UNIDO

Reducing poverty
through sustainable industrial growth

40 YEARS OF SERVICE TO MANKIND 1966 2006

Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economies

Background Paper for the UNIDO Side Event on Sustainable Industrial Development on 8 May 2007 at the Commission for Sustainable Development (CSD-15)

Prepared for UNIDO by:
Aimee McKane, Lynn Price, Stephane de la Rue du Can
Lawrence Berkeley National Laboratory

Acknowledgements

We would like to express our appreciation to the following individuals for their contributions to this paper:
Erik Gudbjerg, Lokalenergi
Klaas Jan Kramer, Lawrence Berkeley National Laboratory visiting researcher
Wayne Perry, Kaeser Compressors
Paul Scheihing, US Department of Energy
Robert Williams, United Nations Industrial Development Organization

Special thanks to Bunmi Adesola of Lawrence Berkeley National Laboratory for her work editing this paper.

Table of Contents

Executive Summary **1**

1. Introduction **5**

2. Overview of Industrial Sector Trends **8**

2.1 Economic Development Trends 8

2.2 Commodity Production Trends 9

2.3 Energy Consumption Trends 11

2.3.1 Historical and Projected Industrial Sector Energy Consumption Trends 11

2.3.2 Historical and Projected Industrial Sector Energy-Related CO_2 Emissions 13

2.3.3 Developed Countries Trends 15

2.3.4 Developing Countries and Transition Economies Trends 16

3. Industrial Energy Efficiency **19**

3.1 Opportunities for Industrial Energy Efficiency 20

3.2 Barriers to Industrial Energy Efficiency Improvement 24

4. Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economies **27**

4.1. Overview – Industrial Standards Framework 27

4.2 Target-Setting Agreements 30

4.2.1 Examples of Successful Target-Setting Agreement Programs 30

4.2.2 Key Program Elements of Target-Setting Programs 32

4.3 Energy Management Standards 38

4.3.1 Supportive Policies and Programs 42

4.4 System Optimization and Capacity Building 47

4.4.1 Building Technical Capacity 47

4.5 Documenting for Sustainability 49

4.5.1 Documentation and ISO 9000/14000 49

4.5.2 Systems Optimization Library 51

4.6 Recognition Programs, Tax and Fiscal Policies, and Carbon Offset Programs 52

4.6.1 Recognition Programs 52

4.6.2 Tax and Fiscal Policies 52

4.6.3 Potential Links to Carbon Offset Programs 59

5. Policy Recommendations **61**

5.1 Getting Started with Target-setting Agreements 61
5.2 Establishing an Energy Management Standard 63
5.3 Capacity Building through Training Experts and Suppliers 64
5.4 Building Industrial Awareness 65

6. Conclusions 67

7. References 70

Appendix 1. Ten World Regions 83

Figures and Tables

Figure 1. Global Production Trends of Seven Energy-Intensive Industrial Commodities.... 10
Figure 2. Historical Industrial Sector Energy Consumption by Major World Region 12
Figure 3. Historical and Projected Industrial Sector Primary Energy, 1971-2030 (EJ) 13
Figure 4. Historical CO_2 Emissions in the Industrial Sector by Region 14
Figure 5. Historical and Projected Industrial Sector CO_2 Emissions, 1971-2030 (MtC) 14
Figure 6. Final Energy Use by Manufacturing Sub Sector in IEA-11 15
Figure 7: Optimizing a Motor System 22
Figure 8: Industrial Standards Framework 28
Figure 9: Energy Management Diagram.. 39

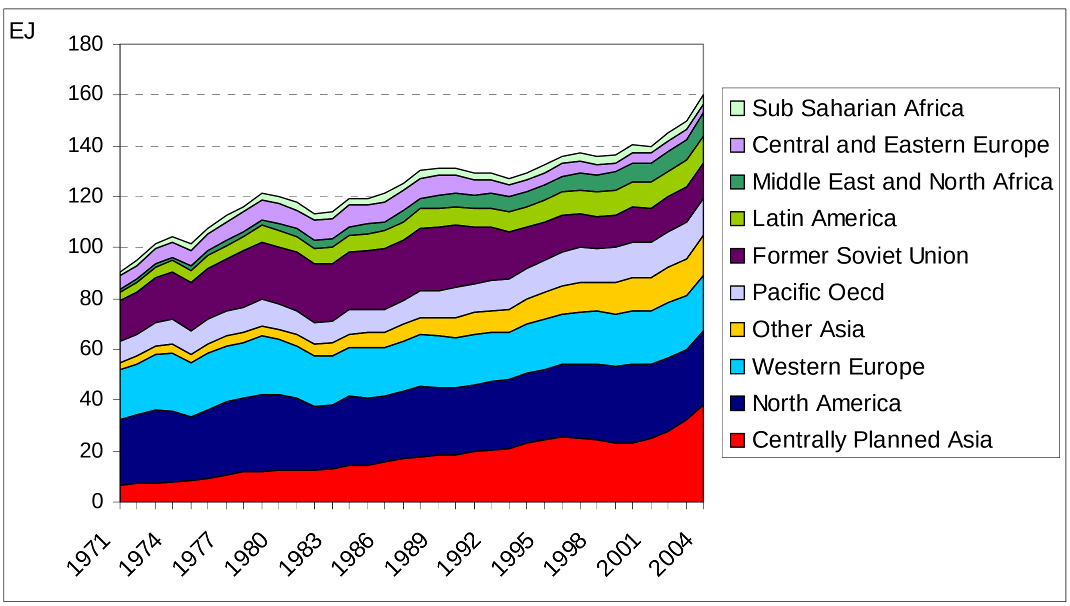
Table 1. Share of Sector GDP by National Income Level 8
Table 2. Primary Industrial Sector Energy Use of Largest Developing Countries and Transition Economies 16
Table 3. Economic Statistics of Key Developing and Transition Economies 17
Table 4. Key Elements of the Industrial Standards Framework 29
Table 5. Energy Management Standards, Details 41
Table 6. Energy Management Standards, Programmatic Context 42
Table 7. Energy Savings from System Improvements (China pilot program) 48

Executive Summary

The industrial sector represents more than one third of both global primary energy use and energy-related carbon dioxide emissions (Price et al., 2006). In developing countries, the portion of the energy supply consumed by the industrial sector is frequently in excess of 50% and can create tension between economic development goals and a constrained energy supply. Further, countries with an emerging and rapidly expanding industrial infrastructure have a particular opportunity to increase their competitiveness by applying energy-efficient best practices from the outset in new industrial facilities.

Figure E1 provides historical primary energy consumption in the industrial sector for ten world regions from 1971 to 2004. Primary energy consumption in the industrial sector grew from 89 EJ in 1971 to 160 EJ in 2004 (Price et al., 2006). Primary energy consumption in developing countries grew at an average annual rate of 4.9% per year over this time period[1] Industrialized countries experienced much slower average growth of 0.6% per year, while primary energy consumption for industry in the countries that make up the former Soviet Union and Eastern and Central Europe declined at an average rate of -0.5% per year.

Figure E1: Historical Primary Industrial Sector Energy Consumption by Major World Region



Source: Price et al., 2006

Despite the potential, policy makers frequently overlook the opportunities presented by industrial energy efficiency to have a significant impact on climate change mitigation, security of energy supply, and sustainability. The industrial sector is extremely diverse and

[1] Developing countries include the region of Centrally Planned Asia, Other Asia, Latin America, Sub Saharan Africa, and Middle East/N. Africa. Developed Countries include Pacific OECD, North America, and Western Europe. Transition economies include Central/E. Europe and Former Soviet Union.

includes a wide range of activities. This sector is particularly energy intensive, as it requires energy to extract natural resources, convert them into raw materials, and manufacture finished products. The common perception holds that energy efficiency of the industrial sector is too complex to be addressed through public policy and, further, that industrial facilities will achieve energy efficiency through the competitive pressures of the marketplace alone.

The principal business of an industrial facility is production, not energy efficiency. This is the underlying reason why market forces alone will not achieve industrial energy efficiency on a global basis, "price signals" notwithstanding. High energy prices or constrained energy supply will motivate industrial facilities to try to secure the amount of energy required for operations at the lowest possible price. But price alone will not build *awareness* within the corporate culture of the industrial firm of the potential for energy savings, maintenance savings, and production benefits that can be realized from the systematic pursuit of industrial energy efficiency. It is this lack of awareness and the corresponding failure to manage energy use with the same attention that is routinely afforded production quality, waste reduction, and labor costs that is at the root of the opportunity.

Companies that have made the shift in organizational culture required to effectively manage energy report many benefits in cost savings, productivity, and operational efficiency. Results reported and documented by multi-national companies with company-level target-setting programs and energy management programs are impressive. Dow Chemical set a target to reduce energy intensity (btu/lb product) from 1994-2005 by 20% and actually achieved 22% ($4B in savings); their energy intensity reduction goal for 2005 to 2015 is 25%. 3M Corporation has reduced its corporate energy consumption by 30% since 2000 through its global energy management program. DuPont has achieved $2B in energy savings since 1990 as part of a corporate goal to achieve a 65% reduction in GHG emissions below 1990 levels by 2020.

Because industrial production is so closely linked to economic growth and prosperity, energy efficiency policy is accompanied by some inherent, although entirely manageable, risk. Industrial energy efficiency is dependent on operational practices, which change in response to variations in production volumes and product types.

The key to effective industrial energy efficiency policy is consistency, transparency, engagement of industry in program design and implementation, and, most importantly, allowance for flexibility of industry response. When these criteria are met, industry has shown that it can exceed expectations as a source of reductions in energy use and corresponding GHG emissions, while continuing to prosper and grow.

This paper presents a portfolio of policy options under the organizing structure of the *Industrial Standards Framework* that meet these criteria. The Industrial Standards Framework proposes a link between International Organization for Standardization (ISO) 9000/14000 quality and environmental management systems and industrial energy efficiency. The Industrial Standards Framework includes:

- target-setting agreements,

- an energy management standard,
- system optimization training and tools,
- capacity building to create system optimization experts, now and in the future,
- a System Optimization Library to document and sustain energy efficiency gains, and
- tax incentives and recognition.

In addition, the Framework could accommodate:
- standardized system optimization methodologies
- certification of energy efficiency projects for trading energy efficiency credits

The purpose of the Framework is to introduce a standardized and transparent methodology into industrial energy efficiency projects and practices including: system optimization, process improvements, waste heat recovery and the installation of on-site power generation. The Framework builds on existing knowledge of "best practices" using commercially-available technologies and well-tested engineering principles. This paper presents numerous examples of successful implementation of elements of the Framework in both developed and developing countries.

Assessments of cost-effective efficiency improvement opportunities in energy-intensive industries in the United States, such as steel, cement, and paper manufacturing, found cost-effective savings of 16% to 18% (Martin et al., 1999, 2000a; Worrell, et al., 2001); even greater savings can often be realized in developing countries where old, inefficient technologies have continued to be used to meet growing material demands (Price et al., 1999; Price et al., 2002; Schumacher and Sathaye, 1999; WEC, 2004).

Within industry, systems that support industrial processes can be found to varying degrees in virtually all industrial sectors, regardless of their energy intensity. These *industrial systems*, which include compressed air, pumping, and fan systems (referred to collectively as motor systems), steam systems, and process heating systems are integral to the operation of industrial facilities, providing essential conversion of energy into energized fluids or heat required for production processes. Motor and steam systems account for 15% and 38%, respectively, of global final manufacturing energy use, or approximately 46 EJ/year. Optimizing industrial systems has a cost-effective improvement potential of 20% or more for motor systems and 10% or more for steam and process heating systems (DOE 2004a).

System optimization offers a way for companies to quickly realize cost, productivity, and operational benefits that can provide the reinforcement needed for management to proceed with the organizational changes required to fully integrate energy efficiency into daily operational practices. Capacity-building training creates a cadre of highly skilled system optimization experts that can provide the necessary technical assistance for industrial facilities to identify and develop energy efficiency improvement projects. A "train the trainer" approach can quickly create greater awareness of the opportunities for energy efficiency, thus addressing a principal barrier. This capacity can continue to provide benefits to industry for many years. After more than a decade of capacity-building, experts trained by the US DOE continue to identify millions of dollars in system optimisation improvement opportunities year after year. In 2005 alone, the Save Energy Now initiative documented 55

PJ in energy savings in the first 200 plant assessments, or $475 million in cost savings. Many of the recommended improvements had paybacks of less than 2 years.

With the renewed interest in energy efficiency worldwide and the emergence of carbon trading and new financial instruments such as white certificates, there is a need to introduce greater transparency into the way that industrial facilities identify, develop, and document energy efficiency projects. The System Optimization Library will standardize and streamline the process of developing and documenting energy efficiency improvement projects. By providing work instructions to support the new, more energy efficient operation, the Library will also increase the likelihood that the resulting energy savings would be sustained.

Taken together, the elements of the Industrial Standards Framework comprise an effective industrial policy package that combines energy reduction targets, energy efficiency standards, system optimization training, and documenting for sustainability. As described in this paper, there are well-documented opportunities for cost-effective energy reduction on the order of 18-20% or more, while reducing industry's CO_2 emissions by 20-33% (IEA, 2007). The time to take action so that industrial energy efficiency becomes "business as usual" is now.

1. Introduction

The industrial sector represents more than one third of both global primary energy use and energy-related carbon dioxide emissions (Price et al., 2006). Industrial motor systems alone are responsible for 7% of global electrical usage (IEA, 2006). In developing countries, the portion of the energy supply consumed by the industrial sector is frequently in excess of 50% and can create tension between economic development goals and a constrained energy supply. Further, countries with an emerging and rapidly expanding industrial infrastructure have a particular opportunity to increase their competitiveness by applying energy-efficient best practices from the outset in new industrial facilities. For example, 80% of global industrial growth in over the past ten years has been in China (IEA, 2007). Including for energy efficiency, as part of the initial design or substantial redesign, is generally less expensive and allows for better overall results than retrofitting existing industrial facilities, as is typically required in more developed countries.

Despite this potential, policy makers frequently overlook the opportunities presented by industrial energy efficiency to have a significant impact on climate change mitigation, security of energy supply, and sustainability. The common perception holds that energy efficiency of the industrial sector is too complex to be addressed through public policy and, further, that industrial facilities will achieve energy efficiency through the competitive pressures of the marketplace alone. Neither premise is supported by the evidence from countries that have implemented industrial energy efficiency programs. The opportunities for improving the efficiency of industrial facilities are substantial, on the order of 20-30% (IEA 2007), even in markets with mature industries that are relatively open to competition.

Energy use in industry differs from energy use in the commercial and residential buildings sectors in several important ways. First, there is the scale of use - industrial facilities are very large individual users of energy relative to commercial or residential customers. These facilities are typically among an energy provider's largest customers and use their purchasing power to get the lowest available price for delivered energy supply. Second, industrial facilities may generate waste (i.e., bagasse, wood scraps or fiber) that can be used for onsite generation to replace some or most of purchased energy. The high level of use tends to reinforce attention to price and availability of supply; with only so much staff-time available for non-production issues, there may be little time to attend to energy efficiency.

Third, energy use in industry is much more related to operational practices than in the commercial and residential sectors. If energy efficient lighting or appliances are installed in a commercial or residential building, those devices supply the same level of service at a reduced energy use without any further intervention from the user. By way of contrast, an industrial facility may change production volumes or schedules, and/or the type of product manufactured, many times during the useful life of the factory. While it is generally true that installation of a more energy-efficient process will result in substantial energy savings over the life of the process, the same cannot be said for the systems that support production, such as compressed air, fans, motor/drives, pumping, steam, and process heating. These energy-using systems may be relatively energy efficient at first, but typically degrade over time, due to changes in production and/or maintenance issues. The presence of energy-efficient components, while important, provides no assurance that an industrial system will be energy-efficient. In fact, the misapplication of energy-efficient equipment in industrial systems is common. The disappointing results from these misapplications can provide a serious disincentive for any subsequent effort to achieve greater energy efficiency.

Example 1.1: Industrial System Energy Efficiency in the United States

A study of 41 completed industrial system energy efficiency improvement projects completed in the US between 1995 and 2001 documented an average 22% reduction in energy use. In aggregate, these projects cost $16.8 million and saved $7.4 million and 106 million kWh, recovering the cost of implementation in slightly more than two years [(Lung et al., 2003)).

A more recent series of three-day steam and process heating assessments conducted in 2006 at 200 industrial facilities by the US Department of Energy, identified a total of $485 million dollars in annual energy savings and 55 petajoules (PJ) of annual natural gas savings, which, if implemented, will reduce US annual carbon dioxide emissions by 3.3 million tons. Six months after their assessments, 71 plants had reported almost $140 million worth of energy savings recommendations either completed, underway or planned (U.S. DOE, 2007a).

Because industrial production is so closely linked to economic growth and prosperity, energy efficiency policy is accompanied by some inherent, although entirely manageable, risk. As previously noted, the needs of industry differ in significant ways from the residential, commercial, or governmental sectors. Failure to recognize those needs can result in policies that fall well short of their potential or, at worst, impede economic growth. The key to effective industrial energy efficiency policy is consistency, transparency, engagement of industry in program design and implementation, and, most importantly, allowance for flexibility of industry response. When these criteria are met, industry has shown that it can exceed expectations as a source of reductions in energy use and corresponding GHG emissions, while continuing to prosper and grow.

Example 1.2: Target Setting Agreements in the United Kingdom

The UK Climate Change Program was established in 2000 to meet both the country's Kyoto Protocol commitment of a 12.5% reduction in GHG emissions by 2008-2012 relative to 1990, and the domestic goal of a 20% CO_2 emissions reduction relative to 1990 by 2010 (DEFRA, 2000). A key element of the Climate Change Program is the Climate Change Levy, which is an energy tax applied to industry, commerce, agriculture, and the public sector. Certain companies can also participate in Climate Change Agreements (CCAs). There are 44 sector agreements representing about 5,000 companies and 10,000 facilities. The goal of the CCAs is to reduce carbon dioxide emissions by 2.5 MtC (9.2 $MtCO_2$) by 2010, which is ten times the estimated savings from the Climate Change Levy without the agreements. During the first target period (2001-2002) total realized reductions were three times higher than the target for that period (Pender, 2004). Sectors did better than expected because industry underestimated what they could achieve via energy efficiency. Industry realized total reductions that were more than double the target set by the government during the second target period (Future Energy Solutions, 2005).

The principal business of an industrial facility is production, not energy efficiency. This may seem painfully obvious, but it is the underlying reason why market forces alone will not achieve industrial energy efficiency on a global basis, “price signals” notwithstanding. High energy prices or constrained energy supply will motivate industrial facilities to try to secure the amount of energy required for operations at the lowest possible price. It may also motivate an industrial facility to investigate options for onsite power production, especially using production waste or excess steam capacity. But price alone will not build *awareness* within the corporate culture of the industrial firm of the potential for energy savings, maintenance savings, and production benefits that can be realized from the systematic pursuit of industrial energy efficiency. It is this lack of awareness and the corresponding failure to manage energy use with the same attention that is routinely afforded production quality, waste reduction, and labor costs that is at the root of the opportunity.

Industry is motivated to take actions that improve energy efficiency for a variety of reasons, including, but not limited to:

- Cost reduction;
- Improved operational reliability and control;
- Improved product quality;
- Reduced waste stream;
- Ability to increase production without requiring additional, and possibly constrained, energy supply;
- Avoidance of capital expenditures through greater utilization of existing equipment assets;
- Recognition as a “green company”; and
- Access to investor capital through demonstration of effective management practices.

However, unless an industrial facility is made aware of the potential for energy efficiency, none of these factors has significance. Oftentimes, facility managers have no knowledge of these opportunities.

Section 2 of this paper provides an overview of trends in industrial sector energy use, including a more in-depth treatment of several countries. Section 3 is a discussion of the current status of industrial energy efficiency practices at both the sector and system level. Section 4 is dedicated to a review of selected energy efficiency policy instruments and examples of their application in industry in both developed and developing countries. Section 5 offers recommendations for a public policy portfolio that combines the most efficacious policy instruments in a coordinated approach to developing sustainable and energy-efficient industries in both developing countries and transition economies. Section 6 offers some conclusion regarding industrial energy efficiency policy.

2. Overview of Industrial Sector Trends

The industrial sector uses 160 exajoules (EJ) of global primary energy, which is about 37% of total global energy use. Primary energy includes upstream energy loses from electricity, heat, petroleum and coal products production (Price et al., 2006).[2] The industrial sector is extremely diverse and includes a wide range of activities. This sector is particularly energy intensive, as it requires energy to extract natural resources, convert them into raw materials, and manufacture finished products. The industrial sector can be broadly defined as consisting of energy-intensive industries (e.g., iron and steel, chemicals, petroleum refining, cement, aluminium, pulp and paper) and light industries (e.g., food processing, textiles, wood products, printing and publishing, metal processing). The aggregate energy use depends on technology and resource availability, but also on the structure of the industrial sector. The share of energy-intensive industry in the total output is a key determinant of the level of energy use.

2.1 Economic Development Trends

Historical trends show that the importance of industry within an economy varies by its stage of economic development. Table 1 shows the economic structure, expressed in terms of value added, for countries grouped by level of income (lower, middle and high income countries). Lower income countries have a higher share of agriculture output in their total GDP than more developed countries. Middle income countries have a higher share of industrial sector output, while high income countries have the highest share of service sector output. The share of industrial sector output tends to increase with income up to a certain level and then decrease as economies become more service-based at a higher level of income.

Table 1. Share of Sector GDP by National Income Level

	Income		Population		GDP		Agriculture		Industry		Services	
	$ per capita		Share of world total		Share of world total		% of national GDP		% of national GDP		% of national GDP	
	1990	2004	1990	2004	1990	2004	1990	2004	1990	2004	1990	2004
Low income	346	529	34%	37%	3%	3%	**32%**	**23%**	26%	28%	42%	49%
Middle income	1,251	2,372	49%	47%	15%	17%	16%	10%	**39%**	**37%**	46%	53%
High income	19,798	32,762	17%	16%	82%	80%	3%	2%	33%	26%	**65%**	**72%**

Source: WB, 2006.

Note: Values in bold represent the income level with the higher share of output as a % of GDP. The country composition of regions is based on the World Bank's analytical regions.

[2] In this paper, we define primary energy as the energy used on-site plus the energy used to produce purchased electricity and other fuels. Factors for converting from on-site energy consumption to primary energy for ten world regions were developed based on International Energy Agency statistics and reported in Price et al., 2006. The use of primary energy allows for a better comparison accounting for the full energy demand of the industrial sector.

The structure of the industrial sector varies between countries and their level of development since the materials demanded by an economy differ through successive stages of development (Cleveland and Ruth, 1999; Gronenberg, 2005). Industrialization drives an increase in materials demand for construction of basic infrastructure needs such as roads, railways, buildings, power grids, etc. As development continues, the need for basic infrastructure declines and consumer demand shifts increasingly towards services. China's industrial energy demand provides an example of an economy consuming a large quantity of energy to supply its growing industrial activity. China's industrial sector energy consumption accounted for over 60% of total energy consumption in 2000 (Zhou, 2006) with the iron and steel and cement industries constituting the largest energy users, accounting for 15% and 14% respectively. Even though these general trends can be observed, economic development trends vary by country and there is no standard development path. India, for example, has a very high share of the service sector, accounting for 51% of total value added; even so, the industrial sector continues to grow, particularly in material production (MOSPI, 2007).

2.2 Commodity Production Trends

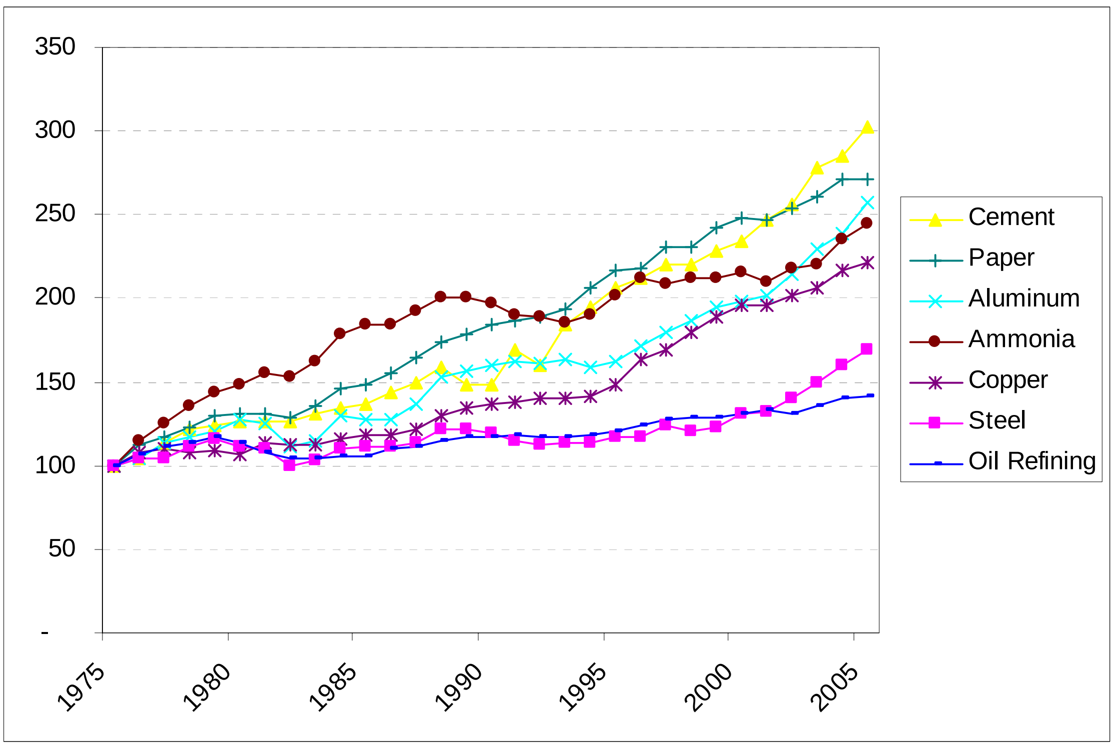
A closer look at some of the major energy-intensive industrial material production trends allows for a better understanding of energy consumption in the industrial sector and potential opportunities for energy savings. In general, production of energy-intensive commodities is declining or stable in most industrialized countries and is growing in most developing countries as infrastructure and housing are being constructed. For example, between 1975 and 2002, production of steel declined at an average rate of -0.8% per year in the US, while growing at a rate of 10.4% per year in China (UN, 2005a; USGS, 2007e). Energy-intensive industries account for more than half of the industrial sector's energy consumption in many developing countries (Dasgupta and Roy, 2000; IEA, 2003a; IEA, 2003b).

Figure 1 shows the trend in global production of seven energy-intensive products from 1975 to 2005. Global cement production tripled over the last 30 years, largely due to the impressive growth of production in China (USGS, 2007a). In 2005, China produced 45% of the world's cement, 20 times more than what it produced in 1975 (USGS, 2007a, UN, 2005a). The second largest world cement producer is India, with 6% of total production, followed by the US with 4% and Japan with 3%. The rising share of production in China and India is mostly used domestically, with only 2% and 4%, respectively, of the cement exported (UN, 2007b).

Growth in the paper industry production is dominated by developed countries, where consumption continues to grow with income. The US is the largest paper producer with 23% of world production, followed by China with 15% and Japan with 8% (UN FAO, 2007). Aluminium production has also grown rapidly, increase of 250% between 1975 and 2005 (USGS, 2007b). China represents the largest producer of aluminium with 23% of world production, followed by the Russian Federation with 12%. Global ammonia production increased 235% between 1975 and 2005 (USGS, 2007c), with Indonesia growing from 8,000 tons to 4.4 million tons in 2005 (UN, 2005a) and establishing itself as the 6th largest producer. Globally, China is now the world's largest producer of ammonia with 32% of world production, followed by India with 9% and the Russian Federation with 8%. Copper production grew 221% over this period, with Chile producing 35% of the world's copper, followed by the US with 8% and Peru with 7% (USGS, 2007d).

Global steel production grew 170% from 1975 to 2005, with China producing 35%, Japan 10% and the US 8%. The pattern of dematerialization is particularly well illustrated by this commodity (USGS, 2007d). Most developed countries experienced decreasing or constant production, while developing countries all experienced increasing production over the period 1975 to 2002. Finally, growth in production of refined petroleum products has been slower compared to the other commodities, but is by far the largest commodity produced globally. Between 1975 and 2005, the production growth of refined oil products increased 141%, which represents an annual average growth of 1.2% (IEA, 2006a, b). The largest producers are the US, China, and the Russian Federation.

Figure 1. Global Production Trends of Seven Energy-Intensive Industrial Commodities



Source: USGSa, b, c, d, e, 2007; FAO,2007.
Note: 1975 = 1000

Recycling rates can have a significant impact on the energy consumed for commodity production. For example, there are two main routes for the production of steel: production of primary steel using iron ore and scrap, and production of secondary steel using recycled scrap (Worrell et al., 1997). Secondary steel production uses one third of the energy required for production of steel from primary materials. However, secondary production of steel is also governed by the availability of waste steel. Developing countries produce a lower share of secondary steel since less scrap steel is available. Only after economies reach some level of steel production does scrap steel become available from their market. The share of secondary steel is equal to 4% in India and 10% in China, compared to 27% in Japan and

59% in the US (USGS, 2007e). Similarly, in the case of aluminium, the energy intensity of the sector depends on the share of secondary aluminium produced. Secondary aluminium production requires only 5% of the energy consumed in the production of primary aluminium. The share of secondary aluminium is small in developing countries compared to the US (30%) and EU (45%). In the case of the paper industry, fiber recycling is also an important factor for reducing pulping energy use. Some developing countries, such as China, import paper from other countries (notably the US and Europe) to supplement their fiber needs (Worrell, 2007). Other materials are influenced by available indigenous resources. For example, ammonia production requires feedstocks, which are generally hydrocarbons from gas or naphtha. However, coal is commonly used as a feedstock in China as coal is more abundant than other fossil fuels. Nevertheless, the production of ammonia based on coal has decreased significantly in China and has been phased out in India due to their much higher energy requirements.

2.3 Energy Consumption Trends

Energy use in the industrial sector varies widely between countries and depends principally on the level of technology used, the maturity of plants, the sector concentration, the capacity utilization and the structure of sub-sectors. Luken (2007) compares regional levels of energy use intensities in 2004 and calculates that if all developing countries met the developed country average manufacturing energy use intensity, energy consumption could potentially be reduced by 70%. This is an approximate estimation, but indicates that opportunities to reduce energy in the manufacturing sector exist and are significant in developing countries.

2.3.1 Historical and Projected Industrial Sector Energy Consumption Trends

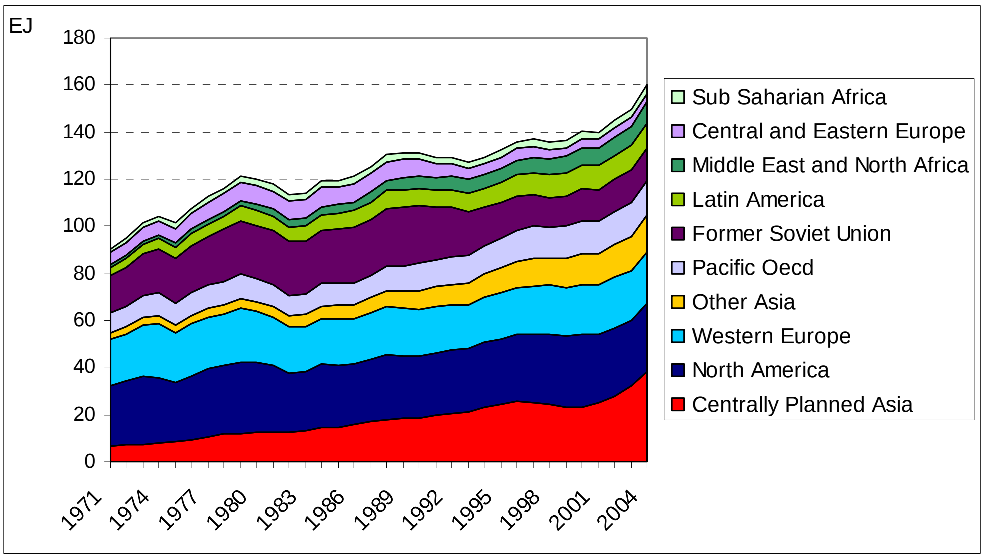
Figure 2 provides historical energy consumption in the industrial sector for ten world regions from 1971 to 2004. Primary energy consumption in the industrial sector grew from 89 EJ in 1971 to 160 EJ in 2004 (Price et al., 2006). Primary energy consumption in developing countries, which accounted for 48% of total industrial primary energy use in 2004, grew at an average annual rate of 4.9% per year over this time period [3] Industrialized countries experienced much slower average growth of 0.6% per year, while primary energy consumption for industry in the countries that make up the former Soviet Union and Eastern and Central Europe declined at an average rate of -0.5% per year.

The Centrally Planned Asia region is the largest industrial energy-consuming region, surpassing North America in 2003. Global growth in industrial energy consumption ranged between 7% and - 4%, with the declines seen in 1975 and 1982, when oil prices increased sharply. The highest growth was in 2004 with 7.1%, due mostly to a strong increase in China's industrial energy demand.

[3] Developing countries include the region of Centrally Planned Asia, Other Asia, Latin America, Sub Saharan Africa, and Middle East/N. Africa. Developed Countries include Pacific OECD, North America, and Western Europe. Transition economies include Central/E. Europe and Former Soviet Union. See Appendix 1 for a listing of which countries are in each region.

The growth in industrial energy consumption has been uneven across regions. The Middle East and North Africa region, the Centrally Planned Asia region, and the Other Asia region represent the three regions with the highest historical growth, with 6.5%, 5.5% and 5.4% average annual growth rates respectively. The growth in industrial energy consumption has been particularly impressive in the Centrally Planned Asia region with a growth rate of 7.5% in 2001, 10.9% in 2002, 16.4% in 2003 and 20.2% in 2004. Growth rates in the Other Asia and Middle East and North Africa regions were also remarkably high in 2004 - 8.3% and 7.1% respectively.

Figure 2. Historical Industrial Sector Energy Consumption by Major World Region



Source: Price et al., 2006

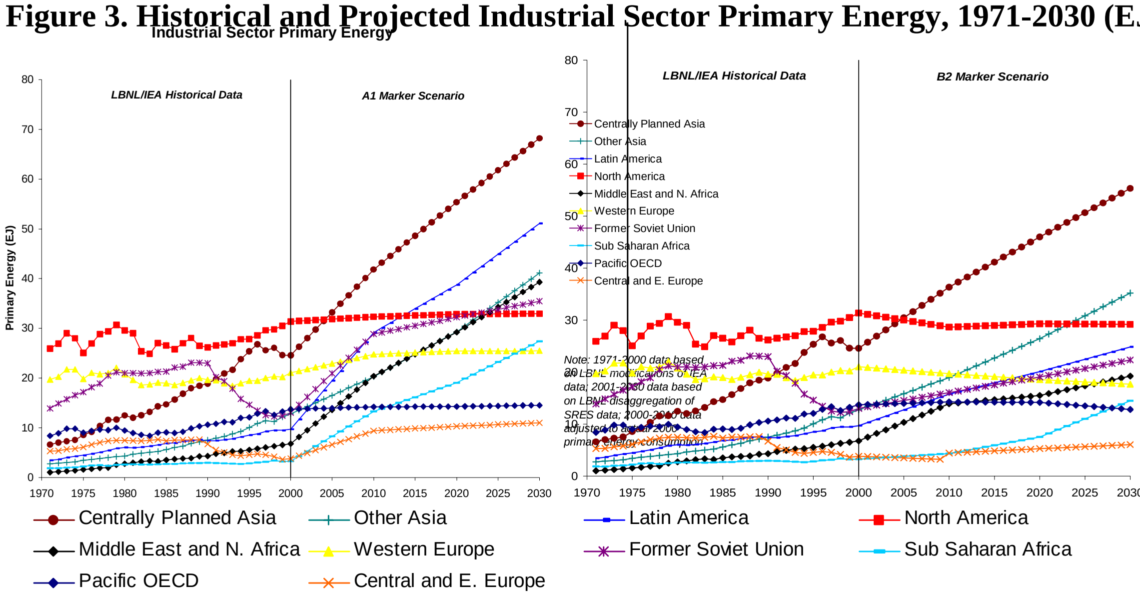
The Central and Eastern Europe, and the Former Soviet Union are the only regions with negative average industrial energy consumption growth rates of -1.0% and -0.4%, respectively, between 1971 and 2004. The decline in industrial energy consumption in these regions was particularly strong after the collapse of the Soviet Union, since many large industrial plants closed down and industrial activity slowed considerably.

The North America and Western Europe regions have both experienced fairly low average annual growth rates of 0.3% even though these two regions still represent one third of global industrial consumption. The Pacific OECD region has experienced a growth similar to the world average of 1.7%. Finally the Latin America and Sub-Saharan Africa regions had average growth of 3.4% and 2.3% respectively.

Figure 3 shows the historical and projected trends in primary energy in the industrial sector for ten world regions based on two scenarios of the Special Report on Emissions Scenarios (Nakićenović et al., 2000) published by the Intergovernmental Panel on Climate Change (IPCC) in 2000. The A1 scenario storyline describes a future of very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies. The B2 scenario storyline describes a world with an emphasis on economic, social, and environmental sustainability, especially at the local and regional levels. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change (Nakićenović et al., 2000).

Both scenarios forecast most growth to occur in the developing countries due to the energy required to fuel their growing economies. In general, the A1 scenario envisions more intensive growth in the developing countries than the B2 scenario. The Centrally Planned Asia region is the region that is expected to have the highest growth by far, reaching an energy consumption level of 68 EJ in the A1 scenario and 55 EJ in the B2 scenario by 2030.

Figure 3. Historical and Projected Industrial Sector Primary Energy, 1971-2030 (EJ)



Source: Price et al. (2006)

2.3.2 Historical and Projected Industrial Sector Energy-Related CO_2 Emissions

In 2004, global energy-related CO_2 emissions from the industrial sector were approximately 10 Gt of CO_2, which represented 37% of global CO_2 emissions (Price et al., 2006) (see Figure 4).[4] The largest emissions are from industrial energy use in the Centrally Planned Asia region, with more than a third of global CO_2 emissions, due to increasing energy-intensive industrial production and the heavy use of coal in the industrial and power sectors. Developed countries account for 35% and transition countries for 11% of global CO_2 emissions from the industrial sector, while the remaining countries account for 54%.

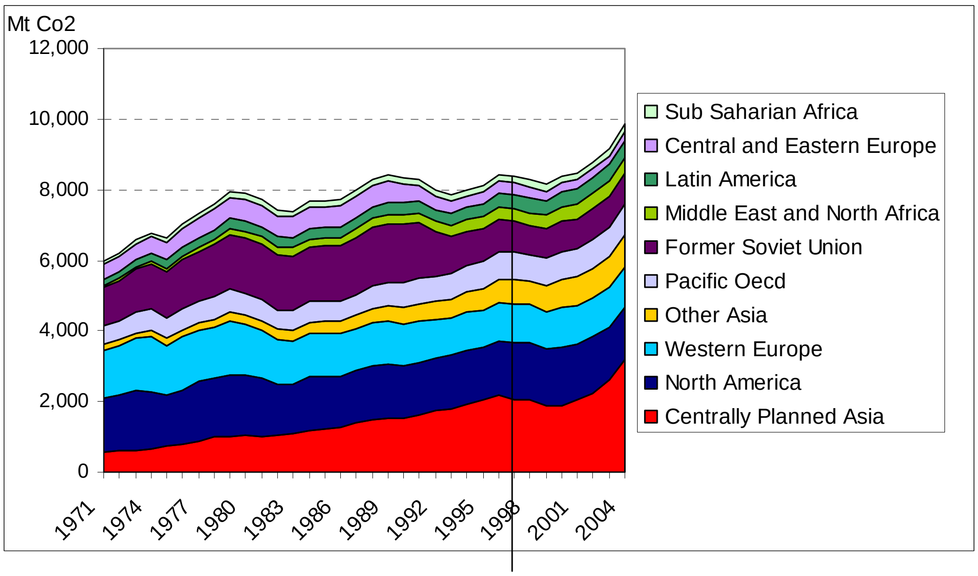
In the A1 and B2 scenarios, industrial CO_2 emissions are projected to continue increasing for all regions until 2010 when CO_2 emissions from the developed countries of the North America, Western Europe and Pacific OECD regions will peak and start declining (see **Figure 5**).[5] In both scenarios, emissions from developing countries and economies in

[4] These calculations account for upstream CO_2 emissions from electricity and heat reallocated in proportion to the electricity and heat consumed. They also account for upstream CO_2 emissions due to the production of petroleum and coal products reallocated similarly according to the use of petroleum and coal products in the industrial sector. For a description of the methodology, see Price et al.,2006.

[5] This is in part due to the scaling between 2000 actual data and 2010 projection for A1 scenario. The non adjusted data for A1 actually show decreasing CO_2 emissions during the period 2000-2010 for developed countries.

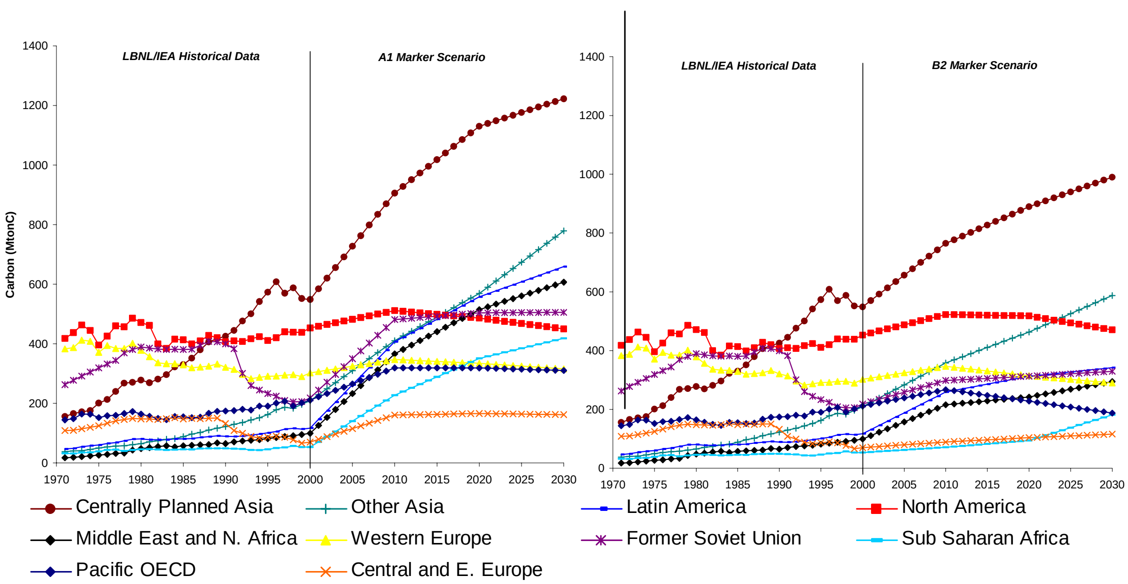
transition are forecast to continue their growth after 2010, albeit at a much slower pace. In absolute terms, developing countries are expected to be by far the largest contributor to the growth in annual emissions due to increased industrial activity. The A1 scenario forecasts that all developing country regions will exceed the CO_2 emissions from developed regions in the industrial sector by 2020. In the B2 scenario, only the two Asian regions will surpass the emissions of the North America region.

Figure 4. Historical CO_2 Emissions in the Industrial Sector by Region



Source: Price et al., 2006

Figure 5. Historical and Projected Industrial Sector CO_2 Emissions, 1971-2030 (MtC)



Source: Price et al., 2006

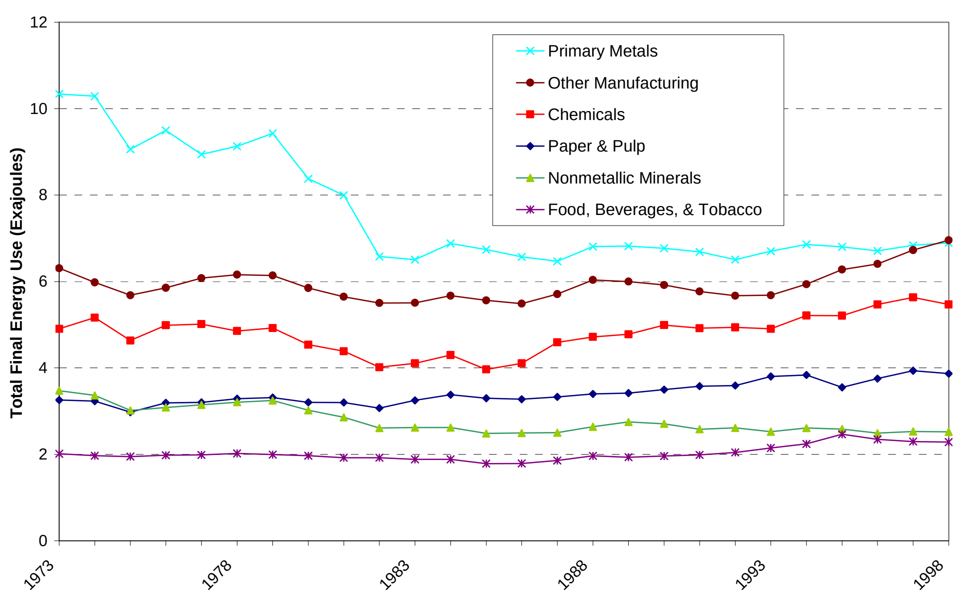
2.3.3 Developed Countries Trends

Developed countries used 41% of global primary energy in 2004 (Price et al., 2006). The observed changes in historical energy use in developed countries are a result of changes in energy efficiency and changes in manufacturing output. In 2003, the IEA published a thorough analysis of the energy use in eleven developed countries (the "IEA-11") to isolate changes in energy consumption due to structural change and due to energy efficiency (IEA, 2003).

Figure 6 shows the trends in energy use by manufacturing sub-sectors in these countries. Primary metals energy use decreased significantly after the first oil price shock of 1973. Energy consumption in the non-metallic minerals sector also declined, but at a slower rate. Since 1982, energy use for production of chemicals has increased.

The IEA analysis showed that changes in industrial energy use in these countries were mostly due to high efficiency gains until the 1980s, at which time the changes were the result of structural adjustments. A recent publication from the IEA estimates that the industrial potential energy savings for the OECD countries as a whole is about 20% by 2050, considering available technology or technology likely to become available in the next two decades (IEA, 2006c).

Figure 6. Final Energy Use by Manufacturing Sub Sector in IEA-11



Source: IEA, 2003
IEA 11: Australia, Denmark, Finland, France, Germany, Japan, Italy, Norway, Sweden, the UK, and the US

2.3.4 Developing Countries and Transition Economies Trends

In 2004, developing countries and transition economies accounted for 48% and 11% of global primary industrial sector energy consumption respectively (Price et al., 2006). Table 2 provides information on the primary energy use of the largest developing countries and transition economies.

Table 2. Primary Industrial Sector Energy Use of Largest Developing Countries and Transition Economies

	Primary Energy 2004 (PJ)	AAGR 94-04	Share
China	28,087	5.1%	29.53%
Russia	6,619	-1.0%	6.96%
India	6,184	3.2%	6.50%
Brazil	3,880	3.8%	4.08%
South Africa	2,117	3.7%	2.23%
Ukraine	1,659	-2.0%	1.74%
Mexico	1,644	2.0%	1.73%
Indonesia	1,523	6.7%	1.60%
Iran	1,523	4.7%	1.60%
Thailand	1,493	5.9%	1.57%

Source: IEA data converted to primary energy by accounting for electricity loses with primary factors developed by Price et al. (2006); SA-DME, 2007; Br MME, 2007.

China is by far the largest industrial consumer with 29.5% of total primary energy used by economies in transition and developing countries. Russia is the next largest, with a share of 7%. However industrial primary energy consumption in Russia declined over the period 1994 to 2004, due to the drop in activity after the collapse of the Former Soviet Union. The next largest consumers are India, Brazil, and South Africa with primary energy use growing at average annual rates ranging from 3.2% for India to 3.8% for Brazil. Indonesia is a fast growing economy with primary industrial energy consumption increasing by 6.7% annually since 1994.

Table 3 shows the evolution of industrial primary energy and industrial value added for some key developing countries as well as selected indicators of development, such as income level and GDP growth.

Table 3. Economic Statistics of Key Developing and Transition Economies

	2003 GDP per Capita (US 2000 $)	AAGR 93-03	GDP AAGR 93-03 (US 2000$)	Industry Primary Energy AAGR 93-03	Industry V.A. AAGR 93-03 (US 2000$)	Industry V.A. (% of GDP)
Mexico	5,792	1.1%	2.7%	2.0%	2.7%	26%
Brazil	3,510	1.1%	2.4%	3.7%	2.0%	19%
S. Africa	3,026	0.7%	2.8%	2.7%	1.9%	31%
Thailand	2,276	2.7%	3.4%	6.7%	4.4%	44%
Russia	2,138	1.1%	0.7%	-2.7%	0.1%	34%
Iran	1,715	2.3%	3.9%	5.3%	0.1%	41%
Egypt	1,622	2.5%	4.5%	2.6%	4.2%	34%
China	1,067	8.0%	8.9%	4.0%	11.2%	52%
Ukraine	812	-1.8%	-2.6%	-4.7%	-3.8%	40%
Indonesia	781	1.6%	3.0%	6.3%	3.9%	44%
India	511	4.4%	6.2%	5.1%	6.5%	27%

Source: WB, 2005. Note: V.A. = Value Added

China's industrial energy consumption is driven by its rapidly-increasing economy, where it accounts for 61% of total primary energy demand in the country. Over 50% of the energy consumption is coal-based. Energy-intensive industries consume more than half the primary energy demand of total industry sector in China (Zhou, 2006). Over the period 1993 to 2003, industrial primary energy grew at a rate of 4.0%, much slower than industrial value added, which grew at a rate of 11.2%. Further analysis shows that from 1996 to 2003, steady energy efficiency improvements in industrial sub-sectors can be observed. However, the effect of structural shift within industrial sub-sectors towards energy-intensive industries has outpaced energy efficiency gains since 2001 (Lin et al., 2006).

The Indian economy has grown rapidly at a pace of 6.2% per year from 1993 to 2003, boosted by its growing service economy but also by increasing industrial value added (6.5%), growing at a rate faster than GDP. The rapid economic growth has been accompanied by commensurate growth in the demand for energy, 5.1% over the period 1993-2003. However, primary energy grew at a slower rate than industrial value added (6.5%), reflecting a slight decoupling, observed since the mid-1980s (Sathaye, 2006). The share of coal in total industrial final energy use is 33%, petroleum products (including feedstocks) represents a larger share of 40%, while electricity and natural gas consume 17% and 10%, respectively.

Indonesia was significantly affected by the 1998 Asian economic crisis, appreciably reducing its industrial activity. The two main energy-intensive industry sectors are the cement and chemical sectors, which are both progressing towards recovery. The chemical industry relies on an abundant natural resource base of crude oil and natural gas, and a large and growing market of more than 240 million people (US Jakarta Embassy, 2006). Indonesia ranked ninth among world natural gas producers and twentieth among world oil producers. During the period 1993 to 2003, industrial primary energy grew at a much higher rate (6.3%) than industrial value added (3.9%).

Among Latin American countries, Brazil consumes a sizeable amount of energy to fuel its industry. In 2003, raw material production used 55% of primary energy, with iron and steel alone representing 21% and increasing at 2.1% between 1993 and 2003. The chemical, pulp and paper, and non-ferrous minerals industries consumed 10% each and increased at an annual average rate of 4.1%, 4.5% and 2.6%, respectively, over the period 1993 to 2003 (Br. MME, 2007). The increase in the energy-intensive industrial primary energy consumption resulted in a strong overall industrial primary energy growth (3.7%), while growth in industrial value added (2.0%) remained lower. Primary industrial energy consumption in Mexico has increased at a moderate rate of 2%, mostly driven by increases in electricity consumption which grew at a high rate of 4.7% compared to fuel consumption, which decreased by 0.7% over the period 1994 to 2004. Mexico's industrial primary energy grew slower than industrial value added over the period 1993-2003.

Russia and Ukraine are the two largest energy consumers in the Central Eastern Europe and Former Soviet Union regions. Russian energy consumption declined 33% between 1993-1998 after the collapse of the former Soviet Union. Since 1998, industrial energy consumption has been growing again at an annual average rate of 1.9%. The industrial sector is still largely characterized by obsolete processes and technologies. For example, in 2004 22% of steel output in Russia and 43% in Ukraine was still produced in open hearth furnaces, by far the least efficient steel-making technology available, compared to only 6% in India and none in the EU-25 (IISI, 2006). Energy consumption in industry in Ukraine also experienced a strong decline of about 40% between 1993 and 1998. However, energy consumption in energy-intensive industry declined at a lower rate than in other industries, which led to growth in the overall energy intensity of the economy in the early 1990s. From 1998-2004, energy consumption remained relatively stable, despite growth in industrial production. This reflects energy intensity improvements and the slight increase in the share of less energy-intensive industries in total production (IEA, 2006d).

South African industrial primary energy consumption increased 2.7% while industrial value added increased only 1.9% during the period 1993 to 2003. The two major contributors to the energy growth were the non-ferrous metals and iron and steel sectors, which grew at a rate of 9.8% and 3.3% respectively. Production of raw material represents 60% of the total industrial primary energy use, with iron and steel alone, representing 25%. The sector of mining and quarrying is also a large industrial energy user with 22% industrial primary energy consumption. South Africa is globally recognized as being a leading supplier of a variety of minerals and mineral products that are exported across the world. South Africa uses coal for more than half its total industry sector needs.

Egypt has one of Africa's most prosperous economies with GDP growing at a rate of 4.5% between 1993 and 2003. Industrial value added grew at a rate 4.2% over the period 1993 to 2003, while industrial energy consumption grew at a slower rate of 2.6%. Egypt's main industry sectors are textiles and the food and beverage industries. However, non-metallic minerals and chemical industries are increasing and will contribute increasingly in the industrial energy demand.

3. Industrial Energy Efficiency

Industrial energy efficiency – or conversely, energy intensity which is defined as the amount of energy used to produce one unit of a commodity – is determined by the type of processes used to produce the commodity, the vintage of the equipment used, and the efficiency of production, including operating conditions. Energy intensity varies between products, industrial facilities, and countries depending upon these factors.

Steel, for example, can be produced using either iron ore or scrap steel. Best practice primary energy intensity for producing thin slab cast steel from iron ore using a basic oxygen furnace is 16.3 gigajoules (GJ) per metric ton, while production of the same product using scrap steel only requires 6.0 GJ/tonne (Worrell et al., forthcoming). The energy intensity of the Chinese steel industry dropped from 29 GJ/ton steel in 1990 to 23 GJ/ton steel in 2000 despite an increased share of primary steel production from 79% to 84%, indicating that the efficiency of steel production improved over this period as small, old inefficient facilities were closed or upgraded and newer facilities were constructed (Editorial Board, 2004). Continued improvements will be realized through further adoption of advanced casting technologies, improved furnaces, pulverized coal injection, and increased recover of waste heat (Zhou et al., 2003).

In the Indian cement industry, energy efficiency improvements are the result of the combined effects of shifting away from inefficient wet kilns toward more efficient semi-dry and dry kilns, as well as adoption of less energy-intensive equipment and practices. Between 1992 and 2002, primary energy use per ton of cement produced in India dropped from 4.8 to 4.2 GJ/t (Sathaye et al., 2005).

Within industry, systems that support industrial processes that can be found to varying degrees in virtually all industrial sectors, regardless of their energy intensity. These *industrial systems*, which include compressed air, pumping, and fan systems (referred to collectively as motor systems), steam systems, and process heating systems are integral to the operation of industrial facilities, providing essential conversion of energy into energized fluids or heat required for production processes. Motor and steam systems account for 15% and 38%, respectively, of global final manufacturing energy use, or approximately 46 EJ/year (IEA 2007).

Because these systems typically support industrial processes, they are engineered for reliability rather than energy efficiency. If energy efficiency were considered during system design these would not be inherently conflicting goals, since energy efficient industrial systems are frequently more reliable than less energy efficient systems. Industrial systems that are oversized in an effort to create greater reliability, a common practice, can result in energy lost to excessive equipment cycling, less efficient part load operation, and system throttling to manage excessive flow. This is the equivalent of driving a car with one foot on the accelerator and one foot on the brake. Waste heat and premature equipment failure from excessive cycling and vibration are side effects of this approach that contribute to diminished, not enhanced, reliability.

More sophisticated strategies create reliability through flexibility of response and redundancy in the case of equipment failure, rather than by brute force. The objective of an energy efficient industrial system is analogous to "just in time" manufacturing—to provide the appropriate level of service needed to support the production process, to have a backup plan to address emergencies, and to keep the entire system well-maintained and well-matched to production needs over time. The energy savings can be substantial, with savings of 20% or more common for motor systems and 10or more for steam and process heating systems (USDOE 2004a) (IEA 2007).

3.1 Opportunities for Industrial Energy Efficiency

The drivers for improving industrial energy efficiency include the desire to reduce overall costs of production in order to maintain competitiveness, reducing vulnerability to rapidly increasing energy prices and price spikes, responding to regulatory requirements for cleaner production (including air quality, solid waste, and greenhouse gas emissions), and meeting consumer demand for greener, more environmentally-friendly products.

Opportunities to improve industrial energy efficiency are found throughout the industrial sector (de Beer et al., 2001; ECCP, 2001; IPCC, 2001). Assessments of cost-effective efficiency improvement opportunities in energy-intensive industries in the United States, such as steel, cement, and paper manufacturing, found cost-effective savings of 16% to 18% (Martin et al., 1999, 2000a; Worrell, et al., 2001); even greater savings can often be realized in developing countries where old, inefficient technologies have continued to be used to meet growing material demands (Price et al., 1999; Price et al., 2002; Schumacher and Sathaye, 1999; WEC, 2004). An estimate of the 2010 global technical potential for energy efficiency improvement in the steel industry with existing technologies identified savings of 24% in 2010 and 29% in 2020 using advanced technologies such as smelt reduction and near net shape casting (de Beer et al., 2000).

In addition to these existing technologies, there is a continuous stream of industrial emerging technologies being developed, demonstrated, and adopted. Emerging technologies, such as direct reduced iron and near net shape casting of steel, separation membranes, black liquor gasification, and advanced cogeneration can bring even further savings as they are commercialized and adopted by industries (Worrell et al., 2004). A recent evaluation of over 50 such emerging technologies applicable to industries as diverse as petroleum refining, food processing, mining, glass-making and the production of chemicals, aluminium ceramics, steel, and paper found that over half of the technologies promised high energy savings, many with simple payback times of three years or less (Martin et al., 2000b). Analysis of energy efficiency improvements related to emerging technologies found potential savings compared to current average energy use of 35% for steelmaking and 75% to 90% for papermaking over the long term (de Beer et al., 1998a; de Beer et al., 1998b).

While the energy efficiency of individual system components, such as motors (85-96%) and boilers (80-85%) can be quite high, when viewed as an entire system, their overall efficiency is quite low. Motor systems lose approximately 55% of their input energy before reaching the process or end use work. For steam systems, the losses are only marginally better, with 45%

of the input energy lost before the steam reaches point of use. In contrast, process heating systems only lose about 18% of their input energy before reaching their end use, but can also lose 30% or more of the delivered energy downstream if adequate waste heat recovery is not present(USDOE 2004b).

Some of these losses are inherent in the energy conversion process; for example, a compressor typically loses about 80% of its input energy to low grade waste heat as the incoming air is converted from atmospheric pressure to the desired system pressure (Compressed Air Challenge 2003). Other losses are due to system inefficiencies that can be avoided through the application of commercially available technology combined with good engineering practices. These improvements in industrial system energy efficiency are cost-effective, with costs typically recovered in two years or less.

Although industrial systems are ubiquitous in the manufacturing environment, their applications are highly varied. They are supporting systems, so facility engineers are typically responsible for their operation, but production practices on the plant floor (over which the facility engineer has little influence) can have a significant impact on their operational efficiency. Other contributing factors include the complexity of these systems and the institutional structures within which they operate. System optimization cannot be achieved through simplistic “one size fits all” approaches

There are several factors that contribute to a widespread failure to recognize system energy efficiency opportunities on a global basis. At present, most markets and policy makers tend to focus on individual system components (motors and drives, compressors, pumps, boilers) with an improvement potential of 2%–5% that can be seen, touched, and rated-- rather than systems with an improvement potential of 20% or more for motor systems and 10% or more for steam and process heating systems which require engineering and measurement to achieve (DOE 2004a) (IEA 2007). Equipment manufacturers have steadily improved the performance of individual system components (such as motors, boilers, pumps and compressors) but these components only provide a service to the users’ production process when operating as part of a system. Terms such as “supply side efficiency” that seek to limit the definition of system energy efficiency to the compressor room, boiler room, or pump house are misleading in the context of system optimization. There is little benefit in producing compressed air, steam, or pumped fluids efficiently only to oversupply plant requirements by a significant margin or to waste the energized medium through leaks or restrictions in the distribution system. System energy efficiency requires attention to the entire system.

The presence of energy-efficient components, while important, provides no assurance that an industrial system will be energy-efficient. Misapplication of energy-efficient equipment (such as variable speed drives) in these systems is common. System optimization requires taking a step back to determine what work (process temperature maintained, production task performed, etc) needs to be performed. Only when these objectives have been identified can analysis be conducted to determine how best to achieve them in the most energy-efficient and cost-effective manner. An illustration of how energy-efficient components can fail to result in an energy-efficient system in shown in Figure 7.

Examples of System Optimization benefits:

- After system optimization training, a Chinese engineer connects two compressed air lines in a polyester fiber plant, saving 1 million RMB annually (about US$ 127,000)
- A US system optimization expert conducts a plant assessment and directs operations staff to close a valve serving an abandoned steam line, saving nearly 1 million USD annually
- A UK facility experiencing difficulty with excess delivery pressure, pump cavitation and water hammer identifies an opportunity to reduce the system head. After trimming the pump impeller for a cost of 377 GBP, the plant realizes energy savings of 12,905 GBP and maintenance savings of 4,350 GBP for a simple project payback of 8 days.

While these examples have been selected for their impact, it is important to understand that the inefficient situations that produced these opportunities occur frequently. The primary cause is quite simple- the employees at industrial facilities rarely have either the training or the time to recognize the opportunities, to take the "step back" to see the big picture.

Figure 7: Optimizing a Motor System

15 kW Motor
Efficiency is ~ 91%

Pump head: 36 m
Flow rate: 97.6 m^3/h
=> hydraulic power: 9.6 kW
Combined pump and motor efficiency = 59%

Pump + Motor + Discharge Valve

There is > 28 m pressure drop across the throttled valve

Useful hydraulic power = 2.1 kW

Actual *System* Efficiency is only 13%

Courtesy of Don Casada, Diagnostic Solutions

Since the efficiency of the system (motor + pump+ throttle valve) is only 13%, replacing the existing motor in this system with a more energy efficient one (example 93%) would accomplish little.

A typical case study may help to further illustrate the opportunities that can be derived from the application of system optimization techniques using commercially available technology.

Case Study 3.1: Textile Mill Lowers Costs and Increases Production after Compressed Air System Improvement

In 1997, a compressed air system improvement project was implemented at the Peerless Division of Thomaston Mills in Thomaston, Georgia. The compressed air system project was undertaken in conjunction with an effort aimed at modernizing some of the mill's production equipment. Once they were both completed, the mill was able to increase production by 2% per year while reducing annual compressed air energy costs by 4% (US$109,000) and maintenance costs by 35% (US$76,000). The project also improved the compressed air system's performance, resulting in a 90% reduction in compressor downtime and better product quality. The project's total cost was US$528,000 and the annual savings are US$185,000 per year, the simple payback is 2.9 years. The mill also avoided US$55,000 in capital costs by installing a more optimal arrangement of compressors (U.S. DOE, 2001).

The goal to increase production and lower production costs for the mill at the same time as production changed to a new type of loom requiring more, and better controlled, compressed air triggered an opportunity to conduct an assessment of the mill's compressed air system. During the system assessment, a problem with *unstable* air pressure was identified (note that this is commonly misdiagnosed as *inadequate* pressure). Instead of increasing the pressure to compensate, thus using more energy, the plant installed storage and controls, properly configured the compressors, and reduced the amount of leakage from piping and drains. As a result, pressure was stabilized, fewer compressors were required to serve increased production, production suffered many fewer work stoppages, and energy use declined.

Without the application of system optimization techniques, the typical outcome would be treatment of the *symptom* (problems maintaining the pressure required for production equipment) rather than the *root cause* (the compressed air supply could not respond adequately to variations in the plant's compressed air requirements).

Improved energy system efficiency can also contribute to an industrial facility's bottom line at the same time as improving the reliability and control of these systems. Increased production through better utilization of equipment assets is frequently a collateral benefit. Maintenance costs may decline because better matching of equipment to demand needs results in less cycling of equipment operation, thus reducing wear. Optimizing the efficiency of steam systems may result in excess steam capacity that can be used for cogeneration applications. Payback periods for system optimization projects are typically short – from a few months to three years – and involve commercially available products and accepted engineering practices.

Case Study 3.2: Town and Village Enterprise (TVE) Experience in China

TVEs came into being in China as rural, collective entities established at the township and village level to provide jobs for surplus rural labor and to provide low cost essential local products. This case study describes a TVE program funded through the Global Environmental Facility beginning in 2001 with UNDP as the International Implementing Agency, UNIDO as the International Executing Agency and China's Ministry of Agriculture as the National Executing Agency.

There are around 23 million TVEs in China, accounting for around 30% of GDP and providing around 143 million mostly unskilled rural jobs. TVEs provide more than half of the total output from the building materials (cement and brick), coking and metal casting sectors. These four TVE sectors account for one-sixth of China's CO2 emissions. TVE levels of technology and management are currently being updated in a step-by-step process from their very backwards 1950's levels – with key enterprise and government drivers to TVE modernization being to improve their competitiveness and reduce their high pollution levels respectively.

TVEs in China have now been largely privatized to their former managers, and still primarily sell their products into local markets. TVEs generally retain strong links to local government and officials for their ongoing land tenure and for managing their exposure to the implementation of the numerous guidelines emanating from central, provincial and district government agencies.

GHG savings of 200,000 tons/yr of CO2 are on track for the pilot projects. Around $49 million was invested in these pilots, including $10 million from commercial sources. In addition, 118 formal replication projects with CO2 reductions of 2 million tons CO2/yr are well underway (730,000 tons CO2 savings already achieved). $2 million from GEF has leveraged around $100 million investment in these replication projects.

The project has also fostered a number of independent energy efficiency project replications without any direct funding support from the TVE project. The project's self-replications in China account for at least 2.5 million tons of CO2/yr, and probably 5 - 10 million tons CO2/yr. There are also independent replications as a direct result of the TVE project in Bangladesh, Guinea, India, Pakistan, USA and Vietnam. At around 10 million tons/yr of CO2 reductions, this gives total project GHG reductions of 50 million tons CO2 for a $8 million GEF investment.

3.2 Barriers to Industrial Energy Efficiency Improvement

There are a number of barriers to adoption of energy-efficient technologies, including willingness to invest, information and transaction costs, profitability barriers, lack of skilled personnel (Worrell et al., 1996), and slow capital stock turnover.

The decision-making process regarding investments in energy-efficient technologies is shaped by firm rules, corporate culture, and the company's perception of its level of energy efficiency. A survey of 300 firms in The Netherlands found that most firms view themselves as energy efficient even when profitable improvements are available (Velthuijsen, 1995). Lack of knowledge or the limited ability of industrial commodity producers to research and evaluate information on energy-efficient technologies and practices is another barrier. In addition, there is often a shortage of trained technical personnel that understand energy efficiency investment opportunities. Uncertainties related to energy prices or capital availability can lead to the use of stringent investment criteria and high hurdle rates for energy efficiency investments that are higher than the cost of capital to the firm (DeCanio, 1993). Capital rationing is often used within firms as an allocation means for investments, especially for small investments such as many energy efficiency retrofits.

The relatively slow rate which industrial capital stock turns over can prove to be a barrier to adoption of energy efficiency improvements since new stock is typically more energy-efficient than existing facilities. For example, an evaluation of electric arc furnaces used for steelmaking in the U.S. found that electricity use was reduced by 0.7% per year between 1990 and 2002 because of the difference in energy intensity between retired facilities and facilities constructed during this period (Worrell and Biermans, 2005). Another barrier is the perceived risk involved with adopting new technology since reliability and maintenance of product quality are extremely important to commodity producers.

Industrial systems continue to offer substantial opportunities for energy efficiency due to a series of reinforcing barriers that are primarily institutional and behavioral, rather than technical. As with sector-based barriers, the organizational culture is extremely important.

First, as previously mentioned, industrial systems are usually not designed with operational efficiency in mind. ***Optimizing systems for energy efficiency is not taught*** to engineers and designers at university- it is learned through experience. Systems are designed to maintain reliability at the lowest first cost investment, despite the fact that operating costs are often 80% or more of the life cycle cost of the equipment. As a result, basic design factors such as pipe size may be too small to optimize performance, and too expensive to retrofit -- requiring a work-around approach to do the best optimization project possible. This emphasis on reliability is further reinforced for facility plant engineers, who are typically evaluated on their ability to avoid disruptions and constraints in production processes, not energy efficient operation. Equipment suppliers also have little incentive to promote more energy efficient system operation, since commissions increase when equipment size is scaled upward. Educating a customer to choose a more efficient approach requires extra time and skill, and risks alienating the customer by bringing current practices into question.

Second, once the importance of optimizing a system and identifying system optimization projects is understood, ***plant engineering and operations staff frequently experience difficulty in achieving management support***. The reasons for this are many, but central among them are two: a) a management focus on production as the core activity, not energy efficiency and b) lack of management understanding of operational costs and equipment life cycle cost. Industrial managers are rarely drawn from the ranks of facilities operation- they come from production and often have little understanding of supporting industrial systems. This situation is further exacerbated by the existence of a budgetary disconnect in industrial facility management between capital projects (incl. equipment purchases) and operating expenses. Operational budgets are typically segregated from capital budgets in industrial organizations, so that energy use, usually the single largest element of system equipment life cycle cost, does not influence purchase. Without energy-efficient procurement practices, lowest cost purchase of elements in the distribution system such as tool quick-connects and steam or condensate drain traps can result in ongoing energy losses that could be avoided through a small premium at initial purchase.

Third, as a further complication, experience has shown that most ***optimized industrial systems lose their initial efficiency gains over time*** due to personnel and production changes.

Since system optimization knowledge typically resides with an individual who has received training, detailed operating instructions are not integrated with quality control and production management systems. Without well-documented maintenance procedures, the energy efficiency advantages of high efficiency components can be negated by clogged filters, failed traps, and malfunctioning valves.

Since production is the core function of most industrial facilities, it follows that the most sophisticated management strategies would be applied to these highly complex processes. Successful production processes are consistent, adaptable, resource efficient, and continually improving- the very qualities that would support industrial system optimization. Because production processes have the attention of upper management, the budgetary disconnect between capital and operating budgets is less evident. Unfortunately, efficient use of energy is typically not addressed in these management systems in the same way as other resources such as labor and materials. An answer lies in fully integrating energy efficiency into these existing management systems.

4. Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economies

4.1. Overview – Industrial Standards Framework

The Industrial Standards Framework proposes a link between ISO 9000/14000 quality and environmental management systems and industrial energy efficiency. A number of management systems are currently used by industrial facilities across most sectors to maintain and improve production quality. ISO has been selected for the Framework because it has been widely adopted in many countries, is used internationally as a trade facilitation mechanism, is already accepted as a principal source for standards related to the performance of energy-consuming industrial equipment, and has a well-established system of independent auditors to assure compliance and maintain certification. For the purpose of this discussion, ISO includes both the quality management program (ISO 9001:2000) and the environmental management program (ISO 14001), which can share a single auditing system. Although the discussion of the Framework will include references to ISO 9000/14000 management systems, the elements of the Framework are equally applicable to other management systems, such as Six Sigma or Total Quality Management.

The Industrial Standards Framework includes:

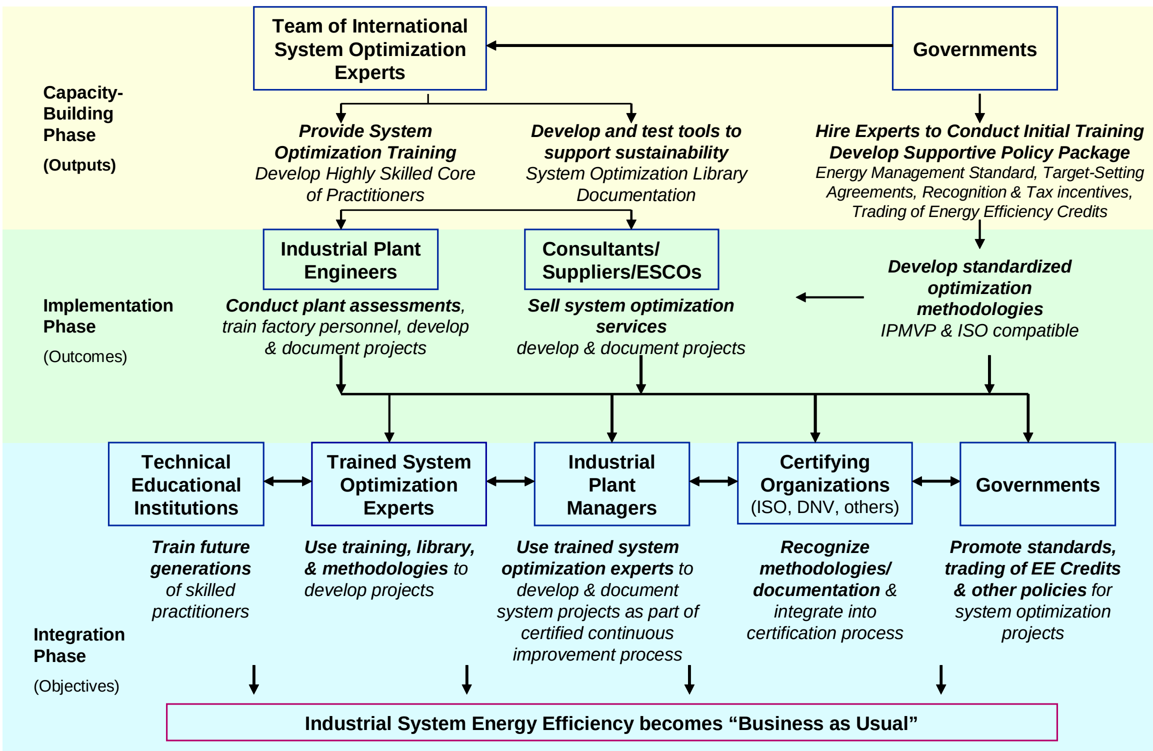
- target-setting agreements,
- an energy management standard,
- system optimization training and tools,
- capacity building to create system optimization experts, now and in the future,
- a System Optimization Library to document and sustain energy efficiency gains, and
- tax incentives and recognition.

In addition, the Framework could accommodate:

- standardized system optimization methodologies
- certification of energy efficiency projects for trading energy efficiency credits

The purpose of the Framework is to introduce a standardized and transparent methodology into industrial energy efficiency projects and practices including: system optimization, process improvements, waste heat recovery and the installation of on-site power generation. The Framework builds on existing knowledge of "best practices" using commercially-available technologies and well-tested engineering principles. It seeks to engineer industrial facilities for reliability and productivity, as well as energy efficiency. Factories can use the Framework to approach energy efficiency incrementally in a way that maximizes positive results and minimizes risk and downtime. The goal is to make optimization for energy efficiency as much a part of typical industrial operating practices as waste reduction and inventory management. The objective is a permanent change in corporate culture using the structure, language, and accountability of the existing ISO management systems. This approach is equally applicable in industrialized or industrializing countries. Figure 8 provides a schematic of how the elements of the Industrial Framework interact to effect an institutional culture change in which industrial energy efficiency becomes "business as usual". Table 4 provides a description of the key elements of the Industrial Standards Framework , their current status of development and implementation, and their compatibility with each other.

Figure 8: Industrial Standards Framework



Source: McKane, 2007

Sections 4.2 - 4.6 will provide additional details on the elements of the Industrial Standards Framework, including: target-setting and negotiated agreements, energy management standards, system optimization training and capacity building, documenting for sustainability through the use of the systems optimization library, and recognition programs, tax incentives, and the relationship between industrial energy efficiency and carbon offset programs, including the Clean Development Mechanism (CDM).

Table 4. Key Elements of the Industrial Standards Framework

Element	Category	Purpose	Current Status	Importance	Compatibility
Energy Management Standard	Standard-Voluntary or Mandatory	Provides organizational guidance for “hardwiring” energy management into company management practices.	Existing standards in Denmark, Ireland, Sweden, Netherlands, US; developing in China, Spain, Korea, Brazil	Essential for management support; compliance w/standard can be met through other elements	Written as possible ISO standard w/ ISO-friendly documentation and continuous improvement requirements
	Training	Prepares management to implement standard	Existing training through Georgia Tech (US)		
System Optimization Library	Tool-Electronic reference document	Provides factory personnel and experts w/guidance on system optimization within the ISO context of procedures, projects, & work instructions	Library samples developed & reviewed; demonstration project planned	Essential- provides an incremental path to continuously improve and maintain system efficiency	Written in ISO language for use in ISO 9000 or 14000 program; supports corporate energy management goals; assist in development of system optimization projects
	Training	Prepares factory personnel and system optimization experts to use Library (follows system optimization awareness training)	Training to be developed as part of demonstration project		
System Optimization Training	Training	Expert training prepares a cadre of engineers to conduct factory assessments, train factory personnel, & assist in project development Awareness training alerts factory personnel to system optimization opportunities	Expert & awareness training developed as part of UNIDO Motor System Program (China)	Essential- provides the technical skills for small group of experts and prepares them to train others	Provides pathway to quickly develop energy-efficiency projects for energy management plan.
ISO 9001:2000 and/or 14001 certification	Independent Certification	Determines whether a factory is meeting ISO objectives for continuous improvement via procedures, projects, & work Instructions	Global program with >770,000 participating companies	Essential to use an energy management system (ISO or other) to document, sustain & improve energy efficiency	Other elements provide path for maintaining certification
Energy efficiency targets by industrial sector	Policy	Provides plant-specific energy efficiency targets based on continuous improvement that is non-prescriptive and developed in cooperation with the industrial sector	Extensive European experience; pilot program developed and demonstrated in Chinese steel industry	Very helpful- engages management in efficiency objectives, becoming a driver to use other elements	Compatible with all elements
Government Recognition of Outstanding Energy Management	Policy	Provides meaningful recognition program for factories who initiate and sustain continuous improvement for energy efficiency	Many examples of effective national recognition programs (See Section 4.6)	Very helpful for motivating companies to become energy efficient	Recognition based on measurable results from other elements

Source: McKane, et al, 2005

4.2 Target-Setting Agreements

Target-setting agreements, also known as voluntary or negotiated agreements, have been used by a number of governments as a mechanism for promoting energy efficiency within the industrial sector. A recent survey of such target-setting agreement programs identified 23 energy efficiency or GHG emissions reduction voluntary agreement programs in 18 countries, including countries in Europe, the U.S., Canada, Australia, New Zealand, Japan, South Korea, and Chinese Taipei (Taiwan) (Price, 2005).

International best practice related to target-setting agreement programs calls for establishment of a coordinated set of policies that provide strong economic incentives as well as technical and financial support to participating industries. Effective target-setting agreement programs are based on signed, legally-binding agreements with realistic long-term (typically 5-10 year) targets, require facility- or company-level implementation plans for reaching the targets, require annual monitoring and reporting of progress toward the targets, include a real threat of increased government regulation or energy/GHG taxes if targets are not achieved, and provides effective supporting programs to assist industry in reaching the goals outlined in the agreements.

This policy instrument is entirely compatible with other aspects of the Industrial Standards Framework. A target-setting agreement provides a broad, but measurable target while an energy management standard provides an industrial facility with a methodology for meeting the target and system optimization techniques identify projects that help the facility meet both the goals of the standard and the efficiency targets of agreement.

4.2.1 Examples of Successful Target-Setting Agreement Programs

Three examples of model target-setting agreement programs are the UK's Climate Change Agreements, Denmark's Energy Efficiency Agreements, and The Netherlands' Long-Term Agreements.

The UK Climate Change Program was established in 2000 to meet both the country's Kyoto Protocol commitment of a 12.5% reduction in GHG emissions by 2008-2012 relative to 1990 and the domestic goal of a 20% CO_2 emissions reduction relative to 1990 by 2010 (DEFRA, 2000). A key element of the Climate Change Program is the Climate Change Levy which is an energy tax applied to industry, commerce, agriculture, and the public sector. The revenues from the levy are returned to the taxed sectors through a reduction in the rate of employer's National Insurance Contributions and used to fund programs that provide financial incentives for adoption of energy efficiency and renewable energy (DEFRA, 2004). Through participation in the Climate Change Agreements (CCAs), energy-intensive industrial sectors established energy efficiency improvement targets and companies that meet their agreed-upon target are given an 80% discount from the Climate Change Levy. There are 44 sector agreements representing about 5,000 companies and 10,000 facilities. The goal of the CCAs is to reduce carbon dioxide emissions by 2.5 MtC (9.2 $MtCO_2$) by 2010, which is ten times the estimated savings from the Climate Change Levy without the agreements (Pender, 2004).

Companies can trade carbon allowances through the UK Emissions Trading Scheme (DEFRA, 2005a). During the first target period (2001-2002) total realized reductions were three times higher than the target for that period (Pender, 2004). Sectors did better than expected because industry underestimated what they could achieve via energy efficiency. When negotiating the targets, most companies believed that they were already energy-efficient, but when they actually managed energy because of the CCA targets, companies saved more than they thought that they could, especially through improved energy management (Future Energy Solutions, 2004). Industry realized total reductions that were more than double the target set by the government during the second target period (DEFRA, 2005b).

In 1990, the Danish Parliament established an ambitious target to reduce its national CO_2 emissions by 20% by 2005, relative to the 1988 level. Under the Kyoto Protocol, a new target was set to reduce GHG emissions by 21% below 1990 levels by 2008-2012. To reach its climate goals, Denmark has undertaken a succession of integrated GHG emissions reduction strategies. In 1996, a system of voluntary Energy Efficiency Agreements was introduced. The revenues raised from the tax applied to industry were returned to the business sector largely through reductions in labor market contributions and grants for energy efficiency investments. The Energy Efficiency Agreements, signed by individual companies or associations of companies with the Danish Energy Agency, were made for periods of three years. Between 1996 and 2001, approximately 300 companies entered into such agreements, representing 60% of total industrial energy consumption in Denmark (Hansen, 2001). Under the agreements, the companies were required to implement all "profitable" energy savings projects, which were defined as projects with payback periods of up to four years, as identified in an energy audit or through internal investigations. In addition, companies were required to introduce energy management and to ensure that investments in new equipment were energy efficient. Subsidies were provided for up to 30-50% of the cost of energy-efficient investments (Bjørner and Jensen 2000; Johannsen, 2002). In 1999, the Ministry of Finance concluded that the business energy and CO_2 taxes created a substantial environmental effect in an economically efficient way, while taking international competitiveness into proper consideration (Finansministeriet 1999). The Energy Efficiency Agreements led to a reduction in energy consumption of 9% (Bjørner and Jensen 2000), reduced energy consumption by 2 to 4% of total energy consumption per agreement after three years (thereby exceeding business-as-usual by about 1% per year) (Togeby et al., 1999), sped up the process of adopting energy-efficiency measures (Krarup et al., 1997), and led companies to take energy management more seriously (Johannsen and Larsen 2000).

In the Long-Term Agreements (LTAs) in The Netherlands, voluntary agreements between the Dutch Ministries and industrial sectors consuming more than 1 petajoule (PJ) per year, were established in support of achieving an overall national energy-efficiency improvement target of a 20% reduction in energy efficiency between 1989 and 2000. The agreements were negotiated between government and industry associations over a two-year period and signed in 1992. Each industry association signed an agreement with the Dutch Ministry of Economic Affairs committing that industry to achieve specific energy efficiency improvements by 2000. In total, 29 agreements were signed involving about 1000 industrial companies and representing about 90% of industrial primary energy consumption in The Netherlands. The average target was a 20% increase in energy efficiency over 1989 levels by 2000 (Nuijen, 1998; Kerssemeeckers, 2002). The overall LTA program ended in 2000 with an average improvement in energy efficiency of 22.3% over the program period (Kerssemeechers, 2002). Recent evaluations of the LTAs found that the agreements helped industries to focus attention on energy efficiency and find low-cost options within commonly used investment criteria (Korevaar et al., 1997; Rietbergen et al., 1998). Although the agreements themselves proved to be successful and cost-effective (Rietbergen et al., 1998), various support measures were implemented within the system of voluntary agreements. It is difficult to attribute the energy savings to a specific policy instrument; rather, it is the result of a comprehensive effort to increase implementation and development of energy-efficient practices and technologies in industry by removing or reducing barriers. This emphasizes the importance of offering a package instead of a set of individual measures. A recent evaluation calculated that the cost of the LTAs was about $10 per tonne of CO_2 reduced (Blok et al., 2004).

Case Study 4.1: China Establishes Target-Setting Program for Energy-Intensive Industries

In 2005, the Chinese government announced an ambitious goal of reducing energy consumption per unit of GDP by 20% between 2005 and 2010. One of the key programs for realizing this goal is the Top-1000 Energy-Consuming Enterprises program. The comprehensive energy consumption of these 1000 enterprises accounted for 33% of national and 47% of industrial energy usage in 2004. The industries included in the Top-1000 Energy-Consuming Enterprise program are large-scale, financially independent enterprises in nine major energy consuming industries: iron and steel, petroleum and petrochemicals, chemicals, electric power generation, non-ferrous metals, coal mining, construction materials, textiles, and pulp and paper. Under the Top-1000 program, 2010 energy consumption targets were announced for each enterprise. Activities to be undertaken through this program include benchmarking, energy audits, development of energy saving action plans, information and training workshops, and annual reporting of energy consumption (Price and Wang, 2007).

4.2.2 Key Program Elements of Target-Setting Programs

The key program elements of a target-setting program are the:

- target-setting process;
- identifying energy-saving technologies and measures, using energy-efficiency tools, guidebooks;
- benchmarking current energy efficiency practices,
- establishing an energy management plan (see Section 4.3 below);
- conducting energy-efficiency audits;
- developing an energy-savings action plan;
- developing incentives and supporting policies;
- measuring and monitoring progress toward targets, and
- program evaluation.

Target-Setting

Typically, the process for setting energy efficiency or GHG emission reduction targets involves making a preliminary assessment of the energy efficiency or GHG mitigation potential of each industrial facility, which includes an inventory of economically-viable measures that could be implemented. These assessments, which can be made by the company themselves or by an independent third party, are then provided to the government and form the basis for discussions and negotiations related to target-setting between the industries and the government. Such assessments are often partially or entirely funded by the government – often as a benefit of participating in target-setting programs -- with funding varying from 40 to 100% of the cost of the audit in countries such as Denmark, the Netherlands, Sweden, and the U.S. (WEC, 2004).[6]

Identification of Energy-Saving Technologies and Measures

Countries with strong industrial energy efficiency programs, whether or not they are associated with agreement programs, provide information on energy-efficiency opportunities through a variety of technical information sources including energy efficiency databases, software tools, and industry- or technology-specific energy efficiency reports. For example, the U.S. Department of Energy's Industrial Technologies Program provides many software tools for assessing energy efficiency of motors, pumps, compressed air systems, process heating and steam systems, as well as Sourcebooks that provide information on these industrial systems and a Quick Plant Energy Profiler online software tool that helps industrial plant personnel understand how energy is being used at their plant and how they may save energy and money.[7]

Case Study 4.2: Peer-to-Peer Information Sharing Network in South Korea

South Korea has a voluntary agreement program with industry managed jointly by the Ministry of Commerce, Industry and Energy and the Ministry of Environment. To encourage information sharing and access to technical assistance among participating companies, the government established the Energy Saving through Partnership (ESP) initiative. Factories in energy intensive sectors (chemical, petrochemical, paper, steel, automotive) using more than 20,000 toe and factories in less intensive sectors (food, electrical, and electronics) using more than 10,000 toe can participate in the ESP. An ESP Council, which includes representatives from these sectors, oversees the activities of the network, which is coordinated by the Korea Energy Management Corporation (KEMCO). Major activities of the ESP include regular conferences and workshops to review and discuss progress toward targets, case studies on successful projects, experiences with new technologies, and benchmarking techniques. The ESP Council also conducts plant tours, hosts lectures by leading energy efficiency experts, and presents awards to outstanding member companies. The ESP website provides members with an email connection for exchanging information and announcements on upcoming activities. The cumulative benefits from benchmarked ESP projects during the period from 200-2004 was 136,577 toe and 383,290 MWh (KEMCO 2005).

Fact sheets or brochures contain information on energy efficiency methods, technologies, processes, systems and programs, or provide results from demonstration projects or annual reports. Reports or guidebooks help promote energy efficiency, advise companies on new technologies, methods or management, and/or give overall sectoral information. Examples include Australia's Energy Efficiency Best Practice Guides, the Canadian Industry Program for Energy Conservation's sector-wide energy efficiency guides with information on each

[6] The exception to this approach is the European Union's Emissions Trading Scheme where the EU countries allocated emissions targets on the basis of past emissions while only small efforts are being made to account for a company's ability to abate its emissions, but with a complex trading market in place to enable enterprises to sell excess emissions credits or purchase emissions credits to cover gaps between their actual performance and their target.

[7] See http://www1.eere.energy.gov/industry/bestpractices/software.html

sector, the Netherlands's annual reports for LTA members, Norway's Industrial Energy Efficiency Network's sector reports, the UK's sector overviews and technology guides, and ENERGY STAR'S Energy Guides for entire industries, which include both process specific and utility energy efficiency measures for ENERGY STAR partners (Galitsky et al., 2004). In The Netherlands, an inventory of energy-efficiency improvement options that consists of a detailed description of the measure followed by the investment costs, energy savings, returns on investment, and whether financial support systems are available for the specific measure are provided for more than 20 industrial sectors.[8] The Dutch LTA-2 program supports knowledge transfer through the establishment of five "Knowledge Networks" on advanced heat exchangers, computer-aided process engineering, process intensification, separation technologies, and industrial drying in which there are regular meeting of members and a website with which to share information (SenterNovem, 2007).

Benchmarking

Benchmarking provides a means to compare the energy use within one company or plant to that of other similar facilities producing similar products or to national or international best practice energy use levels. Benchmarking can compare plants, processes or systems. Canada's Office of Energy Efficiency (OEE) develops benchmarks for energy efficiency of facilities in each sub-sector that is targeted.[9] Norway has developed an extensive benchmarking program modeled after Canada's programs. Germany provides benchmarking services for companies involved in negotiated agreements. As discussed above, benchmarks are a key element of the Benchmarking Covenants in The Netherlands in which participating industrial companies agree to become among the top 10% of the most energy-efficient plants in the world or one of the three most efficient regions (regions defined as geographic areas with a production capacity similar to the Netherlands).

The U.S. ENERGY STAR for Industry program provides a means for measuring how efficiently a manufacturing plant uses energy compared to others in its industry using a tool called the energy performance indicator (EPI). The EPI is an industry-specific tool that ranks or scores a plant based on its energy use and accounts for differences between the plants within an industry by normalizing for activities or factors that influence energy use. The EPI tool has been developed for the cement, corn refining, and motor vehicle manufacturing industries to date and tools for the petroleum refining and pharmaceuticals industries are under development.[10] Lawrence Berkeley National Laboratory has developed an Excel-based spreadsheet tool called BEST: Benchmarking and Energy Saving Tool for use by industry to benchmark a plant's energy intensity to "best practice" and to identify energy-efficiency options that can be implemented. BEST was used by the Jigang steel mill to assist in determination of its energy efficiency target in the Shandong Province (China) energy efficiency pilot project (Price et al., 2003). BEST has also been developed for the California wine industry (Galitsky et al., 2005) and is currently being developed for the cement industry.

---

[8] SenterNovem presents lists with measures for energy efficiency improvements on their website: http://www.senternovem.nl/mja/energie_efficiency/energiebesparende_maatregelen/index.asp. To support sectors and companies to determine the return on investment (ROI), SenterNovem developed a tool to determine ROIs of measures. This tool, developed in Excel, can be downloaded from:
http://www.senternovem.nl/mmfiles/tvt_ncw_tcm24-111964.xls (in Dutch)

[9] http://oee.nrcan.gc.ca/industrial/technical-info/benchmarking/benchmarking_guides.cfm?attr=24

[10] See http://www.energystar.gov/index.cfm?c=in_focus.bus_industries_focus

Case Study 4.3: Target-Setting and Benchmarking in Indian Industries

The Energy Conservation Act 2001 calls for the setting up of industry-specific task forces on energy conservation. In some sectors, the Indian Bureau of Energy Efficiency and others are already implementing benchmarking programs. BEE is currently leading the Indian Industry Programme for Energy Conservation. The activities of this project related to the cement industry for example include formation of a Cement Task Force, energy audits, identification of best practices, and development of energy consumption norms. BEE has set up Task Groups for textiles, cement, pulp and paper, fertilizer, chlor-alkali and aluminum sectors. Industry members participate in this project to share information about best practices, declare their voluntary targets and adopt benchmarks for their processes. A benchmarking tool being developed through the Indo-German Energy Efficiency & Environment Project will provide cement manufacturers with information regarding their relative energy consumption level compared to their peers and to industry average (GOI, 2007).

Energy Management

Changing how energy is managed by implementing an organization-wide energy management program is one of the most successful and cost-effective ways to bring about energy efficiency improvements. Several countries have developed energy management standards and practices as an effective industrial energy efficiency policy mechanism. See Section 4.3 for more information.

In the Shandong Province Energy Efficiency Agreement pilot project in which energy-savings targets were signed between the Shandong Economic and Trade Commission (ETC) and Liagang and Jigang steel mills in China, each steel mill established a management structure for daily management of energy, formulated energy conservation work plans, improved day-to-day management systems for energy measurement, developed energy consumption quotas, maintained energy records, established energy accounting, developed energy balances, oversaw awards and fines, and trained staff related to energy saving. Jigang identified and assigned a full-time energy conservation manager to those units within the plant that are high-energy consuming units and each branch factory, workshop, and group was required to establish a part- or full-time energy management staff. Regular meetings focused on researching energy efficiency opportunities, assessing progress, analyzing weaknesses, guiding further energy conservation technology development, and evaluating progress toward the target were help. Jigang established an accounting reporting system that collects information monthly and reports on progress related to the various energy efficiency indicators and targets. Monthly reports on progress were provided to the Shandong ETC. Liagang established an assessment system which broke down the target for each subsidiary company at the steel mill and made evaluations of progress in terms of 14 assessment indexes. A project evaluation found that the extensive energy management efforts undertaken by the Jigang and Laigang steel mills contributed significantly to the realization of the energy-saving targets (Price et al., 2004).

Energy-Efficiency Audits or Assessments

Energy efficiency audits or assessments involve collecting data on all of the major energy-consuming processes and equipment in a plant as well as documenting specific technologies used in the production process and identifying opportunities for energy efficiency improvement throughout the plant.. Audit reports are usually produced. Tools, informational materials, and other energy efficiency products are often furnished during the audit. Some programs, like Australia's Enterprise Energy Audit Programme or Norway's Industrial Energy Efficiency Network, provide a directory or network of accredited auditors. This is an essential first step in identifying opportunities that can contribute to an organization's energy efficiency targets. In Thailand, which provides industrial firms with grants for energy audits and financial support for conservation planning, some 2,500 factories received energy efficiency audits between 1997 and 2002 (APEC 2003).

Individual plant audits conducted as part of the Dutch Long-Term Agreements included a description of the sector, an assessment of the plant's energy consumption in the base year, a survey of opportunities for energy-efficiency improvement, and a description of the monitoring and energy management techniques used (Nuijen, 2002a). Identified energy-efficiency measures were grouped in five categories: good housekeeping/energy management, retrofit or strategic investments, energy-efficiency investments, cogeneration, and other measures (e.g. changes in feedstock). The individual enterprise audits were done by the company itself and/or by independent consultants. The results of the audits were reported to an independent government agency, and provided the basis for final discussions and negotiations between the industries and the government to establish the final target for the sector. The assessments were further used as a basis for the company Energy Savings Plan which included an assessment of energy consumption in the base year, a survey of opportunities for energy-efficiency improvement, monitoring and energy management, research and development of new energy-efficient technologies, and demonstration projects of energy-saving measures.

As part of the Danish CO_2 Tax Rebate Scheme for Energy-Intensive Industries, energy audits of individual plants were conducted by independent, approved consultants. The energy audit was required to include the following: an energy balance for the plant with a detailed breakdown of energy consumption by processes, description of the energy-efficiency projects at the plant, including potential future projects, recommendations for energy management, and recommendations for energy conservation investments (Ezban et al., 1994).All profitable energy measures were identified, defined as those with a payback of less than four years for heavy processes (like greenhouse heating and production of foodstuff, sugar, paper, cement and glass)and less than six years for light processes The audits were verified by an independent certified verification agency. Sector-wide reports were also prepared to provide an analysis of energy consumption and production processes and to identify the general potential for energy-efficiency improvement in the companies within the sector (Togeby et al., 1998).

For more information on policies to develop energy auditing skills, see Section 4.4, Capacity Building.

Energy Saving Action Plans

An energy action plan outlines a company's plan for improving energy-efficiency during the period covered by energy efficiency targets. The energy action plan is primarily the guidance for the internal implementation of the activities that will be undertaken to reach the 2010 energy-saving target. It also serves as a reference to evaluate progress on an annual basis. The energy action plan should include a description of the facility with respect to energy, a description of the energy-efficiency measures considered, a description of the planned energy-efficiency measures, a timeframe for implementation of the energy-efficiency measures, and expected results in terms of energy efficiency. Once the energy action plan is drafted, it is typical for an independent third party to review the plan and make suggestions for adjustments, if needed. If conditions change at the facility or if planned energy-efficiency projects change, the energy action plan should be revised and submitted to the independent third party for additional review.

In the Dutch LTAs, industry Long Term Plans include evaluation of energy consumption in the base year (1989 in this case), a survey of opportunities for energy-efficiency improvement, company energy plans, monitoring and energy management in each company, research and development of new low-energy technologies, demonstration projects for energy savings measures, assistance to individual companies, and information dissemination (Nuijen, 1998). In LTA2 program, companies are required to draft an Energy Conservation Plan (ECP) setting out their energy efficiency goals, the measures they intend to employ, and a schedule for reaching their goals every four years. The ECP also outlines how the company or institution determines its energy efficiency index (EEI) and how this will be reported.

Monitoring

Monitoring guidelines for energy efficiency and GHG mitigation projects have been developed by numerous entities in order to understand the progress and results of specific energy-efficiency projects. Such guidelines are included in the World Business Council for Sustainable Development and World Resources Institute's Greenhouse Gas Protocol Initiative (WBCSD/WRI, 2002), the Global Reporting Initiative's Energy Consumption Protocol (GRI, 2002), the U.S. Initiative on Joint Implementation, the World Bank's guidelines for the Global Environment Facility, the International Performance Measurement and Verification Protocol, the U.S. Environmental Protection Agency's Conservation Verification Protocols, and the Dutch LTAs (Vine and Sathaye, 1997).

The monitoring requirements of the Dutch LTAs involved reporting on the energy-efficiency improvement achieved annually. The report included data on total energy use, the realized Energy Efficiency Index and progress on the projects carried out to reach the Energy Efficiency Index for that year. The annual reports were submitted to an independent third party to check the reported values for accuracy and to calculate the Energy Efficiency Index (Nuijen, 2002). The UK Climate Change Agreements require that each entity report primary energy used during the target period for each type of fuel, the total carbon emitted during the target period, the throughput during the target period, the information necessary to calculate the adjustment if the target is to be adjusted for product mix or for emissions trading. The reports must be supported by information on how the calculations were made using spreadsheets supplied by the government.

Program Evaluation

Evaluation is different from annual reporting and monitoring because it is undertaken only periodically to investigate why and how things happened within a program and to what extent this is the result of policies or other program activities. Evaluation can answer questions such as "to what extent did a policy program contribute to the desired outcome?" and "was the program cost-effective?" Evaluations can be done during the project in order to identify problems and make adjustments and at the end of the project in order to determine lessons learned for design of future programs.

An evaluation of the Dutch LTAs concluded that 25% to 50% of the savings "can be attributed to the policy mix of long-term agreements and supporting measures" and that "the agreements are valuable policy instruments for energy efficiency improvement if accompanied by ambitious target setting, effective supporting measures and reliable monitoring procedures" (Rietbergen et al., 2002). A 2006 evaluation of the Danish voluntary agreements on energy efficiency found that the agreement scheme addressed company-level barriers such as the lack of information and the Energy Management System (EMS) raised the awareness of energy efficiency. The evaluation showed that companies considered the EMS to be an important instrument in their effort to become more energy efficient. One important factor to the successful implementation of the EMS is the similarity with other management systems, like environmental management system and the quality management system (ISO 9001).

In addition to national programs, a number of multi-national companies have developed company-level target-setting programs and energy management programs with impressive results. Dow Chemical set a target to reduce energy intensity (btu/lb product) from 1994-2005 by 20% and actually achieved 22% ($4B in savings); their energy intensity reduction goal for 2005 to 2015 is 25%. 3M Corporation has reduced its corporate energy consumption by 30% since 2000 through its global energy management program. DuPont has achieved $2B in energy savings since 1990 as part of a corporate goal to achieve a 65% reduction in GHG emissions below 1990 levels by 2020.

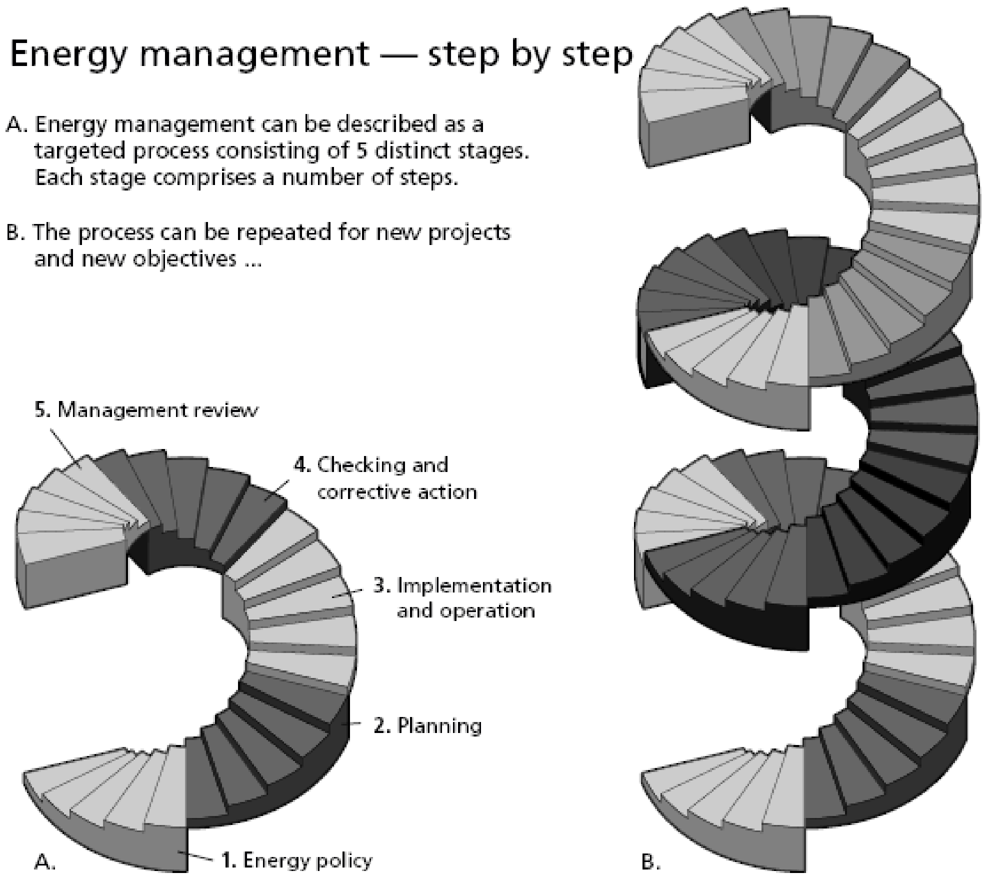
4.3 Energy Management Standards

The purpose of an energy management standard is to provide guidance for industrial facilities to integrate energy efficiency into their management practices, including fine-tuning production processes and improving the energy efficiency of industrial systems. Although the focus of this paper is industrial energy efficiency, it is important to note that the energy management standards referenced here are equally applicable to commercial, medical, and government facilities.

An energy management standard requires a facility to develop an energy management plan. In companies without a plan in place, opportunities for improvement may be known but may not be promoted or implemented because of organizational barriers. These barriers may include a lack of communication among plants, a poor understanding of how to create support for an energy efficiency project, limited finances, poor accountability for measures or perceived change from the status quo.

The six energy management standards presented below use the "plan-do-check-act" approach as illustrated in the diagram below from the Danish DS 2403:2001, Energy Management-Specification.

Figure 9: Energy Management Diagram



Source: Danish DS 2403:2001, Energy Management-Specification.

Typical features of an energy management standard include:

- a strategic plan that requires measurement, management, and documentation for continuous improvement for energy efficiency;
- a cross-divisional management team led by an energy coordinator who reports directly to management and is responsible for overseeing the implementation of the strategic plan;
- policies and procedures to address all aspects of energy purchase, use, and disposal;
- projects to demonstrate continuous improvement in energy efficiency;
- creation of an Energy Manual, a living document that evolves over time as additional energy saving projects and policies are undertaken and documented;
- identification of key performance indicators, unique to the company, that are tracked to measure progress; and
- periodic reporting of progress to management based on these measurements.

In addition, for Denmark, Ireland, and Sweden, the standard includes explicit reference to a commitment to adhere to other applicable relevant regulations and requirements that pertain to the company's energy use.

A successful program in energy management begins with a strong commitment to continuous improvement of energy efficiency. A first step once the organizational structure (energy coordinator, management team) has been established is to conduct an assessment of the major energy uses in the facility to develop a baseline of energy use and set goals for improvement. The selection of key performance indicators and goals help to shape the development and implementation of an action plan. An important aspect for ensuring the successes of the action plan is involving personnel throughout the organization. Personnel at all levels should be aware of energy use and goals for efficiency. Staff need to be trained in both skills and general approaches to energy efficiency in day-to-day practices. In addition, performance results should be regularly evaluated and communicated to all personnel, recognizing high achievement. The use of energy monitoring and process control systems can play an important role in energy management and in reducing energy use. These may include sub-metering, monitoring, and control systems. They can reduce the time required to perform complex tasks, often improve product and data quality and consistency, and optimize process operations (Worrell and Galitsky, 2004).

Table 5 compares the elements of the energy management standards in the countries studied. For all five countries with existing energy management standards (or specifications), the standard has been developed to be entirely compatible with the ISO quality management program (ISO 9001:2000) and environmental management program (ISO 14001). In the case of Denmark, Ireland, and Sweden, the assumption is that industrial facilities participating in ISO 14001 will integrate the requirements of the standard into their existing management documentation and procedures.

Table 5. Energy Management Standards, Details

Participating Countries	Management Commitment Required	Develop energy management plan	Establish energy use baseline	Identify Energy Coordinator	Establish Cross- Divisional Implementation Team	Emphasis on Continuous Improvement	Document Energy Savings	Establish Performance Indicators & Energy Saving Targets	Document & Train Employees on Procedural/ Operational Changes	Specified Interval for Re-evaluating Performance Targets	Reporting to Public Entity Required	Energy Savings Validated or Certified	Year Published	Approx Market Penetration by Industrial Energy Use
Existing														
Denmark	yes	yes	yes	yes	yes	yes	yes	yes	yes	suggests annual	yes	optional[1]	2001	60%[2]
Ireland	yes	yes	yes	yes	yes	yes	yes	yes	yes	industry sets own	yes	optional[1]	2005	25%
Netherlands[3]	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	optional[1]	2000	20-90%[4]
Sweden	yes	yes	yes	yes	unclear	yes	yes	yes	yes	yes[1]	yes	optional[1]	2003	50%elect
United States	yes	yes	yes	yes	yes	yes	yes	yes	yes	industry sets own	no	no	2000	<5%[5]
Under Development														
China	yes	yes	yes	yes	yes	yes	yes	yes	yes	industry sets own	not avail	not avail		

1 Certification is required for companies participating in voluntary agreements (also specified interval in Sweden). In Denmark, Netherlands & Sweden linked to tax relief eligibility.

2 As of 2002, latest date for which data is available

3 Netherlands has an Energy Management System, not a standard, per se, developed in 1998 and linked to Long Term Agreements in 2000.

4 800 companies representing 20% of energy use have LTAs must use the Energy Management System. The 150 most energy intensive companies, representing 70% of the energy use, have a separate, more stringent, bench marking covenant and are typically ISO 14000 certified, but are not required to use the EM System.

5 To date, the US government has encouraged energy management practices, but not use of the standard, therefore market penetration has been very limited. Program policies new in 2007 are designed to address this.

4.3.1 Supportive Policies and Programs

In the six countries studied, the energy management standards are designed to be applicable to all types and sizes of companies; however, in each instance, the largest, most energy intensive industries are the focus of additional programs and initiatives. By concentrating efforts on these large energy users, policy makers seek the greatest reduction in industrial energy consumption and overall GHG emissions. Not surprisingly, the proportionally greatest impact on industrial energy consumption has been in Denmark, which has had financial incentives since 1992 in the form of a CO_2 –tax rebate, coupled with voluntary agreements and, as of 2001, energy management standards. In general, the coupling of target-setting agreements with an energy management standard seems to be particularly effective. An entirely different approach has been taken in the US, which has concentrated on educating industry about system energy efficiency opportunities. The US has not explicitly promoted use of its energy management standard nor offered either financial incentives or penalties for meeting energy reduction targets. As a result, relatively few plants are using the energy management standard.
Table 6 below provides a comparison of these supporting policies.

Table 6. Energy Management Standards, Programmatic Context

Participating Countries	Voluntary or Mandatory Standard	Financial Incentives for Compliance	Technical Assistance Available	Penalties for Non-Compliance	Recognition Program	Linked to Voluntary Agreement	Training Available on Standard Compliance	Industrial Systems Training Available	Case Studies Published	Targeted Plants
Existing										
Denmark	vol	yes[1]	yes	yes[1]	yes	yes	yes	not known	yes	yes
Ireland	vol	yes	yes	no	yes	yes	yes	limited[4]	yes	yes
Netherlands	vol	yes[2]	yes	yes[2]	yes	yes	yes	limited[5]	yes	yes
Sweden	vol	yes[3]	yes	yes[3]	yes	yes	no	no	planned	yes
United States	vol	no	yes	no	planned	no	planned	yes	yes	yes
Under Development										
China	vol	info not yet available						yes		yes

1 Denmark has had a CO2 tax since 1992 that affects larger industries. Tax relief is linked to participation in a voluntary agreement.
2 Netherlands' Long Term Agreement participants must develop an energy management plan
3 Sweden has had a energy tax since 1/2005.Tax relief for process-related electricity linked to participation in a voluntary agreement.
4 Ireland plans to expand training offerings
5 Netherlands training available on specific topics

Denmark

Denmark has had a CO_2 tax in place since 1992 on all energy sources in Denmark. Because of concerns that the tax would make energy-intensive Danish industries non-competitive, the government introduced voluntary agreements that offered a CO_2- tax rebate for adopting energy management practices and undertaking energy efficiency measures. To be eligible, companies had to be listed by the Danish Energy Authority as energy-intensive and the company's energy-tax load had to exceed 4 percent of the company's value added in the year prior to signing the agreement. These agreements have become an important driver in encouraging use of the energy management standard in Denmark. Energy-intensive companies that enter into agreements for tax benefits must implement all energy-efficiency measures related to heavy processes with a payback period of four years or less; for less energy intensive companies signing agreements, the implementation requirement expands to measures with payback periods of six years or less.

According to Persson and Grudbjorg [2006]-

> The Danish Energy Authority has implemented several different policy measures to make industry invest in energy-efficiency and energy conservation actions. The most effective ones used by the Danish Energy Authority have been:
>
> - Voluntary agreements
> - Subsidies
> - Information activities

The Danish Energy Authority, as the result of a 2002 evaluation of the voluntary agreement system, found that half of the companies involved had reduced their energy usage by 20%. According to Larsen, *et al* [2005]-

> The intentions behind the development of Danish energy management during the last 10 years has been to transform it from a rather technical monitoring and measurement system to a management system with more focus on information, communication, internal and external audits and employee involvement.

The energy management system (introduced as a standard in 2001) was felt to be an advantage to the participating companies. Participating companies have cited other benefits such as better product quality, increased production capacity, and increased employee engagement. Active energy management in Denmark has been positively correlated for industrial firms with number of employees, CO_2- tax agreements, subsidies, and the number of environmental inspections by the local government. The role of training in system optimization techniques in achieving energy savings needs clarification.

Ireland

Sustainable Energy Ireland (SEI) has a well-integrated array of program offerings to encourage use of their energy management standard, IS 393, introduced in 2005. A three-day training session is offered on energy management that addresses topics such as energy management goals, benchmarking, establishing energy performance indicators, and an overview of energy improvement opportunities with a focus on motor driven systems. Companies are encouraged to join the Large Industry Energy Network (LIEN) to share and learn from each other during implementation of the energy management standard. The most energy intensive sites in Ireland (annual energy bill of €2 million or greater) are being recruited to participate in the Energy Agreements Programme, entering into an agreement with SEI that requires implementation of IS 393, including certification of compliance by an outside party. The target group comprises 60-100 industrial energy users, particularly those subject to the requirements of the EU-Emission Trading Scheme. As of January 2007, 25 companies were participating. Participants are eligible for an array of services to assist them in setting and meeting their energy management goals. Participation in a recognition program and case studies are also encouraged. A separate program for smaller companies is under development.[11]

Netherlands

In The Netherlands, guidance for establishing an Energy Management System based on the ISO standard for environmental management systems has been developed in support of the Long-Term Agreements. This Energy Management System Specification was developed in 1998 in cooperation with Bureau Veritas, an ISO 14001 certification institute and introduced into the Long –Term Agreements program activity in 2000. Companies that signed or joined LTA2 have the obligation to implement an energy management system within two years.

The 150 most energy intensive companies, representing 70% of total industrial energy use, have a separate bench marking covenant with the government. These industries are required to be among the top 10% most energy efficient in their sector worldwide. Many of these companies are also ISO 14001 certified.

Sweden

Sweden has had a voluntary agreement program since 1994, but only added an energy management standard as a program requirement in 2003. Prior to that time, the voluntary agreement had few incentives for participation and the results of the program could not be measured (Linden and Carlsson-Kanyama, 2002, as cited in Price 2005). In 2005, after Sweden imposed a tax on industrial process-related electricity, the Programme for Improving Energy Efficiency in Energy-Intensive Industries (PFE) was launched. Managed by the Swedish Energy Agency, the PFE offers reduced taxation for companies that introduce and obtain certification for a standardized energy management system and undertake electrical energy efficiency improvements. The program requires a five-year initial commitment, with specific milestones to report by the end of two years, as follows:

- implementation of the energy management standard that is certified by an accredited certification body;
- completion of an in-depth energy audit and analysis to baseline use and identify improvement opportunities. A list of measures identified in the energy audit with a payback of three years or less must be submitted to the Swedish Energy Agency;
- establish procurement procedures that favor energy efficient equipment, and
- establish procedures for project planning and implementation.

By the end of five years, the company must implement the listed measures, demonstrate continued application of the energy management standard and procurement procedures, and assess the effects of project planning procedures. As of January, 2007, 126 companies had signed up to participate in PFE, representing approximately 50% of all industrial electricity use. To join, companies must be in certain eligible classes, use electricity in their manufacturing process, have energy costs of at least 3% of production value or pay at least 0.5% of value-added in energy-related taxes, and have the economic

[11] For more information, see http://www.sei.ie/

means to carry out the program. To assist companies in compliance, the government has published handbooks on energy management, energy audits and analysis, routines for purchasing and planning, and a template for calculating life cycle cost in accordance with program requirements. The role of training for participating companies needs to be clarified.[12]

United States

Georgia Institute of Technology (Georgia Tech) first developed a comprehensive energy management standard for industry in 2000 that has served as a model for several subsequent national standards. Although the standard was adopted by the American National Standards Institute (ANSI), it has received little public recognition or support and is not widely used in the US. The US has, however, developed a great deal of technical capability in industrial energy efficiency, especially motor, steam, and process heating systems.

Since 1993, the US Department of Energy (USDOE) has been developing and offering an extensive array of technical training and publications to assist industrial facilities in becoming more energy efficient through its BestPractices program. In October 2005, USDOE initiated a program to offer an Energy Saving Assessment (ESA) demonstration for steam or process heating systems in 200 plants with an annual energy use of 1TBtu or higher. Eight months after completion of the assessments, 134 plants had reported almost $222 million worth of energy savings recommendations either completed, underway, or planned. Based on the success of the first year, the program was expanded in 2006 to include motor systems.[13]

In 2002, the US Environmental Protection Agency (USEPA) began a voluntary program, Climate Leaders, which works with companies to develop long-term comprehensive climate change strategies. Using the GHG emissions protocol developed by the World Resources Institute and the World Business Council for Sustainable Development, 59 companies have set and report progress on a corporate-wide GHG reduction goal to be achieved over 5 to 10 years. These goals are evaluated against the projected performance of the relevant sector. In 2003, the USEPA began offering information on energy management guidelines and benchmarking as part of its ENERGY STAR for Industry program. The program also includes energy performance indicators for selected industries that companies can use to benchmark their performance, gaining recognition if they are in the upper quartile.[14]

Collectively, these activities encourage companies to manage energy, but do not explicitly encourage use of an energy management standard. However, recently USDOE and USEPA have joined together to develop a collaborative program to certify plants for energy efficiency that implement energy management standards, based on an updated version of the Georgia Tech/ANSI energy management standard. This program is expected to greatly increase use of the standard by US industries.

---

[12] For more information, see http://www.stem.se/

[13] For more information about BestPractices see http://www1.eere.energy.gov/industry/bestpractices/

[14] For more information, see http://www.energystar.gov/

China

The China Standard Certification Center (CSC) has been authorized by the Chinese government to develop a series of national energy management standards. Three standards are planned for release by March 2008: Management System for Energy – Requirements, Management System for Energy - Guidelines for performance, and Management System for Energy - Guidelines for Auditing. The draft Requirements standard has much in common with the other energy management standards in use elsewhere.

As discussed in Section 4.1, the Chinese government has selected the Top-1000 Energy Consuming Enterprises as a major source of potential energy savings to meet national energy reduction goals. The Chinese energy management standards will be completed in 2008 and will be added to the portfolio of policy instruments and program offerings to assist these plants in meeting their goals.

Going Global: An International Approach to Industrial Energy Management

As shown in Table 4.3, the existing energy management standards have many features in common. This is not accidental. All the standards reviewed in this paper have been developed by individuals well-versed in the ISO management model for continuous improvement. The US standard, developed by Georgia Tech/ANSI, was based on ISO management principles. The Danish standard, issued a year later, has most of the same features and makes explicit references to ISO 14001. Both the Irish and Swedish standards acknowledge their similarity and relationship to the Danish standard. The Chinese standard now under development is using the Georgia Tech/ANSI standard as a reference. Brazil, Spain, and Korea have also initiated work on an energy management standard.

The European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) have formed a task force and undertaken development of a set of three European standards related to energy management including: energy service companies – ESCOs, energy managers and experts, and energy management systems. The Task Force 189- Energy Management convened in November 2006 with 24 participants from 10 countries, and decided to create three ad hoc Project Teams to develop the standards. The standard on energy management systems has been assigned to Sweden and will be a simple compilation of existing Danish, Swedish and Irish Standards and the Netherlands Specification, conform to the ISO 14 000 structure and requirement. It will also take in account the German VDI Specification on EMS.

A dialogue on international harmonization of energy management standards has recently been initiated by the ISO Secretariat, UNIDO, CEN, and the countries with experience with energy management standards who participated in a UNIDO experts' group meeting on this topic in March 2007. Developing countries have requested UNIDO's support to conduct a feasibility study to identify opportunities, costs, and barriers resulting from widespread adoption of an international energy management standard.

4.4 System Optimization and Capacity Building

System optimization seeks to design and operate industrial systems (i.e. - motor/drive, pumping, compressed air, fan, and steam systems) to provide excellent support to production processes using the least amount of energy that can be cost-effectively achieved. The process of optimizing existing systems includes:

- Evaluating work requirements;
- Matching system supply to these requirements;
- Eliminating or reconfiguring inefficient uses and practices (throttling, open blowing, etc);
- Changing out or supplementing existing equipment (motors, fans, pumps, compressors) to better match work requirements and increase operating efficiency;
- Applying sophisticated control strategies and variable speed drives that allow greater flexibility to match supply with demand;
- Identifying and correcting maintenance problems, and
- Upgrading ongoing maintenance practices.

Please note that a system that is optimized to both energy efficiency and cost effectiveness may not use the absolute least amount of energy that is technically possible. The focus is on achieving a balance between cost and use that applies energy resources as efficiently as possible.

4.4.1 Building Technical Capacity

Since system optimization is not taught in universities or technical colleges, UNIDO has worked with a team of international experts to develop and pilot in China a training curriculum specifically designed to build the necessary technical capacity.

A carefully organized training program can have a significant impact. As a result of the United Nations Industrial Development (UNIDO) China Motor System Energy Conservation Program, 22 engineers were trained in system optimization techniques in Jiangsu and Shanghai provinces. The trainees were a mix of plant and consulting engineers. Within two years after completing training, these experts conducted 38 industrial plant assessments and identified nearly 40 million kWh in energy savings. A list of typical system optimization projects identified through this initiative is described below.

Table 7. Energy Savings from System Improvements (China pilot program)

System/facility	Total cost (US$)	Energy savings (kWh/year)	Payback period
Compressed air /forge plant	18,600	150,000	1.5 years
Compressed air /machinery plant	32,400	310,800	1.3 years
Compressed air /tobacco industry	23,900	150,000	2 years
Pump system /hospital	18,600	77,000	2 years
Pump system /pharmaceuticals	150,000	1.05 million	1.8 years
Motor systems /petrochemicals (an extremely large facility)	393,000	14.1 million	0.5 years

Source: Robert Williams, UNIDO 2005

The goal of capacity-building training is to create a cadre of highly skilled system optimization experts. Careful selection is needed of individuals with prior training in mechanical or electrical engineering, who have an interest and the opportunity to apply their training to develop projects. This training is intensive and system-specific. Experts may come from a variety of backgrounds, including, but not limited to: government sponsored energy centers, factories, consulting companies, equipment manufacturers and engineering services companies. Experts in pumping systems, compressed air systems, ventilating systems, motors and steam systems should be used to develop local experts through an extensive training program. Training should include both classroom and hands-on measurement and system assessment instruction and include at least a year of access to follow-up technical assistance from the instructors to assist the trainees in developing their first few projects. The resulting system experts are prepared to evaluate and optimize one or more industrial motor-driven systems or steam systems

Ideally, the completion of the intensive training program is coupled with recognition for the competency of the trained local experts through a certificate. Testing of skills through the successful completion of at least one system optimization assessment and preparation of a written report with recommendations that demonstrates the ability to apply system optimization skills should be a prerequisite for any recognition.

The trained local experts should also be prepared to offer awareness level training to factory operating personnel on how to recognise system optimization opportunities. This awareness training can be used to build interest in and a market for the local experts' system optimization services. In addition, awareness training can provide a basic understanding of system optimization for factory operating personnel to apply in identifying energy efficiency project opportunities.

4.5 Documenting for Sustainability

With the renewed interest in energy efficiency worldwide and the emergence of carbon trading and new financial instruments such as white certificates, there is a need to introduce greater transparency into the way that industrial facilities identify, develop, and document energy efficiency projects. Historically, industrial energy efficiency projects have been developed by plant engineers, frequently with assistance from consultants and/or suppliers with highly specialized technical skills. Under this scenario, implementation of energy efficiency improvements is dependent on individuals, often “champions” within an industrial facility or corporation, working in cooperation with consultants or suppliers who have substantial knowledge based on years of experience. This approach is not easily understood by others without this specialized technical knowledge, penetrates the market fairly slowly, and has no assurance of persistence, since champions may leave the company or be re-assigned after project completion.

In order to ensure persistence for energy efficiency savings from system optimization projects, a method of verifying the on-going energy savings under a variety of operating conditions is required. ISO 9000/14000 Series Standards would require continuously monitoring an organization’s adherence to the new energy system-operating paradigm.

4.5.1 Documentation and ISO 9000/14000

The purpose of ISO 14001 is to provide a framework for organizations to achieve and demonstrate their commitment to an environmental management system that minimizes the impact of their activities on the environment (a similar framework for ISO 9001:2000 pertains to quality). The framework does not include any specific requirements, only a means of achieving goals set by the organisation. This ISO standard also provides for an audit procedure to verify that established policies of the organization are being followed. To maintain certification, participating companies must maintain a Quality Environmental Management (QEM) Manual.

The environmental management system model for this standard is composed of six elements: (1) The establishment of an environmental policy by the organisation; (2) Planning; (3) Implementation and operation; (4) Checking and corrective action; (5) Management review; and, (6) Continual improvement.

Once top management has defined the organisation’s environmental policy, the next step is planning. In the ISO 14001-1996 Environmental management systems – Specification with guidance for use, Section 4.3.1 states:

> “The organization shall establish and maintain (a) procedure(s) to identify the environmental aspects of its activities, products or services that it can control and over which it can be expected to have an influence, in order to determine those which have or can have significant impacts on the environment. The organization

shall ensure that the aspects related to these significant impacts are considered in setting its environmental objectives".

There are two approaches to establishing and maintaining efficient operation of energy systems. Both approaches involve the "Planning" phase and the "Implementation and operation" phase of ISO 14001. As an alternative for operations that are ISO 9000 certified, but not ISO 14000, these same steps can be incorporated into the ISO 9000 Quality Standards.

First, a set of standards can be developed in the ISO format that can be incorporated in the "Planning" portion of ISO 14001.[15] From those standards, work instructions can be written for the "Implementation and operation" portion. By making these "best practices" standards part of ISO certification, an organization ensures that these best practices will become part of the organization culture through the continuing audit procedure required by ISO. By making these best practices ISO-friendly, organizations can easily incorporate them into existing ISO systems. The number of standards incorporated can be determined by the individual organisation. As more goals are reached, new standards can be included, further improving the energy efficiency of the steam and motor systems' operation and making efficiency part of the culture. Second, for organisations that are involved in carbon financing, ISO standards can be developed that are specific to that organisation's on-going commitment to energy efficiency and pollution reduction.

A procedure refers to a general description of a process and is incorporated into a company's QEM Manual. The first step is for a company to develop a policy of efficient operation of energy systems within their facility, then develop and implement system procedures that are consistent with that policy.

The company must develop procedures for energy systems. The company must document those procedures and keep the documentation up to date. Each procedure should:

- specify its purpose and intended scope
- describe how an activity is to be performed
- describe who is responsible for carrying out the activity
- explain why the activity is important to the efficient operation of the system
- identify a timetable for the activity
- explain what equipment is required to complete the activity
- detail the documents and records that need to be kept

Procedures may also refer to detailed work instructions that explain exactly how the work should be performed.

---

[15] The use of the term "standard" in this context broadly refers to a company-specific operational standard as part of the company's ISO plan, not an energy efficiency standard per se. The inclusion of energy-efficient best practices as part of these operational standards is what is discussed here.

A project refers to a specific activity designed to contribute to meeting the ISO requirement for continuous improvement. Examples of projects include: initiating a leak management program or replacing a throttle valve on a pumping system with a speed control device. Work instructions are step-by-step information (text, diagrams, photos, specifications, etc) to assist operations staff in maintaining the improvements realized through implementation of a project. Examples include: instructions on how and when to check leaks and repair them or maintenance information to ensure that the pump system speed control device continues to function efficiently. Work instructions are typically posted for or easily accessible to operations staff.

The regular external audit process assures that proper and efficient operation of industrial energy systems is maintained and becomes part of each firm's operating culture, while transferring much of the burden and cost associated with regulatory compliance enforcement to these independent auditors. Linkage to ISO will also provide verification of results for financial backers (including future CDM carbon traders), and provide a clear methodology for recognizing "investment grade" projects, which will help stimulate a significantly higher level of industrial energy efficiency.

4.5.2 Systems Optimization Library

To enable firms to comply with the energy management standards and to more easily include energy efficiency projects as part of a company's continuous improvement plan (whether ISO or not), UNIDO and its partners have developed the concept for a System Optimization Library. The System Optimization Library is an electronic reference document that organizes energy efficiency opportunities by system and includes a series of procedures, projects, and work instructions written in an ISO-compatible format that are designed to facilitate integration of energy efficiency system improvements into ISO 9000/14000 operational and compliance materials. The advantage of the Library is that it will standardize and streamline the process of developing and documenting energy efficiency improvement projects. By providing work instructions to support the new, more energy efficient operation, the Library will also increase the likelihood that the resulting energy savings would be sustained.

Providing evidence that sufficient documentation exists to support the persistence of energy savings is a critical pre-requisite to consider industrial energy efficiency projects for white certificates or carbon credits. Without such evidence, the value of these projects may be subject to deep discounts, since there would be no assurance that energy savings would persist over the life of the project (often ten years or more) without significant degradation in energy efficiency.

4.6 Recognition Programs, Tax and Fiscal Policies, and Carbon Offset Programs

4.6.1 Recognition Programs

Recognition programs have proven to be effective mechanisms for rewarding industrial facilities who participate in public programs to encourage more energy efficient behavior. Recognition programs also "lead by example", by building greater awareness of the benefits of industrial energy efficiency among companies that may not yet be active. Finally, recognition programs create peer pressure within sectors that encourages more energy efficient practices, as companies receiving awards or other types of recognition seek to use them for competitive advantage.

Most countries who have instituted industrial energy efficiency programs also have recognition programs. In many countries, a recognition program is developed early in the process of creating a comprehensive industrial energy efficiency program. The advantages to this approach include: creating momentum for the program, providing positive public relations for both the company and the sponsoring government agency or ministry, and collecting case studies as examples for future training efforts. In addition, recognition programs are typically very cost-effective, serving as a stimulus for future energy savings far beyond their nominal cost. An effective recognition program is performance-based and provides awards or other benefits only if supported by documented energy saving improvements. As described in Section 4.2, recognition programs are frequently used as an element of target-setting agreements.

Thailand offers the Prime Minister's Industrial Award, recognizing top-achieving firms that institute a comprehensive energy management plan and report their results. Australia has an annual ceremony for their Greenhouse Challenge Plus program awardees, which is held at Parliament House and hosted by the Minister for Industry, Tourism and Resources. Programs in the UK, Ireland, Sweden, Denmark, Korea, and the Netherlands all have recognition programs associated with their target-setting agreement programs, in addition to tax incentives, for companies who document substantial reductions in energy use. Canada, Germany, and Switzerland also have recognition programs based on energy or GHG emissions reduction achievements. The US Environmental Protection Agency offers an ENERGY STAR for Industry award to companies who are in the top quartile of their sector based on reported energy performance.

4.6.2 Tax and Fiscal Policies

Tax and fiscal policies for encouraging investment in energy-efficient industrial equipment and processes operate either through increasing the costs associated with energy use to stimulate energy efficiency or by reducing the costs associated with energy efficiency investments. Various forms of these instruments have been tried in numerous countries over the past three decades. In addition, integrated policies that combine a variety of financial incentives in a national-level energy or GHG emissions mitigation program are also found in a number of countries. Such integrated policies are often national-level energy or GHG programs that combine a number of tax and fiscal policies along with other energy efficiency mechanisms such as voluntary agreements.[16]

Energy or CO2 Taxes

Energy or energy-related carbon dioxide (CO_2) taxes have been used in a number of countries to provide an incentive to industry to improve the energy management at their facilities through both behavioral changes and investments in energy-efficient equipment. Taxes on energy or energy-related CO_2 emissions were first adopted in a number of northern European countries in the early 1990s. Such taxes are now found in Austria, the Czech Republic, Denmark, Estonia, Finland, Germany, Italy, the Netherlands, Norway, Sweden, Switzerland, and the UK. In target-setting programs that involve the use of energy taxes, such as the Climate Change Agreements in the UK and the Danish energy efficiency agreements, rewards for meeting agreed-upon targets are provided in the form of a reduction of the required energy tax (DEFRA, 2004; Togeby et al., 1999). The French AERES agreements include a penalty fee imposed at the end of two evaluation periods if the targets are not met (AERES, 2004).

In 1991, the Swedish Carbon Tax was introduced. Industries were only required to pay 50% of the tax to maintain competitiveness and certain high energy-using industries such as commercial horticulture, mining, manufacturing, and the pulp and paper industry were fully exempted from the tax. In 2004, an EU directive led to an increased electricity tax of 0.5 €/MWh which affected most Swedish industrial companies. As a result, the Programme for improving energy efficiency in energy-intensive industry (referred to as "PFE") was introduced. Companies that join the PFE are eligible for a tax reduction if they fulfill the program requirements of recording company energy use and introducing a standardized energy management system during the first two years of the program, analyzing the company's situation and generating a list of measures to improve electricity efficiency that can be implemented over the next three years of the program, and establishing purchasing and planning criteria directed toward more energy-efficient equipment. At the end of PFE's first year in 2005, 126 companies representing more than half of Swedish industrial sector electricity consumption are participating in the program (Swedish Energy Agency, 2005; Swedish Energy Agency, 2006).

Grants and Subsidies

Beginning in the 1970s, grants or subsidies for investments in energy efficiency were among the first policy measures to be implemented and remain the most widespread fiscal incentives used today. A recent survey found that 28 countries provide some sort of grant or subsidy for industrial energy efficiency projects (WEC, 2004). Grants or subsidies are public funds given directly to the party implementing an energy efficiency project. Those providing the grants or subsidies, generally the public sector, do not seek a direct financial benefit in the form of return on investment. Due to problems with free-

[16] Much of this section is based on information from Galitsky et al., 2004.

riders, prohibitively high transaction costs or complex and long procedures to process forms, international best practice is to restrict such grants or subsidies to certain types of investment, such as a selected list of equipment with a long payback time but high efficiency gains, or to investments of a certain size or level of cost-effectiveness.

Developing countries with higher risk market environments for investments may find that direct public funding in the form of grants or subsidies are a viable option for encouraging investment in energy efficiency. Public funds may also be needed where competition with more traditional investments such as infrastructure expansion receives most of the available financing, where non-asset based energy efficiency projects are perceived to be riskier than asset-based investments, where energy efficiency projects are too small to gain enough attention or where energy prices do not reflect real costs of energy and are too low for energy efficiency projects to procure enough financial benefit for individual companies.

Australia's Greenhouse Gas Abatement Programme (GGAP) targets all sectors of the economy but focuses on large scale emission reduction projects, especially those that exceed 250,000 tonnes of CO_2 equivalent emission reductions annually (Greenhouse Gas Abatement Programme, n.d.). In the first two application rounds, 15 projects and almost \$145 million were offered, with a goal of 27 million tonnes of GHG abatement (Kemp and Macfarlane, 2003). In its subsidy program, Denmark prioritized the distribution of grants and subsidies to energy-intensive industries and companies involved in a voluntary agreement (Danish Energy Agency, 2000).

Other subsidy schemes focus more on small- or medium-sized enterprises, which may not otherwise be able to afford to undertake large energy efficiency projects. The Netherland's BSET Program focused on small- or medium-sized enterprises, covering up to 25% of the costs for specific technologies such as heat recovery, heat pumps and absorption cooling (Kræmer and Stjernström, 1997). The Scottish Clean Energy Demonstration Scheme (SCEDS) also focuses on small- to medium-sized businesses. SCEDS funds grants up to 80,000 GBP (\$150,000 2005 US) for development, demonstration, application and replication of energy efficiency measures and renewable technologies in Scotland (SEEO, n.d.).

Some programs tie grants to a cost-effectiveness criterion. Thailand's Energy Conservation Program Fund (ECF), which was created in 1995 as a part of the Energy Conservation Promotion Program (ENCON) and is funded from a tax on petrol ECF, provides subsidies in both the public and private sectors, covering up to 50% of the costs for a facility up to 500,000 Baht (US\$12,000). In order for a facility to meet Thailand's cost-effectiveness criteria, Thailand's program requires that each efficiency measure achieve an internal rate of return above 9% (WEC, 2003; WEC, 2004).

Norway's IEEN program provides grants up to 20% in any sector investing in energy management or energy monitoring. Like Thailand, Norway also tied grants to cost effectiveness in its program that ran from 1990-1993, but Norway set a maximum limit on the rate of return as well as a minimum, from 7 to 30% (MURE II, n.d.). From the 487 projects given a grant, a total of 1050 GWh/year was saved with a total investment of 1,200 million NOK ($188 million 2005 US). Only 16.5% of these costs were IEEN subsidized (198 million NOK or $31 million 2005 US).

Energy Efficiency Loans and Innovative Funding Mechanisms

Loans subsidized by public funding as well as loans that are offered at interest rates below market interest rates can be directed for investments in energy efficiency. Public, or soft, loans are loans subsidized by public funding that are offered at interest rates below market interest rates for investments in energy efficiency. Often these loans are combined with innovative funds or partially fund innovative funds. Like grants, the goal of subsidized loans is to promote energy efficiency measures until they achieve market acceptance level and can be funded on their own. According to WEC (2004), public loans are less popular than subsidies in the countries surveyed.

Innovative funding mechanisms aimed at increasing the involvement of banks and private capital in energy efficiency investments are also being used in some countries. In an effort to reduce public debt, trends show a movement toward these types of private sector, rather than the public sector, funds (WEC, 2004). By involving the private sector who seeks profits from their loans, these countries hope to develop a self-sustaining market in the long term, while obtaining a good return on investment in the short term. Generally, both private, “innovative” and public, “soft” loans are used in a given scheme; many innovative funds themselves employ partial public funding.

Higher risk market environments that exist in developing countries and emerging economies may make it more difficult to raise finance from banks that tend to be conservative in investments, and who are not used to the idea of energy efficiency generating cash (WEC, 2004). Developing countries may also face competition with more traditional investments like expansion of industrial plants or power generation. In addition, energy efficiency projects without large capital investments are often perceived as riskier and/or are too small to attract multilateral financial institution lending.

Innovative funding mechanisms include equity participation through energy service companies (ESCOs), guarantee funds, revolving funds, and venture capital. ESCOs are private companies that provide project identification, engineering, design, installation, ongoing servicing and maintenance, monitoring and verification of savings, and/or financing of energy and energy efficiency projects. As a part of a private fund geared towards energy efficiency, the ESCO’s role is to help to acquire and manage projects within the fund. According to WEC (2004), economies in transition can especially benefit from ESCOs if initial funding can be raised or provided, though they have only very recently been developed there.

With a few exceptions, such as industrial purchased steam or co-generation, ESCOs have had little impact on the development of energy efficiency projects that involve industrial systems. There are many reasons for this, including: high cost of opportunity identification and deal completion, limited replicability site to site, and lack of expertise in specific industries (Elliott, 2002). ESCOs typically enter industrial markets with experience from the commercial sector and tend to concentrate on measures such as lighting and heating, ventilating, and air conditioning that are found in commercial buildings, which miss most of the energy savings at industrial sites. In recent years, suppliers of industrial system equipment have begun providing “value added” services that may include everything from a broader range of product offerings (sophisticated controls, drives, valves, treatment equipment, filters, drains, etc) to complete management of the industrial system as an outsourced provider. Their success appears to be attributable to their specialized level of systems skill and familiarity with their industrial customers’ plant operations and needs (Elliott, 2002).

Guarantee funds provide a guarantee to the banks granting loans in the medium and long term. Many countries have guarantee funds, but these funds are generally not adequate in guaranteeing financing for energy efficiency projects and most of them have ceilings on the guarantees. In these cases, guarantee funds for energy efficiency can be offered in addition to the national guarantee fund. Guarantee funds cover credit risks associated with financing energy efficiency. To maximize their efficiency, a good assessment of the potential benefits is key. France, Hungary and Brazil have all established guarantee funds for energy efficiency (WEC, 2004).

With revolving funds, the reimbursement of the loans is recycled back into the fund to support new projects. These funds generally require public or national intervention to support them, either through subsidizing interest rates (low or zero) or by subsidizing the principal investment. They can be implemented at the local or national levels and can be applied to any sector. Thailand’s Energy Conservation (ENCON) Promotion Act helped set up the ENCON Fund. The agreement to start the fund with six financial institutions was signed in 2003 with a total of 2 billion Gaht ($500 million May 2005 equivalent). The fund is fixed for three years with the intention that at that point the scheme should become self-sustaining without the need for public intervention. This trend has already begun, with more banks applying to become a part of the scheme (WEC, 2004).

The UK’s Carbon Trust is a government-funded independent non-profit organization that assists businesses and the public sector to reduce carbon emissions by 60% by 2050 as outlined in the UK Government’s Energy White Paper (UK Department of Trade and Industry, 2003). The Carbon Trust provides interest-free loans to small- and medium-sized enterprises, funds a local authority energy financing scheme, promotes the government’s Enhanced Capital Allowance Scheme, and has a venture capital team that invests between £250,000 to £1.5 million ($284,000 to $2.8 million 2005 US equivalent) per deal as a minority stakeholder alongside private sector investors. VC investments include early-stage carbon reduction technologies as well as management teams that can deliver low carbon technologies (Carbon Trust, 2005a).

Tax Relief

Tax relief for purchase of energy-efficient technologies can be granted through tax exemptions, tax reductions, and accelerated depreciation. Such schemes are found in 22 countries (WEC, 2004). A common approach is to provide a list of technologies for special tax treatment. Depending upon the specific program, this tax treatment could be:

1) accelerated depreciation where purchasers of qualifying equipment can depreciate the equipment cost more rapidly than standard equipment, 2) tax reduction where purchasers can deduct a percentage of the investment cost associated with the equipment from annual profits, or 3) tax exemptions where purchasers are exempt from paying customs taxes on imported energy-efficient equipment.

Accelerated Depreciation

Accelerated depreciation programs are found in Canada, Japan, The Netherlands, and Singapore. In Canada, the Accelerated Capital Cost Allowance Class 43.1 allows taxpayers an accelerated write-off at a rate of 30% for specified energy efficiency and renewable energy equipment. Typically, equipment investments can be depreciated at annual rates between 4% and 20% (Canada Department of Finance, 2004). In addition, the program includes the costs of pre-feasibility and feasibility studies, negotiation costs, site approval costs, etc. (Government of Canada, 1998).

In Japan, under the 1993 Energy Conservation and Recycling Assistance Law, an accelerated depreciation allowance equal to 30% of the acquisition cost is available for investments in heat pumps, floor heaters, CHP systems, district heating and cooling systems, high efficiency electric trains, low emission vehicles, energy-efficient textile manufacturing equipment, solar power systems, small- and medium-size hydro generators, and equipment for producing recycled paper and plastics (Anderson, 2002).

The Netherlands also provides the Accelerated Depreciation on Environmental Investment program (VAMIL), which allows an investor to more rapidly depreciate its investment in environmentally-friendly machinery, reducing operating profits and tax payments. This program has been in effect since 1991 and includes equipment that reduces water use, soil and air pollution, noise emissions, waste production and energy use. To qualify, the equipment must have relatively good environmental impacts, be not yet widely accepted in the country, have no negative side effects, and have the potential for a substantial market in the country. The list of qualifying equipment is updated regularly. Costs associated with obtaining advice on the purchased machinery are also subject to accelerated depreciation (IISD, 1994; SenterNovem 2005a).

Under Singapore's Income Tax Act, companies that invest in qualifying energy-efficient equipment can write-off the capital expenditure in one year instead of three. Unlike the Canadian and Dutch programs, however, expenses related to acquiring information or consultant fees for identifying and analyzing the equipment purchase are not included in this program. Replacement equipment, such as new air-conditioning systems, boilers, and water pumps, along with energy-saving equipment such as high efficiency motors, variable speed drive motors, or computerized energy management systems qualify (NEEC, 2005).

Tax Rebates

Programs in which companies deduct the cost of energy-efficient equipment from their annual profits are found in Japan, Korea (Republic of), The Netherlands, and the UK. Japan's Energy Conservation and Recycling Assistance Law also provides a corporate tax rebate of 7% of the purchase price of energy-efficient equipment for small and medium-sized firms (WEC, 2001). In the Republic of Korea, a 5% income tax credit is available for energy-efficiency investments such as replacement of old industrial kilns, boilers, and furnaces; installation of energy-saving facilities, co-generation facilities, heat supply facilities, or energy-saving equipment; alternative fuel using-facilities; and other facilities that reduce energy by 10% (UNESCAP, 2000).

Tax Deductions

In The Netherlands, under the Energy Investment Deduction (Energie Investeringsaftrek, EIA) program, originally 40% and now 55% of the annual investment costs of energy-saving equipment can be deducted from the fiscal profit during the calendar year in which the equipment was procured, up to a maximum of 107M €. Qualifying equipment is provided on an "Energy List" and the costs associated with obtaining advice for purchased equipment can also be included. Approval is granted by SenterNovem, an agency under the Dutch Ministry of Economic Affairs. The budget for this program in 2005 is 137M € (Aalbers et al., 2004; SenterNovem, 2005b).

The UK's Enhanced Capital Allowance Scheme allows a business to claim 100% first-year tax relief on their spending on qualifying energy-saving technologies specified in the "Energy Technology List" on their income or corporation tax return. Businesses can write off the entire capital cost of their investments in energy-saving technologies against their taxable profits for the year during which they make the investment (HM Revenue & Customs, n.d.). The technologies that currently appear on the 2004 Energy Technology List are: air-to-air energy recovery, automatic monitoring and targeting, boilers, combined heat and power (CHP), compact heat exchangers, compressed air equipment, heat pumps for space heating, HVAC zone controls, lighting, motors, pipework insulation, refrigeration equipment, solar thermal systems, thermal screens, variable speed drives, and warm air and radiant heaters (Carbon Trust, 2005b).

Tax Exemption

A full exemption from Germany's petroleum tax is provided for highly efficient combined heat and power (CHP or cogeneration) facilities that have monthly or annual utilization rates of 70% or greater (German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, 2004). A Romanian program exempts imported energy-efficient technologies from customs taxes and exempts the share of company income directed for energy efficiency investments from income tax (Alliance to Save Energy et al., n.d.). In November 2000, the Energy Efficiency Law was passed by the Parliament of Romania. The law covers the efficient use of energy in all areas. One element of the law is that "devices, machine tools, equipment and technologies for increasing energy efficiency are exempt of custom taxes" (CEEBICNet Market Research, 2004).

4.6.3 Potential Links to Carbon Offset Programs

Industrial Energy Efficiency Projects and Joint Implementation (JI) and Clean Development Mechanism (CDM)

As previously discussed in Section 3, a number of barriers prevent industrial facilities from making investments in energy efficient technologies and practices. For developing countries, this is particularly unfortunate, as many of these countries have rapidly expanding industrial infrastructure. If steps are not taken now to introduce energy efficiency into this emerging infrastructure, the loss in global energy efficiency will be not only substantial, but virtually non-recoverable in terms of wasted energy and excessive GHG emissions. The Kyoto Protocol's flexibility mechanisms, the Clean Development Mechanism (CDM) and Joint Implementation (JI), can address primarily financial barriers.

Even though a number of countries have made energy efficiency a CDM priority, it doesn't seem to be working well for the industrial sector. Among the 563 CDM projects approved up to 22 March 2007, only 19 are industrial end-use efficiency projects, representing only 3% of the total number of registered CDM projects . The estimated GHG reductions from these projects are < 300 kt CO2e per year, which is a miniscule share of global energy efficiency potential. The projects are also limited in terms of their geographical distribution (all but two projects in India) and a range of applied technologies and energy efficiency know-how (Arquit Neiderberger 2007).
.

At a recent meeting hosted by UNIDO, Climate Technology Initiative (CTI), and UK Trade & Investment, the international climate change community expressed its concern with the limitations encountered by energy efficiency projects, and demand-side industrial energy efficiency projects in particular. Their under-representation in the CDM pipeline is not only a lost opportunity in terms of carbon emission reduction (CER) volumes, but is also a growing challenge to the CDM itself, particularly in light of the uncertainties with the post- 2012 regulatory framework and the growing demand for projects with shorter pay-back period and the potential for the deliver of quality emission reductions. The remaining text in this section is drawn from the thematic summary of the meeting (UNIDO, 2007).

> The participants concluded that was crucial to build on the large body of existing knowledge on international protocols/best practice that has been built since the 1973 oil crisis. This requires engaging government regulators and industry energy efficiency experts (incl. utilities, ESCOs, technology providers, end-users) with experience in the implementation and evaluation of public and private energy efficiency regulatory, incentive, contracting, training, and audit programs. Ideally, a "community of practice" on energy efficiency CDM would be built.
>
> There is an urgent need for top-down guidance on key energy efficiency design issues, including:
>
> - Emission reduction quantification methodologies: Most energy efficiency programs/protocols offer a menu of approved options that can be selected by the project proponents, typically including (i) use of default abatement factors ("deemed savings" approach), (ii) calculated (engineering) methods for discrete equipment/systems, sometimes in conjunction default efficiencies and other

parameters, (iii) before/after metering/modeling, typically applied to more complex systems, such as buildings and (iv) sometimes, reliance on energy monitoring plans audited by third parties (this is the approach followed under JI Track 2).

- Baseline adjustment requirements/techniques for routine and non-routine factor
- Decisions on whether it is necessary and, if so, how to treat "gross-to-net" energy saving issues (including leakage, rebound effects, free riders, spillovers)
- Definition of related default abatement factors, efficiencies and other parameters to enhance transparency, consistency and certainty.

> Such issues are not new to CDM, and regulators have made decisions in the context of existing regulatory programs about how to handle them. The previous practice under the CDM – with the exception of small-scale and sink-related methodologies – has been to derive guidance and tools based on bottom-up submissions. However, since there are so few approved … methodologies to draw from, and the approval process has been inconsistent, a top-down approach that draws on methodologies for demand efficiency projects already available outside of the CDM world is urgently needed.

One recommendation from the meeting was to form a network of energy efficiency experts to advise the CDM Methodology Panel. Another was to make greater use of measurement and verification protocols (e.g. International Performance Measurement & Verification Protocol [IPMVP]), energy management standards, evaluation guidebooks on DSM and energy audits and other technical and engineering tools is needed in order to improve transparency, consistency and certainty of energy efficiency methodologies and consequently, energy efficiency projects in CDM.

A case study of JI and CDM in the cement industry is described below.

JI and CDM- – Cement Plant Case Study

As of April 2007, there is only one registered JI project in the cement industry – conversion of a wet process plant to a dry process plant in the Ukraine, which is estimated to save 3 $MtCO_2$ in 2012. An energy efficiency project in a cement plant in Romania, estimated to save 0.8 $MtCO_2$ in 2012, is at the validation stage where proposed projects are evaluated to see if they meet the general requirements of a JI project before proceeding to the registration phase (Fenhann, 2007a).

There are 25 registered CDM projects in the cement industry with another 53 in various stages of the pre-registration process, including 34 that began the validation process in either 2006 or 2007, as of April 2007. The registered projects include the use of alternative fuels, waste heat recovery and use for electricity generation, blending waste materials with cement clinker, and energy efficiency. All of these options both save energy and reduce GHG emissions. Nineteen of the registered projects are in India, two are in Indonesia, and China, Israel, Malaysia, and Morocco each have one project. These 25 registered projects are estimate to save 22 $MtCO_2$ in 2012 (Fenhann, 2007b).

5. Policy Recommendations

This section provides some practical considerations for beginning an industrial energy efficiency program based on the portfolio of policies in the Industrial Standards Framework discussed in this paper. The key to an effective industrial energy efficiency policy is to find a balance between consistency and flexibility. Consistency in program message, goals, target industries, and basic program offerings is critical.

When announcing an industrial program, a policy maker should assume that industry will require at least a year to accept it and another year or more to respond. Most industries require at least 12-18 months for completion of an energy efficiency project after an assessment is done and opportunities have been identified. This is because any planned capital improvements must wait to be included in the following year's budget cycle. Changing organizational behavior takes time and permanent market change takes even longer. Assume that an industrial energy efficiency program will take at least five years to fully mature. Small improvements to the program or "tweaking" during this period can be helpful- especially in response to industry input; but re-branding and major meddling with the program design are counterproductive and to be avoided. If funds are too limited to consider a full-scale launch, a graduated program could begin with system optimization training (expert and awareness), followed later by target-setting agreements, energy management standards, and documentation for sustainability. For any program element to be successful, industrial markets must be engaged. This point is addressed in the section on partnerships.

5.1 Getting Started with Target-setting Agreements

Typically, the process for setting energy efficiency or greenhouse gas (GHG) emission reduction targets involves making a preliminary assessment of the energy efficiency or GHG mitigation potential of each industrial facility which includes an inventory of economically-viable measures that could be implemented. These assessments, which can be made by the company themselves or by an independent third party, are then provided to the government and form the basis for discussions and negotiations related to target-setting between the industries and the government.

In the UK, the process for setting the Climate Change Agreement targets began with information-gathering on the part of the government. The government obtained information regarding energy efficiency potential in energy-intensive industries through the Energy Efficiency Best Practices Program which produced good practice guides and case studies, new practice case studies, and information on future practices as well as through a report prepared by ETSU (now AEA Energy & Environment) on projections of industrial sector carbon dioxide emissions under a business-as-usual scenario as well as two scenarios that included all cost-effective and all technically-possible technologies. Then, for the ten largest energy-consuming sectors, individual companies made estimates of what energy efficiency improvements they could make based on an assessment of their potential and provided this information to their trade associations. The starting point for the major industries was studies establishing what would be expected under business-as-usual and what could be achieved if all cost-effective measures were adopted, which was based on recent history of efficiency measures, rates of technology uptake, expected growth rates, and investment plans. Once this information was gathered, negotiations took place with each sector. The sector then offered a target for the whole sector to the government. Negotiation then drew the process forward, with government often requiring the industry sector to improve their offer to a more challenging level, based on information on cost effective processes and general standards of energy management in the sector.

For the Long-Term Agreements (LTAs) in The Netherlands, voluntary agreements between the Dutch Ministries and industrial sectors consuming more than 1 petajoule (PJ) per year, were established in support of achieving an overall national energy-efficiency improvement target of a 20% reduction in energy efficiency between 1989 and 2000. The targets were divided among the various industrial sectors with most industries also adopting a target of 20% reduction, but some establishing different targets based on assessments of their energy-efficiency potential. For example, the petroleum refining industry's overall target was a 10% reduction, while the target for Philips Lighting was a 25% reduction. The process for establishing the industrial sector targets began with a preliminary assessment of the energy efficiency potential of the sector by the industry. A quantified target was then set for the improvement of energy efficiency in the sector, based on the outcome of the study. A Long-Term Plan (LTP) described how the sector planned to realize its target. The LTAs include commitments for individual companies, such as the preparation of an energy conservation plan (ECP) and annual monitoring of developments in energy efficiency, expressed using an energy efficiency index (EEI). Then NOVEM, the Dutch Agency for Energy and Environment, established an inventory of economically viable measures that could be implemented by the companies in each industrial sector and based on this inventory set a target for energy efficiency improvement for each sector. The LTA for the period 1989-2000 was successful and resulted in an improvement of the average energy efficiency of 22.3%.

Following the LTAs, the Dutch government established the Energy Benchmark Covenant program for large energy-intensive industries. The Benchmarking Covenants, which began in 2001, use a benchmarking approach for target-setting. Using this approach, the participating company hires an expert third party to perform a study of the international best practice in terms of energy efficiency for all of its processing plants once every four years. International best practice is determined one of two ways:

1) Determination of the regions outside the Netherlands comparable with the Netherlands in terms of size and number of processing plants, and which may meet the best international standards. The average energy efficiency of similar processing plants in these regions will be determined. The best international standard is the average energy efficiency in the region with the best average.
2) Determination of the energy efficiency of comparable processing plants outside the Netherlands. These will be ranked according to energy efficiency levels. The best

decile of these processing plants in terms of energy efficiency will then be determined. The best international standard is at least the value of the energy efficiency within that top 10%. If Companies or sectors can support a claim that in their situation, a different percentage than the 10% mentioned above is the determining factor for realizing a similar effort with the first method described, this percentage shall apply. The Benchmarking Commission will determine whether sufficient support has been provided for the claim, after receiving recommendations from the independent authority.

If it is not possible to conduct either of the two studies outlined above, then the energy efficiency of the best processing plant outside of the Netherlands will be determined and the benchmark will be set at 10% below the energy efficiency of this facility. Companies can provide information supporting the use of a different percentage given their specific situation. The Benchmarking Commission then determines whether sufficient support has been provided for the claim, after receiving recommendations from the independent authority. On the basis of the information provided by the studies outlined above, the total target for energy efficiency improvements for the entire facility will be determined using the weighted average of the calculated energy efficiency figures. The results of the international best practice study are then sent to the independent authority which verifies the accuracy and completeness of the expert third party's methods and results of the study.

5.2 Establishing an Energy Management Standard

As previously discussed, a number of energy management standards are currently in use, and the process of developing and international standard is being initiated. These standards all have much in common and provide a good foundation for developing a national energy management standard. Countries may choose to use an existing standard and to develop country-specific guidance details for implementation.

This work is typically undertaken by a governmental standards-making agency. Even if the agency decides to adopt an existing energy management standard, an advisory committee should be formed to participate in the process. The advisory committee should include representatives from companies with medium and large industrial facilities and from several of the industrial sectors most important to the country's economic growth. The advisory committee should also include respected members of the consulting engineering and supplier community who have extensive experience in industry. To be effective, this group should number no more than fifteen persons. The purpose of the advisory committee is to ensure that the standard, as adopted, can be practically applied to the country's industries and to build ownership in use of the standard prior to its announcement.

In addition to the advisory committee, a public comment period is typically required. The length of this period and the number of informational workshops will be determined by the requirements of the implementing country and the effort required to provide access to information about the proposed standard. Again, this public comment period can be used to build ownership of the energy management standard prior to its formal announcement. Industrial companies do not like sudden changes in governance, so providing information well in advance can improve the chances for success of the standard.

The standard itself is fairly straightforward; the accompanying guidance provides the detail needed to assist companies in implementing the standard. As discussed below, training will be required to familiarize companies with the requirements of the standard. Technical assistance will also be needed to help companies develop the necessary organizational structure for identifying and developing energy efficiency improvement projects for continuous improvement.

An energy management standard can be issued initially as a voluntary standard coupled with a recognition program for companies who demonstrate that they are applying the standard. A requirement for compliance with the energy management standard is a very effective element of a program of target-setting agreements, with penalties for non-compliance clearly identified. A phase-in period is required for industrial firms to develop the organizational infrastructure needed to effectively implement the standard-this transition period is needed to avoid unnecessary disruptions in industrial operations.

Standards Training
Training will be needed to prepare industrial firms to comply with energy management and standards. A "train the trainer" approach that engages interested system optimization experts and representatives from large companies in understanding and learning how to apply these standards is recommended. The program could recognize experts and representatives from large firms as qualified to offer their services to industrial firms who are developing their compliance plans. Government representatives and their designees will need specialized training in standards oversight and enforcement.

5.3 Capacity Building through Training Experts and Suppliers

A comprehensive training program is typically required to create a cadre of system optimization experts who are prepared to identify energy efficiency measurements and to develop efficiency improvement projects. For maximum effectiveness, the training should be targeted to plant and consulting engineers, as well as equipment suppliers.

Experts Training
The purpose of this training is to prepare a group of experts who will be expected to: (1) Provide awareness training to encourage plants to undertake system optimization improvements; (2) Conduct plant assessments to identify system optimization opportunities; (3) Work with plants to finance and develop projects based on these findings; and, (4) Prepare case studies of successful projects. A one-to-one, one-to-many, training and implementation scheme has been tested and proven effective. In this approach, international experts are engaged in the initial capacity-building to create a core of highly-skilled experts who will become a resource to their country and the region

for years to come. To ensure success of the training, selection of the individuals to be trained must be rigorous and based on technical and training capabilities. Successfully negotiating this selection process will require the international team and the country coordinators to develop a shared vision of the project goals, which will vary somewhat from country to country in response to cultural, organisational, and social requirements. This cadre of experts will also form the nucleus for future training of additional experts.

Suppliers Training

Concurrent with experts training, it is an excellent idea to conduct training to introduce equipment suppliers, manufacturers' representatives, and vendors to system optimization techniques. Each training session should focus a specific system type and be offering a mix of theory and practical considerations. The purpose of this training is to prepare manufacturers, suppliers, and vendors to: (1) participate in reinforcing the system optimization message with their customers; and (2) assist them in identifying what will be required to reshape their market offerings to reflect a system services approach. Combining the expert training and vendor training is not recommended, as their needs are different and the dynamics of the supplier/customer relationship could distract from the overall learning experience.

5.4 Building Industrial Awareness

A core element of any industrial energy efficiency program is an information campaign. This campaign should introduce industry to the basic concepts of energy management and industrial system optimization. The message needs to be appropriate to plant managers and needs to make a direct link, through brief examples no more than a couple of sentences long, between industrial energy efficiency and cost savings, improved reliability, and greater productivity. If international corporations have already established or plan to establish industrial facilities in the country, they may be important allies in this campaign.

Once the in-country system optimization experts have been trained, additional awareness messages will be needed to help them build the market for system optimization services. It is important for the government to be active during this early stage of market transformation- for instance, hosting factory awareness training sessions as part of the program response to the announcement of the energy management standard. A list of the trained experts should be kept and made available to companies seeking energy efficiency services.

Developing Enabling Partnerships

For an industrial energy efficiency policy to become effective, government officials will need to form partnerships. These enabling partnerships are needed to:

- build ownership in the proposed efforts to change existing practices and behaviors for greater energy efficiency;

- reach many industrial firms with the energy efficiency message through existing business relationships (such as with suppliers, trade associations, etc);
- develop credibility within specialized industrial sectors;
- ensure that proposed policies are practical given the current situation of industry in the country;
- engage the financial community and assist them in understanding the financial benefits of industrial energy efficiency;
- recruit the best talent to become trained in system optimization techniques; and
- successfully launch an industrial energy efficiency program.

The specific organizations that make effective partners will vary from country to country, but generally include: industrial trade associations, professional engineering societies or associations, equipment manufacturers and suppliers and their associations, leading and/or growing industrial companies, power companies, technical universities, and commercial lenders.

6. Conclusions

Industrial energy efficiency is frequently overlooked by policy makers concerned about energy supply and use. Although designing an industrial energy efficiency program takes time and must be undertaken with some care, the opportunities for improving the efficiency of industrial facilities are substantial, even in markets with mature industries that are relatively open to competition. Developing countries with an emerging and expanding industrial infrastructure have a particular opportunity to mitigate GHG emsissions while increasing their competitiveness by applying energy efficient best practices from the outset in new industrial facilities.

Evaluations of experience with target-setting agreements show that while results have been varied, with some programs appearing to just achieve business-as-usual savings (Chidiak, 2002; OECD, 2002) or to have weak targets (Butterman and Hillebrand, 2000), the more successful programs have seen significant energy savings (Bjørner and Jensen, 2002), even resulting in a 50% increase over historical autonomous energy efficiency improvement rates (Reitbergen et al., 2002) and they can be cost-effective (Phylipsen and Blok, 2002). These agreements have important longer-term impacts including changes of attitudes and awareness of managerial and technical staff regarding energy efficiency, addressing barriers to technology adoption and innovation, establishing greater potential for sustainable energy-efficiency investments, promoting positive interactions between different actors involved in technology research and development, deployment, and market development, and facilitating cooperative arrangements that provide learning mechanisms within an industry (Delmas and Terlaak, 2000; Dowd et al., 2001).

The most effective agreements are those that are legally binding, set realistic targets, include sufficient government support – often as part of a larger environmental policy package, and include a real threat of increased government regulation or energy/GHG taxes if targets are not achieved (Bjørner and Jensen, 2002; Krarup and Ramesohl, 2002). Overall, international experience shows that target-setting agreements are an innovative and effective means to motivate industry to improve energy efficiency and reduce related emissions, if implemented within a comprehensive and transparent framework (IEA, 1997a; IEA, 1997b).

International experience with energy management standards in industry has been very positive. With the exception of companies participating in the Netherlands' bench marking covenants, compliance with an energy management standard or specification has been an essential requirement of target-setting agreements worldwide. For the covenants, the energy reduction targets are so stringent that it can be reasonably assumed that the participating companies have energy management plans for continuous improvement, a key element of any energy management standard.

Because energy management standards have been in force since 2000 or later, most programs have not yet been subject to an independent evaluation. Their effectiveness can be inferred by the number of companies that seek affiliation with the programs, even when there is no penalty assessed for non-participation. Once a company meets the requirements of an energy management standard-- establishing a cross-divisional management team led by an energy coordinator who reports directly to management; establishing a strategic plan that requires measurement, management, and documentation for continuous improvement for energy efficiency; developing policies and procedures to address energy purchase, use and disposal; initiating projects to reduce energy use on an ongoing basis; establishing key performance indicators to measure progress, and regularly documenting and reporting this progress-- energy efficiency becomes part of organizational culture. This is the goal of the Industrial Standards Framework.

Companies that have made this shift in organizational culture report many benefits in cost savings, productivity, and operational efficiency. Results reported and documented by multi-national companies with company-level target-setting programs and energy management programs are impressive. Dow Chemical set a target to reduce energy intensity (btu/lb product) from 1994-2005 by 20% and actually achieved 22% ($4B in savings); their energy intensity reduction goal for 2005 to 2015 is 25%. 3M Corporation has reduced its corporate energy consumption by 30% since 2000 through its global energy management program. DuPont has achieved $2B in energy savings since 1990 as part of a corporate goal to achieve a 65% reduction in GHG emissions below 1990 levels by 2020.

System optimization offers a way for companies to quickly realize cost, productivity, and operational benefits that can provide the reinforcement needed for management to proceed with the organizational changes required to fully integrate energy efficiency into daily operational practices. Capacity-building training creates a cadre of highly skilled system optimization experts that can provide the necessary technical assistance for industrial facilities to identify and develop energy efficiency improvement projects. A "train the trainer" approach can quickly create greater awareness of the opportunities for energy efficiency, thus addressing a principal barrier. This capacity can continue to provide benefits to industry for many years. After more than a decade of capacity-building, experts trained by the US DOE continue to identify millions of dollars in system optimisation improvement opportunities year after year. In 2005 alone, the Save Energy Now initiative documented 55 PJ in energy savings in the first 200 plant assessments, or $475 million in cost savings. Many of the recommended improvements had paybacks of less than 2 years.

Finally, due to the operational dependence of industrial energy efficiency, developing an effective system of ongoing documentation is extremely important. With the renewed interest in energy efficiency worldwide and the emergence of carbon trading and new financial instruments such as white certificates, there is a need to introduce greater transparency into the way that industrial facilities identify, develop, and document energy efficiency projects. The System Optimization Library will standardize and streamline the process of developing and documenting energy efficiency improvement projects. By providing work instructions to support the new, more energy efficient operation, the Library will also increase the likelihood that the resulting energy savings would be sustained. Providing evidence that sufficient documentation exists to support the persistence of energy savings is a critical pre-requisite to consider industrial energy efficiency projects for white certificates or carbon credits. Without such evidence, the value of these projects may be subject to deep discounts, since there would be no assurance that energy savings would persist over the life of the project (often ten years or more) without significant degradation in efficiency.

Taken together, these elements comprise an effective industrial policy package that combines energy reduction targets, energy efficiency standards, system optimization training, and documenting for sustainability. The industrial sector represents more than one-third of global primary energy use (Price, et al 2006) and 36% of carbon dioxide emissions (IEA 2007). As described in this paper, there are well-documented opportunities for cost-effective energy reduction on the order of 18-20% or more (Martin et al., 1999, 2000a; Worrell, et al., 2001, DOE 2004a, IEA 2007), while reducing industry's CO2 emissions by 20-33% (IEA, 2007). The time to take action so that industrial energy efficiency becomes "business as usual" is now.

7. References

Aalbers, R.F.T., H.L.F. de Groot, and H.R.J. Vollebergh, 2004. *Effectiveness of Subsidizing Energy Saving Technologies: Evidence from Dutch Panel Data*, 6th IAEE European Energy Conference on Modelling in Energy Economics and Policy. http://www.saee.ch/saee2004/Aalbers_DeGroot_Vollebergh_IAEE.pdf

Almeida, A., F. Ferreira, and D. Both, 2005. *Technical and Economical Considerations to Improve the Penetration of Variable Speed Drives for Electric Motor Systems*, *IEEE Transactions on Industry Applications*, January/February 2005

Alliance to Save Energy, Municipal Network for Energy Efficiency, U.S. Agency for International Development, U.N. Economic Commission for Europe, n.d. *Survey of Energy Efficiency Laws and Policy Provisions in 22 Countries and Two Regions: Recommendations for Policymakers.* Washington, DC: Alliance to Save Energy.

American National Standards Institute, 2005, MSE 2000:2005 A Management System for Energy, Washington, DC, USA http://webstore.ansi.org/ansidocstore/product.asp?sku=ANSI%2FMSE+2000%3A2005

Anderson, D., 2002. Progress Toward Energy Sustainability in OECD Countries. Helio International. http://www.helio-international.org/Helio/anglais/reports/oecd6.html#top

Arquit Niederberger, A. *Energy Efficiency Projects in CDM and JI: Seminar Issues Paper*, prepared for UNIDO/CTI/UK Trade and Investment Seminar 19-20 March, Vienna, Austria

Association des Entreprises pour la Réduction de l'Effet de Serre (AERES), 2004. *Rapport 2003-2004: de la Première Période d'Engagement*, http://www.aeres-asso.org

Bjørner, T.B. and Jensen, H.H.,

2000. *Industrial Energy Demand and the Effect of Taxes, Agreements and Subsidies.* Copenhagen: AKF Forlaget.

2002. *Energy Taxes, Voluntary Agreements and Investment Subsidies – A Micro-Panel Analysis of the Effect on Danish Industrial Companies' Energy Demand*, Resource and Energy Economics 24: 229-249.

Blok, K., H.L.F. de Groot, E.E.M. Luiten, and M.G. Rietbergen, 2004. *The Effectiveness of Policy Instruments for Energy-Efficiency Improvements in Firms: The Dutch Experience.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Brazil Ministério de Minas e Energia, Br MME, 2007. *Energy Balance Statistics, 1970-2005*. http://www.mme.gov.br/

Butterman H. G. and Hillebrand B. 2000. *Third Monitoring Report: CO2 Emissions in German Industry 1997-1998*, RWI Papiere 70. http://www.rwi-essen.de

Canada, Department of Finance, 2004. Background Information: Class 43.1 (Income Tax Regulations). http://www.fin.gc.ca/activty/consult/class431-2e.html

Carbon Trust, 2005a Develop Low Carbon Technology: Venture Capital. http://www.thecarbontrust.co.uk/carbontrust/low_carbon_tech/dlct2_4.html

Carbon Trust, 2005b The Enhanced Capital Allowance Scheme: Products and Claims. http://www.eca.gov.uk/etl/page.asp?pagecode=000100020001

CEEBICNet Market Research, 2004. Energy Efficiency in Romania. http://www.mac.doc.gov/ceebic/countryr/Romania/EnergyEfficiency.htm

CEN/CENELEC BT/TF 189 Project Team Energy Management Systems presentation 25 January 2007, Brussels, Belgium.

Chidiak, M. 2002. "Lessons from the French Experience with Voluntary Agreements for Greenhouse Gas Reduction" *Journal of Cleaner Production* 10(2).

Cleveland, C.J., and Ruth, M., 1999. *Indicators of Dematerialization and the Materials Intensity of Use*, Journal of Industrial Ecology, Vol. 2, pp. 15 - 50.

Danish Energy Agency, 2000. Green Taxes for Trade and Industry – Description and Evaluation. http://www.ens.dk/graphics/Publikationer/Energibesparelser_UK/Green-tax-uk-rap.PDF

Danish Standards Association

2001, DS 2403:2001, Energy Management-Specification, Charlottenlund, Denmark

2001, Energy Management- Guidance on energy management, Charlottenlund, Denmark DS/INF 136 E

Dasgupta, M. and Roy, J., 2000. *Manufacturing Energy Use in India: A Decomposition Analysis*, Asian Journal of Energy and Environment, 1(3).

DeCanio, S.J., 1993. *Barriers within Firms to Energy-Efficient Investments*, Energy Policy 21: 906-914.

de Beer, J.G., E. Worrell, and K. Blok. 1998a. *Future Technologies for Energy Efficient Iron and Steelmaking*. Annual Review of Energy and Environment 23: 123-205.

de Beer, J., 1998b. Potential for Industrial Energy-Efficiency Improvement in the Long Term. Utrecht University PhD Thesis,

de Beer, J.G., J. Harnisch, and M. Kerssemeeckers. 2000. *Greenhouse Gas Emissions from Iron and Steel Production.* IEA Greenhouse Gas R&D Programme, Cheltenham, UK.

de Beer, J., D. Phylipsen, and J. Bates, 2001. *Economic Evaluation of Carbon Dioxide and Nitrous Oxide Emission Reductions in Industry in the EU*. Brussels: European Commission, DG Environment.

De Keulenaer, H., 2004. *Energy Efficient Motor Driven Systems,* Energy & Environment 15 (5): 873-905.

De Keulenaer, H., R. Belmans, E. Blaustein, D. Chapman, A. De Almeida, and P. Radgen, 2005. *Energy Efficient Motor Driven Systems*, Proceedings of EEMODS 05, Heidelberg, Germany.

Delmas, M. and Terlaak, A.. 2000. "Voluntary Agreements for the Environment: Innovation and Transaction Costs," *CAVA Working Paper* 00/02/13, February.

Department of Environment, Food, and Rural Affairs (DEFRA)

2000. *Climate Change: The UK Programme – Summary*. http://www.defra.gov.uk/environment/climatechange/cm4913/index.htm

2004. *Climate Change Agreements: The Climate Change Levy*. http://www.defra.gov.uk/environment/ccl/intro.htm

2005a. *UK Emissions Trading Scheme*. http://www.defra.gov.uk/environment/climatechange/trading/uk/index.htm

2005b. *News Release: Industry Beats CO2 Reduction Targets.* 21 July 2005. http://www.defra.gov.uk/news/2005/050721b.htm

Dowd, J., Friedman, K, and Boyd, G. 2001. "How Well Do Voluntary Agreements and Programs Perform At Improving Industrial Energy Efficiency," *Proceedings of the 2001 ACEEE Summer Study on Energy Efficiency in Industry*. Washington, DC: American Council for an Energy-Efficient Economy.

Editorial Board, 2004. *China Steel Yearbook 2004*. Beijing.

Elliott. R. Neal , 2002. *Vendors as Industrial Energy Service Providers*, American Council for an Energy Efficient Economy, Washington, DC.

European Climate Change Programme (ECCP), 2001. *Long Report.* Brussels: European Commission, DG Environment.
http://europa.eu.int/comm/environment/climat/pdf/eccp_longreport_0106.pdf

European Fertilizer Manufacturers Association (EFMA), 1997. *Production of Ammonia: Description of Production Processes.* Brussels, Belgium : EFMA.

Fenhann, J., 2007a. *JI Pipeline.* Roskilde, Denmark: UNEP Risø Centre. http://www.cd4cdm.org/Publications/JIpipeline.xls

Fenhann, J., 2007b. *CDM Pipeline.* Roskilde, Denmark: UNEP Risø Centre. http://www.cd4cdm.org/Publications/CDMpipeline.xls

Finansministeriet, 1999. *Evaluering af grønne afgifter og erhvervene*. Schultz Forlag.

Future Energy Solutions, AEA Technology, 2004. *Climate Change Agreements – Results of the First Target Period Assessment.* Version 1.2. http://www.defra.gov.uk/environment/ccl/pdf/cca_aug04.pdf.

Future Energy Solutions, 2005. *Climate Change Agreements: Results of the Second Target Period Assessment*, Version 1.2. , Didcot, UK: AEA Technology. www.defra.gov.uk/environment/ccl/pdf/cca_aug04.pdf

Galitsky, C., L. Price, and E. Worrell., 2004. *Energy Efficiency Programs and Policies in the Industrial Sector in Industrialized Countries.* Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-54068).

Galitsky, C., E. Worrell, A. Radspieler, P. Healy, and S. Zechiel, 2005. *BEST Winery Guidebook: Benchmarking for Energy and Water Savings Tool for the Wine Industry*. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-3184).

German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2004. *The Ecological Tax Reform: Introduction, Continuation and Development into an Ecological Fiscal Reform.*
http://www.bmu.de/files/pdfs/allgemein/application/pdf/oekost_en.pdf

Ginny, K., 2005, *ANSI/MSE 2000:2005 The U.S. National Standard*, presented at the First European Conference on Energy Management, 23-24 November 2005, Milan, Italy.

Ginny, K., W. Meffert, and M. Brown, 2007, Georgia Institute of Technology, personal communication.

Global Reporting Initiative, 2002. *Energy Consumption Protocol* http://www.globalreporting.org/GRIGuidelines/Protocols/EnergyProtocol.pdf.

Government of Canada, 1998. *Tax Incentives for Business Investments in Energy Conservation and Renewable Energy*.
http://www2.nrcan.gc.ca/es/erb/erb/english/View.asp?x=469&oid=111

Greenhouse Gas Abatement Program (GGAP), n.d. Website. Available at: http://www.greenhouse.gov.au/ggap/index.html.

Groenenberg, H., K. Blok, and J. P. v. d. Sluijs, *Projection of Energy-intensive Material Production for Bottom-up Scenario Building*. Ecological Economics, 2005, Vol. 53 (1), pp. 75-99.

Hansen, M.D., 2001. *The Danish Experience with Efficiency Improvement in Industrial and Commercial Sectors*, Workshop on Best Practices in Policies and Measures, 8-10 October 2001, Copenhagen.

HM Revenue & Customs, n.d. ECA – 100% Enhanced Capital Allowances for Energy-Saving Investments.
http://www.hmrc.gov.uk/capital_allowances/eca_guidance.htm#claimingfya

Intergovernmental Panel on Climate Change (IPCC), 2001. *Climate Change 2001: Synthesis Report*. Cambridge, UK and New York, NY: Cambridge University Press. Glossary: http://www.ipcc.ch/pub/syrgloss.pdf

International Energy Agency (IEA)

1997a. Voluntary Actions for Energy-Related CO_2 Abatement. Paris: OECD/IEA

1997b. *Voluntary Approaches for Mitigating Greenhouse Gas Emissions*. Conference Proceedings, Bonn, Germany 30-31 October 1995. Paris: OECD/IEA.

2006, *Industrial Motor Systems Energy Efficiency: Toward a Plan of Action.* http://www.iea.org/Textbase/work/workshopdetail.asp?WS_ID=255

2006a. Energy Balances of Non-OECD Countries: 2003-2004. Paris: IEA.

2006b. Energy Balances of OECD Countries: 2003-2004. Paris: IEA.

2006c. Energy Technology Perspectives: Scenarios and Strategies to 2050. Paris: IEA.

2006d. *Ukraine Energy Policy Review 2006*. Paris: IEA.

2007 (June publication), Indicators for Industrial Energy Efficiency and CO_2 Emissions: A Technology Perspective. Paris :IEA
http://www.iea.org/w/bookshop/b.aspx?new=5

International Institute for Sustainable Development (IISD), 1994. *Accelerated Depreciation of Environmental Investments in the Netherlands*. http://www.iisd.org/greenbud/acceler.htm

International Iron and Steel Institute, IISI, 2006. *Steel Statistical Yearbook, 2006*. IISI: Brussels, Belgium.

Johannsen, K.S., 2002. *Combining Voluntary Agreements and Taxes – An Evaluation of the Danish Agreement Scheme on Energy Efficiency in Industry.* Journal of Cleaner Production 10: 129-141.

Johannsen K. and Larsen, A., 2000. *Voluntary Agreements – Implementation and Efficiency. The Danish Country Study. Case Studies in the Sectors of Paper and Milk Condensing.* Copenhagen: AKF Forlaget.

KEMCO, *2005 Annual Report*, Korea Energy Management Corporation, Gyeonggi, Republic of Korea

Kemp, David of the Minister for the Environment and Heritage and Macfarlane, Ian of the Minister for Industry, Tourism and Resources, 2003. *Funding for Substantial Greenhouse Gas Abatement Projects.* Joint media release, May 29, 2003.

Kerssemeeckers, M., 2002. *The Dutch Long-Term Voluntary Agreements on Energy Efficiency Improvement in Industry*. Utrecht, The Netherlands: Ecofys.

Korevaar, E., J. Farla, K. Blok and K. Schulte Fischedick, 1997. *A Preliminary Analysis of the Dutch Voluntary Agreements on Energy Efficiency Improvement,* The Energy Efficiency Challenge, Proc. 1997 ECEEE Summer Study, Splinderuv Mlyn, Czech Republic, 9-14 June 1997.

Kræmer, T. Pipi and L. Stjernström, 1997. Energy Policy Instruments – Description of Selected Countries. Available at http://www.akf.dk/index_eng.html

Krarup, S., M. Togeby, and K. Johannsen, 1997. *De første aftaler om energieffektivisering – erfaringer fra 30 aftaler indgået i 1996.* Working paper. Copenhagen: AKF Forlaget.

Krarup, S. and Ramesohl, S. 2000. *Voluntary Agreements in Energy Policy--Implementation and Efficiency.* Kobenhavn: AKF Forlaget.

Larsen, A., M. Togeby, and K. Hansen, 2005, *Energy Management in Danish Industry-Practice and Policy Implications*, presented at the First European Conference on Energy Management 23-24 November 2005, Milan, Italy.

Lin, J., N. Zhou, M. Levine, and D. Fridley. *Achieving China's Target for Energy Intensity Reduction in 2010: An exploration of recent trends and possible future scenarios* Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-61800).

Lung, R.B., A. McKane, and M. Olzewski, 2003. *Industrial Motor System Optimization Projects in the U.S.: An Impact Study*. Proceedings of the 2003 American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Industry. Washington, DC: ACEEE.

Martin, N., E. Worrell., and L. Price, 1999. *Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the U.S. Cement Industry*, Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-44182).

Martin, N., N. Anglani, D. Einstein, M. Khrushch, E. Worrell, and L. Price, 2000a. *Opportunities to Improve Energy Efficiency and Reduce Greenhouse Gas Emissions in the U.S. Pulp and Paper Industry*. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-46141).

Martin, N., E. Worrell, M. Ruth, L. Price, R.N. Elliott, A.M. Shipley, and J. Thorpe, 2000b. *Emerging Energy-Efficient Industrial Technologies*. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-46990) and Washington, DC: American Council for an Energy-Efficient Economy.

McKane, Aimee, 2007, *Industrial Energy Management: Issues Paper*, prepared for UNIDO Experts Group Meeting: Using Energy Management Standards to stimulate persistent application of Energy Efficiency in Industry, Vienna, Austria, 21-22 March 21. http://www.unido.org/en/doc/61189

McKane, Aimee, forthcoming, Chapter 17: Industrial Energy Efficiency, *Regulation and Sustainable Energy in Africa*, United Nations Industrial Development Organization and the Renewable Energy and Energy Efficiency Partnership, Vienna, Austria

McKane, A. and Medaris, B., 2003. *The Compressed Air Challenge: Making a Difference for U.S. Industry*. Berkeley, CA: Lawrence Berkeley National Laboratory.

McKane, A., W. Perry, A. Li, T. Li, and R. Williams. 2005. *Creating a Standards Framework for Sustainable Industrial Energy Efficiency*, Proceedings of EEMODS 05, Heidelberg, Germany LBNL-58501, http://industrial-energy.lbl.gov/node/147

M.K. Jaccard & Associates, 2004. *Case Study on Fiscal Policy and Energy Efficiency: Baseline Study*. Prepared for The National Round Table on the Environment and the Economy. http://www.nrtee-trnee.ca/eng/programs/Current_Programs/EFR-Energy/Case_Studies/200406_Energy-Efficiency-CS/200406_Energy-Efficiency-CS-EA_1-Introduction_E.htm

Moomaw, W. R., J. R. Moreira, K. Blok, D. Greene, K. Gregory, T. Jaszay, T. Kashiwagi, M. Levine, M. MacFarland, N. S. Prasad, L. Price, H. Rogner, R. Sims, F. Zhou, E. Alsema, H. Audus, R. K. Bose, G. M. Jannuzzi, A. Kollmuss, L. Changsheng, E. Mills, K. Minato, S. Plotkin, A. Shafer, A. C. Walter, R. Ybema, J. de Beer, D. Victor, R. Pichs-Madruga, H. Ishitani, 2001. *Technological and Economic Potential of Greenhouse Gas Emissions Reduction* Chapter 3 in *Climate Change 2001: Mitigation*. Intergovernmental Panel on Climate Change. Geneva: United Nations and World Meteorological Organization.

MOSPI, Ministry of Statistics and Programme Implementation, India, 2007, *National Account Statistics 2007*, New Delhi, web: www.mospi.nic.in/

MURE II, n.d. MURE (Mesures d'Utilisation Rationnelle de l'Energie) Database. Available at: http://www.isis-it.com/mure/index.htm.

National Energy Efficiency Committee (NEEC), 2005. Incentive Scheme: One-Year Accelerated Depreciation Allowance for Energy Efficient Equipment and Technology. http://www.neec.gov.sg/incentive/home.shtm

National Standards Authority of Ireland, 2005, I.S.393:2005 Energy Management Systems- Requirements with guidance for use, Dublin, Ireland.

Nakicenovic, N., J. Alcamo, G. Davis, B. de Vries, J. Fenhann, S. Gaffin, K. Gregory, A. Grubler, T.Y. Jung, T. Kram, E.L. La Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Riahi, A. Roehrl, H-H. Rogner, A. Sankovski, M. Schlesinger, P. Shukla, S. Smith, R. Swart, S. van Rooijen, N. Victor, and D. Zhou, 2000. *Special Report on Emissions Scenarios: Report of Working Group III of the Intergovernmental Panel on Climate Change.* London: Cambridge University Press.

Nuijen, W., 1998. *Long Term Agreements on Energy Efficiency in Industry,* in Martin et al., (eds.) *Industrial Energy Efficiency Policies: Understanding Success and Failure,* Proceedings of a Workshop Organized by the International Network for Energy Demand Analysis in the Industrial Sector. Utrecht, The Netherlands, June 11-12, 1998. (LBNL-42368).

Nuijen, W., 2002. *Energy Efficiency Monitoring in Dutch Industry*. Presentation at the Workshop on Voluntary Agreements for China's Industrial Sector: Integrating International Experiences into Designing a Pilot Program, February 25-27, 2002.

Organization for Economic Cooperation and Development. 2002. *Voluntary Approaches for Environmental Policy: Effectiveness, Efficiency and Use in Policy Mixes*, OECD, Paris.

Pender, M., 2004. *UK Climate Change Agreements.* Presentation to China Iron and Steel Association Delegation.

Persson, Agneta and Erik Grudbjerg, 2005. *Do Voluntary Agreements Deliver? Experiences from Denmark and expectations for Sweden*, proceedings of the 7th European Council for an Energy Efficient Economy Summer Study, Mandelieu la Napoule, France

Phylipsen G. J. M. and Blok, K. 2002. "The Effectiveness of Policies to Reduce Industrial Greenhouse Gas Emissions" *AIXG Workshop on Policies to Reduce Greenhouse Gas Emissions in Industry – Successful Approaches and Lessons Learned*. 2-3 December 2002, Berlin.

Phylipsen, D., K. Blok, E. Worrell, and J. de Beer, 2002. "Benchmarking the Energy Efficiency of Dutch Industry: An Assessment of the Expected Effect on Energy Consumption and CO_2 Emissions", *Energy Policy*, 30, 663-679.

Plant Surveys International, Inc. (PSI), 2004. *Energy Efficiency and CO_2 Emissions Benchmarking of IFA Ammonia Plants (2002-2003 Operating Period).* General Edition. Commissioned by the International Fertilizer Industry Association (IFA).

Price, L., 2005. *Voluntary Agreements for Energy Efficiency or Greenhouse Gas Emissions Reduction in Industry: An Assessment of Programs Around the World*. Proceedings of the 2005 ACEEE Summer Study on Energy Efficiency in Industry. Washington, DC: American Council for An Energy-Efficient Economy, http://industrial-energy.lbl.gov/node/107

Price, L., C. Galitsky, J. Sinton, E. Worrell, and W. Graus, 2005. *Tax and Fiscal Policies for Promotion of Industrial Energy Efficiency: A Survey of International Experience*. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-58128).

Price, L., J. Sinton, E. Worrell, D. Phylipsen, X. Hu, and J. Li., 2002. *Energy Use and Carbon Dioxide Emissions from Steel Production in China*, Energy, The International Journal 27(2002): 429-446 (LBNL-47205).

Price, L. and Wang, X., forthcoming. *Constraining Energy Consumption of China's Largest Industrial Enterprises Through the Top-1000 Energy-Consuming Enterprise Program*, Proceedings of the 2007 ACEEE Summer Study on Energy Efficiency in Industry. Washington, DC: American Council for An Energy-Efficient Economy.

Price, L., E. Worrell, and D. Phylipsen, 1999. *Energy Use and Carbon Dioxide Emissions in Energy-Intensive Industries in Key Developing Countries*, Proceedings of the 1999 Earth Technologies Forum. Washington, DC: U.S. EPA.

Price, L., E. Worrell, W. Nuijun, and K. Blok, 2004. *Shandong Province Energy Efficiency Agreements Pilot Evaluation of Progress to Date*. Report to the Energy Foundation.

Price, L., S. de la Rue du Can, J. Sinton,, and E. Worrell., 2006. *Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions*. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-56144).

Rietbergen, M., J. Farla, and K. Blok, 1998. *Quantitative Evaluation of Voluntary Agreements on Energy Efficiency*, in Martin et al., (eds.) *Industrial Energy Efficiency Policies: Understanding Success and Failure*. Proceedings of a Workshop Organized by the International Network for Energy Demand Analysis in the Industrial Sector. Utrecht, The Netherlands, June 11-12, 1998. (LBNL-42368).

Rietbergen, M., J. Farla, and K. Blok, 2002. *Do Agreements Enhance Energy Efficiency Improvement? Analysing the Actual Outcome of Long-term Agreements on Industrial Energy Efficiency Improvement in The Netherlands*. Journal of Cleaner Production 10 (2002) 153–163.

Sathaye, J., L. Price, S. de la Rue du Can, and D. Fridley, 2005. *Assessment of Energy Use and Energy Savings Potential in Selected Industrial Sectors in India*. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-57293).

Sathaye J., S. de la Rue du Can., S. Kumar, M. Iyer, C. Galitsky, A. Phadke, M. McNeill, L. Price, and R. Bharvirkar, 2006. *Implementing End-use Efficiency Improvements in*

India: Drawing from Experience in the US and Other Countries. Berkeley, CA: Lawrence Berkeley National Laboratory. (LBNL-60035).

Schumacher, K. and Sathaye, J., 1999. *India's Cement Industry: Productivity, Energy Efficiency and Carbon Emissions.* Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-41842).

Scottish Energy Efficiency Office (SEEO), n.d. Website, available at: http://www.energy-efficiency.org/index.jsp

SenterNovem

2005a. MIA and Vamil: Tax Relief for Investments in Environmental Friendly Machinery. http://www.senternovem.nl/mia/Topnavigatie/English.asp

2005b. EIA: Tax Relief for Investments in Energy-saving Equipment and Sustainable Energy. http://www.senternovem.nl/eia/Topnavigatie/English.asp

2007. Knowledge Networks. http://www.technology.novem.nl/en/index.htm

South Africa Department of Minerals and Energy, SA DME, 2007. *Energy Balance Statistics, 1993, 1994, 2003, 2004*. http://www.dme.gov.za/energy/documents.stm

Sustainable Energy Ireland, 2007, website information for businesses http://www.sei.ie/index.asp?locID=158&docID=-1

Swedish Standards Institute, 2003, SS627750, Energy Management-Specification, Stockholm, Sweden

Swedish Energy Agency

2005. *PFE – Program for Improving Energy Efficiency in Energy-Intensive Industries: Tax Exemption for Efficient Electricity Consumption*. Eskilstuna, Sweden: SEA.

2006. *The First Year with PFE: 2005 Report on the Programme for Improving Energy Efficiency in Industry.* Eskilstuna, Sweden: SEA

2007, *Programme for Improving Energy Efficiency in Energy-intensive Industries* http://www.stem.se/WEB/STEMEx01Eng.nsf/F_PreGen01?ReadForm&MenuSelect=F78F2B2CB1DE4525C12570FB00428BD8

Togeby, M., K. Johannsen, C. Ingrslev, K. Thingvad, and J. Madsen, 1999. *Evaluations of the Danish Agreement System*. Proceedings of the 1999 American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Industry. Washington, DC: ACEEE.

UK Department of Trade and Industry, 2003. *Our Energy Future: Creating a Low Carbon Economy*. http://www.dti.gov.uk/energy/whitepaper/ourenergyfuture.pdf

United Nations (UN), 2007a. *United Nations Commodity Production Statistics*. CD-ROM.

United Nations (UN), 2007b. *United Nations Commodity Trade Statistics Database*. http://comtrade.un.org/db/

United Nations Food and Agriculture Organization, 2007. *FAOSTAT*. http://faostat.fao.org/faostat/form?collection=Forestry.Derived&Domain=Forestry&servlet=1&hasbulk=0&version=ext&language=EN

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), 2000. *Promotion of Energy Efficiency in Industry and Financing of Investments.* http://www.unescap.org/esd/energy/publications/finance/index.html

United Nations Industrial Development Organization, 2007. *Energy Efficiency in CDM and JI - Thematic Summary*, UNIDO/CTI/UK Trade and Investment Seminar 19-20 March, 2007, Vienna. http://www.unido.org/en/doc/61189

U.S. Department of Energy,

1998. *United States Industrial Motor Systems Market Opportunities Assessment,* Washington, DC: US DOE.

2001. http://www1.eere.energy.gov/industry/bestpractices/pdfs/thomastonmill.pdf

2004a, *Energy Loss Reduction and Recovery in Industrial Energy Systems,* prepared by Energetics, Washington, DC. http://www.eere.energy.gov/industry/energy_systems/analysis.html

2004b, *Energy Use, Loss, and Opportunities Analysis: U.S. Manufacturing & Mining*, prepared by Energetics and E3M, Washington, DC http://www.eere.energy.gov/industry/energy_systems/analysis.html

2005, *Estimation of Energy Savings Outcomes from BestPractices Activities, Fiscal Year 2004*, prepared by Oak Ridge National Laboratory (internal report)

US Department of Energy, 2007, BestPractices website http://www1.eere.energy.gov/industry/bestpractices/

US Environmental Protection Agency, 2007, ENERGY STAR website, http://www.energystar.gov/index.cfm?c=industry.bus_industry&layout=print

United States Geological Survey,

2007a. *Mineral Commodity Summary: Cement.* http://minerals.usgs.gov/minerals/pubs/commodity/cement/

2007b. *Mineral Commodity Summary: Aluminium.*

http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/

2007c. *Mineral Commodity Summary: Nitrogen*.
http://minerals.usgs.gov/minerals/pubs/commodity/nitrogen/

2007d. *Mineral Commodity Summary: Copper*.
http://minerals.usgs.gov/minerals/pubs/commodity/copper/

2007e. *Mineral Commodity Summary: Steel*.
http://minerals.usgs.gov/minerals/pubs/commodity/copper/

US Jakarta Embassy, 2006. *Petroleum Report Indonesia, 2005-2006,*. June 2006. Embassy of the United States of America. http://www.usembassyjakarta.org/

Velthuijsen, J.W., 1995. *Determinants of Investment in Energy Conservation*. SEO, University of Amsterdam, The Netherlands.

Vine, E. and Sathaye, J., 1997. *The Monitoring, Evaluation, Reporting and Verification of Climate Change Mitigation Projects: Discussion of Issues and Methodologies and Review of Existing Protocols and Guidelines*. LBNL-40316. Berkeley, CA: Lawrence Berkeley National Laboratory.

Williams, R, A. McKane, Z. Guijn, S. Nadel, J. Peters, and V. Tutterow. 2005. *The Chinese Motor System Optimization Experience: Developing a Template for a National Program*. Proceedings of EEMODS 05, Heidelberg, Germany. LBNL-58504 http://industrial-energy.lbl.gov/node/294

Williams, R., A. McKane, and R. Papar. 2006. *Energy Management Standards: An Incentive for industrial system energy efficiency?* Co-generation and On-Site Power Production, Nov-Dec 2006, Volume 7, Number 6, pp.83-91.

World Bank, 2006. *World Development Indicators. Development Data Center*. E-Book. http://devdata.worldbank.org/wdi2006/contents/cover.htm

World Bank, 2005. *World Development Indicators. Development*. CD-ROM.

World Business Council for Sustainable Development and World Resources Institute, 2002. *Greenhouse Gas Protocol Initiative*. http://www.ghgprotocol.org/

World Energy Council

2001. Japan: Extract from the Survey of Energy Resources. London: WEC. http://www.worldenergy.org/wec-geis/edc/countries/Japan.asp#top

2003. Survey on Energy Efficiency Policy Measures. London: WEC.

2004. Energy Efficiency: A Worldwide Review – Indicators, Policies, Evaluation. London: WEC.

Worrell, E. and Biermans, G. 2005. *Move over! Stock Turnover, Retrofit and Industrial Energy Efficiency*, Energy Policy 33: 949-962

Worrell, E., M.D. Levine, L. Price, N. Martin, R. van den Broek, and K. Blok, 1996. *Potentials and Policy Implications of Energy and Material Efficiency Improvement: A Report to the United Nations Division for Sustainable Development.*

Worrell, E., N. Martin, and L. Price, 2001. *Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the U.S. Iron and Steel Industry*, Energy, The International Journal 26, 2001: 513-536: (LBNL-47910).

Worrell, E., L. Price, C. Galitsky, M. Neelis, N. Aden, N., N. Zhou, and D. Fridley, forthcoming. *World Best Practice Energy Intensity Values for Selected Industrial Sectors.* Berkeley, CA: Lawrence Berkeley National Laboratory.

Worrell, E., L. Price, and C. Galitsky, 2004. *Emerging Energy-Efficient Technologies in Industry: Case Studies of Selected Technologies.* Prepared for the National Commission on Energy Policy. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-54828).

Worrell E., L. Price, N. Martin, J. Farla, and R. Schaeffer R, 1997. *Energy Intensity in the Iron and Steel Industry: A Comparison of Physical and Economic Indicators*. Energy Policy, Vol. 25, Nos. 7-9, pp. 727-744, 1997

Worrell, E., L. Price, N. Aden, N. Zhou, and D. Fridley, forthcoming. *World Best Practice Energy Intensity Values for Selected Industrial Sectors.* Berkeley, CA: Lawrence Berkeley National Laboratory.

Worrell, E., N. Martin, N. Anglani, D. Einstein, M. Khrushch . *Proceedings Paper Machine Technology*, February 7-8, 2001, Lanaken, Belgium.

Worrell, E., N. Martin, and L. Price, 1999. *Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the U.S. Iron and Steel Industry.* Berkeley, CA: Lawrence Berkeley National Laboratory. (LBNL-41724)

Zhou, F., et al., 2003. *China's Sustainable Energy Scenarios in 2020*. China Environmental Publishing House, Beijing.

Zhou, N., D. Fridley, J. Lin,, N. Aden., S. de la Rue du Can, L. Price, M. A. McNeil, J. Sathaye, and M. Levine. 2007. *Energy Use in China: Sectoral Trends and Future Outlook*. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL- 61904).

Appendix 1. Ten World Regions

Regions/Countries	
Pacific OECD	Australia, Japan, Korea and New Zealand.
North America	Canada and the United States.
Western Europe	Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Gibraltar, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and United Kingdom.
Central and Eastern Europe	Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, Former Yugoslav Republic of Macedonia (FYROM), Hungary, Poland, Romania, Serbia/Montenegro Slovak Republic and Slovenia.
Former Soviet Union	Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan
Latin America	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guyana, Grenanda, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St Kitts and Nevis, St Lucia, St Vincent and Grenadine, Suriname, Trinidad and Tobago, Uruguay and Venezuela
Middle East and North Africa	Algeria, Bahrain, Egypt, Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen.
Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Congo, Cape Verde, Central African Republic, Chad, Democratic Republic of Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Swaziland, United Republic of Tanzania, Togo, Uganda, Zambia and Zimbabwe
Centrally Planned Asia	China, Chinese Taipei, Hong Kong, DPR of Korea and Vietnam.
Other Asia	Afghanistan, Bangladesh, Bhutan, Brunei, Fiji, French Polynesia, India, Indonesia, Kiribati, Malaysia, Maldives, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand and Vanuatu.