica	1996
Japan	2007
Jordan	2008
Kenya	2007
Korea, Rep. of	2006
Kuwait	2001
Kyrgyzstan	2007
Latvia	2008
Lebanon	1998
Lithuania	2008
Luxembourg	2007
Macao SAR China	2006
Macedonia, Former Yugoslav Rep. of	2007
Madagascar	2006
Malawi	2001
Malaysia	2007
Malta	2008
Mauritius	2007
Mexico	2006
Moldova, Rep. of	2008
Mongolia	2008

(continued)

Table A9.1 *(continued)*
Data years used for computing the Competitive Industrial Performance index

Indicator and economy	Year used
Morocco	2008
Nepal	2002
Netherlands	2007
New Zealand	2007
Niger	2002
Nigeria	1996
Norway	2006
Oman	2007
Pakistan	2006
Palestinian Territories	2008
Panama	2001
Paraguay	2002
Peru	2007
Philippines	2006
Poland	2007
Portugal	2007
Rica	2008
Romania	2008
Russian Federation	2008
Rwanda	1999
Senegal	2002
Singapore	2008
Slovakia	2007
Slovenia	2008
South Africa	2008
Spain	2007
Sri Lanka	2008
St. Lucia	1997
Sudan	2001
Swaziland	1995
Sweden	2007
Switzerland	2007
Syrian Arab Rep.	1995
Taiwan Province of China	1996
Tanzania, United Rep. of	2007
Thailand	2006
Trinidad and Tobago	2006
Tunisia	2006
Turkey	2006
Uganda	2000
United Kingdom	2007

Indicator and economy	Year used
United States	2007
Uruguay	2007
Venezuela, Bol. Rep. of	1998
Viet Nam	2000
Yemen	2006
Zimbabwe	1995
Exports per capita	
Bangladesh	2007
Cambodia	2008
Cameroon	2006
Eritrea	2003
Gabon	2006
Georgia	2008
Ghana	2008
Iran, Islamic Rep. of	2006
Mongolia	2007
Niger	2008
St. Lucia	2008
Swaziland	2007
Syrian Arab Rep.	2008
Share of manufactured exports in total exports	
Bangladesh	2007
Cambodia	2008
Cameroon	2006
Eritrea	2003
Gabon	2006
Georgia	2008
Ghana	2008
Iran, Islamic Rep. of	2006
Mongolia	2007
Niger	2008
St. Lucia	2008
Swaziland	2007
Syrian Arab Rep.	2008
Share of medium- and high-technology activities in manufactured exports	
Bangladesh	2007
Cambodia	2008
Cameroon	2006
Eritrea	2003
Gabon	2006

Table A9.1 *(continued)*

Data years used for computing the Competitive Industrial Performance index

Indicator and economy	Year used
Georgia	2008
Ghana	2008
Iran, Islamic Rep. of	2006
Mongolia	2007
Niger	2008
St. Lucia	2008
Swaziland	2007
Syrian Arab Rep.	2008
Share in world manufactured exports	
Bangladesh	2007
Cambodia	2008
Cameroon	2006
Eritrea	2003
Gabon	2006
Georgia	2008
Ghana	2008
Iran, Islamic Rep. of	2006
Mongolia	2007
Niger	2008
St. Lucia	2008
Swaziland	2007
Syrian Arab Rep.	2008

Source: UNIDO 2010g; UN 2011.

Annex 10

Components of the Competitive Industrial Performance index by economy

Table A10.1
Indicators of industrial performance by economy, 2005 and 2009

Economy	Manufacturing value added per capita (2000 US$)		Share of manufacturing value added in GDP (percent)		Share of world manufacturing value added (percent)	
	2005	2009	2005	2009	2005	2009
Albania	202	295	13.29	16.27	0.01	0.01
Algeria	133	135	6.25	6.13	0.07	0.07
Argentina	1,393	1,622	17.20	16.44	0.82	0.93
Australia	2,389	2,608	10.33	10.45	0.74	0.79
Austria	4,584	5,077	18.25	19.74	0.58	0.61
Azerbaijan	50	69	4.19	2.95	0.01	0.01
Bahamas	1,097	972	6.76	5.75	0.01	0.00
Bangladesh	63	82	15.70	17.28	0.15	0.19
Barbados	338	290	3.64	3.12	0.00	0.00
Belgium	3,912	3,814	16.31	15.30	0.62	0.57
Bolivia, Plurinational State of	140	161	13.22	13.52	0.02	0.02
Botswana	152	167	3.46	3.86	0.00	0.00
Brazil	594	594	15.00	13.71	1.69	1.66
Bulgaria	331	373	15.73	15.10	0.04	0.04
Cambodia	80	111	19.62	22.69	0.02	0.02
Cameroon	139	146	20.56	20.54	0.04	0.04
Canada	3,939	3,236	15.46	12.72	1.93	1.54
Chile	989	982	17.30	16.21	0.25	0.24
China	492	754	34.11	35.70	9.82	14.45
Colombia	370	408	16.83	14.24	0.25	0.28
Costa Rica	998	1,006	22.16	19.95	0.07	0.07
Cyprus	1,002	998	7.67	7.21	0.01	0.01
Czech Republic	1,780	2,246	26.55	30.13	0.28	0.33
Côte d'Ivoire	107	98	19.17	17.35	0.03	0.03
Denmark	3,963	3,705	12.54	12.01	0.33	0.29
Ecuador	211	248	13.26	14.33	0.04	0.05
Egypt	291	353	17.71	18.09	0.32	0.39
El Salvador	510	509	23.16	22.63	0.05	0.05
Eritrea	12	9	7.24	6.33	0.00	0.00
Estonia	1,105	1,073	17.77	17.49	0.02	0.02
Ethiopia	6	8	4.95	4.39	0.01	0.01
Fiji	266	274	11.59	12.94	0.00	0.00
Finland	6,463	6,839	24.55	25.95	0.52	0.52

Share of medium- and high-technology production in manufacturing value added (percent)		Manufactured exports per capita (US$)		Share of manufactured exports in total exports (percent)		Share of world manufactured exports (percent)		Share of medium- and high-technology products in manufactured exports (percent)	
2005	2009	2005	2009	2005	2009	2005	2009	2005	2009
16.98	14.09	190	276	91.14	82.00	0.01	0.01	10.38	6.82
11.28	11.28	239	263	17.05	20.28	0.10	0.10	1.75	0.66
19.32	19.32	571	739	56.04	54.41	0.27	0.31	32.44	42.36
22.48	23.01	2,293	3,115	47.24	45.05	0.56	0.69	34.02	25.67
41.56	44.28	12,401	13,645	90.91	90.81	1.25	1.21	60.05	59.50
11.95	7.33	216	260	41.43	15.23	0.02	0.02	21.95	12.92
2.43	2.43	547	1,411	65.28	81.81	0.00	0.01	65.49	46.55
20.20	20.20	57	76	93.42	91.76	0.11	0.11	3.98	4.34
38.11	38.11	1,115	991	90.84	91.74	0.00	0.00	27.35	40.30
43.52	42.02	28,380	31,073	90.45	90.26	3.58	3.44	56.14	56.45
5.05	5.05	98	225	32.08	41.83	0.01	0.02	7.81	2.84
28.64	28.64	2,317	1,667	96.29	93.39	0.05	0.03	4.35	6.18
33.10	34.97	459	494	73.68	64.63	1.04	1.02	48.16	40.24
26.97	28.34	1,173	1,589	80.48	73.97	0.11	0.13	28.47	35.32
0.26	0.26	153	223	74.85	75.23	0.03	0.03	1.14	3.38
11.01	11.01	35	54	29.25	28.07	0.01	0.01	5.10	2.88
38.20	38.37	7,684	5,914	72.01	65.47	3.00	2.09	59.05	58.03
23.06	15.41	1,288	1,374	52.61	44.95	0.25	0.25	11.31	10.63
41.61	40.70	550	860	95.04	96.29	8.76	12.18	57.67	59.77
20.71	20.71	219	260	46.56	37.44	0.12	0.13	37.94	38.41
17.00	18.15	1,243	1,053	75.21	74.06	0.07	0.05	60.24	61.75
9.66	12.13	1,635	1,329	89.18	85.92	0.02	0.01	60.99	50.08
38.93	35.74	7,064	10,060	93.78	92.62	0.87	1.08	64.11	67.62
14.99	14.99	212	213	54.68	41.49	0.05	0.04	36.40	25.02
35.31	36.73	11,613	13,096	79.33	81.21	0.76	0.75	55.71	53.41
8.45	6.31	151	230	20.03	22.80	0.02	0.03	18.62	19.07
28.55	25.72	84	182	64.68	58.85	0.07	0.15	11.76	27.59
19.13	19.13	468	475	91.49	88.16	0.04	0.04	14.66	16.60
9.85	11.96	1	1	38.88	38.88	0.00	0.00	20.62	20.62
20.88	29.07	5,289	6,783	91.81	90.36	0.09	0.09	47.79	41.38
6.26	7.73	1	2	9.90	12.45	0.00	0.00	1.52	44.05
1.83	1.83	685	572	81.24	77.65	0.01	0.01	5.61	8.77
43.40	51.21	11,763	10,455	95.25	94.11	0.75	0.58	57.43	57.48

(continued)

Table A10.1 *(continued)*

Indicators of industrial performance by economy, 2005 and 2009

Economy	Manufacturing value added per capita (2000 US$)		Share of manufacturing value added in GDP (percent)		Share of world manufacturing value added (percent)	
	2005	2009	2005	2009	2005	2009
France	3,291	2,989	13.94	12.60	3.05	2.65
Gabon	188	187	4.40	4.31	0.00	0.00
Gambia, The	15	16	4.71	4.47	0.00	0.00
Georgia	123	185	12.62	15.30	0.01	0.01
Germany	5,090	5,250	21.44	21.72	6.40	6.17
Ghana	25	27	8.79	8.35	0.01	0.01
Greece	1,385	1,610	9.96	10.65	0.23	0.26
Honduras	184	277	17.66	19.81	0.02	0.03
Hong Kong SAR China	938	724	3.19	2.27	0.10	0.08
Hungary	1,287	1,266	21.92	21.55	0.20	0.18
Iceland	3,627	4,134	10.06	11.44	0.02	0.02
India	80	99	14.13	13.74	1.38	1.69
Indonesia	258	295	28.07	27.08	0.89	1.00
Iran, Islamic Rep. of	306	363	16.01	16.74	0.32	0.38
Ireland	7,774	6,560	25.95	22.98	0.49	0.42
Israel	2,899	3,143	14.55	13.97	0.30	0.32
Italy	3,221	2,894	16.63	15.29	2.87	2.43
Jamaica	382	292	11.71	8.10	0.02	0.01
Japan	8,608	7,929	22.12	20.71	16.75	14.45
Jordan	344	401	16.76	16.86	0.03	0.04
Kenya	43	46	10.05	10.19	0.02	0.03
Korea, Rep. of	3,854	4,562	28.86	29.43	2.81	3.16
Kuwait	1,516	2,208	7.85	10.35	0.06	0.09
Kyrgyzstan	46	50	14.64	13.30	0.00	0.00
Latvia	601	541	11.92	10.87	0.02	0.02
Lebanon	643	627	12.58	9.87	0.04	0.04
Lithuania	939	993	19.34	19.40	0.05	0.05
Luxembourg	4,686	4,500	9.09	8.37	0.03	0.03
Macao SAR China	775	1,064	3.52	2.90	0.01	0.01
Macedonia, Former Yugoslav Rep. of	305	345	16.13	15.98	0.01	0.01
Madagascar	26	27	11.21	11.08	0.01	0.01
Malawi	15	17	10.60	9.70	0.00	0.00
Malaysia	1,412	1,390	32.39	27.92	0.55	0.54
Malta	1,492	1,387	14.83	13.16	0.01	0.01
Mauritius	773	787	17.52	16.10	0.01	0.01

Share of medium- and high-technology production in manufacturing value added (percent)		Manufactured exports per capita (US$)		Share of manufactured exports in total exports (percent)		Share of world manufactured exports (percent)		Share of medium- and high-technology products in manufactured exports (percent)	
2005	2009	2005	2009	2005	2009	2005	2009	2005	2009
46.56	47.48	6,354	6,583	90.94	90.52	4.70	4.32	66.03	65.46
5.39	5.39	652	685	16.60	14.93	0.01	0.01	7.95	10.65
9.63	9.63	2	23	65.23	62.05	0.00	0.00	18.96	52.78
21.01	17.26	157	291	81.08	84.86	0.01	0.01	40.67	48.92
57.16	58.84	10,781	11,818	94.82	93.35	10.80	10.27	72.52	71.33
18.76	18.76	48	31	35.31	19.61	0.01	0.01	8.11	18.10
12.03	12.82	1,213	1,358	79.24	77.27	0.16	0.16	36.38	38.35
7.16	7.16	91	144	48.00	40.82	0.01	0.01	21.12	27.79
30.23	28.80	39,858	41,716	96.38	93.19	3.41	3.23	65.35	70.37
53.11	54.36	5,576	7,178	93.67	91.99	0.68	0.75	75.85	78.44
14.18	14.18	3,934	4,337	38.04	32.88	0.01	0.01	42.64	51.29
39.41	34.13	77	124	87.84	88.17	1.06	1.57	22.60	28.86
32.98	32.72	244	304	64.35	61.91	0.67	0.76	33.17	30.60
39.63	39.63	100	133	11.97	14.79	0.08	0.10	26.34	25.15
51.91	51.27	24,440	24,136	95.71	95.68	1.23	1.13	57.37	56.63
53.56	57.76	5,375	6,420	96.54	96.25	0.44	0.48	38.74	59.66
37.11	37.29	5,897	6,293	95.37	93.94	4.19	3.91	54.04	54.85
18.77	18.77	538	443	95.35	92.48	0.02	0.01	4.31	19.09
53.94	54.63	4,366	4,133	98.18	96.72	6.77	5.57	82.34	78.71
22.15	24.34	611	789	79.29	78.14	0.04	0.05	37.33	50.63
11.44	5.21	56	56	58.14	49.76	0.02	0.02	15.14	25.69
54.27	55.12	5,801	7,246	97.66	96.76	3.37	3.71	75.34	75.80
8.00	8.00	4,361	7,424	40.60	42.67	0.15	0.23	9.19	18.89
2.08	4.76	56	49	44.84	26.90	0.00	0.00	20.72	34.55
14.99	23.78	2,011	2,543	90.70	83.39	0.06	0.06	23.22	38.15
10.83	10.83	386	561	82.79	67.50	0.02	0.02	33.43	39.50
16.41	23.92	3,178	4,148	90.90	85.78	0.13	0.15	35.64	38.28
11.47	16.49	24,354	23,899	91.57	90.55	0.13	0.12	39.13	40.51
3.55	3.55	5,127	1,882	98.00	95.43	0.03	0.01	10.54	25.77
14.11	12.71	891	835	88.96	85.89	0.02	0.02	20.18	18.08
3.03	3.28	28	40	68.07	77.13	0.01	0.01	8.85	9.98
9.24	9.24	9	13	25.33	16.38	0.00	0.00	18.74	18.85
47.38	46.12	4,702	4,849	86.35	85.11	1.46	1.40	72.30	64.48
35.34	47.00	5,541	5,101	92.65	92.77	0.03	0.02	74.92	76.92
3.32	2.98	1,514	1,265	94.12	91.75	0.02	0.02	21.22	8.66

(continued)

Table A10.1 *(continued)*

Indicators of industrial performance by economy, 2005 and 2009

	Manufacturing value added per capita (2000 US$)		Share of manufacturing value added in GDP (percent)		Share of world manufacturing value added (percent)	
Economy	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**
Mexico	1,022	911	16.78	15.17	1.62	1.42
Moldova, Rep. of	71	66	15.13	12.57	0.00	0.00
Mongolia	26	37	4.58	5.24	0.00	0.00
Morocco	225	241	14.51	13.34	0.10	0.11
Nepal	18	19	7.68	7.18	0.01	0.01
Netherlands	3,295	3,329	13.19	12.71	0.82	0.78
New Zealand	2,242	1,769	14.71	11.94	0.14	0.11
Niger	11	10	6.62	5.60	0.00	0.00
Nigeria	18	23	4.11	4.48	0.04	0.05
Norway	3,781	4,117	9.34	9.82	0.27	0.28
Oman	699	670	7.04	7.53	0.03	0.03
Pakistan	103	123	17.21	18.81	0.25	0.30
Palestinian Territories	111	104	11.10	12.00	0.01	0.01
Panama	315	336	7.12	5.94	0.02	0.02
Paraguay	193	183	14.22	12.76	0.02	0.02
Peru	355	446	14.81	14.99	0.15	0.18
Philippines	247	258	22.09	21.07	0.32	0.34
Poland	960	1,351	18.39	21.25	0.56	0.73
Portugal	1,621	1,546	14.59	13.97	0.26	0.24
Qatar	1,958	2,628	5.98	5.35	0.02	0.03
Romania	297	353	13.16	13.20	0.10	0.11
Russian Federation	461	444	18.96	15.80	1.01	0.89
Rwanda	25	17	9.98	5.62	0.00	0.00
Senegal	60	54	11.95	10.41	0.01	0.01
Singapore	6,785	6,996	26.04	23.76	0.45	0.45
Slovakia	1,961	2,987	41.44	36.38	0.16	0.23
Slovenia	2,717	3,005	23.75	23.41	0.08	0.09
South Africa	550	572	16.39	15.59	0.40	0.40
Spain	2,346	2,178	14.95	13.66	1.55	1.39
Sri Lanka	146	176	14.07	13.68	0.04	0.05
St. Lucia	221	199	4.65	4.19	0.00	0.00
Sudan	32	34	6.92	5.90	0.02	0.02
Swaziland	335	460	24.11	28.83	0.01	0.01
Sweden	6,392	6,110	21.25	19.93	0.88	0.80
Switzerland	6,780	7,384	19.39	19.60	0.77	0.79
Syrian Arab Rep.	148	194	11.77	14.26	0.04	0.06

Share of medium- and high-technology production in manufacturing value added (percent)		Manufactured exports per capita (US$)		Share of manufactured exports in total exports (percent)		Share of world manufactured exports (percent)		Share of medium- and high-technology products in manufactured exports (percent)	
2005	2009	2005	2009	2005	2009	2005	2009	2005	2009
39.67	39.59	1,675	1,700	81.71	81.18	2.12	1.95	75.16	76.89
6.89	9.84	220	262	78.20	75.86	0.01	0.01	10.32	23.37
5.24	5.31	212	452	51.48	62.93	0.01	0.01	3.09	1.91
26.89	28.86	290	343	78.95	78.68	0.11	0.12	27.62	33.17
12.12	12.12	22	22	87.02	71.70	0.01	0.01	9.18	20.80
41.46	38.61	16,163	18,862	87.69	85.78	3.20	3.27	59.88	55.94
16.51	16.50	2,754	2,905	52.66	51.09	0.14	0.13	30.37	27.28
28.15	28.15	19	25	62.16	73.98	0.00	0.00	21.96	5.10
33.44	33.44	4	17	2.48	5.15	0.01	0.03	74.87	34.73
28.54	30.24	5,593	7,139	25.90	28.97	0.31	0.36	46.10	56.13
15.84	16.75	672	2,309	9.58	26.28	0.02	0.07	38.82	40.07
25.23	24.57	90	86	88.84	83.32	0.17	0.15	8.72	11.25
1.89	1.51	78	107	86.93	88.83	0.00	0.00	19.65	17.67
5.60	5.60	65	48	21.89	20.60	0.00	0.00	11.26	15.17
12.87	12.87	74	116	26.44	23.33	0.01	0.01	13.38	14.73
12.93	14.44	307	451	48.95	48.19	0.10	0.14	5.31	6.19
38.87	45.27	466	391	95.61	92.96	0.48	0.38	81.48	79.59
27.42	31.57	2,003	3,146	87.41	88.85	0.93	1.26	54.41	59.17
18.14	20.69	3,133	3,521	94.85	93.42	0.40	0.40	43.74	40.77
22.09	17.44	3,257	10,121	11.06	22.58	0.03	0.09	63.06	34.58
25.01	32.79	1,208	1,738	94.79	92.97	0.32	0.39	33.68	54.10
23.36	25.47	635	769	41.37	40.01	1.11	1.14	27.57	26.47
27.43	27.43	9	13	54.82	51.73	0.00	0.00	16.06	36.02
29.75	29.75	87	109	69.24	70.02	0.01	0.01	31.57	20.41
76.99	75.03	49,784	53,536	97.49	96.67	2.61	2.56	72.75	69.29
36.05	48.43	5,501	9,711	94.77	94.38	0.36	0.55	55.79	65.82
35.72	45.06	8,241	10,213	92.19	91.86	0.20	0.22	59.93	64.20
23.44	21.60	677	743	69.11	67.71	0.39	0.38	47.57	46.51
29.68	30.88	3,835	4,176	87.67	86.18	2.02	1.97	61.02	58.18
10.49	12.11	242	257	76.53	71.43	0.06	0.05	7.80	8.16
7.83	7.83	290	810	73.49	83.31	0.00	0.00	28.15	34.60
9.19	9.19	106	8	87.03	3.38	0.05	0.00	2.68	15.57
0.03	0.03	1,067	905	94.11	92.94	0.01	0.01	16.92	29.75
50.51	50.02	12,977	12,772	95.61	94.47	1.42	1.24	61.22	57.98
53.47	62.23	16,580	21,241	94.01	92.86	1.49	1.69	67.16	69.52
21.52	21.52	88	364	25.83	52.39	0.02	0.06	16.48	25.06

(continued)

Table A10.1 *(continued)*

Indicators of industrial performance by economy, 2005 and 2009

Economy	Manufacturing value added per capita (2000 US$)		Share of manufacturing value added in GDP (percent)		Share of world manufacturing value added (percent)	
	2005	2009	2005	2009	2005	2009
Taiwan Province of China	4,192	5,101	25.28	26.19	1.45	1.68
Tanzania, United Rep. of	24	28	7.30	7.32	0.01	0.02
Thailand	895	1,004	35.91	37.35	0.86	0.93
Trinidad and Tobago	684	898	7.34	8.47	0.01	0.02
Tunisia	412	476	17.21	17.19	0.06	0.07
Turkey	917	950	27.11	20.31	1.02	1.04
Uganda	25	25	9.21	6.91	0.01	0.01
United Kingdom	3,683	3,330	13.63	12.06	3.38	2.91
United States	5,604	5,334	15.28	14.83	25.56	23.70
Uruguay	1,162	1,296	17.86	14.46	0.06	0.06
Venezuela, Bol. Rep. of	864	915	17.37	16.22	0.35	0.37
Viet Nam	118	171	22.42	26.15	0.15	0.22
Yemen	29	29	5.33	5.17	0.01	0.01
Zimbabwe	41	33	9.49	9.61	0.01	0.01

Source: UNIDO 2010g; UN 2011.

Share of medium- and high-technology production in manufacturing value added (percent)		Manufactured exports per capita (US$)		Share of manufactured exports in total exports (percent)		Share of world manufactured exports (percent)		Share of medium- and high-technology products in manufactured exports (percent)	
2005	2009	2005	2009	2005	2009	2005	2009	2005	2009
44.08	44.08	8,069	8,435	97.18	96.24	2.22	2.05	70.29	71.45
3.72	1.42	10	27	23.57	40.46	0.00	0.01	15.39	20.44
41.96	46.16	1,521	1,973	88.32	83.73	1.16	1.35	61.88	59.56
36.31	39.38	4,564	3,156	62.87	46.45	0.07	0.04	20.68	24.28
9.83	9.32	884	1,158	85.12	84.60	0.11	0.13	31.41	39.64
25.10	28.97	911	1,143	91.67	87.00	0.81	0.92	40.73	42.29
10.59	10.59	8	25	27.00	52.84	0.00	0.01	28.92	31.38
43.68	41.50	5,299	4,636	87.36	86.39	3.87	2.99	67.37	63.52
48.08	49.33	2,621	2,625	89.89	86.04	9.52	8.62	73.64	67.81
10.67	13.68	477	626	46.63	39.11	0.02	0.02	17.38	22.62
34.28	34.28	774	706	37.34	35.69	0.25	0.21	14.85	4.91
20.26	20.26	206	406	54.18	64.22	0.21	0.38	21.44	25.61
3.30	3.89	29	36	10.77	13.71	0.01	0.01	20.56	22.25
30.55	30.55	48	65	45.40	39.30	0.01	0.01	28.87	15.46

Annex 11

Indicators of the Competitive Industrial Performance index by region and income group

Table A11.1
Manufacturing value added per capita, 2005–2009 (2000 US$)

Group	2005	2006	2007	2008	2009
World	1,086	1,127	1,172	1,174	1,107
Developed countries	4,918	5,072	5,209	5,152	4,712
Developing countries	354	377	411	429	437
Region					
East Asia and the Pacific	519	563	634	678	724
Excluding China	587	619	652	652	654
Europe	546	577	638	655	613
Excluding the Russian Federation	689	782	878	911	894
Latin America and the Caribbean	714	740	766	779	721
Excluding Brazil	784	828	857	871	797
Middle East and North Africa	422	449	467	474	459
Excluding Turkey	284	303	315	325	326
South and Central Asia	90	99	106	107	111
Excluding India	117	127	135	138	142
Sub-Saharan Africa	80	81	83	83	81
Excluding South Africa	33	33	33	34	35
Income					
High income non-OECD	3,124	3,385	3,612	3,560	3,559
Upper middle income	695	726	762	774	721
Lower middle income	278	301	337	361	387
Low income	48	52	55	58	61
Least developed countries	36	38	40	42	43

Source: UNIDO 2010g.

Table A11.2
Share of manufacturing value added in GDP, 2005–2009 (percent)

Group	2005	2006	2007	2008	2009
World	18.2	18.3	18.5	18.4	18.0
Developed countries	17.3	17.4	17.5	17.3	16.5
Developing countries	21.3	21.0	21.4	21.5	21.8
Region					
East Asia and the Pacific	29.8	29.3	30.1	30.5	31.4
Excluding China	23.6	22.9	23.0	22.6	23.5
Europe	18.3	17.9	18.3	17.8	17.5
Excluding the Russian Federation	17.5	18.5	19.4	19.2	19.2
Latin America and the Caribbean	16.1	15.9	15.7	15.5	14.8
Excluding Brazil	16.7	16.5	16.3	16.2	15.4
Middle East and North Africa	16.5	15.2	15.2	15.1	14.8
Excluding Turkey	12.2	12.3	12.3	12.3	12.2
South and Central Asia	14.7	15.1	15.1	14.7	14.8
Excluding India	16.0	16.6	16.8	16.9	17.0
Sub-Saharan Africa	12.3	12.0	11.9	11.7	11.4
Excluding South Africa	8.6	8.3	8.2	8.1	8.1
Income					
High income non-OECD	16.6	16.2	16.4	16.0	16.8
Upper middle income	17.6	16.9	16.9	16.6	16.0
Lower middle income	26.5	26.5	27.2	27.5	27.9
Low income	13.9	14.1	14.5	14.6	15.0
Least developed countries	11.3	11.3	11.4	11.3	11.4

Source: UNIDO 2010g.

Table A11.3

Share of manufacturing value added in world manufacturing value added, 2005–2009 (percent)

Group	2005	2006	2007	2008	2009
World	100	100	100	100	100
Developed countries	72.7	71.8	70.5	69.2	66.7
Developing countries	27.3	28.2	29.5	30.8	33.3
Region					
East Asia and the Pacific	14.8	15.4	16.7	17.7	20.0
Excluding China	4.9	4.9	5.0	5.0	5.3
Europe	1.9	1.9	2.0	2.1	2.0
Excluding the Russian Federation	0.9	1.0	1.1	1.1	1.1
Latin America and the Caribbean	5.5	5.5	5.5	5.6	5.5
Excluding Brazil	3.8	3.9	3.9	3.9	3.8
Middle East and North Africa	2.2	2.3	2.3	2.3	2.4
Excluding Turkey	1.2	1.2	1.2	1.2	1.3
South and Central Asia	2.2	2.3	2.4	2.4	2.7
Excluding India	0.8	0.8	0.8	0.9	0.9
Sub-Saharan Africa	0.6	0.6	0.6	0.6	0.7
Excluding South Africa	0.2	0.2	0.2	0.2	0.3
Income					
High income non-OECD	2.6	2.7	2.8	2.7	2.9
Upper middle income	9.3	9.3	9.4	9.5	9.3
Lower middle income	15.0	15.7	16.9	18.1	20.5
Low income	0.4	0.5	0.5	0.5	0.6
Least developed countries	0.3	0.3	0.3	0.3	0.3

Source: UNIDO 2010g.

Table A11.4

Share of medium- and high-technology production in manufacturing value added, 2005–2009 (percent)

Group	2005	2006	2007	2008	2009
World	53.1	54.4	55.4	56.3	55.8
Developed countries	59.0	61.0	62.3	63.7	63.6
Developing countries	39.8	40.3	41.6	42.5	43.0
Region					
East Asia and the Pacific	43.3	43.6	45.2	45.8	46.0
Excluding China	43.0	42.9	48.7	50.4	50.5
Europe	36.1	36.4	37.3	37.7	36.5
Excluding the Russian Federation	33.1	33.7	34.8	36.1	35.9
Latin America and the Caribbean	33.0	33.5	34.0	34.8	33.3
Excluding Brazil	28.3	29.1	28.9	28.5	27.1
Middle East and North Africa	32.5	31.9	32.4	33.6	35.6
Excluding Turkey	29.6	29.2	29.4	30.5	33.0
South and Central Asia	43.4	43.6	44.2	45.0	47.3
Excluding India	27.5	27.2	27.7	28.3	29.0
Sub-Saharan Africa	25.5	25.8	25.9	26.3	24.2
Excluding South Africa	14.4	14.1	14.3	14.9	14.9
Income					
High income non-OECD	46.1	47.0	54.5	55.6	55.8
Upper middle income	35.0	35.4	35.9	36.6	35.3
Lower middle income	41.6	41.9	42.7	43.5	44.5
Low income	20.7	20.2	20.3	20.6	20.7
Least developed countries	18.2	17.3	17.0	17.0	16.7

Source: UNIDO 2010f.

Table A11.5
Manufactured exports per capita, 2005–2009 (current US$)

Group	2005	2006	2007	2008	2009
World	1,356	1,535	1,740	1,917	1,490
Developed countries	5,650	6,302	7,120	7,755	5,927
Developing countries	534	629	725	824	665
Region					
East Asia and the Pacific	938	1,115	1,301	1,442	1,209
Excluding China	1,887	2,131	2,319	2,440	2,040
Europe	1,077	1,294	1,607	2,028	1,466
Excluding the Russian Federation	1,815	2,193	2,771	3,329	2,622
Latin America and the Caribbean	726	803	861	1,000	767
Excluding Brazil	884	969	1,029	1,187	929
Middle East and North Africa	458	585	697	880	639
Excluding Turkey	332	458	532	695	502
South and Central Asia	78	91	98	109	102
Excluding India	81	93	76	51	44
Sub-Saharan Africa	99	113	116	138	98
Excluding South Africa	40	52	44	51	38
Income					
High income non-OECD	14,065	16,276	17,762	19,239	15,537
Upper middle income	932	1,055	1,203	1,406	1,075
Lower middle income	309	380	457	530	444
Low income	56	69	82	83	71
Least developed countries	34	41	35	22	13

Source: UN 2011.

Table A11.6
Share of manufactured exports in total exports, 2005–2009 (percent)

Group	2005	2006	2007	2008	2009
World	86.0	84.7	85.5	83.2	84.2
Developed countries	89.3	88.8	88.7	87.4	87.5
Developing countries	79.9	78.0	80.2	76.8	79.2
Region					
East Asia and the Pacific	92.6	92.3	92.7	91.8	92.1
Excluding China	90.9	90.1	89.9	88.1	88.2
Europe	62.5	66.4	62.1	61.4	63.3
Excluding the Russian Federation	89.2	88.6	89.1	88.7	88.4
Latin America and the Caribbean	66.8	62.8	67.7	61.9	61.9
Excluding Brazil	65.0	60.1	66.7	59.9	61.1
Middle East and North Africa	59.7	54.8	58.4	51.5	57.1
Excluding Turkey	47.1	43.9	46.9	40.7	47.1
South and Central Asia	64.5	66.2	86.6	86.0	86.7
Excluding India	38.7	41.3	86.4	78.4	77.7
Sub-Saharan Africa	61.7	37.9	41.2	39.6	41.0
Excluding South Africa	52.2	23.7	24.1	21.5	23.7
Income					
High income non-OECD	92.0	87.6	88.2	85.7	87.3
Upper middle income	67.2	66.4	67.3	63.7	65.5
Lower middle income	85.5	83.1	87.5	84.2	86.6
Low income	53.7	52.7	57.6	53.9	56.0
Least developed countries	61.0	62.8	60.4	33.6	24.6

Source: UN 2011.

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Table A11.7
Share in world manufactured exports, 2005–2009 (percent)

Group	2005	2006	2007	2008	2009
World	100	100	100	100	100
Developed countries	66.9	65.5	64.9	63.8	62.3
Developing countries	33.1	34.5	35.1	36.2	37.7
Region					
East Asia and the Pacific	21.5	22.5	23.0	23.1	24.8
Excluding China	12.5	12.5	12.0	11.5	12.4
Europe	3.1	3.2	3.5	3.9	3.6
Excluding the Russian Federation	1.9	2.0	2.2	2.4	2.4
Latin America and the Caribbean	4.5	4.4	4.2	4.4	4.4
Excluding Brazil	3.5	3.3	3.1	3.3	3.3
Middle East and North Africa	1.9	2.2	2.3	2.6	2.5
Excluding Turkey	1.1	1.3	1.4	1.6	1.5
South and Central Asia	1.5	1.6	1.5	1.5	1.8
Excluding India	0.4	0.4	0.3	0.2	0.2
Sub-Saharan Africa	0.6	0.6	0.6	0.7	0.6
Excluding South Africa	0.2	0.3	0.2	0.2	0.2
Income					
High income non-OECD	9.4	9.5	9.2	9.0	9.3
Upper middle income	10.0	10.0	10.0	10.6	10.4
Lower middle income	13.3	14.5	15.4	16.2	17.5
Low income	0.4	0.5	0.5	0.4	0.5
Least developed countries	0.2	0.2	0.2	0.1	0.1

Source: UN 2011.

Table A11.8
Share of medium- and high-technology production in manufactured exports, 2005–2009 (percent)

Group	2005	2006	2007	2008	2009
World	63.2	62.9	62.3	60.8	61.6
Developed countries	67.1	66.8	66.1	64.7	65.1
Developing countries	55.2	55.4	55.2	54.0	55.8
Region					
East Asia and the Pacific	62.7	62.7	62.1	60.4	62.3
Excluding China	66.2	66.6	65.5	62.7	64.8
Europe	39.8	40.4	42.3	43.0	45.3
Excluding the Russian Federation	47.0	48.7	50.7	52.1	54.4
Latin America and the Caribbean	53.6	55.6	54.3	52.7	51.9
Excluding Brazil	55.3	58.6	57.1	54.8	55.5
Middle East and North Africa	34.7	33.4	33.4	35.6	39.8
Excluding Turkey	30.0	27.5	26.6	31.5	38.2
South and Central Asia	19.3	19.7	20.9	25.2	26.7
Excluding India	11.0	10.9	9.4	10.7	11.1
Sub-Saharan Africa	36.7	35.5	39.2	42.6	37.5
Excluding South Africa	18.2	18.5	19.4	25.8	20.8
Income					
High income non-OECD	66.5	66.4	65.2	63.6	67.1
Upper middle income	50.4	51.3	50.4	48.3	49.9
Lower middle income	52.1	52.3	53.4	53.2	54.3
Low income	16.2	18.0	19.2	23.4	25.0
Least developed countries	7.3	5.8	8.5	14.6	21.7

Source: UN 2011.

Annex 12

Summary of world trade, by region and income group

Table A12.1
Total exports, 2005–2009 (US$ billions)

Group	2005	2006	2007	2008	2009
World	9,815	11,434	12,997	14,966	11,540
Developed countries	6,055	6,831	7,767	8,627	6,616
Developing countries	3,761	4,603	5,230	6,339	4,924
Region					
East Asia and the Pacific	1,875	2,261	2,640	2,975	2,507
Excluding China	1,113	1,293	1,422	1,545	1,308
Europe	462	525	689	880	607
Excluding the Russian Federation	240	291	366	450	336
Latin America and the Caribbean	561	663	671	859	668
Excluding Brazil	444	528	516	666	519
Middle East and North Africa	551	724	828	1,131	758
Excluding Turkey	477	639	723	1,002	657
South and Central Asia	217	258	232	281	239
Excluding India	117	138	87	102	69
Sub-Saharan Africa	94	171	169	212	144
Excluding South Africa	48	120	105	138	90
Income					
High income non-OECD	1,106	1,358	1,491	1,725	1,318
Upper middle income	1,264	1,468	1,670	2,092	1,549
Lower middle income	1,321	1,689	1,968	2,412	1,968
Low income	70	89	100	111	89
Least developed countries	34.0	40.9	41.2	47.1	34.7

Source: UN 2011.

Table A12.2
Primary exports, 2005–2009 (US$ billions)

Group	2005	2006	2007	2008	2009
World	1,449	1,837	1,984	2,653	1,843
Developed countries	563	662	761	941	703
Developing countries	886	1,175	1,224	1,712	1,140
Region					
East Asia and the Pacific	128	163	174	215	165
Excluding China	93	120	126	159	123
Europe	153	155	229	299	200
Excluding the Russian Federation	24	30	36	48	39
Latin America and the Caribbean	176	235	205	311	234
Excluding Brazil	147	198	159	252	183
Middle East and North Africa	307	417	461	684	402
Excluding Turkey	300	411	453	675	393
South and Central Asia	87	103	59	81	57
Excluding India	75	87	42	60	36
Sub-Saharan Africa	34	102	95	121	82
Excluding South Africa	21	84	72	99	66
Income					
High income non-OECD	243	346	371	500	303
Upper middle income	408	486	540	747	513
Lower middle income	204	302	272	418	286
Low income	30	40	41	47	37
Least developed countries	13.3	16.1	17.1	27.2	22.3

Source: UN 2011.

Table A12.3

Resource-based manufactured exports, 2005–2009 (US$ billions)

Group	2005	2006	2007	2008	2009
World	1,592	1,863	2,175	2,622	1,973
Developed countries	979	1,122	1,302	1,527	1,153
Developing countries	613	742	873	1,095	820
Region					
East Asia and the Pacific	204	248	299	377	296
Excluding China	141	171	204	261	201
Europe	110	135	161	211	141
Excluding the Russian Federation	57	66	81	99	72
Latin America and the Caribbean	118	126	146	187	149
Excluding Brazil	87	87	99	129	102
Middle East and North Africa	108	143	168	198	139
Excluding Turkey	96	132	153	177	123
South and Central Asia	45	57	66	84	67
Excluding India	9	12	9	12	9
Sub-Saharan Africa	28	33	32	38	28
Excluding South Africa	15	21	18	18	12
Income					
High income non-OECD	159	204	240	290	209
Upper middle income	264	302	357	465	339
Lower middle income	181	227	264	326	262
Low income	9	9	12	14	11
Least developed countries	7.9	9.2	6.5	7.6	4.8

Source: UN 2011.

Table A12.4
Low-technology manufactured exports, 2005–2009 (US$ billions)

Group	2005	2006	2007	2008	2009
World	1,501	1,700	1,981	2,184	1,720
Developed countries	801	890	1,032	1,133	867
Developing countries	700	810	949	1,051	853
Region					
East Asia and the Pacific	444	527	629	704	575
Excluding China	201	216	237	249	204
Europe	76	85	104	118	82
Excluding the Russian Federation	63	72	90	102	72
Latin America and the Caribbean	61	62	64	69	53
Excluding Brazil	48	48	51	54	42
Middle East and North Africa	52	61	73	86	69
Excluding Turkey	24	30	33	39	33
South and Central Asia	58	66	68	62	64
Excluding India	27	30	30	18	18
Sub-Saharan Africa	8	10	11	12	9
Excluding South Africa	3	3	6	6	3
Income					
High income non-OECD	159	169	184	188	151
Upper middle income	162	177	203	225	172
Lower middle income	358	437	530	609	505
Low income	22	27	32	30	25
Least developed countries	9.2	11.4	12.8	5.5	2.0

Source: UN 2011.

Table A12.5

Medium-technology manufactured exports, 2005–2009 (US$ billions)

Group	2005	2006	2007	2008	2009
World	3,228	3,649	4,265	4,724	3,558
Developed countries	2,424	2,696	3,121	3,374	2,492
Developing countries	805	953	1,144	1,351	1,066
Region					
East Asia and the Pacific	455	533	641	738	613
Excluding China	267	291	324	351	291
Europe	103	126	165	212	148
Excluding the Russian Federation	81	102	135	168	123
Latin America and the Caribbean	149	176	191	214	157
Excluding Brazil	117	141	150	165	129
Middle East and North Africa	62	76	97	120	98
Excluding Turkey	36	45	57	72	63
South and Central Asia	20	24	27	37	32
Excluding India	6	6	6	6	3
Sub-Saharan Africa	16	18	22	30	19
Excluding South Africa	3	3	3	6	3
Income					
High income non-OECD	223	251	285	307	256
Upper middle income	297	348	408	485	354
Lower middle income	281	349	444	551	449
Low income	4	5	7	8	7
Least developed countries	1.3	1.3	1.6	1.7	1.7

Source: UN 2011.

Table A12.6
High-technology manufactured exports, 2005–2009 (US$ billions)

Group	2005	2006	2007	2008	2009
World	1,931	2,236	2,424	2,565	2,239
Developed countries	1,205	1,359	1,435	1,509	1,280
Developing countries	726	877	989	1,056	960
Region					
East Asia and the Pacific	633	772	877	912	824
Excluding China	405	480	513	504	456
Europe	17	20	25	34	31
Excluding the Russian Federation	12	18	21	30	27
Latin America and the Caribbean	50	55	54	64	55
Excluding Brazil	42	45	42	51	45
Middle East and North Africa	17	19	20	28	30
Excluding Turkey	15	18	18	24	27
South and Central Asia	6	8	10	15	17
Excluding India	0	0	3	3	3
Sub-Saharan Africa	3	4	3	3	3
Excluding South Africa	0	3	0	0	0
Income					
High income non-OECD	310	369	393	414	367
Upper middle income	122	139	144	143	140
Lower middle income	292	367	449	495	448
Low income	2	3	3	5	5
Least developed countries	0.2	0.3	0.4	0.5	0.5

Source: UN 2011.

Annex 13

Country and economy groups

Table A13.1

Countries and economies by region, and largest developing economy in each region

East Asia and the Pacific				
American Samoa	Hong Kong SAR China	Malaysia	Norfolk Island	Thailand
Australia	Indonesia	Marshall Islands	Northern Mariana Islands	Timor-Leste
Brunei Darussalam	Japan	Micronesia, Federated States of	Palau	Tokelau
Cambodia	Johnston Island	Mongolia	Papua New Guinea	Tonga
China	Kiribati	Myanmar	Philippines	Tuvalu
Cook Islands	Korea, Dem. People's Rep. of	Nauru	Pitcairn	Vanuatu
Fiji	Korea, Rep. of	New Caledonia	Samoa	Viet Nam
French Polynesia	Lao People's Dem. Rep.	New Zealand	Singapore	Wallis and Futuna Islands
Guam	Macao SAR China	Niue	Solomon Islands	
Developing Europe				
Albania	Denmark	Iceland	Malta	San Marino
Andorra	Estonia	Ireland	Moldova, Rep. of	Serbia
Austria	Faeroe Islands	Isle of Man	Monaco	Slovakia
Belarus	Finland	Italy	Netherlands	Slovenia
Belgium	France	Latvia	Norway	Spain
Bosnia and Herzegovina	Germany	Liechtenstein	Poland	Sweden
Bulgaria	Gibraltar	Lithuania	Portugal	Switzerland
Channel Islands	Greece	Luxembourg	Romania	Ukraine
Croatia	Holy See	Macedonia, Former Yugoslav Rep. of	**Russian Federation**	United Kingdom
Czech Republic	Hungary			
Latin America and the Caribbean				
Anguilla	Cayman Islands	Falkland Islands (Malvinas)	Martinique	St. Kitts and Nevis
Antigua and Barbuda	Chile	French Guiana	Mexico	St. Lucia
Argentina	Colombia	Grenada	Montserrat	St. Vincent and Grenadines
Aruba	Costa Rica	Guadeloupe	Netherlands Antilles	Suriname
Bahamas	Cuba	Guatemala	Nicaragua	Trinidad and Tobago
Barbados	Dominica	Guyana	Panama	Turks and Caicos Islands
Belize	Dominican Republic	Haiti	Paraguay	US Virgin Islands
Bolivia, Plurinational State of	Ecuador	Honduras	Peru	Uruguay
Brazil	El Salvador	Jamaica	Puerto Rico	Venezuela, Bol. Rep. of
British Virgin Islands				

Table A13.1 *(continued)*
Countries and economies by region, and largest developing economy in each region

Middle East and North Africa				
Algeria	Egypt	Kuwait	Palestinian Territories	Tunisia
Armenia	Georgia	Lebanon	Qatar	**Turkey**
Azerbaijan	Iraq	Libya	Saudi Arabia	United Arab Emirates
Bahrain	Israel	Morocco	Sudan	Western Sahara
Cyprus	Jordan	Oman	Syrian Arab Rep.	Yemen

North America				
Bermuda	Canada	Greenland	St. Pierre and Miquelon	United States

South and Central Asia				
Afghanistan	**India**	Kyrgyzstan	Pakistan	Turkmenistan
Bangladesh	Iran, Islamic Rep. of	Maldives	Sri Lanka	Uzbekistan
Bhutan	Kazakhstan	Nepal	Tajikistan	

Sub-Saharan Africa				
Angola	Congo, Dem. Rep. of	Guinea	Mozambique	Sierra Leone
Benin	Congo	Guinea-Bissau	Namibia	Somalia
Botswana	Côte d'Ivoire	Kenya	Niger	**South Africa**
Burkina Faso	Djibouti	Lesotho	Nigeria	Swaziland
Burundi	Equatorial Guinea	Liberia	Reunion	Tanzania, United Rep. of
Cameroon	Eritrea	Madagascar	Rwanda	Togo
Cape Verde	Ethiopia	Malawi	St. Helena	Uganda
Central African Rep.	Gabon	Mali	São Tomé and Príncipe	Zambia
Chad	Gambia, The	Mauritania	Senegal	Zimbabwe
Comoros	Ghana	Mauritius	Seychelles	

Note: Bold type denotes the largest developing country in each region.
Source: UNIDO, based on UN Statistics classification.

Table A13.2
Countries and economies by income group and least developed countries

High-income OECD				
Australia	Finland	Ireland	Netherlands	Spain
Austria	France	Italy	New Zealand	Sweden
Belgium	Germany	Japan	Norway	Switzerland
Canada	Greece	Korea, Rep. of	Portugal	United Kingdom
Czech Republic	Hungary	Luxembourg	Slovakia	United States
Denmark	Iceland			
High-income non-OECD				
Andorra	Cayman Islands	Greenland	Malta	San Marino
Antigua and Barbuda	Channel Islands	Guam	Monaco	Saudi Arabia
Aruba	Croatia	Hong Kong SAR China	Netherlands Antilles	Singapore
Bahamas	Cyprus	Isle of Man	New Caledonia	Slovenia
Bahrain	Equatorial Guinea	Israel	Northern Mariana Islands	Taiwan Province of China
Barbados	Estonia	Kuwait	Oman	Trinidad and Tobago
Bermuda	Faeroe Islands	Liechtenstein	Puerto Rico	United Arab Emirates
Brunei Darussalam	French Polynesia	Macao SAR China	Qatar	US Virgin Islands
Upper middle income				
Algeria	Costa Rica	Latvia	Namibia	Seychelles
Argentina	Cuba	Lebanon	Palau	South Africa
Belarus	Dominica	Libyan Arab Jamahiriya	Panama	St. Kitts and Nevis
Bosnia and Herzegovina	Dominican Rep.	Lithuania	Peru	St. Lucia
Botswana	Fiji	Macedonia, Former Yugoslav Rep. of	Poland	St. Vincent and the Grenadines
Brazil	Gabon	Malaysia	Romania	Suriname
Bulgaria	Grenada	Mauritius	Russian Federation	Turkey
Chile	Jamaica	Mexico	Samoa	Uruguay
Colombia	Kazakhstan	Montenegro	Serbia	Venezuela, Bolivarian Rep. of

Table A13.2 *(continued)*
Countries and economies by income group and least developed countries

Lower middle income				
Albania	Côte d'Ivoire	Iran, Islamic Rep. of	Nicaragua	Sudan
Angola	Djibouti	Iraq	Nigeria	Swaziland
Armenia	Ecuador	Jordan	Palestinian Territories	Syrian Arab Rep.
Azerbaijan	Egypt	Kiribati	Pakistan	Thailand
Belize	El Salvador	Lesotho	Papua New Guinea	Timor-Leste
Bhutan	Georgia	Maldives	Paraguay	Tonga
Bolivia, Plurinational State of	Guatemala	Marshall Islands	Philippines	Tunisia
Cameroon	Guyana	Micronesia, Federated States of	São Tomé and Príncipe	Turkmenistan
Cape Verde	Honduras	Moldova, Rep. of	Solomon Islands	Ukraine
China	India	Mongolia	Sri Lanka	Vanuatu
Congo	Indonesia	Morocco		

Low income				
Afghanistan	Congo, Dem. Rep. of	Korea, Dem. People's Rep. of	Myanmar	Togo
Bangladesh	Eritrea	Kyrgyzstan	Nepal	Tanzania, United Rep. of
Benin	Ethiopia	Lao People's Dem. Rep.	Niger	Uganda
Burkina Faso	Gambia, The	Liberia	Rwanda	Uzbekistan
Burundi	Ghana	Madagascar	Senegal	Viet Nam
Cambodia	Guinea	Malawi	Sierra Leone	Yemen
Central African Rep.	Guinea-Bissau	Mali	Somalia	Zambia
Chad	Haiti	Mauritania	Tajikistan	Zimbabwe
Comoros	Kenya	Mozambique		

Least developed countries				
Angola	Comoros	Kiribati	Myanmar	Sudan
Afghanistan	Congo, Dem. Rep. of	Lao People's Dem. Rep.	Nepal	Tanzania, United Rep. of
Bangladesh	Djibouti	Lesotho	Niger	Timor-Leste
Benin	Equatorial Guinea	Liberia	Rwanda	Togo
Bhutan	Eritrea	Madagascar	Samoa	Tuvalu
Burkina Faso	Ethiopia	Malawi	São Tomé and Príncipe	Uganda
Burundi	Gambia, The	Maldives	Senegal	Vanuatu
Cambodia	Guinea	Mali	Sierra Leone	Yemen
Central African Rep.	Guinea-Bissau	Mauritania	Solomon Islands	Zambia
Chad	Haiti	Mozambique	Somalia	

Source: UNIDO based on World Bank classification (http://data.worldbank.org/about/country-classifications/country-and-lending-groups).

Annex 14

Industrial energy efficiency policy measures

Table A14.1

Industrial energy efficiency policy measures in selected developing countries

Country	Information policies						Institutional, regulatory and legal policies					
	Awareness and education campaign	Training for firm personnel	Energy management systems	Government agency for energy efficiency	Technical assistance	Network building	Development of codes, standards, product labelling	Elimination of energy subsidies	Mandatory energy-efficiency targets and energy audits	Voluntary agreements on energy efficiency	Demand-side management programmes	Recognition programmes
Argentina				✔	✔		✔				✔	
Bolivia				✔			✔				✔	
Brazil	✔			✔			✔		✔		✔	
Chile	✔			✔	✔					✔		
China		✔	✔	✔			✔	✔	✔	✔		✔
Colombia	✔			✔			✔				✔	
Costa Rica				✔			✔					
Dominican Rep.				✔								
Ecuador				✔								
Egypt	✔	✔		✔	✔		✔	✔	✔			
Ethiopia												
Ghana			✔	✔	✔		✔		✔			
Guatemala											✔	
Honduras		✔		✔					✔			
India	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Indonesia	✔			✔		✔	✔	✔	✔	✔	✔	✔
Liberia	✔											
Malaysia	✔		✔	✔			✔	✔	✔	✔		
Mexico		✔		✔			✔				✔	✔
Moldova				✔	✔							
Mozambique												
Nigeria		✔		✔								
Peru		✔		✔			✔					
Philippines	✔		✔	✔			✔		✔	✔		✔
Romania			✔	✔			✔	✔		✔		
Russian Federation	✔		✔	✔			✔	✔	✔			
Senegal												
South Africa			✔	✔	✔		✔			✔	✔	
Tanzania												
Thailand	✔		✔	✔	✔	✔	✔			✔	✔	
Tunisia	✔			✔			✔		✔			
Turkey	✔	✔	✔	✔					✔	✔		
Uganda												
Ukraine				✔								
Venezuela	✔			✔			✔				✔	
Viet Nam	✔	✔		✔	✔		✔		✔		✔	
Zambia												
	15	8	10	29	9	3	21	7	13	10	12	5

Source: Official documentation and websites. See http://ieep.unido.org.

Financial and investment policies				Technology policies				
Subsidies	Energy-efficiency funds and low-interest loans	Energy services companies	International financing for industrial energy efficiency	Industrial energy-efficiency research and development	Demonstration campaigns	Facilitating deployment of industrial energy technologies	Enhancing local absorptive capacity	International cooperation
			✔					✔
	✔	✔						
	✔	✔	✔					
✔	✔	✔	✔	✔				✔
	✔							
			✔					
	✔	✔						
			✔					
	✔		✔		✔			✔
							✔	
			✔					
	✔							✔
	✔	✔	✔	✔		✔		✔
✔	✔		✔				✔	
✔	✔	✔	✔	✔	✔	✔	✔	✔
	✔		✔					
	✔		✔					
							✔	
			✔	✔				✔
			✔					
	✔						✔	
	✔	✔	✔		✔			✔
✔	✔	✔	✔	✔				✔
✔			✔					
							✔	
✔	✔	✔			✔			✔
✔		✔	✔					✔
✔	✔		✔	✔	✔		✔	
							✔	
		✔	✔					
	✔		✔		✔		✔	✔
							✔	
8	18	11	21	6	6	2	10	12

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