Technology Action Plan

INDUSTRIAL SECTOR ENERGY EFFICIENCY

MAJOR ECONOMIES FORUM
ON ENERGY AND CLIMATE

DECEMBER 2009

Technology Action Plan: Industrial Sector Energy Efficiency

Report to the Major Economies Forum on Energy and Climate

Prepared by the United States
in consultation with MEF Partners

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PREFACE

The Leaders of the 17 partners[1] of the Major Economies Forum on Energy and Climate (MEF) agreed on 9 July 2009 that moving to a low-carbon economy provides an opportunity to promote continued economic growth and sustainable development as part of a vigorous response to the danger posed by climate change. They identified an urgent need for development and deployment of transformational clean energy technologies, and established the Global Partnership to drive such low-carbon, climate friendly technologies.

Plans were created to stimulate efforts among interested countries to advance actions on technologies including advanced vehicles; bioenergy; carbon capture, use, and storage; buildings sector energy efficiency; industrial sector energy efficiency; high-efficiency, low-emissions coal; marine energy; smart grids; solar energy; and wind energy. These plans include a menu of opportunities for individual and collective action that may be undertaken voluntarily by interested countries, in accordance with national circumstances. Further actions may be identified in support of these plans in the future.

[1] Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, the United Kingdom, and the United States

OVERVIEW

The global industrial base is diverse and expansive—encompassing manufacturing, mining, construction, energy-intensive processes, and other operations that ultimately convert raw materials into finished products. Overall, industry accounts for one-third of the world's total energy consumption and, as a result, a similar share of the world's fossil fuel carbon emissions. And while incremental improvements have continuously reduced energy intensity, overall emissions continue to rise due to global industrialization.

Accelerated deployment of energy-efficient industrial technologies and practices has significant potential to reduce carbon emissions while also diminishing other adverse environmental consequences associated with industrial operations; however, unlocking energy efficiency in the industrial sector involves unique challenges. For example, beyond energy-related emissions, there are substantial greenhouse gas (GHG) emissions from industrial processes.

To help government and industry better understand how to substantively improve industrial efficiency performance, this report highlights best practices and policies that are successfully advancing the use of efficient industrial technologies across the world. Within this context, this report outlines potential goals for participating countries and recommends specific priority actions to accelerate technology development and deployment.

HIGHLIGHTS OF THE INDUSTRIAL ENERGY EFFICIENCY TECHNOLOGY ACTION PLAN

1. GHG Emissions and Mitigation Potential

- **Energy consumption and emissions production levels are high.** The industrial sector consumes one-third of the world's energy and produces 36% of current fossil CO_2 emissions.
- **Energy-efficient industrial technologies are available now.** By 2030, efficiency improvements based on existing technologies could reduce projected global industrial emissions roughly in half —eliminating 4 gigatonnes (Gt) of CO_2.

2. Development and Deployment: Barriers and Best Practice Policies

- **Barriers** to the development and deployment of energy-efficient industrial technologies and practices include: conflicting market signals, limited capital availability, inadequate information flow, lack of expertise, inadequate workforce capabilities, performance risks and costs for new technology, insufficient capital allocation for upgrades, and counterproductive policies.
- **Best practice policies** that can help overcome these barriers include energy assessments, energy management programs, minimum energy performance standards, combined heat and power incentives, appropriate financial incentives and tax treatment, and new vehicles for capital mobilization.

3. Opportunities to Accelerate Development and Deployment

- **Supporting innovation:**
  - Invest in pilot deployments of emerging technologies and multilingual software tools for analyzing plant energy systems.
  - Develop and demonstrating technology through collaborative R&D, centers of excellence, and basic research on next generation industrial efficiency technologies.
  - Fund energy efficiency research that benefits multiple industries (e.g., steam systems, motors design and usage, water, industrial buildings, etc).
- **Accelerating deployment:**
  - Build deployment capacity through partnerships, diagnostic tools, training, and qualification systems for energy managers.
  - Work to ensure adequate supply of energy-efficient equipment and materials.
  - Establish industry benchmarks and create consistent methodologies for performance auditing.
  - Provide financial support to lower hurdle rates, reduce credit and performance risks, reduce upfront costs, and encourage scale up of new efficient technologies.
  - Streamline regulation and tax policy.
- **Facilitating information sharing:**
  - Launch an international industry recognition campaign to offer participating organizations a means to promote their positive actions to their stakeholders, their competitors, and the general public.
  - Share best practices in energy management through formal education, supplier working groups, industry conferences and associations, and a database of business cases highlighting specific opportunities such as combined heat and power applications.
  - Share non-sensitive technology and knowledge freely among countries to ensure greatest efficiency at initial construction (i.e., through knowledgeware, technical assistance teams).
  - Educate industry stakeholders about the ancillary benefits of energy efficiency (e.g., incorporating energy into top level management thinking and improving employee satisfaction).
  - Demonstrate the value of portfolio management strategies to improve industrial energy efficiency (e.g., government programs for zero-cost facility energy efficiency assessments).
  - Develop a framework for public reporting of energy use by corporations (similar to the Global Reporting Index) to support benchmarking.

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1. INDUSTRIAL SECTOR: GHG EMISSIONS PRODUCTION AND MITIGATION POTENTIAL

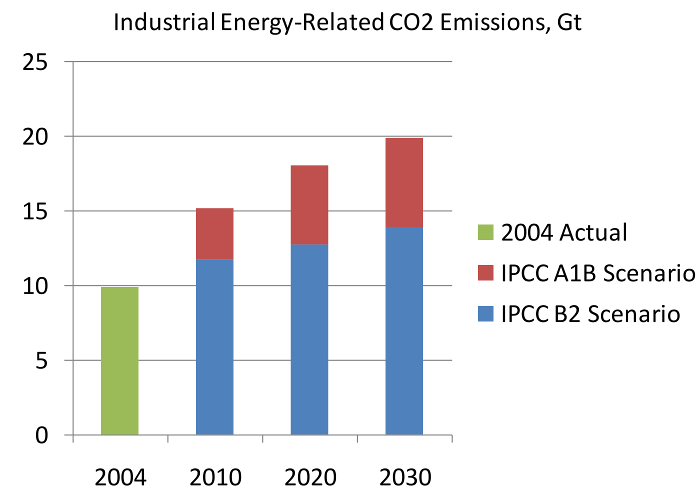
In July 2009, the leaders of the countries in the Major Economies Forum (MEF) on Energy and Climate noted the scientific view that any increase in global average temperature should not exceed 2°C over pre-industrial levels, and promised to work with each other to reduce global greenhouse gas emissions.[2] Improving the energy efficiency of the industrial sector (generally defined to encompass manufacturing, mining, and construction activities) is a key strategy for achieving such emissions reductions.[3]

GHG Emissions Production from the Industrial Sector

The industrial sector consumes over one-third of the world's energy—an estimated 150 exajoules (EJ) in 2007, up by about 65% from 1971.[4] This represents 36% of global carbon dioxide (CO_2) emissions from fossil fuels (IEA 2007 and 2009a).[5]

The Intergovernmental Panel on Climate Change (IPCC) projects the growth of industrial CO_2 emissions through 2030 using two scenarios (IPCC 2007). As illustrated in Figure 1, both scenarios show significant increases in total industrial energy-related CO_2 emissions through 2030, ranging from 1.3% to 2.7% annually (or 41% to 102% above 2004 levels in 2030). Sources such as the U.S. Energy Information Administration (EIA) predict fairly similar growth rates.

FIGURE 1. GROWTH IN INDUSTRIAL CO_2 EMISSIONS



Source: IPCC 2007

Reducing these emissions requires an understanding of the unique challenges in the industrial sector, including significant variation in the composition of industry

2 The carbon emission goal to stabilize temperatures at 2°C above pre-industrial levels is based on the scientific consensus developed by the IPCC in its Fourth Assessment Report (IPCC 2007).

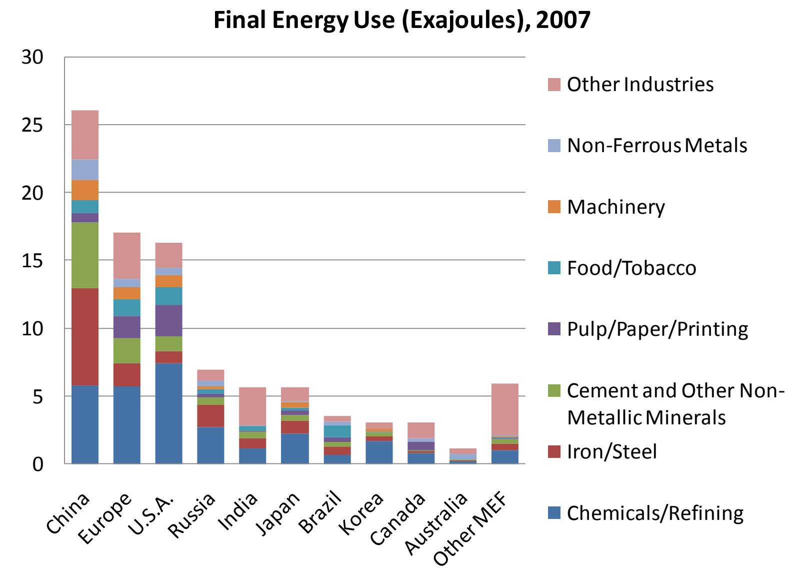
3 In some countries, agriculture and forestry are considered part of the industrial sector for data collection purposes. With a broader definition of industry and greater inclusion of feedstock energy use, industrial energy consumption can be a significantly higher share of total energy use. For example, in the International Energy Outlook published by the U.S. Energy Information Administration, the industrial sector share of world energy use slightly exceeds 50% of total consumption on both a primary and final energy-use basis.

4 The total for final energy consumption (i.e., excluding electricity conversion losses) is 116 EJ.

5 This estimate includes process-related CO_2 emissions but excludes an estimated 16–18 EJ of biomass feedstock used by industry. In addition to energy-related CO_2 emissions, the industrial sector also produces process-related CO_2 and CO_2 equivalent emissions (e.g., due to chemical reactions, or use of industrial process gases) that amplify the challenge. This paper, unless otherwise noted, refers to only indirect CO_2 emissions from energy production and direct process-related CO_2 emissions; other non-CO_2 greenhouse gases (GHGs) are not considered.

within a given country or region. Even among the MEF countries the composition of the industrial sector varies greatly, as indicated in Figure 2.

FIGURE 2. INDUSTRIAL ENERGY USE BY MEF COUNTRY (2007)



Source: IEA 2009a

The expected increase in global industrial energy use is attributable to rapid expansion of industrial production, especially in developing countries serving global markets. China has emerged as the world's largest producer of energy-intensive commodity materials, such as iron and steel, ammonia, and cement. Moreover, the industrial sector often accounts for a higher share of total energy use in developing than developed countries.

Industrial Energy Use by Subsector and Fuel

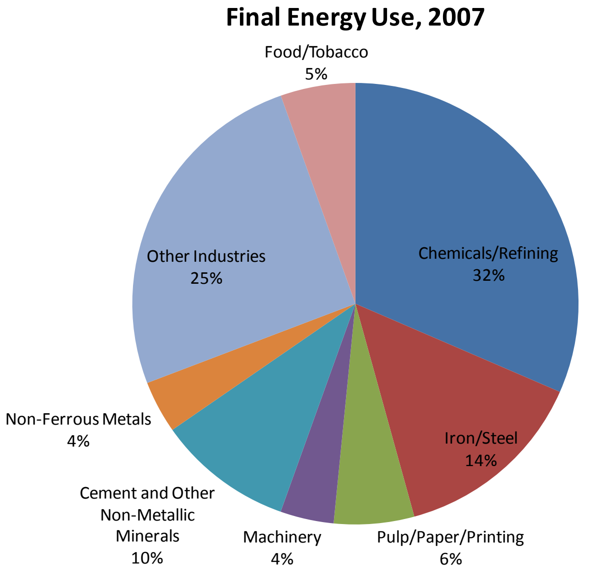
MEF countries account for the vast majority of global energy use in the major energy-intensive manufacturing industries (Table 1). The large primary materials industries—chemical, petrochemicals, iron and steel, cement, paper and pulp, and other minerals and metals—are energy-intensive and account for about two-thirds of industrial energy use (Figure 3).

TABLE 1. MEF SHARE OF ENERGY USE BY MAJOR MANUFACTURING INDUSTRY

Manufacturing Industry Sector	MEF Share of World Energy Use for Sector, 2007
Chemicals/Refining	80%
Iron/Steel	89%
Cement and Other Non-Metallic Minerals	88%
Pulp/Paper/Printing	94%
Food/Tobacco	93%
Machinery	92%
Non-Ferrous Metals	92%

Source: IEA 2009b

FIGURE 3. INDUSTRIAL ENERGY BY SUBSECTOR



Source: IEA 2009a

Final energy use in industry is distributed fairly evenly among four primary sources: coal and coal products (26%), oil and oil products (25%), natural gas (21%), and electricity (19%).[6] Other sources, such as biomass, waste, and other heat sources, account for the remaining 9% (IEA 2007). Fuel choices have significant carbon footprint implications because of variations in carbon content and thermal efficiency. The variation in CO_2 emission rates associated with electric power illustrates these differences—to produce 1 megawatt-hour (MWh) of electricity, supercritical coal-fired power plants emit approximately 1.7 times the amount of CO_2 as natural gas combined cycle units (NETL 2007). Moreover, appropriately managed biomass and renewable sources are net-zero CO_2 sources (IPCC 1996; EIA 2002).

Industrial Energy Intensity

Energy intensity is in part driven by the composition of industry and in part by the technologies that the countries use. The composition of industry varies by country, reflecting differences in the level of economic development, available natural resources, government policies, and other factors. These differences cause considerable variation in industrial energy intensity among countries when compared to factors such as population and gross domestic product. Countries with significant extractive industries (e.g., mining, oil and gas production, etc.) but relatively smaller populations, such as Canada and Australia, have inherently higher industrial energy intensity relative to population. Figure 4 illustrates these variations with respect to population and GDP. Developing countries tend to have lower industrial energy consumption per capita than developed countries, but this measure tends to increase over time with increasing industrialization of the economy, as illustrated by Korea. Since 1973, energy consumption has increased in all sectors in Korea, reflecting higher incomes, but the largest increases have been for industry because of significant increases in industrial output.

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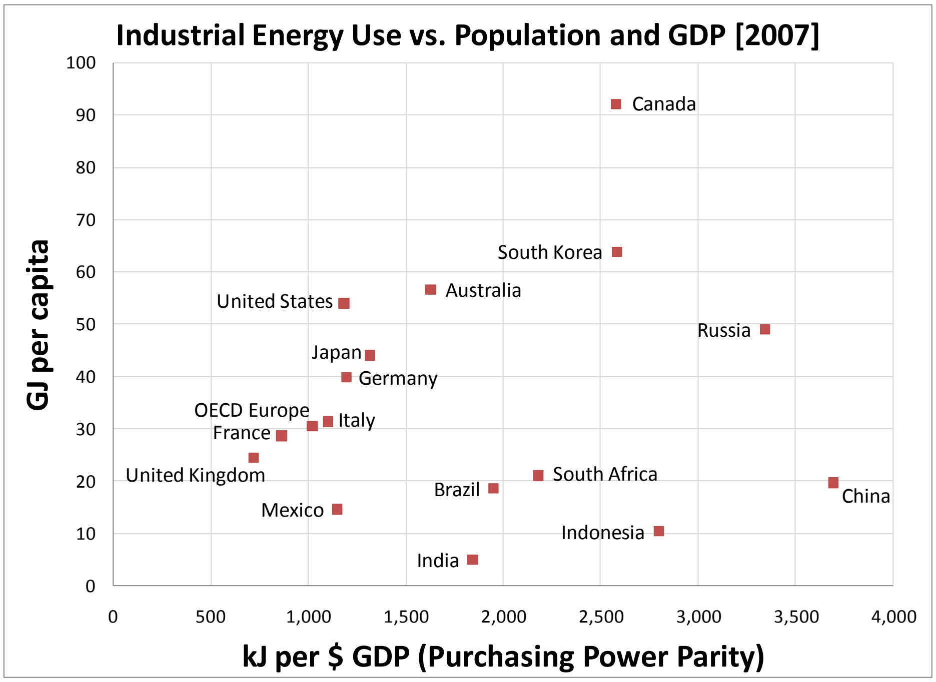
6 Intermediate sources of energy used to produce electricity are not reflected in these numbers.

FIGURE 4. ENERGY INTENSITY OF MEF COUNTRIES



Sources: IEA 2009a and World Bank Group 2009

Within each manufacturing sector, energy intensity can also vary substantially across different countries, even for relatively mature industries such as iron, steel, and cement. The reasons for these variations include the process employed, the size and age of individual facilities, the cost of energy, and the policies that affect energy efficiency. The energy efficiency indices for primary steelmaking, cement clinker, and ammonia production shown in Table 2 illustrate the substantial variations in energy intensity among countries.[7] See Appendix A for more detail regarding the potential for key industrial technologies to reduce energy consumption.

TABLE 2. ENERGY INTENSITY FOR SELECT INDUSTRIAL PROCESSES, 2004
(100 = most efficient country; higher numbers = poorer performance)

	Primary Steel	Cement Clinker	Ammonia
Japan	100	100	Not Available
Korea	105	110	Not Available
Europe	110	120	100
U.S.	120	145	105
China	150	160	133
India	150	135	120
Russia	150	165	111

Source: IEA 2006

[7] Many Asian facilities built since 2004 have significantly lower energy intensity than the average values listed in Table 2.

Mitigation Potential for the Industrial Sector

Efficiency has improved substantially in all the energy-intensive manufacturing industries in every region over the last 25 years. For existing plants, this trend reflects learning-by-doing and the adoption of improved technology. Generally, new manufacturing plants are more efficient than old ones, because they employ more advanced technology and tend to be larger than existing facilities (IEA 2007).

Industry has many opportunities to continue to enhance the energy efficiency of its operations and institute other improvements that will reduce its carbon emissions, as illustrated in the sidebar.[8] The IPCC indicates that by 2030, efficiency improvements could help cut global industrial emissions by 53%, or 4 gigatonnes of carbon equivalent (Gt CO_2e) (IPCC 2007). A 2007 report by Vattenfall using International Energy Agency (IEA) data estimates the abatement potential of industry around the globe at 6 Gt CO_2e at an average cost of €22 per tonne, although a substantial portion of this is not directly related to efficiency improvements (Vattenfall AB 2007). McKinsey estimates 6.2 Gt CO_2e in abatement potential by 2030 for the industrial sector, but again, not all of this potential is related to energy efficiency (McKinsey 2009a).

Energy and Carbon Reduction Measures

- Increase the efficiency of industrial processes (e.g., high-efficiency boilers and process heating systems, improved separation systems).
- Integrate heat, power, and processing (e.g., advanced combined heat and power technologies).
- Reduce materials waste or increase materials utilization (e.g., near-net shape processing).
- Substitute low- and no-carbon power sources (e.g., natural gas, biopower, wind, and geothermal).
- Develop alternative products (e.g., material substitutes for cement products).
- Reduce non-energy and high-global-warming-potential greenhouse gases (e.g., alternatives to consumable carbon anode in aluminum production and perfluorocarbons (PFCs) from semiconductor manufacturing).
- Develop revolutionary manufacturing approaches (e.g., nanomanufacturing systems).

A 2007 IEA analysis also suggests that substantial opportunities remain to improve worldwide industrial efficiency and reduce CO_2 emissions. This report indicates potential technical energy savings of 25 to 37 EJ per year based solely on proven efficiency technologies and best practices. Additionally, the IEA concluded that the manufacturing industry alone, by improving its energy efficiency by 18% to 26%, can help to reduce the industrial sector's annual CO_2 emissions by 1.9 to 3.2 Gt CO_2 (19 to 32%) (IEA 2007). A summary of the IEA analysis results is provided in Table 3. The table includes energy and CO_2 savings potential and energy savings percentage on a global basis for several energy-intensive industries and processes. For more detail regarding the potential of specific industrial technologies, see Appendix A.

Example Technology Opportunity

Petroleum refining relies heavily on atmospheric distillation to process crude oil. Recent estimates for the U.S. refining industry indicated energy use for this process at nearly five times the theoretical minimum energy requirement. While real-world limitations make it impossible to operate at the theoretical minimum, a more practical minimum level indicates potential savings of 54% compared to average energy use (USDOE 2006).

[8] While efficiency is a fundamental tool to reduce emissions contributing to climate change, efforts to reduce process-related emissions are also important.

TABLE 3. ENERGY AND CO_2 SAVINGS POTENTIAL

Technology	Current Potential (per IEA 2007[9])		
	Energy Potential (EJ/year)	CO_2 Potential (Mt/year)	Average Energy Savings
Motor Systems	6–8	340–750	
Steam Systems	1.5–2.5	110–180	
Combined Heat and Power	2–3	110–170	
Manufacturing Sector			
Chemicals/Petrochemicals	5–6.5	370–470	13–16%
Iron and Steel	2.3–4.5	220–360	9–18%
Cement	2.5–3.0	480–520	28–33%
Pulp and Paper	1.3–1.5	52–105	15–18%
Aluminum	0.3–0.4	20–30	6–8%
Other Metals and Minerals	0.8–1.4	60–100	13–25%
TOTAL	**25–37**	**1900–3200**	**18–26%**

Sources: IEA 2007

[9] IEA 2007 estimates "the technical energy and CO_2 savings available in energy intensive industries worldwide."

2. Development and Deployment: Barriers and Best Practice Policies

Governments can help industry to overcome technology, economic, and information-related barriers that limit industrial efficiency. This chapter discusses the barriers that prevent the realization of the full value of energy efficiency in industry and illustrates some of the best practices employed in a variety of countries to overcome these obstacles.

Barriers to Development and Deployment

The development and deployment of more efficient industrial technologies and practices is impeded by a range of barriers that affect industries across the world. This section enumerates some of the most significant barriers in order to help countries better focus their actions to enable industrial efficiency.

Counterproductive Policies

Energy costs are an important profitability driver for industry, so clear and accurate price signals are crucial motivators of efficiency in this sector. In particular, energy subsidies and failure to price emissions of greenhouse gases or other pollutants systematically mute incentives for efficiency investment. Uncertainty about future energy prices may also discourage certain suppliers and manufacturers from investing in the development or deployment of energy efficiency technologies; on the other hand, such price volatility may induce others to invest in efficiency as a strategy to reduce profit variability.

Other more detailed policy choices are also important to ensure optimal energy efficiency investment (Krarup 2002). For example, China found that it was rewarding exporters of energy-intensive products with tax rebates to a degree that energy efficiency was neglected. As a result, it systematically reduced or eliminated tax rebates for hundreds of energy-intensive products (Price et al. 2009).

Limited Capital Availability

In some cases, industrial firms may face significant limits on their overall access to finance. Energy-saving technologies then legitimately have to compete for financial and technical resources against projects that achieve other company goals, such as increased production, safety and environmental improvements, and improved quality.

More commonly, senior management may require very high rates of return on all capital investments as a simple strategy to limit the performance risk. This requirement is particularly likely if the long-term market viability of the company is in question. Senior management may also simply cap the total investment capital available to facilities managers, effectively forcing facilities managers to focus on immediate fixes rather than substantial efficiency upgrades.

Inadequate Information Flow

In many cases, industrial managers are simply unaware of energy efficiency opportunities and low-cost ways to implement them. A study of small industry in India found that—due to a highly competitive environment and inadequate knowledge—entrepreneurs rarely pursue energy efficiency and assume that larger firms or the government will handle the development of new efficiency technologies. These entrepreneurs were also reluctant to borrow funds to modernize their plants. Lacking an effective professional network, the entrepreneurs in these companies had few opportunities to expose themselves to progressive solutions (Nagesha 2006).

Lack of Expertise

Taking advantage of complex systems to achieve energy efficiency requires sophisticated experience that many organizations lack (Price et al. 2009, Sardianou 2008). Firms that want to improve their operations require substantial expertise to select technologies, integrate them into current operations, maintain them over time, and upgrade them as advancements are made.

Industrial managers can be overwhelmed by the numerous programs that promote energy efficiency, and without in-house energy experts, may find it difficult to trust third-party information. Consultants may lack the industry-specific knowledge necessary to provide accurate energy efficiency services and may use proprietary information gained by working inside a plant to assist competitors. Moreover, smaller organizations may be less willing or able to pay for information or expertise.

Firms also have varying levels of trust in government, contractors, or trade associations. For example, one study of Swiss foundries discovered that industrial trade group expert consultation was valued more than that of a national government consultation program (Rohdin et al. 2007).

Inadequate Workforce Skills

Skilled personnel are required to enable diffusion of high-efficiency technologies (Sardianou 2008, Worrell 2001a). Moreover, after the installation of energy efficiency measures, employees need continual training to optimize energy performance (UNIDO 2007). Experts have similarly found that a failure to effectively train the workforce responsible for maintaining energy efficiency systems erodes their effectiveness over time (Sardianou 2008). Developing a skilled workforce can be a challenge in any firm, but firms operating in developing countries and small- to medium-size enterprises (SMEs) may find it particularly difficult.

Performance Risks and High Costs for New Technology

Concern about new technologies adversely affecting production can be a significant deterrent to action. In today's manufacturing environment, where plants often operate almost continuously, integrating new technologies presents reliability and operational risks. Small technology changes, particularly in large integrated process plants, can lead to major changes in process and product performance. Uncertainty about potential energy savings and other benefits can be a further disincentive to take action. Early decommissioning of existing equipment may be seen as fiscally unwise, notably when there is uncertainty about the return on investment for new, energy-efficient equipment, especially in smaller organizations.

Small companies may have particular risk aversion regarding production interruptions caused by equipment replacement or retrofitting. A 2009 Organisation for Economic

Co-operation and Development (OECD)/IEA evaluation concluded that SMEs need specific incentives to enable "least life-cycle cost capital acquisition decisions" (IEA 2009b). A study on the Swedish foundry industry identified fear of production disruptions as the second most important barrier to efficiency for SMEs, following limited access to capital (Rohdin et al. 2007). Often, smaller organizations will purchase inefficient used equipment, or simply purchase more energy, rather than invest in efficient technology (Worrell 2001b).

In addition to greater risks, new energy-efficient technologies also tend to have longer payback periods than traditional equipment. Uncertainty about the total cost of the installation can add to the risk. Because industry is extremely diverse in the processes it employs and the products it manufactures, most technologies have limited markets. Even technologies used in multiple applications often require costly development and testing for each specific application.

Current Best Practice Policies

Many countries have implemented policies to overcome barriers to the development and deployment of energy-efficient industrial technologies. Through this experience, best practice policies have emerged.

A study of OECD countries found that a crosscutting mix of voluntary agreements, equipment standards, fossil fuel subsidy reductions, technical assistance, and financial incentives creates an optimal environment for energy efficiency adoption (Geller et al. 2006). The Carbon Trust, a UK program described in the sidebar, is an example of a program that uses multiple approaches to enable firms to be more energy efficient.

Specific best practices principles and success stories are described below.

THE CARBON TRUST

In the UK, the government-funded Carbon Trust works to help cut carbon emissions by providing business and the public sector with expert in-depth advice, auditing services, free tools and publications, finance (including interest-free loans for small- and medium-sized businesses), carbon and energy management scheme accreditation, and by stimulating demand for low-carbon products and services. Between 2001 and 2007, the Trust helped save over 17 million tonnes of carbon and cost savings of over £1 billion. The Carbon Trust also seeks to cut future carbon emissions by developing new low carbon and energy efficient technologies.

Rational Pricing of Energy

In contrast to the real estate sector, energy costs substantially drive profitability for many industrial firms. As a result, industrial firms typically track energy expenditures relatively closely, including any shifts in energy prices. This level of attention makes rational energy pricing particularly important as a tool to promote industrial energy efficiency.

Consistent with the recent call by the G20 to phase out fossil fuel subsidies, it is important to begin implementing rational energy pricing by eliminating any policies that artificially depress energy prices for industry. The next step is to then account for environmental externalities, including greenhouse gas emissions.

Carbon emissions trading schemes represent one policy option that provides financial incentives to invest in energy efficiency improvements by accounting for environmental costs. Since 2005, the EU Emissions Trading Scheme (EU-ETS) has set a declining cap on emissions from large industrial sectors, including power generation. By incentivizing the least-cost options to reduce emissions, which often include energy efficiency measures, cap and trade can provide a significant driver for improvements in efficiency.

Energy Assessments and Energy Management

Energy assessments are performed by skilled personnel that collect and analyze data on all major energy-intensive equipment, providing an evaluation of current energy

ENERGY MANAGEMENT PROGRAMS RESULT IN LARGE ENERGY SAVINGS

Information Approach: U.S. Energy Assessments and Industrial Assessment Centers
The U.S. Department of Energy provides trained experts to perform free Energy Savings Assessments (ESAs) at energy-intensive manufacturing facilities. Since 2007, these experts have also trained plant personnel to use their software tools and other resources. More than 70% of the ESA recommendations were implemented, in progress, or planned for implementation within six months after the recommendations were delivered. ESAs are performed at around 200 plants per year. For small- and medium-sized manufacturers, DOE established a program to partner with 26 universities at Industrial Assessment Centers (IACs) throughout the United States to train and conduct comprehensive energy assessments. IAC energy assessments are conducted at approximately 300 plants per year. Engineering faculty and students provide the assessment and deliver a confidential report to the industrial facility with detailed analysis on cost, waste reduction, productivity, performance, and payback estimates. Over 90% of participants reported that assessments played an influential or highly influential role in the implementation of their energy-saving projects (DOE 2007).

Incentive Approach: The Danish Voluntary Agreements on Energy Efficiency in Industry
Since 1996, energy-intensive industrial firms can obtain a tax rebate by entering a voluntary agreement with the Danish Energy Agency. Ninety-eight percent of the energy used in heavy processes and 8–9% of the Danish energy consumption were covered in 2008. To be eligible, companies must commit to introduce energy management and carry out special investigations on specific primary production processes. Additionally, companies must undertake energy flow screenings and implement investments that improve energy efficiency with a simple payback of less than four years. Energy management is the cornerstone of the agreement consistent with the Danish standard for energy management systems established in 2001 (DS 2403). Danish experience shows that energy management alone contributes a 10–15% reduction in companies' energy consumption.

Regulatory Approach: Japan's Law Concerning the Rational Use of Energy
Japan's Law Concerning the Rational Use of Energy, which first came into force during the 1979 energy crisis, requires active energy management and mandates efficiency standards for certain equipment. The law compels companies with energy consumption exceeding a specified level to meet certain energy performance targets. It also requires companies to appoint an energy management supervisor at the board level and designate a separate corporate energy management and planning leader. Both energy managers are responsible for all company sites.

The law has been amended several times since 1979—most recently in 2009—and remains at the vanguard of international best practice energy management policies. A recent amendment expanding the scope of the regulation from site-specific to company-wide is expected to significantly expand the number of companies and total energy consumption that the law affects. The law previously required each facility to improve energy intensity by 1% per year. New regulations to set medium- and long-term targets based on benchmarking indicators for key energy-intensive industries (e.g., iron and steel, cement manufacturing).

A national qualification system for energy managers is also in place. Its success in reaching plants not directly affected by the law is indicated by the fact that the number of trained personnel is now about six times the number of facilities requiring energy managers under the law (Sakamoto 2009). Also supporting the energy efficiency goals described in the law are financial incentives, such as low-interest financing, industrial improvement bonds, and tax exemptions (Environmental Intelligence Analysis 2009).

consumption and recommendations for energy-efficient practices or products (Price et al. 2008). Assessments also contribute to demand for qualified energy management skills. Government action to stimulate the assessment process has a proven track record of success. Examples include the U.S. Energy Savings Assessments and Industrial Assessment Centers described in the text box above.

Continuous energy improvement can be institutionalized through energy management programs. Energy management programs provide a platform to establish high-level goals, and can encourage greater uptake of energy-efficient technologies and practices. Programs can include a variety of measures: clear and aggressive targets for energy improvements, assessment and training programs to help identify energy-saving technologies and practices, and benchmarking and standards to provide a methodology and optimization techniques for meeting the efficiency targets. Both energy assessments and energy management programs can enable comparisons across entire plants, processes, or systems, and can help managers understand their relative energy performance to make more informed decisions about aligning investments with corporate commitments to energy savings (Price et al. 2008). Energy assessments and management programs also facilitate consistent benchmarking for industry, permit meaningful data sharing, and allow energy efficiency comparisons between similar plants and with national or international energy efficiency or energy-use levels (UNIDO 2007).

Successful energy management programs have several important elements, including the following:

- An executive-level commitment to energy efficiency through specific, established goals and an organizational structure that encourages energy improvements
- Facilities managers or other operational managers who are allowed access to capital on reasonable terms to make efficiency improvements
- Aggressive, yet realistic, internal targets that are explicit, legally binding, measurable, and performance-based with a 5–10-year horizon; appropriate targets stimulate cost-effective energy savings measures while granting enough time to plan and implement investments that help establish a culture for active energy management (Price et al. 2008)
- For voluntary energy management programs, implicit or explicit external pressure on industry to meet targets (e.g., if targets are not achieved, the government has an option to increase regulation or taxes; such programs have been found to be cost effective and to provide energy savings beyond business-as-usual) (UNFCCC 2002, IPCC 2007)
- Training programs that include educating on-site technical staff, as their familiarity with the intricacies of the plant operations enables them to evaluate and communicate to management the energy matters specific to their plant
- A recognition element that can provide positive public relations for the participating firms and, in public/private arrangements, for the sponsoring government agencies (McKinsey 2009b)
- Annual monitoring and reporting of progress toward energy goals, using reporting mechanisms supported by standardized protocols analogous to GHG reporting registries; this reporting may be enforced (e.g., programs with a formal recognition element receive benefits only if energy improvements are demonstrated via documented monitoring and reporting) (Price et al. 2008)

- Benchmarking information, collected through annual monitoring and reporting, available to SMEs as well as large energy-intensive firms (IEA 2009b)
- Investment in specialized third-party assessments to identify opportunities unique to a facility's processes and equipment (Brown et al. 2007)
- Access to an integrated set of complementary public programs that offer technical and financial support for their energy management plans (e.g., information sharing, technical assistance, financial assistance, awards and recognition, and a standard protocol for measuring energy improvements) (Price et al. 2008, Galitsky et al. 2004)

Information and Advice

The availability of trusted, independent, and expert advice, whether through government programs or other mechanisms, can play a significant role in supporting and facilitating action by business to improve energy efficiency. This can include support for energy assessments and implementation of energy or carbon management schemes. Specific mechanisms include providing access to free or subsidized energy auditing services, independent accreditation, and financial support, as well as dissemination of best-practice information targeted to specific business sectors.

To be effective, such services need to be adequately tailored to the businesses concerned. For example, SMEs tend to seek advice on reducing their overall resource use and impacts across the range of energy, water, and materials resource use/waste,

Industrial Equipment Energy Efficiency Standards Are Reducing Energy Consumption

Canada: Through Natural Resources Canada's (NRCan) Office of Energy Efficiency (OEE), certain industrial equipment is regulated to ensure minimum energy performance levels. For example, crosscutting support system components such as boilers, chillers, and electric motors are subject to energy efficiency standards. OEE provides support to industry through technical assistance and disseminating information, such as public access to third-party-certified energy efficiency ratings on industrial equipment. Canada's OEE also provides benchmarking guidelines for comparing its physical energy intensity to the average for its sector and to the best-in-class. The program developed tools to help plants gauge energy use by fuel type and energy intensity, which can be compared to sector energy efficiency standards in cement, food processing, mining, petroleum refining, potash, and pulp and paper (Price et al. 2008). NRCan estimates that by the year 2010, the Energy Efficiency Act and Energy Efficiency Regulations will result in an annual energy savings of 176 petajoules.

United States: Section 313 of the Energy Independence and Security Act (EISA) of 2007 requires minimum energy performance standards for general purpose motors. The American Council for an Energy-Efficient Economy (ACEEE) estimates that these new motor standards will result in electricity savings of more than 8 trillion kWh by 2030 and save electric consumers nearly US$500 million. Such significant energy savings are expected because motors account for over two-thirds of the electricity consumed in the industrial sector in the United States (ACEEE 2007).

International: The International Electrotechnical Commission established a standard (IEC 60034-30) that defines energy efficiency classes for industrial application motors and helps unify international testing methods, efficiency categories, and labeling protocols. The European Commission Eco-design Regulatory Committee recommended that the IEC standards become mandatory for certain electric motors, superseding the voluntary efficiency standards, which helps harmonize the motor energy standards set by the European Commission with those of the United States.

whereas larger companies are more likely to seek separate, specialist advice for each resource stream. Such services should also have a sufficiently high profile so that business knows where and how to access them. National programs can benefit from scale and experience, whereas regional or local programs provide local knowledge and add value through local relationships, augmenting national programs.

Minimum Energy Performance Standards

Minimum energy performance standards for widely used industrial equipment (e.g., motors, fans, boilers) offer a cost-effective approach to reducing energy consumption. Minimum standards help to overcome information barriers and push the least efficient products out of the market. Standards designed and customized for the specific operating environment of each industry are more effective (McKinsey 2009b).

Successful minimum energy performance standards include the following characteristics:

- Mandated but based on a cooperative approach—mandated standards produced through interactive industry-government processes generally result in lower implementation costs, even when aggressive standards are recommended (BIAC 2004)
- Financial and technical assistance options, as part of an overall package of policy measures
- Implemented by leveraging complementary tools and software (e.g., models, data assessment tools, tutorials, and searchable databases), which encourage greater coordination and increase awareness and understanding of energy conservation options among plant operations personnel—these resources can successfully translate turnkey projects from a one-time energy savings project into regular energy improvements over time (Galitsky et al. 2004)

Combined Heat and Power (CHP) Incentives

Combined Heat and Power (CHP) applications can provide thermal energy (e.g., steam, heat, cooling, dehumidification) and power (e.g., electricity,

Combined Heat and Power Incentives

European Union: Feed-in tariffs involve an agreement between a utility or distribution company and a CHP operator. The agreement stipulates that if the CHP operator generates excess electricity, the operator is paid a pre-negotiated rate for supplying it to the grid. The advantage to CHP operators is that such arrangements guarantee a long-term (typically 15–20 years) revenue stream for electricity, which is a byproduct of increasing energy efficiency overall at the facility. The guaranteed revenue has been proven in European applications to encourage investment in CHP, which is complementary to helping plants meet thermal energy needs—the primary use of industrial CHP systems. The agreement often includes provisions to pass on any increased monetary savings or cost to consumers, thus mitigating the financial risk for the utility (ORNL 2008).

European Commission: The Cogeneration Directive (2004/8/EC), approved by the European Commission in 2004, promotes and develops high-efficiency CHP through a variety of support schemes. The directive encourages businesses to expand CHP capacity from a combination of technological solutions and favorable policy landscape. Key components include identification and assessment of CHP potential by country, feed-in tariffs, grants and loans, tax incentives, and reports on implementation progress. Amendments have been proposed to further strengthen the initiative, such as mandates to identify energy savings potential from waste heat, setting minimum efficiency requirements for micro-CHP, and incorporating cogeneration in the national energy efficiency plans (INFORSE 2008).

United States: Interconnection between a CHP system and the electric grid allow CHP operators to sell excess electricity to other users connected to the grid. Disparate interconnection rules make it difficult for CHP equipment manufacturers to design and produce modular packages. In the United States, procedures and model standards that help ensure the electric grid is safe, secure, and reliable for connection to CHP systems have been developed by National Association of Regulatory Utility Commissioners (NARUC), Interstate Renewable Energy Council (IREC), and others. Uniform standards have been instrumental in facilitating connectivity of CHP systems to the grid, making investments in CHP more attractive for industrial companies (ORNL 2008).

direct mechanical drive) to numerous industrial processes. CHP applications can involve many fuel types and can apply to projects with a wide range of capacities. CHP offers stand-alone energy efficiency benefits within a plant and has grown to represent more than 20% of electricity generation in several EU countries. Most CHP capacity is found in large industrial applications, such as chemicals, paper, refining, food processing, and metals manufacturing.

Successful CHP incentives have three main attributes:

- The ability to overcome traditional utility rate structures that link revenues to the amount of electricity sold—successful incentives often involve formal agreements between the utility and the CHP operator and account for the full value of CHP to the ratepayer (e.g., avoided costs associated with constructing additional generation capacity and infrastructure)
- A portfolio of supporting standards, incentives, business models, and technical assistance that can stimulate widespread market penetration of CHP systems (e.g., interconnection standards can help ensure the systems are reliably and cost-effectively connected with the grid, enabling expansion of CHP and financial incentives can further encourage investments) (ORNL 2008)
- Personnel trained in installation, operation, and maintenance of CHP systems as well as managing the technical complexities of grid interface

Other Financial Incentives

Financial incentives can stimulate investment in energy-efficient technologies by reducing cost and helping to raise awareness. Examples include subsidies, grants, and tax benefits, such as tax reductions, tax exemptions, or accelerated depreciation. Considering energy efficiency investments must compete with projects that are central to a company's product line or mandated by regulation, incentives can tilt a company's investment decision toward energy efficiency. Incentives can also aid in attracting capital despite investor perceptions of uncertain future returns from energy efficiency measures (Brown et al. 2007, Jaffe et al. 2005). Financial incentives to encourage industrial energy savings are in place in most developed and developing countries (WEC 2008).

Successful financial incentives:

- Result in spillover effects that expand penetration of the technologies beyond the initial target market
- Maximize "additionality" (incentives are used by investors who would not have made the energy efficiency investment otherwise)—a common approach for achieving additionality is to apply criteria that limit incentives to projects of a certain size, or to target specific practices or technologies (e.g., restricting grants to certain types of equipment with long payback periods but high efficiency gains) (IPCC 2007, Price et al. 2008)
- Are part of an integrated package that combines a variety of financial incentives

Enhanced Capital Allowances Encourages Companies to Invest in Energy Efficiency

The UK Enhanced Capital Allowances (ECAs) provide businesses with 100% tax rebate for the first year on qualifying energy efficiency capital expenditure. The program encourages businesses to invest in targeted energy-saving equipment, which is specified on an Energy Technology List. Companies with qualified purchases receive a credit on the capital cost of their investment against their taxable profits. Types of technologies that qualify include boilers, combined heat and power, compressed air, heat exchangers, motors and drives, pipe work insulation, and others (Carbon Trust 2007). For a specific piece of equipment to be eligible, it must meet a set of energy-saving criteria, which are reviewed on an annual basis as a best practice.

with other mechanisms to improve energy efficiency, such as voluntary agreements, that provide clear signals that motivate management to improve energy efficiency

- Include simple and transparent processes that limit transaction costs (Price et al. 2005)

The UK Enhanced Capital Allowance Program, described in the box above, illustrates best practice in providing financial incentives. In the Netherlands voluntary agreements, combined with financial incentives, have resulted in significant energy savings, as described in the sidebar.

The Netherlands Long-Term Agreements: Integrating Voluntary Agreements with Financial Incentives

The Long-Term Agreements (LTAs) program in The Netherlands encourages voluntary public/private agreements between the Dutch government and energy-intensive industrial sectors. The first program included prescriptive energy management steps and committed partners to achieve specific energy efficiency improvements. The LTAs built on the ISO 14001 standard for environmental management and provide guidance for creating company or site-specific energy management systems. A second LTA program (LTA2) runs from 2001 to 2012 and is focused on smaller businesses and industry. The targets for companies that join LTA2 are set based on independent research assessment of best practices in the sector, and they are required to establish an energy management system within two years.

The LTA programs include conducting an assessment of the energy efficiency potential of the subsector, establishing commitments for individual companies, producing an energy conservation plan, and monitoring progress in energy efficiency in terms of an energy efficiency index (Price et al. 2008). Audits of individual plants are also conducted as part of the LTAs, which help to determine an appropriate commitment level for each company and provide a baseline for the energy conservation plan. Participating companies monitor and report energy improvements annually, and the reports are reviewed by industry associations, the Dutch government, and an independent third party. Financial support includes a 55% deduction of the annual investment of energy-saving equipment provided on an "Energy List" published by the government, and an Accelerated Depreciation on Environmental Investment program allows firms to rapidly depreciate its investment in energy-saving and environmental equipment.

About 1,000 firms were involved in the LTA program, representing about 90% of sector's primary energy consumption in the country. The average target for the LTA program—guided by national goals—was about 20% improvement between 1989 and 2000. The LTA program contributed to 27–44% energy savings, a 50% increase over energy efficiency rates in The Netherlands prior to the program (IPCC 2007). Industrial companies participating in the LTA2 program have achieved an energy efficiency improvement of 19% in 2005 compared to 1998 (Price et al. 2008).

Utility Energy Efficiency Programs

Utilities deliver energy efficiency financing and technical solutions through multiple channels. Their direct link to customers provides them with a market and the ability to recapture investments through regular utility payments, using the threat to terminate services to ensure repayment. When combined with financing authority, whether through public benefit charges or other facilities that enable the utilities to accumulate the capital to deploy energy efficiency solutions, utilities have provided effective programs.

Some governments have elected to spur energy efficiency solutions by requiring utilities to finance and deliver energy efficiency technology through demand-side management (DSM) and related programs. Brazil has a DSM program that requires all distribution utilities to make energy efficiency investments, as described in the box below.

Utilities usually market DSM and other energy efficiency programs through their direct link to customers (i.e., the billing process) and deliver energy efficiency technologies by working with outside contractors. The PacifiCorp "Energy Finanswer Program," described in the box below, was so successful that the utility was able to sell its portfolio of projects to a major commercial bank.

Often, regulators allow utilities to collect a public or systems benefit charge (SBC) to accumulate the capital needed to finance energy efficiency programs. SBCs can be based on total consumer energy use and are collected as part of the utility bills. The revenues associated with the SBC are in turn invested in energy efficiency solutions.

SBCs are in broad use. In India, the Maharashtra Electricity Regulatory Commission has levied an SBC on industry to fund renewable energy and energy efficiency programs within the state. In Brazil, the utility regulator has required each utility to set aside 1% of annual net revenues, with a portion committed to energy efficiency investments. Since the Brazilian SBC program began in 1998, utility funds invested in energy efficiency programs have totaled hundreds of millions of dollars, with estimated savings of several thousand GWh. In the United States, 17 states and the District of Columbia have collected SBC funds ranging from several million to several hundred million U.S. dollars. Because these funds are based on energy use, rather than more volatile tax revenues, funds have remained stable despite severe cuts in public spending in 2009.

Capital Mobilization

Governments and development banks have pioneered programs that help to reduce financing costs, accumulate funds for energy efficiency investments, and aggregate transactions to achieve savings. Some of the most effective programs have been implemented in developing countries.

BRAZIL DSM PROGRAMS BEGAN IN 1998

The Brazilian energy regulator ANEEL requires electric power distribution companies to undertake energy efficiency measures. To fulfill this obligation companies must present projects to ANEEL that conform to guidelines. The utility program must establish goals for energy efficiency measures and financial investments. In addition, ANEEL requires evaluation plans be provided for delivered programs. Companies include projects in the Annual Program against Electrical Energy Waste.

PACIFICORP "ENERGY FINANSWER" PROGRAM

PacifiCorp "Energy Finanswer" Energy Efficiency Finance Program for the Commercial and Industrial Sector illustrates how a utility can facilitate industrial energy efficiency investments. PacifiCorp has promoted use of energy efficient motors, lighting, and other technologies to commercial and industrial customers in its Oregon service territory as a means to meet its demand management goals. PacifiCorp chose this program design to reduce ratepayer financed rebates and shift more of its energy efficiency program costs to the participating end-user, while still maintaining an attractive customer offer.

The utility has organized a group of equipment vendors, engineers, and contractors, who offer energy efficiency products and services. The utility then provides: (1) funding for energy audits to assess the energy efficiency potential for qualified technologies with customers in the utility service area, and (2) a lease financing program, with the utility providing financing to customers to implement the energy efficiency projects over four to five years. The utility also provides technical assistance to end-users on project engineering, development and contracting.

Financing services are marketed by the trade allies to end-user customers. When a customer signs up for the program, the trade ally completes the documentation. Once the utility verifies the documentation, the financing is closed. The customer repays the utility as part of its monthly utility bill. The utility takes the risk of customer non-payment but, because it has a "lien-at-the-meter" (whereby power service can be cut in the event of non-payment), the default rate is very low. This program started operations in late 1992. In its first three years of operation, the program provided financing for over US$32 million of projects. The utility eventually packaged and sold a portfolio of these lease assets to a major commercial bank.

Successful energy efficiency financing programs in developing countries illustrate the importance of fully integrated approaches to delivering energy efficiency. The World Bank has found that lack of domestic sources of capital is rarely the true barrier to efficiency. Rather, inadequate organizational and institutional systems for developing projects and accessing funds play a larger role. A major factor in the inefficient use of energy is inadequate capital markets due primarily to weak policy frameworks. The interplay between the national policy and institutional framework and financial intermediation mechanisms is critical to the success of energy efficiency programs (Taylor, et al. 2008).

Successful capital mobilization programs do the following:

- Search out cost-effective measures and provide technical expertise to help install and maintain the technical solutions
- Ensure funds are available to cover the risks associated with the energy efficiency business, where traditional collateral and strong credit records may not prevail and available data are insufficient to make accurate risk assessments (see the Dexia-FondElec Energy Efficiency and Emissions Reduction Fund box below)
- Enable financial institutions to: address local legal, regulatory, and market enabling conditions; enlist the partners needed to market the programs and deliver the technology; and prepare their own staffs for the special technical issues associated with financing energy efficiency projects—one program that integrates all of these activities is the China Utility-Based Energy Efficiency Finance Program (CHUEE), as described in text box below
- Provide effective marketing of the programs to the customers and effective links between the financing agents and those that will deliver the energy efficiency solutions

DEXIA-FONDELEC ENERGY EFFICIENCY AND EMISSIONS REDUCTION FUND

Created by Dexia Bank of France, FondElec Group, and the European Bank for Reconstruction and Development, the Dexia-FondElec Fund brings capital to facilitate private sector investments in energy efficiency to industrial sector companies in Central and Eastern Europe. The fund supports energy efficiency projects directly or through energy service companies (ESCOs), which provides a means to improve energy efficiency without additional public debt. The fund gives preference to projects that involve broad participation by the private sector and that encourage replication throughout the region, ultimately expanding the market for energy efficient technologies.

The fund has been successful because of its strict criteria for cost-effectiveness, which involves screening potentially funded projects by the fund's investors. In addition, the fund retains technical experts who are experienced in working on energy sector projects in developed and developing countries. The sizes of the projects are limited to focusing on small to medium enterprises, which limits competition with strategic investors and diversifies the investment portfolio (Price et al. 2005).

The China Utility-Based Energy Efficiency Finance Program (CHUEE) Continues to Grow the Energy Efficiency Business in China

CHUEE is an integrated model of energy efficiency finance that provides energy users with the complete portfolio of services needed to effectively implement energy efficiency projects in China: marketing, delivery, and financing.

Founded by the International Financial Corporation in 2006, CHUEE operates through a network of partners that together deploy the skills and resources critical to successful energy efficiency finance programs. Each of the components of the network plays a critical role in the delivery of energy efficiency solutions and securing the capital needed to implement them.

- The IFC (and its funding partners, the Global Environmental Facility [GEF], the Ministry of Employment and Economy of Finland [MEE], and the Norwegian Agency for Development Cooperation [Norad]) provide financing for risk sharing and technical assistance.
- Local financial institutions, primarily Chinese commercial banks, are the lending agents, sharing credit risks with the IFC, as well as receiving technical assistance from the IFC that helps them to establish energy efficiency finance products, design customer outreach programs, and develop project audit and review processes.
- CHUEE employs a wide range of marketing partners that deliver the technical solutions and links to customers. CHUEE's marketing partners include energy management companies, equipment suppliers, and utilities that can reach multiple market segments and provide technology solutions that address the differing needs of those markets. Marketing partners also provide a means to bundle small projects and reduce the transaction costs that can otherwise preclude financing energy projects.

CHUEE financial partners include three Chinese partner banks that accept applications from project developers: Industrial Bank, Bank of Beijing, and Shanghai Pudong Development Bank. The CHUEE program has leveraged a loan portfolio valued at over RMB1 billion, with the goal of mobilizing RMB5–10 billion of energy efficiency project financing by 2012.

Support for Efficiency in Developing Countries

In addition to DSM programs, such as Brazil has enacted, and financing programs supported by development financing institutions, such as CHUEE, developing countries have worked to apply the Kyoto Protocol clean development mechanism (CDM) to energy efficiency project financing barriers. Since 2004, the share of self generation and industry projects have increased from almost nil to over 20% of all CDM projects. (UNEP 2009) In practice, however, the barriers to effective use of CDM credits are significant and include the large transaction costs that result from the small, distributed nature of individual industrial projects. Among measures that may overcome these barriers is the development of industry sector based or programmatic methodologies and benchmarks that can aid in project preparation and reduce transaction costs.

3. Actions to Accelerate Development and Deployment

To achieve transformational gains in global industrial efficiency, MEF countries will need to pursue substantial new actions to develop and deploy industrial energy efficiency. Many of these goals and actions rely on, or can be effectively leveraged through, coordinated action among countries, including support for existing international forums. This chapter describes the landscape of opportunity for more ambitious national and collaborative action to promote industrial efficiency.

Menu of Opportunities for Individual and Collective Action

Chapter 2 illustrates multiple best practices that point to specific individual and collective country actions that can help to reduce market barriers and realize the full potential of industrial sector energy efficiency. Key categories of action for consideration include the following:

- Supporting innovation:
  - Develop new technologies.
  - Demonstrate new technologies.
- Accelerating deployment:
  - Establish voluntary industry standards and otherwise reduce investment risk.
  - Build deployment capacity.
  - Improve relative economics between advanced clean energy technologies and conventional technologies to encourage market-based adoption.
  - Establish and strengthen regulation.
- Facilitate information sharing:
  - Share best practices and knowledge.
  - Enhance public awareness.

The following section outlines a menu of actions within each category, generally listed in increasing order of ambition. Interested countries should consider adopting one or more of the actions in each category, as applicable to their unique circumstances.

Supporting Innovation

- Ensure multilingual applications of existing and new software tools for analyzing plant energy systems (e.g., analytical tools for motor-driven systems, steam, process heating, and plant-wide evaluation).
- Fund basic research on next generation industrial efficiency technologies.
- Build collaborative RD&D mechanism for next generation industrial efficiency technologies.

- Build domestic (or international) centers of excellence on key efficiency drivers (e.g., motor systems, steam systems).
- Develop funding agency for energy efficiency research that benefits multiple industries (e.g., steam systems, motors design and usage, water, etc.).
- Fund pilot deployments of emerging technologies.

Accelerating Deployment

- Expand partnerships with leading manufacturers. Work to ensure adequate supply of energy efficient equipment and materials and anticipate potential bottlenecks.
- Develop and communicate long-term efficiency targets to reduce compliance uncertainty.
- Expand international collaboration on minimum energy performance standards for end-use equipment.
- Develop energy management training programs to encourage organizations to rethink energy consumption and encourage employee buy-in.
- Develop integrated facility and process design and auditing training programs for engineers, contractors, and operators. Train operations managers in data collection and monitoring energy performance.
- Create a consistent and comparable methodology for efficiency performance auditing.
- Create a national qualification system for energy managers (e.g., Japanese Energy Managers Accreditation Program).
- Set process and facility standards to incorporate all net present value (NPV)-positive components. Establish best practices that ensure that standards for industrial efficiency are periodically evaluated and strengthened (e.g., efficiency of refrigeration equipment).
- Expand policy support for distributed energy systems and combined heat and power (e.g., CHP/District Heating and Cooling [DHC] Collaborative).
- Expand the capacity for sub-national public agencies to develop energy efficiency policies.
- Harmonize national and international process and facility test procedures (e.g., IEC, IEMA, ANSI, etc.)
- Remove border tariffs on energy efficiency technologies.
- Provide fiscal incentives and lower the required hurdle rate of return for industry energy efficiency investments (e.g., tax credits) and reduce disincentives (e.g., streamline depreciation schedules) to enable acceleration of efficiency benefits to corporations.
- Create financial instruments that encourage "total cost of ownership" thinking rather than fixation on upfront cost.
- Apply emissions trading or emissions tax scheme to provide incentives for industrial energy efficiency.
- Create insurance- and publicly-funded risk guarantees or other commercial financial incentives to enable lenders and borrowers to reduce credit and

performance risks and to support manufacturers and energy service companies (ESCOs).

- Ensure enforcement of existing standards.
- Create uniform national equipment standards, wherever possible, to enable manufacturer economies of scale. Broaden industrial equipment efficiency standards across product categories.
- Set industry-specific savings targets (mandatory or voluntary).
- Establish industry benchmarks with clear underlying drivers (i.e., to facilitate application to different businesses) and coordinate measurement standards for industrial performance.
- Set point source emissions or energy use limits for industrial facilities.

Facilitating Information Sharing

- Catalog and develop energy simulation and other software tools, develop guidelines for application, and bring to the attention of senior managers.
- Sponsor industry conferences to share experiences and best practices of industrial energy efficiency policies and programs.
- Influence the agenda of industry associations and professional societies to enhance scientific and business collaboration on key technologies.
- Survey energy managers within industrial corporations to codify best practices and identify obstacles.
- Harmonize terminology for process and facility efficiency technologies and practices (e.g., CHP).
- Share non-sensitive technology and knowledge freely among countries to ensure greatest efficiency at initial construction (e.g., through knowledgeware, technical assistance teams).
- Develop and maintain a blinded database of business cases and analyses at an industry level to encourage investment and share best practices for overcoming barriers to energy efficiency.
- Educate industry stakeholders about the ancillary benefits of energy efficiency (e.g., employee satisfaction).
- Institutionalize energy management thinking by encouraging its inclusion in the curriculum of relevant colleges and universities.
- Launch an international industry recognition campaign to offer participating organizations a means to promote their positive actions to their stakeholders, their competitors, and the general public.
- Assess opportunities for energy management through supply chain coordination and convene stakeholders to coordinate adoption (e.g., efficiency targets coordinated across supply chain, collaborative training programs across all stakeholders, and consistent optimization and auditing techniques applied throughout supply chain).
- Collect and evaluate country reports and compare main items of industrial efficiency standards.

- Demonstrate the value of portfolio management strategies to improve industrial energy efficiency (e.g., government program for zero-cost facility energy efficiency assessments).
- Develop a framework for public reporting of energy use by corporations (similar to the Global Reporting Index) to support companies benchmarking relative to peers.
- Incorporate energy into top-level-management thinking (e.g., ISO 50001, annual reporting similar to safety, 10k, required appointment of corporate energy management supervisor).
- Consider requiring network-enabled facility electricity and primary fuel consumption monitors and reporting to relevant government agencies to enable proactive identification of efficiency opportunities.
- Demonstrate proven technologies in high-growth geographies, providing technology access to capital- and resource-constrained areas.

Actions by Individual Countries

To accelerate development and deployment of industrial energy efficiency, countries should consider adopting one or more of the actions in each of the categories outlined above. More generally, they may wish to start by developing a national industrial efficiency roadmap that identifies and appropriately sequences high-impact actions from each category as appropriate to their unique circumstances.

In some cases, countries may further wish to define targets for deployment of specific technologies, such as CHP. Certain countries may choose to translate these goals into minimum standards or even mandatory deployment requirements.

In any case, countries will need to assess progress against their own action plan, and course correct as needed. At a minimum, they may want to ensure that they are establishing policies or taking other enabling actions on the schedule envisioned in their road map. Similarly, they may establish a matrix of demonstration projects categorized by solution type in order to ensure they are addressing the full range of promising energy-efficient industrial technologies.

Coordinated or Cooperative Actions

Beyond the individual efforts described above, countries should consider the vital role of international coordination and cooperation for the deployment energy efficiency solutions for industry. The Global Partnership aims to assist all countries seeking to develop and deploy industrial efficiency technologies and practices. Building on the ongoing partnerships described below, as appropriate for each participating country, would be an important step.

Support ISO 50001 Plant Energy Management Standard

Description

The International Organization for Standardization (ISO), the world's largest developer and publisher of international standards, has identified energy management as a priority with significant potential to save energy and reduce greenhouse (GHG) emissions worldwide. The ISO 50001 energy management standard is an international framework for industrial plants or entire companies to manage energy, including all aspects of procurement and use.

Implementation

ISO 50001 is being developed through a project committee consisting of 35 participating countries and five observing countries. ISO 50001 will provide organizations and companies with technical and management strategies to increase energy efficiency, reduce costs, and improve environmental performance. Member countries can support the ISO development effort and identify industry leaders that are candidates for early adoption and implementation.

Expand Policy Support for Distributed Energy Systems and Combined Heat and Power

Description

The IEA's latest report on CHP identifies proven solutions that governments have used to advance CHP and district energy, setting out a practical "how-to'' guide with options to consider for design and implementation. The report concludes that these technologies require the creation of a government "champion" to identify and address market barriers (IEA 2008a).

Implementation

The IEA created the International CHP/District Heating and Cooling (DHC) Collaborative in 2007 to help evaluate global lessons learned and guide the G8 and other efforts. The CHP/DHC Collaborative will continue to assess global markets and policies for these important technologies, and provide guidance for implementation. Member countries could collaborate with this ongoing effort and identify opportunities to replicate best practices for the global community.

Coordinate the Development of Low-Carbon Supply Chain Methodologies

Description

In general, a supply chain encompasses any sequence of processes involved in the production and distribution of a product. The energy use represented by a single company in the production of a final product does not reflect the energy embodied in its supply chain. In many cases, supply chain energy consumption can be several times the energy used by a single core company. An industry may require many different materials and components produced using energy-intensive processes at outside supplier facilities.

Implementation

Member countries could work through organizations such as the International Partnership for Energy Efficiency and Collaboration (IPEEC), the IEA, and other multilateral forums to identify supply chains with large energy savings opportunity, wide reach across industries, and significant economic value. Working through existing organizations, member countries could support the establishment of establish supplier working groups to evaluate technology options and approaches to decrease the embedded energy intensity of final products.

Create Multilingual Software Tools for Analyzing Plant Energy Systems

Description

The U.S. Department of Energy and others have created numerous software tools to identify and analyze energy system savings opportunities for industrial facilities. These tools could achieve broader use and greater savings if expanded to a broader set of languages and adopted widely among the member countries.

Implementation

Member countries could collaborate on the development of multilingual, updated versions of existing software tools as well as create new software tools to allow industrial plant personnel worldwide to identify and analyze opportunities. Working through existing organizations, such as the IPEEC and IEA, member countries could develop a multi-year plan for sponsorship of the translation and distribution activities.

Provide Leadership in Industrial Energy Efficiency Management

Description

The member countries have encouraged industrial energy efficiency within their respective countries. The result is a knowledge base that, while tailored to the industrial cross-section of a particular country, can also provide valuable guidance to other countries—especially developing countries.

Implementation

There are significant opportunities to broadly expand the dissemination of information and provide education. Organizations such as the (IPEEC) are already in place and have an opportunity to build on awareness and convert to action. For example, member countries could institutionalize energy management thinking by starting at the community college/university level that would carry through to the management of industrial companies, and result in an industrial workforce trained in energy management at all levels. Other options are to promote best practices for industrial plant energy management via IPEEC and coordinate measurement standards for industrial performance.

Launch an International Industry Recognition Campaign

Description

Several government agencies in the United States recognize significant achievements of companies and organizations in partnership with government programs focusing on energy and climate. Recognition and marketing materials offer the participating companies and organizations useful tools to promote their positive actions to their stakeholders, their competitors, and the general public. Winners of recognition awards receive a high level of media attention, and recognition of accomplishments have been very well received by industry as many companies have asked how they can get awards. The recognition program may also focus on early adopters of highly efficient equipment, such as motors and boilers that can make a significant impact on energy savings.

Implementation

Member countries have several existing programs to draw upon, and multiple leading institutions, such as the World Business Council for Sustainable Development, that are potential partners for implementing a global recognition program. The member countries could scope and develop a plan for supporting and launching a recognition program.

APPENDIX A: POTENTIAL FOR KEY INDUSTRIAL TECHNOLOGIES TO REDUCE ENERGY CONSUMPTION

In the long term, development of advanced technologies should be pursued with the goal of achieving a significant reduction between current energy use and theoretical minimum requirements for major energy-intensive materials by 2050. This development should include high-volume materials such as steel, cement, aluminum, paper, and ethylene. Efficiency targets should be set for each of these materials. Clean sheet redesign of current process equipment offers enormous potential savings, and can be implemented as new industrial facilities are constructed.

In addition, the potential for significant infrastructure changes in industry provides another opportunity to drastically reduce industrial carbon emissions. Transformational developments in next-generation manufacturing concepts hold great promise for revolutionary advances in energy efficiency and carbon abatement.

To successfully reach this long-term goal, the public and private sectors must take action to develop the underlying science and technology solutions. Much higher levels of government funding of industrial RD&D will be required. Countries should aspire to provide sustained commitments that significantly increase RD&D funding for industrial energy efficiency technology compared to existing levels.

FUTURE ADVANCEMENTS THROUGH TRANSFORMATIONAL R&D

Substantial investment is needed in high-risk R&D that can offer enormous benefits, if successful. A few promising technology options are highlighted below.

Computational Technology: Process simulation enables more effective design and operation, leading to increased efficiency and improved productivity and product quality. Integrated modeling of fundamental physical and chemical properties can enhance understanding of industrial material properties and chemical processes.

Advanced Industrial Materials: Research on advanced materials can reduce energy requirements and emissions in most industries. Characterization of materials at the nanoscale can lead to engineered materials with improved functionality.

Nanotechnology and Nanomanufacturing Systems: Researchers and developers must be able to scale up the production of promising nanostructures to a commercially useful scale without losing their unique and valuable properties. Potential products include: low-friction materials, anti-fouling surfaces, highly selective separation membranes, and low-cost, effective catalysts for chemical manufacturing.

Suggested elements of a successful technology development program include the following:

- Developing technology roadmaps
- Strengthening technology R&D programs
- Strengthening basic research contributions
- Enhancing opportunities for partnerships
- Increasing international cooperation
- Supporting cutting-edge technology demonstrations

- Ensuring a viable technology workforce of the future
- Providing a supporting technology policy framework.

Two key technologies are:

- Motor systems
- Boiler, steam systems, and CHP

Other significant opportunities are found in reactions and separations used by the chemical, petrochemical, and food processing industries, and in process heating systems used in the metal and mineral industries.

Motor Systems

According to the IEA, motor-driven equipment accounts for approximately 15% of total manufacturing final energy use and 60% of manufacturing final electricity use worldwide. Motor systems are made up of a range of components centered on a motor-driven device such as a compressor, pump or fan. Motor systems lose an average 55% of their input energy before reaching the process or end-use work. Based on worldwide experience, it is estimated that industries can cost-effectively reduce the electricity use of motor systems by 20–25%, although the potential will vary from plant to plant.

High-efficiency motors use better quality materials, are made more precisely and are about 85–96% efficient, depending on size. Premium efficiency motors are the most energy efficient motors widely available today. Although the cost of a high efficiency motor is 10–25% more than a standard motor, motor energy losses decrease by 20–30%.

IEA estimates the potential opportunity of 2.6 EJ/year in final energy savings worldwide, also resulting in 340–750 Mt of CO_2 abatement on a primary energy basis (IEA 2007). McKinsey indicates that motor system improvements are highly attractive. On their cost curve for the chemical industry, the average savings are estimated at €50–60 per tonne CO_2 abated (McKinsey 2009a)

Boilers, Steam Systems, and Combined Heat and Power

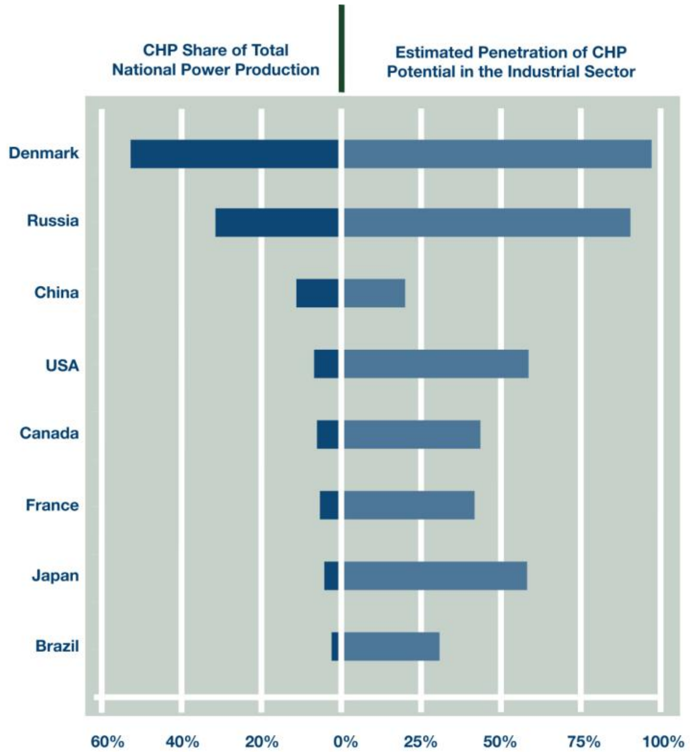
Steam is used extensively as a means of delivering energy to industrial processes, and accounts for about 38% of final industrial energy demand (IEA 2007). Steam holds a significant amount of energy on a unit mass basis that can be extracted as mechanical work through a turbine or as heat for process use. Steam is also used to control temperatures and pressures during chemical processes, strip contaminants from process fluids, dry paper products, and serve as a source of hydrogen for steam methane reforming in chemical and petroleum refining applications. For steam systems, the losses are also significant, with an estimated 45% of the input energy lost before the steam reaches point of use (DOE 2004). The efficiency of a steam system can also be increased through the application of best practices or by replacing the steam boiler with a heat pump in case low temperature heat is needed. Higher efficiency boilers currently under development and demonstration also offer the promise of higher efficiencies.

Experience with well-managed industrial facilities in OECD countries indicates that there is an opportunity to improve energy efficiency by 10%. The IEA estimates the potential opportunity at 1.5 to 2.5 EJ/year of final energy savings worldwide and 110 to 180 Mt CO_2 (IEA 2007).

A good option for improving the energy efficiency of a steam system is through a CHP system. CHP, also known as cogeneration, has been used for more than a century at industrial and municipal sites around the world. CHP is used in industries that have high and relatively constant steam and electric demand, as well as access to byproduct or waste fuels.

CHP is the sequential or simultaneous generation of multiple forms of useful energy (usually mechanical and thermal) in a single, integrated system. CHP systems consist of a number of individual components—prime mover (heat engine), generator, heat recovery, and electrical interconnection. CHP is not a single technology, but a group of technologies that can use a variety of fuels to provide reliable electricity, mechanical power, or thermal energy at a factory, university campus, hospital, or commercial building—wherever the power is needed. The type of equipment that drives the overall system typically identifies the CHP system. Prime movers for industrial CHP systems include steam turbines, gas turbines, combined-cycle systems and reciprocating engines, as well as microturbines and fuel cells for smaller systems. These prime movers are capable of burning a variety of fuels including natural gas, coal, oil, and biomass or waste fuels to produce shaft power or mechanical energy. Although mechanical energy from the prime mover is most often used to drive a generator to produce electricity, it can also be used to drive rotating equipment, such

FIGURE 5. CHP SHARE OF TOTAL POWER PRODUCTION AND CURRENT PENETRATION OF INDUSTRIAL CHP
(Share of Estimated Potential for Select Countries)



Source: IEA 2006 and IEA 2008a

as compressors. Thermal energy from the system can be used in direct process applications (e.g., process heating, drying) or indirectly to produce steam, hot water, hot air for drying, or chilled water for process cooling.

CHP microturbines and fuel cells offer promise for small-scale industrial applications that have not previously used CHP. For traditional CHP-using sectors, research is contributing to increased efficiencies and new applications. While the traditional method of separately producing usable heat and power has a typical combined efficiency of 45%, CHP systems can operate at efficiency levels as high as 80%. The IEA estimates the potential opportunity at 2–3 EJ/year of final energy savings worldwide and 110–170 Mt CO_2 (IEA 2007). The opportunity for CHP varies considerably by country. Figure 5 (above) shows the proportion of power production using CHP and the penetration of CHP technology against the estimated potential within the industrial sector for several countries.

APPENDIX B: INTERNATIONAL INDUSTRIAL EFFICIENCY DEPLOYMENT COLLABORATIONS

Multilateral collaborations with specific industrial initiatives include the IEA—a research-based institution that provides policy recommendations for cross-segment industrial energy efficiency—and UNIDO, which focuses specifically on efforts that can be applied across SME industry segments for energy efficiency and sustainability. Other collaborations exist that are either specific to certain industries or more regional in nature.

Key Multilateral Collaborations with Specific Industrial Initiatives

IEA Industrial Energy-Related Technologies and Systems (IETS)

Formed in 2005, the Industrial Energy-Related Technologies and Systems implementing agreement (IETS) is an 11-member program that fosters cooperation among OECD and non-OECD countries to accelerate research and technology development of cross-segment, sustainable, industrial-related energy technologies. This group focuses on sharing experiences and technologies for energy-intensive processes used across multiple industrial segments. Examples of such processes include biorefining, drying and dewatering, membrane separation, and separation systems. Members create Implementing Agreements (IAs) in order to cooperate on specific research and demonstration projects and gain knowledge from project results. IEA also works with the International Standards Organization (ISO) to promote international standards development for industrial energy efficiency. The MEF members belonging to this group are Belgium, Brazil, Canada, Denmark, Finland, Korea, The Netherlands, Norway, Portugal, and the United States (IEA 2008d).

United Nations Industrial Development Organization (UNIDO)

UNIDO Environment and Energy priority provides policy and partnership expertise and technology transfer services across industries with a focus on Energy Management Standards, process improvements for SMEs and improvements to motor, steam, and pressurized air systems (Gielen 2009). In addition to project development, UNIDO facilitates multilateral agreements on environmental initiatives as part of several Millennium Development Goals (MDGs). Within the knowledge and technology transfer realm, US$100 million in projects have been initiated. UNIDO is also an executing agency for the Global Environment Facility (GEF). UNIDO has 173 members, including all MEF members except Canada and classifying the European Union as a partner (UNIDO 2007).

General Collaborations that Include Industrial Energy Efficiency

Asia-Pacific Partnership on Clean Development and Climate (APP)

The Asia-Pacific Partnership on Clean Development and Climate (APP) created specific task forces through which collaborative projects are undertaken, including identification of best-practices in clean development and energy efficiency in the aluminum, cement, and steel industries. APP activities include workshop facilitation, best-practice sharing, compilation of data and performance indicators, and development of deployment projects. Australia, Canada, China, India, Japan, Korea, and the United States are members of the APP.

International Partnership for Energy Efficiency Cooperation (IPEEC)

Formed by the G8 Energy Ministers and Brazil, China, India, Mexico, and Korea in 2009, this organization addresses energy efficiency at a high level. The declaration states that "the purpose of the International Partnership for Energy Efficiency Cooperation is to facilitate those actions that yield high energy efficiency gains. Participants in the Partnership choose to take action in the areas of their interest on a voluntary basis." Industrial processes are mentioned as part of the best-practices information sharing, but not as an explicit priority (IPEEC 2009). IPEEC has 11 members, including all MEF members except Australia, Indonesia, and South Africa.

International Cooperation on Energy Efficiency: Working Together for a Low-Carbon Economy—IEA and the United Nations Economic Commission for Europe

This is a recent agreement consisting mainly of a 2008 conference and an agreement on priorities from the IEA, UNECE, and the Energy Charter Secretariat. The Energy Charter Secretariat leads The Energy Charter. The UN/IEA created a Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA), which requires members to pursue policy actions that improve energy efficiency and reduce negative environmental impact of the energy cycle. In addition to sharing practices among members, experts, and international organizations, specific strategies are targeted for analysis, such as taxation, energy-pricing policy, environmental-related subsidies, and other financial incentives. The Energy Charter began in 1991 in order to establish multilateral agreements between nation states to mitigate risks and create a level playing field for energy exporters and importers. Fifty-three member states have signed or acceded to the Energy Charter Treaty and the PEEREA. Of the 53 members, eight MEF countries and the European Community are members or signatories of PEEREA.

World Business Council for Sustainable Development (WBCSD)

While not focused specifically on industry, case studies in industry are included and WBCSD facilitates specific projects centered on energy use and CO_2 emissions in the cement industry. Under its Energy & Climate Focus Area, WBCSD gathers case studies and shares best practices and performance data on energy efficiency efforts around the world. Companies from all non-European MEF countries and many European Union countries are represented in WBCSD.

World Energy Council (WEC)

The World Energy Council (WEC) convenes a Program Committee on Energy Efficiency Policies and Indicators. This committee surveys and evaluates energy efficiency trends and policies worldwide, including industrial areas. Additionally, regional programs are managed focusing on deployment activities and best-practice identification and promotion. These may or may not be industrial projects. Ninety-three countries belong to WEC, including all MEF members.

Specific Industrial Sector Collaborations

International Aluminum Institute

The International Aluminum Institute (IAI) comprises 25 members responsible for 80% of world primary aluminum products. IAI includes an Aluminum for Future Generations Sustainability initiative that includes a goal of "10% reduction in average smelting energy usage by IAI Member Companies per tonne of aluminum produced by 2010 versus 1990." This goal requires standard reporting by the members and includes information sharing (IAI 2009). Aluminum producers having concerns in all MEF countries are members of this organization.

IEA's Cogenerated Heat and Power (CHP)/District Heating and Cooling (DHC) Collaborative

Focusing on low-carbon solutions, the CHP/DHC Collaborative assesses global markets and policies and produces data on current installations, assesses technology growth potentials for key markets, and documents best practice policies, offering insights to policymakers and industry seeking to advance these low-carbon solutions. IEA created the International CHP/DHC Collaborative to help evaluate global lessons learned and guide the G8 and similar efforts. The G8 directed that, "IEA will advise on alternative energy scenarios and strategies aimed at a clean, clever and competitive energy future" (IEA 2009b). IEA's 28 country membership includes most MEF countries, except Brazil, China, India, Indonesia, Mexico, Russia, and South Africa. Industrial partners have concerns in hundreds of states, including all the MEF countries.

World Steel Organization

The World Steel Organization addresses environmental concerns that include energy efficiency mainly through benchmarking, goal setting and reporting, and sharing of best practices. Over 50 steel companies have signed a 2008 policy on sustainable development that includes commitments to optimizing the "eco-efficiency of our products through the product life cycle, including increased resource and energy efficiency in the production of steel and during the use of steel products." Steel companies or associations having concerns in all MEF countries are members of this organization. Regular members are commercial steel producers or "market-based" steel producers of at least two million short tons of steel per annum. Other associations, smaller and state companies, and steel-related organizations can become affiliate or associate members (World Steel Organization 2009).

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