WORKING PAPER 14/2011

Barriers to energy efficiency: International case studies on successful barrier removal

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

DEVELOPMENT POLICY, STATISTICS AND RESEARCH BRANCH
WORKING PAPER 14/2011

Barriers to energy efficiency: International case studies on successful barrier removal

Ernst Worrell
Professor, Energy, Materials and Environment
Copernicus Institute for Sustainable Development and Innovation
Utrecht University

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2011

Acknowledgements

This working paper was prepared by Prof. Ernst Worrell, Copernicus Institute for Sustainable Development and Innovation, Utrecht University, as background material for the UNIDO Industrial Development Report 2011,under the supervision of Ludovico Alcorta, Director, Development Policy, Statistics and Research Branch, UNIDO.

The designations employed, descriptions and classifications of countries, and the presentation of the material in this report do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. The views expressed in this paper do not necessarily reflect the views of the Secretariat of the UNIDO. The responsibility for opinions expressed rests solely with the authors, and publication does not constitute an endorsement by UNIDO. Although great care has been taken to maintain the accuracy of information herein, neither UNIDO nor its member States assume any responsibility for consequences which may arise from the use of the material. Terms such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment. Any indication of, or reference to, a country, institution or other legal entity does not constitute an endorsement. Information contained herein may be freely quoted or reprinted but acknowledgement is requested. This report has been produced without formal United Nations editing.

This document reflects work in progress and, as such, has been edited neither in language nor in style. Its distribution is limited for the purposes of eliciting comments and reviews only.

Table of Contents

List of Figures

1 Introduction

Industry uses nearly 40 percent of worldwide energy to produce materials and products consumed by us all on a daily basis. In the process it contributes almost 37 percent of global greenhouse gas emissions (GHG). Globally, and in most countries, CO_2 accounts for more than 90 percent of CO_2-eq GHG emissions from the industrial sector, and energy use is the key source of the emissions. Energy intensity of industry has steadily declined in most countries since the oil price shocks of the 1970s, as evidenced by studies from around the world.

Historically, industrial energy efficiency improvement rates have typically been around 1 percent/year. However, various countries have demonstrated that it is possible to double these rates for extended periods of time (i.e., 10 years or more) through the use of policy mechanisms. Still, large potentials exist to further reduce energy use and GHG emissions in most sectors and economies, if these are successful in reducing barriers that limit the uptake of energy efficient practices and technologies.

Barriers in the end-use of energy are defined as forces or mechanisms that can be observed to operate in specific markets in such a way as to inhibit behaviours or investments that would increase the efficiency of energy use. In the context of classical economics, market failures occur when barriers are found to inhibit actions that would increase both energy efficiency and economic efficiency. In this context, if a barrier is found to inhibit investments that would be cost effective in a generally accepted economic framework, it is termed a market failure. Some barriers may be observed to inhibit investments in energy efficiency, but unless these investments are economically efficient, they cannot be termed market failures. Another way to view this issue is that an energy efficiency policy invention is economically efficient if its benefits outweigh the costs of intervention.

A wide body of literature has documented the existence of barriers. Classical economic theory admits to relatively few types of market barriers that can lead to market failures (Sorrell, 2005). Different classifications exist for barriers that impede energy efficiency improvement (see, e.g., IPCC, 2001; IEA, 2007). A typical classification may be:

1. Principal-agent barriers
2. Information/transaction cost barriers
3. Externality cost barriers
4. Other barriers.

1. Principal-agent barriers. Stemming from classical concepts of agency theory and asymmetric information, the principal-agent problem occurs when one party makes decisions affecting end-use energy efficiency in a given market, and a different party bears the consequences of those decisions. Common examples include the new homes market, the commercial leasing market and the rental housing market.

2. Information cost barriers. Energy efficiency at the end-use level in a given market is an aggregate function of many small decisions. Thousands or millions of decisions may be made in a given market and time period for such end uses as home appliances, vehicles or commercial equipment. In many cases, the decision-maker in these small investments lacks the information or expertise to make a decision that would maximize both energy efficiency and economic efficiency. By contrast, energy supply investments, which typically occur in fewer and larger projects, are usually large enough to bear the cost of obtaining the expertise and information needed to make well-informed decisions. In this sense, the information costs attached to end-use efficiency decisions can lead to market failures.

3. Externality cost barriers. Economists acknowledge that when the nominal market price for energy does not reflect its full cost to society as a whole, market failures can result. Environmental impacts, health impacts and other "externality costs" are widely recognized as imposing indirect costs on society for the direct use of energy.

4. Other barriers. There is also a substantial literature devoted to other kinds of barriers that have been observed to inhibit economically-attractive efficiency investments. Cognitive and behavioural factors depart from the classical economics framework in that they posit variations and limitations in the perceptions, motivations and behaviours of individuals and organizations. Classical economics is firmly rooted in the assumption that all actors in a market think and behave rationally to maximize their own economic interests; in this framework, there is a strong aversion to "looking inside the heads" of consumers or organizations.

The concept of bounded rationality argues that classical economics fails to be descriptively accurate, since it assumes that individuals make decisions in a completely rational optimizing way. Bounded rationality assumes that people and organizations make decisions bounded by constraints on their time, attention, resources and ability to process information. It argues that their choices will thus not be fully rational and optimizing, and that individuals adopt rules of thumb to make "good enough" decisions rather than spending the time and effort needed to reach optimum decisions.

Similarly, firm failures have been observed that significantly limit energy efficiency investment by organizations, even when such investments are found to be otherwise economically efficient. One of the implications of transaction cost economics and behavioural economics is that the bright line between market failures and other outcomes becomes blurred. The picture becomes more of a continuum from outcomes that are fully rational from an energy and economic viewpoint to those that clearly evidence failure, with a large body of situations in between in which classical failures may be difficult to prove, but in which efficiency investment can be improved while increasing economic efficiency. Analyses in Germany (Gruber and Brand, 1991), Norway (Sæle et al., 2005), and the United States (Anderson and Newell, 2002) have shown that even when cost-effective opportunities are identified that satisfy the investment criteria of the company, between 40 and 60 percent of the suggestions are typically implemented.

Hansen and Lund (2002) looked at strategies for optimizing companies' energy management through employee involvement. In particular, they sought to identify the factors crucial to the successful integration of a new energy management system, where in the system the most effective results could be obtained, and what methodologies had been adopted. The results of their work on 14 Danish companies showed that the implementation of an energy management system is not a guarantee that employees will become involved. Four factors are important for this to take place:

- The existence of change agents, specifically persons in addition to the individual in charge of energy
- Managerial behaviour, including: committing to energy efficiency as a legitimate part of the business, establishing communication channels with employees, and realistically allocating time and money to energy efficiency measures
- Effective organization of production and responsibility for energy management incorporating such factors as horizontal networks, delegation of responsibility to production groups and line management commitment, and
- Knowledge management through skills development, acceptance of change and internal liaison.

In this report, several case studies are presented that document the success of policies to accelerate the implementation of energy efficient technologies. The case studies highlight both corporate policies (related to energy management within a company) as well as successful public policies. Furthermore, several other issues are addressed, e.g., the co-benefits of energy efficiency improvement and the role of international trade in second-hand technologies. Most of the material has not been documented before in public literature.

Documenting the full benefits of energy efficiency improvement has always been difficult. The first case study documents the importance of technology characterization in the assessment of energy efficient technologies. Both in the analysis of energy-efficient technologies by analysts and companies, the full benefits are often not accounted correctly, putting up a barrier to energy efficiency improvement. The case study demonstrates that including full accounting of the benefits of technologies can dramatically affect the profitability, and hence the uptake of these technologies and measures.

While full accounting of costs and benefits is important, a pre-condition to even realize that energy-efficiency improvement exists is the existence of an energy management system within the company. While many companies exist that have well-functioning energy management systems, too many companies in all countries of the world still lack an energy management system. The case study in Chapter 3 documents the results of a benchmarking study of Canadian cement plants. It demonstrates that companies that have a well-functioning energy management system score better in the uptake of energy-efficient technologies and the performance level achieved by the plants/companies.

Chapter 4 documents the energy management system of the multinational building material company Cemex with plants in many parts of the world. Cemex's energy management system is an example of a well-organized energy management system. Cemex is just one example of a company with a well-functioning energy management system. Other companies include such diverse companies as Alcoa, Toyota, ExxonMobil, 3M, Johnson & Johnson, and many other multinationals.

The next two chapters document the success that can be achieved with public policy. Both examples discuss industrial cogeneration (Combined Heat and Power, or CHP). The first case study shows the importance of tailoring policy design to the barriers that limit the uptake of energy efficient technologies, in this case CHP in The Netherlands. Two different periods in

CHP development can be identified in the way that policy was designed and supported the development. However, it also shows that a changing policy environment can also limit further growth (due to deregulation of the power markets). The second case study (Chapter 6) documents the enormous successful development of CHP policy in a developing country. It shows that interesting policy developments are not limited to industrialized countries, but can be found in many developing countries as well. Mauritius has supported the development of industrial CHP in the sugar industry with a consistent set of policies to remove barriers to the development of this domestic energy resource, with positive impacts on both the sugar companies as well as the national economy of Mauritius.

Chapter 7 reports on an ongoing industrial energy efficiency program in a developing country, which has become the largest global emission source of greenhouse gas emissions. China has realized that the rapidly increasing energy use in its economy may limit future development of China's economy. Given that 70 percent of China's energy use is used by industry, a large program was initiated with aggressive goals to realize strong improvements in energy efficiency in the top 1000 largest industrial companies in China. The program is still running and only early results are reported. The design of a consistent program focused on large energy users is a good example for policy makers.

The final case study documents a specific issue for developing countries. Today, large amounts of industrial equipment, including complete refineries or steel plants, are traded, and many end up in developing countries. Due to the lack of access to capital, companies may decide to purchase used equipment instead of state-of-the-art equipment. This will almost certainly result in increased energy use, as the equipment used has a higher energy intensity than modern equipment. The case study documents the size of this market, and shows that the energy and economic impact on a company may be negative, as the higher energy costs exceed the savings in capital costs.

2 Co-benefits of energy efficiency improvement

Research and development efforts across all industries are driven by the goal of improving the productivity of industrial processes. Improvements can come in a variety of ways, including lower capital costs and operating costs, increased yields, and reductions in resource and energy use. Any industrial technology development will incorporate one or more of these improvements. Some innovations may primarily be aimed at one goal, but also generally include beneficial impacts on other impacts of a production process. For example, switching from vertical shaft kilns in the Chinese cement industry, not only reduces energy intensity, but at the same time improves product quality as clinker quality is more consistent, and reduces the emission of air pollutants.

Certain technologies that are identified as being “energy-efficient” because they reduce the use of energy will bring a number of additional enhancements to the production process. These improvements, including lower maintenance costs, increased production yield, safer working conditions, and many others, are collectively referred to as “productivity benefits” or “non-energy benefits”, because in addition to reducing energy, they all increase the productivity of the firm. In general, productivity expresses a relationship between the quantity of goods and services produced by a business or an economy and the quantity of labor, capital, energy, and other resources that are needed to produce those goods and services.

Understanding the full benefits and properly incorporating them into cost analyses is important because these improvements can significantly change the cost assessment of the technology and result in a more favourable evaluation. At the project level, the effect of productivity benefits on cost assessments could determine whether or not a project is undertaken.

In the steel industry in many developing countries electric arc furnaces are used to melt scrap to produce steel. In these furnaces scrap is added using a bucket. Electrodes are lowered into the scrap and a high electric current melts the scrap. The hot offgases of the furnace can, however, be used to preheat scrap. After many years of development, various successful scrap preheating systems are now used around the world. The shaft furnace is the most common type and consists of a vertical shaft that channels the offgases to preheat the scrap. The scrap can be fed continuously or through a so-called system of ‘fingers’. The systems make almost 100 percent scrap preheating possible, leading to potential energy savings of 100-120 kWh/t compared to typical power usage of 450-550 kWh/tonne steel. The energy savings depend on the scrap used, and the degree of post-combustion. Despite the high energy savings, low power prices in many (developing) countries limit the uptake of this technology.

However, the scrap preheating systems lead to reduced electrode consumption, improves product yield improvement by 0.25-2 percent and increases productivity by up to 20 percent (i.e. as tap-to-tap times are reduced more steel can be produced with the same capital) and reduce flue gas dust emissions by 25 percent (reducing hazardous waste handling costs) The production costs savings amount up to US$5/tonne (excluding saved electricity costs).

Incorporating these benefits in the cost-benefit analysis makes scrap preheating an interesting opportunity with relatively small payback periods, even when electricity prices are relatively low.

3 Energy management is key to realize energy efficiency

Energy management practices are key to the successful implementation of energy efficiency as a sustained effort. Proper management of energy use and costs is essential to improve energy efficiency. A well-functioning energy management system provides the enabling environment to identify opportunities for and to realize energy savings in a sustained manner. Energy management practices vary widely in industry.

A benchmarking study of energy efficiency, technology use, and energy management practices of the Canadian cement industry has demonstrated that companies/plants with well-functioning energy management practices perform better in the uptake of energy-efficient technologies and the improvement of energy efficiency.

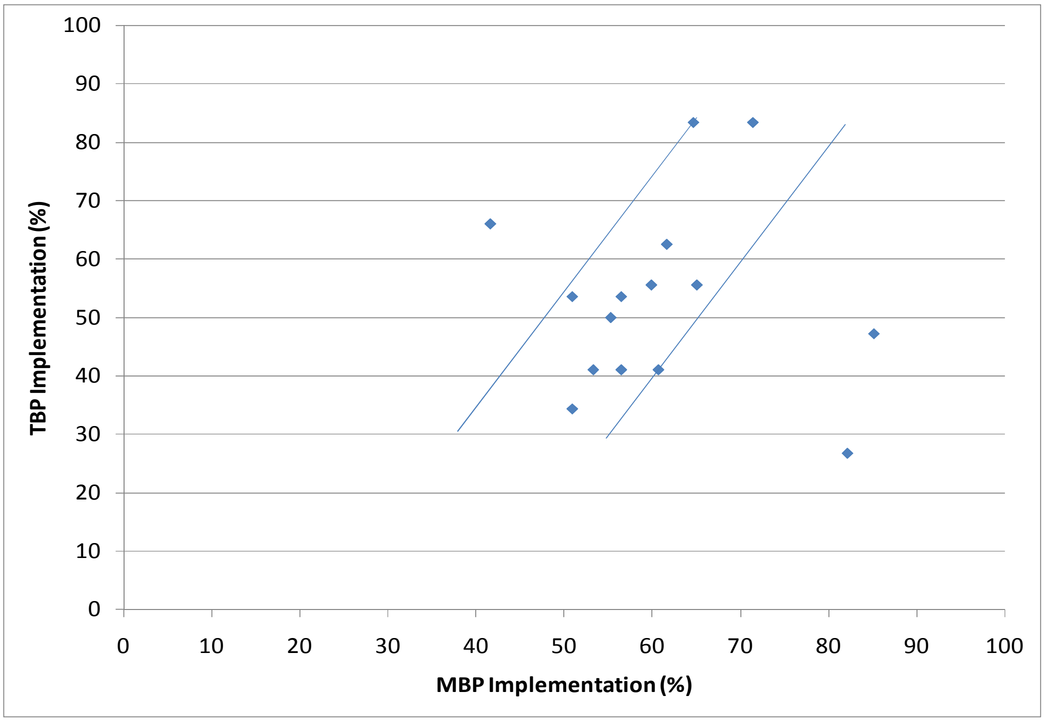
As an energy intensive industry, energy efficiency has always been important to the Canadian cement manufacturing industry. Energy constitutes about 40 percent of Canadian cement manufacturing production costs and about 82 percent of the energy is from carbon intensive fossil fuels, such as coal and petroleum coke. Over the past 16 years the energy intensity of the Canadian cement manufacturing sector has improved by 11 percent, but with increased energy prices, economic slowdown, and pressure to reduce greenhouse gas emissions there is an increased urgency to further improve energy efficiency. In 2008 there were fifteen Portland grey cement manufacturing facilities across Canada. The fifteen Portland grey cement facilities consumed more than 61 PJ of energy in Canada in 2006. The challenge facing the sector, as with many other industrial sectors, is to not only to identify the opportunities to improve energy efficiency, but also to understand the underlying factors that impede the implementation of the opportunities. To address these challenges the Cement Association of Canada (CAC) commissioned an innovative and comprehensive integrated energy management benchmarking study. Within the study three survey instruments were developed and used to obtain input from all 15 Canadian Portland Grey cement plants:

- Management best practices (MPB) survey.
- Energy technical practices (TPB) survey.
- Energy use and efficiency (EEI) survey.

For each of the surveys scores up to 100 can be achieved, with 100 being the highest score. The MPB survey was based on international energy management programs and guidelines (e.g. from Canada, USA and Australia). The TPB survey benchmarks the degree of implementation of best practice technologies by process step. The EEI benchmarks energy use and efficiency across plants and process steps. The tool can calculate various indicators including: total energy intensity (GJ/tonne cement); fuel intensity (GJ/tonne cement / clinker); electricity intensity (kWh/tonne cement); and, an energy efficiency index (EEI). The EEI allows for more meaningful direct comparison between plants with significant structural differences. A theoretical 'best practice' plant was constructed, normalizing with an EEI of 100.

The results from the surveys were used to calculate the implementation of MBP and TBP, and the energy use and efficiency benchmarking tool was used to determine the EEI. A scatter plot of the MBP and TBP implementation by the fifteen facilities are presented in Figure 1. With the exception of three outliers, the correlation between MBP and TBP implementation shows a general trend where a higher implementation of MBP by a facility is associated with a higher implementation of TBP. Figure 1 illuminates the range of total benchmarks for the fifteen facilities, and the correlation between MBP and TBP implementation

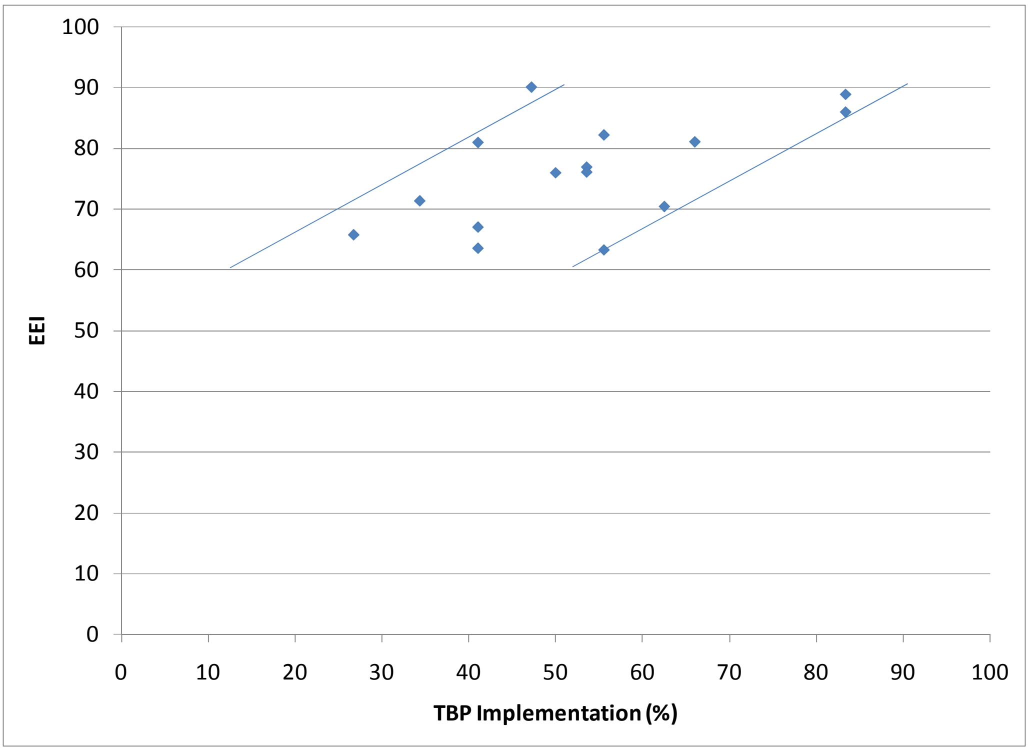
Figure 1 **Total facility MBP implementation versus TBP implementation**



The total facility TBP implementation scores are compared with the facilities' total EEI in Figure 2 as a scatter plot. The results show a trend where facilities that have implemented more TBPs tend to have a higher EEI and are more energy efficient.

The benchmarking results can be used to set a goal, or benchmark, for the Canadian cement industry. The EEI results show that more than 50 percent of the facilities have an EEI above 75, which is generally used as a benchmark for industry. Due to the high efficiency already attained by the cement industry the bar for the cement sector can be raised by selecting an EEI benchmark of, for example, 82. This is the EEI achieved by the top quartile. Implementing the opportunities highlighted by the MBP and TBP benchmarking results will assist individual facilities in achieving the industry EEI benchmark.

Figure 2 **Total facility TBP implementation versus EEI.**



Although the Canadian cement sector provides a limited sample of fifteen plants in one industrial sub sector, it clearly illustrates the importance of good energy management practices in managing costs and energy use. The results illustrate a relationship between the EEI and TBPs where facilities that have achieved an EEI of more than 85, have implemented at least 45 percent of the TBPs. Similarly the relationship between TBPs and MBPs indicates that facilities that have achieved a TBP score of at least 75 percent generally has to implement at least 60 percent of the MBPs. It is recommended that the application of the integrated approach in other industrial sectors be researched to further improve the understanding of the relationship between the three elements in industry.

4 Energy management systems – The value of information

Changing how energy is managed by implementing an organization-wide energy management program is one of the most successful and cost-effective ways to improve energy efficiency. A sound energy management program is required to create a foundation for change and to provide guidance for managing energy throughout an organization. Continuous improvements to energy efficiency therefore typically only occur when a strong organizational commitment exists. Energy management programs help to ensure that energy efficiency improvements do not just happen on a one-time basis, but rather are continuously identified and implemented in a process of continuous improvement.

In companies without a clear program in place, opportunities for improvement may be known, but may not be promoted or implemented because of organizational barriers, even when energy is a significant cost. These barriers may include a lack of communication among plants, a poor understanding of how to create support for an energy efficiency project, limited finances, poor accountability for measures, or organizational inertia to changes from the status quo.

A successful program in energy management begins with a strong organizational commitment to continuous improvement of energy efficiency. This involves assigning management duties, establishing an energy policy, and creating a cross-functional energy team. Steps and procedures are then put in place to assess performance through regular reviews of energy data, technical assessments, and benchmarking. Evaluating performance involves the regular review of both energy use data and the activities.

Companies around the world have implemented energy management systems to manage energy use data around the corporation. The leading example is probably the Kaizen system implemented by Toyota as part of the lean-production system TPS (Toyota Production System). However, other industries have also been successful in developing global systems. A successful example is the Cemex. Cemex, founded in 1906, is a global building materials company with operations in more than 50 countries, producing annually over 96 Million tonnes of cement. It operates 85 cement plants and hundreds of concrete and aggregate sites around the world. For a cement plant, energy costs typically constitute 30-40 percent of operation expenses, making energy cost an important cost factor (around US$ 250 million annually for Cemex). To manage energy, Cemex has established an energy management system, that includes all levels of the corporation, and that makes energy part of the culture of the company.

To manage and control energy use on a continuous basis, Cemex has developed a web-based information system that can be accessed throughout its operations around the world. It has different systems for fuel management, alternative fuels management, power management, as well as individual plant performance. This allows the plant operator as well as corporate staff to monitor energy use on a daily basis. It produces reports on a daily, weekly and monthly basis, including scorecards and management overview reports for the executive level of the company. At the site level, it is used as input for monthly energy team meetings at each plant to review past performance and develop and implement projects for improvement.

The scorecard provides an easy to review overview of the performance of a plant over time, against targets, as well as against other plants. This makes the scorecards an important tool in managing energy use.

Cemex is a leader in energy management, and has been able reduce energy intensity consistently with 1 percent/year. It is also looking for other ways to reduce energy costs by increasingly use alternative materials for cement production (to substitute energy intensive clinker) and increased use of alternative fuels. However, further potential for energy efficiency improvement remains.

5 The success of industrial CHP in The Netherlands

Combined heat and power (CHP), or cogeneration, has been used for over a century at industrial and municipal sites around the world. CHP is the sequential or simultaneous generation of multiple forms of useful energy (usually mechanical and thermal) in a single, integrated system. CHP is used by a number of industries that have high and relatively constant steam (and electric) demand. Compared to separate production of heat and power, CHP typically requires only ¾ the primary energy required by separate generation. This reduced fuel consumption leads to economic and environmental benefits of CHP, including reduced fuel use, reduced transmission losses and costs, as well as reduced CO_2 emissions.

The adoption of CHP by industry is typically limited by a handful of key factors. Barriers preventing greater use of CHP by industrial plants include:

- Power access regulations and utility practices (e.g. feed-in tariffs, exit fees, backup fees; interconnection standards and fees);
- The unique nature of CHP projects lead to perceived and actual delays and increased costs in air permitting, and have prevented CHP from receiving favourable treatment under greenhouse gas emissions trading schemes; and
- Project cost-effectiveness (relative fuel and electricity prices).

A number of countries have been successful in stimulating industrial CHP, such as Finland, India, and The Netherlands. In The Netherlands CHP generates about 30 percent of all power. Industrial CHP accounts for about 20 percent of total power generation. The high share of industry can be explained by the existence of a large chemical industry (about 25 percent of the total European chemical industry). This industry accounts for 70 percent of the total industrial CHP (excluding refineries). In Dutch CHP policy three periods can be distinguished:

- In the period 1982-1987:the Dutch government introduced regulation to set a realistic feed-in tariff for CHP, and introduced subsidies and other favourable financing mechanisms for CHP units. By 1990 around 10 TWh of power was generated by CHP, of which the vast majority in industrial CHP units.
- This was followed in the period 1989-2000 by a new electricity act that split utilities in generation and distribution companies, while allowing distribution companies to start joint-ventures with industrial companies to operate CHP units. Simultaneously the distribution utilities entered in a negotiated agreement with the government to reduce CO_2 emissions and improve energy efficiency. These two periods resulted in a large boost of CHP capacity in The Netherlands; not only in industry but also in horticulture and district heating. In 2000, CHP produced over 27 TWh of electricity, of which 20 TWh in industry and refineries (either industry owned or a joint venture), resulting in annual energy savings of 90 PJ.
- The initial success in expanding industrial CHP until the year 2000 has unfortunately been followed by a period that almost stopped new development of CHP due to further deregulation and abolishment of support mechanisms and regulated feed-in tariffs for CHP. From the peak in 2000-2001, actual industrial CHP production actually declined, as it was not always financially attractive to operate industrial CHP.

The case study demonstrates that public policy and design of a regulatory framework were essential in stimulating the development of CHP and realizing important energy savings.

However, it also demonstrates that policy (in this case power market deregulation) can also have unintended consequences and actually negating the earlier success. Hence, careful design of regulatory and market structures is essential to realize energy efficiency improvements.

6 Successful cogeneration policy in Mauritius

Today, nearly 40 percent of all power in Mauritius is generated in industrial cogeneration (combined heat and power, CHP). This constitutes more than a tripling since 1988, when the Government of Mauritius started to develop industrial cogeneration.

In the late 1980's Mauritius was faced with the challenge of meeting the expanding need for power due to economic development in the country. With the potential for hydropower exhausted, the government was looking for other power supply options. This was found in the sugar cane industry. At that time only three sugar mills produced power and exported this to the grid. The other mills used the bagasse (a by-product of cane sugar processing) inefficiently to produce heat and power for own consumption. The government undertook a number of policy initiatives to remove barriers that hampered the development of industrial power generation and export to the grid:

1988: The Sugar Industry Efficiency Act was introduced to improve the economic efficiency and viability of the sugar industry. A system was designed that linked the export duty rebate based improved sugar recovery, use of bagasse for power production, and the use of marginal lands.

1991: Bagasse Energy Development Programme was designed by the High Powered Committee on Bagasse Energy to optimize and expand bagasse power generation from 70 to 120 GWh, and investigate the potential to use other by-products for power generation. This was accompanied with investment subsidies (up to 50 percent). Furthermore, coordination was established between the different ministries, utility, and the Mauritius Sugar Authority. The committee determines the power purchasing power agreements, avoided cost of power generation, and recommended prices for power generated from bagasse and coal.

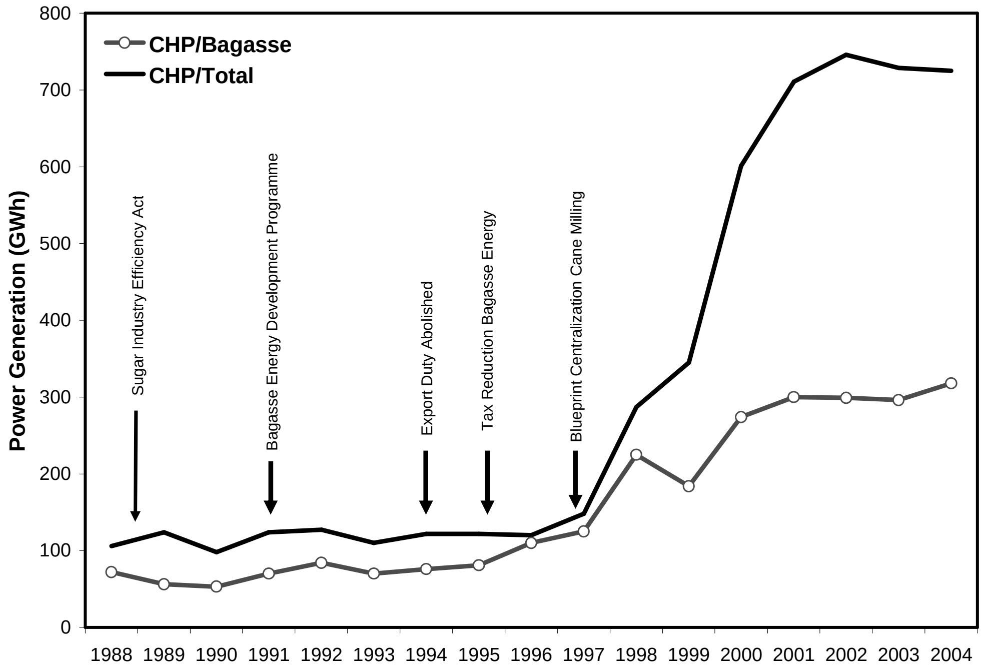
1994: Export duty was abolished, while cane growing and milling was separated.

1995: A new income tax act was introduced in the favour of bagasse energy generation, reducing the tax to 15 percent.

1997: The government introduced the Blueprint on Centralization of Cane Milling Activities to consolidate sugar mills, but also enhance the production of power generation in the sugar industry.

By 2004, 10 out of 13 sugar mills generated power from bagasse, while seven co-fire coal in the same installation outside the crop and harvesting season. Figure 3 depicts the development of power generation from bagasse and total (bagasse and coal). Most power stations were started up in the late 1990's, partially with support from international funding agencies. Further consolidation of the industry is taking place in response to WTO, and it is expected that any surviving mill will also generate power.

Figure 3 Power production from cogeneration in the sugar industry in Mauritius. Key policy developments are depicted.



Importantly, the focus on increased power generation from bagasse and the export of excess power has dramatically increased the energy efficiency of the sugar mills. The amount of exported power per ton of bagasse has steadily increased in the period, due to improved operations in milling, power generation, and steam use and distribution. The new situation provided an incentive to use a till then almost worthless by-product to produce a new product: power.

The case study demonstrates how the government has taken on the challenge to turnaround a previously inefficiently used domestic resource to a source of income (allowing for the survival of the sugar industry in a liberalized international trade regime) and power for the country. It has systematically addressed the key barriers for cogeneration (e.g. power purchase agreements, power pricing, financing, taxation) to allow for a rapid expansion of power generation. This has reduced the reliance on energy imports, while at the same time securing sustainable energy to allow the economy to grow. Energy efficiency improvement at the mills was incentivized to use bagasse more efficiently and increase income due to power exports to the grid. Today, Mauritius could be ranked among the top industrial cogenerators based on the share of total power generated by cogeneration installations.

7 China's Top-1000 Enterprises Program

Energy use in China has grown dramatically over the past decades, making China now the larges emitter of CO_2 emissions, and the second largest energy user in the world (after the USA). Industry consumes over 60 percent of all energy in China, making industry a top priority in China's energy efficiency policy. In 2005, the Chinese government announced an ambitious goal of reducing energy consumption per unit of GDP by 20 percent between 2005 and 2010. One of the key initiatives for realizing this goal is the Top-1000 Energy-Consuming Enterprises program. In April 2006, the Top-1000 program was launched by the Department of Resource Conservation and Environmental Protection of the National Development and Reform Commission (NDRC), the National Bureau of Statistics (NBS), the State-owned Assets Supervision and Administration Commission, the Office of National Energy Leading Group, and the General Administration of Quality Supervision, Inspection and Quarantine.

The industries included in the Top-1000 program are large-scale enterprises in nine major energy-consuming industries (iron and steel, petroleum and petrochemicals, chemicals, electric power generation, non-ferrous metals, coal mining, construction materials, textiles, and pulp and paper). The energy consumption of these 1000 enterprises accounted for 33 percent of national and 47 percent of industrial energy usage in 2004. China's Top-1000 program is modeled on experiences with international negotiated agreements. This policy was first piloted within the steel industry in Shandong (between 2000 and 2005) in a project initiated by the China Sustainable Energy Program with technical support of Lawrence Berkeley National Laboratory (USA) and the China Energy Conservation Association. Negotiated agreements focusing on industrial energy efficiency improvement have been implemented in industrialized countries since the 1990s. These agreements typically include a contract between the government and industry (associations, companies) with jointly negotiated targets and have a long-term outlook (e.g. 5-10 years). Industries participating in such an agreement can receive government support, such as facility audits, assessments, benchmarking, monitoring, information dissemination, and financial incentives.

The national government has established the guiding principles and goals of the program including selection of the Top-1000 enterprises. The overall program is aimed at achieving annual energy savings equivalent to about 3 EJ (Exajoule, 10^{18} J). The energy saving authorities of the local government (province, district, or city) are directed to lead and implement the Top-1000 program, including the tracking, supervision, and management of the energy-saving activities of the enterprises. Under the Top-1000 program, 2010 energy consumption targets were determined for each enterprise. Participating enterprises in the Top-1000 program can take advantage of a number of financial support programs to help implement energy efficiency projects.

By 2007, over 95 percent of the participating enterprises have established targets and 94 percent has submitted plans to attain the target. First statistical reports show that in 2006 companies achieved savings of 0.6 EJ and in 2007 around 1.1 EJ. If this performance is kept up, it is expected that the 2010 program’s goal will be achieved or exceeded.

The case study shows that a comprehensive effort by the government can enhance the rate of energy efficiency improvement. Especially when combined with a well established regulatory background, good monitoring and support mechanisms such a comprehensive can be successful However, how a negotiated agreement is a structured and the degree to which it will be a success is very dependent on the regulatory and cultural history in a specific country.

8 Trade in used industrial equipment

As plants close, equipment and even complete plants, are often relocated across the globe. Especially, developing countries are major importers of used or second-hand industrial equipment. There is no reliable data on the size of this market. Estimates for the global trade in used industrial equipment vary between US$ 80 and US$ 150 billion per year. The importance of this trade varies by industry with most trade taking place in the petroleum refining and chemical industries, followed by the steel and paper industries. This can exist of complete refineries, blast furnaces, coke plants to individual furnaces, boilers and motors. The plant is taken apart in the industrialized country, packaged and shipped to the new host country. There it is re-constructed and sometimes refurbished.

It is assumed that when a developing country in early stages of development lacks sufficient know-how and a supporting infrastructure to implement state-of-the-art equipment. As it develops, the importance of used equipment becomes smaller, and increasingly modern equipment will be applied. Yet, it seems that countries that also import state-of-the-art equipment are also large importers of used equipment. A detailed analysis by Utrecht University (The Netherlands) based on 130 plants found that in recent years, the largest recipient (by far) of used industrial equipment is China. The United States and Europe constitute the largest sources of used industrial equipment. There are a number of companies that operate in this market. Some companies are specialized traders in used equipment, while others are technology suppliers or refurbishers that also trade in used equipment.

The major advantage of purchasing used equipment is the relatively low capital cost. While older equipment needs more manpower to maintain and operate, this is not an issue in developing countries. However, this older used equipment will have a higher energy intensity then state-of-the-art equipment, and hence result I increased energy costs. Over the (remaining) lifetime of the equipment, this may result in increased costs for the developing country’s industry.

For example, for a typical motor system 95 percent of the costs over the total life-cycle are energy costs, while capital costs represent less than 5 percent of the total cost of ownership. Hence, for a motor system, using second-hand equipment will usually result in increased costs for the new owner over purchasing a new high-efficiency motor, leading ultimately to a higher economic and environmental cost for the developing country. The same principal may apply to complete plants. Depending on a number of factors, the purchase of used equipment may make sense or not. For energy costs the study by Utrecht University found that the key factors are:

- Age of the equipment
- The remaining (technical) lifetime of the equipment
- The rate of energy efficiency improvement of the particular technology
- Costs of purchasing, and relocating the equipment (generally estimated at 45-60 percent of a new plant).

The study found that in some cases, the re-location of the used plant will likely result in increased costs of ownership and increased energy use, while for a few cases the relocation actually resulted in cost savings for the host country. In the former cases, the lack of capital has resulted in sub-optimal economics. The purchase of a state-of-the-art plant would have resulted in improved overall economics as well as reduced energy consumption.

References

Anderson, S.T. and Newell, R.G. 2002. *Information Programs for Technology Adoption: The Case Study of Energy Efficiency Audits* Washington DC, Resources for the Future.

Gruber, E and Brand, M. 1991. "Promoting energy conservation in small and medium-sized companies" *Energy Policy, April 1991*

Hansen, K. and Lund, H.T. 2002. "*Employee involvement and energy management*" AKF Forlaget, Copenhagen, Denmark.

International Energy Agency (IEA). 2007. *Mind the Gap*. IEA/OECD, Paris, France.

International Panel on Climate Change (IPCC). 2001. *Climate Change 2001: Mitigation. A Report of Working Group III of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK.

Marbek Resource Consultants, Ecofys, and Cement Etc. 2008. *Canadian Cement Industry Benchmarking*. Project report issued to Cement Association of Canada.

Price, Lynn, Xuejun Wang, Jiang Yun. 2009. *China's Top-1000 Energy-Consuming Enterprises Program: Reducing Energy Consumption of the 1000 Largest Industrial Enterprises in China.* Lawrence Berkeley National Laboratory, Berkeley, California, USA.

Rensburg, Henri van, Ernst Worrell, and John Cuddihy. 2009. "Integrated Benchmarking Moves from Uncertainty to Solutions." *Proceedings 2009 ACEEE Summer Study on Energy Efficiency in Industry*, Niagara Falls, NY, July 28-31, 2009.

Sæle, H et al (2005) "What prevents organizations from implementing energy saving measures? Case studies of Norwegian public and commercial companies" *Proc. 2005 Summer Study European Council for an Energy Efficient Economy,* ECEEE, France.

Sorrell, S. et al. 2005. *Reducing Barriers To Energy Efficiency In Public And Private Organisations.* SPRU—Science and Technology Policy Research, University of Sussex.

Printed in Austria
V.11-87165—December 2011—300

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Telephone: (+43-1) 26026-0, Fax: (+43-1) 26926-69
E-mail: unido@unido.org, Internet: www.unido.org