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Author
Worrell, E.

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OPPORTUNITIES FOR
SUSTAINABLE ENERGY

ENERGY EFFICIENCY

5.1. ENERGY AND SUSTAINABLE DEVELOPMENT

Energy is used throughout the economy, and is one of the most important drivers for modern economic development. It is used to manufacture all kinds of consumer goods, heat or cool buildings, cook our food, and provide light and communication. These activities are also called energy services. We are interested in performing the energy service, rather than in using energy. There is a growing awareness of the serious problems associated with the provision of sufficient energy to meet human needs and to fuel economic growth worldwide. Environmental, health, social, economic, and security issues are affected directly or indirectly by energy use.

Current energy production and usage patterns rely heavily on combustion of fossil fuels, a key factor in the unprecedented increase in carbon dioxide (CO_2) concentrations, which contribute to climate change, in the Earth's atmosphere. Other key environmental problems are regional (acidification of soil and water), local (smog, urban air quality, solid wastes, effluents, and thermal pollution), and indoor air pollution. In many areas of the world, particularly the developing country mega-cities, the health and environmental effects of such patterns of energy use are even more extreme, as technologies and policies for abating pollution and producing cleaner energy are not always available or implemented. Health is adversely affected not only by environmental pollution, but also by indoor use of fuels and the supply of energy.

Energy supply and use are directly connected to the economic and social agenda. Many studies have shown that low-income households often have no access to commercial or low-polluting fuels. The use of biomass for cooking in many parts of the developing countries results in negative social and health impacts, especially for women. Reliance on energy imports also affects the security of many countries, directly and indirectly. Increased reliance on imported fuels makes the economy more vulnerable for supply disruptions and may lead to social conflicts, as many primary commodity prices are influenced by energy prices.

Historically, countries concentrated on the increased supply of energy sources, despite the potential negative impacts on sustainable development. However, in 1987, the World Commission on Environment and Development (WCED) concluded that the best route to sustainable development of the energy system is a *"low energy path"*, which means that nations should take the opportunities *"to produce the same levels of energy services with as little as half the primary energy currently consumed"*. The improvement of energy efficiency is now generally viewed as the most important option to reduce the negative impacts of the use of energy and/or fossil fuels in the near term. Energy efficiency is defined as *decreasing the use of energy per energy service without substantially affecting the level of these services.*

The main factors affecting energy growth in an economy include the energy consumed per unit of economic activity, the size and structure of the economy, and the rate of population growth. If an economy is growing rapidly, or population growth is high, then energy demand rises commensurately, assuming there is no change in the level of energy consumption per unit of economic output. The amount of energy consumed per unit of economic growth is affected by how efficiently energy is used to provide energy services in an economy. Shifts in the structure of economies also influence energy use, specifically in economies where the overall level of enerfy services—required to produce additional economic output—changes. All else being equal, reducing economic or population growth also leads to reductions in energy demand. In the near and medium term, the most effective and feasible policies for restraining energy growth involve improving the efficient use of energy and encouraging the shift to a less energy-intensive economic and industrial structure.

Despite the limited access to energy in many developing countries, large potential for energy efficiency improvement exists in all sectors. However, many barriers may limit the implementation of energy-efficient practices and technologies. Policies and actions by many stakeholders, including policy-makers, consumers, and private industry, affect the barriers and the actual implementation of energy efficiency. In this chapter, we discuss energy use, the stakeholders, barriers, and potential actions that can be taken. We start with a discussion of the potential benefits of energy efficiency improvement measures, followed by an overview of current energy use patterns around the world and in developing countries, by sector. We then assess practical approaches to energy efficiency improvement, including assessment of opportunities and mechanisms. Although many different mechanisms can be used to implement energy-efficient practices and technologies, we highlight one as an example, i.e., energy service companies (ESCO). An energy service company takes over the supply of energy services, rather than supplies energy sources. This description is followed by a more generic description of barriers and policies which support implementation of energy-efficient practices and technologies.

1.1. MAKING THE CASE FOR ENERGY EFFICIENCY

5.1.1. Introduction

Energy efficiency opportunities can be found in almost all energy end uses, sectors, and energy services. Many studies over the past decades have assessed the potential for energy efficiency

improvement, and always have found opportunities. Much of the potential of energy efficiency improvement depends on how closely the processes used have approached their thermodynamic limit. Thermodynamic analyses of many processes have demonstrated a large difference between the thermodynamic energy needed to provide an energy service and the actual observed energy consumption. The difference is called the theoretical potential for energy efficiency improvement. In practice, the thermodynamic minimum energy consumption can not be achieved, and extra energy added to the thermodynamic minimum defines the technically achievable minimum energy consumption.

Furthermore, there are differences between what is technically achievable as an energy efficiency improvement in a specific instance, what is economically feasible, and what is actually possible. We can identify an economic potential for energy efficiency improvement, namely the potential savings that can be achieved at a net positive economic effect, such as the benefits of the measures being greater than the costs. In practice, the definition of the economic potential may vary, based on the differences in assessment methods, assumptions, and system boundaries. Many studies have indeed shown that there is a further efficiency gap, even at current economic conditions, suggesting the existence of other barriers for implementing energy efficiency measures. The market potential tries to close this gap, and is defined as the potential energy savings that may be realised in practice, at current marker conditions.

The technical, economic and market potential of energy efficiency are amenable through interventions by stakeholders. Research and development activities by academia and industry affect the availability of technologies, as well as the costs of such technologies. The economic potential is not only influenced by the costs of technology, but also by energy prices and policies such as taxes and targeted subsidies. The market potential is a function of the economic attractiveness of a measure and of many barriers. The barriers may be removed or reduced in size by measures and policies at corporate, regional, national, and international levels.

In this section we focus on the economic potential for energy efficiency improvement and discuss the benefits of energy efficiency improvement measures. In the following sections we describe analytical tools to assess the potential in a specific situation, as well as policy opportunities for energy efficiency improvement.

5.1.2. The Potential for Energy Efficiency Improvement

Many studies have indicated that there is a sizeable potential for energy efficiency improvement. It is estimated that the United States uses its primary energy sources with only a 2.5 percent efficiency to fulfil its energy services. A 50 percent reduction in energy demand is technologically feasible, and in the long term even a 80 percent reduction is feasible. Other studies have also shown that there is considerable scope for energy efficiency improvement in different sectors and contexts. Energy efficiency improvement opportunities can be found in energy end uses and conversion, as well as in distribution and transmission. Transmission losses for power generation in developing countries can often be very high.

The potential for profitable and economic energy efficiency improvement in all sectors for the next 20 years is estimated at 25-35 percent in most industrialised and developing countries at today's energy prices. Implementing these improvements depends on the levels of industrialisation, economic structures, as well as many other issues. The potential for energy efficiency improvement may also vary by country and sector. Described below are estimates of the potential for energy efficiency improvement in different sectors.[1]

[1] *Worrell, E., M. Levine, L. Price, N. Martin, R. van den Broek and K. Blok (1997), "Potentials and Policy Implications of Energy and Material Efficiency Improvement", Department for Policy Coordination and Sustainable Development, United Nations, New York, NY.*

Agriculture. Energy consumption in agriculture is divided into direct (on-farm) and indirect (e.g., fertilisers and pesticides) energy use. Direct commercial energy consumption varies significantly depending on agricultural practice and crop. In traditional agriculture, direct energy consumption can be solely non-commercial, including important sources such as animal and human labour. We focus on direct on-farm consumption of commercial energy.

Energy can be saved in tractor use by improved control of gears (estimated technical savings of 5-30 percent), maintenance and developments of diesel engines (10-35 percent), and reduced tillage (35-70 percent of energy use for tillage). High energy savings (25-85 percent) are possible through proper design, retrofit and maintenance of irrigation pumps and use of low-friction pipes. Energy savings of up to 60 percent in industrialised countries are also feasible in drying products, livestock production, and horticulture.

Industry. Significant potential exists in all industries to improve energy efficiency. A small number of energy-intensive industries are responsible for half of industrial energy use on a global level, and even more for developing countries. These sub-sectors are: iron and steel, chemicals, petroleum refining, pulp and paper, and cement.

- A large number of energy-efficient technologies are available in the *steel industry,* including continuous casting, energy recovery, and increased recycling, with the technical potential for energy efficiency improvement ranging from 25 to 50 percent, even in industrialised countries.
- A few bulk *chemicals*, such as ammonia and ethylene, represent a major portion of energy use in this sub-sector. The potential for energy savings in ammonia making is estimated at up to 35 percent in the European Union and at around 20-30 percent in Southeast Asia. Saving estimates for ethylene production are only available for industrialised countries and are estimated to be up to 12 percent (including feedstocks).
- Energy savings in *petroleum refining* are possible through improved process integration, cogeneration, and energy recovery. Compared to state-of-the-art technology, the savings in industrialised countries are estimated to be 20-30 percent, and estimated savings are higher for developing countries.
- *Paper* is produced in many countries, and the process consists of wood pulping and paper-making from the pulp (and waste paper). Large energy savings can be accrued in nearly all process stages, for instance, through improved dewatering technologies, energy and waste heat recovery and new pulping technologies. The technical savings potential is estimated to be as high as 40 percent, with estimates for long-term savings being even higher.
- Energy savings in *cement production* are possible through increased use of additives (replacing the energy-intensive clinker), use of dry process, and large numbers of energy efficiency measures (e.g., reducing heat losses and use of waste as fuel). Compared to today's best practice, potential savings are estimated at 15-40 percent in developing countries.
- In *other industries,* energy is used for a large variety of energy end uses. Steam and motive power are the major end uses of energy. In steam systems, energy savings of about 25 percent are typically possible—by improving the efficiency of steam boilers (process control, reduction of excess air, preparation of feedwater), steam distribution (leaks, steam traps), and use and recovery (process integration and heat exchangers). Motor systems are the largest electricity users in industry, but are often oversized (reducing the efficiency of operation), while inefficient throttles, used to control pressures and leaks, may lead to pressure losses. Many programmes have identified potential savings of up to 20-50 percent through motor system efficiency improvement.

Buildings. The buildings sector includes a wide variety of specific energy applications, such as cooking, space heating and cooling, lighting, food refrigeration and freezing, office equipment, and water heating. These applications are end-use services, emphasising that what is important is not the energy consumed but the service delivered, such as cooked food, a warm space, or a lit office. A wide variety of energy efficiency measures exist for all end uses, such as space conditioning (including changes in the building envelope), efficient appliances (in households and offices), improved lighting, motors in ventilation, and energy management systems. Studies estimate the technical potential savings of 25-50 percent up to the year 2000 in residential buildings for various industrialised countries. In commercial buildings, estimates vary from 25-55 percent in industrialised countries to 50-60 percent in developing countries

Transport. Transport energy use can be reduced by improving the efficiency of transportation technology (e.g., improving automobile fuel economy), shifting to less energy-intensive transport modes (e.g., substitution from passenger cars to mass transit), improving the quality or changing the mix of fuels used in the transportation system, and improving the quality of the transportation infrastructure. For all modes of transport, substantial opportunities exist to improve transportation equipment. The technical savings potential for passenger cars and trucks is estimated at 15-55 percent. Energy savings in railway traffic are estimated at 10-35 percent worldwide. Significant reductions in energy use can be achieved by encouraging shifts to less energy-intensive modes of transport and urban planning.

5.1.3. Benefits of Energy Efficiency Improvement

As discussed above and in other chapters, environmental, health, social, economic, and security issues are affected directly or indirectly by energy use. Hence, energy efficiency improvement may reduce the negative impacts on any or a number of these issues. The magnitude of the effect on each of the issues may depend on the specific energy efficiency measure, technology used, fuels saved or used, and local circumstances. The benefits may also vary for the different stakeholders.

On the national level, energy efficiency improvement is going to lead to reduced environmental impacts of energy use and reductions in the negative health effects of air pollution from combusting fuels or producing energy carriers. It is also going to affect the macro-economics, as well as vulnerability for imported fuels. For example, the effect of the latter depends heavily on the local circumstances. Replacement of charcoal by LPG as cooking fuel in Dakar, Senegal, results in a net fuel saving, as well as reduction of greenhouse gas emissions (due to the deforestation, transport and methane emissions from charcoal manufacture) and reduced indoor air pollution. However, the measure leads to increasing imports of LPG. Most energy efficiency measures can result in more efficient use of domestic and imported fuels, thus reducing the vulnerability for imported fuels.

For the private end user, energy efficiency benefits may vary, even if macro-economic effects on the environment and external debt are not reflected in energy prices. Since energy-efficient technology is generally modern and innovative, it not only reduces energy costs, but also can lead to increased productivity, reductions in material losses, maintenance, and labour costs, as well as reductions in air pollution (eliminating the need for expensive air pollution controls). Ultimately, these benefits improve the productivity of a firm, although they are insufficiently quantified, and hence not included in the cost-benefit analyses of many project assessments. These benefits need to be appraised in the development of energy efficiency projects. **Error! Reference source not found.** shows an example of the benefits of energy efficiency projects in the steel industry.

5.1.4. Drivers for Energy Efficiency

The drivers for energy efficiency may vary over time and by country. Inefficient energy use contributes to many economic, social, environmental, health, and security issues, as discussed above. These adverse effects become drivers for improved efficiency, depending on the magnitude and urgency of the problems. In industrialised

BOX 1. NEAR NET SHAPE CASTING IN THE STEEL INDUSTRY

Advanced industrial technologies that show a number of inherent advantages are being developed. Such advantages include lower capital costs and environmental emissions, compared to state-of-the-art processes. The new technologies can "leapfrog" the problems associated with current production technologies in steel-making. The introduction of energy-efficient technologies in industry is dependent on a large number of factors. In the past, several new technological developments have shown rapid introduction in the steel industry, e.g., continuous casting, the demonstration of which, starting in 1947, has led to the eventual replacement of ingot casting in over 60% of the world steel production. Continuous casting dramatically reduces material losses in the casting stage, reduces production costs through lowered handling, and saves energy in ingot reheating due to the decreased material losses.

Near net shape casting implies the direct casting of the metal into (or near to) the final shape, e.g., strips or sections, replacing hot rolling. In conventional steel-making, steel is first cast and stored. The cast steel is reheated and treated in the rolling mills to be reshaped. Near net shape casting integrates casting and the first rolling steps. Originally, the technology has been proposed in the previous century by Bessemer. The current status of this technology is the so-called thin slab casting. Instead of slabs of 120-300 mm thickness, slabs of 30-60 mm thickness are produced. The cast thin slabs are directly reheated in a coupled furnace, and then directly rolled in a simplified hot strip mill. The technology is increasingly applied in developing countries (e.g., Korea and Mexico), showing that this medium scale technology suits the size of the often smaller steel plants in developing countries.

In the thin slab casters, energy used for casting and rolling is reduced with 75% relative to conventional technology. Capital cost of a new plant is 30-60% lower than conventional technology, depending on the capacity of the rolling mill. This results in sharp reductions in production costs. The application of thin slab casting technology by Nucor has led to successful entry and expansion of Nucor in this market in the USA.

countries, vulnerability to imported fuels and high energy prices have been the main driving force of energy efficiency improvement during the decade around the oil shocks. With the prices of oil declining after 1986, this factor has become less important. More recently, emerging environmental problems, such as local air pollution, and acid precipitation due to fossil fuel combustion, have become important environmental drivers. Today, potential climate change due to the emissions of greenhouse gases is the main environmental driver for increased energy efficiency in many industrialised countries.

High energy prices make energy efficiency improvement economically more attractive by reducing the payback period of a measure (see below). During periods of high energy prices (1973-1985), energy efficiency improvement rates were much higher than in periods with low energy prices (1986-today).[2] Similar variations can be found among countries which have alternating periods with high and low energy prices. Thus, energy efficiency levels in Europe and Japan tend to be higher than the US (which currently has low energy prices). Likewise, the reduction of subsidies for energy in China, initiated after energy price reforms of 1993, has contributed to increased interest in energy efficiency.

Deregulation of the energy sector may lead to energy price increases or decreases. Many analysts have argued that the organisation of the energy market leads to unfavourable treatment of energy efficiency. The energy supply-side sector used typically much lower discount rates than energy consumers, who depend on commercial banks for capital availability. Deregulation of utilities reduces the state influence, and, therefore, the access to low-cost capital. Deregulation in some developing countries, e.g., in Latin-America (Colombia, Peru, Costa Rica) and Africa, has led to price increases for energy, and to subsequent increased interest in energy efficiency. The World Bank is a strong proponent of deregulation. However, deregulation and subsequent price increases may negatively affect the access of low-income households to energy services. These effects need to be taken into account when designing a framework for deregulation. Deregulation in industrialised countries is expected to result in lower energy prices, because of the competition, especially for large energy consumers and customers. Hence, this may result in reduced interest in energy efficiency, as has been observed in some states in the US, where the power sector is being deregulated.

Today, the local, regional, and global environments are major drivers for increased efficiency and clean use of energy. Currently, the debate around climate change is an important driver for energy

[2] *Schipper, L. and Meyers, S. with Howarth, R. and Steiner, R. (1992),* Energy Efficiency and Human Activity: Past Trends, Future Prospects, *Cambridge University Press, Cambridge, UK.*

efficiency improvement, which is a crucial "no-regret" opportunity to reduce the emission of greenhouse gases. While climate change is not a determining issue for energy policy in developing countries, a low-carbon energy development pattern is likely to have many benefits with respect to health, environmental, economic, and security issues. For example, in the cement industry, energy use typically accounts for 30 percent of the production costs. Hence, energy-efficient technologies stand to substantially reduce the production costs of cement, a material critical in the build-up of the infrastructure of the country. Many new cement plants in developing countries are among the most efficient in the world, leading to lower energy intensities in selected developing countries than in some industrialised countries.

5.2. STARTING AN ENERGY EFFICIENCY PROGRAMME

5.2.1. Introduction

Energy intensity, services, and technologies vary widely by sector, as do the economic characteristics of the sectors. When designing an energy efficiency programme or project, the specific characteristics of the country need to be taken into account. A successful project is going to be sustainable in itself; it may also lead to replication by other stakeholders or in other sectors. In this section, we first discuss the different energy services typically found in each of the four sectors: agriculture, industry, buildings, and transport. Since the discussion is not expected to be complete, the bibliography provides further suggestions for more detailed studies. For each of the sectors, we discuss the general energy usage trends, energy uses and services, and, briefly, energy-efficient practices and technologies.

This section also providea a discussion of various tools needed for project assessment. This followa the discussion of trends. Tools include the means to assess opportunities for a specific project or sector and to appraise the opportunities that are identified. Financing of a project is important, and is often a bottleneck for project development in developing countries. We briefly discuss several project financing schemes. When implementing a project, sound project management is needed. It includes adaptation of technologies to local circumstances, training of personnel, and sufficient "after-care" to deduct lessons learned for future projects (including monitoring and evaluation).

5.2.2. Energy Use: Trends and Services in Developing Countries

Energy use is a function of population, economic activity, and the energy intensity of the activities. While increased demand due to population growth is a general driver for increased energy use, the demand of energy services may vary, and hence the economic activity mix and energy intensity of the mix. Energy intensity is defined as the amount of energy used to perform an activity. While on a high aggregation level, the activity is often defined as generating a unit of gross domestic product (GDP), on the lower aggregation levels, energy intensity is often expressed as the production of a tonne of steel, or the heating of a square meter of office space. Hence, energy intensity is directly linked to the type of activity and energy service performed. The economy of any country includes a huge variety of energy services, and the distribution or mix of these determines the overall energy intensity. This is called the structural effect. Energy savings can result by changing towards a less energy-intensive mix of energy services, or by improving the efficiency with which an energy service is provided. In this chapter, we concentrate on improving the energy efficiency, rather than macro-economic policies that may alter the mix of activities.

FIGURE 1. PRIMARY ENERGY CONSUMPTION IN THE WORLD AND IN DEVELOPING COUNTRIES, BY SECTOR.

Source: Price et al. *(1998). Note: Primary energy is expressed in exajoules (10^{18} J).*

Global primary energy demand has grown by 2.5 percent from 1971 to 307 EJ in 1990. After 1990, global growth has tapered off and increased to only 319 EJ, primarily due to large declines experienced in Central and Eastern Europe, because of the political and economic restructuring in many of these countries. **Error! Reference source not found.** provides an overview of the main energy use trends in deve-loping countries. Below we discuss the main trends in the most important sectors, as well as the typical energy services that are found in each of the sectors. We discuss four sectors: agriculture, industry, buildings (including domestic energy use and office buildings), and transport. Industry is the largest energy consuming sector, followed by buildings, transport, and agriculture.

Agriculture. Increasing degrees of mechanisation lead to higher energy inputs per unit of product. Direct energy consumption per hectare of arable land in world agriculture increased 3.3 percent per year on average between 1980 and 1990, and per unit product only 1.1 percent per year. The difference can be explained by the increase in productivity per hectare. For developing countries, these figures are 4.2 and 1.4 percent per year, respectively. Energy use for agriculture in deve-loping countries is estimated at 4.6 EJ, or half of the global energy consumption in this sector.

The major end uses of energy in agriculture are traction (tractors for mechanised agriculture) and irrigation. Tractors are, by far, the greatest consumers of fuel in field operations, accounting for 90-95 percent of the fuel used. Energy con-sumption in field operations is affected by many factors, including weather, soil type, depth of tillage operations, field size, speed, degree of mechani-sation (manpower, animal power, and mechanical power), and management ability. Mechanisation is done for the purpose of increased labour pro-ductivity, improved quality of work, and over-coming time constraints or critical operations (e.g., land clearing). It may improve yields through better land preparation, more precise placement of seed and fertiliser and more efficient harvesting. In North America, tractors are used for nearly all crop production operations. In developing countries, they are often used only for tillage and transportation. It has been estimated that about 15 percent of the world's cropland is irrigated, and that this area produces about 30 percent of the world's food. We can distinguish between systems powered by gravity and systems in which water has to be lifted by pumps over a certain height. Other direct on-farm commercial energy input consists mainly of energy for drying, direct energy for animal production, and direct energy for horticulture, such as heating, cooling, ventilation, and lighting.

Energy efficiency improvement opportunities include more efficient use of tractors, use of more efficient diesel engines in tractors, and reduced tillage. No studies estimating the energy savings of these measures in developing countries are available. In developing countries, energy efficient irrigation technologies have been studied in more depth. Retrofitting inefficient pumps is estimated to save 20-50 percent on energy for irrigation, as found in studies in India and Africa.

Industry. In 1995, industry has accounted for 41 percent (131 EJ) of global energy use. Between 1971 and 1992, industrial energy use has grown at a rate of 1.9 percent per year, slightly less than the world energy demand growth of 2.3 percent per year. This growth rate has slowed in recent years, falling to an annual average growth of 0.2 percent between 1990 and 1995, primarily because of declines in industrial output of the economies in transition (EIT) in Central and Eastern Europe. Energy use in the industrial sector is dominated by OECD countries, which account for 45 percent of world industrial energy use. Developing countries and the EITs use 32 percent and 23 percent of world industrial energy, respectively. More efficient technologies exist for all industrial sectors.

Energy services in the industrial sector vary widely, due to the wide variety of products produced and processes used. These include the extraction of natural resources, conversion into raw materials, and manufacture of finished (consumer) products. A large part of energy is consumed by the energy-intensive raw material conversion industries, such as cement, steel, and petroleum refining industries. In these industries, energy is a considerable part of the production costs, often in the range of 20-30 percent, making energy efficiency an important cost-reduction strategy. Besides these energy-intensive industries, many small-scale industries exist in developing countries. These can be energy-intensive operations, such as sugar-making and brick-works, but also less energy-intensive processes, such as food processing or consumer products industries. These plants are often operated on a small scale, which may hinder the implementation of energy efficiency measures (see below). In the energy-intensive industries, most energy is used for the specific conversion processes, although large amounts of energy are used to produce steam (e.g., in the chemical and pulp and paper industries) or by motors. In less energy-intensive industries, energy is often used for utilities, steam production, drives, and motors. For a more thorough description of processes used in these industries and typical energy consumptions, see e.g., WEC (1995) and Worrell *et al.* (1997).

Energy efficiency opportunities can be found in all industries, including light and energy-intensive industries. While in energy-intensive industries major opportunities can be found in the processes used, these can be most economically implemented when constructing a new plant[3] or retrofitting an existing plant. Studies of many energy-intensive industries in developing countries have shown significant potential for energy efficiency improvement in the process industries. Estimates for energy efficiency improvement in the steel industry in developing countries can be up to 50 percent, while savings in the cement industry can vary from 5 to 40 percent. In the less energy-intensive industries, opportunities are found in the utilities. Often, old or badly maintained steam boilers can result in large energy losses, aggravated by badly insulated steam distribution networks and malfunctioning steam traps. Even in the US, energy savings in these systems can easily combine to an overall cost-effective potential of 25 percent. Savings in electricity use for motors (using over half of industrial electricity consumption) can be high, especially if a systems approach is used to

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[3] *Most capacity expansion of energy intensive industries is currently found in developing countries. However, risk aversion and capital costs may often limit the implementation of innovative energy-efficient technologies. Trade in used industrial equipment from industrialised countries occurs in any sector, resulting in low-cost, but energy-inefficient, plants. This may ultimately result in increased costs for energy imports and negative impacts on trade balance and the environment.*

optimise the motor system to the energy service provided. Important measures include improved maintenance (e.g., pressurised air systems), sizing of the motor to the load, and adjustable speed drives. **Error! Reference source not found.** outlines various energy efficiency measures in industry.

Buildings. Approximately 36 percent of world primary energy is consumed by commercial and residential buildings. Between 1971 and 1992, average growth in energy use for buildings has been 2.7 percent per year, faster than the global average energy use. Global buildings energy use has been 109 EJ (commercial fuels only) in 1995, with industrialised countries consuming 58 percent of the total, followed by developing countries (22 percent), and the EITs (20 percent). Energy use in residential buildings is about twice that of commercial buildings worldwide. However, energy demand in commercial buildings has grown about 50% more rapidly than demand in residential buildings for the past two decades. Buildings in developing countries use approximately 25 EJ, three quarters of which are accounted by residential buildings, although in the rest of the world, growth of energy use has been more pronounced in commercial buildings (including government services, schools, and hospitals). The share of electricity in buildings energy use is now estimated at around 20 percent in residential buildings and over 40 percent in commercial buildings.[4] This demonstrates the important growth of the use of appliances and office equipment.

Energy use in residential buildings is generally a function of the household size and income level. In developing countries, urban areas are generally associated with higher average incomes, and wealthier populaces exhibit consumption patterns similar to those in industrialised countries, where purchases of appliances and other energy-using equipment increase with greater disposable income. For example, the degree of penetration of refrigerators in urban China is

TABLE 1. EXAMPLES OF EFFICIENCY IMPROVEMENT MEASURES IN ENERGY-INTENSIVE INDUSTRY

IRON AND STEEL
Heat recovery for steam generation, pre-heating combustion air, high efficiency burners
Adjustable speed drives, coke oven gas compressors, heat recovery coke oven gases, and dry coke quenching
Efficient hot blast stove operation, waste heat recovery for hot blast stove, top gas power recovery turbines, direct coal injection
Recovery of gas and heat, optimised oxygen production, increase scrap use
Scrap pre-heating in the electric arc furnace, oxy-fuel injection in furnace
Heat recovery, recovery of inert gases, efficient ladle pre-heating
Continuous casting, thin slab casting, recuperative burners in reheating furnace
PETROCHEMICALS
Petrochemicals
Process management and thermal integration (e.g. optimisation of steam network).
Mechanical vapour recompression
Optimised compressor and pump systems, adjustable speed drives
Auto-thermal reforming
Cogeneration, combined heat and power production
PULP AND PAPER
Continuous digester, displacement heating/batch digesters
Black liquor gasification/gas turbine cogeneration
Falling film black liquid evaporation, lime kiln modifications
Improved boiler design/operation, cogeneration, and distributed control systems
Heat recovery in paper machine, long nip press
CEMENT
Improved grinding media, roller mills, high-efficiency classifiers
Dewatering with filter presses and slurry thinners
Optimise heat transfer in clinker cooler, use of waste fuels
Dry-suspension pre-heater and pre-calciner kilns, blended cements
OVERALL
Optimisation of boiler, boiler control systems
Maintenance of steam distribution system, steam traps, and process integration (pinch analysis)
Optimisation of motor systems, pumps and compressors, reduce air leakages, adjustable speed drives

Source: WEC, 1995

[4] *Price, L.K., L. Michaelis, E. Worrell, and M. Khrushch (1998), "Sectoral Trends and Driving Forces of Global Energy Use and Greenhouse Gas Emissions", in* Mitigation and Adaptation Strategies for Global Change, ***3,*** *pp.263-319.*

estimated at nearly 90 percent, while in rural China, it is estimated at less than 10 percent (1996). In comparison, refrigerators are only found in 22 percent of the urban households in India.

In industrialised countries, a large part of energy is used for space conditioning (heating, cooling, ventilation). In the US, space conditioning uses over half of the energy in residential buildings, and over a third in commercial buildings. Not many detailed studies have assessed energy use in buildings in developing countries. Space heating is not common in many developing countries, with the exception of countries (or regions) with colder climates, such as Argentina and China. However, with increasing income levels, air conditioning is increasing. Air conditioners have been found in 8 percent of urban households in China in 1995 (compared to 58 percent in Thailand in 1993), but have increased rapidly since then. In general, in developing countries, cooking and water heating dominate residential energy use, followed by lighting, small appliances, and refrigerators, although even the urban poor often have no access to electricity. For example, in many African countries, less than 10 percent of the households have access to electricity. Hence, energy uses in the residential sector depend strongly on local circumstances and development patterns.

In commercial buildings, appliances are the most important energy users, followed by space conditioning and lighting. Specific electricity use in commercial buildings (expressed in energy consumption per square meter) in industrialised countries shows a steady increase over time, while fuel use shows a decline over time in all countries. Unfortunately, not much is known about energy use in commercial buildings in developing countries.

Improved building practices can reduce the energy requirements, as well as increased efficiency of space conditioning equipment, and improved controls. Improved building practices include urban planning (e.g., proper orientation of buildings and tree planting), choice of building materials (e.g., light materials reflect more solar energy and need less cooling), adequate insulation levels, proper sealing, and energy saving window designs. **Error! Reference source not found.** gives an overview of energy-efficient technologies in buildings.

TABLE 2. SUMMARY OF SELECTED ENERGY-EFFICIENT TECHNOLOGIES AND PRACTICES FOR BUILDINGS

SERVICE	TECHNOLOGY/PRACTICE
BUILDING ENVELOPE	**Energy-efficient windows** **Insulation (walls, roof, floor)** **Reduced air infiltration**
SPACE CONDI-TIONING	**Gas-fired, condensing furnaces** **High-efficiency heat pumps** **Air conditioner efficiency measures (e.g., thermal insulation, improved heat exchangers, advanced refrigerants, more efficient motors, see below)** **Centrifugal compressors, efficient fans and pumps, and variable air volume systems for large commercial buildings**
APPLIANCES	**Advanced compressors, evacuated panel insulation (refrigerators)** **Use of horizontal axis technology (clothes washers)** **Higher spin speeds in washing machine/spinner, heat pump dryers**
COOKING	**Improved efficiency of biomass stoves (developing countries)** **Efficient gas stoves (ignition, burners)**
LIGHTING	**Compact fluorescent lamps** **Improved phosphors** **Solid state electronic ballast technology** **Advanced lighting control systems (incl. daylighting and occupancy sensors)** **Task lighting**
MOTORS	**Variable speed drives** **Size optimisation** **Improvement of power quality** **Controls**
OTHER	**Building energy management systems** **Passive solar use** **Solar water heaters**

Source: WEC,1995.

Transport. Since 1971, global transport energy use has grown at a rate faster than total world primary energy use and has nearly doubled, jumping from 37 EJ to 69 EJ in 1995. The rate of growth in consumption for developing countries has been rapid over this time period (4.7 percent) while growth in industrialised countries and economies in transition has been more moderate (2.2 and 2.7 percent, respectively). Transport energy is divided between passenger and freight transport, both of which include several modes, such as automobile, truck, rail, ship, or air. Road transport, by passenger car and commercial trucks, accounts for the vast majority of total energy use (73 percent), followed by air (12 percent), rail (6 percent), and other modes (9 percent). The industrialised countries dominate transport energy use, accounting for two-thirds (43 EJ) of total world energy consumption in transport. Transport energy use has grown rapidly in developing countries and is estimated at 18 EJ (1995). Rapid economic growth has been accompanied by increased demand, resulting in a tremendous growth in road energy consumption, averaging 6 percent annually. Studies have found a strong relation between income levels and transport demand, both for passenger and freight transport. However, in addition to income level, important factors include changes in economic structure, the quality and density of infrastructure, and fuel prices. Hence, Asia has shown the fastest growth in energy consumption for transportation. It accounts for about half of the total transport energy use, followed by Latin America and Africa. The issue of the growth and demand for transport infrastructure is particularly salient for developing countries. The shift from labour-intensive to service-oriented economies has led to both increasing passenger transport and road freight transport intensities, reflecting the increased economic activity and demand for personal mobility. It may even be expected to be higher in the future, depending on increasing income levels. Car ownership in Bangkok, for example, has increased from 49.7 cars per 1000 persons in 1970 to 108.3 cars per 1000 persons in 1986, an average annual increase of 5 percent. Similar dramatic increases have occurred in other Asian countries as well. In developing countries, the share of energy use from road transport has increased to match industrialised countries levels (80 percent), while the share of rail has declined to about 8 percent of total energy use. Fuel intensities in developing countries are often much higher than industrialised countries, due to poor roads, infrastructure, and maintenance.

Transport energy use can be reduced by improving the efficiency of transportation technology (e.g., improving automobile fuel economy), shifting to less energy-intensive transport modes to achieve the same or similar transport service (e.g., substitution from passenger cars to mass transit), changing the mix of fuels used in the transportation system, and improving the quality of the transportation infrastructure (roads, railways). For nearly all modes of transport, substantial opportunities exist to improve transportation equipment. Measures that reduce energy use in conventional automobiles include improving engine technologies and the transmission, as well as reducing the load on the vehicle. Fuel intensities in developing countries are often much higher than in industrialised countries, and, therefore, hold even greater potential for improvement. In China, for example, recent estimates of fuel intensities for diesel and gasoline trucks in 1991 have been 36 and 37 litre/100km, respectively, or 25 percent higher than intensities in industrialised countries. These figures are also influenced by poor roads, infrastructure (see below), and maintenance, partly due to the wide variety and age of cars used.

Significant reductions in energy use can be achieved by encouraging shifts to less energy-intensive modes of transport. Shifting commuting from passenger cars to buses can result in a relative intensity drop of 200 percent. However, increasing the load factor (i.e., the number of passengers travelling) of the automobile through carpooling can have a similar effect. One study of the US estimates that 12 percent of inter-city truck-kilometres can shift to rail for the movement of goods, an important shift given the fact that road transport is four times as energy-intensive as rail. Transport

BOX 2. SUSTAINABLE URBAN TRANSPORT IN CURITIBA, BRAZIL

In almost every country, urbanisation is accompanied by more intensive use of motorised transportation. In many urban areas of developing countries, this development has occurred very rapidly, with negative consequences for urban planning, air quality, traffic congestion, energy consumption, and human health. Especially in many Asian cities, e.g., Bangkok and Jakarta, the increased transport demand has lead to uncontrolled growth of the number of motor vehicles. Combustion of fossil fuels in motor vehicles produces a number of pollutants that induce health risks. Automotive combustion engines are also major sources of greenhouse gases, i.e. CO_2 and nitrous oxides (N_2O).

The city of Curitiba, Brazil, is an excellent example of a sustainably managed transport system. In the 1960s, with a crippled transport system and burgeoning growth, the city has shown the characteristics of any large city in a developing country. Conventional wisdom may have led to the construction of more road capacity, which may have reduced travel time by personal car, but increased traffic loads and further aggravated the situation. However, starting in the 1960s, the local authorities in Curitiba have taken a path different from that of other cities, developing an integrated plan for transport, urban planning, infrastructure, business, and local community development. By planning and zoning residential and industrial development along so-called "arteries" in the proximity of public transport, transportation needs have been managed sustainably. The arteries are supplemented with a system of ring roads. Express buses on separate lanes are responsible for most of the transport load on the arteries and ring roads. Separate bus lines operate in close connection with the express buses and enter the residential areas. The public transport system now transports over 1 million people daily and accounts for over 70% of all weekday trips. Although Curitiba has the second highest per capita car ownership in Brazil (one car for every three people), Curitiba's gasoline use per capita is 30% lower than that of comparable Brazilian cities, and has lead to estimated annual fuel savings of 27 million litres (or 0.6 GJ/capita). The system has also reduced travel time and increased convenience. This systematic approach of integrating transport into urban planning has reduced space use, traffic congestion, as well as air pollution and energy use, making Curitiba one of the most attractive cities in Brazil, with downtown pedestrian areas and large green areas throughout the city. Curitiba is a successful example for many cities in developing and industrialised countries, where everyday traffic congestion leads to air pollution, health complaints, and economic damage.

infrastructure improvements can occur through increasing the availability or supply of infrastructure, or by reducing demand. Given the high costs of supply expansion, planners are beginning to examine methods to reduce the demand by transport vehicles, or to better optimise the use of existing infrastructure. Actions that can increase the load factor for any particular mode are also desirable, such as the construction of High Occupancy Vehicle lanes (HOVs) in passenger transport. Policies that encourage large shifts to public transit systems in densely populated areas, such as Singapore, Curitiba, and Manila, have been shown to reduce overall energy demand. Land use planning is an important tool to encourage shifts to mass transit. In Curitiba (see also **Error! Reference source not found.**), Brazil, the city's bus line accounts for 70 percent of total transport, and per-capita energy use is 30 percent lower than comparable Brazilian cities. This example and other studies indicate that land use planning and transportation system policies can reduce energy consumption in other developing countries.

5.2.3. Understanding Energy Efficiency Options

For successful implementation of an energy efficiency project, it is important to carefully assess opportunities technically and economically, including all of the investment costs and unintended consequences, as well as energy savings and productivity increases.

Information dissemination, through generalised campaigns and targeted energy audits, is essential to assisting energy consumers in understanding and employing technologies and practices leading to more efficient energy use. Residential energy audits performed in the US in the 1980s have been shown to have realised average net savings of 3-5 percent with benefit/cost ratios between 0.9 and 2.1. Commercial and industrial customers that received audits reduced their electricity use by an average of 2-8 percent, with the higher savings rates achieved when utilities have followed up their initial recommendations with strong marketing, repeated follow-up visits, and some financial incentives to implement the

BOX 3. INTERNATIONAL COOPERATION IN ENERGY AUDITING

Information and methods to identify and assess opportunities for energy efficiency are essential steps in the implementation of these practices and technologies. Energy audits for industries have been used as a tool to bridge the information gap. In India, energy audits for industry had a bad reputation, as historically these have been often subsided and provided at almost no cost. Often, the quality of the audits has been very low. In addition, the recommendations have been seldom implemented by the recipient. The cooperation between Tata Energy Research Institute (TERI), Bangalore, India, and the German organisation for Technical Cooperation (GTZ) aims to strengthen the capabilities of the TERI Bangalore Centre, provide energy audits for industry, and strengthen the capabilities of offering high-quality advice to industry. The Indo-German project provides various forms of training and improves measuring instruments for energy audits, as well as helps to establish south-south cooperation and to reorganise the institutions by building specialised teams for the various industrial sectors. The energy audit programme now has eight years of experience in providing energy audits to industry in Southern India, and has expanded from eight to 28 energy experts. This has provided the critical mass for the success of the project. It is planned to replicate this process in other parts of India and in other countries. Currently, the Jordan-German Rational Use of Energy Project is an attempt to replicate the good experiences from India by twinning the Jordan institute with TERI.

recommended measures. Energy audit programmes exist in numerous developing countries, and an evaluation of programmes in 11 different countries have found that, on average, 56 percent of the recommended measures have been implemented by audit recipients. The Industrial Assessment Centre (IAC) programme is a successful long-term project in the US. It is run jointly by 30 universities and provides free audits to small and medium-sized enterprises. Since 1976, over 7,700 audits with 53,000 recommendations have been done. Approximately 42 percent of the identified energy saving measures have actually been imple-mented. The programme has also resulted in auditing manuals and a database of audit results.[5] **Error! Reference source not found.** describes a developing country audit programme to improve energy efficiency in industry.

The likely success of implementation for a given project depends on the full economic assessment of the found opportunities. A cost-benefit analysis includes, on one hand, an assessment of the costs (e.g., investments, costs for training, financing, and insurance), and, on the other hand, the cost-reductions due to implementation of the project (e.g., reduced energy purchasing costs, reduced operation and maintenance costs, financial assessment of productivity benefits, reduced material losses, and, potentially, reduced permitting and compliance costs due to reduced environmental emissions). It is important to assess the total life cycle costs (LCC) of a project, as the total energy costs over the life-time of energy-using equipment often exceed the initial investment costs. This helps to assess the overall economic impact of an investment, especially if future energy price changes are likely. A number of economic instruments are available to assess the probability of profit from an investment, e.g., the internal rate of return, the simple payback period (PBP), and the net present value. Economic handbooks discuss these methods in more depth. The PBP is often used in industrial practice to make preliminary evaluations, because it is simple to use and easy to calculate. It is calculated according to formula 1 (see below). **Error! Reference source not found.** provides an example of a calculation for the imple-mentation of a thin slab caster (see also **Error! Reference source not found.**).

Formula (1): PBP = I / (SEPC - OM)
where:
I: total investments
SEPC: saved energy purchase costs (energy savings by fuel multiplied by the purchasing costs)
OM: net change in operation and maintenance costs (including productivity benefits)

All measures with a payback period that satisfy a pre-set criterion are assumed to be financially attractive. However, the payback period criterion can vary largely, depending on the nature of the firm and the size of the investment. Thus, it is not clear beforehand what criterion one should use. A survey—carried out in the Netherlands in 1983/84 among a restricted number (16) of industrial companies in order to assess the

[5] *The publications and database can be found at http://oipea-www.rutgers.edu.*

BOX 4. CALCULATING THE SIMPLE PAYBACK PERIOD OF AN INVESTMENT

In the steel industry, a thin slab caster is an innovative technology that saves energy and production costs (see also Error! Reference source not found.**). The typical investments are estimated at US$134/tonne steel capacity (I=134). Cost savings consist of energy savings and productivity benefits. Energy savings are estimated at GJ/tonne and kWh/tonne. Assuming US energy prices, this can amount to savings of US$10.5/tonne (SEPC=10.5). Productivity benefits consist of reduced capital costs, increased throughput, lower operation costs, and reduced material losses. Together, these amount to savings of US31/tonne (OM=- 31).**

If we would only account for the energy savings in this project, the payback period would equal 134/10.5, or almost 13 years. This investment would not be attractive for a retrofit of an existing steel plant.

However, if we account for productivity benefits, the payback period amounta to 134/(10.5+31),or just over 3 years. This evaluation shows the real value of the project and makes thin slab casting an interesting energy efficiency option.

effectiveness of stimulating measures—has shown that the simple PBP is used in almost all companies to make a preliminary evaluation of investments. Although that survey has been carried out for another purpose and the number of companies is limited, we can use the results to obtain insight into the payback period used in industrial practice. The survey has shown that the payback criterion used varies widely and does not depend on the size of the firm. Only in some cases, a sharply defined criterion has been used. The weighted average is 3.8 years. This distribution has been more or less confirmed by a German study performed in 1989 among 500 industrial firms.[6] The average payback period criterion is 4.1 years. This distribution holds for general investments. For energy-saving investments, 69 percent of the firms require the same payback period as for other investments, 8 percent requiring a shorter payback period and 10 percent a longer one. A complicating factor in financial analyses may be high inflation rates, as historically have been found in Latin America and Africa. This basically reduces the financial attractiveness of any investment.

5.2.4. Financing Mechanisms: a Brief Introduction

The technical and economic information can be used to develop a business plan for the project or programme, in order to obtain financing. Various innovative financing mechanisms are available, including third-party financing, leasing, and through intermediaries, such as energy service companies (ESCOs). Financing is key to the success of a project. Private sector financing is becoming increasingly important in all sectors, as public or multilateral funding is reduced. Key factors are the scale of the investment and whether the investment is a project or a venture (i.e., the start of a new company). Four levels of financing can roughly be distinguished: micro (less than US$10,000), small (US$10,000-500,000), medium (over US$500,000), and large (over US$20M). Large lending institutions (e.g., multilateral development banks) are not able to deal with small-scale projects. Since most energy efficiency projects vary from micro to medium, they typically fall outside the scope of these institutions, unless special programmes have been developed.

Microcredit may be more important for small-scale projects (see also Chapter 7). Microcredit is based on traditional banking principles, but is designed to lend money to low-income groups. The concept can be very successful in countries with an underdeveloped financial infrastructure. The Grameen Bank in Bangladesh is a successful example of a microcredit institution for the rural poor. Established in 1974, the Grameen Bank now started provides funding for energy technologies in villages by developing solar energy systems. In addition, it is cooperating with international suppliers of energy services and energy-efficient equipment.

Leasing is a very common way of financing for all kinds of equipment, from photocopiers to airplanes. When equipment is leased, the user does not have to borrow funds for the capital

[6] *Gruber, E. and Brand, M. (1991), "Promoting Energy Conservation in Small and Medium-Sized Companies",* Energy Policy, ***19,*** *pp.279-287.*

investment. In energy efficiency leasing arrangements, the monthly lease payments are lower than the expected energy savings, while the technology leasing company is responsible for operation and maintenance (IEA, 1997). The International Financing Corporation (IFC) has been very active in promoting leasing companies. Leasing is proving to be an important way to finance the use of environmentally-sustainable and energy-efficient equipment. IEA (1997) provides an example of how a lease for energy-efficient heating equipment, put up by a Hungarian Bank, made it possible for an ESCO (see below) to guarantee energy savings in retrofitting municipal buildings.

Third-Party Financing is used to finance entire projects. A third party finances and carries out the work under its own responsibility and guarantees the work. The investment is recovered through operational savings over a pre-defined period of time. The risk is completely assumed by the third party. This financing mechanism is common in the construction of new power plants, such as build-own-operate-transfer (BOOT) agreements (David and Fernando, 1995). The contract negotiations may often be very difficult and time-consuming, as demonstrated by experiences in Malaysia and other developing countries (David and Fernando, 1995). Third-party financing may also be used to construct industrial cogeneration plants. In many countries, industrial cogeneration has attracted attention to reduce energy use and emissions (e.g., Denmark, Netherlands, and US). In these countries, joint ventures of energy supply or distribution companies with industrial (heat using) companies are set up to build new cogeneration power plants, where the steam is used by the industry, and part of the electricity is exported to the grid. Third-party financing is not yet common for many energy end use efficient technologies, although ESCOs can be viewed as a third party financier (IEA, 1997).

1.2. ENERGY SERVICE COMPANIES: ONE APPROACH IN DETAIL

Energy service companies (ESCOs) provide energy-saving services to consumers, either directly, or through utility demand-side management (DSM) programmes. ESCOs typically provide engineering and managerial expertise to help customers assess and implement energy efficiency improvements. These companies assume technical, financial, and operational risks, as well as arrange project financing. ESCOs then either receive a fee based on achieved energy savings, or sign a contract for the provision of energy savings at specified prices. An ESCO, or an Energy Service Company, is a business that develops, installs, and finances projects designed to improve the energy efficiency and maintenance costs for facilities over a set time period. ESCOs generally act as project developers for a wide range of tasks and assume the technical and performance risk associated with the project. Typically, they offer the following services: development, design, and financing energy efficiency projects; installation and maintenance of the energy-efficient equipment involved; measurement, monitoring, and verification of the project's energy savings; and assumption of the risk that the project will save the amount of energy guaranteed.[7]

These services are bundled into the project's cost and are repaid through the dollar savings generated. The ESCO employs a wide array of cost-effective measures to achieve energy savings. ESCOs often perform on the basis of performance-based contracting. When an ESCO undertakes a project, the company's compensation,

[7] *See, e.g., International Energy Agency (1997),* Energy Efficiency Initiative (Volume 1 and 2), *IEA/OECD, Paris, France; and, World Bank (1999), and* The Energy Service Industry, The Experience of the United States and Canada, *Energy Sector Unit, Energy, Mining and Telecommunications Department, The World Bank, Washington, DC.*

BOX 5. DESIGN AND IMPLEMENTATION OF A BIDDING PROGRAM

An example of a bidding programme is the PowerSaving Partners (PSP) programme of the Pacific Gas & Electric utility in California, US. In the programme, ESCOs have bid to provide 20 MW of power through various energy services. After a public announcement, 42 bids have been received, for a total of 130 MW. The bids have been evaluated on economics first, followed by an evaluation of six criteria: 1) measurement and evaluation; 2) programme development; 3) marketing plan; 4) compatibility; 5) comprehensiveness; and 6) location. The top 13 bids have been selected based on meeting the above criteria. Contract negotiations have been started with these 13 companies. Key issues in the negotiations have been the risk of project financing, compared to the avoided costs for the utility, measurement and verification protocols used, pricing structure over the contract period, contract administration by PG&E, time constraints for negotiations, complexity of the PSP programme design, and the disparity of professionalism and experience among bidders.

The final contract included a fixed payment price for the energy services, so that the risk of lower avoided costs would fall with the utility (on average the costs of the programmes were only 43% of the avoided costs of the utility). The risks of performance, however, were with the ESCO. ESCOs were paid on the basis of measured and verified savings. The PSP programme resulted in savings of 19.2 MW, and the total package was cost-effective and profitable.

and, often, the project's financing, are directly linked to the amount of energy that is actually saved. In the US, various utilities have organised bidding programmes in which ESCOs bid for a project through performance-based contracting. Experiences with these bidding programmes have shown that almost all cases have been cost-effective, compared to the costs of energy supply. Although the specific costs of energy savings of these bidding programmes have been slightly higher than that of utility DSM, the users bear significantly less risk in bidding programmes. Experiences with energy performance contracts can also be found in countries like Hungary, where international ESCOs, with the help of financial consortia, offer energy services based on performance contracts for building upgrades. The lack of knowledge on performance-based contracting and the perceived credibility have been obstacles in introducing ESCOs in these new markets. In Brazil a market for ESCOs is emerging. The current ESCOs in Brazil are technically competent, but the lack of experience, credibility, good measurement, and verification practices are barriers to market acceptance. Third-party financing has been very limited in Brazil, and needs to be expanded through investment banks to finance ESCO projects.

Typically, energy efficiency measures in ESCO projects require a large initial capital investment and offer a relatively long payback period. The customer's debt payments are tied to the energy savings offered under the project, so that the customer pays for the capital improvement with the money that comes out of the difference between pre-installation and post-installation energy use and other costs. For this reason, ESCOs verify, rather than estimate, energy savings. International metering and verification (M&V) protocols are being developed to provide a generally accepted standard procedure.[8] Most performance-based energy efficiency projects include the maintenance of all or some portion of the new equipment over the life of the contract, which compares to a BOOT-contract in energy supply. The cost of this ongoing maintenance is folded into the overall cost of the project. **Error! Reference source not found.** showcases the procedures of a specific competitive bidding process from the utility's perspective. Despite the specific background of the project, general lessons can be learned on programme deve-lopment and negotiations.

Historically, the energy service industry is relatively young. Most US ESCOs place the industry's origins in the late 1970s and early 1980s, when energy prices have risen. About 30 US utilities have used ESCOs as a component of their DSM programmes to reduce demand in resi-dential, commercial, and industrial facilities between 1987 and 1994.[9] The most recent review of the US market shows that independent

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[8] *More information on the IPMVP can be found at http://www.ipmvp.org*

[9] *Goldman, C.A. and Kito, M.S. (1995), "Review of US Utility Demand Side Bidding Programs",* Utilities Policy, ***1****(5), pp.13-25.*

ESCOs are slowly declining, while utility-owned and retail ESCOs are increasing their market share within a deregulating environment for power supply. It also appears that performance contracting is being overtaken by other forms of energy service contracts, although this may be the effect of changing markets and also stands to be shaped by public policies.

If well-designed, public policies and deregulation of the power sector may provide an important role for ESCOs. Experiences with power market deregulation in six countries (Argentina, Chile, New Zealand, Norway, UK, and US) have shown that ESCOs are only interested in the largest commercial and industrial energy consumers. Energy service markets for small and medium energy users have failed to emerge in most countries, except for New Zealand, where regulation prescribes retail competition on the basis of service, not price. This shows that the success of ESCOs depends strongly on the policy framework in a specific country, underlining the important role of all parties, including policy-makers, utilities, and energy consumers.

1.3. ROLE OF INSTITUTIONS

Society is a complex organisation of relationships and activities (see also Chapter 6). This is also true for energy efficiency policy. A wide range of stakeholders is involved in all steps of an energy efficiency policy, from formulation to implementation. The stakeholders need to develop partnerships and nurture the relationships with each other, in order to develop and implement successful policies. These partnerships can take various forms. Voluntary agreements (see below) can be seen as a form of a private-government partnership. These partnerships are not a one-time effort, but rather a continuous development. Despite the importance of the partnerships, all partners do have distinct roles and responsibilities in the development process. For simplicity, we define three major stakeholders: governmental and quasi-governmental organisations, private sector (including NGOs), and academia (e.g., research institutes and universities).

The **government** may consist of the policy-making body, energy agencies, as well as state-owned utilities. Policy-makers' primary responsibility is to establish a legal and institutional framework for energy efficiency, as well as to establish the right conditions for energy efficiency and environment. In order to implement this effectively, the government needs to establish policies and tools for effective efforts to improve energy efficiency, specifically in the area of cost effectiveness. To improve the effectiveness over time and answer the changing conditions, the government needs to conduct policy evaluations (or outsource them to an independent third party). It can also lead by example, using its purchasing power to provide a market for new energy-efficient products. The US government Federal Energy Management Programme (FEMP) is an example of this. Quasi-governmental organisations, such as energy agencies and utilities, also have their distinct roles. An energy agency is primarily a clearinghouse for information, building relationships and partner-ships, as well as implementing programmes. For example, many European countries have an independent energy agency that plays a central role in programme implementation. State-owned utilities traditionally need to focus on improving the efficiency of generation and distribution of energy. However, utilities would need to consider least-cost planning strategies to energy services, through DSM programmes and rate structures that encourage energy efficiency.

The **private sector** encompasses a wide variety of stakeholders, such as industries, associations, private utilities, financing (banks), equipment manufacturers, and NGOs. Each of these has its own set of objectives. Industries and associations form primary partnerships for energy efficiency programmes. An association may serve as an information clearinghouse for their members and may support an infrastructure to implement innovative technologies. It is also the primary partner to participate in agreements and negotiations with the government, in order to achieve targeted results or implement policy objectives in the most effective way. By doing so, it promotes democratic decision-making processes. Technology suppliers and users play the most important role in the development, commercialisation, promotion, and marketing of energy-efficient technologies. This also stresses the role of innovative financing concepts and new organisations in the implementation of these technologies. Finally, NGOs play an important role in the public dissemination of information about the importance of energy efficiency, the participation and promotion of democratic decision-making processes, and the development of active partner networks.

Academia consists of research and teaching organisations. It plays an important role in the research and development of new technologies, technology assessment, and independent monitoring and evaluation of policies. Universities and research establishments develop science and technologies for energy efficiency and environmental sustainability, promote assessment capabilities for technology and policies, and monitor and evaluate policies. Universities and schools are also very important in developing a knowledge infrastructure for environmentally-sustainable practices.

5.3. BARRIERS

There are many barriers to the implementation of energy efficiency improvement measures. Empirical quantitative research on the size of the barriers, while limited, underlines the large diversity between individual investors (e.g., firms and consumers). More than one of the described measures apply, more or less, to an investor. The target group has large implications for policy formation aimed at increasing the implementation of energy-efficient measures and equipment. Although most of the empirical research has studied industrialised countries, similar barriers can be found in all countries. Developing countries suffer from all the factors that inhibit market acceptance of energy-efficient technologies in industrialised countries, plus a multitude of other institutional problems.[10]

5.3.1.1. Unwillingness to Invest

The decision-making process to invest in energy efficiency improvement, like any investment, is shaped by the behaviour of individuals or of various actors within a firm. Decision-making processes in firms are a function of their rules of procedure, business climate, corporate culture, managers' personalities, and perception of the firm's energy efficiency. A study in the US determined nine "types" of managers, depending on industrial development type and management characteristics. A recent analysis of the Green Lights programme in the US has demonstrated the shortcomings in traditional decision-making processes, as investments in energy efficient lighting show much higher payback than other investments.[11] These analyses demonstrate the need for a better understanding of the decision-making process.

[10] *Worrell, E., M. Levine, L. Price, N. Martin, R. van den Broek and K. Blok (1997),* Potentials and Policy Implications of Energy and Material Efficiency Improvement, *Department for Policy Coordination and Sustainable Development, United Nations, New York, NY.*

[11] *DeCanio, S.J. (1998). "The Efficiency Paradox: Bureaucratic and Organizational Barriers to Profitable Energy-Saving Investments",* Energy Policy*, **26**, pp.441-454*

In markets with strong growth and competition, efficiency, with respect to energy and other inputs, is necessary to survive. In contrast, stagnating markets are poor theatres for innovation and investment, and instead rely on already depreciated equipment to maintain low production costs. A favourable market expectation has been perceived as an important condition for investing in energy efficiency. Also, in markets where increased energy costs can still be recovered in the product price, firms do not have the incentive to invest in energy efficiency improvement. It appears that firms often perceive themselves as energy efficient, even though there exists significant potential for profitable energy efficiency improvement. Energy awareness as a means to reduce production costs does not seem to be a high priority in many firms, despite a number of excellent examples in industry worldwide.

5.3.1.2. Lack of Information and High Transaction Costs

Consumers often have no knowledge of energy efficiency. If they do have such knowledge, they often cannot afford even small increases in equipment costs or have other priorities. Reddy[12] makes the important point that the problem of this knowledge gap concerns not only consumers of end-use equipment, but all other actors in the market. Many producers of end-use equipment have little knowledge of ways to make their products energy efficient and little or no access to the technology for producing the improved products. End-use providers are often unacquainted with efficient technology.

In developing countries, financial institutions are hesitant to take risks in promoting new technology to an even greater degree than in industrialised countries. The government itself is little involved in providing the essential information necessary for consumers to make intelligent choices on energy efficiency. Indeed, in many developing countries, it is the government that owns and operates the energy supply companies; in these cases, the government often suffers from the same supply biases as the utilities that it runs. Energy supply companies (private or government-owned) often have significant political power, which often counteracts the efforts of agencies of government that promote energy efficiency. This presents a particularly vexing problem for energy efficiency in developing countries, as a governmental leadership role is essential to overcome the considerable imperfections in the markets of these countries.

Cost-effective energy efficiency measures are often not undertaken as a result of lack of information or knowledge on the part of the consumer, lack of confidence in the information, or high transaction costs for obtaining reliable information. Information collection and processing consumes time and resources, which is especially difficult for small firms and individual households.

Evaluations of electric utility demand-side management programmes showed that lighting retrofits resulting in large energy savings and short payback were rejected by the vast majority of building owners and managers, until the utility provided a programme with large incentive payments for the installation of the systems. In an evaluation of one of the utility programmes, more than 65 percent of the participants (all of whom had rejected the lighting retrofit without the utility program) stated that in the future they would invest in more efficient lighting systems without an incentive. Information in the broadest sense of the term was required to achieve market acceptance. The sceptical building managers needed to be convinced that the system would save energy, be cost-effective, could be installed without major disruptions, and would perform as well as the traditional lighting system.

Many individuals are quite ignorant of the possibilities for buying efficient equipment, because energy is just one of the many criteria in acquiring equipment. The information needs of the various actors are diverse and must lead to a diversified set of information sources. Public authorities and utilities play an important role in providing this information. However, in many

[12] *Reddy, A.K.N. (1991), "Barriers to Improvements in Energy Efficiency",* Energy Policy, ***19,*** *pp.953-961.*

developing countries, public capacity for information dissemination is lacking. Training is essential, especially in energy conservation planning and policy-making, because of the focus on energy supply in many developing countries.

5.3.1.3. Profitability Barriers

There is compelling evidence that residential consumers substantially under-invest in energy efficiency or, stated differently, exhibit high returns to make such investments. An analysis from a large number of consumer choices between two refrigerators differing only in the price and energy consumption has shown that consumers typically require a return on investment of 40 percent or more, in order to purchase the more efficient refrigerator.

A large number of standard accounting procedures is available for firms to determine the economic feasibility and profitability of an investment. Many investors use instruments, such as simple payback period, rate of return, or net present value to evaluate energy efficiency projects. When energy prices do not reflect the real costs of energy, consumers under-invest in energy efficiency. Energy prices, and hence the profitability of an investment, are also subject to large fluctuations. The uncertainty about energy price, especially in the short term, seems to be an important barrier. The uncertainties often lead to higher perceived risks, and, therefore, to more stringent investment criteria and a higher hurdle rate.

An important reason for high hurdle rates is capital availability. Capital rationing is often used within firms as an allocation means for investments. This leads to high hurdle rates, especially for small projects, from 35 to 60 percent, which is much higher than the cost of capital (approximately15 percent). On the supply side, the costs of capital are much lower, leading to imperfections of the capital market. Utilities and investors in power supply typically operate with payback periods of 20 years or longer. These capital market imperfections lead to bias against end-use investments vis-à-vis energy supply. This also seems to apply to international loans. From this perspective, energy efficiency investments in developing countries are put at a disadvantage.

5.3.1.4. Lack of Skilled Personnel

Especially for households and small and medium sized enterprises (SMEs), the difficulties installing new energy-efficient equipment, compared to the simplicity of buying energy, may be prohibitive. In many firms (especially with the current development toward *lean* firms), there is often a shortage of trained technical personnel, because most personnel are busy maintaining production. A survey in The Netherlands suggests that the availability of personnel is seen as a barrier to investing in energy-efficient equipment by about one-third of the surveyed firms. In the EITs, the disintegration of the industrial conglomerates may lead to loss of expertise and hence similar implementation problems. Outsiders (e.g., consultants and utilities) are not always welcome, especially if proprietary processes are involved. In developing countries there is hardly any knowledge infrastructure available that is easily accessible for SMEs. Such knowledge is important, because SMEs are often a large part of the economy in developing countries, and are often inefficient. In addition, the possible disruption of the production process is perceived as a barrier, leading to high *transition costs*. Transition costs may include the costs of not fully depreciated production equipment, although the investment in itself may be economically attractive. The size of the transition problems may be reduced by maintaining a good infrastructure for efficiency improvement. This seems especially true for small consumers (e.g., households and SMEs).

5.3.1.5. Other Market Barriers

In addition to the problems identified above, other important barriers include: (1) the "invisibility" of energy efficiency measures and the difficulty of demonstrating and quantifying their impacts; (2) lack of inclusion of external costs of energy production and use in the price of energy; and (3) slow diffusion of innovative technology into markets. A full discussion of these topics is beyond our scope. Many companies are risk-averse with regard to a possible effect on product quality, process reliability, maintenance needs, or the uncertainty about the performance of a new technology. Firms are, therefore, less likely to invest in new technology. Aversion of perceived risks seems to be a barrier, especially in SMEs.

There are other barriers to energy efficiency in residential markets. For dwellings that are rented, there are few incentives for the renter to improve the property that he/she does not own; similarly, the landlord is uncertain of recovering his/her investment, either in higher rents (as it is difficult to prove that improved thermal integrity saves the renter money in utility bills) or in the utility bills (as the bills depend on the behaviour of the renter). The same sort of problem can exist in commercial buildings between builders and owners. Builders are often required to minimise first costs in order to win bids, and many building owners do not have sufficient expertise to recognise the benefit of higher first costs to reduce building operating costs. Likewise, utilities have the incentive to promote greater energy use and not to promote greater efficiency by their customers, unless markets are transformed.

Gadgil and Sastry[13] stress that rigid hierarchical structure of organisations and the paucity of organisations occupying the few niches in a given area lead to strong and closed networks of decision-makers who are often strongly wedded to the benefits they receive from the status quo. They describe how the hierarchy in India leads to the discontinuation of an innovative programme for a utility to lease compact fluorescent lamps to its customers. Among the difficulties in adopting energy efficiency in India, at least ten major barriers have been found: lack of information about products; limited ability to pay even small increased first costs; very low electricity prices; limited foreign currency (which makes difficult the purchase of modern equipment from outside the country); poor power quality (which often interferes with the operation of the electronics needed for energy-efficient end-use devices); shortage of skilled staff to select, purchase, and install efficient equipment; a large used equipment market which keeps inefficient equipment operating long after its useful life; high taxes that increase the first cost differential between efficient and inefficient products; very high risk-aversion of the lending community; and many small and/or outdated industrial activities that do not have resources to produce efficient equipment.

[13] *Gadgil, A. Sastry, A. (1994), "Stalled on the Road to Market: Lessons from a Project Promoting Lighting Efficiency in India,"* Energy Policy, ***22,*** *pp.151-162.*

Many policies have been used to accelerate the implementation of energy efficiency improvement measures. Although most of the empirical research has studied industrialised countries, examples of successful policies can be found in all countries. Based on the literature and case studies, we present several examples of successful policies and programmes in developing countries.

5.3.2. Information Programmes

Information programmes are designed to assist energy consumers in understanding and employing can be the most important source of information, followed by personal information from equipment manufacturer, as well as exchanges between colleagues is also an important information source.

Information programmes are often components of larger energy efficiency activities, so evaluations of their effectiveness are limited. Information programmes by themselves have been shown to result in energy savings of 0-2 percent. A US utility that launched a 2-year advertising promotional campaign for energy efficiency has found that participation rates in its programmes often doubled, but that savings have not necessarily been persistent for long periods. Developing countries, such as China, Brazil, Mexico, India, and Thailand, have developed large-scale information programmes to promote lighting and other residential technologies, although few detailed assessments exist on the effectiveness of these efforts. In general, information campaigns are most effective when the provider is a trusted organisation and when the information is provided face-to-face.

The Norwegian Industry Energy Efficiency Network (IEEN) was established in 1989. The main objectives are to improve energy efficiency in small and medium-sized enterprises and decision-making capabilities in industry. IEEN has built on previous experiences in Canada with the Canadian Industry Programme for technologies and practices to use energy more efficiently. These programmes aim to increase consumers' awareness, acceptance, and use of particular technologies or utility energy conservation programmes. Examples of information programmes include educational brochures, hotlines, videos, home energy rating systems, design-assistance programmes, audits, energy use feedback programmes, and labelling programmes. As noted before, the information needs are strongly determined by the situation of the actor. Therefore, successful programmes need to be tailored to meet these needs. Trade literature Energy Conservation. Today, more than 500 companies among 13 different sectors, from dairies to the primary aluminium industry, and representing 70 percent of Norwegian industrial energy use, are organised in IEEN. Individual companies join voluntarily and are required to provide an annual statement on energy use and production volumes. Each year, the collected data is analysed and processed to produce a sector's benchmark. The benchmark provides information on how a specific firm is operating among the other company members. The benchmarks are shown in a bar diagram for various products of each industry sector. While the data points of competitors are confidential, each individual company knows its own status. The benchmark data is actively used to motivate companies to improve energy efficiency. A recent survey among IEEN members shows that a vast majority of the firms agree that participation in the network is important. The Norwegian programme has been already replicated in Poland and Croatia.

Energy audit programmes are a more targeted type of information transaction than simple advertising. Energy audit programmes exist in numerous developing countries, and an evaluation of programmes in 11 different countries has found that, on average, 56 percent of the recommended measures have been implemented by audit recipients. Audits have been discussed in more detail in section 3.3.

Education and training ,both for customers and for industrial energy managers, offer perhaps the greatest potential for achieving long-term energy efficiency savings. The importance of training for developing countries is highlighted below. For industrialised countries, training often has proven to be a highly cost-effective option for achieving savings. One US utility has measured the effect of energy efficiency education for low-income customers and found annual savings 8 percent higher than for customers who have not received the information and training.

test procedures) provide the necessary underpinnings for other energy efficiency policies.

5.3.3. Market Transformation Programmes

Market transformation programmes are basically a collection of the instruments discussed in this section. These are organised in a way to bring about a change in a specific market. Examples can be found in many countries, where targeted approaches using various incentives have been used to introduce compact fluorescent lighting (i.e., Brazil) or efficient motors in the market (i.e., Canada). We discuss several approaches that have been used in practice. The role of ESCOs has been discussed in section 5.4.

Utility **Integrated Resource Planning (IRP),** which has been applied primarily in industrialised countries, is used to assess all options for meeting energy service needs, including utility-sponsored end-use efficiency programmes. The novel feature of IRP is that it requires utilities to look beyond the utility meter and into the ways that electricity is used, in order to find the least-cost way of providing energy service. IRP programmes in the US have shown a wide variety of end-use efficiency measures that are less costly than energy supply additions. Two major problems occur: 1) inducing the utility to carry out end-use efficiency programmes; and 2)

These examples point to the fact that better information, training, and audits have a role to play in energy efficiency policies. However, information alone has not been very effective in getting consumers to actually commit to purchasing energy-efficient products. Analyses of consumer information programmes in the US has found that these programmes alone generally result in much lower energy savings than expected. However, information programmes, combined with various other approaches, can be very effective. People are much more likely to pay close attention to information, if they are likely to use it; incentive programmes which get the attention of consumers, when combined with the provision of high-quality information, have proven to be successful in many utilities. Information programmes (e.g., labels for appliances and other information derived from

designing these programmes so that they are, in fact, cost-effective. In the US, utilities traditionally have been subject to rate of return regulation, i.e. the utility obtains profit from its "rate base", consisting of its investment in generation, transmission, and distribution. This results in a strong disincentive for end-use efficiency programmes. This is a dilemma. While the end-use efficiency is desirable from an individual consumer and a social perspective, the utility has strong incentives to increase supply and disincentives to reduce demand under rate of return regulation. In the early 1980s, a new approach provided incentives to utilities for promoting end-use efficiency programmes. These incentives consisted of: 1) recovery of all costs of carrying out the programmes; 2) increased profits for demonstrated successful end-use efficiency programmes; and 3) recovery of foregone profits resulting from reduced sales. This represents a transfer of financial resources from the ratepayer to the utility—increasing the utility profitability—and has been extremely successful in promoting utility end-use efficiency programmes. Certain types of regulatory reforms that remove the financial disincentives could lead to increased utility energy efficiency investments in the US. US utility expenditures on demand-side management (DSM) programmes tripled in 5 years to US$3 billion in 1994. The 25 utilities with the largest estimated energy savings resulting from these programmes, representing 25 percent of the total electricity sales, spent an average of 2.1 percent of revenues on these programmes.[14] Perhaps most remarkably, utility expenditures on DSM in the early 1990s were between 7 and 10 percent of expenditures on all supply, transmission, and distribution.

There have been many evaluations of individual utility DSM programmes, and most have been shown to be more cost-effective than energy supply. It is, nonetheless, difficult to accurately measure the performance of these programmes. Electricity used is a measurable quantity. Electricity saved is much more elusive. The relative invisibility of energy savings acts as a disincentive to consumer investment. It is not easy to overcome consumer scepticism, even of energy efficiency measures that perform extremely well, when evidence for success is uncertain in the absence of extensive statistical studies. One study, which has evaluated US$190 million of commercial lighting programmes in 20 utilities including all costs and energy savings of the programmes, has shown an average cost of energy savings to be 3.9 cents per kWh. This is considerably less than the marginal cost of new power at the time the programmes have been implemented.

There has been interest in IRP and the establishment of DSM programmes in many developing countries. Thailand has launched a

[14] *Hadley, S. and Hirst, E. (1995),* Utility DSM Programs from 1989 Through 1998: Continuation or Cross Roads? *Oak Ridge National Laboratory, Oak Ridge, USA.*

multi-sectoral DSM programme to invest US$180 million over five years. It is aimed at saving 225 MW of peak demand and 1,000 GWh annually. This is estimated to be half the cost of new supply. The programme includes design assistance for new commercial buildings, as well as lighting retrofits in existing buildings. China has also shown considerable interest in IRP, with several utilities developing plans. Utilities in Mexico and Brazil have been active in DSM programmes. Brazil's national electricity conservation programme (PROCEL) is estimated to have saved the equivalent of a 250 MW power plant. The cost-benefit ratio has been estimated to be more than ten to one, with savings of US$500 million and programme costs of US$35 million.

Experiences with deregulation of power production in Europe and the US have demonstrated a declining interest in DSM programmes. New innovative programs are being developed to ensure energy efficiency programmes. For example, in many states in the US, the so-called public-benefit charges are applied to electricity sales. These charges are used to fund research and development (R&D) activities, as well as energy efficiency promotion programmes. Several private utilities have entered the ESCO market as a way to retain large energy-consuming customers.

An innovative policy mechanism, designed to transform the market towards the production and consumption of more efficient products, is **"market aggregation",** or the organised use of buyer demand to stimulate new supplies of a product or service. If a significant share of buyers of a given type of product demand a more efficient product, then this can "pull" the market to a more efficient product mix. Government agencies can play a key role in aggregating the buyers to reduce risk for the producer, and in providing incentives for the production of more efficient products. Market pull activities are now gaining greater interest in industrialised countries, and eventually may become a model for developing countries. NUTEK, the Swedish National Board for Industrial and Technical Development, has successfully undertaken several technology procurement projects for more efficient refrigerator-freezers, laundry equipment, high-performance windows, computer monitors, office lighting, electronic ballasts, and other products. In the US, recent activities include a federal procurement program (FEMP), which directs all federal agencies to purchase energy-efficient products that are in the top 25 percent of the market. Other voluntary programmes are the so-called "Golden Carrot" programmes, applied in Sweden and the US and involving subsidies to design and produce a refrigerator more efficient than the level set by the appliance standards. The winning design has become the basis for the next generation of refrigerators. Golden Carrot programmes have been launched for other appliances.

BOX 6. INTRODUCING CFLs THROUGH MARKET TRANSFORMATION STRATEGIES

Compact fluorescent lamps (CFLs) are thin fluorescent tubes that are bent several times to fit in a small space. CFLs can be used in many applications, have a long life-time (on average 6 years), and result in electricity savings of approximately 60-80% compared to incandescent lamps. CFLs have been developed in the 1970s and first marketed in 1978. In 1988, nearly 10 million CFLs have been sold in the US, representing about 1% of the incandescent lamp market. By 1992, CFL sales have reached 35-40 million, or 4-5% of the market, equivalent to an annual market growth of 33%/year, but because of their relatively long lifetime, the market share of CFLs is, in fact, higher.

The success of CFLs in penetrating the US market can be attributed to several factors. The main incentives that had a large impact have been product improvements (i.e., size reduction, improved shape, instant on lamps), cost reductions, utility incentives through DSM programmes, and energy and maintenance cost savings in the commercial sector. It is estimated that in 1991 utility incentives have been involved in half of the CFL sales in the US. In other countries, the introduction of CFLs has also been rapidly. In The Netherlands, the penetration of CFLs in households is now among the highest in the world. The utilities have pursued DSM programmes since the early 1990s to reduce the emissions of CO_2 and NO_x and reduce energy use. The DSM programmes aim at sales of 15 million CFLs in a period of five years, with an average penetration goal of 3.5 lamps per household. By 1995, a penetration of 2.15 CFLs per household has been achieved, saving approximately 64 GWh annually. Several utilities have provided rebates of 25% on CFL purchases by clients, as well as information campaigns. Other very successful CFLs market transformation programs can be found in Brazil (Procel) and Mexico (Ilumex).

5.3.4. Energy Price Reform

Markets are a powerful and fundamental force in wide-scale implementation of energy efficiency.

Subsidies that depress prices of energy provide a significant disincentive for energy efficiency. The removal of this barrier (low energy prices) is an important step toward creating an investment climate in which energy efficiency can prosper.

Worldwide, consumer energy prices typically do not reflect the full costs of energy production, transmission, and distribution because these prices are often subsidised. Furthermore, the energy prices do not include environmental costs. In 1991, world fossil fuel subsidies reduced consumer energy prices by 20-25 percent. Energy subsidies have been most significant in the developing countries and in Eastern Europe and the former Soviet Union. Between 1979 and 1991, electricity prices in developing countries were on average 40 percent lower than electricity prices in OECD countries. A survey of electricity prices of over 60 developing countries found that electricity subsidies grew during the 1980s. In 1991, the average electricity price in developing countries was 4 cents/kWh while the marginal costs were about 10 cents/kWh. Subsidies have decreased during the 1990s, but are still considerable in many countries.

Energy prices in some areas are beginning to more closely reflect costs in response to commercialisation of the electricity industry and investment by independent power producers. For example, Thailand has essentially eliminated across-the-board subsidies, electricity prices in Korea have reached the level of costs, and energy prices in Poland are being adjusted to reflect full economic costs. In Chile, energy prices have risen following power sector privatisation and reforms that eliminated government inter-vention in setting prices. In Colombia, Peru, Jamaica, Costa Rica, and Bolivia privatisation of part or all of the energy supply industry is currently taking place, and is expected to lead to deregulation of electricity prices. After many years of trying, the Chinese government initiated significant energy price reforms in 1993. As of 1994, 90 percent of all making other changes to reduce heat from houses of low-income families, show relatively few free riders. An interesting type of subsidy has been the coal was no longer subject to price regulations, and the price of this coal reflected most of the supply costs. In 1993, electricity price reforms in China led to prices for new power projects being based on the cost of generation plus a return on capital. This change, combined with higher prices for power from existing power plants, means that electricity prices may, in time, approach deregulated marginal costs.

International lending organisations, led by the World Bank, have been strong proponents of energy price deregulation in developing countries. The largest hurdle to such price increases involves the impact on low-income consumers. This is a serious problem in many developing countries, as low-income urban families often spend a substantial portion of their income on energy. Recent surveys in urban areas of developing countries show the poorest 20 percent of the population spending 20 percent of their income on energy. It should be noted that, very often, in developing countries, the poorest have no access to commercial energy at all. The impacts of higher energy prices on the urban poor can be mitigated in several ways. A low tariff for the lowest consumption block can be instituted, or subsidies for energy efficiency improvements can be targeted at low-income urban dwellers.

5.3.5. Financial Incentives

Direct subsidies, tax credits, or other favourable tax treatments have been a traditional approach to promoting activities that are thought to be socially desirable. Incentive programmes need to be carefully justified to assure that social benefits exceed costs. Direct subsidies might also suffer from the "free rider" problem, where subsidies are used for invest-ments that would be made anyway. Estimates of the share of "free riders" in Europe range from 50 to 80 percent, although evaluation is often difficult. However, other subsidy programmes, e.g., the federal grants in the US, for improving insulation and provision of low-interest loan funds for energy efficiency projects, with the government absorbing the difference in interest payments. In some European countries, there have been promising results from experiments with the so-called "green" funds that provide low-interest loans from private funds.

An example of a financial incentive programme that has had a very large impact on energy efficiency is the energy conservation loan programme that China has instituted in 1980. This loan programme is the largest energy efficiency investment programme ever undertaken by any developing country, and currently commits 7-8 percent of total energy investment to efficiency, primarily in heavy industry. The programme not only funded projects whose average cost of conserved energy was well below the cost of new supply, it also stimulated widespread adoption of efficient technologies beyond the relatively small pool of project fund recipients. The programme has contributed to the remarkable decline in the energy intensity of China's economy. Since 1980 energy consumption has grown at an average rate of 4.8 percent per year (compared to 7.5 percent in the 1970s) while GDP has grown twice as fast (9.5 percent per year), mainly due to falling industrial sector energy intensity. Of the apparent intensity drop in industry in the 1980s, about 10 percent can be attributed directly to the efficiency investment programme,[15] and the rest comes from unsub-sidised efficiency investments, efficiency improve-ments incidental to other investments and housekeeping measures.

5.3.6. Regulations and Guidelines

Regulatory programmes have proven effective in promoting energy efficiency gains. Examples include appliance energy efficiency regulations, automobile fuel economy standards, and commercial and residential building standards programmes. In such programmes, the government passes a requirement that all products (or an average of all products sold) meet some minimum energy efficiency level. Energy efficiency standards are applied in many countries for various energy uses. Standards can be performance-based, i.e., they do not mandate how the manufacturer is to meet them (i.e., what technologies or design options to use) and are used for appliances or cars, e.g., the CAFE standards in the US (Corporate Average Fleet Efficiency, see below).

Appliance energy efficiency standards have been aggressively pursued in the US. Since the passage of the National Appliance Energy Conservation Act (NAECA) by the US Congress in 1987, the federal government has mandated standards for such products as refrigerators, water heaters, furnaces and boilers, central air conditioners and heat pumps, room air conditioners, clothes washers, dryers and dishwashers, ovens, and lighting ballasts. NAECA requires a periodic update on all standards, with the timing of new standards differing among different products. The standards in the US are currently being revised. From the viewpoint of economic and energy savings, these standards have been a major success. The standards already in effect are expected to reduce primary energy consumption in the US by 1.1 EJ/year by the year 2000, and 2.75 EJ/year by 2015, avoiding the equivalent of 31 500 MW power plants by the year 2000.

The auto fuel economy standards were promulgated in the US at a time (1975) when its autos consumed about 80 percent more fuel per vehicle mile than European or Japanese autos. By 1992, the average U.S. fuel consumption had declined from 18 litres/100km to 12 litres/100km, while the European and Japanese fuel intensities changed very little. Much of this reduction in fuel intensity was a result of the standards. Estimates of the impact of the standards by themselves varied between 15 and 50 percent out of the total savings gained for new automobiles.

Building energy standards may be performance or component-based standards. While most residential standards specify the measures to be

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[15] *Sinton, J.E. and Levine, M.D. (1994), "Changing Energy Intensity in Chinese Industry",* Energy Policy, ***22,*** *pp.239-255.*

included in the building, some also have an alternative or performance pathway, allowing the builder to choose different combinations of measures to meet a specified performance level. The actual energy savings from building energy standards are more difficult to estimate than for appliances and automobiles, as buildings are not mass-produced.[16] Where performance standards are used, the standard is a design standard, meaning that the design, rather than the building itself, needs to meet the code. Faulty construction practice is not dealt with, and is typically responsible for a significant share of poor energy performance of buildings. The operation of a building, which is not affected by building energy codes, plays a major role of the actual performance of buildings. Building commissioning, where systems are tested and maintenance personnel are trained to ensure correct performance of systems, can help deal with this problem for new buildings. In spite of these limitations on energy standards for buildings, they are important policy tools. Because buildings are long-lived, consume large quantities of energy, and can be made more energy efficient at much lower cost when new than after they have been built and occupied, even energy standards that in their implementation are far from perfect can still yield significant economic and energy benefits. Building energy standards are in use or proposed in a large number of countries. A survey of energy standards that received replies from 57 countries, more than half of which do not belong to the OECD, found that 27 had mandatory standards (of which four were residential only and two were commercial only), 11 had voluntary or mixed standards, 6 had proposed standards, and only 13 (all developing countries) had no standard.[17]

[16] *To assure performance every individual building has to be tested. In practice, buildings are not tested, and the degree to which post-standards buildings meet the standards has been established through a small number of experiments.*

[17] *Janda, K.B. and Busch, J.F. (1993),* Worldwide Status of Energy Standards for Buildings, *Lawrence Berkeley Laboratory, Berkeley, USA.*

5.3.7. Voluntary Agreements

Generally, a voluntary agreement is a contract between the government (or another regulating agency) and a private company, association of companies, or other institution. The content of the agreement may vary. The private partners may promise to attain a certain energy efficiency improvement, meet an emission reduction target, or, at least, attempt to do so. In turn, the government partner may promise to support this endeavour financially or to refrain from other regulating activities.

- Some examples of voluntary agreements directed at energy efficiency improvement are discussed.[18] Agreements have been reached between The Netherlands' government and associations of *industrial companies* to improve the energy efficiency in the year 2000 by 20 percent, compared to the 1990 situation. In Denmark, agreements can be closed between the government and industrial companies. Companies that enter into such an agreement are exempted from paying the Danish carbon tax. Also, in other countries, such as Finland, Germany, and Japan, agreements have been reached.
- The US Environmental Protection Agency (EPA) has created voluntary programmes to reduce greenhouse gas emissions in *buildings*. These programmes are known as EPA's Energy Star programmes. The Green Lights program, launched in 1990, involves an agreement between the EPA and corporations, in which the corporation commits to all cost-effective lighting retrofits and the EPA commits to providing technical support. By 1994, Green Lights has had 1682 participants, including 37 percent of the *Fortune 500* firms, representing 130 million m^2 of floor space. EPA estimates that the programme saved 1 TWh of electricity in 1994. Other green programmes include Energy Star Computers, which has achieved agreement of the major

[18] *International Energy Agency (1996),* Voluntary Actions for Energy-Related CO_2 Abatement in IEA Member Countries, *IEA/OECD, Paris, France.*

manufacturers to provide energy-saving features on their computers, and Energy Star Buildings.

- German car manufacturers have given a voluntary statement to reduce the specific fuel consumption of cars they make and sell in the year 2005 by 25 percent, compared to the year 1990.

Experiences with early environmental voluntary agreements (VAs) varied strongly—from successful actions to failures. The first evaluation of the Dutch Long-Term Agreement, halfway the program period, shows promising results, in that most sectors stand to achieve their targets. Voluntary agreements can have some apparent advantages over regulation, in that they may be easier and faster to implement, and may lead to more cost-effective solutions. The Global Semiconductor Partnership is an example of an international voluntary agreement to reduce PFC emissions, while avoiding regulation.

5.4. CONCLUSIONS

Energy efficiency improvement reduces air pollution (global warming, acid precipitation, and smog in the urban and industrial environment), waste production (ashes), and water and thermal pollution. Efficiency improvement is a cheap energy source. Economic benefits are the reduced costs of energy transformation and generation, reduced fuel imports, and increased energy security. Technologies do not now, nor stand to in the foreseeable future, provide a limitation on continuing energy efficiency improvements. Significant potential exists for energy savings through energy efficiency improvement in all sectors of society, and these savings can change current unsustainable consumption patterns. Three factors have played a major role in the considerable energy efficiency improvements in the past decades: increasing energy prices (except for the past five to ten years), energy policies aimed at bringing energy efficiency into the market, and technological development.

Barriers to efficiency improvement can include: unwillingness to invest, lack of available and accessible information, economic disincentives, and organisational barriers. The degree to which a barrier limits efficiency improvement is strongly dependent on the situation of the stakeholder. Specific implementation barriers may apply to selected stakeholders and/or technologies. This means that no single instrument can "do the job", and policies need to tailor activities to the specific barriers for a target group of stakeholders. A range of policy instruments is available, and innovative approaches or combinations have been tried in some countries. Successful policies can contain regulation and guidelines, economic instruments and incentives, voluntary agreements and actions, information, education and training, as well as research, development, and demonstration policies. Successful policies with proven track records in several sectors include efficiency standards and codes, technology development, as well as utility/government programmes and partnerships.

A policy aimed at sustainable development places energy efficiency improvement in the middle of the economic and environmental policy field. Energy efficiency facilitates the introduction of renewables and "buys time" for the development of low-cost renewable energy sources. However, energy efficiency does not receive attention appropriate for the important role it needs to play in development of an environmentally-sustainable society. Regulatory frameworks typically do not recognise energy efficiency improvement as an energy source. A balanced approach is required to place supply and demand on an equal footing. Changes are needed to fulfil the promise of energy efficiency and to fulfil energy needs more sustainably, accounting for social, economic, and environmental issues.