Evaluating GHG Emission Reductions in Energy Efficiency Projects

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The findings, interpretations and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the view of the World Bank, its Executive Directors, or the countries they represent.

This document is dedicated to the memory of Ian Lewis

Ian was passionate about his commitment to clean energy. His colleagues knew him for his unbounded enthusiasm and his limitless drive to do things right. In his quest for developing an international business in emission trading he frequently travelled uncharted territories. His thirst for knowledge was contagious to those who worked with him and tireless to those who attempted to keep up with him. Ian's considerable contribution to this project was much appreciated by his colleagues at Cumming Cockburn Limited and the other members of the project team.

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PCF*plus*

PCF*plus* is a research, training, and outreach program designed to complement the Prototype Carbon Fund (PCF). While an important goal of the PCF is to disseminate its experience, PCF objectives and resources restrict its research and outreach activities to those directly associated with project implementation. PCF*plus* is intended to assist PCF stakeholders (staff, participants and host countries), and the international community at large in understanding the complex issues related to the implementation of markets for project-based greenhouse gas emission reductions under the Clean Development Mechanism (CDM) and Joint Implementation (JI), with a view to reducing transaction costs and risks of doing business in the emerging GHG market.

The research component of PCF*plus* brings a unique set of strengths to the climate change research arena. Most importantly, it will be able to draw on and elucidate the lessons of PCF's pioneering activities. Its location in the World Bank enables it also to link with a wide range of climate-related programs, including the National Strategy Studies on JI/CDM, Bank-administered GEF projects in the climate area, and the broad range of Bank projects and studies involving energy and land use. PCF*plus* Research is administered by the Bank's Research Group, providing extensive in-house expertise in environmental economics, public finance, and development economics, and ensuring analytical rigor.

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6 – Regulatory Drivers of the Carbon Market – Market Intelligence Issue #2
7 – Joint Implementation in the context of EU accession – the case of the Czech Republic
8 – Regulatory Drivers of the Carbon Market – Market Intelligence Issue #3
9 – Regulatory Drivers of the Carbon Market – Global Executive Summary
10 – Applying sustainable development criteria to CDM projects: PCF experience

Executive Summary

The trading mechanisms introduced by the Kyoto Protocol provide an additional incentive to achieve energy savings by rewarding greenhouse gas Emission Reductions (ERs), but to be eligible, Energy Efficiency projects (EE projects) must pass the "environmental additionality" test. That is, they must demonstrate that emissions would be lower than otherwise (the "baseline" emission scenario). To target the abatement potential of small to medium size EE projects, it is necessary both to devise efficient ways to assess a great number of project opportunities and to develop standard procedures to determine the baseline. These streamlined procedures must be inexpensive and easy-to-use, while producing credible reductions.

Relying on EE intermediaries, like Energy Service Companies (ESCOs) or similar private and public entities, is a potentially attractive way to limit transaction costs. ESCOs "manage" large portfolios of energy efficiency projects, including financial and technical assessments of potential measures and financing, implementation and monitoring of cost-effective measures. Additional carbon funding might therefore make additional energy efficiency measures cost effective and so enable ESCOs to go beyond their business-as-usual practices. Targeting the ESCO rather than EE projects, requires an understanding of the business-as-usual behavior of ESCO clients (types of EE technology, their emission baselines, etc.). The business-as-usual baseline an ESCO sets for its clients is the baseline from which the emission reductions are measured.

The objectives of this study were to assess business-as-usual ESCO or ESCO-like intermediary activities; and to elaborate standard procedures for baseline determination for small to medium, demand-side EE projects in the sectors where ESCO or ESCO-like intermediaries are likely to invest with additional carbon funding. The study focused on economies in transition (EIT), particularly the Czech Republic, thus assuming that the EE projects will be carried out under Article 6 of the Kyoto Protocol (Joint Implementation, JI).

Energy projects in Central and Eastern Europe (CEE) over the past decade, driven by economics and the need to improve air quality, have reduced CO_2 emissions per capita by 24%, thereby matching current average values for EU countries. Much of this comes from fuel conversion away from relatively dirty coal. ESCO activity in the region remains low, due to lack of management knowledge and commitment, limited experience with energy performance contracts (EPC), and lack of suitable financing. The skills of existing ESCOs in the Czech Republic were deemed adequate, if not exceptional, although this may not be the case throughout the entire CEE.

The mechanisms introduced by the Kyoto Protocol (Trading, Joint Implementation, Clean Development Mechanism) have been established in the USA for more than a decade, and have the demonstrated capability to reduce the cost of lowering emissions. COP-7 in November 2001 agreed on the rules for the Kyoto mechanisms in sufficient detail to allow ratification of the Protocol to proceed.

The emissions limitation commitments and trading mechanisms established by the Kyoto Protocol give emission reductions an economic value. Recent projections of the international permit price in 2010, assuming the United States does not ratify, average approximately US\$2.60/tCO_2e (2001 dollars) with a range from \$0 to \$13.90/tCO_2e. The Prototype Carbon Fund pays approximately \$3.00/tCO_2e. For prices in this range the additional revenue generated by the sale of emission reduction credits is likely to be small; less than 5%.

The quantity of credits generated by an energy efficiency project is small relative to the quantities typically transacted, so projects will need to be aggregated or bundled to reduce the transaction costs. Typical transactions have a total value of $25,000 to $50,000 representing 10,000 to 25,000/tCO_2e. Depending upon the fossil-fuels displaced, it might take electricity savings of 10 to 100 GWh to generate emission reductions of this magnitude. Individual energy efficiency projects usually generate energy savings of the order of 10s to 100s of MWh per year over a 5 to 10 year life. Clearly, numerous projects will need to be aggregated to produce a transactable quantity of emission reductions. ESCOs can aggregate credits generated by projects they implement, although they have as yet no experience in doing this.

Energy efficiency projects need an emission baseline from which to calculate the emission reduction achieved. The emission baseline should reflect the emissions that would have occurred in the absence of the project - the energy efficiency measures the ESCO would implement ignoring the value of emission reduction credits.

Defining the emission baseline in practice is difficult. It can be defined using a behavioural model of energy efficiency investment decisions, control groups held to represent typical behaviour towards similar projects, and various kinds of benchmarks derived from sectoral data.

Most energy efficiency projects will be smaller than the maximum energy saving for small-scale energy efficiency projects under the CDM; 15 GWh per year. The simplified procedures being developed for small-scale CDM projects may include simplified baseline methodologies that could be used for non-CDM projects as well.

Where a project-specific emission baseline is appropriate for an energy efficiency project, the energy baseline can be adapted to fill much of this need. An energy baseline calculated assuming no value for emission reduction credits is used as the reference or baseline project. This approach requires a hurdle rate for the internal rate of return (IRR) to determine which measures would be implemented. Hurdle rates vary across facility owners, ESCOs and other intermediaries and depend, in part, upon the perceived barriers that need to be overcome to implement the measures.

One objective of this project was to develop a model of ESCO and client behaviour that could be used to define the measures that would be implemented assuming no value for emission reduction credits – the emission baseline. This was to be done through analysis of energy efficiency projects implemented in the Czech Republic and other CEE countries. Internal rates of return would be related to the barriers faced by the project, ESCO and client characteristics, and other factors.

Unfortunately, the data were inadequate to fully realize this objective. The project IRRs for 15 projects in the Czech Republic for which reasonably complete data were available ranged from 1% to 250% with a median value of 43%. The values for most of the projects were between 30% and 60%, which is similar to North American results for ESCO projects. The corresponding payback periods ranged from 0.4 to over 18 years, although most values were between 2 and 3.5 years.

Once the energy efficiency measures corresponding to the emission baseline are identified, the on-site emission reductions associated with those measures project are calculated using emission coefficients for different energy forms. To complete the emission baseline for this reference project, baselines for off-site emissions changes – those at electricity generating stations, district heating plants and other locations – need to be added.

The most complex issue in preparing the emission baseline is likely to be calculation of emission reductions due to avoided electricity generation. Various methods are available, but the methods that can be applied in a particular situation depend upon the data available. Electricity efficiency measures typically account for a significant share of the total savings of energy efficiency projects, thus the treatment of the emission reductions associated with those measures has a substantial impact on the credits generated. Participation of the electricity generator in the project will help resolve the eligibility and ownership of credits due to avoided electricity generation.

The methodology for calculating the emission baseline should be transparent and replicable so that adjustments for assumed values, such as hours of operation, output levels, and weather conditions, etc., can be incorporated as appropriate over the life of the project.

A model has been developed that assesses and accommodates energy investment behaviour for three cases: business as usual, client, and third party, where third parties may be ESCO-like intermediaries. The basic approach is to develop a relatively simple spreadsheet model that combines a cash flow model with a normative decision model. As a further enhancement, there is also requirement to examine and assess the barriers that may exist for any given project. The model was calibrated and tested with a number of specific projects undertaken in the Czech Republic.

The model is a user-friendly tool that will allow examination of potential energy efficiency projects from two perspectives – the Client's and the ESCO's. The model provides standard information regarding discounted cash flow, but also allows for enhanced scenario analysis related to sensitivity to the nature of financing, interest rates and the value of emissions. The last parameter is particularly interesting as it gives the user a perspective on what the value of emission reductions may need to be to justify projects which are not cost effective.

The Report concludes with a discussion of specific applications and their relevance for future assessments. It includes a discussion of potential improvements to the modelling framework and a discussion of further data development and collection. It is important to note that much of the modelling and calibration effort was research oriented – that is, the outcome and relevance was not established a priori. Rather, the model framework and calibration factors were a result of information collected as part of the study. The current modelling framework is sufficient to assess the economics of third party energy efficiency investments. Further enhancements to the framework would require more research into the existence of specific barriers to energy efficiency in the marketplace and their importance to third party investors.

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1. Climate Change and the Kyoto Mechanisms

1.1 Introduction

In 1995 the Intergovernmental Panel on Climate Change (IPCC) concluded that "the balance of evidence suggests that there is a discernible human influence on global climate."[1]. Concern for the possible consequences of global climate change induced by human activities led to the United Nations Framework Convention on Climate Change in 1992 and negotiation of the Kyoto Protocol in 1997. The latter agreement, once it enters into force, would legally bind industrialized nations that are parties to the Protocol to limit their national greenhouse gas emissions to specified targets during the 2008 to 2012 commitment period.

The Kyoto Protocol incorporates mechanisms that enable industrialized countries to meet their emissions limitation commitments, in part, through reduction of greenhouse gas emissions in other countries. Energy efficiency improvements often reduce greenhouse gas emissions associated with combustion of fossil fuels and can generate emission reductions that qualify for the Kyoto mechanisms. To qualify for the Kyoto mechanisms energy efficiency projects must demonstrate that they reduce emissions below what they would otherwise have been (the “baseline” emission scenario) and meet a variety of other requirements.

This project addresses the development of robust standard methodologies to determine emission baselines for energy efficiency projects, especially those undertaken by Energy Service Companies (ESCO), utility Demand-Side Management (DSM) programs, and other energy efficiency intermediaries. The methodology will be used in conjunction with measurements and engineering analyses to quantify the emission reductions achieved, particularly to meet the requirements of the Kyoto mechanisms of Joint Implementation (JI) and Clean Development Mechanism (CDM).

1.2 Role of Energy Efficiency in Climate Change Mitigation

Energy efficiency is a low cost way to significantly reduce CO_2 emissions in the near-term.[2] Many studies of the potential for energy efficiency find that energy use can be reduced by 15-20% or more with simple paybacks of less than two years. These reductions are cost-effective on the basis of energy savings alone: the attendant reductions in CO_2 and other emissions are an added benefit. For this reason, energy efficiency is often referred to as a 'no regrets' option for climate change mitigation.

Energy efficiency is the provision of the same level of energy services with less energy input. As the bulk of world energy (about 75%) is produced from fossil fuels, this has an immediate and direct impact on greenhouse gas emissions. On average, a 1 GJ reduction in energy demand results in a 58 kg reduction in CO_{2E} emissions, as well as a 0.033 kg reduction in NO_X and a 0.11 kg reduction in SO_2. Depending on the fuel affected, reductions can range up 92 kg $CO_{2E,}$ 0.14 kg NO_X and 0.47 kg SO_2.

The 'efficiency-gap' between the cost-effective and actually realized energy efficiency potential is commonly attributed to 'barriers'. These are various types of perceived risks and information asymmetries that cause investors to demand far higher performance from energy efficiency investments than they would from other investments. Barriers are discussed extensively in Chapter 5.

1 IPCC, 1996, p. 5.
2 CO2 emissions due to fossil fuel combustion are estimated to be the largest contributor to human-induced climate change.

1.3 The Kyoto Mechanisms

The United Nations Framework Convention on Climate Change (UNFCCC), which came into force in 1994, has as its objective stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. As a first step to meeting this objective industrialized countries undertook to try to return their greenhouse gas emissions to 1990 levels by 2000.

Based on scientific information from the IPCC, the parties to the UNFCCC concluded in 1995 that larger emission reductions were needed to stabilize atmospheric concentrations of greenhouse gases. The process of negotiating further emission reductions resulted in the Kyoto Protocol. The Kyoto Protocol proposes a national emissions limitation commitment for 2008-2012 for 38 industrialized countries listed in its Annex B. The Protocol will come into force once it has been ratified by 55 countries accounting for at least 55% of the 1990 CO_2 emissions by industrialized countries, which is expected to occur late in 2002.

The Kyoto Protocol established three 'mechanisms' that industrialized countries can use to help attain their emission limitation commitments:

- *Article 6 - Joint Implementation (JI)*. An Annex B country can help finance an emission reduction project in another Annex B country. Credits equal to part or all of the emission reduction can be transferred by deducting it from the host country's allowed emissions and adding it to those of the investor country.

- *Article 12 - Clean Development Mechanism (CDM)*. An Annex B country can undertake an emission reduction project in a non-Annex B (developing) country. Once the resulting emission reduction has been 'certified' by the CDM Executive Board, credits equal to the reduction can be transferred to the investor country.

- *Article 17 - Emissions Trading*. Annex B countries are free to sell portions of their allowed emissions, surplus to their own needs, to other Annex B countries.

These three mechanisms are forms of emissions trading. Emission trading is described in Chapter 3.

1.4 Emissions Trading and Energy Efficiency Investment

Negotiation of the rules for the Kyoto mechanisms was completed in November 2001. CDM projects can begin to generate credits immediately, while JI projects cannot begin to generate credits until 2008.

The CDM Executive Board was given a mandate to develop simplified modalities and procedures for the following small-scale CDM project activities:

- Renewable energy project activities with a maximum output capacity of 15 megawatts (or an appropriate equivalent);

- Energy efficiency improvement project activities which reduce energy consumption, on the supply and/or demand side, by up to the equivalent of 15 gigawatt/hours per year;

- Other project activities that both reduce anthropogenic emissions by sources and directly emit less than 15 kilotonnes of carbon dioxide equivalent (CO_{2E}) annually.

This mandate reflects the international interest in stimulating investment in energy efficiency projects to reduce greenhouse gas emissions. The simplified modalities and procedures will make is easier and less costly to earn tradable credits for emission reductions generated by energy efficiency projects, many of which are relatively small.

Annex B countries that meet specified conditions will have considerable freedom to determine how credits for emission reductions can be earned for JI projects, including energy efficiency projects, they host. The quantity of credits issued for a JI project in an Annex B country that does not meet the specified conditions will need to be approved by an international process similar to that for CDM projects.

Despite the potential differences due to the project size, the Kyoto mechanism, and the host country, energy efficiency projects will be able to generate tradable credits for the greenhouse gas emissions reduced.

1.5 Energy Efficiency Opportunities in Transition Economies

When examining energy efficiency opportunities, it is important to consider the specifics of the energy efficient applications, the nature of the equipment being replaced and the behavioural aspects associated with the existing equipment. Generally, energy using equipment in the EITs is older and less efficient than equipment in Western Europe or North America. Despite this, energy intensity (as measured in GJ/person or GJ/building) is often much lower in the EITs than in North America. This is due to the use patterns. For a variety of reasons, individuals and corporations in the EITs are more attentive to ensuring energy use is kept to a minimum. In the Czech Republic, for instance, it is common practice to rely heavily on natural lighting and ventilation. Air conditioning is rarely found, lights are used only when absolutely necessary, and space heating requirements are low because of lower thermostat settings. As a result, energy use by these end uses is lower than what would be expected based on the vintage of equipment. This conservation ethic affects the cost effectiveness of proposed energy efficiency initiatives.

Initial expectations by the Project Team regarding retrofit potential and cost effectiveness needed to be revised to accommodate these use patterns. For example, commercial chiller and lighting projects that have been so widely implemented by ESCOs in North America have very limited application in the EITs considered as part of this project. (In any event, as in all ESCO type efforts, successful projects need to start with a proper energy audit of the facility). Cost effective projects are more likely to come from sectors/applications where there is both antiquated equipment and high intensity of use. Building types with extended operating hours such as hospitals, industrial plants or transportation terminals, or end uses such as, street-lighting, transit lighting, steam boilers and district heating, are notable examples that were identified by the Project Team through surveys of various stakeholders.

In the case of boilers and district energy, much of the activity to date has focused on replacing older coal based boilers with new natural gas boilers. The new systems have the combined advantaged of higher efficiency and reduced maintenance, however much of the impetus for these projects comes from their reduced air pollutantemissions rather than energy efficiency. Energy efficiency is a by-product of the retrofit. This is an important consideration for many EITs. The intrinsic value of implementing non-coal solutions is significant because of the very real concerns about air pollution. This value is generally not captured in a typical discounted cash flow model and represents an important consideration in model calibration.

1.6 Purpose of this Work

This project develops a framework for the evaluation of energy efficiency projects undertaken for climate change mitigation and subsequent emission reduction trades under the Kyoto Protocol. The specific needs were for the development of an easy-to-use modelling framework that assessed energy efficiency investments from a variety of perspectives. A standardized discounted cash flow model was developed to examine investments for base case, client and third party cases. The model was enhanced through the inclusion of a qualitative component which addresses specific barriers to energy efficiency investments in the marketplace. As a further requirement, the project required a detailed examination of ESCO behaviour in the Czech Republic and the testing/calibration of the model using Czech specific data. All major ESCOs were interviewed as part of the development of a specification of the marketplace. This proved to be particularly enlightening and helped to guide the specification of the model.

1.7 Report Outline

Chapter 1, *Climate Change and the Kyoto Mechanisms*, introduces the study by reviewing the climate change issue, the role of fossil energy in climate change, and the opportunity to mitigate climate change impacts through energy efficiency measures. It also reviews the history of the Kyoto Protocol and the potential role of emissions trading in helping Annex B countries meet their commitments under the Protocol.

Background on *Energy Efficiency Investment in Central and Eastern Europe* is provided in Chapter 2. Distinctions between the energy intensity of economies, technical efficiency and economic efficiency are clarified. The potential of energy efficiency and the limited progress to date are discussed and the notion of 'barriers' is introduced to account for this 'efficiency gap'.

Chapter 3 turns to *Flexibility Mechanisms and Energy Efficiency Investment*. It describes a variety of policy measures and business approaches that have been employed to reduce barriers and encourage energy-efficiency investment. The techniques and the barriers they address are described, and quantitative studies of their effectiveness are summarized. Based on these results, the potential of the incentive provided by emissions trading to stimulate energy efficiency investments is assessed.

Chapter 4 examines the issues surrounding *Baseline Setting for Energy Efficiency Projects*. The baseline is the energy consumption that would have occurred if the energy efficiency measures had not been implemented. The energy baseline is important for contracts where the costs of the measures implemented are recovered from the resulting savings. The methods used to identify energy efficiency measures and establish the energy baseline are described.

Chapter 5, *The Analysis of Barriers to Energy Efficiency Investments* considers the effects of purported barriers first within the neo-classical economic context of rational, utility-maximizing behaviour. Then competing social and psychological perspectives are considered. This chapter provides the theoretical underpinnings for the investment models developed in Chapter 7.

Chapter 6, *Modelling Energy Efficiency Investment Behaviour,* develops an investment model for energy efficiency projects. This chapter is concerned with financial additionality. Besides its use in evaluating the financial additionality of projects, the model can be used to estimate business-as-usual energy efficiency investment behaviour and the incremental cost of emission reductions. The model developed is calibrated and tested with data from more than 50 real projects in Eastern Europe.

Chapter 7, *Model Application to the Czech Republic,*starts with a general discussion of energy efficiency projects undertaken in the Czech Republic and the nature of the audit and evaluation data collected for these projects. An application of the model using actual data reported for a specific project is presented and discussed showing the various input and output parameters, including their significance for future assessments.

Conclusions from the project are summarized in Chapter 8.

References

1. Anderson, D., "Energy-Efficiency and the Economics of Pollution Abatement" in *Annual Review of Energy and the Environment* 18:291, 1993.

2. Bertram, G. "Tradeable Emission Permits and the Control of Greenhouse Gases", in *Journal of Development Studies* 28(3):423, 1992.

3. Cline, W., *The Economics of Global Warming*, Washington, DC: Institute for International Economics, 1992.

4. Goldemberg, J. (ed.), *Issues and Options: The Clean Development Mechanism*. New York, US: United Nations Development Program, 1998.

5. Grubb, M., et al., *The Kyoto Protocol: A Guide and Assessment*. London, UK: Earthscan Publications, 1999.

6. IEA, *Energy Efficiency and the Environment*. Paris, FR: International Energy Agency, 1991. http://www.ieagreen.org.uk/

7. IPCC, *Climate Change 1995: The Science of Climate Change*. Cambridge, UK: Cambridge University Press, 1996.

8. ---- ibid., *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change*. Cambridge, UK: Cambridge University Press, 1996.

9. ---- ibid., *Climate Change 1995: Economic and Social Dimensions of Climate Change*. Cambridge, UK: Cambridge University Press, 1996.

10. Lovins, A. and L. Lovins, "Least-cost Climatic Stabilization" in *Annual Review of Energy and Environment* 16:433, 1991.

11. Schipper, L. and S. Meyers, *Energy Efficiency and Human Activity: Past Trends, Future Prospects*. Cambridge, UK: Cambridge University Press, 1992.

12. Skea, J. and S. Sorrell (eds.), *Pollution for Sale: Emissions Trading and Joint Implementation*. Aldershot, UK: Edward Elgar, 1999.

13. UNFCCC, *Kyoto Protocol to the United Nations Framework Convention on Climate Change*. New York, US: United Nations, Document FCCC/CP/L7/Add.1, 1997 at http://www.unfccc.int/resource/docs/convkp/kpeng.pdf

2. Energy Efficiency in Eastern and Central Europe

2.1 Introduction

Central and Eastern Europe (CEE) is defined as the contiguous region extending from the Baltic to the Black Sea, comprising – from north to south - Poland, the Czech and Slovak Republics, Hungary, Romania and Bulgaria. CEE is the most seriously polluted region in Europe, and is also an important source of pollution for surrounding countries as far away as Scandinavia.

Before the political changes in 1989, the CEE countries were authoritarian regimes with centrally planned economies. Absolute priority was given to production targets, with no account taken of ecological impacts. Economic development was highly focused on the expansion of heavily polluting industries, i.e. heavy industry and the energy and raw material economy, with serious consequences on the environment [10].

2.2 Energy and Environment in Central and Eastern Europe

The character of the centrally planned economies in the CEE countries, with no private ownership and no markets, did not create economic incentives for efficient use of natural resources, including energy. While political representatives publicly advocated energy conservation and efficiency from the mid-1970s onwards, no funds were provided for energy efficiency investments. The technologies used were obsolete, and pollution abatement measures were hardly undertaken at all.

The adverse environmental effects on the region were compounded by the consumption of very low quality, domestic coal, due to the lack of oil and gas resources in the region. The main energy source, lignite, has the lowest carbon content of all coals. The emissions produced by plants using lignite - SO_2, NO_X, particulates and other air pollutants – affected not only CEE countries, but other European states as well. Contamination of the air and acidification of the soil and water by SO_2 and NO_X have damaged the ecological balance, and caused many serious human health problems, including respiratory diseases, cancer, cardiovascular problems, and disorders of the nervous and immune systems.

However, since the early 1990’s negative environmental impacts from the energy sector have gradually been reduced, for the following reasons:

- new environmental laws with emission limit values have been implemented
- large investments have been made in environmental protection
- the process of crowding out domestic lignite use by gaseous and liquid fuels has significantly lowered specific emissions per unit of energy consumption
- the energy intensity and absolute consumption of primary energy sources have dropped

Between 1990 and 1998 per capita emissions of CO_2 declined by 24%, of SO_2 by 35%, and of NO_X by 20% in the region, although not uniformly across all countries in the region. Although SO_2 emissions per capita were still 3.6 times higher than in the EU, the values of the other emissions reached the average values for the European Union. The fall in CO_2 emissions was mainly due to the switch to cleaner fuels, especially natural gas, which is reflected in a reduction of the carbon intensity of the primary energy supply by 10%. This value was still one third above the EU average in 1996 (Figures 2-1 through 2-4).

Figure 2-1:
SO_2 Emissions per Capita in Central and Eastern Europe (1990-1998) [15,16,43,44,45,46,47,48]

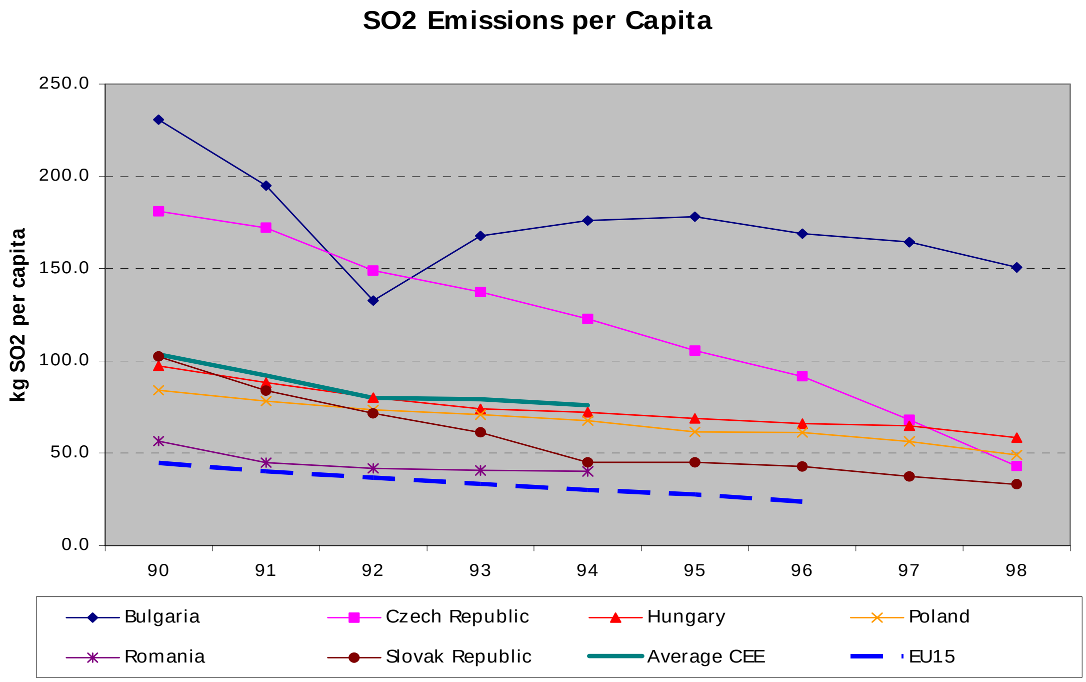


Figure 2-2:
NO_X Emissions per Capita in Central and Eastern Europe (1990-1998) [15,16,43,44,45,46,47,48]

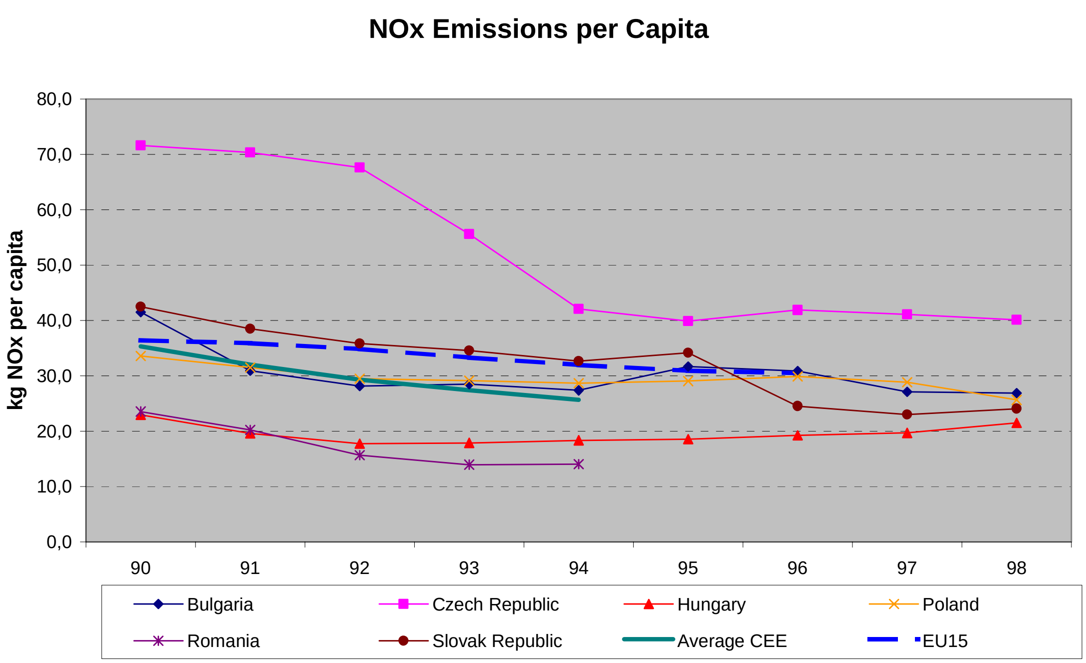


Figure 2-3:
CO_2 Emissions per Capita in Central and Eastern Europe (1990-1998) [15,16,43,44,45,46,47,48]

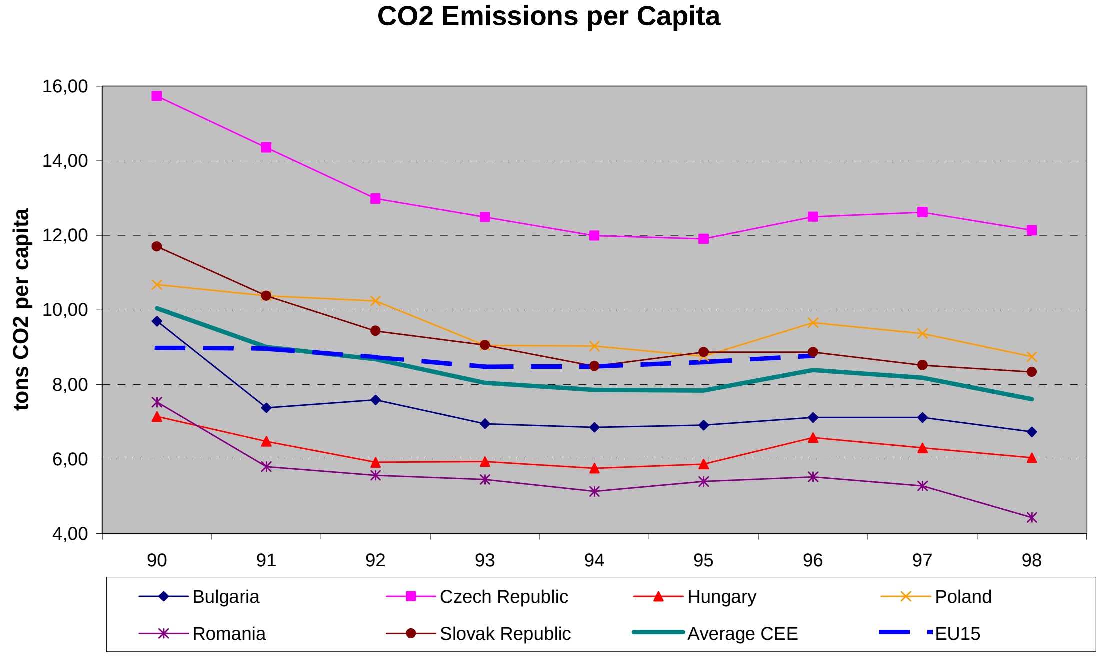
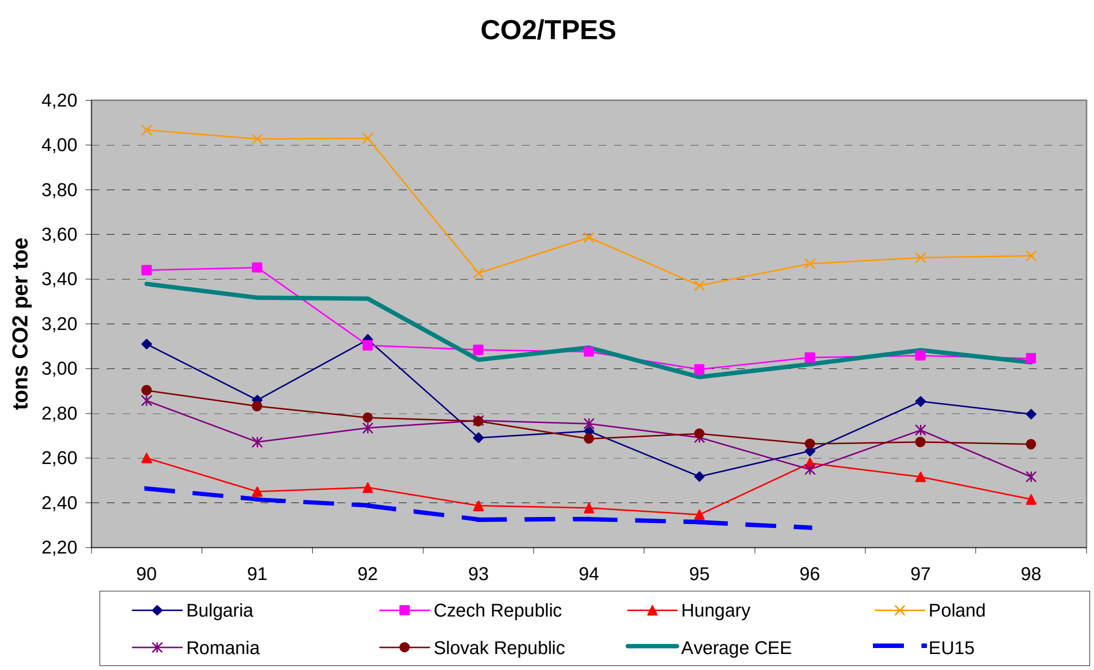


Figure 2-4:
CO_2 Emissions per Total Primary Energy Supply in Central and Eastern Europe (1990-1998) [15,16,43,44,45,46,47,48]



A good example of the improvements made is the case of the 'Black Triangle' lying between the cities of Krakow in Poland to the north, Dresden in the former East Germany and Prague in the Czech Republic to the south. This area is home to Europe's largest basin of lignite coal. In 1991, the ministers of environment of the three countries, together with a representative of the European Union, initiated the "Black Triangle Regional Program" to bring plants into compliance with European standards, focusing on SO_2 in particular. Significant progress has already been made using circulating fluidized-bed boilers, flue gas limestone washing, high-efficiency electrostatic precipitators, coal cleaning technology, denitrification equipment, low-NO_2 emission burners, exhaust gas recirculation equipment, improved control systems, and in-plant and regional monitoring systems [29]. This has resulted in a radical drop in emissions in the Czech Republic and Poland.

Further progress is expected as harmonization with EU environmental law continues (since all countries in the region as defined are involved in the EU accession process). Moreover, the countries are obliged to fulfil the commitments of ratified international protocols, such as the protocols to the Convention on Long-range Trans-boundary Air Pollution and the Kyoto Protocol if it comes into force. A further, very important factor is the process of energy market liberalization discussed below.

Energy Efficiency in the CEE Region

Before 1989, priority in Central and Eastern Europe was given to the development of energy intensive industries with energy prices set centrally well below real costs. Under the previous regimes, energy allocations were often set by the amount used in the previous year, so there was an incentive to consume. Since the changes in 1989, the CEE countries have been struggling in the area of energy efficiency with such issues as outdated technologies, poor energy management, heavily subsidized industries and heavily subsidized energy use.

Between 1990 and 1998, the overall use of primary energy fell by 16% in the CEE region, while overall GDP rose by 3%. This decline in consumption is equivalent to a fall in overall energy intensity (TPES/GDP) of 19% (Figure 2-5).

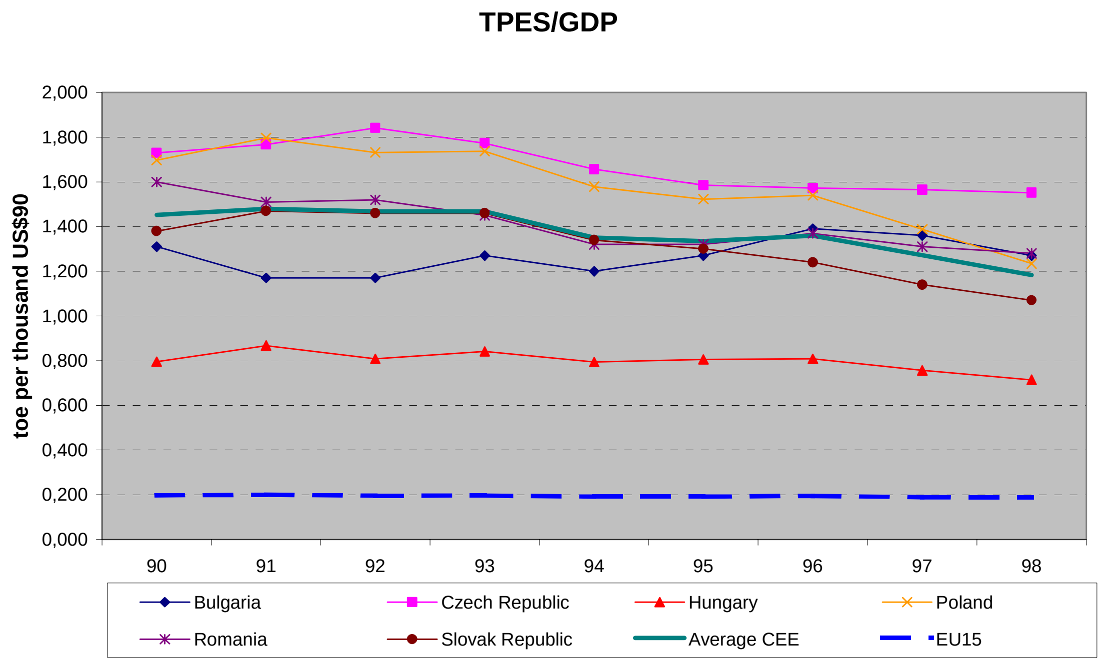
The energy efficacy of the economy has improved mainly on account of:

- changes in the economic structure towards the patterns of modern economies, with a decline in the proportion of heavy industries and a rise on that of services,

- introduction and implementation of new, more efficient technologies, techniques and equipment on both the supply and demand sides.

The energy intensity (TPES/GDP in toe/USD) of the region is still six times higher than in the European Union, although in reality, this disproportion is largely due to the relatively lower prices of goods in the CEE region, and thus the lower value of the GDP in foreign currency. Removal of this distortion by converting the region's GDP on the basis of purchasing power parity yields the more favorable ratio of a two times higher intensity (TPES/GDP in toe/USD PPP) than that in the EU (Figure 2-6). Nevertheless, given lower economic development, the Central and Eastern European countries consume only 65% of the primary energy per capita of the European Union [16,17] (Figures 2-7 & 2-8).

Figure 2-5:
Total Primary Energy Supply per GDP in Central and Eastern Europe (1990-1998)



[15,16]

Figure 2-6:
Total Primary Energy Supply per GDP Converted by Purchasing Power Parities in Central and Eastern Europe (1990-1998) [15,16]

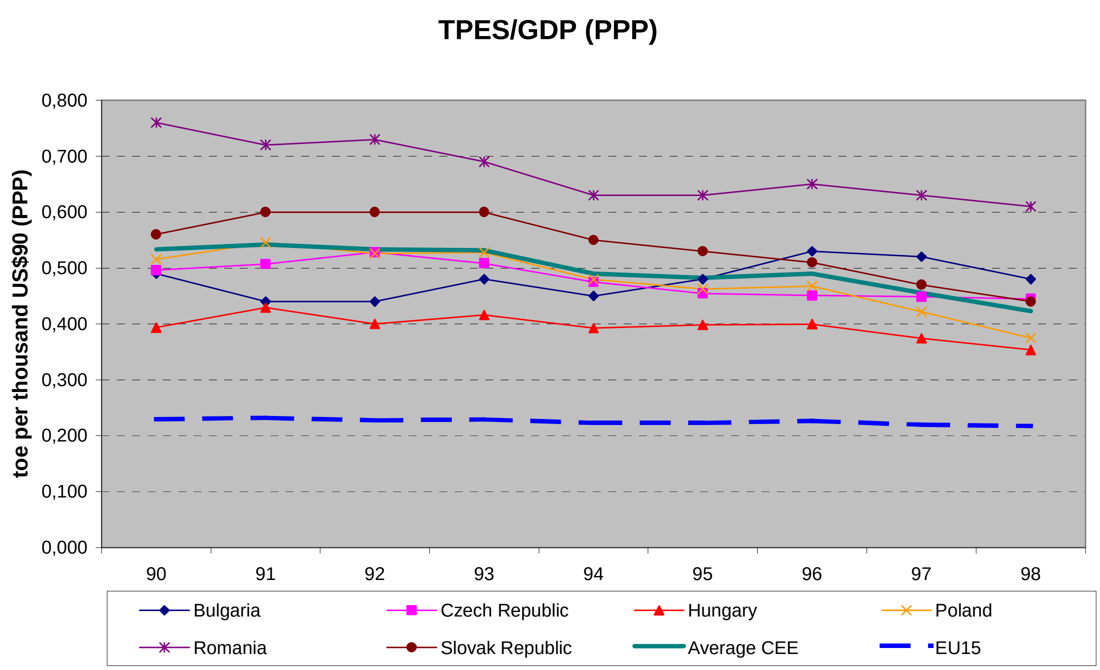


Figure 2-7:
GDP per Capita Converted by Purchasing Power Parities in Central and Eastern Europe (1990-1998) [15,16]

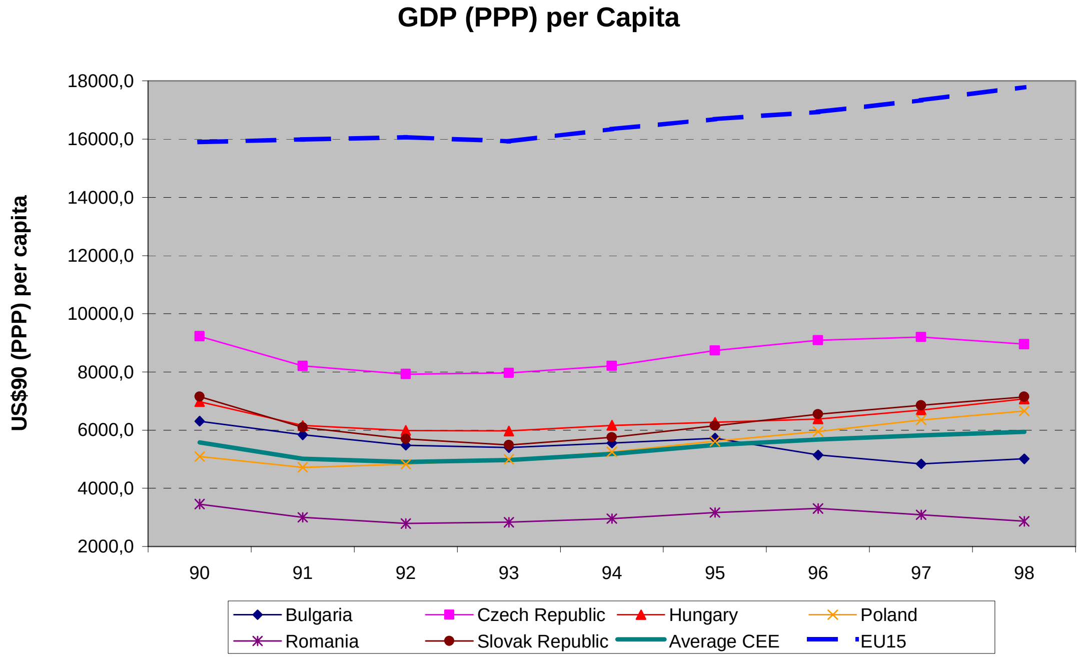
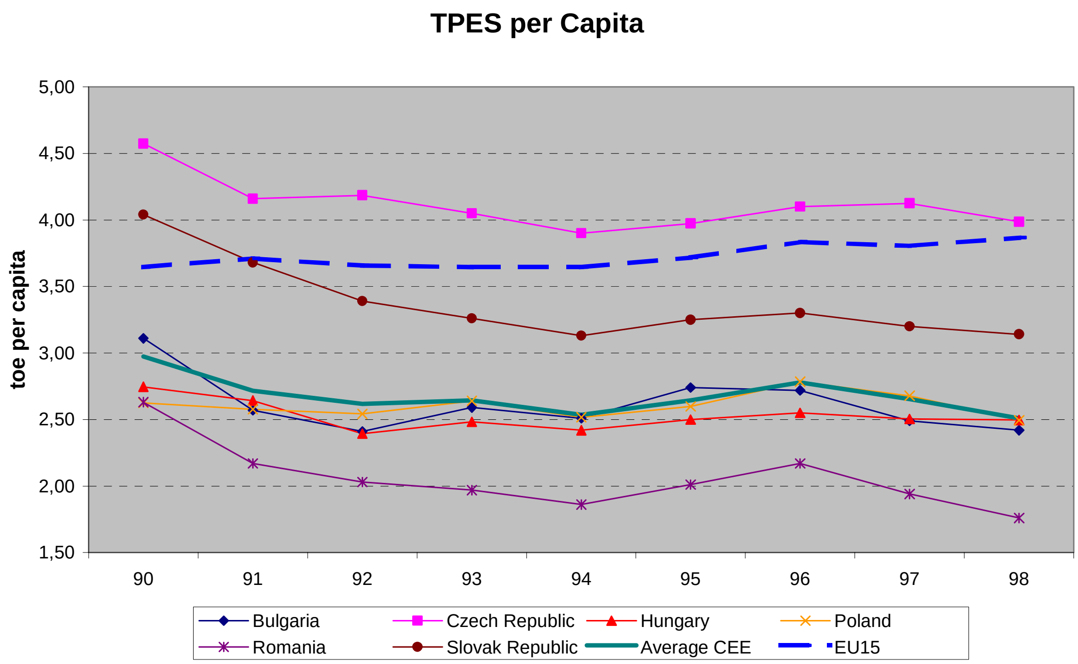


Figure 2-8:
Total Primary Energy Supply per Capita in Central and Eastern Europe (1990-1998) [15,16]



There has been a strong need to improve energy efficiency in the CEE region, for the following reasons:

- to be competitive on the EU and world markets
- to improve the foreign trade balance by lowering the high imports of energy
- to comply with the requirements for entry into the European Union
- to fulfil international commitments such as the Protocol to the Energy Charter on Energy Conservation, and other international protocols, mostly concerned with air pollution control
- to reduce the adverse environmental effects of the energy use [1]

Energy price reforms have been unevenly implemented in CEE countries. In many, there is complete deregulation of the prices of gasoline and other oil products but, by and large, prices for certain consumers, primarily households, are still kept below world prices or cost of production [15]. However, as all of the countries claim to be following the process of energy market liberalization, the full deregulation of energy prices is expected. The large subsidies for energy use were substantially lowered in the 1990's, but some still remain. Harmonization with EU law, which restricts opportunities for subsidizing industry, is another of the driving forces in eliminating the remaining state financial support.

Most of the CEE countries have detailed energy efficiency strategies or action plans. However, there are cases where the energy efficiency strategy has been defined, but the action plan has not been comprehensively implemented. Only a few countries appear to have programs that are truly independent of international support, which is available mostly from the EU – this shows that energy efficiency has not become a priority in the nations across the region [17].

The spectrum of policies and measures supportive of energy efficiency introduced or planned by CEE countries include economic instruments, regulations, information, education and public awareness campaigns, and is described in more detail below [37].

Cross-sectoral measures:

- *Energy and fuel prices and taxes*: removal of energy price distortions, differentiated tax for different fuels

- *Education, public awareness campaigns*

- *International co-operation*

Energy transformation

- *Air pollution regulations* with the primary objective of local air quality improvement are highlighted by several countries as a tool affecting the amount and share of fossil fuel consumption; fuel switching (especially from coal and heavy oil to gas) and increases in efficiency are the main instruments. Allocation of revenues from pollution charges to the environmental fund is reported by several countries.

- *Promotion of renewable energy sources and technologies*: Tax allowances and direct subsidies are among the most frequent instruments.

- *Energy efficiency improvements in production, transmission and distribution*: low efficiency in production - mainly due to obsolete equipment, esp. old district heating boilers - and great losses during distribution due to the poor state of networks can be found in some parts of the region. The most common rectification measures are the construction or reconstruction of power plants with the use of energy efficient technologies, support of CHP and the reconstruction of distribution networks. The instruments include direct subsidies (including co-financing, soft loans) and technical assistance. The minimum energy efficiency standards in power production and distribution are legally binding.

Efficient use of energy in industrial, residential, commercial and institutional sectors:

- *Economic instruments*: tax incentives or subsidies for efficient equipment.
- *Economic and technical consultancy*
- *Reduction of energy consumption in buildings* (improvement of thermal insulation in buildings, installation of heat meters, efficient lighting, etc.): regulations and standards for new construction, demonstration projects, investment subsidies, energy audits
- *Reduction of energy consumption in industry*: pilot projects including energy audits, direct subsidies
- *Standards and labels for energy products* [32]

With respect to private investment in energy efficiency, there have been attempts to start energy performance contracting (EPC) in all of the countries. Most energy service company (ESCO) activity has been in the Central European Countries though the number of firms is very small.

2.3 CEE Country Review

Since the economies, energy sources, energy efficiency barriers, and rates of progress vary considerable by country, the following sections review each country independently.

2.3.1 Bulgaria

Bulgaria's historical emphasis on heavy industry has caused substantial damage to its environment. The structure of primary energy consumption has changed little in the last decade, and in 1998 the proportion of coal was 36 percent, oil and nuclear energy each slightly above 20 percent and natural gas about 15 percent. Thermal plants run largely on domestically produced coal, but a high proportion of this capacity is approaching, or has already passed, the normal age of obsolescence. Most coal-fired plants are environmentally unsatisfactory [21, 22]. Bowing to EU pressure and offers of financial assistance, Bulgaria has agreed to an early closure of its two oldest nuclear reactors, and to the modernization of the two remaining reactors at Kozloduy [16].

National GHG emissions in 1997 stood at 62% of the Kyoto Protocol base year level (1988), so the emissions are well below its Kyoto Protocol target of 92% of base year emissions for the period 2008 - 2012 [2]. The predicted emissions of GHG in 2010 range from 84-102% of the base year emissions. The energy industry is the biggest source of SO_2 (83%), NO_X (30%) and particulate (41%) emissions at the national level [34]. In the last decade, Bulgaria has experienced a significant decrease in air pollution, mostly as a result of a slow economy with reduced production - between 1990 and 1998, both SO_2 and NO_X emissions fell by more than 35 percent [43].

Specific priority environmental problems include water, air and soil pollution, nuclear waste from mines and power plants, and solid waste management. Certain mining areas have higher levels of radioactivity than some nuclear plants. The energy sector and the mining industry generate significant waste quantities as a result of the raw materials or technologies used, which makes their future operation problematic given present economic conditions.

In 1992, an Environmental Protection Act was passed which established a National Environmental Fund and a Municipal Environmental Protection Fund. Recent plant closures have helped alleviate many emissions, but have reduced the flow of funds for environmental efforts resulting from pollution fines. Environmental policy includes such measures as tax relief for companies who use environmentally sound technologies. Efforts to bring Bulgaria's environmental assessments into harmony with European Community standards are promising. As part of Bulgaria's energy strategy, flue gas desulfurization is to be installed on existing power plants.

Energy Policies
In the early 1990's, the Bulgarian economy, plagued by triple-digit inflation, contracted by a third. However, it has been recovering from economic recession since 1998, although GDP growth was again slightly negative in 1999, partly due to the war in Kosovo. Between 1990 and 1998, primary energy consumption fell by 26%, which was mostly due to a 24% decline in GDP, as energy intensity dropped by 3% in the same period [16,17].

The fixed prices of heat supplied to households and subsidized entities are well below operating costs, while gas and electricity tariffs for households are lower than for industry. All energy prices were scheduled to be liberalized by the end of 2001, with faster growth in household prices anticipated. Some improvements are also still required in gas and electricity market deregulation, and in reducing state intervention in the coal sector. No clear timetable has yet been set for the unbundling and privatization of the power monopoly NEK [14]. After the recent drastic increases in energy and fuel prices, the attitude in this respect has abruptly changed; however, there is still no purpose-oriented activity to encourage energy conservation on the basis of either incentives or penalties [8].

Bulgarian energy strategy has clearly identified energy efficiency as a key element, with one of the priorities being to introduce EU-compatible standards relating to industry consumption, combustion processes, household appliances, heating and insulation norms, efficiency norms for motor vehicles, etc.

The new National Action Plan for Energy Saving in Bulgaria (2001) comprises programs oriented towards different economic sectors, in housing construction, centralized district heating, industry, households and communal services, transport and agriculture. Quantitative targets have been laid down and defined for some of the sectors.

According to the Energy Strategy, energy efficiency measures such as improved energy planning and management and technological innovation could lead to around a 17% reduction in energy intensity in 2005. This includes the effects of structural changes in the economy, which account for about half of this improvement [14].

In certain sectors and manufacturing areas, energy intensity reaches 6-7 times the level of the European average. Currently a process of change of ownership is underway in industry, and the restructuring of a number of sectors is forthcoming. Energy efficiency improvements in industrial plants usually requires substantial amounts of funding, and are often conducive to staff cuts [8].

The building sector accounts for one third of the total energy consumption in Bulgaria. This proportion is approximately equal to the values in developed countries, and in the near future its weight is expected to remain constant or increase. Buildings in Bulgaria have well defined owners, and offer substantial technical opportunities for energy conservation; moreover, the measures required to realize these energy savings are easy to implement, accessible, and relatively cheap [8].

The promotion of energy performance contracting is very important, as it is difficult for potential EPC customers to obtain commercial loans to implement energy efficiency projects because of problems in the banking sector and the insolvency of the relevant firms, however and EPC industry is not sustainable without the support of the local commercial banking system. The Bulgarian State Energy Efficiency Agency has begun a new project to implement energy saving performance contracting in Bulgaria. The final result will be the implementation of some pilot projects in the building sector, which will mean the first application of energy saving performance contracting in this country, although some elements of this approach have already been used (e.g. in the Gabrovo Hospital). The process encompasses the elaboration of a list of buildings with a determination of their energy saving potential, a call for tender with the nomination of an appropriate ESCO, and a plan to enter into energy performance contracts [41].

2.3.2 Czech Republic

The energy sector of the Czech Republic relies heavily on domestic coal and lignite, with the adverse environmental consequences described above. Solid fuels account for around half of all primary energy sources. Gas and oil are imported, and account for 39 percent of primary energy consumption. About 20% of electricity is produced by one nuclear generating station, and a second nuclear power plant is in the process of being commissioned into service. This will raise the total electricity supplied by nuclear plants to almost 40%.

During the 1990's large investments were made in the reduction of pollution resulting from the energy industry. The national monopoly power utility (CEZ) alone invested about 40 billion CZK (ca 1.4 billion USD) between 1992 and 1998 to reduce emissions of air pollution and to meet the requirements of the Clean Air Act and emission limit values. The largest environmental investments went into the "Black Triangle" area described above. Most energy plants, including power plants, industrial and municipal heat and power and district heating plants were upgraded to meet emission limit values by the end of 1998. The environmental upgrade typically included switching to higher quality fuel, or even a major investment in the energy plant itself to increase overall efficiency, including for example the upgrading of district heating networks and exchange stations [38].

At the present time, the compulsory emission limit values for existing sources are comparable to, or are only slightly less strict than, the limit values set in EU legislation. However, new, much-stricter emission limit values for NO_X and SO_2 are being proposed to comply with commitments under the ACETO Protocol to the Convention on Long-range Trans-boundary Air Pollution, and the EU Proposal for a Directive on emissions from large combustion plants [3].

Energy Policies

Between 1990 and 1998, national emissions levels decreased dramatically: national GHG emissions in 1998 were 77% of the Kyoto Protocol base year level (1990), so the emissions are well below the target of 92% base year emissions for the period 2008 - 2012. The predicted emissions in 2010 range between 79 - 99% of the base year emissions.

SO_2 emissions have decreased to about a quarter of their 1990 level, and NO_X emissions to half of their original level. However, total nitrogen oxide emissions have remained almost constant over the last four years as a result of transport emissions – mobile sources accounted for 60% of NO_X emissions in 1999. Emissions of heavy metals and volatile organic compounds have fallen by about 40% since 1990. In the same period, annual emissions of persistent organic compounds have fallen by 13-41%. Despite these positive trends, emissions of sulfur and nitrogen oxides per capita remain above the EU average by 20% and 37% respectively [5]. Attention needs now to be focused more on the environmental improvement of transport, as this is constantly growing and is becoming one of the most problematic sources of emissions of certain pollutants such as NO_X, while also being responsible for the exceeding of ambient standards in areas with heavy traffic.

Before 1989, the central planning system in Czechoslovakia led to widespread inefficiency in energy use. Since then, consumption of primary energy sources and the intensity of energy use have exhibited favorable trends. Between 1990 and 1999, the consumption of primary energy in what is now the Czech Republic fell by 10%, while energy intensity decreased at an average annual rate of 2.4% per year. Energy intensity decreased in the residential/commercial sector and in industry, in contrast to the transport sector where it increased [20]. In the last decade, the share of solid fuels in final demand has constantly declined, from 39% in 1991 to 19% in 1999 [11].

Despite these trends, the Czech Republic's energy intensity (TPES/GDP) in 1999, converted on the basis of purchasing power parity, was still about 2.3 times the corresponding figure for IEA Europe. The main reasons for this are:

- the much lower level of GDP,
- the structure of primary energy sources, with a higher reliance on solid fuels,
- the historical structure of industrial production, where the proportion of energy-intensive production processes remains high (metallurgy, production of building materials, etc.)
- lower building and appliances standards
- lack of energy saving incentives with a history of low energy prices, which in comparison to EU countries still remain much lower in the household sector [20].

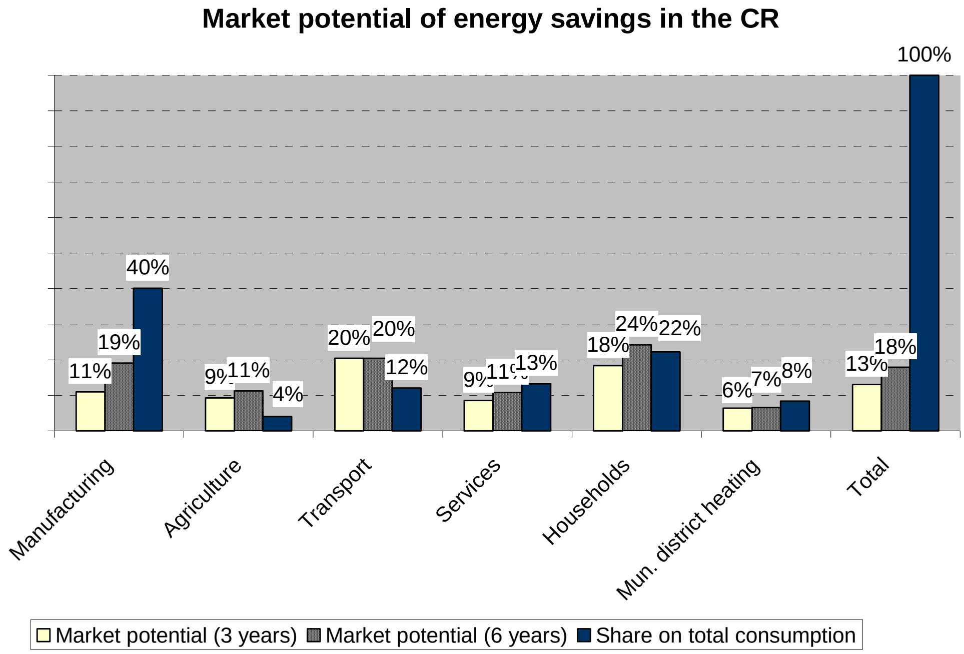
The country is now facing the challenge of designing and implementing a comprehensive energy efficiency policy for every end-use energy sector. The energy efficiency potential of the Czech Republic is quite large: in 1999, the National Energy Efficiency Study [33] estimated the market potential of energy savings at 13% and 18% with an amortization period of up to 3 and 6 years respectively (Figure 2.9). The largest absolute market potential can be found in manufacturing industry (4% and 8%); however, these estimates considered solely the economic characteristics of potential projects, with no account taken of market barriers, so the realization of the whole potential cannot be expected on a market basis alone.

Consistent with its policy of supporting energy efficiency in the Czech Republic, the main governmental activities are:

- energy policy and environmental policy documents which officially highlight the importance of energy efficiency
- financial programs of the Czech Energy Agency and the State Environmental Fund, providing financial support for energy efficiency projects and renewable energy projects

The National Energy Policy approved by the government in January 2000 gives targets in the area of energy management. The long-term targets of the energy policy include a gradual reduction of energy use to match the level of advanced industrial countries. The government intends to give priority to the realistic and economic utilization of the best technologies available, to energy savings and to a strict compliance with environmental legislation.

Figure 2-9:
Market potential of the energy savings in the Czech Republic with the payback period up to 3 and 6 years [33]



Direct subsidies for energy prices from the state budget have been eliminated, although some indirect subsidies, especially for mine closures (about 100mil.USD in 2001) still remain. The electricity and gas prices for households are cross-subsidized, as they are lower than the prices for small companies in contrast to the liberalized markets in the EU. According to the National Energy Policy all energy prices should be liberalized by the end of 2002.

The *State Program to Support Energy Savings and the Use of Renewable Sources of Energy* is authorized and the budget renewed annually by the Ministry of Industry and Trade and executed by the *Czech Energy Agency*. It financially supports energy saving measures in the spheres of the production, distribution and consumption of energy, the wider use of renewable and secondary sources of energy, and the development of co-generation production of heat and power (CHP), counsulting, the implementation of new low energy consuming technologies, education, public education and promotions leading to the more economic use of energy [20].

The Ministry of Environment provides financial resources, through the mediation of the State Fund for the Environment, mostly for the utilization of renewable and secondary sources, but also for energy efficiency measures aiming to reduce emissions and pollutants, for the conversion of fossil fuels, the mitigation of greenhouse gases etc.

The new Energy Management Act implemented in 2001 is contributing to the efficient use of energy, although some of the provisions included employ a centralist and directive approach. One of the most controversial provisions is the obligation of house owners, under threat of sanctions, not to exceed the determined maximum value of heat consumption. Another unusual measure concerns the requirement for minimum energy efficiency standards to be met by power producers and distributors. The Act is a framework law, and the measures are specified in detail in subsequent regulations. The Act institutes the following main duties:

- the government is required to approve a four-year National Program for Economical Energy Management and the Use of Renewable and Secondary Energy Resources which *inter alia*, deals with the various types of subsidies from the State budget for relevant programs.

- the drawing up of territorial energy plans at the level of the newly established administrative regions;

- the establishment of compulsory minimum energy efficiency standards in power production and distribution, and in the construction and operation of buildings;

- the obligation to equip certain energy appliances with energy labels; and

- compulsory energy auditing in cases where consumption exceeds the set limit for heat and electricity producers, and when applying for a state subsidy.

In the Czech Republic energy performance contracting has been in place since 1992; this approach has, however, developed slowly. A number of ESCOs firms have emerged on the market, many of them officially claiming EPC to be their sphere of interest. Nevertheless, only a few companies have implemented their own projects and have the EPC method as their main activity. Other companies, for various reasons, are still striving to implement their first projects [39].

2.3.3 Hungary

Hungary is relatively poorly endowed in terms of natural resources, and has to import just over 50% of its energy needs. Coal was the most important source of energy, but oil and natural gas replaced it as the primary source of energy by the end of the 1970's. Oil and gas deposits are small, and Hungary has therefore traditionally relied on imports of energy from the former Soviet Union. Nuclear power supplies more than 50% of total domestic electricity production. A number of fossil fuel power plants and local gas distribution companies have been privatized since 1995 [7].

Hungary's greenhouse gas emissions are quite high in proportion to the country's population or gross domestic product. The largest proportion of CO_2 emissions is generated by fuel combustion; in the period 1985 – 1987, this stood at about 80Mt/year, but this had dropped to 68 Mt by 1990. The share of the residential sector reaches almost 25% of total CO_2 emissions [12]. Hungary is now committed to reduce its CO_2 emissions by 6% during 2008-2012, relative to 1985-87 levels. Levels of SO_2 emissions fell by 41% between 1998 and 1999, while NO_X emissions fell by 9% in the same period.

Energy Policies

Between 1990 and 1998 primary energy consumption fell by 11%, which was mostly due to a drop in energy intensity of 10%, as GDP declined by only by 1% in the same period [16].

The official Energy Policy Concept was approved in 1993. It established the National Energy Savings and Energy Efficiency Improvement Program, adopted in 1995. The Energy Saving Action Plan focuses on the penetration of renewables, energy efficiency improvement, efficiency labelling, and education, information, and encouraging technological innovation. In 2000 the Energy Efficiency, Environment and Energy Information Agency was founded, with the aim of promoting energy efficiency activities and operating the energy statistics system [30].

Information and advisory services at the customer service offices of electricity and gas suppliers are now of higher quality than in previous years. A governmental resolution issued in 1999 regulates the development of the institutional framework for energy conservation activities. As per the resolution, a new organization is being established for intensifying co-ordination between domestic and international resources hitherto utilized separately, and for ensuring their efficient use [30].

Realization of investments improving energy conservation among consumers is not easy, due to a lack of available resources. Generally, investment financing may take place in the framework of preferential credits. The preferential credit lines originate in variously organized funds, and are disbursed by certain commercial banks, chosen by tender.

Several financing schemes promoting energy efficiency measures operate in Hungary, including:

- *The German Coal Aid Revolving Fund,* which has the objective of replacing traditional energy sources with renewables and introducing energy saving businesses.
- *The PHARE revolving fund,* which is a soft-loan credit facility established to support energy efficiency investments by small to medium enterprises (SMEs) from both the public and private sectors.
- *Preferential Interest Borrowing Facilities,* which are a financial means offered to housing collectives for energy efficiency investments in apartments,
- *The Energy Saving Credit Program* which is an energy efficiency investment aimed at the modernization of energy use in municipally owned institutions.
- *SCORE*, which is a Dutch/Hungarian program aimed at helping the improvement of energy efficiency in Hungary by the establishment of institutions and the support of demonstration type projects, and
- *Activities Implemented Jointly*, which is an agreement between the governments of Hungary and the Netherlands to jointly realize a series of AIJ projects and promote AIJ as a feasible concept.

As clients often cannot afford to install energy-saving equipment, ESCOS invest in the equipment and services necessary to generate savings and are repaid from those savings through contractual arrangements known as energy performance contracts. The typical problems of energy performance contracting in Hungary are related in particular to the legal harmonization of the ESCO leasing scheme, the harmonization of municipal, bank and ESCO interests, and the harmonization of debt amortization and service charges. An example is the project by Pest County that included the modernization of the heating of eight municipal buildings under an ESCO leasing contract with annual energy consumption decreasing by 50%. This project was implemented by Raiffeisen Unicbank, which offers direct and ESCO leasing schemes for energy-efficient equipment on commercial terms [18].

2.3.4 Poland

The most notable features of Poland's energy sector are its heavy dependence on coal, which accounts for 90% of the country's primary energy production, and the depth of power sector restructuring both to date and planned for the future. The increasing availability of natural gas is also significant from the point of view of energy efficiency [6]. While coal still feeds around 80% of national power production, the industry is now in decline and the country is increasingly dependent on imports of other fuels. Restructuring is politically sensitive and has been slow to take off [22].

Poland's main energy-related environmental problems are:

- air pollution from burning coal, which accounts for almost 90% of SO_2 emissions, 79% of NO_X emissions, and over 98% of particulate emissions

- water pollution related to coal mine dumping of saline water into rivers, and to refinery effluents of insufficiently treated water, and

- solid waste from coal mines and power plants.

Since 1990, flue gas desulfurization and low-NOx technology have been introduced, and as the share of lower sulfur coal has increased, the environmental performance of many power plants has improved considerably. New emissions standards for existing plants that came into effect in 1998 are in line with EU standards. Under these standards, all new coal and lignite plants require flue gas desulfurization, low-NOx burners and improved fly ash particulate removal [46].

Mainly due to improvements in energy efficiency, the emissions intensity of the Gross Domestic Product (GDP) was substantially reduced between 1988 and 1999 – by 61.3% for SO_2, by 45.5% for NO_X, by 78.1% for particulates, and by 39.6% for CO_2. National GHG emissions in 1997 were at 74% of the Kyoto Protocol base year level (1988), so the emissions are well below the 2008-2012 target of 94% of base year emissions. Emissions in 2010 are predicted to fall between 67-81% of the base year emissions.

Energy Policies

Poland's transition from a centrally planned economy, which commenced in 1988, was among the most rapid of all the countries in the region. While GDP grew by 22% between 1988 and 1999, primary energy consumption decreased by 30%, which caused a reduction in energy intensity of 35% [16].

The most significant piece of energy-related legislation is the 1997 Energy Act, which, although primarily concerned with supply-side issues, contains a number of articles relevant to energy efficiency. Article 45 explicitly creates the framework for DSM activities, by stating that energy tariffs "… may include costs of co-financing by energy enterprises of projects and services the purpose of which is to reduce energy and fuel consumption by customers…" The Energy Act also provides the basis for the energy efficiency labelling of equipment in compliance with EU Directives.

A thermo-modernization program has been introduced in Poland to protect households against the worst impacts of deregulating heat prices. State funds such as the Liquidation of Technical Failures have been made available to provide financial support to owners of housing who wish to improve the thermal properties of their dwellings. Other programs have provided credit to owners of local heating networks of up to 6 MW wishing to modernize their systems.

The National Fund for Environmental Protection is made up of fines and fees paid by firms exceeding various pollution emission limit values. It offers grants and soft loans for environmental investments, including energy efficiency.

The ECOFund was created by converting 10% of Poland's debt, and is designed to fund projects with positive international environmental impacts. Certain energy efficiency projects are eligible for support, with grants of up to 30% of the investment cost available.

The "National Program for the Reduction of Sulfur Dioxide Emissions" will have an impact on the economics of investments in energy efficiency, particularly where retrofitting of coal-fired plant with pollution abatement equipment proves prohibitively expensive [6].

In the old commercial banks an effective debt-restructuring scheme has been introduced; bank regulation has also been tightened and is now generally regarded as among the region's best. Although still often accused of an unwillingness to take on private-sector projects, in their defence the banks cite a lack of suitable proposals or a lack of profitability and accounting transparency on the part of the projects' proponents [22]. Apart from commercial loans, a few ESCO companies have financed several energy efficiency projects in Poland.

2.3.5 Romania

Romania has its own natural gas and oil reserves, for which reason these fuels account for a higher proportion of primary energy consumption (38% and 29% respectively) in comparison to other CEE countries, while the share of coal is relatively lower (18% in 1998).

With its past focus on heavy industry, industrial pollution is one of the greatest threats to Romania's environment, although - mainly due to a fall in industrial output - emissions of SO_2 declined by 30%, and NO_X and CO_2 by 40% between 1990 and 1998. National GHG emissions in 1994 were at 60% of the Kyoto Protocol base year level (1988), so the reduction in emissions was well below the target of 92% of base year emissions. Since then, CO_2 emissions have fallen even further, to 52% of the base year emissions.

In 1995, as one of the last countries in the region to update its environmental legislation, Romania passed the Law on Environmental Protection, which has paved the way for the introduction of additional legislation addressing particular environmental issues. It has also introduced the Environmental Fund, which uses pollution fees to finance environmental protection.

Economic difficulties have, however, prevented Romania from aggressively tackling its environmental problems. Frequent strikes by coal miners and other industrial workers have contributed to political instability, which hinders the Government's ability to implement reforms. Environmental fees and government expenditure are not sufficient to cover the costs of all the environmental protection programs needed. International institutions and non-governmental organizations provide some much-needed funding [47].

Energy Policies

Between 1990 and 1998, primary energy consumption fell by 35%, which was partly due to a drop in GDP of 19%, and partly to an energy intensity decline of 20% over the same period [15]. In the period 1997 to 1999, the economy was characterized by falling GDP with high inflation, which ranged between 35% and 150% yearly.

The modernization of the energy sector has been constrained by the preservation of state monopolies, continued subsidies to domestic consumers and a failure to restructure the coal, electricity and gas industries, which suffer from major overstaffing. The government is implementing proposals to restructure the energy sector, introduce competition, eliminate subsidies and attract foreign investment, but progress has been slow and is proving to be costly. The main issues in the energy sector are:

- the low efficiency of energy use due to old and inefficient technologies and the dilapidated state of assets, compounded by poor operations and maintenance;
- the successive vertical integration of enterprises, an absence of a competitive environment, and inadequate regulatory systems;
- a lack of economic criteria in planning and investment selection;

- over-employment and operational inefficiencies;
- the weak financial position of sector entities and the accumulation of inter-enterprise arrears [47].

Policies and programs specifically aimed at promoting energy efficiency in Romania are relatively limited:

- The 1998 Energy Law, which lays down the principles for energy sector restructuring and privatization, contains some elements placing a responsibility on utility companies to promote energy efficiency.
- A pilot project will be undertaken in a number of different industrial sub-sectors, and the results disseminated to other SMEs.
- Relevant documents on labelling and minimum energy efficiency standards have been adopted.
- Power sector modernizations have been supported from a fund created through a levy on electricity and heat sales [26,16].

Beside direct investments, the following public controlled sources are funding energy efficiency projects:

- The greater part of the Special Fund for the Energy Sector is used for modernization and to increase the efficiency of production sector projects; part could also be used for financing energy efficiency project implementation, both in the industrial sector and the municipalities.
- The R&D Fund is not only for R&D projects, but also for feasibility studies and small pilot projects. Examples are projects such as “Opportunity for implementing in Romania Long Term Agreements between government and industry in order to reduce specific energy consumption”, or the “National program for implementing Energy Efficiency Protocol of Energy Charter“ being performed in 1999.
- International assistance programs in the field of energy efficiency have granted funds for studies, training and consultancy as well as for the implementation of identified measures throughout these projects. (PHARE, SYNERGY, THERMIE, USAID, JICA etc.)

However, the funds provided from the state budget are rather limited, and it is also difficult to obtain commercial financing for energy efficiency projects in Romania. Moreover, the financial system is characterized by major weaknesses, including a lack of transparency, political pressures on banks, high levels of bad loans and a lack of liquidity, centralization, and a low proportion of foreign banks [25]. However, incipient activities such as ESCO type companies were developed by SMEs, such as ENERGY SERV, Eco-Erg, ICEMENERG, CONSENERG, CONSPROIECT, and ARCON Synergy among others.

2.3.6 Slovak Republic

The Slovak Republic is one of those countries with few domestic primary energy resources and therefore imports some 89% of its primary energy mostly from the Russian Federation. Its energy industry has been oriented towards the high usage of brown coal and natural gas, while by contrast the proportion of oil is smaller in comparison to the western countries. The share of coal decreased by 5% between the years 1990 and 1996, and today it represents around 29% of primary energy resources. Oil represents 18% of primary energy, with a relatively stable share that is nevertheless significantly lower than the West European average of 42%. Natural gas represents 32% of primary energy with the European average being some 20%.

Industry constitutes a 42% share of total energy consumption, the domestic sector 25% and services 17%. The share of industry is decreasing, while the shares of the domestic sector, services and transport are growing.

According to the official national energy policy document, in terms of decreasing domestic CO_2 production several tools can be usefully implemented. The overall restructuring of the national economy is desirable to decrease its energy intensity. Programs supporting energy efficiency and renewable energy measures are also considered, as is steering the fuel portfolio towards lower carbon content fuels.

National GHG emissions in 1996 were at 76% of the Kyoto Protocol base year level (1990), so the reduction in emissions was well below the 2008-2012 target of 92% of 1990 emissions. Between 1996 and 1999 CO_2 emissions fell by more than 20%, mostly due to the declining absolute consumption of brown coal and coke and the increased proportion of natural gas and primary nuclear heat use.

Although SO_2 and NO_X national emissions showed a declining tendency in 1993-1997, the current level is not sufficient to meet the Slovak Republic's commitments under the ACETO Protocol to the Convention on Long-range Trans-boundary Air Pollution. The most critical issue is SO_2 emissions. The industrial sector share is 51%, and the power generation industry has reduced its contribution to 40% mainly due to the measures adopted by the national power generating company Slovenské electrárnE. At present it seems feasible that by the year 2006 there will be a substantial reduction of SO_2 emissions in the Slovak Republic.

Energy Policies

The Slovak economy has since 1990 been undergoing a transition from a centrally planned to a free market-oriented economy. This process has been accompanied by decreases in industrial production and related energy consumption.

Between 1990 and 1998 primary energy consumption fell by 21%, which was due mostly due to a drop in energy intensity of 22% as GDP increased by 2% in the same period [16].

The Slovak energy system is characterized by an inefficient use of energy, despite the slowly improving trend. Slovakia uses energy 6 times more inefficiently than the EU average when using currency exchange rates, or 2 times more inefficiently with the use of PPP exchange rates. The main reasons for this are considered to be the high proportion of industry in GDP production and the high proportion of energy intensive industry on the Slovak economy as a whole, as well as long-term distortions in energy prices. On the other hand, per capita primary energy consumption reaches only 80% of the EU level.

The main focus of the Slovak government as regards energy efficiency has been partly on financing direct energy efficiency programs (ca 30 million US$ between the years 1993 and 1999) and partly on changing energy prices to avoid energy cross subsidies. Nevertheless, direct energy efficiency subsidies are not considered to be sufficient to reverse the high inefficiency in energy use, and regulated price increases were not fully implemented due to political obstacles. Between the 1993 and 2000, electricity cross subsidies reached some US$1.3 billion. This means that the domestic sector, for historic and social reasons, was paying less than small businesses for the same electricity consumption [28].

Energy efficiency improvements have therefore been due in the main to the slow transformation of the economy towards less energy-intensive and more service-oriented production. Direct investments in energy efficiency entrepreneurialism have been undertaken only by the EBRD, which has given loans to two ESCO companies.

2.4 Summary of Potential

There remains a great potential, and a great need, for energy efficiency and its concomitant economic and environmental benefits in Central and Eastern Europe (CEE).

Since the early 1990s, economic needs and the desire to move toward a market economy have provided the greatest energy efficiency incentives and has helped to foster an ESCO industry in some areas. For most CEE countries, a major energy efficiency driver in recent years has been the need to meet EU environmental standards as a step toward admission into the European Union.

The level of the potential and the need for energy efficiency has varied by country and is expected to continue. Energy supply, use and energy efficiency efforts vary significantly as noted in the above brief overviews. However, in all countries, economic conditions have played a major role. The conditions, such as triple digit inflation in Bulgaria, have often made it difficult to find energy efficiency financing.

Table 2-1 identifies some energy efficiency projects in CEE countries and the types of energy efficiency measures undertaken.

A prevalent weakness across most CEE countries remains the inability of commercial banking to finance energy efficiency. This problem is partially due to the level of basic banking procedures as well as bad debts which have often driven up interest rates. Many bankers in the region do not view energy efficiency as an investment and remain uneasy regarding the due diligence required to evaluate energy efficiency projects.

Energy centers throughout the region, such as SEVEn in the Czech Republic, FEWE in Poland and CENEF in Russia, have done much to build awareness of the economic and environmental advantage of energy efficiency and to acquaint consumers with new technologies. Conferences, such as SEVEn's Energy Efficiency Business Week and Slovakia's ENEF, have made significant contribution to this effort.

With reference to Table 2-1, it would be extremely helpful if the CEE countries were to implement a strong measurement and verification procedures, such as the International Performance Measurement and Verification Protocol (IPMVP) (discussed in Section 3.3). The economic, energy, and environmental benefits have achieved could be documented. Further, such information would provide greater motivation for similar projects to be undertaken.

The Growing ESCO Role

The ESCO industry's growth has been partially due to some ESCOs' abilities to finance the projects themselves as well as the support of donor agencies, such as EBRD, US AID, IFC, and Thermie and PHARE of the EU.

The most common barrier to the growth of an ESCO industry has been the inability of commercial banking to support such an effort. Without such support, sustained ESCO development in any country is extremely difficult.

Established measurement and verification procedures would improve ESCO business procedures and would also foster greater confidence in potential customers. In the US, the use of the IPMVP has been instrumental in enhancing ESCO project financing.

2.4 EPC Experience in the Czech Republic

Compared with other CEE countries and even with EU-countries, the Czech Republic has proceeded very quickly with the use of EPC for energy efficiency. The concept of using non-traditional approaches to energy management and to the financing of energy projects by means of innovative financing models reached the Czech Republic at the end of 1992 when Czech experts were introduced to this new financing instrument at the first Energy Efficiency Business Week in Prague. At the beginning of 1993 experts from an American energy service company came to the Czech Republic to investigate the possibility of making use of EPC under the conditions of an economy in transition. Beginning in 1994 a new subsidiary company had concluded energy service contracts with the first clients. From this first founding of an ESCO company to the present, nearly a dozen similar companies are busy in the Czech market delivering energy management services.

A significant milestone of the development of EPC in the Czech Republic was the provision of training organized by the European Union PHARE-program in 1996. By the end of 1996, more than 19 companies had participated. About one fifth of these began to integrate EPC in their business activities. The Czech Energy Agency (CEA) has provided financial support for a number of EPC-projects through subsidies. To date, there are a total of about 50 projects completed or in negotiation.

Typical energy efficient measures include:

- automatic control systems
- investment in boilers
- equipment for energy distribution in buildings
- other energy efficiency utilities

It is interesting to note the absence of lighting, which constitutes the one of the most popular measures in North America. In the Czech Republic, this measure makes economic sense only where lighting system operating times are extended or continuous.

The application of EPC has produced variable results across different sectors. Some reasons for this are described below.

Public sector: This sector is ideally suited to application of EPC because it does not immediately react to trade development fluctuations. The principal barriers to penetration relate mainly to existing rules for treating investment, requirements for public tenders and the very complicated management structures. The most suitable candidates are those public institutions (municipalities) which can decide for themselves how to treat investment means and thus have a real interest in energy savings.

Schools: For some primary schools and all universities, EPC can be applied directly wherever the school is responsible for its operating costs. Some schools do not have separate legal status, resulting in split incentives. Where investment size is less than USD 33,000 (CzK 1,000,000), transaction costs are generally too high. Most projects have ranged upward to twice that level.

Health Care: Health care facilities are organized either as state-administered or local public sector, generally financed by health insurance companies. As operating payments are not directed to any specific purposes, allocation decisions can be made locally. In some cases, EPC can be hindered by high insolvency and low credit standing. Transaction costs are generally not a limiting factor due to the size of the investment.

Industry: Return on investment set by ESCOs for industrial companies are higher than for the public sector, due to the greater perceived risk. Most EPC projects are for medium to large companies with high-energy consumption, financial stability and solvency, and with well developed markets. Some industrial companies suffer from incomplete privatization and unclear production programs. Most ESCOs are cautious about this sector.

The most common barriers to EPC implementation are:

Financial barriers: The Czech banking sector is not yet willing to grant loans to institutions dealing with state property. Because of rather high inflation rates, loan interest guarantees for long term loan cannot be given. Also, many of the potential clients have other investment priorities. The larger ESCOs, however, are generally well financed.

Legislative and contractual barriers: In the public sector, most EPC projects must be submitted for public tender, a practice which tends to evaluate proposal on traditional and/or inappropriate parameters, e.g. lowest price, shortest payback. Strict regulations must be fulfilled by the financial operators of government founded organizations. Greater flexibility in the public sector is needed to undertake EPC projects without unnecessary obstacles.

Economic Barriers: Energy prices are still rather low in the Czech Republic, so other investments are often more attractive. Consideration of an EPC governing a longtime commercial relationship must take into account the devaluation of money. This has a considerable influence on estimating the risks on both sides of the agreement.

Psychological barriers: The EPC approach is a rather unconventional procedure compared with more traditional retrofit contacts. As a result, energy consumers often have difficulty understanding the principles.

In spite of all these barriers, more than 50 projects have been initiated.

One barrier which does not exist is technical competence of the energy engineers. During visits to four ESCOs, the project team found that the knowledge and understanding of energy efficiency and EE measures was outstanding among the various project engineers.

Table 2-1:
Sample of Energy Efficiency Projects
in Eastern and Central Europe

Project Name	Year	Type	Description
Bulgaria			
Bácstej		AIJ	dairy, equipment efficiency
Bourgas	1995	ESCO	district heating
Pleven	1999	AIJ	district heating
RENEVER	2001	ESCO	district heating, lighting
Varna	1997	ESCO	boiler efficiency
?EE demo zone	1999	ESCO	district heat/retrofits/street lighting
?EAPS	1996	ESCO	gas conversion
? water cos.	1994	ESCO	district heating
Czech Republic			
Boží Dar	1994	ESCO	Renewable, heating retrofit
Bulovka	1995	ESCO	hospital steam services
Cizkovice	1998	AIJ	cement plant efficiency
Děčín	1995	AIJ	natual gas - district heat/cogeneration
Harmanice	1995		biomass

Project Name	Year	Type	Description
Horni Podluzi	1998	ESCO	heating retrofit, fuel switch
Ivančice	1996	ESCO	heating retrofit
Jeseník			wind - electric supply
Kardašova Řečice			biomass - district heat
Kladno	1997	ESCO	coal/gas cogeneration
Kyjov	2001		waste heat utilization
Liberec	1998	ESCO	cogeneration
Mladá Boleslav	1995	AIJ	fuel substitution
Movenpick	1996		demand controls
Mrakotin			biomass - district heat
Staré Město			biomass - district heat
Svitavy		ESCO	solar heating
Velesin			natural gas -district heat
Velky Senov	1998	ESCO	heating retrofit, fuel switch
ELI	2000		lighting retrofits
Hungary			
Bacstej Pst		AIJ	energy process redesign
Balatonfured	1995	ESCO	lighting retrofit
Dorog Eromu	2000	AIJ	fuel substitution, cogeneration
Graf Esterhazy	1995	ESCO	hospital, heating system efficiency
Marriot	2000	ESCO	lighting retrofit
Papa	1995	ESCO	lighting retrofit
Pest	1996	ESCO	modernize heating system
Szombathely		ESCO	CHP/biomass (GEF)
? municipalities	1997	AIJ	
?EDCP		ESCO	industrial energy efficiency
Poland			
Bielsko-Biala	1998	ESCO	district heat, eliminate coal stoves
Byczyna	2000	AIJ	heat supply modernization
Katowice	1994		district heat
Krakow		ESCO	energy efficiency (GEF)
Mi_dzybrodzie		ESCO	heating retrofit
Olcza		ESCO	renewable energy
PELP	1995	DSM	re-lamping incentive
Radom	1997	ESCO	LFG recovery
Rybnick		ESCO	fuel switch, thermal upgrade
Rydultowy		ESCO	fuel switch
Skowczow	1998	ESCO	district heating
Szamotuly	1999	AIJ	sustainable CHP
Wodzislaw Slaski		ESCO	district heat, eliminate coal boilers
Romania			
Buzan	1999	AIJ	thermal energy
Giurgiu	1992	ESCO	district heating
Iasi Hotel	1995	ESCO	heating retrofit
Pascani	1999	AIJ	thermal energy
Sibiu Flats	1995	ESCO	heating retrofit
Targo Mures	1997	AIJ	anaerobic wastewater methane
power plants	1997	AIJ	emission reductions
water		AIJ	energy efficiency, water supply

Project Name	Year	Type	Description
efficiency		ESCO	energy efficiency (GEF)
thermal	1997	ESCO	district heating
Slovak Republic			
Benadicka	1992	ESCO	insulation retrofit
Kramare	1991	ESCO	insulation, control retrofit
Poprad	1996	ESCO	heating retrofits
Rajec	1996	ESCO	fuel switch, coal to biomass
Stary Smokovec	1995	ESCO	building retrofits
Swiss	2000	AIJ	cogeneration, controls
dairy	1999	AIJ	fuel switch
	1999	AIJ	fuel switch
?	1998	AIJ	fuel switch, biomass

References

1. Alliance to Save Energy, *Central Europe Energy Efficiency Programs*, http://www.ase.org/programs/international/ee/index.htm

2. Bulgaria - *National Report to the Conference of the Parties under the UNFCCC*, 1999

3. COM(1999) 611, EU Commission Proposal - *Directive on the limitation of emissions of certain pollutants into the air from large combustion plants*, Brussels 1999

4. Charles University Environment Center: *Czech Republic 2000, Ten Years on: Environment and Quality of Life*, Charles University 2000

5. *The Czech Republics Second Communication to the UNFCCC*, 1997

6. ECEE: *The Market for Energy Efficiency in Poland, The Export Council for Energy Efficiency,* Washington DC, 1999, http://www.ecee.org/pubs/poland.htm

7. EIU: *Hungary- Country profile 1998 - 1999, The Economist Intelligence Unit*, London, 1998

8. EnEffect, Energy Conservation Policy, http://www.eneffect.bg/ , 2001

9. FFU*: Instruments and Options for Environmental Policy during the Accession Process of EU Associated Countries in the Area of Environment and Energy, FFU/ Oeko-Institut, ecologic GmbH*, Berlin, 2000

10. Hardi, P. *Environmental Protection in East-Central Europe, Bertelsmann Foundation Publishers*, Gütersloh 1994

11. Havlickova, M., et al., *Energy and Economic Bulletin for the Czech Republic*. Prague, CZ: SEVEn, 2000. http://www.svn.cz/

12. HCSD: Hungary- *Stabilisation of the Greenhouse Gas Emissions, Hungarian Commission on Sustainable Development*, Budapest, 1994

13. Hungary - *First National Report to the Conference of the Parties to the UNFCCC*, 1994

14. IEA, *Black Sea Energy Survey*, 2000

15. IEA: *Energy Balances of Non-OECD Countries Efficiency Initiative,* Paris, 2000

16. IEA: *Energy Balances of OECD Countries Efficiency Initiative,* Paris, 2000

17. IEA: *Energy Efficiency Initiative, Volume II, IEA/OECD*, Paris, 1997/2001

18. IEA: *Energy Efficiency Update- Hungary, IEA/OECD*, Paris, 2001

19. IEA: *Energy policy – Slovakia – overview 1997*, IEA / OECD, Paris, 1998

20. IEA: *In-depth Review of the Czech Republic Energy Policy* – 2000, 2001

21. EIU, Bulgaria - *Country Report,* the Economist Intelligence Unit Ltd., UK, 3rd quarter 1999

22. EIU, *Bulgaria - Country Profile,* the Economist Intelligence Unit Ltd., UK, 1998

23. EIU, *Hungary - Country Profile 1998-99,* the Economist Intelligence Unit Ltd., UK, 1998

24. EIU, *Poland - Country Profile*, The Economist Intelligence Unit, UK, 1998

25. EIU, *Romania - Country Profile*, The Economist Intelligence Unit, UK, 1999

26. IIEC (International Institute for Energy Conservation), *The Market for Energy Efficiency in Romania* http://www.ecee.org/pubs/romania.htm, 1999

27. ITC, *The Market for Energy Efficiency in Poland*. Washington, DC: American Council for an Energy Efficient Economy, https://secure.solarhost.com/clients/aceee/orderfor.htm

28. Krivošík J.: *Energy Subsidies in the Slovak Republic*, SEVEn, Prague, 2001

29. Manczyk H. *The Black Triangle: Reducing Air Pollution in Central Europe*, International District Energy Association 90th Annual Conference and Trade Show in Boston on June 12, 1999.

30. MEH: *Report on the activities of the Hungarian Energy Office in 1999*, Budapest 2000

31. Ministry of Economy of the Slovak Republic: *Energy Policy of the Slovak Republic* , Bratislava 1999

32. Ministry of Environment and Water of Bulgaria: National Strategy, Environmental Sector, Sofia 2000

33. *National Energy Efficiency Study – The Czech Republic*, prepared by SRCI CS, ECN, March Consulting Ltd., SEVEn, RAEN Ltd., DHV AIB, DHV CR Ltd., SEO for the World Bank, Ministry of Industry and Trade and the Ministry of Environment of the CR, Prague 1999

34. *Poland - Second National Report to the Conference of the Parties to the UNFCCC*, Warsaw 1998

35. *Romania - Second National Report to the Conference of the Parties to the UNFCCC*, 1998

36. Rotaru C. et al. *Country Report: Romania, Energy Efficiency and Climate Change Policy*, CTI Seminar in Ostritz, October 1999

37. SEVEn, *Country Needs Assessment for Capacity Development for Climate Change Protection, Eastern Europe and Central Asia Region*, for GEF, Prague 1999

38. SEVEn, *Energy and Environment in the Czech Republic*, Prague 2000

39. SEVEn, *Study of the Czech Energy Services Market*, Prague 1999

40. *Slovakia - Second National Communication on Climate Change to the UNFCCC*, 1998

41. State Energy Efficiency Agency of Bulgaria, "*Strategy for energy saving performance contracting implementation in Republic of Bulgaria"*, Bulgaria, http://seea.government.bg/SEEAFiles/SEEAEnglish.htm, 2001

42. Szollos J., Krivošík J.: *Energy – State and Preconditions of the Sustainable Development in SR, in: National Strategy of Sustainable Development in the Slovak Republic*, MZP SR, UNEP, REC, Bratislava, 2000

43. U.S.DOE*, An Energy Overview of the Republic of Bulgaria,* http://www.fe.doe.gov/international/bulgover.html

44. U.S.DOE, *An Energy Overview of the Republic of Czech Republic*, http://www.fe.doe.gov/international/czekover.html

45. U.S.DOE, *An Energy Overview of the Republic of Hungary*, http://www.fe.doe.gov/international/hungover.html

46. U.S.DOE, *An Energy Overview of the Republic of Poland,* http://www.fe.doe.gov/international/plndover.html

47. U.S.DOE, *An Energy Overview of Romania,* http://www.fe.doe.gov/international/plndover.html

48. U.S.DOE, *An Energy Overview of the Slovak Republic*, http://www.fe.doe.gov/international/slvkover.html

49. Guide to Energy Efficiency Bankable Proposals. http://europa.eu.int/en/comm/dg17/bank.htm

50. Financing Energy Efficiency in Countries Making the Transition to a Market Economy Policies and Measures. Annex I Expert Group on the United Nations Framework Convention on Climate Change. Working Paper No. 10 http://www.oecd.org/env/docs/cc/gd97189.pdf

3. Flexibility Mechanisms and Energy Efficiency Investment

3.1 Introduction

Emissions trading [14,18] is a relatively new policy instrument designed to lower the cost of reducing emissions. Entities that reduce their emissions below their regulatory requirements are allowed to sell their surplus reductions to others, who can use them to offset emissions exceeding their regulatory requirements. Emissions trading provides an incentive for firms whose abatement costs are less than the market price to create and sell surplus emission reductions, and for firms whose abatement costs are above the market price to buy these reductions.

Individual participants may emit more or less than the regulatory requirements, but the total emissions across all participants will be equal to or less than the total permitted by regulation. It can be shown that a fully developed emissions trading system produces emission reductions at the least overall cost to the economy.

Energy efficiency projects are an economically attractive source of emission reductions, but investors often demand unusually high financial returns from these projects. The reason for this is often attributed to the presence of investment 'barriers', described in Chapter 5, that are characteristic of energy efficiency projects. These include uncertainties regarding specific savings and difficulties in measuring and verifying energy savings. Emissions trading provides an additional financial incentive to undertake these projects as well as a disciplined procedure for measuring and verifying both emission reductions and energy savings. For these reasons, it is thought that emissions trading will provide an important new stimulus to energy efficiency investment.

This chapter provides background information on emissions trading and energy efficiency investment essential for understanding the balance of this report. The first section introduces emissions trading and its role in the Kyoto Protocol. This is followed by two sections that describe processes and methods for identifying, implementing and financing energy efficiency projects. The chapter concludes by discussing the valuation of emission reductions in an emissions trading system and the potential impact of emissions trading on energy efficiency investment decisions.

3.2 Emissions Trading and the Kyoto Protocol

Emissions trading is an integral part of the proposed Kyoto Protocol to limit greenhouse gas emissions; it includes three mechanisms that are forms of emissions trading..

This heavy reliance on emissions trading was largely due to advocacy of this instrument by the United States. The United States was the first nation to use emissions trading in a significant way and, by the time of the Kyoto Protocol, had accumulated nearly 20 years of practical experience in its use. European countries were more comfortable with the use of carbon taxes and found emissions trading to be somewhat at odds with their approach to environmental regulation. The rules for implementation of the Kyoto mechanisms agreed at COP-7 in November 2001 rely heavily on the US emissions trading experience.

Experience with Emission Trading

New Zealand economist Henry Gordon first proposed the use of tradable permits in 1954 for fisheries management. Canadian economist John Dales [3] first elaborated their use in pollution control in 1968.

The US Environmental Protection Agency began to experiment with emissions trading in 1976 when it introduced its offset policy [14]. This policy allowed new emission sources to be built in areas that exceeded air quality standards provided that they obtained offsetting emission reductions from other sources in the area. In 1979 EPA allowed firms to 'bubble' emissions from several facilities and manage the emissions together, offsetting emissions at one source with reductions at another within the bubble. These policies evolved into the formal Emission Trading Program ('ETP') in 1986, a 'baseline-and-credit' trading scheme for seven pollutants in 247 control regions across the United States. This program introduced banking of emission reduction credits for the first time. By 1990, the program was estimated to have achieved more than $10 billion in capital cost savings for industry [18].

The flagship trading-program is EPA's SO2 Allowance Program in the US electric power sector, a cap-and-allowance trading system introduced by the 1990 Clean Air Act amendments. This program has been very successful, reducing total emissions by more than 25% from allowable levels at a total cost estimated to be 30% lower than under conventional command-and-control regulation [5].

The successful demonstration of emissions trading in the ETP and SO2 Allowance programs generated widespread interest in this approach. Trading systems were established by numerous states, including California, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Pennsylvania and Texas; by the EPA for NOX control in the 22-state Ozone Transport region and for refineries in the lead phase-out program; and internationally for control of stratospheric ozone-depleting substances under the Montreal Protocol.

Emissions Trading Systems

There are two main types of emissions trading systems: cap-and-allowance and baseline-and-credit. The difference between the two is largely in how tradable permits are created. In either case the commodity traded is an emission permit that allows the holder to emit a unit mass (e.g., one metric tonne) of a given pollutant.

In a *cap-and-allowance system*, the regulator sets an annual cap on total emissions by sources subject to the trading program. The cap can be progressively tightened to achieve the overall emission reduction objective.

Each year, a quantity of tradable permits, called allowances, equal to the cap is allocated among the emitting entities. At the end of the year, each entity must surrender a quantity of allowances equal to its actual emissions during that year. An entity has surplus allowances when its actual emissions are less than the quantity allocated. An entity whose emissions exceed its allocated allowances must purchase surplus allowances from others. An entity can reduce its emissions, and so generate surplus allowances, through investments that lower emission rates, operating changes that reduce emission levels, or reductions in demand for the entity's products.

In a *baseline-and-credit* system, tradable permits, called credits, are created by undertaking emission reduction projects. A typical baseline-and-credit system reduces the emission rate of a source, but does not control absolute emissions: conventional regulations limit maximum emissions of any entity.

Emission reductions are measured relative to an emission baseline, expressed either as an absolute emission level or, more commonly, as an emission rate per unit of physical activity (eg. kg/widget produced). The activity measure should be appropriate for the type of project. The baseline rate may be defined in several different ways: it may be the historical pre-project rate, a sectoral average rate, or a rate that satisfies emission reduction objectives. As proponents justify their own projects, an independent review and verification process is required to ensure that the claims made are truthful and satisfy environmental and programmatic criteria.

A *hybrid* trading allows sources that are not part of the emissions trading program to generate emission reduction credits by implementing emission reduction projects. The emission reduction credits can be used by participants in the cap-and-allowance or baseline-and-credit program to achieve compliance. The emission reduction projects by sources outside the trading program increase the supply of permits available to participants in the trading program and so help reduce the cost of compliance. Independent review and verification of the emission reduction credits is required to ensure environmental integrity. Relatively few hybrid systems exist today: California's RECLAIM and Ontario's NOX and SO2 trading system are examples.

An energy efficiency project implemented by an ECSO at a source that is a participant in a cap-and-allowance program will reduce the source's emissions and so reduce the quantity of allowances it needs for compliance. This means it will need to purchase fewer allowances or will have more surplus allowances to sell. An energy efficiency project implemented by an ESCO at a source that is a participant in a baseline-and-credit program will reduce its emissions and so reduce the quantity of credits it needs to buy or increase the quantity of credits it can sell. The emission reductions due to the energy efficiency project need to be independently verified. An energy efficiency project implemented by an ECSO at a source that is not a participant in an emissions trading program may be able to generate credits that can be used by participants in an emissions trading program. The emission reductions due to such a project need to be independently verified.

Comparison of Trading Systems

Cap-and-allowance is simple and inexpensive to administer and effectively controls the absolute quantity of emissions by the participants. It is well suited to large emitters whose actual emissions can be accurately measured. The cost savings depend upon differences in emission reduction costs among participants, so a diversity of control options is desirable. An emissions trading program also requires enough participants to create a competitive market.

Transaction costs are higher in a baseline-and-credit system due to the need for project documentation, review and verification. The proponents of projects generally pay these costs. Administration is more complex because each project involves unique baseline, measurement, quantification and verification issues: standardisation reduces cost and complexity to the degree it can be achieved. Baseline-and-credit is best suited to sectors with many or small emitters using diverse technologies; where caps are infeasible or premature; or where a project-based approach is necessary for other reasons. Table 3.1 [14], summarizes the main features of the two systems.

Table 3.1
Comparison of Credit and Allowance Trading Systems

Criterion	Cap-and-Allowance	Baseline-and-Credit
Permit	Allowance	Credit
Scope	All emissions	Emission reductions
Permit Creation	Allowances distributed by regulatory authority	Emission reductions from baseline approved by regulatory authority
Tradability	All allowances can be traded	Only credits - emission reductions - can be traded
Regulatory Impact	Must be designed into regulatory structure	May be added incrementally to existing structure
Eligibility	Specific sources	Potentially any sector
Participation	Mandatory	Mandatory

Emissions Trading in the Kyoto Protocol

The Kyoto Protocol establishes a hybrid cap-and-allowance trading program where each Annex B party has an emissions limit for 2008-2012 and any party can implement emission reduction or sequestration projects to generate credits that can be used to offset emissions by Annex B parties.

Each Annex B party agrees to limit its greenhouse gas emissions to a specified amount for 2008-2012, its 'assigned amount' for the commitment period.[3] Each Annex B country is free to choose its own emission reduction and sequestration policies, but must measure its emissions in accordance with international standards set by the IPCC. Non-Annex B parties have no obligation to reduce emissions and therefore do not have assigned amounts.

Article 17 Emissions Trading is a cap-and-allowance system. Any portion of an Annex B country's assigned amount (measured in AAUs) can be traded to another Annex B country: the amount traded is deducted from the seller's assigned amount and added to the buyer's. Both countries are expected to keep their emissions within the final assigned amount and will be subject to penalties for non-compliance. A country may find that it has a tradable surplus of assigned amount for a variety of reasons, including reduced economic growth, structural shifts away from emission intensive industries, or successful domestic emission reduction policies.

Article 6 Joint Implementation is a mechanism for implementing emission reduction or sequestration projects in Annex B countries. An investor can implement an emission reduction project in an Annex B country in return for credits called Emission Reduction Units (ERUs). The investment can be made by any legal entity, including a government or a corporation, but the governments of both the host and investor countries must approve the transaction. The quantity of credits transferred is subject to negotiation and may be less than the quantity created by the project.

The host country is required to subtract the ERUs from its assigned amount. The ERUs are added to the assigned amount of an Annex B country specified by the investor. In effect, some of the host country's AAUs are converted to ERUs which are added to the assigned amount of the investor country so the overall emissions cap on Annex B countries is protected.

Article 12 Clean Development Mechanism is a mechanism for implementing emission reduction or sequestration measures in non-Annex B parties. Credits, called Certified Emission Reductions (CERs), equal to the emission reductions or sequestration achieved are issued by the CDM Executive Board after the reductions have been certified by independent experts. The CERs are added to the assigned amount of an Annex B country and so allow higher emissions in that country.[4]

The four types of permit under the Kyoto Protocol are the Assigned Amount Unit (AAU), the Emission Reduction Unit (ERU), the Certified Emission Reduction (CER) and the Removal Unit (RMU).[5] The denomination of each unit is one metric tonne (1 Mega-gram, Mg) CO2 equivalent.

[3] A party is a country that has ratified the Protocol. The terms party and country are used interchangeably. A country that has not ratified the Protocol – a non-party – is not eligible to use the Kyoto mechanisms.

[4] Although total emissions of Annex B countries may rise as a result, global emissions should not change if the CERs reflect the reductions achieved.

[5] Annex B countries are permitted to undertake specified actions to enhance sequestration of greenhouse gases by sinks. Units issued for the net sequestration achieved by such actions are called Removal Units (RMUs).

Current Status of the Mechanisms

The Kyoto Protocol was accepted by the Parties to the UNFCCC at COP-3 in Kyoto in December 1997. Subsequent conferences were concerned with developing sufficient agreement on the implementation details of the Protocol to allow ratification. This was achieved at COP-7 in Marrakech in early November 2001. It is expected that ratification by enough countries to enable the Protocol to come into force will occur in 2002.[6]

The CDM Executive Board was elected at Marrakech and it is currently developing an accreditation process for independent entities to validate proposed projects and certify emission reductions achieved. It is also developing simplified modalities and procedures for small-scale projects.

National emissions trading programs are also being developed in a number of countries. Denmark implemented a mandatory trading program for CO2 emissions by electricity generators in 2001. The UK has established a voluntary trading program, with strong incentives to participate, that covers about 10,000 sources. The Commission of the European Union has released a Directive, which if adopted, would require all member states to establish a domestic trading program for energy-related CO2 emissions by specified sources beginning in 2005. Other Annex B countries, including Australia, Canada, Japan and New Zealand, have been studying alternative designs for domestic emissions trading.

3.3 Energy Efficiency Projects and Emissions Reductions

Emissions trading is expected to provide a significant new financial incentive for energy efficiency projects. This section describes how the financial value of emission reductions is determined in an emissions trading market. The following section examines the impact of emissions trade on energy efficiency investments.

Spot Markets

In a fully developed emissions trading system with enough participants to create a liquid and competitive market [7], the market price at any instant will approach the marginal cost of the last unit of emission reductions demanded.[7]

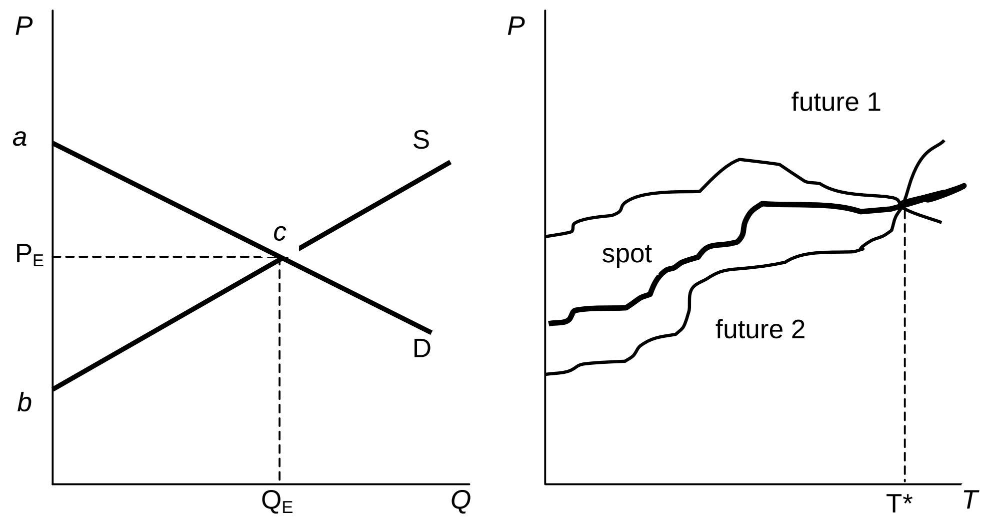
The demand for emission permits is driven by environmental regulations that require firms to reduce emissions below anticipated levels. Non-compliance with these regulations usually invokes severe penalties, whose cost is greater than market price of emission permits. This ensures that if a firm's marginal abatement cost to comply with regulatory requirements is greater than the market price, its least cost option will always be to purchase permits in the market.

In the following diagram, Panel 3.1a shows how the spot price is determined by the equilibrium of supply and demand at a particular instant. The supply curve S represents the marginal cost (price) at which permit holders will supply to the market and the demand curve D represents the marginal cost avoided by purchase of permits. The market comes to equilibrium at point *c* where the marginal price of the last unit supplied is equal to the marginal cost avoided for the last unit demanded. The market price is PE and the quantity traded is QE. The area *abc* represents the total gain from trade.

[6] To come into force, the Protocol must be ratified by at 55 nations, collectively representing 55% of the Annex B carbon dioxide emissions in 1990.

[7] The average abatement cost is the total cost of an emission reduction divided by the magnitude of the reduction; the marginal abatement cost is the incremental cost of the last unit of emission reduction.

Figure 3.1
Pricing in Spot and Future Markets



Future Markets and Option Value
The trajectory of market prices over time is a sequence of spot prices determined by the process above. Regulations, technological opportunities, economic conditions, historical experience and future perceptions, all of which are subject to change, will affect the evolution of spot prices. While there is no way of knowing exactly what prices will be in the future, it is known that they will be related to the underlying emission abatement costs of the market participants at the time.

Future market prices can be estimated by applying the marginal abatement cost curves of countries or regions participating in the Kyoto Protocol to emission scenarios. The scenarios take into account anything that is known about future emission, the reduction targets of trading program participants, local trading system rules, and so on. The marginal abatement cost curves are estimated from macroeconomic or microeconomic models, and incorporate a host of assumptions about economic growth, inflation, technical progress, relative prices and other matters. Many studies along these lines have been published. They are nothing more than educated estimates.

The prices offered for future deliveries of emission reduction credits in forward and options contracts are another source of information about future market prices. Both are contracts for future delivery of credits at an agreed price: in a forward contract the buyer is obligated to accept delivery; in an option the buyer can decline the delivery but pays an up-front 'premium' for this right. The Black-Scholes method is a widely used approach to pricing option contracts that takes account of the uncertainty ('volatility') of future prices. A brief and self-contained introduction is found in **[16].**

A futures market trades in a specialized set of forward contracts that are re-priced daily to give a continuous sequence of estimates of future price. Figure 3.1b illustrates how the value of future contracts for some future time T* will converge towards the actual spot price realized at T*. A futures market, because of the large number of independent participants, provides the best available estimates of future prices. Futures markets do not yet exist for GHG permits but can be approximated from knowledge of forward and option prices.

Transaction Costs

To an individual buyer or seller, the value of an emission reduction will be its market price less any costs incurred by the individual in completing the market transaction. These transaction costs include:

- costs to prepare protocols and other emission reduction project documentation
- costs of special instrumentation and monitoring activities
- costs for third party verification of emission reduction claims
- fees charged for review and certification by approval authorities
- registration fees
- brokerage fees and search costs to match buyers with sellers
- legal fees to complete purchase-sales contracts
- cost of insurance on future deliveries
- buyer's due diligence costs

Transaction costs are poorly understood at this time and will be significantly influenced by the rules and procedures established for future trading systems. Most of these costs will be project specific.

For example, at Clean Air Canada, the cost to prepare a protocol is typically in the range $10,000 to $50,000, depending on the complexity of the project. Review fees (reviewers are paid fixed stipends) range from $5,000 to $10,000. Annual credit creation reports by an independent third party verifier cost $5,000 to $10,000 to prepare and $1,000 to review. The verifier's liability is limited to the direct cost of the report: and costs would increase significantly if the verifier bore contingent liabilities.

In this case, sellers treat these transaction costs as an incremental investment to obtain incremental revenue from emission trade. The investment risk is extremely high in an early informal market where the ultimate validity or use of credits is unknown. Sellers at Clean Air Canada are demanding very fast paybacks on transaction costs, usually on the order of 3 months; the longest payback known to have been accepted was 1.5 years. The minimum project size meeting this criterion net of transaction costs is $50,000.

3.4 Energy Efficiency Project Finance

This section examines the potential impact of emission trade on the financial returns from energy-efficiency investments for the range of prices that might be expected up to the end of the first commitment period. Implications for financial intermediaries and project aggregators are also briefly discussed.

Pricing in Early Markets

The early market, as the term is used here, refers to emissions trading in the period before the implementation of formal emission trading systems with well-defined rules, procedures and institutions, by regulatory authorities.

An informal and voluntary GHG emission trade has been in existence since 1997, and has to date traded some 55 million Mg-CO2E with a cumulative value estimated to exceed US $100 million **[14].** Purchasers in this market are generally large firms, such as oil producers and electric utilities, facing significant potential carbon liabilities. These firms are attempting to hedge against emission reduction obligations if the Kyoto Protocol is ratified and to gain early experience with emission trade. Given the high degree of uncertainty regarding ratification, emission trading rules and the future recognition of the 'early-reduction' credits they have purchased, prices are low and purchase contract terms are often stringent.

At the time of writing, this informal market is purchasing current year emission reductions at US $0.50 - $1.50/Mg-CO2E, depending on the perceived quality of the reductions and the creditworthiness of the seller. The spot market is extremely thin, with occasional purchases made by firms with voluntary commitments or that have been required to mitigate emissions from a new plant. Virtually all reductions are sold under future (50-75%) or option (25-50%) contracts ending between 2007 and 2015. Option premiums are usually in the range $0.25 - $0.75/Mg-CO2E and exercise prices typically escalate at 6-7% annually. With few exceptions, the reductions are non-additional consequences of projects that were undertaken for other reasons.

Emission reductions are also being purchased through programs undertaken by national governments, multilateral agencies and a few NGOs and private investment groups. Major examples are the World Bank's Prototype Carbon Fund and the Netherlands's ERUPT program. These programs typically purchase emission reductions from new projects that are expected to qualify as CDM of JI projects.

Purchases under these programs are essentially prepaid forward contracts. Project evaluations conform to current expectations of international rules and attempt to establish that the project is environmentally and financially additional. The governments involved approve projects and credit transfers and so the permits have much lower risk than the voluntary market described above. Prices offered are typically in the range US $2.00 to $4.00/Mg-CO2E, though a few trades have recently been made for government-backed permits at prices up to $12.00/Mg-CO2E.

Long-term Market Price Scenarios

With the advent of formally regulated and competitive greenhouse gas markets in the future, likely circa 2005, spot prices should tend towards marginal abatement cost as discussed in the previous section. Many estimates of the marginal cost of greenhouse gas abatement have been produced over the past decade.

Two basic approaches are used to model the evolution of marginal cost for a given emission reduction scenario: top-down and bottom-up. The top-down approach uses a macroeconomic model and adjusts carbon prices until the desired reductions are achieved. A key assumption in these models is the price-elasticity of demand for carbon-based goods and services. The bottom-up approach models the microeconomic decisions to adopt new technologies and aggregates these to obtain a picture for the economy as a whole. Key assumptions here include the range of technical options available, their price and performance, and the investment criteria applied. Table 3.2 summarizes recent price estimates from several models.

Table 3.2
Estimates of the International Price of Tradable Carbon Permits in 2010 Under the Kyoto Protocol: The Effect of Withdrawal by the United States
(2001US\$ per metric tonne of carbon dioxide (CO_2))

Source	Currency Units	With the US in the Protocol	After US Withdrawal from the Protocol		
			Competitive Market	Strategic Behaviour by Annex B Sellers	
		$\$/tCO_2$[a]	$\$/tCO_2$[a]	$\$/tCO_2$[a]	Hot Air Sold
Babiker et al. (26)	1995US\$	<\$15.20	<\$1.60	\$7.60	50%
Blanchard, Criqui and Kitous (27)	1995US\$	\$8.50	\$0	\$5.10	10%
Böhringer (28)	?1995US\$[b]	\$18.80	\$0	\$17.30	40%
Böhringer and Löschel (29)	1995US\$[c]	\$11.30	\$0	\$9.70	50%
Buchner, Carraro & Cersosimo (30)	1990US\$	\$8.00[d] \$15.00[e]	\$5.20[d] \$13.90[e]		
Ciorba, Lanza and Pauli (31)	?1997US\$	\$11.40[f]	\$3.80[f]		
Den Elzen and de Moor (32)	1990US\$	\$10.40	\$2.90 \$0 to \$3.20[g]	\$6.10[k] \$5.10 to \$6.90[g]	60%
Eyckmans, Van Regemorter and van Steenberghe (33)	1995US\$	\$24.50	\$6.00 \$1.00 to \$13.40[g]	\$16.50	100%
Grötter (34)	?2000US\$[b]	\$4.20 to \$5.60[g]	\$0 to \$3.90[g]	\$0 to \$30.60[g]	
Hagem and Holtsmark (35)	1995US\$[h]	\$16.70	\$5.60		
Jotzo and Michaelowa (36)	1995US\$	\$1.80	\$1.00 \$0.70 to \$1.30[g]	\$1.20	50%
Jotzo and Tanujaya (37)	?1995US\$[b]		\$0.30[i]	\$13.50	50%
Kemfert (38)	1995US\$	\$15.80	\$2.40		
Löschel and Zhang (39)	1995US\$[c]	\$12.50	\$0	\$20.10[j] \$13.90[j] \$10.90[j]	36% 43% 45%
Manne and Richels[k] (40)	1997US\$	\$39.10	\$0.80[l]	\$33.70[m]	15%
de Moor et al. (41)	1995US\$			\$4.60 to \$6.10[g]	
MIT EPPA[n] (42)	1995US\$		\$0.60		
Nordhaus (43)	?1995US\$[b]		\$3.60[o]		
Vrolijk (44)	2000US\$	\$5.20	\$0.20	\$2.50[p]	0%
WHETHER[q] (45)	2000US\$		\$2.00		
Average[r] Range		**\$14.30** \$1.80 to 39.10	**\$2.60** \$0 to \$13.90	**\$12.20** \$1.20 to 33.70	

Notes:

a. Where necessary, reported values are converted from tC to t/CO_2, converted to 2001US\$ using the GDP implicit price index (1990 = 86.51, 1995 = 98.10, 1997 = 101.95, 2000 = 107.04 and 2001 = 109.37), and rounded to the nearest \$0.10.
b. Currency units not specified.
c. Currency units not specified, but results derived using the POLES model which uses 1995US\$.
d. Including induced technological innovation and diffusion, but no spillover effects.
e. Including induced technological innovation and diffusion with spillover effects.
f. Annex I trading only.
g. Price range for the sensitivity cases analysed.
h. A separate report on the model indicates that the currency unit is 1995US\$.
i. A minimum price of \$1/tC is assumed.
j. The estimates assume respectively (1) a cartel involving all countries with hot air that maximizes the revenue from the sale of permits, (2) countries with hot air maximizing their revenue from the sale of hot air subject to the behaviour of the other sellers (Nash equilibrium), and (3) Russia maximizing its revenue from the sale of permits with other sellers accepting the market price.
k. Values are scaled from the figures in the paper.
l. Assumes banking is prohibited, so all hot air permits are sold during the first commitment period.
m. Assumes anticipatory behaviour and banking.
n. Personal communication, John Reilly, October 2001, 1995US\$2/tC.
o. Nordhaus calculates the shadow price of carbon as \$9.68/tC in 2005 and \$13.99/tC in 2015, averaging these values yields \$11.84/tC or \$3.22/tCO_2 for 2010.
p. Price calculated assuming all "hot air" is banked; personal communication Christiaan Vrolijk, May 2002.
q. Personal communication, Peter Wooders, Environmental Resources Management, November 2001. 2000\$2/tCO_2.
r. Ranges are excluded from the calculation of the average.

As shown in Table 3.2, analyses of the international permit market subsequent to the US withdrawal from the Kyoto Protocol have assumed both a competitive market and strategic behaviour by Russia, the Ukraine and other central and eastern European countries. The models used to analyse the international permit market differ in several ways that affect the price, including the emissions covered (energy related CO2 only to all greenhouse gases), the coverage of sinks (none to maximum allowable sinks), the projected 2010 emissions in the absence of emissions limitation policies, the scale of CDM activity (none to all reductions from business-as-usual emissions in developing countries), and transaction costs for project-based mechanisms (none to 30%). Such differences lead to a range of price estimates.

If the international permit market is a competitive market, the price is in 2010 is expected to be approximately US$2.60/tCO2e (2001 dollars) with a range from $0 to $13.90/tCO2e. The Prototype Carbon Fund pays approximately $3.00/tCO2e, which is almost identical to the average price projected for a competitive market. If Russia and the Ukraine are able to act strategically, the estimated permit price in 2010 is $12.20/tCO2e with a range from $1.20 to $33.70/tCO2e.

Although the United States has withdrawn from the Kyoto Protocol, President Bush announced a Climate Change Initiative, which has the objective of reducing the greenhouse gas intensity of the US economy by 18% between 2002 and 2012. This is essentially a "business-as-usual" target.[8] The US could adopt domestic policies to limit greenhouse gas emissions over the next decade.[9] Any domestic policy in the US that allows the use of foreign permits for compliance will affect the international permit market. Depending upon the size of such a US demand, the supply of Kyoto mechanism permits from other countries could increase enough to reduce the market power of Russia and the Ukraine, leading to a price between the cases shown in Table 3.2.

The brokerage community expects prices in 2010 to be in the range US $10 - $50/Mg-CO2E, and most likely under $25/Mg-CO2E. This range is consistent with the estimates in Table 3.2 covering both the competitive market and strategic behaviour cases. The range in these estimates depends largely on the assumed geographic extent, project eligibility rules and transaction costs in the market.

Impact on Project Returns

Emissions trading provides a potential new source of revenue for many energy efficiency projects. The net present value of this revenue depends on many factors, including the magnitude and time pattern of payments for emission permit sales and transaction costs and the discount rates applied to these cash flows. The effect on project investment criteria, such as IRR, can only be determined by including these cash flows in a financial model of a specific project.

For example, consider an electrical efficiency project such as a lighting retrofit. To make it realistic, assume a retrofit of 750-160W-T12 luminaires with T8 bulbs and electronic ballasts in a 25 story office building. The lights operate 12 h/day and the retrofit reduces electricity consumption for lighting by 30% to give an annual reduction of 157 MWh. The price of electricity is $0.10/kWh, fossil generating units are on margin 80% of the time that the lighting system operates, and the emission rate for these fossil units is 850 kg-CO2/MWh. The retrofit produces an annual energy cost saving of $15,700 and reduces annual

[8] See de Moor et al. 2002, for an analysis.

[9] Oregon requires new energy facilities to offset part of their greenhouse gas emissions. Massachusetts and New Hampshire have passed legislation that will cap CO_2 emissions by fossil-fired generating units in each of these states prior to 2008. Proposals for a national cap on CO_2 emissions by fossil-fired generating units are under consideration by the Congress.

emissions by 106 Mg-CO2. Finally, we assume that the CO2 price is net of transaction costs and ignore inflation.

If the CO2 price is $1/Mg-CO2, the emission reduction is worth $106/year and increases annual revenue by 1.02%. At $5/Mg-CO2, revenue increases 5.1% and so on. In general, the effect of emissions trading is to fractionally increase project revenue in proportion to the price paid for emission reductions. It can also be seen that the impact of emissions trading on project revenue varies directly with the magnitude of emission reduction and inversely with energy price and the magnitude of energy savings.

Now assume that the retrofit has a 2-year gross payback (so the installed cost is $31,400) and a 5-year life. The real IRR of the retrofit, based on energy savings alone, is 41.04%. The IRR rises by 1.49% to 41.65% with emissions trading at $1/Mg-CO2 and by 7.43% to 44.09% at $5/Mg-CO2. The change in IRR is not exactly proportional to CO2 price because of the time pattern of the cash flow; this nonlinearity can be expected to increase as year-to-year changes in cash flow become more pronounced.

If the project cost is increased by 50% to $47,100, the gross payback from energy savings increases to 3 years and energy-related IRR falls by 51.6% to 19.86%. The revenue cash flows are unchanged, but emissions trading now has a greater impact on IRR, as can be seen by comparing the %-change in IRR columns in Table 3.3: the impact of emission trade on IRR varies directly with project cost.

Table 3.3
Emission Trade Impact on Example Lighting Project

$/Mg-$CO_2$ Price	Revenue, $/year		2-year Payback		3-year Payback	
	Total	CO_2	IRR, %	% chng.	IRR, %	% chng.
0	15,700	0	41.04	0.00	19.86	0.00
1	15,860	160	41.65	1.49	20.32	2.33
5	16,501	801	44.09	7.43	22.15	11.55
10	17,301	1,601	47.10	14.76	24.41	22.91
15	18,102	2,402	50.08	22.02	26.63	34.10
20	18,903	3,203	53.03	29.20	28.82	45.13
25	19,704	4.004	55.95	36.32	30.98	56.02

To evaluate the marginal abatement cost, assume that the proponent requires a 25% IRR to proceed with the project. The 2-year payback project exceeds this hurdle and is undertaken without any need to sell emission reduction credits. The project is 'financially non-additional' (see Section 4.3) and the marginal abatement cost is zero.

The 3-year payback project on the other hand requires an further $1,813/year in revenue to achieve the required 25% IRR. This equates to a price of $11.32/Mg-CO2 for a 106 Mg/year reduction. The project is 'financially additional' and would be undertaken only if the emission reductions could be sold at $11.32/Mg-CO2. If the market price is higher, the payback would be shorter; if lower the project would not be undertaken at all.

The difficulty with this approach to marginal abatement cost and financial additionality is that it requires an estimate of the IRR (or equivalent decision criterion) at which the project would be undertaken spontaneously. The financial model developed in Chapter 6 attempts to address this problem for energy efficiency projects.

Role of Intermediaries

The lighting example above, while a typical energy efficiency project, does not by itself produce a marketable quantity of emission reductions. The minimum requirement for a brokered trade is currently in the range of US $25,000 to $50,000. This minimum is set by transaction costs, which tend to be high in today's informal over-the-counter GHG trade. These costs include the brokerage fee, normally paid by the seller, the buyer's transaction costs for due diligence investigation and the costs for emission-related project documentation, measurement, verification and approvals. The threshold may be relaxed somewhat if efficient exchanges are established, but the value of emission reductions from most energy efficiency projects will be small for the foreseeable future.

This suggests a role for intermediaries - ESCOs, investment funds, or marketing 'pools' - to aggregate emission reductions from multiple projects and deliver transactable quantities to the market. An intermediary specialising in lighting retrofits would need to aggregate the reductions from 50 projects similar to the example above to obtain a transactable quantity of credits at $5.00/Mg-CO2.

An important advantage of project aggregation is the opportunity to diversify delivery risks across multiple independent projects. The emission reductions at a particular building may be less than planned if, say, a major tenant moves out, but this is unlikely to happen to 50 buildings simultaneously. Diversifying the types of projects in terms of both technology and economic sector and country can further reduce delivery risk. An intermediary can also capture significant economies of scale, by standardising project selection procedures, contracts, and monitoring and verification methods, and by developing a high level of specialised expertise in emission marketing. Finally, such an intermediary, by providing 'one-stop shopping' for qualified credits, would reduce transaction costs for both buyers and brokers.

The use of intermediaries in GHG trading is in its infancy. A key distinction between intermediaries will likely centre on the allocation of delivery risks and responsibilities; two basic approaches come to mind:

Agency Model. Here the intermediary makes no project investment and does not take title to emission credits. Credits are transferred to the agent on consignment as they are created. The sellers, which may be facility owners or ESCOs, are individually responsible for delivery. The agent is essentially a broker that bundles credits for sale and is paid on commission. A third-part underwriter [11] might insure deliveries, with premiums paid by sellers: cooperative agreements where the portfolio provides a degree of self-insurance are also possible. This option may be legally complicated, but requires no investment by the agent, gives the sellers access to higher prices and provides some tax advantages related to the timing of income.

Investor Model. This is probably a more feasible option, especially for the bundling of small projects. The investor agrees to purchase and take title to emission reductions as they are created under long-term agreement. Payments may be made up-front as an incremental project investment, or annually on delivery. The investor earns the difference between the purchase price and the resale price, and requires sufficient capital for payments, unsold inventories, market losses and underwriting of deliveries. The investor guarantees deliveries to buyers and has recourse to sellers for deficiencies. This option is more straightforward legally and could be set up as a public corporation or a mutual fund. The Prototype Carbon Fund essentially operates this way.

ESCOs are specialists in energy efficiency projects, but have as yet no experience in the trading of emission reductions from these projects.

In summary, energy efficiency projects often reduce greenhouse gas emissions. The emissions limitation commitments and trading mechanisms established by the Kyoto

Protocol give emission reductions an economic value. For the range of prices projected, the additional revenue generated by the sale of emission reduction credits is likely to be small; less than 5%. The quantity of credits generated by an energy efficiency project is small relative to the quantities typically transacted, so projects will need to be aggregated or bundled to reduce the transaction costs. ESCOs can aggregate credits generated by projects they implement, although they have as yet no experience in doing this.

Energy Efficiency Projects and Emissions Reductions

Energy efficiency projects are generally identified and developed by personnel or firms that are specialised in this field. Many large industrial firms have energy managers responsible for identifying opportunities to reduce energy costs. Smaller firms may retain an energy consultant, usually a professional engineer. Energy Service Companies (ESCOs) generally offer comprehensive energy services only to organizations which have an annual utility bill exceeding USD200,000. A defining characteristic of an ESCO [1,2] is that it will accept payment based on the actual performance of the project. ESCOs often invest in or arrange third-party financing of their projects

The development of energy efficiency projects follows the sequential steps of the typical engineering project development cycle. These are opportunity identification, pre-feasibility assessment, feasibility study, detailed design, construction, commissioning and operation.

Energy Audit

Opportunity identification and pre-feasibility assessment of energy efficiency projects are normally completed during the audit phase. Many industrial firms, commercial enterprises and households have their facilities audited by independent Energy Auditors, whose costs may be subsidised by government. The first step is usually a walk-through survey to determine the gross savings potential and decide if further work is warranted. If further work seems warranted, a systematic energy will then be conducted, having the following characteristics:

- *Facility Data Analysis*. This step uses utility bills, drawings and discussions with facility operators to determine the patterns and characteristics of energy use by the facility. Typically three or more years of utility bills will be analysed to identify historical patterns, including peak and average demand, and to correlate demand for fuels and electricity with weather, production and other drivers. Utility rate structures are assessed to identify opportunities for fuel substitution and load management. Normalised measures or Energy Use Indices, such as kWh electricity use per m2 building area or GJ per tonne of product, are calculated and compared with industry standards to assess the relative efficiency of the facility.

- *Baseline Energy Use*. This step develops a quantitative model of facility energy use. As the aim of energy efficiency projects is to reduce energy costs, the baselines are generally developed for the metering points where purchased fuels and electricity enter the facility or sub-metering points for major processes within it. The baseline (see section 4.2) is generally a simple engineering model of energy use calibrated against historical utility and weather or production data. Baseline data include the conditions, such as hours of operation, inherent in the consumption for a specific period. This analysis typically cites the major variable that will be addressed in developing the annual Adjusted Baseline.

- *Evaluation of Measures*. The energy saving each of the identified opportunities is estimated relative to the baseline and valued according to the utility rate schedules. Implementation costs are estimated and the opportunities ranked, usually in order of increasing payback period. The level of analysis is sufficient to identify which ECMs warrant implementation, which are included as recommendations to the client in an audit report.

The *Investment Grade Energy Audit* (IGA) has recently emerged as a better guide to investment opportunities. A study by Texas A&M of the predictive consistency of traditional energy audits found that <u>pre-qualified</u> engineers' predicted savings varied from actual savings by an average of 25%. Further analysis revealed that most auditors assumed that facility and process conditions viewed at the time of the audit would stay that way throughout the life of the project. The IGA attempts to assess how the energy saving measures will behave *over time.*

Project Feasibility and Design

Some ECMs are obvious and can be implemented at negligible cost. This is particularly true of operations and maintenance (O&M) energy efficient practices. An effective audit does not overlook the value O&M personnel can bring to a project, for example, correcting thermostat set-points to ensure that heating and cooling systems do not run simultaneously. One study, designed to evaluate the effectiveness of a US energy efficiency grants program found that up to 80% of the savings in an effective energy management program could be attributed to O&M energy efficient practices. Other measures, the ones of interest in this report, require a formal capital investment decision. Project feasibility and design studies provide the technical and financial analysis to support these decisions.

An engineer will normally undertake the feasibility study on behalf of the project investor, who may be the facility owner, an ESCO, a utility, a government agency or some combination of these parties. Section 3.4 describes the financing alternatives for energy efficiency projects, but the feasibility study ~~is~~ should be essentially the same for all investors and methods of financing. Those audits, however, that are backed by guaranteed results are usually more exact and increasingly reach IGA calibre.

The feasibility study will normally require more extensive site visits to obtain more detailed information. Original drawings, if available at all, usually have to be corrected to show actual dimensions and installed equipment. Investigations will focus on the particular processes affected by the proposed project, and may include field measurements and short-term monitoring of performance. These data will be used to construct and calibrate the project baseline.

A preliminary engineering design, sufficient to configure and size all equipment involved in the ECMs, will be undertaken. The complexity of the design process will depend on the project. In this, engineering models, ranging from simple algebraic formulas to sophisticated computer simulation programs, will be used to predict the performance of the new installation and the expected savings relative to the baseline conditions. Finally, a detailed project cost estimate will be prepared, usually using manufacturer's quotations for the major equipment and engineering estimates for labour and sundry items.

The engineer usually undertakes the project financial analysis. This is typically an 'engineering economic' DCF model [19] using the cost and performance data developed above with financial parameters provided by the client. The values assigned to these parameters depend on the client (who may be a facility owner, ESCO, or a utility) and the intended sources of finance. Financing options are reviewed in the next section.

The project is usually recommended based on IRR or NPV, but would not have been subject to feasibility study if it had not earlier satisfied a simple payback criterion. One of the main purposes for the financial analysis is to delineate the revenue and expenditure cashflows to ensure that the project can safely cover its recurrent financing costs.

For performance contracts, described in Section 3.4, a number of contract-related details must also be determined at the feasibility stage. These include specification of a method for baseline calculation and the measurement and verification procedures to be used. Following a decision to proceed with the project, additional detailed engineering design work, including preparation of working drawings, specifications, commissioning and acceptance procedures, construction schedules and tender documents, will normally be required.

Construction and Commissioning
Construction contracting options are well understood and standardised. Options are selected based on control of technical and financial risks. Most construction contracts terminate with the owner’s final acceptance of the completed installation, at the time of commissioning or after a short warranty period, and so do little to address long-term operational and financial performance risks. Performance contracts are an exception to this. The main alternatives are:

- *Owner-Builder*. Relatively small projects can be designed by the owner’s engineering staff and installed by maintenance personnel: re-lamping in a school or office, or motor replacement in an industrial plant, are examples of projects that can accomplished in-house. Larger projects can be undertaken with subcontractors managed by the owner acting as a general contractor. The owner accepts all design and construction risks.

- *Spec-Bid*. The owner contracts with a consulting engineer for a design and specification, and tenders the installation to construction contractors. The engineer often provides project management and construction inspection services. The owner usually purchases major equipment directly to avoid extra mark-ups by the contractor. This traditional approach puts the bulk of design and construction risks on other entities, though recourse will depend on a legal interpretation of contracts and the creditworthiness of the party at fault. The owner will still be at risk for the financial (energy savings) performance of the project.

- *Design-Build*. This is the most common contracting approach for complex process-oriented and heavy industrial projects. A single engineering-contracting organization takes responsibility for both design and construction and delivers the completed project on a ’turn-key’ basis. The project is defined in functional terms and acceptance is based on demonstrating functionality through commissioning tests. This approach reduces the amount of management time the owner must devote to the project and minimizes design and construction risk.

- *Performance Contracting*. This is a variation on design-build that is frequently used for energy efficiency projects. An Energy Performance Contract (EPC) is undertaken by an Energy Service Company (ESCO), specialized in the design and construction of energy efficiency projects. Unlike conventional design-build, some part of the contract is tied to the energy savings performance of the project, thus reducing or even eliminating the owner’s financial risk. EPCs are further discussed in Section 3.4 below.

Commissioning tests the completed installation according to pre-defined standards and procedures. Design and installation errors are found and corrected, defective equipment is identified and replaced, and the system is adjusted and tuned to perform as intended. The successful commissioning of the installation is normally a contract condition for acceptance of the engineer’s and the contractor’s work by the client. For this reason, an independent professional commissioning contractor often supervises the commissioning.

Some performance contracts determine the magnitude of energy savings achieved from the commissioning test result. In these ’one-time’ guaranteed savings contracts, there is no further requirement for measurement and verification (M&V) of ongoing savings. There is frequently an overlap of commissioning services and M&V procedures; so owners must guard against paying for the same service twice. As well, the establishment of contracted “base case” use is critical for the maintenance of the contract. If the ESCO perceives that base use has changed for reasons outside the boundaries of equipment performance (longer work hours in the building, for example), then it may wish to re-negotiate its contract and understanding of the base use.

Monitoring, Measurement and Verification
Both Energy Performance Contracts and Demand-side Management programs require ongoing monitoring of energy use and verification of energy savings. For EPCs, this is the central issue as contract payments will be tied to the savings actually achieved. To facilitate the negotiation of these contracts and to reduce the potential for disputes with clients, the ESCO industry encouraged the development of M&V protocols, the most widely used being the *International Performance Monitoring and Verification Protocol* (IPMVP), which was initially sponsored by the US DOE. **[23].**

The IPMVP provides four M&V options. The options provide generic approaches to the M&V problem. The choice of an option is based on consideration of the ECM, load variability, and the nature of the EPC contract. The engineering details of measurement are also covered in a host of other standards: the forthcoming ASHRAE Guideline 14P on *Measurement of Energy and Demand Savings* is specifically designed to be compatible with the IPMVP. The IPMVP options are:

- *Option A - Partially Measured Retrofit Isolation*: Savings are determined by partial field measurement of the process(s) affected by the ECM. "Partial measurement' means that some parameters are stipulated based on historical, comparative or commissioning data. For example, in a lighting retrofit the operating hours might be stipulated from historical experience, and the power draw of the lighting circuit measured periodically. This option is best suited to simple measures and steady loads. It is the least cost option to implement (0.5-3% of capital cost, 0.1-0.5% of operating cost), but provides the least accurate estimate of savings .

- *Option B - Retrofit Isolation*: Savings are determined by field measurement of both the performance and operational variables of the process(s) affected. Measurements may be continuous or periodic, or involve sampling. This option is indicated where savings are significantly affected by load variations or where equipment performance characteristics are nonlinear: a chiller retrofit would be an example. Compared to Option A, the cost is generally higher due to the greater frequency of metering (2-8% of capital cost, 0.5-3% of operating cost).

- *Option C: Whole Facility*: Savings are determined at the facility level from utility metering and possibly sub-metered data. The computational techniques used are similar those employed in audit phase facility baseline determination and involve adjustments for weather, production, occupancy, etc. This option is indicated where the process affected by the ECM cannot be measured directly (e.g. insulation retrofits and other envelope measures), or where there is a complex interaction between the ECMs and/or other processes; e.g., ECMs that significantly affect internal heat gains, EMCS installations). This option provides the clearest measurement of savings - at the utility meter - but separating the effect of the individual ECMs from other unrelated changes in demand can be difficult. Operating costs range from 0.5 to 3%.

- *Option D - Calibrated Simulation*: This is a further elaboration of the whole facility approach, used when the complexity of energy interactions defies conventional engineering analysis or when historical baseline data are unavailable. In this option, savings are determined by computer simulation. A base case model of the facility is developed using drawings, equipment specifications, load profiles and other information, and calibrated with utility, weather and other measured data. Savings are then calculated by introducing the ECMs (including measured field performance data) into the simulation. This option is indicated where the interactions are complex, nonlinear and/or dynamic. Building simulation models such as DOE-2 are themselves complex and require specialist skills to calibrate and use properly. The costs are typically 2-8% of capital cost and 0.5-3% of operating cost. Properly done, especially with **hourly data, it can be very accurate;** however, the relatively high costs are only warranted on large projects.

Energy Savings and Emission Reductions

Direct savings that occur at the owner's facility are the motivation for most energy efficiency projects undertaken by facility owners and ESCOs. Where energy efficiency results in reduced fuel consumption, there will be an associated direct emission reduction. The CO2 reduction depends on the carbon content of the fuel and ranges from 53.1 kg-CO2/GJ for natural gas to 92.2 kg-CO2/GJ for coal.

Additional indirect savings occur in the upstream energy supply systems as a result of reduced extraction, processing and transmission energy use. These indirect savings are most pronounced in the electricity supply system, where they provide the motivation for the majority of DSM programs.

Financial savings to the utility include energy-related savings in fuel purchases and load-related savings from deferral or avoidance of investment in new generating capacity. These depend on the impact of the efficiency measure on the load profile, which determines which of the utility's generating units is affected. When the marginal generating unit is fossil-fired, the ECM will produce an indirect emission reduction by reducing fossil fuel consumption at the utility. The CO2 reduction again depends on the carbon content of the fuel and ranges from 440 kg-CO2/MWh for combined-cycle natural gas units to over 1,000 kg-CO2/MWh for conventional coal-fired plants. No emission reductions are produced when hydraulic or nuclear generation is on margin.

Project Financing Options

Since the 1970's, when the potential of energy efficiency to reduce costs and national dependence on imported energy supplies was first recognized, a wide range of financing options have been developed for energy efficiency projects. In general these options seek to translate energy cost reductions into cash payment flows.

The impetus for this has been the low propensity of facility owners to invest in energy efficiency projects, even when they offer returns that are several times greater than the owner's cost of capital or the average return on investment within the sector. The existence of this 'efficiency gap' is attributed to various investment 'barriers', described in Chapter 5, that are somewhat unique to energy efficiency projects.

Owner Financing

The business of a facility owner is the production of some good or service for sale. Energy is just one among several factors of production, and usually accounts for a relatively small share of total production costs. The cost and availability of capital to the business is largely controlled by its earnings potential and creditworthiness. In consequence, the business will invest its scarce capital to maximise earnings and asset value. Cost reduction *per se* is not a primary objective, and most firms will prefer a revenue-producing to a cost-reducing project by at least 2:1.

Significant capital budgeting decisions will be based on a formal financial analysis such as provided by a project feasibility study. Though the decision may involve a host of considerations, it is related to a discounted cash flow criterion such as net present value (NPV) or internal rate of return (IRR). For generality, all considerations in the investment decision can be considered to be embodied in the IRR.

The IRR is the discount rate that makes the present value of project benefits exactly equal to the present value of project costs. If the IRR is greater than the investor's 'hurdle rate' the project is selected. The hurdle rate is the firm's opportunity cost of capital, the return the investor would normally expect from business investment, and a project-specific 'risk premium'. The risk premium includes the impacts of direct project risks (e.g. the savings are less than expected) and indirect project costs (on the firm's borrowing capacity and cost of capital for example). The risk premium is a subjective measure as no two investors will perceive risk in exactly the same way.

The financing choices available to a firm include use of retained earnings (equity), borrowing (debt) or leasing (expense). The first two options can affect the firm's cost of capital if the investment size is significant and possibly restrict its ability to respond to other investment opportunities. It should be noted that more than one of the following options can be used to finance a project.

- *debt* is usually the least-expensive source of capital, but its cost and availability depends on the leverage or debt-equity ratio of the firm. An important test for the use of debt is the project's coverage ratio, the ratio of net earnings to debt service costs. A high ratio indicates a high probability that the project can service its own debt.

- a *lease* is essentially a debt whose principal is not reported as a balance sheet liability: only the current period payment is shown as an expense on the income statement. This has the advantage of minimising impact on the client's debt-equity ratio and access to capital, but is generally available only for removable equipment. Leasing costs are only slightly higher than conventional debt.

- *equity* is the most expensive source of capital. The cost and availability of equity depends on the overall performance of the firm, earnings per share for public corporations and usually dividends per share for private corporations. The firm will invest as little equity as possible. The amount is determined by lender's requirements and the desired coverage ratio.

The empirical evidence is that facility owners generally demand very high returns on energy efficiency investments. A firm that enjoys an average return of 10% will often require a 50% or higher return from an energy efficiency project. Clearly, many investors are applying large risk premiums to these projects.

Energy Performance Contracting

Energy Performance Contracting (EPC) is an innovative arrangement that allows a facility owner to implement a comprehensive, customised package of energy efficiency improvements with limited risk, and often no front end capital costs to the owner. Most of the technical, financial and maintenance risk is the responsibility of a private sector company specialising in energy performance contracting services, typically an ESCO. The essence of energy performance contracting is that some part of the contract is based on the ESCO's performance in achieving energy savings.

Unlike a facility owner, selling energy savings is an ESCO's core business and primary source of revenue. The ESCO specialises in undertaking energy efficiency projects and as a result is better able to assess costs and manage the risks involved. Energy Performance Contracts through ESCOs address many of the investment barriers experienced by facility owners.

There are several types of Energy Performance Contract, depending on how risks and returns are shared between the performance contractor and the client [2,8] and on how the investment is apportioned between the performance contractor, the facility owner and third-party lenders. As an investor, the ESCOs decision-making approach is no different from that of the facility owner described above.

- *Shared Savings* contracts were the first type of EPC to be used. In these contracts, the ESCO is an investor receiving a percentage (typically 50%-70%) of the savings cash flow over the duration of the agreement. The ESCO assumes essentially all project risks, and expects commensurate returns. For the ESCO, financing is usually non-recourse and they may use their own capital or establish special private investment funds to undertake these contracts. In part because the ESCO's investment is not fully disclosed, clients are often suspicious that the ESCO could be receiving a 'windfall' at their expense, even though they would not have undertaken the project themselves. Since shared savings contracts are predicated on the future (often unstable) price of energy, they have fallen into disfavour. For the client, a shared savings provides the advantages of an "off balance sheet" transaction.

- *Paid from Savings* contracts (also referred to as *First-in, First-out* contracts in Canada) are debt instruments, where the ESCO is an intermediary between the project lender and the client. The ESCO takes most or all of the savings (typically 70% or more) and guarantees that that the savings will be sufficient to pay off the debt within the loan term (typically 7 years). These contracts are a type of shared savings, and are often offered by OEM ESCOs for specific pieces of equipment. The contract will normally allow the ESCO to make additional energy efficiency improvements at its own cost, should the savings be insufficient to meet the debt obligation. Any deficiency in debt repayment is the responsibility of the ESCO. Windfalls - savings greater than expected - either accrue to the client or are shared in an agreed manner with the ESCO. The interest rate charged on the loan depends on whether the ESCO or the client is considered to be the credit risk, and the loan is treated as unsecured.

  A *Paid From Savings* contract generally has a shorter term and is more transparent than a shared savings contract. This contract can also be set up as an off balance sheet transaction. Shared Savings and Paid from Savings contracts can work to the detriment of the consumer if energy prices or the level of savings increase unless a payment cap is stipulated in the contract.

- *Guaranteed Savings* contracts provide a guarantee from an ESCO that a minimum level of energy savings will be obtained in an otherwise owner-financed energy efficiency project. The owner can invest internally generated or borrowed funds, the cost of which depends on the strength of the owner's balance sheet and the investment opportunities available. The ESCO guarantee may be 'one-time', that a certain level of savings is demonstrated at the time of commissioning, or 'on-going' for a specified period of time (usually 5-10 years). The owner contracts directly with lenders for project financing. Most commonly, the owner is obligated to pay the debt in full, and the ESCO guarantees that the value of the energy saved will satisfy the debt service obligations unless the price of energy goes below a specified floor price. A disadvantage to the owner is that a guaranteed savings transaction cannot be done off-balance sheet.

The EPC business arrangement requires that the owner and the performance contractor enter into a long-term relationship (typically up to 10 years) since both parties will have a direct interest in how the facility is operated and the savings calculated. These interests may sometimes conflict. Because of the transaction costs involved for energy audit, proposal submission and contract negotiation, ESCOs generally require a minimum US $200,000 project value before considering an EPC approach.

In North America, performance contracting has been most frequently used in the institutional building sector, where hospitals, schools and university buildings are built for specific purposes and have a relatively consistent level of use and occupancy over a long period of time. Commercial buildings tend to have greater fluctuations in use, ownership and occupancy. This makes a performance contract more complex, and the evaluation of energy savings over time more difficult. There has been relatively little use of performance contracting (or ESCO activity) in the industrial sector, as manufacturers are generally reluctant to place any aspect of their production process in the hands of an outside company. For most industrial facility managers, the upside potential of gains in energy efficiency, which represent small savings in production costs, is far outweighed by the considerable risk of interfering with production. Many of the EPC projects that have been undertaken have been limited to plant utilities such as heating, cooling, or compressed air.

- *Chauffage Contracts ("heating")* originated as a French term for district heating contracts and refers to any contract where energy supply as well as energy efficiency is provided by the ESCO. Sometimes the term "chauffage" is used to apply only to the supply of end-use energy or to asset monitization. For example, a hospital or an industrial plant may sell its boiler house to an ESCO and take back a chauffage contract for the supply of steam and possibly electricity at specified prices. The ESCO will normally upgrade the plant and provide all maintenance and operating personnel.

In these contracts the customer pays for a conditioned environment by the square foot or square meter. The customer may enjoy savings by avoiding the need to invest in plant upgrades, eliminating ongoing maintenance and staffing costs, improving the reliability of supply and by stabilizing or even lowering energy prices. Often however, the main motivation to enter into a chauffage contract is that the customer is free to concentrate on their core business.

Chauffage contracts typically have a longer-term, perhaps as long as 20-30 years, and often involve large asset values. The ESCO is the owner/operator and evaluates their investment as the acquisition of a productive asset. The main risk to be considered is the long-term viability of the customer's business, as the customer is the sole market for the plant output. Depending on the creditworthiness and track record of the ESCO, up to 80% of the project cost can usually be debt financed with the balance equity financed by the ESCO.

Demand-Side Management

DSM programs are based on avoided costs, where a portion of the savings enjoyed by the utility as a result of ECM is shared with the customer undertaking the measure.

Demand Side Management (DSM) programs are undertaken by energy supply utilities to influence customer energy use and produce desired changes in the magnitude and timing of the utility's load. Energy efficiency measures, as well as peak load reduction and load-shifting measures, are encouraged at customer facilities. Customers are given financial incentives, based on the utility's savings, to undertake these measures.

Energy savings at customer facilities in DSM programs can again be measured and verified using the appropriate IPMVP options. The determination of savings to the utility is a little more complicated because it may need to account for 'free riders' (who would have implemented the ECM without receiving the DSM incentive) and 'spillover' or 'market transformation' effects (where the DSM program induces others to implement the ECM without the program incentive). A variety of social science techniques, including surveys and control groups, are frequently used to estimate these effects. In practice, the utility responsible for delivering the EE programs will simply subtract these participants from the gross savings. The net result is the "discounted" savings for the program. It is akin to the notion of additionality. Section 4.2 discusses baseline setting for DSM.

Utilities will often contract with ESCOs to purchase savings they have obtained at customer facilities. In these contracts, the ESCO has a contract with the utility to reduce demand or energy (or both) to an agreed upon level. Note that during the 1990's, 87% of the bid DSM in the U.S. was performed by ESCOs.

Other Sources of Finance

Other parties that may provide financial incentives for energy efficiency projects include governments and, in a few cases, mortgage lenders. Governments frequently provide financial incentives and programs to encourage energy efficiency investments. The most common of these are:

- information programs, to raise awareness of energy efficiency measures
- labelling programs, to make equipment energy use clearer to purchasers
- audit programs, subsidizing all or a portion of the cost of energy audits
- grants, subsidizing a portion of the cost of implementing ECMs

Some mortgage lenders, notably FNMA ('Fanny Mae') in the US, consider energy costs in determining the mortgage-carrying capacity of their customers. Most customers have used this to purchase larger energy-efficient homes than they could otherwise afford.

References

1. Anon., *The Energy Service Industry: The Experience of the United States and Canada*. Washington, US: World Bank, Energy Sector Unit, Occasional Paper 12, 1999 at http://www.worldbank.org/

2. Bullock, C. and G. Caraghiaur, *A Guide to Energy Service Companies*. Liburn, US: Fairmont Press, 2001.

3. Dales, J., *Pollution, Property and Prices*. Toronto, CA: University of Toronto Press, 1968.

4. Dixit, A. and R. Pindyck, *Investment Under Uncertainty*. Princeton, NJ: Princeton University Press, 1994.

5. Ellerman, A, et al., *Emissions Trading Under the US Acid Rain Program: Evaluation of Compliance Costs and Allowance Market Performance*. Cambridge, US: MIT Center for Energy and Environmental Policy Research, Report 97-xxx, 1997 at http://www.ceepr.mit.edu/

6. Haites, E. and F. Mullins, *Linking Domestic and Industry Greenhouse Gas Emission Trading Systems*. Geneva, CH: International Emission Trading Association, 2001 at http://www.ieta.org/

7. Hansen, S. and J. Weisman, *Performance Contracting: Expanding Horizons*. Liburn, GA: Fairmont Press, 1998.

8. Hirshleifer, J. and D. Hirshleifer, *Price Theory and Applications*. Upper Saddle River, US: Prentice-Hall, 6th ed., 1998.

9. Hirst, E. and J. Reed, *Handbook of Evaluation of Utility DSM Projects*. Oak Ridge, US: Oak Ridge National Laboratory, Report ORNL/CON-336, 1991.

10. IEA, *International Emission Trading: From Concept to Reality*. Paris, FR: International Energy Agency, 2001.

11. Janssen, J., *Risk Management of Investments in Joint Implementation and Clean Development Mechanism Projects.* St. Gallen, CH: University of St. Gallen, Institute for Economy and the Environment, Ph.D Thesis, 2001 at http://www.iwoe.inisg.ch/kyoto

12. Krarti, M., *Energy Audit of Building Systems*. Boca Raton, US: CRC Press, 2000.

13. Natsource, Review and Analysis of the Emerging International Greenhouse Gas Market. Washington, US: World Bank, 2001 at http://www.prototypecarbonfund.org/docs/Natsource_public_report_final.pdf

14. Ross, M., "The Capital Budgeting Practices of 12 Large Manufacturing Firms" in *Financial Management* 15(4):15, 1986.

15. Ross, S., *An Introduction to Mathematical Finance*. Cambridge, UK: Cambridge University Press, 1999.

16. Skea, J. and S. Sorrell (eds.), *Pollution for Sale: Emissions Trading and Joint Implementation*. Aldershot, UK: Edward Elgar, 1999.

17. Swisher, J., et al., *Tools and Methods for Integrated Resource Planning: Improving Energy Efficiency and Protecting the Environment*. Risø, DK: UNEP Collaborating Center on Energy and the Environment, 1997 at http://

18. Szonyi, A., et al., *Principles of Engineering Economic Analysis.* Toronto, CA: John Wiley, 1982.

19. Tietenberg, T., et al., *International Rules for Greenhouse Gas Emissions Trading*. Geneva, CH: United Nations Conference on Trade and Development, Report UNCTAD/GDS/GFSB/ Misc.6, 1999. http://www.unctad.org/en/subsites/etrade/publications.htm

20. ---- ibid., *Emissions Trading: An Exercise in Reforming Public Policy*. Washington, DC: Resources for the Future Inc., 1985.

21. Thumann, A. and F. Wainright, *Financing Energy Projects Deskbook*. Liburn, US: Fairmont Press, 2000.

22. UNFCCC, *Marrakech Accord under the Framework Convention on Climate Change*. New York, US: United Nations, 2001 (unedited draft) at http://www.unfccc.int/cop7/docs/accord_draft.pdf

23. USDOE, *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy Savings*. Report MVP2000. at http://www.ipmvp.org/

24. Weyant, J. (ed.), *The Costs of the Kyoto Protocol: A Multi-Model Evaluation*. Cleveland, US: International Association of Energy Economists, Special issue of Energy Journal, 1999.25.

25. Buchner, Barbara, Carlo Carraro and Igor Cersosimo, "On the Consequences of the U.S. Withdrawal from the Kyoto/Bonn Protocol," Nota di Lavoro 102.2001, Fondazione Eni Enrico Mattei, Milan, DECEMBER 2001, at: http://www.feem.it/web/activ/_activ.html

4. Baseline-Setting in Energy Efficiency Projects

4.1 Introduction

A baseline is a reference level used to quantify the change in a system brought about by an activity. The base year, usually 1990, greenhouse gas emissions of Annex B countries are used as reference levels or baselines for measuring their emission reductions under the Kyoto Protocol. The allocations made to participants under a cap-and-allowance trading system are baselines.

For energy efficiency and emission reduction projects, the baseline is often defined as 'what would have happened in the absence of the project'. While the baseline is still a reference level in this case, its determination requires answering the counterfactual question "what would have happened". Such baselines are necessarily hypothetical and uncertain.

Energy baselines are established for energy efficiency projects undertaken through performance contracts and used to determine the energy savings achieved. Methods for the development of energy baselines are well established and widely accepted. The IPMVP offers strong guidance in establishing a historical “base year” and procedures to adjust annual baselines. Calibrated engineering models that predict baseline energy consumption as a function of observable meteorological and operating parameters. While counterfactual, the uncertainties in the energy baseline estimates stem largely from technical issues of model specification and measurement uncertainty and can be quantitatively assessed.

Emission baselines are established for emission reduction projects and used to determine the emission reductions achieved. While the technical quantification of emission baselines is similar to that of energy baselines and uses calibrated engineering models of emissions, there are a number of other considerations. The most important of these are leakage and additionality. Leakage is concerned with external emissions impacts of the project and additionality with the likelihood the project would have been undertaken or emission reductions produced in the absence of emission trade.

This chapter begins by reviewing the practice for setting energy baselines in energy efficiency projects, and then turns to an examination of the new issues that arise in defining emission baselines. An approach to developing emission baselines for energy efficiency projects that builds upon familiar energy baseline methods is then described. The chapter concludes by describing methods for assessing leakage, additionality and uncertainty in emission baselines.

4.2 Current Practice for Energy Efficiency Baselines

Energy efficiency baselines were briefly introduced in section 3.3 and their role in the project development cycle described. This section introduces the more technical aspects of baseline construction for energy efficiency projects.

Criteria and Use of Energy Baselines

The term 'baseline' can refer to many things in an energy efficiency project, distinguished by level of analysis and degree of detail. By level, a baseline can be established for a process, an individual facility, or a program involving many facilities; by detail it can be the cursory baseline of a preliminary energy audit or the detailed baseline of a specific project feasibility study.

A facility baseline is determined in an energy audit and used to screen and rank energy efficiency measures. More detailed facility baselines may be prepared where warranted to establish the feasibility of projects, in particular to relate project energy savings to metered quantities. Process baselines are normally prepared during the feasibility studies for specific projects.

The baseline is a key part of a performance contract between an ESCO and a client. The baseline in this case serves to define the legal basis for contract payments. These baselines are determined for a specific project and may or may not be same as the facility baseline. Most ESCO projects are retrofits and their baselines are calibrated with historical, pre-project data. Although the baseline is adjusted for demand and load changes, due to weather or occupancy for example, the basic assumption is that the pre-project conditions would continue in the absence of the energy efficiency project for the duration of the contract. Exceptions to this assumption include: 1) contract provisions so variables for annual baseline adjustments are established; and 2) contract language, usually referred to as a re-open clause, that provides for a renegotiated historical baseyear to accommodate significant material changes.

Demand-Side Management (DSM) programs and other multi-project initiatives implement the same energy efficiency measure at multiple sites. Experience indicates that at least some of the sites are likely to have implemented the measure in the absence of the program, these sites are called 'free riders' because they collect the incentives offered for actions they would have implemented anyway. The energy savings achieved by program participants must be reduced by those of the free riders to get the energy savings attributable to the program. In some cases a program affects such a large share of the actions that it induces energy savings by non-participants (often termed "free drivers"). The energy savings by non-participants can be attributed to the program in such cases. The need to adjust the estimated savings of participants has implications for the monitoring and verification procedures; in particular control groups and sophisticated statistical analyses may be needed to estimate the energy savings due to the program.

There are no specific or mandatory standards for energy efficiency baselines, though a number of widely accepted approaches exist. International Performance Measurement and Verification Protocol offers international consensus of accepted procedures, but is not a mandatory standard.

Modelling of Energy Use

An energy baseline is an engineering model of greater or lesser complexity that predicts energy use as a function of empirical variables and parameters. The choice of a baseline model is based on the specific objectives and processes involved and it is impossible to discuss all of the possibilities here. Instead, this section attempts to give a general overview of the procedures and issues involved.

Judgement is required in developing or selecting a model that is appropriate for the problem at hand. A major constraint is the quality and availability of data, particularly over the full range of operating conditions. This often dictates the form of the model, and strongly influences its predictive accuracy. At the facility level, gas and electric utility billing records provide reliable data on the total use of these energy forms, generally reported on a monthly basis. Other fuels, such as coal or oil, are not continuously metered and their total use may only be known on a seasonal or annual basis from purchase records. Historical weather data is usually readily available for the period of interest. Regardless of techniques, there is a significant body of literature supporting the various approaches and the standardized approaches are well accepted.

Calibration and Acceptance

Calibration involves estimating model parameters from known or measured data, analyzing the quality of the fit to that data and possibly revising the model. Ideally the completed model will be tested with a data set not used for its calibration.

Section 4.8 describes a method to estimate uncertainties in physical measurement. This section discusses uncertainty in regression models. There are three main types of error in regression models:

- *Mis-specification Errors* arise when the functional form of the model does not correctly represent the process being modelled. A linear model might be assumed when significant nonlinearities are present, important variables might be neglected or irrelevant variables included. This introduces both systematic and random errors in the model results. Mis-specification errors can be detected by studying the pattern of the model residuals (differences between measured and predicted values) and minimized by understanding of the underlying physical processes.

- *Prediction Errors* arise because even a perfectly specified model must be calibrated with measured data that is subject to random error. As a result, the model will not account for all of the variability in the measured data (so its $R^2 < 1$) and the regression coefficients determined must also be considered random variables. In the absence of mis-specification and extrapolation errors, the prediction error of an ordinary least squares regression should be unbiased.

- *Extrapolation Errors* arise when the model is used with input values outside of the range of values with which the model was calibrated. As discussed above, it is a common problem that records will not exist for important process data such as equipment loading profiles or operating schedules. The missing data is filled in with short-term measurements, which may not be representative of the full range of operating conditions. The result is a systematic error, biased towards the calibration data.

The uncertainty analysis procedures given in standard texts on linear regression do not always apply to energy baseline models, because of nonlinearities introduced by the change point behaviour: [21] describes uncertainty analysis procedures for energy baseline models.

In the end, the acceptability of an energy baseline is largely a negotiated issue. If the client is satisfied with the contract payments likely to be triggered by the proposed baseline, the baseline is acceptable.

4.3 Emission Baselines: Issues and Options

An emission baseline predicts the quantity of emissions that would be expected from a process, facility or group of facilities in the absence of some action.

Indirect Emission Impacts - Ownership

An energy efficiency project will have a direct impact on emissions within the facility, and an indirect impact on emissions outside of the facility. A high efficiency boiler retrofit for example will have a large impact on combustion-related emissions within the facility, and a (usually small) impact on emissions related to the production, refining and transport of that fuel. A lighting retrofit will have a (usually small) direct impact on heating load and related emissions with in the facility, but may have a significant impact on the electric utility's emissions. The indirect emission impacts of energy efficiency projects are generally confined to the affected fuel and electricity supply sectors. Ownership of the indirect emission reductions due to energy efficiency projects may be unclear; do the reduced emissions of the electricity generating unit belong to the electric utility or the customer implementing the efficiency measures?

Indirect emission reductions, when they occur in a capped sector, confer economic benefits on that sector because they result in surplus tradable allowances. If the emissions of electricity generators are capped, allowances equivalent to the indirect emission reductions could be transferred to the energy efficiency projects that created them. Then the electricity generators would buy them back at the prevailing market price or implement other emission reduction actions to achieve compliance. If energy efficiency projects were allowed to claim credit for these indirect reductions without the transfer of affected allowances, the reductions would be counted twice. If energy efficiency projects are not able to claim the reductions, the electricity generators would be able to increase their emissions at no cost. This is an issue in trading system design and registry accounting. The accounting issues are easy to solve for indirect reductions in the electric power sector, the most important sector where this occurs.

Leakage

Increased emissions at other sources due to a project are called leakage. Leakage usually involves an intentional or unintentional shift of activity from a participating site to other facilities. Energy baselines are normally bounded at the customer's facility and, except in the case of DSM, do not consider such 'external' impacts. Leakage is usually not a significant concern for energy efficiency projects since they tend to reduce costs and hence do not induce shifts in activity. However, if a project replaced a boiler with steam from a cogeneration facility and did not count the emissions associated with the steam production, those emissions would constitute leakage. The estimated savings for a project should be reduced by any leakage.

Leakage can impose costs on others. These include increased compliance costs for the affected sectors, if their absolute emissions are subject to regulation or to the national economy if it has an allocated amount under the Kyoto Protocol. This is a particular concern for countries that transfer JI credits to investor countries. For these reasons, a project's credited emission reductions should be net of leakage to the extent that the emission increases at other locations can be practically determined.

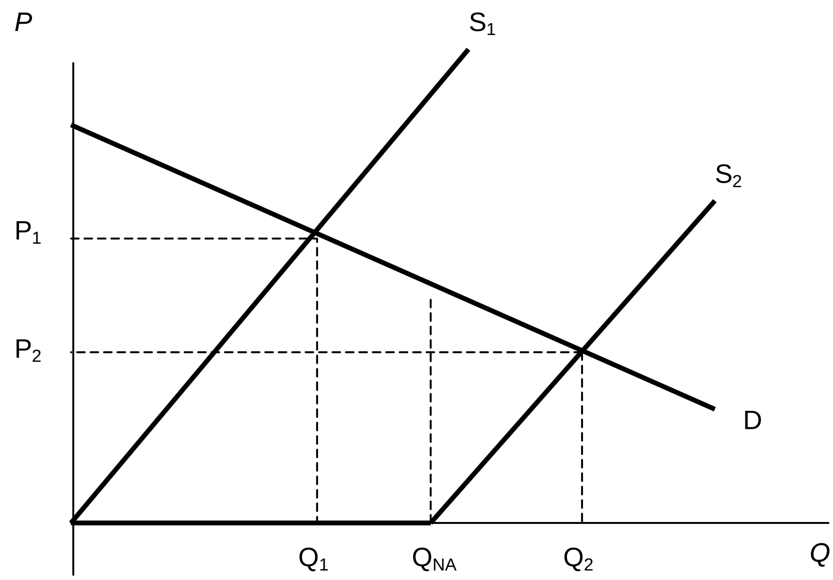
Additionality

Additionality is the 'degree to which the emissions reduction would not have otherwise occurred'. The Kyoto Protocol requires that emission reduction projects be additional, but does not specify how this will be determined. Two main types of additionality are discussed in the literature: environmental additionality asks whether the emission reductions would occur without the project, and financial additionality asks whether the project would have been undertaken without the economic incentive offered by emission trade [x]. Under the Marrakech Accords, only environmental additionality is a requirement for project approval, but financial additionality could be used as an indication of environmental additionality.

Figure 4.1 illustrates the consequences of crediting non-additional emission reductions [3]. As a non-additional project would have been implemented 'anyway' for other reasons, the emission reductions produced are supplied at no cost. If allowed into the emissions market, the credits will crowd out the supply of real and additional emission reductions, shifting the supply curve from S_1 to S_2, lowering the market price and reducing the gains from trade. Society, through credit purchasers, pays a total of P_2Q_{NA} to these suppliers to acquire what are otherwise free emission reductions. Finally, as these credits can be use to justify emission increases by the purchasers, total emissions are as much as Q_{NA} greater than the Q_1 that would have been obtained if only fully-additional credits had been allowed.

Additionality is not considered in determining energy efficiency baselines for performance contracts, but is an issue in DSM programs. A 'free rider' is someone who receives a financial incentive through a DSM program for implementing an energy efficiency project or measure that they would have undertaken in the absence of the program. The energy savings attributed to these free riders are financially non-additional and regulators require that they be estimated and deducted from the savings reported by the program.

Figure 4.1
Effect of Crediting Non-Additional Emission Reductions



If it can be established that the project would not have been implemented otherwise, is financially additional, environmental additionality is generally easy to determine. It is sufficient to show that 1) the emission reductions are a direct consequence of the project, 2) they could not occur in the absence of the project and 3) neither the project nor the reductions are legally required for any reason. The first two conditions establish that it is the project and only the project that produces the reductions (the reductions are 'real'). The third establishes that the reductions were made voluntarily (they are 'surplus').

Given these conditions, it should be noted that laws and regulations requiring emission reductions have the consequence of removing the financial incentives. Such regulations move emissions reduction out of the market place and into a command and control economy.

Financial additionality is difficult to evaluate, some would say impossible as it requires determining the investor's intent. Given the economic and environmental consequences of crediting non-additional reductions described above however, the issue cannot be ignored. There are two main approaches available to evaluate the financial additionality of projects:

- *Behavioural Models* attempt to estimate the likelihood that an investor would actually implement a project in the absence of emission reduction incentives. These are the same DCF models as used in project feasibility assessment, but with hurdle rates and other parameters adjusted to reflect actual investment behaviour. In the case of energy-efficiency projects for example, it is well known that investors will apply much higher hurdle rates than neo-classical theory would predict. The main problem in developing such models is to determine, from empirical data, how the parameters should be modified for a particular project or investor. Chapter 6 describes a behavioural model for energy efficiency projects.

- *Control Groups* are comparable groups of investors who can be questioned about their willingness to invest in projects similar to the one being evaluated. Such groups have been frequently used to evaluate free rider effects in DSM programs. The main problem here is in finding an adequate control group, one that is representative of the investment behaviour being investigated and yet truly independent in its decision making. As emissions trading proliferates and begins to influence energy and other prices throughout the economy, it will become increasingly difficult to find control groups that are not already influenced by it.

Baseline Quality

A baseline is an estimate of what the emissions would have been in the absence of an emissions reduction project. The baseline can not be observed; it can only be estimated. A baseline therefore involves judgement as to what is a reasonable estimate. Since project proponents and credit purchasers have an incentive to exaggerate the baseline -- claim that emissions in the absence of the project would be higher to increase the credits received -- independent review of proposed baselines is essential to ensure environmental integrity. A baseline is more likely to be accepted as being a reasonable estimate of what the emissions would have been by an independent expert if it is:

- T*ransparent*: all data, methods and assumptions used in defining the baseline and quantifying the emission reductions are clearly and publicly disclosed.
- *Replicable*: the procedures and methods used to calculate the baseline are sufficiently well documented that an independent analyst or evaluator will obtain the same baseline for a given project.

Analysis of the uncertainty associated with a proposed baseline will enhance its quality. Sources of uncertainty include unknown measurement and statistical regression errors, which can be readily quantified, and the more fundamental uncertainties regarding the adequacy of baseline construction methods, financial additionality evaluation or the completeness of information provided by the proponent, which are much more difficult to quantify.

Analyses of sources of uncertainty can also help reduce transaction costs while ensuring adequate rigor. The uncertainty analysis identifies which assumptions, measurements and inputs have the biggest impact on the estimated emission reductions. Resources can then be focused on reducing those sources of uncertainty rather than on reducing sources of uncertainty that will have little impact on the quantity of credits issued.

Methodological Options

A comprehensive review of the methods proposed for emission baseline determination is found in Ellis [5]. Ellis identifies 22 different methods for determining baselines, but it is possible to generalize the approaches used. Table 4.1 shows a simple classification of baseline construction options.

Table 4.1
Baseline Construction Options

Scope	Type	Information Source
Single Project	Historical: retrofit	Bottom-up from specific project
	Comparative: greenfield	
Multi-Project	Performance benchmark	Technology + project specific
	Technology benchmark	Technology only
	Objective benchmark	Top-down from emission targets

Baselines may be constructed bottom-up from project-specific information or top-down from the country's Kyoto commitment (for an Annex B country) or a reference economic scenario (for non-Annex B countries). The various other methods proposed are distributed between these two poles.

Single-project baselines rely exclusively on project specific information. This is the only approach available in the absence of standardized methods and has been the most frequently used approach to date. Most projects have been retrofits to a pre-existing system and their baseline has been constructed from historical performance data. Where there is no pre-existing condition, another 'typical investment' project for which historical data is available can be proposed as a baseline. Compared to the multi-project approaches, project specific baselines are much more expensive to construct and justify, more difficult and subjective to evaluate and more amenable to gaming.

Multi-project baselines are standard baselines, or standard methods for baseline construction, that can be applied to projects of a specified type. These baselines generally use pre-defined 'benchmark' parameters, usually in conjunction with project-specific information. Benchmark parameters may include standard emission factors for specific fuels or technologies as well as standard equipment efficiencies, operating conditions, etc. The benchmarks can be based on average performance, average new installation performance or best available technology performance. At the extreme, a 'top-down benchmark' can be defined as the emission rate per unit physical input or output that meets a targeted emission level. Top-down benchmarks are especially suited to hybrid trading systems, where they can ensure the environmental equivalency of surplus allowances and project-based credits.

4.4 Proposed Approach for Energy Efficiency Projects

The sale of emission reduction credits can have a significant impact on the net cashflow from energy efficiency projects at prices expected within the first commitment period. The magnitude of the increase depends of course on the energy conservation measures (ECMs) being implemented, the fuels displaced, credit transaction costs and the prices offered for credits. The primary motivation for undertaking these projects will continue to be energy cost savings, but the incremental income from credit sales may be the decisive factor that makes otherwise infeasible energy efficiency projects worth undertaking. For this reason, the evaluation of emission reduction crediting opportunities should be made an integral part of energy efficiency analysis and project development.

Overview of the Method

The proposed integration of emission reduction credit assessment into the conventional energy efficiency project cycle is illustrated in Figure 4.2.

Pre-Conditions. The pre-conditions determine the energy baselines developed in later stages of the project cycle. Most energy efficiency projects are retrofits to an existing process or facility, and the pre-conditions are described in the energy audit. The pre-condition can also be a design for new construction. To reduce ambiguity and gaming, the proposed design should represent 'typical' practice for that class of construction and meet all existing energy efficiency codes and standards.

Opportunity Identification. Opportunities to reduce energy costs are identified through energy audits as described in Section 3.2. For new construction, the same procedures can be followed to identify energy-conserving design changes. There is of course no historical data at the design stage, so the cost and performance of ECMs must be based on engineering estimates. The conventional energy audit is expanded to include emission estimates. Standard emission factors appropriate for the fuels used in the locality are applied to the facility baseline and ECMs identified in the audit. ECM costs and benefits are valued with and without credit sales and ranked in order of increasing payback period.

Figure 4.2
Assessing Emission Reductions in the Energy Efficiency Project Development Cycle

Energy Efficiency	Development Stage	Emission Reduction
	Pre-conditions (Existing or Proposed) ⇓	
• facility baseline • ECMs: conservation measures • ECM paybacks w/o credits	Audit/Opportunity Identification ⇓ Initial ECM Selection ⇓	• facility emissions • ECM emission reductions • Emission reduction credit valuation • ECM payback w/credits
• ECM baseline model • ECM cost, performance • financing options • ECM - M&V plan • project IRR w/o credits	ECM Feasibility ⇓ Final ECM Selection ⇓	• impacts/boundaries • emission reduction baseline model • emission reduction - M&V plan • transaction costs • credit sales options project IRR w/credits
	GHG Project Approvals ⇓ Implement/Commission ⇓	• project documentation • additionality of credits • alternate project • reference project
• actual energy savings • EPC payments?	Monitor/Verify	• actual emission reductions • credit sales revenue

Initial ECM Selection. The selection of ECMs to consider for possible implementation is generally based on payback. It is possible that the investor may apply different payback criteria to energy savings and emission credits. The former has mainly technical and procedural risks and these can be assumed by an ESCO under a performance contract. The latter have market and regulatory risks that are much more difficult to estimate or control. It is expected that the investor will first select the ECMs that meet the payback criterion without credits, and then consider additional ECMs that meet the criterion only with credits. Note that in some cases, where credit value is low and transaction costs high, it will not be worthwhile to claim credits for an otherwise attractive ECM.

ECM Feasibility. The changes required up to this point in the development cycle are quite simple and easily implemented by energy auditors. The most extensive changes occur at the feasibility stage and require that practitioners, including engineers and ESCOs, become familiar with several new and arcane concepts unique to emission trade. Again, a ’with credits’ analysis is undertaken in parallel with the conventional ’without credits’ analysis.

The 'without credits' case, described in Section 3.3, is done first. It provides: an energy baseline for the ECM at the process or facility level; an estimate of the performance of the ECM and the expected reduction from baseline energy consumption; a financial strategy for implementation of the ECM, which may include owner or ESCO financing; and a project DCF analysis. Any energy efficiency project should include a measurement and verification (M&V) plan, which will specify the procedures for measuring and calculating baselines and energy savings and include these costs in the project budget.

The 'with credits' case is similar to the previous case, but addresses leakage, additionality and other new issues. It provides: a specification of the project boundary and emissions affected by the ECM; an emissions baseline; an estimate of the expected reduction from baseline emissions resulting from the ECM; an analysis of the emission-related transaction costs and credit sales revenues; and a new project DCF analysis. There are five main steps in this analysis:

1. *Establish Project Boundaries*: This step identifies all emissions that are significantly affected by the project. The object of an energy efficiency project is to reduce the energy demand of a process and hence the energy expenditure of the facility. This will influence both fossil fuel-related emissions within the facility (direct impacts) and beyond it (indirect impacts). The direct impacts within the facility can be derived from the previous energy analysis, but the assessment of impacts on surrounding systems is new. The project boundary is set to include all significant direct impacts -- indirect emission reductionsin the fuel and electricity supply systems or leakage occur outside the project boundaries. Procedures for determining project boundaries are discussed in Section 4.5 below.

2. *Develop Emission Models.* With the project boundaries established, the next step is to develop emission models. These are engineering models of emissions, very similar to the energy models previously discussed, used to quantify baselines and emission reductions. There may be several baselines and reductions to quantify. Baselines for direct reductions are generally modified versions of the energy baselines calibrated with process or facility emissions data. Indirect reductions will require models to be developed and calibrated for energy suppliers such as electricity generators. Leakage will require models of emissions due to increased activity at other sources. Section 4.6 discusses the construction of emission models and baselines.

3. *Prepare Measurement and Verification Plan*. Trading rules and the preferences of credit purchasers will largely dictate the measurement and verification requirements for emission reductions. Given this, the measurement and verification plan must collect the data needed to calibrate and adjust the emission models and reliably quantify emission reductions. Only requirements that are incremental to the energy measaurement and verification plan are included in this.

4. *Estimate Credit Price and Transaction Costs*. The transaction costs include the incremental measurement and verification costs above as well as any other costs required for documentation, approval and marketing of the emission reductions. The credit price may be based on a known offer, the opinion of an emissions broker or be estimated using the methods described in Sections 3.5 and 3.6.

5. *Financial Analysis*. The incremental costs and revenues from emission credit sales are added to the 'without credits' ECM project cash flow and a 'with credits' IRR is calculated. Both cases, with or without credits, are evaluated in comparison to the project pre-condition.

Final ECM Selection. The ECM is implemented if its IRR exceeds the investor's minimum acceptable rate of return or 'hurdle rate'. This is the investor's opportunity cost of capital, the return the investor can obtain from other readily available investment opportunities, adjusted for project risk. As noted in Section 3.4, facility owners tend to apply high hurdle rates to energy efficiency projects, because of the higher perceived risks of energy efficiency projects and a variety of investment barriers that are peculiar to these projects. ESCOs apply hurdle rates more typical of productive investments. The same hurdle rate should be applied to both cases as the overall project risk is little changed by the addition of emission reductions.

GHG Project Approvals. Approval of the greenhouse gas emission reduction claims will normally be sought following the final ECM selection and before project construction. This might be considered to be an element of the feasibility study process, as it reduces regulatory risks in the investment decision. The approval authorities may include the administrators of domestic trading systems, host and donor governments approving JI or CDM projects, the CDM Executive Board and others, Supplementary greenhouse gas emission reduction financing and/or credit purchase commitments may also be sought at this stage.

The first step is to document the project in the form required by the authorities whose approval is sought. At this early stage of market development, few formal standards for greenhouse gas emission reduction project documentation exist, though there is little dispute over the kind of information that must be provided. Most of the information required can be obtained directly from the feasibility study described above. The Project Design Document for CDM projects provides a comprehensive list of the relevant information. Where documentation standards do not exist, the documentation guideline developed by Clean Air Canada [15] can be used. Approval authorities will pay particular attention to:

- the project definition, its proposed boundaries and impacts
- satisfactory demonstration of environmental additionality
- the reasonableness of the emission baseline, and
- the adequacy of the proposed measurement and verification plan.

GHG investors and credit purchasers will also be concerned with:

- the adequacy of the project financing and development plan
- maintenance plans and the reliability of future credit deliveries, and
- the creditworthiness of the project participants, should things go wrong

Host governments for JI and CDM projects will seek assurance that the emission reductions are financially additional, because the transfer of credits out of the country will potentially constrain their future greenhouse gas emission reduction options and increase mitigation costs. This is a sovereign decision. Domestic programs must also be concerned to ensure financial additionality for the reasons explained in Section 4.3 above, but can often eliminate the need for a specific test through appropriate program design.

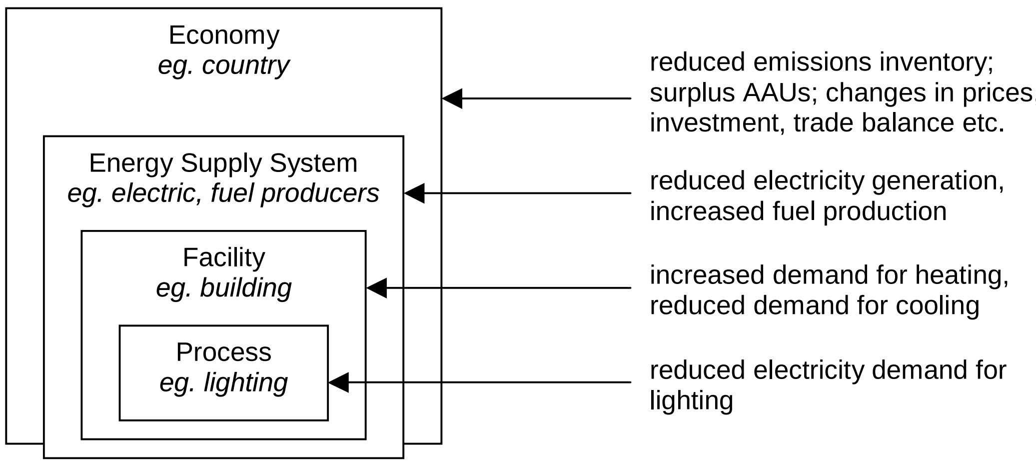
The ECM is considered to be financially additional if its selection depends on the availability of income from credit sales. Project proponents or investors, who of course stand to gain from credit sales, will not provide reliable information on the hurdle rate that they apply in these circumstances. This requires that a 'reasonable' hurdle rate be developed through an objective process. Options for doing this, discussed in Section 4.7, include behavioural modelling of the investment decision, the use of control groups exhibiting similar behaviour and comparison with benchmark projects that went ahead independently in the absence of emission crediting.

The outcome of this analysis is two projects: a 'reference' project that would go ahead 'anyway' without credits, and an 'alternate' project that is implemented only because of the higher IRR obtained through credit sales.

4.5 Establishing Project Boundaries

Hierarchy of Project Impacts
An energy efficiency project takes place within a hierarchy of systems: it affects a process within a facility, which is in turn surrounded by an energy supply system operating within an economy. Figure 4.3 illustrates such a hierarchy for a lighting retrofit in a commercial building.

Figure 4.3
Hierarchy of Project Impacts



The dictionary defines a facility as "a building or an installation for some kind of activity". This definition would allow a district-heating facility to include a central boiler plant, the heat distribution piping, and terminal heating equipment on the customer's premises. For the purpose of defining the boundary of the facility in the system hierarchy, a facility can be defined to include all of the systems that are part of the proponent's activity and that are under the direct control of the proponent. With this definition, all impacts occurring inside the facility boundary are considered to be direct impacts, and all impacts outside it indirect impacts, of the proponent's activity.

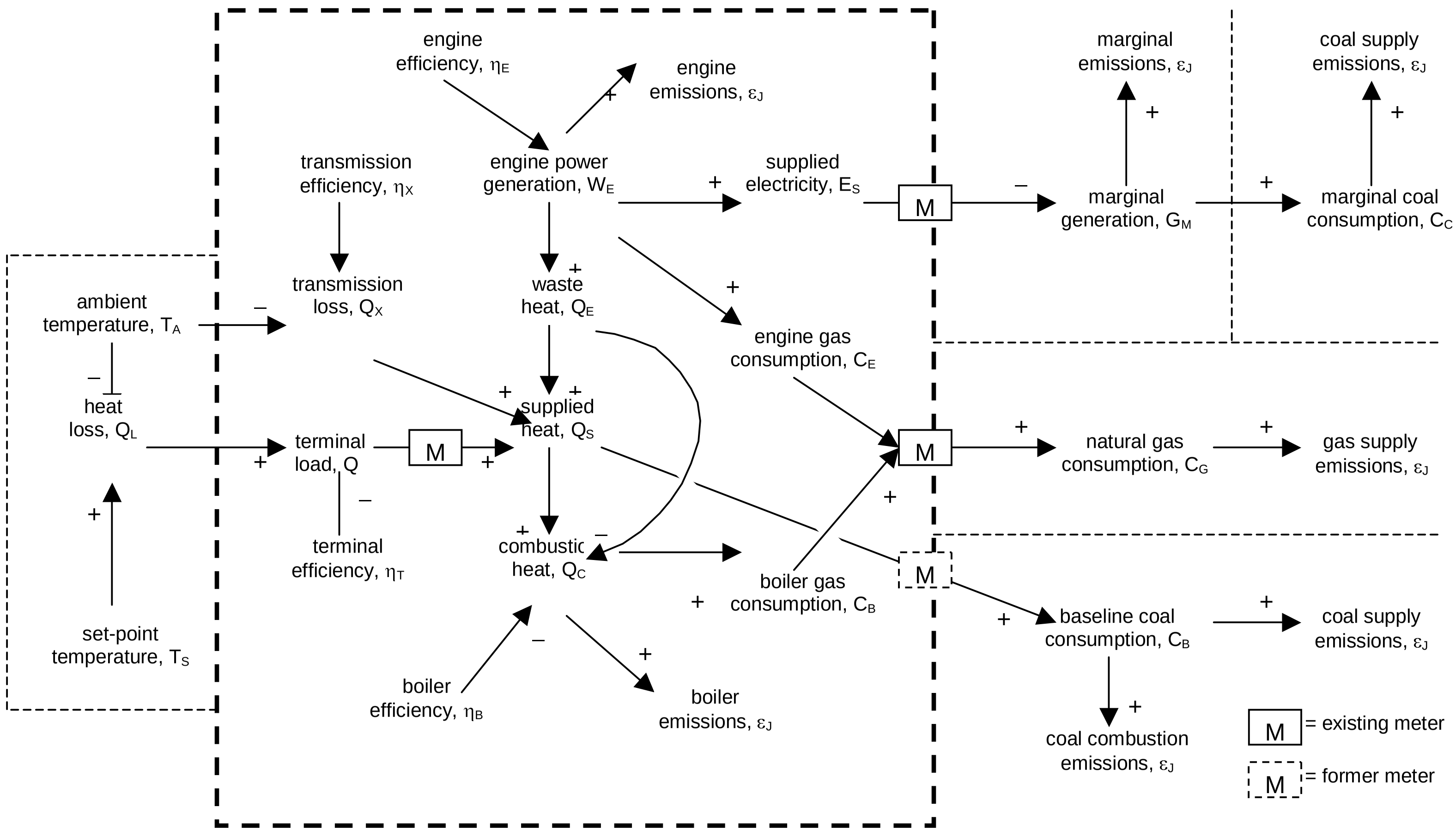
In general, the magnitude of indirect impacts will diminish rapidly with distance from the facility boundary. A lighting retrofit in a commercial building will impact demand for heating fuel and electricity, and possibly emissions in the energy supply system, but is not likely to affect prices or generation dispatch decisions. A very large national lighting retrofit program, on the other hand, might be expected to affect the prices and relative demands for fuels, reduce or eliminate dispatch of marginal generating units, and possibly affect the nature and timing of utility expansion decisions, in turn producing discernible impacts on the economy.

Influence Diagramming
An influence diagram is a simple tool to identify and portray project impacts. An influence diagram is a graph whose vertices are identifiable elements of the system and whose edges show the direction of influence of one element on another. System elements must be quantifiable, at least in principle. An element A has an influence on another element B if a change in the magnitude A causes a change in the magnitude of B.

The notation for influence diagrams used here is taken directly from systems dynamics modelling [2]. Systems dynamics relies heavily on influence diagramming to build mathematical models that can be directly implemented and solved using simulation programs such as STELLA or VisSim. Unlike other modelling systems, elements from a variety of domains, including engineering and economics can be freely mixed. Many other fields, such as environmental and social impact assessment [17], use similar diagramming approaches to describe interactions in complex systems.

Figure 4.4 shows an example influence diagram for a combined heat and power plant, as may be found in a hospital or a district heating system. This particular diagram is based on the Bynov district heating plant in Decín, CZ. A gas-fired boiler supplies hot water through a transmission system to terminal radiator units in flats, each of which has its own thermostatic control. Electricity is generated by a gas-fired engine-generator set. During the heating season engine waste heat is supplied to the hot water load, reducing boiler fuel consumption. Outside of the heating season, engine waste heat is rejected in a cooling tower. Prior to the installation of the CHP plant, Bynov supplied district heat from a coal-fired boiler and did not produce electricity.

Figure 4.4
Combined Heat and Power (CHP) Plant Influence Diagram Example



To draw the diagram, one starts by identifying the elements influencing final energy demand, and then works back through the chain of energy conversions to the ultimate energy supplies. Influences are indicated by arrows indicating the direction of the influence (from A to B) and a sign near the influenced element B indicating whether its magnitude increases (+) or decreases (–) when the influencing element A increases. Each influence is considered in isolation by temporarily assuming all other elements to have constant values (this is the '*ceteris paribus*' condition in economics or 'small-signal' assumption in engineering). Every influence is one-way: if A influences B and B also influences A, two arrows will be drawn as above. Finally, each element is labelled with a symbol identifying the measured or calculated quantity associated with it.

The heavy dashed line indicates the facility boundary. Within the facility there are four discernible processes: boiler, engine, transmission and terminal units. Light dashed lines delineate external systems. These are the client (final demand) system, the electricity and gas supply systems, and the coal supply system providing fuel for the marginal utility generators. The baseline coal use and principal metering locations are also indicated.

Impact Sensitivities and Boundaries

Chains are terminated when the sensitivity to influences becomes small. Any sensitivity that is smaller than the measurement accuracy of the variable involved can be considered insignificant. Most industrial measurements have accuracies of ±2-10%, and energy-related emission estimates are normally accurate to ±5%.

Price related impacts can be estimated if price elasticities of supply and demand are known. Most energy conservation projects have a small impact on the demand for the affected energy form(s) so the effect of a project on energy prices is likely to be small. The reduction in energy cost due to the energy savings may induce the proponent to increase its consumption of energy services somewhat; the so-called snapback effect. This response would generally occur within the project boundaries.

In general one or more baseline models is required for each level of the hierarchy affected by the project. In the example in Figure 4.3, the project boundary would probably be the facility. Estimation of the emission reductions due to a lighting retrofit would require a baseline for the lighting load and an associated baseline for the building's energy use. Baselines for entities, such as the electric utility, affected through indirect emission reductions or leakage will also be needed to calculate those impacts of the project. In Figure 4.3 they would fall into the economy level of the hierarchy.

4.6 Developing Emission Baseline Models

The criteria for and uses of emissions baselines are described in a manner similar to what was done for energy baselines. Project baselines have access to more specific data than is used in national inventories, but all project baselines should be consistent with the inventory accounting approach.

Emissions baselines are based on calibrated engineering models of emissions, very similar to the energy-use models previously discussed. Energy baseline models developed for energy performance contracts or from energy audits can often be converted into emission models by applying emission factors per unit energy demand, though some care is required to ensure that all significant emission impacts due to actions within the facility are accounted for. Actions that replace fossil fired processes with electrical processes, for example, reduce emissions within the project boundaries, but increase emissions by the electricity generator. Baselines for impacts beyond the facility boundary will generally not be available in advance and so must be determined from scratch. These are again based on engineering models. The influence diagram described in the previous section can facilitate the identification of impacts and the design of the model.

Criteria for and Use of Emission Baselines

An estimated emission baseline is needed when the project is being evaluated to be able to calculate the economic value of the net emission reductions that will be generated. However, credits for emission reductions are almost always based on the emission reductions actually achieved. To calculate the emission reductions actually achieved, the emission baseline must reflect ex post conditions such as building occupancy, hours of operation, and weather conditions, which may differ from those projected when the project was being evaluated.

CDM projects will need to comply with international rules. Proposed projects must be reviewed by an independent accredited "operational entity" which will review the proposed emission baseline and other aspects of the project. Based upon the assessment by the operational entity, the CDM Executive Board will decide whether to register the project and, in so doing, accept the proposed emission baseline calculation. The baselines of registered projects will be precedents for other projects.

Annex B countries that meet specified eligibility criteria can implement their own approval processes for JI projects. The approval process, including, the emission baseline calculation, is therefore likely to vary across Annex B countries. Annex B countries that do not meet the eligibility criteria will be able to host JI projects, but the projects will be subject to an international review process similar to that for CDM projects. Since CDM projects will be registered several years before JI projects can begin to generate emission reduction credits, the emission baselines accepted by the CDM Executive Board may set precedents that effectively apply to JI projects as well.

At present it appears that in agreeing to register a project, the CDM Executive Board agrees to accept an emission baseline calculation *methodology*. For example, that the emission baseline will be calculated using a specified building energy model and specified emission coefficients for the different energy forms. The emission baseline used to determine the emission reductions generated would be calculated using the specified model and actual values for the inputs to the model, such as weather conditions, occupancy, and hours of operation. The emission baseline methodology for a registered project will be fixed for the crediting period, the operating life of the project to a maximum of seven or ten years. Over time the CDM Executive Board could decide to change the calculation methodologies it accepts, but such changes will apply only to new projects.

Projects will always have financial uncertainties because actual performance will always differ from the estimates used to evaluate the project. Projects, likewise, will always have environmental uncertainties because the emission baseline will be adjusted to reflect actual conditions so the emission reductions achieved will differ from the estimates. The economic consequences of the environmental uncertainty are incorporated into the financial analysis through the revenue attributed to the emission reduction credits. For the next few years project developers will also face regulatory uncertainties because the practices of the CDM Executive Board and national governments will be unclear.

Adapting Energy Baseline Models

The emissions model is an algebraic expression that has two components: one producing a measure of physical activity, and the other determining emissions as a function of that activity. The latter is often simply a constant emission factor per unit activity.

Energy baseline models, as described in Section 4.2, predict the demand for a specific purchased fuel or energy form as a function of more fundamental variables such as occupancy, production, weather conditions and so on. In general such an energy model can be converted to an emission model by considering the predicted energy demand to be the activity, and then applying an appropriate emission factor or function to it for each emission of interest. Before doing this, the energy baseline model must be checked to confirm that it is complete and correct.

The energy baseline model will be concerned with energy demand by a facility or a process within that facility. As the ultimate aim of these baselines is to evaluate energy cost savings, energy impacts that have or are thought to have a negligible effect on costs will probably have been ignored. They might however involve significant impacts on emissions. Again, drawing an influence diagram can help to identify these other impacts, which will be influenced by and functionally related to the energy demand predicted by the baseline model.

For example, consider a model of lighting load. The model predicts the electrical energy demand for lighting as a function of the number of lamps, light output, occupancy and efficiency. The effects of waste heat from lighting on heating and cooling loads will probably have been ignored, but may have emission impacts depending on the fuels and processes involved. These emissions will be proportional to the lighting waste heat, which is simply the predicted lighting energy demand times (1 - lighting efficiency).

The model is used to predict energy demand by fuel type for a given period using actual values of the input variables, such as occupancy, weather and production. The predicted energy use by fuel type is converted to an emission baseline by applying an appropriate emission coefficient to each fuel type and summing the total emissions. Emission coefficients for most fuel types are well known and should be avialable from the national emissions inventory, the IPCC, or other sources.

Baselines for Indirect Impacts

The indirect impacts are those occurring beyond the facility boundary in systems beyond the control of the facility owner. For energy efficiency projects, the largest indirect impacts will normally be on electric utilities. A project that reduces the electrical energy demand of a facility, such as a lighting retrofit or variable-speed drive installation, will produce a corresponding reduction in the utility's generation. A project that converts a fossil-fired process to an electrical process increases the electrical demand. The impact on the utility's emissions depends on what generating unit supplies the extra load or that would have supplied that reduced demand.

The utility's power generation must be exactly equal to the power demanded at every instant: in general there is no economical means for a utility to store surplus electricity generation for later use. The utility has a variety of generating units that it runs to meet the current load. The generating units are dispatched in order of increasing marginal cost of energy supply, subject to technical limitations. The last or marginal unit dispatched must be capable of varying its output to follow instantaneous changes in the load.

Energy efficiency projects are typically small in relation to utility generating units and so affects only the marginal unit dispatched by the utility. If this unit is fossil-fired, the efficiency project will reduce the amount of energy generated and hence the fuel consumption and emissions of the unit. The project does not affect the emission rate of the marginal unit: this is controlled by the utility. The appropriate emission rate for small projects, then, is the rate of the marginal generating unit during each period that the electrical demand is reduced or increased. Very large projects could affect the dispatch of the system, and so may require modeling of the generating system to determine the appropriate emission rates.

The operator of the electricity system should be able to provide the marginal emission rates for different periods during the year. Those emission rates can be applied to the electrical loads when developing the emission baseline.

Attribution of indirect emission reductions to a project can give rise to double counting or disputes over ownership. If the utility's emissions decline over the life of the energy efficiency projects, the utility could claim credit for its emission reductions. The indirect emission reductions claimed by an energy efficiency project would cover part of the same reduction. Since the emission reductions have a value, there may be disputes over ownership of the reductions. One approach is to require the project proponent to enter into an agreement with the utility that specifies the ownership of any indirect emission reductions claimed by the proponent. An alternative approach is to ignore any indirect emission reductions and to reduce the direct emission reductions achieved by the amount of any indirect emission increases.

4.7 Financial Additionality

Financial additionality is often proposed as a test of environmental additionality. If a project would have been implemented as a routine commercial decision, the emission reductions would occur as a matter of course and hence are not additional reductions. Assessing financial additionality can be difficult. For a specific project, the proponent has the financial data and may be able to manipulate those data if needed to demonstrate that the project would not be financially viable without the emission reduction credits. For projects that are relatively large, or are rarely implemented an independent financial analysis using standard assumptions concerning variables such as the minimum rate of return required for commercial viability could be used to assess financial additionality. For projects that involve measures that are frequently implemented, financial additionality can be determined using a behavioural model such as the one developed in Chapters 5 through 7, control groups held to represent typical behaviour towards similar projects, and various kinds of benchmarks derived from sectoral data. None of these approaches is perfect and it is impossible to predict how someone would have behaved with certainty. For that reason, we advocate that behavioural models be combined with one or both of the other approaches and that the final judgement be based on plausibility.

Criteria for and Use of Additionality

To earn credits emission reduction actions should reduce emissions below what they otherwise would have been - the emission baseline. An energy efficiency project typically implements a package of the most cost-effective measures that yield an acceptable financial return. Those measures can be considered to be commercially viable and likely to be implemented in any case. Emission reductions associated with those measures could be argued not to meet the additionality test. Any additional measures, and the emission reductions associated with them, would be additional.

Behavioural Models

A behavioural model attempts to predict whether or not a particular investment project would be undertaken under a given set of conditions. Generally, this is a conventional discounted cash flow model of the project whose parameters have been adjusted to reproduce observed investment behaviour. A behavioural model for energy efficiency projects is developed and tested in chapters 6 through 8 of this report.

Control Groups

A control group is a group of individuals, entities, or facilities similar to the participants in the energy efficiency project but which do not participate in the project. The actions of the control group can be used as an indication of what the participants in the energy efficiency project would have done in the absence of the project. The control group for a lighting retrofit project, for example, would provide an estimate of the penetration of efficient lighting in the absence of the energy efficiency project.

A control group would ideally be selected prior to the start of the project so that information on the behaviour of the control group can be collected over the same time period as for project participants. Unfortunately that often is not successful if participation in the project is voluntary. The project participants may differ from those expected to participate when the project is designed and a control group is selected. A lighting retrofit project, for example, might be targeted at office buildings but attract mainly of hospitals. A control group of office buildings may not provide accurate information on what hospitals would have done in the absence of the project. Selecting a control group ex post to match the characteristics of the participants makes collection of data on the past actions of the control group more difficult.

Benchmark Projects

Instead of a control group, a reference or benchmark project sometimes can be used to provide an indication of what would have happened in the absence of the energy efficiency project. The benchmark project must be representative of the participants in the energy efficiency project and obviously can not itself be part of the energy efficiency project. As it became apparent that hospitals were participating in the lighting retrofit project, a representative hospital, possibly in a neighbouring jurisdiction, could be selected as a benchmark project.

4.8 Measurement and Verification

Energy savings and emission reductions are calculated as the difference between the baseline and actual energy consumption or emissions. Thus actual emissions must be monitored to determine the emission reductions achieved. For energy efficiency projects the familiar procedures used in energy performance contracting can be adapted to the requirements of emissions trading.

Criteria for and Use of M&V

Where widely accepted standards for monitoring and verification exist they should be used. The key measurement and verification standards for building energy use is the IPMVP. The principles embodied in this standard and those being developed, such as ASHRAE 14p, can be readily applied to measurement and verification of industrial and other energy efficiency projects. To calculate actual emissions the monitored energy use of each fuel type is multiplied by the emission coefficient for that fuel type and emissions are summed over all fuel types. The emission coefficients should be the same ones used to calculate the emission baseline.

Statistical Evaluation of Multiple Projects

When an energy efficiency project consists of hundreds of measures implemented at different locations, the energy saving and emission reduction associated with each measure is likely to be small -- the distribution of energy efficient lamps to residences, for example. Monitoring the use of each of the measures implemented would be prohibitively expensive. Instead a sample of the measures implemented can be monitored to get a valid estimate, with a known margin of error, of the energy saving from which the emission reduction can be calculated. Depending upon the nature of the participants and the measures implemented, the participants may need to be stratified appropriately and a sufficient number selected from each sub-group to provide a valid estimate of the energy use of the entire group.

Baseline Adjustments

Monitoring also identifies developments that warrant adjustments to the baseline. Since the emission baseline is derived from the energy baseline, relevant developments are those that affect what the energy use or the emissions would have been in the absence of the energy efficiency project. Adjustments of the energy baseline for developments such as changes in occupancy or the systems affected, are a normal practice in performance contracting projects. The emission baseline may be adjusted for developments that affect additionality, such as energy efficiency or environmental regulations that would require implementation of measures that were part of the project or the percentage of the measures that would have been implemented otherwise as estimated from the control group or other sources.

Quantification of Reductions

Verification of the emission reductions achieved involves a host of matters, including checking instrument calibration, dealing with missing data and outliers, use of check data, and assessing the quality of the estimates. Most of these issues affect the monitored energy use, but some may affect adjustments to the emission baseline. The measured energy use as adjusted to address these issues is converted to actual energy use by means of emission coefficients. The actual emissions are subtracted from the adjusted emission baseline to obtain the emission reduction actually achieved.

Evaluating Quality and Uncertainty

Uncertainty can be defined as a measure expressing 'the degree to which we do not know the truth'. An empirical quantity such as the power consumption of an electric circuit is held to have a true value at any instant, regardless of whether or how it is observed. Because of the limited precision of measuring instruments and the unavoidable presence of random and systematic errors, the true value can only be approximated.

A procedure for estimating the uncertainty of physical measurements is described in the ISO *Guide to the Expression of Uncertainty in Measurement* ("GUM"). Consider the above electric power measurement as an example. This requires the simultaneous measurement of two primary quantities, the voltage E and the current I. Power is calculated by taking the product of these two in the 'data reduction' equation $P = EI$ (the calculation is implicit in a wattmeter). In the GUM method:

- *Identify Sources of Uncertainty*.

- *Calculate Standard Uncertainties of Primary Quantities*. The 'standard uncertainty' of a primary quantity is taken to be the standard deviation of the distribution of measured values, found through frequency or Baysian statistics. For measurement to a tolerance $\pm a$, the standard uncertainty is $a/\sqrt{3}$.

- *Calculate Combined Uncertainty of the Result*. The 'combined uncertainty' of the two primary measurements, found by root sum of squares of the product of each standard uncertainty with the sensitivity (partial derivative) of the final power result to that variable.

- *Calculate Expanded Uncertainty of the Result*. The expanded uncertainty expresses the combined uncertainty at a specific confidence level, generally 95%. This is done by multiplying the combined uncertainty by a 'coverage factor' obtained from Student's t-distribution. This requires knowing the number of degrees of freedom in the measurement: for a single measured variable sampled N times, this is simply N-1.

References

1. Carter, L., "Modalities for the Operationalization of Additionality" in *International Workshop on Activities Implemented Jointly*, Leipzig, March 1997. http://www.northsea.nl/Jiq/paper.htm

2. Cellier, F., *Continuous System Modelling*. New York, US: Springer-Verlag, 1991.

3. Chomitz, K., *Baselines for Greenhouse Gas Reductions: Problems, Precedents, Solutions*. Washington, US: World Bank. rev. ed., 1998 at http://www.worldbank.org/

4. Coleman, H. and W. Steele, *Experimentation and Uncertainty Analysis for Engineers*. New York, US: John Wiley. 2nd ed., 1999.

5. Ellis, J., et al., *Emission Baselines: Estimating the Unknown*. Paris, FR: International Energy Agency, 2000.

6. Fels, M. and K. Keating, "Measurement of Savings form Demand-Side Management Programs in US Utilities" in *Annual Review of Energy and Environment* 18:57, 1993.

7. Hargrave, T., et al., *Options for Simplifying Baseline Setting for Joint Implementation and Clean Development Mechanism Projects.* Washington, US: Center for Clean Air Policy, 1998 at http://www.ccap.org/

8. Harrison, D., et al, *Critical Issues in International Greenhouse Gas Emissions Trading: Setting Baselines for Credit-Based Trading Programs. Lessons Learned from Relevant Experience*. Palo Alto, US: Electric Power Research Institute. Technical Progress Report, June 2000.

9. Hirst, E. and J. Reed, *Handbook of Evaluation of Utility DSM Projects*. Oak Ridge, US: Oak Ridge National Laboratory, Report ORNL/CON-336, 1991.

10. Houghton, J., et al., *Revised 1996 IPCC Guidelines on National Greenhouse Gas Inventories*. Paris, FR: Organization for Economic Cooperation and Development, 3 vols., 1996. http://www.iea.org/ipcc/invs1.html

11. IPCC, *Good Practice Guidance and Uncertainty Management in Greenhouse Gas Inventories*. Geneva, CH: Intergovernmental Panel on Climate Change, 2000 at www.ipcc-nggip.iges.or.jp/gp/

12. ISO, *Guide to the Expression of Uncertainty in Measurement*. Geneva, CH: International Standards Organization, 1993.

13. Jackson, T., et al (eds.), *Flexibility in Climate Policy: Making the Kyoto Mechanisms Work.* London, UK: Earthscan, 2001.

14. Krarti, M., *Energy Audit of Building Systems*. Boca Raton, US: CRC Press, 2000.

15. Lewis, I., et al., *Guidance Manual on Emission Reduction Reporting Requirements*. Toronto, CA: Clean Air Canada Inc., Report CACI/GM-01-R1, August 2001 at http://www.CleanAirCanada.org/

16. McInnes, G. (ed.), *CORINAIR Atmospheric Emission Inventory Guidebook*. Copenhagen, DK: European Environmental Agency, 1st ed., 1996 at http://www.eea.dk/

17. Porter, A., et al., *A Guidebook for Technology Assessment and Impact Analysis*. New York, US: North Holland, 1980.

18. Reddy, T., et al., "Uncertainty in Baseline Regression Modelling and the Determination of Retrofit Savings" in *ASME Journal of Solar Energy* 120(8):185, 1998.

19. Ridge, R., et al., *An Evaluation of Engineering and Statistical Models for Estimating Gross Energy Impacts*. Boca Raton, US: Association of Energy Services Professionals, CADMAC Study 2001M. 1996.

20. Stoecker, W., *Design of Thermal Systems*. New York, US: McGraw-Hill, 3rd ed., 1989.

21. Swisher, J., et al., *Tools and Methods for Integrated Resource Planning: Improving Energy Efficiency and Protecting the Environment*. Risø, DK: UNEP Collaborating Center on Energy and the Environment, 1997 at http://

22. Telnes, E. and R. Ybema (eds.), *Operational Guidelines for Baseline Studies, Validation, Monitoring and Verification of Joint Implementation Projects*. Netherlands Ministry of Economic Affairs. http://www.senter.nl/

23. UNEP/OECD/IEA, *Expert Workshop on Identifying Feasible Baseline Methodologies for CDM and JI Projects* (Roskilde, DK: May 2001). Paris, FR: Organization for Economic Cooperation and Development, 2001 at http://www.oecd.org/

24. USDOE, *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy Savings*. Report MVP2000 at http://www.ipmvp.org/

25. ---- ibid., *Measurement and Verification Guideline for Federal Energy Projects.* Washington, DC: US Department of Energy, Office of Federal Energy Management Programs, Report DOE/GO-100096-248, 1996 at http://eren.doe.gov/

26. Vine, E. and J. Sathaye, *Guidelines for the Monitoring, Evaluation, Reporting, Verification and Certification of Energy-Efficiency Projects for Climate Change Mitigation Projects.* Berkeley, CA: Lawrence Berkeley National Laboratory, Report LBNL-41543, 1999. http://eetd.lbl.gov/ea/ccm/ccPubs.html

5. Analysis of Barriers to Energy Efficiency Investments

5.1 Introduction

As previously noted, there is apparently a large ’efficiency gap’ between the cost-effective energy efficiency potential identified in engineering-economic studies and the actual realization of energy efficiency measures in the marketplace. ’Barriers’ are put forward to account for this gap.

Studies of energy efficiency potential invariably take a ’bottom-up’ approach. Individual energy efficiency measures are identified and their typical implementation costs and energy savings analyzed using engineering methods. The economic potential for each measure is assessed within a neo-classical context, usually by determining the discounted net present value of the measure on a life-cycle basis. In this determination, energy savings representing avoided energy purchases are the benefits, while incremental equipment cost for the energy efficient option plus on-going incremental operational expenses represent the costs. A discount rate representing the future value of money is used to discount future benefits and costs streams. The measures are then ranked in order of decreasing present value and their total potential determined by summing them across the sectors and stock-populations involved.

These studies generally describe three or four increasingly stringent levels of energy efficiency potential:

- *resource potential*. This is used in studies of renewable energy systems and identifies the ultimate stock or resource limits on the use of a measure. The potential use of solar water heaters for example is constrained by the amount of solar radiation available.

- *technical potential*. This is the ultimate limit on the use of a measure dictated by the technical characteristics of the measure and the stock-population to which it is applied. For a solar water heater this might include such considerations as the availability of suitable roof orientations, limits on the size of the collector, and limitations on the ability to store heat for long periods. Cost is not a consideration at this level.

- *economic potential*. This is the fraction of the technical potential that should be realized by rational cost-minimizing investors in accordance with mainstream economic theory. It is generally assumed that there are no constraints on the availability of capital and that investors will undertake all projects exceeding their marginal cost of capital.

- *market or achievable potential*. This is the fraction of economic potential that is thought or shown to be implemented without special efforts to influence investment behaviour. The difference between economic and market potential is the ’efficiency gap’, presumed to result from ’barriers’.

Barriers are meant to explain why investors do not behave according to the ideal given by an economic model. Of course, the model itself is at least partly at fault: even economists are not entirely rational utility-maximizing beings.

This chapter presents a neo-classical model of ideal energy-efficiency investment behaviour and discusses the various barriers that have been held to account for real behaviour. The purpose is not to explain the existence of an efficiency gap, but rather to develop the theoretical underpinnings for a model of actual energy-efficiency investment behaviour. That model will be derived in Chapter 7 and evaluated in Chapter 8.

The barriers to be discussed are summarized in Table 5.1 and are grouped into four categories. Rational or economic barriers and Market Failures are both accommodated within the neo-classical tradition. The former are perhaps not barriers at all, but rather consequences of the approximations made in applying the model in practice. Market Failures are the classic barriers described in price theory and welfare economics. Psychological and Organizational barriers are at odds with the fundamental neo-classical assumption of rationality.

Table 5.1
Taxonomy of Barriers

Barrier	Description
Rational	
Heterogeneity	technology may not be cost-effective in particular instance
Hidden Cost	extra costs/benefit loss not reflected in engineering models
Risk	stringent investment criteria may be rational response to risks
Access to Capital	debt/equity, coverage ratios of firm/project
Market Failure	
Imperfect Information	insufficient information for economically efficient decision
Adverse Selection	transaction costs prevent benefits from being revealed
Split Incentives	landlord-tenant problem
Product availability	restricted access to new products
Psychological	
Bounded Rationality	“satisficing” rather than optimizing
Form of Information	form of information may not be suitable to stimulate action
Credibility	agent may not trust information sources
Inertia	agent resists change, downgrades contrary information
Organizational	
Bounded Rationality	routines systematically neglect energy efficiency
Principal-Agent	principal uses strict criteria to control agent
Power	agent lacks power to initiate action
Other	
Externalities	private price less than social cost
Regulatory mispricing	prices based on average, not marginal costs
Inseparability	energy efficiency features not separable from other features

It is important not to confuse energy efficiency with efficient energy use [31]. The former is an engineering measure: how much energy is required to produce a unit of output. The latter measures the economically optimal use of energy in conjunction with capital, labour and other scarce resources to maximize output.

5.2 Ideal Investment Behaviour

Before discussing the effects of different barriers on energy efficiency investment, we present a brief description of ideal, barrier-free investment behaviour.

The neo-classical ideal assumes that all economic actors are rational, utility-maximizing beings with stable preferences. Each actor is fully informed about all available opportunities and selects projects in order of decreasing marginal utility.

This of course implies that economic actors are constantly optimizing their behaviour. While neo-classical economics does not claim that shoppers are evaluating the net present values of different breakfast cereals at the food store, it does maintain that they behave as if they do and that their choices reveal implicit present values and discount rates. With this assumption, the neo-classical model represents all empirical economic behaviour.

As economic actors are rational by definition, it follows that any difference between a theoretical prediction and observed behaviour must be the result of a cost or benefit or discount rate not captured in the model. The model is then corrected to account for these 'hidden' factors. To the extent a hidden cost or benefit factor is measurable, we can quantify that directly in the model. Typically, however, aggregate adjustments to the discount rate are used as a net adjustment factor – the idea being that most perverse model outcomes can be overcome with an appropriate change to the discount rate. Indeed, there is a long history of studies that measure the impacts of various "barriers" on discount rates. We use quotations here to reflect the fact that the term 'barriers' was not generally used. Instead, terms like socio-economic characteristics were used to describe variations in discount rates.

Most of the discount rate studies, which were conducted in the 1970s and early 1980s, were based on consumer studies. However, many of the consumer conclusions also apply to firms. For example, the split incentives problem (landlord-tenant issues) has resulted in lower measured discount rates for consumers that own their dwellings rather than rent. Similarly, the access to capital issue is very similar to consumers' distribution of income. Several studies have shown that discount rates fall as incomes rise.

In the case of corporations undertaking investments, the neo-classical utility to be maximized is profit or return on investment (ROI). Profit maximization will result from increases in production or decreases in production costs that occur as a result of the investment. Increases in production will include both higher quantity and higher quality. Decreases in production factor costs will include technological advancement, lower labour to output ratios and decreases in energy use, among others.

It is important to note that investments in the various factors of production often carry much different expectations regarding both ROI and overall effectiveness. For instance, in the industrial sector, it has been observed that investments designed to increase production are typically favoured over those designed to save energy, even when the ROI is ostensibly the same. What may appear to be a less than ideal investment behaviour caused by 'barriers' may upon further examination be seen as a rational response to conditions experienced by the investor. Again, however, an adjustment to the various discount rates can be made equate the outcomes.

As applied to energy efficiency investments, two important distinctions need to be made: corporations undertaking energy efficiency investments as part of a profit maximization strategy focused on their own resources, and corporations who invest in energy efficiency as a profitable undertaking in and of itself. In the latter case, these investments occur at others' facilities. Energy Service Companies (ESCOs) are an example of third party intermediaries that participate in this kind of investment. Third party investors often have access to information and capital and are better versed in assessing factors such as risk than non-specialist energy investors. As such, many of the barriers that may exist for typical investors, are diminished or eliminated for ESCOs.

5.3 Economic Barriers

Economic or rational barriers are those that relate directly to the various costs and benefits of the investment.

Heterogeneity

Studies of energy efficiency potential extrapolate the costs and benefits of measures for a typical investor to all other investors in the study population. This produces an error to the degree that the costs and benefits of the measure are not in fact the same for all investors. The economic potential can be overestimated because it neglects variability in the population. A few of the more important costs and benefits that will likely vary between investors are:

- *cost and access of capital* will vary based on the size and financial soundness of the company;
- *discount rate and payback criteria*
- *value of energy saved* will depend on individual pricing which can vary based on size, nature of price contracts etc

Hidden Cost

In addition to the possible variability in costs and benefits across the study population, it is possible that some of the real costs and loss of benefits experienced by investors are not reflected in the engineering-economic models used. The economic potential is overestimated because it neglects certain costs. Examples of costs that are often neglected in studies of energy efficiency potential include:

- *overhead costs* for energy management, such as specialist staff, energy audits and inventories, maintenance of energy accounting and information management systems
- *transaction costs*, such as consultant studies, project management, tendering costs, costs of work disruption, and staffing and training costs
- *lost-benefit costs* such as changes in workplace or service environment or in product reliability, quality or yield

Risk

The notion of willingness to undertake risk in investment is critical. Clearly, all investments involve some element of risk. Payback is often directly related to the level of risk with very risky investments offering significant payback potential. Low risk investments may be underwritten by government or corporate entities such that yield is guaranteed. For energy efficiency investments, performance contracts represent a comparable arrangement, wherein a third party energy efficiency delivery agent guarantees the savings and return of investment. Stringent investment criteria are often the rational response to risks and ideal investment behaviour will seek to identify and quantify all the various risks associated with the potential investment. Major risks include:

- *macroeconomic risks* such as risk of recession, interest rate changes, regulatory changes or changes in fuel price or availability
- *business risks* such as changes in business or sectoral performance and the risk of loan default and borrowing constraints
- *technical risks* such as un-accounted for operational costs associated with new equipment

5.4 Market Failures

There are a number of failures in the marketplace which mitigate against the adoption of cost effective energy efficiency. These are specific to the working of the marketplace or the relationship between the players. They generally do not relate to the players themselves.

Imperfect information

There may not be enough information in the marketplace to support an economically efficient decision. Related to this is the high information or search costs often associated with identifying energy efficient opportunities and the idea of “asymmetric information” – information available to sellers and buyers which is inconsistent.

Adverse selection

Adverse selection describes cases where the actual transaction costs deter the investment or eliminate the benefits altogether. These transaction costs include time, materials and labour involved in obtaining an energy efficient product or service.

Split Incentives

The notion of split incentives in energy efficiency investments is often described as the landlord-tenant problem. It occurs when institutional relationships separate the benefits of energy efficiency improvements from the purchasing decision. This often occurs in typical landlord/tenant relationships where the energy efficiency benefits do not impact the tenant payment streams.

Product Unavailability

Distribution of new energy efficient products and services tends to be limited until demand is firmly established.

5.5 Psychological Barriers

Psychological barriers address the fundamental neo-classical assumption that all economic actors behave rationally and optimize their behaviour. This is clearly not the case in practice and the existence of psychological barriers is offered as part of the reason.

Bounded Rationality

The notion of bounded rationality, elaborated by Frederick March and Herbert Simon, holds that economic actors will select the first satisfactory option rather than attempt to find the optimal alternative. This phenomenon has been termed “satisficing”. For energy efficiency investments, bounded rationality often occurs at the design or technology selection stage of a project. Designers will choose a product or design specification they are familiar with, rather than undertaking the research activity associated with selecting a more efficient option. If energy costs are relatively low and stable, economic actors more likely to focus on reducing other costs, increasing revenues, or on other issues rather than on evaluating energy efficiency options.

Form of Information

Informed decision makers are the key to rational economic behaviour. In many instances, the nature or form of the information is insufficient to stimulate action. This is often the case for energy efficiency investments as the information may be highly technical in nature, yet the decision maker requires more fundamental accounting type data.

Credibility

The decision maker may not trust the various information sources. Again, like the form of the information, the credibility of the delivery agent is extremely important. This is especially true for new types of investments like energy efficiency via third party delivery.

Inertia

Humans often resist change for personal reasons. Investments in new technologies or via new delivery agents may threaten current decision makers such that these individuals may downplay the relative worth of the information.

5.6 Organizational barriers

Organizational barriers are those that occur within organizations and relate to the “system” rather than the individual.

Bounded Rationality

Like the bounded rationality discussed in Section 3.4 above, many organizations support routines that systematically neglect energy efficiency. As indicated earlier, it has been noted that many industrial facilities favour production investments rather than energy savings investments, even when the paybacks are the same.

Principal-Agent
Relationships between the principal and agent can prevent energy efficient investments if the principal uses strict criteria to control the agent.

Power
Similar to the principal-agent challenge, the agent may lack the power to initiate action.

5.7 Other Barriers

There are a number of other barriers that may be in place which can impact the energy efficiency investment outcomes. These include both barriers related to pricing and general environmental factors.

Externalities
Externalities are costs that are borne by someone other than the owner of an activity and not reflected in the market price of the activity. Environmental pollution is a common example: where regulation is absent or incomplete, damage costs will be incurred by society or some group within it other than the polluter. In this sense, the private price charged is less than the full costs imposed on society.

Regulatory Mispricing
Prices of energy may be based on average costs which are less than marginal costs. This goes against all neo-classical theory which indicates that price should equal marginal cost.

Inseparability of Product Features
Energy efficiency features are not separable from other features of a product or service.

5.8 Relative Importance of Barriers

The barriers discussed in the previous sections have been identified as occurring in the North American marketplace. That said, it is clear that some are more important than others. Measuring the incidence of barriers – how often they exist, and/or the extent that they impede cost-effective solutions, has never been attempted. One indicator of the relative importance of barriers is the number of energy efficiency programs that have been designed to overcome particular ones. Using information for currently available energy efficiency programs where the barriers being addressed were identified, the two most prevalent barriers were high information or search costs and organizational practices or custom, followed by performance uncertainties, hassle or transaction costs, product or service unavailability and asymmetric information. Looking at the top six barriers, they fall into three basic groups:

- Lack of information regarding energy efficiency
- Availability of energy efficient products
- Organizational practices regarding energy efficiency

In the case of third party intermediaries in North America, the evidence indicates that markets have been successfully transformed by improving information availability and by addressing organizational practices. Energy utilities have used their channels of communication to promote specific energy efficient technologies through the development of programs which inform the end user, designers and contractors. Perhaps the two best examples are T8 lighting with electronic ballasts and high efficiency natural gas furnaces and boilers.

In both these cases, the energy utilities have provided their customers with information describing the technology and its advantages in a manner specific to the target audience, followed by case studies about success stories. At the same time, they worked with the supply chain to ensure availability of reliable, cost effective products. Some early programs offered incentives for adopting the technology, using the argument that reduced energy consumption avoided investment in additional supply capacity. More recently, however, incentives have been de-emphasized in favour of information and assistance to the market.

References

1. Ackerlof, G., "The Market for Lemons" in *Quarterly Journal of Economics* 84(3):488, 1970.

2. DeCanio, S. and W. Watjins, "Investment in Energy Efficiency: Do the Characteristics of Firms Really Matter?" in *Review of Economics and Statistics* 80():95, 1998.

3. Golove, W. and J. Eto, *Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency*. Berkeley, CA: Lawrence Berkeley National Laboratory, Report LBL-38059, 1996.

4. Howarth, R. and A. Sanstad, "Discount Rates and Energy Efficiency" in *Contemporary Economic Policy* XIII(x):101, 1995.july

5. ---- ibid., et al., "The Economics of Energy Efficiency: Insights from Voluntary Participation Programs" in *Energy Policy* 28(6-7):xxx, 2000.

6. Jaffe, A. and R. Stavins, "The Energy-Efficiency Gap: What Does it Mean?" in Energy Policy 22(10):804, 1994.

7. Kahneman, D. and A. Tversky, "Prospect Theory: An Analysis of Decision Making Under Risk" in *Econometrica* 47(X):263, 1979.

8. Kempton, W. and L. Layne, "The Consumer's Energy Analysis Environment" in *Energy Policy* 22(10):857, 1994.

9. Komor, P. and R. Katzev, "Behavioural Determinants of Energy Use in Small Commercial Buildings: Implications for Energy Efficiency" in *Energy Systems and Policy* 12(x):233, 1988.

10. ---- ibid. and L. Wiggins, "Predicting Conservation Choice: Beyond the Cost-Minimization Assumption" in *Energy* 13(8):633, 1988.

11. Koomey, J. and A. Sanstad, "Technical Evidence for Assessing the Performance of Markets Affecting Energy Efficiency" in *Energy Policy* 22(10):826, 1994

12. ---- ibid., et al., "Energy-Efficient Lighting: Market Data, Market Imperfections and Policy Success" in *Contemporary Economic Policy* XIV(x):98, 1996.

13. Levine, M., et al., *Energy Efficiency, Market Failures and Government Policy*. Berkeley, CA: Lawrence Berkeley National Laboratory Report LBL-35376, 1994.

14. Lutzenhiser, L., "Social and Behavioural Aspects of Energy Use" in *Annual Review of Energy and the Environment* 18:247, 1993.

15. March, J., "Bounded Rationality, Ambiguity and the Engineering of Choice" in *Bell Journal of Economics* 9(x):587,1978.

16. Milgrom, P. and J. Roberts, *Economics, Organization and Management*. Englewood Cliffs, US: Prentice-Hall, 1992.
17. Narayanan, M., "Observability and the Payback Criterion" in *Journal of Business* 98(3):309, 1985.

18. Sanstad, A. et al., "How High are Option Values in Energy Efficiency Investments?" in *Energy Policy* 23(9):739, 1995.

19. ---- ibid. and R. Howarth, "Normal Markets, Market Imperfections and Energy Efficiency" in *Energy Policy* 22(10):811, 1994.

20. Simon, H., "Rationality in Psychology and Economics" in *Journal of Business* 59(x):209, 1986.

21. Sorrell, S., et al., *Reducing Barriers to Energy Efficiency in Public and Private Organisations*. Brighton, UK: University of Surrey, SPRU Report JOS3CT970022, 2000 at

22. Statman, M. and J. Sepe, "Managerial Incentive Plan and the Use of the Payback Method" in *Journal of Business Finance and Accounting* 11(1):61, 1984

23. ---- ibid., "The Persistence of the Payback Limit: A Principal Agent Perspective" in *The Engineering Economist* 27(2):95,1982.

24. Stern, P., "What Psychology Knows About Energy Conservation" in *American Psychologist* 47:1224, 1992.

25. ---- ibid., "Blind Spots in Policy Analysis: What Economics Doesn't Say About Energy Use" in *Journal of Policy Analysis and Management* 5(2):200, 1986

26. Stigilitz, G. and A. Weiss, "Credit Rationing in Market with Imperfect Information" in *American Economic Review* 71:393, 1981

27. Sutherland, R., "The Economics of Energy Conservation Policy" in *Energy Policy* 24(4):361, 1996.

28. Tietenberg, T., *Environmental and Natural Resource Economics*. Reading, US: Addison-Wesley, 5th ed., 2000.

6. Modelling Energy Efficiency Investment Behaviour

6.1 Introduction

As discussed in Chapter 3, the neo-classical requirements for modeling investment behaviour use the notion of profit maximization or return on investment. For the purposes required here, a model needs to be developed that assesses and accommodates energy investment behaviour for three cases: business as usual, client, and third party, where third parties may be ESCO-like intermediaries. This model can be furthered enhanced through the specification of a number of more qualitative features – specifically, analysis of barriers in the marketplace.

The essence of this decision modeling is to devise an approach which facilitates predictions of whether a given proposed project would have been undertaken in preference to a business as usual project. The question is: "what project, if any, would the project sponsor have undertaken in the absence of emissions reduction funding?", and further, "does emissions reduction spending increase the likelihood of investment?" The basic approach taken here is to develop a relatively simple spreadsheet model that combines a cash flow model with a normative decision model. As a further enhancement, there is also requirement to examine and assess the barriers that may exist for any given project. This is a generalized model, though the "calibration" relied on data collected in the Czech Republic. The approach developed here is significantly more robust than the data collected in the Czech Republic would allow. Therefore, this model has been built for an ideal approach to data collection, combining complex ideas such as naturally occurring savings and technology inflation that can be used for any application (i.e. in any country).

6.2 Theoretical Background

Quantitative Model. For the requirements of this project, the appropriate model is commonly referred to as a discounted cash flow (DCF) model. This type of model is commonly used by the financial industry to assess capital investments. It uses both current information regarding prices and costs plus projections of a variety of parameters to examine life cycle costs and benefits of the investment in question. Future values are typically discounted to reflect the decision-maker's sensitivity to the value of future money. The model output or result is usually a specification of return on investment (ROI) or internal rate of return (IRR). The result will provide the user with an understanding of the payback period of the particular investment. In most cases, decision makers balance this result against other competing criteria that they have for their specific investment portfolios.

For energy efficiency investments, the key parameters that will drive an investment relate to the cost of the equipment (including financing costs), its energy use, the appropriate equipment life, future energy prices and the discount rate. The DCF model developed for this assessment starts with this basic model structure. Other considerations such as the existence of alternative financing, enhanced returns due to the existence of carbon trading and the impact of barriers are built onto this basic structure.

*Barrier Model***.** While the theoretical foundation for the specification of a DCF model to be applied in an energy efficiency investment regime is well founded, there is less agreement about how the existence of market imperfections such as barriers can be applied in that framework. Much of the literature indicates that the best mechanism to use to assess the impacts of factors like barriers in the marketplace or market imperfections is the implicit discount rate. This reflects how consumers and businesses weigh capital and operating costs. In a well-functioning market, decision-makers should make an energy efficiency investment when the return exceeds that of other potential investments (or the cost of borrowing). Put differently, the implicit discount rate should equal the cost of capital.

Unfortunately, research into implicit discount rates for energy-efficiency projects has shown that they are often far higher than the cost of capital. Among the reasons often cited for high implicit discount rates are:

1. uncertainty about future energy prices and associated returns,
2. uncertainty about the savings associated with efficient equipment,
3. lack of awareness and information,
4. short "tenure," which effectively reduces the life of an energy-efficient investment,
5. renter/owner incentive differences,
6. builder incentives to minimize construction costs,
7. costs and benefits that are hard to measure and are effectively eliminated from financial analyses.

The difference between a theoretical prediction and observed behaviour—differences in the cost of capital and the implicit discount rate or the internal rate of return on an investment—are attributed to one or more of these market barriers. To the extent a hidden cost or benefit factor is measurable, it can be quantified directly in a modelling exercise. However, consistent with the implicit discount rate literature, a market barriers model applies adjustments to the IRR go/no-go decision to measure the impacts of various barriers.

As indicated, decision makers' IRR expectation represents their sensitivity to risk – the higher the IRR expectation, the more sensitive to risk they are. When decision makers have perfect information regarding the investment they are likely to be less sensitive to risk, and will have a lower IRR expectation. The decision maker's cost of capital is one of the key determinants of IRR. In cases where there is little associated risk with an investment, the decision maker's IRR will be close to or the same as his cost of capital. This is an important consideration for the model specification outlined below, however it should be noted that this is rarely the case with energy efficiency investments.

The specific need is the development of a model which examines energy efficiency projects compared to a specification of an assumed business as usual case. The intent of the model is to determine what the typical energy efficiency investment behaviour is, and then examine the economics associated with projects that are over and above that typical behaviour. Examples of these kinds of projects include those where there is extra financing available, where government or utilities get involved to promote higher efficiency and so on.

6.3 Model Description and Specification

Based upon the theoretical requirements outlined above, a model is specified which allows for the examination of energy efficiency investments from the perspective of a client or from that of an intermediary – such as an ESCO. The general intent is to accommodate the fact that intermediaries may have access to financing, grants, specific information, or technologies which allow them to consider investments that a client may not – i.e. they have a lower expected IRR. It is important to note that in this framework, the nature of the investment with respect to the costs and savings is generally the same – only the perspective and sensitivity to IRR is different. That said, the model will accommodate third party investments beyond those of the client case (in fact, intermediaries such as ESCOs typically invest up to a certain payback threshold). The modeling is enhanced by the inclusion of parameters designed to address barriers.

To analyze and predict client and intermediary behaviour, we have created a spreadsheet model that contains both qualitative and quantitative aspects. First, the barrier model attempts to assess the implied IRR for a project by assessing if certain barriers exist. If those barriers do exist, the model integrates the expected rise in IRR with the cost of capital to create an implied IRR. Specifically, the model requires the user to answer Yes/No to the following questions:

1. Client uncertainty about the savings associated with efficient equipment
2. Uncertainty about future energy prices and associated returns
3. Lack of awareness and information
4. Private Firm or Institution
5. Other

After assessing if each particular barrier is an issue, the model requires an estimate for how much that specific barrier impacts the expected IRR. For example, a client has a 10% cost of capital. This client assesses that the uncertainty of energy savings requires 5% more for an internal rate of return as a risk premium on their investment. The barrier model adds an additional 5% to the cost of capital, thereby making the implied IRR 15%. This process continues for the remaining four barriers. The Project Team used its judgement regarding the expected ranges of impact on IRRs, and has provided an explanation to help guide the user as part of the Users Manual.

Given the lack of research to date in this specific area, it is not possible to "calibrate" the provided ranges with market behaviour. Indeed, one of the potential benefits of primary market research is the calibration of the barrier model.

Using detailed quantitative information on the project technologies and energy use, the quantitative section of the model will return IRR, payback and life-cycle costs for business as usual, client, and ESCO cases. The model will attempt to reach the implied IRR given in the barrier section through either an adjustment to the financing mix, a decrease in the financing rate on the loan or an increase to the carbon credits applied.

The quantitative model has been calibrated using data reported in the Czech Republic; however it can be used for any country and any currency. It also allows for flexibility and complexity in future situations. Specifically, the model accommodates data beyond what has been reported by the projects in the Czech Republic. This capability will provide for more comprehensive modeling efforts in the future.

The model builds an analysis for three cases—business as usual, client and third party (where "ESCO" is used a proxy for any third party intermediary). The baseline perspective assumes that there is no specific focus on investing in energy-efficient technologies. The model accounts for natural improvements in efficiency by allowing baseline energy consumption to decline over the planning horizon. This is an indication of "naturally occurring" conservation — increases in energy efficiency as equipment fails, either through mandatory codes and standards or because the new equipment is more efficient than the old equipment (i.e. rate of technical progress). The rate of increase is set by the user, however, experience in North America indicates that an increase of .5% per year is adequate in the absence of detailed rate of technical progress or technical potential studies.

For the business as usual case, the capital costs will generally be the projected cost of replacing the technology at the end of its useful life. Baseline additionality is also considered, given that the replacement technology will be more efficient due to naturally occurring technological improvements or improved efficiency standards.

It is useful to note that the structure and calculations of the client case and the ESCO case are exactly the same. The difference is only in perspective. Relative to the business as usual case, the client and ESCO cases install more efficient technologies (at potentially different capital costs) and use different funding sources. Further, an ESCO requires a separate assessment because it is assumed that ESCOs may provide even greater savings by installing efficient technologies (with different costs) beyond those that the client considers. Again, the ESCOs can have different costs of capital, funding sources and loan rates than both the client and business as usual case. Presumably, the cost of financing will be lower for the ESCO's due to their availability of funds. As well, in the case of emissions based funding, it is expected that ESCOs (or similar organizations) will have the knowledge and capability to capitalize on potential emissions credits that many clients may not. Further, ESCOs' profit motives have been shown to achieve greater savings persistence over time; thus, assuring greater emission reductions over time as well. Because comprehensive energy efficiency projects can address multiple technologies, the model accommodates up to three concurrent technology retrofits.

For the client and ESCO cases additional inputs are required that identify up to three funding sources for the proposed energy-efficiency investment, and if financing is proposed, the applicable interest rate. Carbon credits generated by a project are also identified for the client or ESCO cases. For additional detail on each of the model inputs, see section 6.4.

The model as designed uses Czech currency (CZk), but can be modified to accommodate any currency. All cost inputs are required in the local currency. Energy usage is input in GigaJoules (GJ). The model documentation provides conversion factors from common energy units to GJ.

As indicated, the model solves for IRR based upon the project data and projections of the various costs and energy prices. This IRR is compared to a pre-specified expected IRR. The pre-specified IRR represents the client's (or ESCO's) tolerance to risk. If the solved IRR is greater than the expected IRR, then it is assumed that the project will go ahead – it is not additional. If it is less than the expected IRR, the project is assumed to be additional in nature.

The model employs a unique goal/seek feature which allow users to determine by how much certain specific parameters would need to change to make the solved IRR match the expected IRR. The parameters considered are those that are likely to be used or impacted by a third party intermediary – specifically, amount and nature of financing, financing rate and value of emissions. Clearly, the nature of the funding and its rate will impact IRR, and ESCOs often have access to funding at lower rates than clients. The value of emissions is an important consideration as the ability to sell or trade the emissions that result from an energy efficiency investment can make projects more economic. The model will provide details on what the values of the various parameters would need to be to make the project meet the specified IRR. It is important to note that the constraints necessary to run this iterative function requires reasonable data inputs, thus all cases cannot return possible options.

6.4 Data Requirements

The data requirements for the modeling exercise relate to the need to develop a rigorous cash flow energy model and a model that incorporates an analysis of barriers. The model is more robust than the data collected in the Czech Republic required, so fields where data were not reported are set to zero. The initial data requirements are as follows:

For business as usual and energy efficient cases, the quantitative data required as input parameters include:

- Energy use/savings projections
- Equipment life
- Projection of relevant energy prices
- Discount rate(s)

Model Inputs & Calculations

Energy Rate Information. The model allows for three fuel types to be used for each case. It requires only a current rate and inflation estimate and will calculate future values as part of the algorithm. The model is also flexible for energy types and allows up to three non-standard inputs.

Inflation and Cost of Capital. The regional rate of price inflation must be input as well as the cost of capital for each of the business as usual, client and ESCO cases.

Funding Types. The data collected reported various types of funding with correspondingly different impacts on the cost and savings of a project. The model allows for the client and ESCO cases to vary their funding sources between grants, self-contributions, and loans. The model assumes that the business as usual case is funded by 100% self-contribution.

Technology Age. Because of the varying ages of the projects seen in the Czech Republic, this 20-year model accommodates shorter equipment life by assuming re-investment and crediting unused service life. In addition, the model allows for the business as usual case to use an outstanding service life on a current technology, and then naturally re-invest. In contrast, the client and business as usual cases invest immediately in a new energy-efficient technology. All investments must report the new technology service lives.

Annual Energy Use. To accurately measure the energy savings, the model requires the type and quantity of energy used for each technology.

Additionality. ***A***dditionally accounts for natural increases in energy efficiency. The business as usual case energy use is reduced by this value annually.

Capital Costs. The data collected in the Czech Republic provides the project capital cost and maintenance costs before and after the project. The model also accommodates technology inflation, and salvage value. The model requires the above data for each of the cases - business as usual, client and ESCO. In the Czech examples, business as usual capital costs were not reported. Thus, without this information, the model understates the actual cost of the business as usual case, or overstates the investment cost of the client or ESCO case above the business as usual. In turn, this will overstate the payback and IRR for the non-business as usual cases.

Pollution Penalties. Given the emission factors reported by the Czech data and the penalty levels as reported by SEVEn, the model computes pollution penalties on NOx, SO_2 and CO_2 where appropriate. It treats pollution penalties as a cost and no savings are available for reducing below the prescribed level.

Other benefits/savings. While information of this nature was not reported for the projects examined, it is an important factor to consider in an energy model. Non-energy benefits may be difficult to quantify, but factors such as societal benefits and productivity gains can impact overall cost-effectiveness for any given project. This has been the experience in North America where energy efficiency investments often provide value over and above the reductions in energy use.

Carbon Credits. To address the likelihood of emission-reducing incentives, the model accommodates the existence of carbon off-sets as an input feature. The model uses Current Czech data as a default.

6.5 Model Calibration

The initial model framework was based upon the Project Team's knowledge of ESCO behaviour, life cycle cost models, and greenhouse gas emission reduction. Adjustments to the initial specifications were made based upon data and observations from the Czech Republic (a discussion of relevant data and information is provided in Chapter 7). Specifically, the model was adjusted to accommodate various types of funding sources and the different impacts these have on the cost analyses. The model was also adjusted to allow for non-standard fuel types and changing fuel types between cases.

Model calibration consisted of testing the model with a number of specific projects undertaken in the Czech Republic (see Appendix A for a complete list of project data). It is important to note that no econometric or regression techniques were used to develop probabilistic estimates in the qualitative section. This relates to the lack of data and information required to support this kind of activity. While interviews and data collection were undertaken in the Czech Republic, pre and post assessments or rigorous surveys of clients were not.

The Barriers section of the model relies on standardized assumptions developed based upon North American experience. A selection of the most relevant barriers are specified, with values postulated based on expert judgement. Unfortunately, due to a lack of qualitative data for the Czech Republic, it was not possible to develop estimates for these parameters based upon the Czech experience. As indicated earlier, it is not possible to "calibrate" the provided ranges with market behaviour. Indeed, one of the potential benefits of primary market research is the calibration of the barrier model. The following table shows the barriers addressed in the model and example survey questions that could correspond to primary research.

Table 6.1
Barriers

Barrier	Assess if Barrier impacts case (yes/no)	Assess quantity of impact on IRR
Uncertainty about the savings associated with efficient equipment	Do you have significant experience with this energy efficient measure? Are you confident in the level of expected savings?	How would uncertainty with energy savings impact your expected rate of return?
Uncertainty about future energy prices and associated returns	Would volatile energy prices impact your operational costs significantly? Do you feel comfortable in your expectation of future energy prices?	How would uncertainty with energy prices impact your expected rate of return?
Private Firm rather than Institution	Are you considered a private or institutional organization? Does this impact your long-term planning horizon?	How does your long-term horizon impact your expected rate of return?
Lack of awareness and information	Does a lack of information prevent assessment of the value of energy efficiency equipment?	How does lack of information impact your expected rate of return?
Client Decision Making Process Creates Difficulty for ESCO? **	Will the client bureaucracy reduce the profitability of the project?	How does client process difficulty impact your expected rate of return?
Other	What other barriers exist for installing energy efficiency measures?	How do other barriers impact your expected rate of return?

** ESCO barrier only

6.6 Application and Interpretation

Chapter 7 provides examples of the model's application to actual projects reviewed in the Czech Republic. From a quantitative perspective, the model's life-cycle cost analysis and IRR results represent the standard method used to analyze energy efficiency (or other) investments. Without employing the model's probability features, a standard assessment can be done which will provide the basic information regarding the economics of a potential investment. Many would recognize that the standard assessment of the economics of energy-efficiency projects (comparing the project IRR to the cost of capital) is not an accurate predictor of which energy-efficient projects will be undertaken. Use of the qualitative aspects can be used to better predict which projects will proceed (or not) by comparing project IRRs to the implicit IRR calculated for clients or for ESCOs. This analysis can be enhanced using the goal-seek feature of the model to determine how much either financing rates or the values of emissions would have to change to make any given investment meet its specified implicit IRR.

6.7 Reliability of Results and Limitations of the Model

Using data from the Czech Republic, the Project team verified that the model calculates project economics, however only quantitative data from client projects that were implemented was available. Rigorous testing of the model's more sophisticated capabilities would require the availability of a broader range of quantitative data from client and ESCO projects and the collection of qualitative data regarding the evaluation and assessment of project opportunities. This is beyond the scope of this effort, and the data necessary for this purpose should be obtained from the United States and Canada where there is a long, varied history of third party/ESCO experience with energy efficiency investments. As a result, at this point the primary limitation of the model is the availability of robust, verified data to test both the barrier and the financial model fully. Further, the Project Team used its current experience to create the barrier model using the implied IRR approach, but data has not been collected and studied to make this a tested approach. To our knowledge, this research has not been done in US or Canada and therefore would require a study using primary research to collect data on projects and expectations of ESCOs in North America. A study of this type would also address several other concerns noted above:

1. What is a plausible range of target IRRs?
2. Do these targets differ among different project types, or among nature of project sponsor (private, public, local government)?
3. What level of confidence should be attached to the values?
4. What are the main reasons for below normal IRRs? Are there types of projects or types of decision-makers who are more prone to base project decision on non-IRR considerations?

We feel that this research would address the very important modelling issues raised over the course of this study, and perhaps more importantly, greatly expand the scope of global knowledge related to ESCO decision-making.

References

1. Chomitz, Kenneth M., “Baselines for Greenhouse Gas Reduction: Problems, Precedents, Solutions”. World Bank, July, 1998

2. Jaffe and R. Stavins, “Energy Efficiency Investments and Public Policy,” The Energy Journal, Vol. 15, No. 2 (1994), pp. 43-65.

7. Model Application to the Czech Republic

7.1 Introduction

The following sections describe efforts undertaken to test and calibrate the model. Most of the effort focused on collecting and testing project data from the Czech Republic. Because of the involvement of the Czech Energy Agency and the Czech Energy Efficiency Association, the Czech data and experience was, a piori, expected to yield the best possible data-set.

For most of the projects examined, the notion of additional/non-additional was difficult to address. Energy efficiency projects have been undertaken for a variety of reasons in the Czech Republic beyond simply energy savings. One recent change is the implementation of a state requirement, through the Czech Energy Agency (CEA), that stipulates that certain facilities must undertake an energy audit within a set deadline, with larger enterprises having a shorter timeframe. For this reason, base case behaviour cannot be easily determined. As well, funding from a number of sources including national and international agencies has been made available for energy efficiency investments. This makes it difficult to determine what would have occurred under a business as usual scenario. Interviews with the major ESCO intermediaries active in the Czech Republic indicated that their investment criteria is also impacted by the availability of outside funding and their desire to establish new lines of business in the Czech Republic (all but one of the active ESCOs are foreign owned).

As indicated, to facilitate testing of the model, data were collected for a number of energy efficiency projects in the Czech Republic. These represented projects that were either completed or were close to it. Unfortunately, it was not possible to collect information regarding key decision criteria prior to any of the projects going forward. This information would have been useful for specifying expected IRRs and establishing parameters in the barriers section of the model. That said, the project data collected represents the best information currently available for this kind of exercise. Complete data detailing the type and nature of the projects, savings, costs and equipment types were provided. As part of the project, a large number of projects from other countries in Eastern Europe were also reviewed, however it was not possible to collect the detailed data needed for model calibration from these secondary research exercises. This is an important consideration for future investigations. It is unlikely that secondary research will establish all the various data needed to adequately use the model (note that SEVEn staff invested significant resources to prepare and “clean” the data used to test the model). That is, primary research will be required, including detailed reviews of project data and interviews with the relevant decision maker(s).

7.2 Czech Project Data

A detailed data collection exercise was undertaken in the Czech Republic, spearheaded by SEVEn, the Czech Energy Efficiency Agency. SEVEn collected detailed data from 18 energy efficiency and fuel switching projects delivered over the past two to three years. Many of the projects were delivered or supported by the Czech Energy Agency (CEA) and funded by various national or international agencies. Interviews with key players in the marketplace, including SEVEn auditors and program managers, CEA program managers, plant managers at specific projects and senior management of all energy service companies currently active in the Czech Republic, were undertaken as part of the research. These interviews provided key qualitative information regarding the current infrastructure constraints to energy efficiency in the marketplace and also helped to put the modelling exercise into perspective vis a vis the challenges of implementing energy efficiency in an economy in transition.

As part of the data collection exercise, a detailed reporting framework was established to ensure consistency in definitions and set minimum reporting requirements. These requirements were established iteratively as the model was developed. This effort resulted in a reporting framework that will provide the necessary data for DCF assessments in environments where various funding arrangements are available.

Each project reviewed had a specific function and typically employed one to two energy types. Funding sources were reported by organization across the following categories: grants, debt financing, and equity. Maintenance costs were reported before and after technology contribution. Energy use and emissions for each technology option were also provided. The data collected for the 18 projects was used directly to calibrate and test the eventual model developed. It is important to note that the 18 projects had detailed evaluations done by both the CEA and SEVEn. This ensured the high quality of the data provided. As indicated, a number of other projects were reviewed as part of this exercise, however since the assessment involved only secondary research, these data were typically found to be incomplete.

The CEA provided aggregate data for all projects and audits undertaken from 1996 – 2001. There are two categories of data available: energy audits co-financed by the CEA in the 2000, and project information for projects realized with the financial support of the CEA between 1996-2000.

The main aggregate data taken from the audits supported is provided in Table 7.1 below. While not project specific, these data provide an understanding of the magnitude of savings achieved to date. The CO_2 savings were calculated using standard emissions factors and are seen to be reasonably accurate.

Table 7.1.
Audit Data

	Number	Investment costs	Annual energy savings	Annual cost savings	Annual CO_2 savings	Expected lifetime	Total CO_2 saved
		Thousands of CZK	GJ/year	Thousands of CZK/year	t/year	Years	t
Heat production and CHP	19	415899	209931	24663	22352	359	523079
Housing sector	115	738611	156122	46838	5953	3535	230047
Schools, health service, public services	289	1542910	657873	49333	49333	6452	1478033
All sectors	**423**	**2 697 420**	**1 023 927**	**120 834**	**77 638**	**10 346**	**2 231 159**
Average per project		6377	2421	286	184	24	5275

Since 1996, the CEA has been supporting the delivery of energy efficiency and renewable projects with a variety of technology-focussed energy efficiency programs. These programs represent the cornerstone of the Czech government's energy efficiency efforts. The programs also collect detailed evaluation data for the various projects delivered. These data are provided to SEVEn under a monitoring and evaluation agreement. The 21 projects reviewed represent a sub-set of specific project delivered via the CEA.

The SEVEn CEA programs are as follows:

I. Technical measures for energy efficient operation of residential buildings and single-family row houses and detached homes.
II. Technical measures for energy efficient operation of buildings and their equipment used for education.
III. Technical measures for energy efficient operation of buildings and their equipment used for health care.
IV. Technical measures for energy efficient operation of buildings used for community services and by public institutions.
V. Greater utilisation of renewable and secondary sources of energy and cogeneration.
VI. Optimisation of energy supply to residential areas.
VII. Energy conservation in industry, applications of modern technologies and materials to energy efficiency measures and support for energy efficiency measures and alternative sources of energy in transportation and agriculture.

Table 7.2 below presents summary information for the projects supported by the CEA between years 1996-1998, categorized by program type. Again, while not project specific, the table provides an indication of total savings achieved. The CEA programs have been very effective at delivering energy efficiency. The new requirement for large industrial and commercial facilities to undertake an energy audit of their facilities will set the stage for even more energy efficiency investments. In fact, these audits represent a significant opportunity for third party investors (ESCOs in particular) to begin to offer energy efficiency products and services as part of a comprehensive audit based service.

Table 7.2

Summary results of individual programs for the years 1996-1998 (delivered)

	Grant funding	Total investments	Energy saved annually	Energy saved over project period	Total investments/ Total energy saved
1996-1998	[million CZK]	[million CZK]	[GJ/year]	[GJ]	[CZK/GJ]
I.	248	1,056	159,173	7,043,188	150
II.	94	306	86,699	2,443,361	125
III.	64	240	183,858	3,822,843	63
IV.	36	138	54,762	1,697,746	81
V.	151	863	1,156,279	34,643,222	25
VI.	208	1,560	593,171	20,229,990	77
VII.	38	225	307,795	8,419,850	27
Total I.-VII.	**839**	**4,389**	**2,541,737**	**78,300,200**	**56**

[1] In the case of energy produced from renewables, the energy 'saving' is the energy production saved from non-renewable sources.

As indicated, detailed project data were provided by SEVEn. The data requirements and project data for these are provided in Appendix A.

A number of key observations were made during the data collection exercise in the Czech Republic. These include:

Existence of Counter-intuitive Internal Rates of Return. The original hypothesis was that the energy projects reviewed would have IRRs that were somewhat realistic, either because they were established a priori, or because they fell out of a proper analysis of the project. For some projects reviewed, however, IRRs were actually negative which was initially counter-intuitive. Upon further examination and discussions with project managers it was discovered that these projects were often implemented purely out of the desire to lower emissions. The economics did not matter. Implicitly, these projects had a very high value of emissions, however, that was not incorporated into the IRR analysis as this type of investment behaviour was not seen to be sustainable. (These projects were not included in the sample projects reviewed.)

Discount Rate. Many of the projects examined used a discount rate of 10% which seems low based on North American experience. This relates to the “societal” nature of the projects. These energy projects were undertaken as part of an environmental plan, not necessarily as investments with strict payback expectations, as might be the case with a third party intermediary. Interestingly, this discount rate is relatively close to the cost of capital which suggests that investments of this nature are barrier indifferent.

Fuel Prices. Fuel prices, both base year and forecasts were provided for all major fuels including electricity, natural gas, coal and oil. It is important to note that electricity prices are currently in a transitional period. There is significant subsidization, both generally and within segments of the economy. This is only a temporary phase, however and fuel prices are expected to rise significantly in some sectors – notably residential. Price adjustments will be phased in gradually starting in 2002 with a more actual reflection of cost of service expected by 2005 (subject to change). This does not imply that all subsidization will be eliminated.

Nature of third party (ESCOs) involvement. To date, there have been very few projects delivered via third parties in the Czech Republic. ESCOs are relatively new and the infrastructure is in its infancy. As discussed in earlier, a lack of knowledge regarding ESCOs has been a barrier thus far. The 18 projects reviewed were those that had been undertaken by ESCOs were small in scope and investment, and entirely in the institutional market, mainly schools and hospitals. Some private sector energy companies have moved heavily into district energy, buying up existing plants and modernizing or completely replacing the plant and distribution systems. Cogeneration has been an important part of this activity. In many cases, the local municipality or region has retained a minority partnership in the new district energy company.

As indicated, the 18 projects reviewed were all client in nature. While detailed discussions were undertaken with all active ESCOs in the Czech Republic, the Project Team was not able to collect project data for the various ESCO projects. This represents an area of potential improvement for the future.

Availability of grants, loans and incentives. The 18 projects reviewed received a variety of funding support. Unlike most third party projects in North America, grants are available from various funding agencies. This clearly affects the economics of any given projects. Loans have also been used extensively. The existence of different types of financing impacts the requirements of the model. Grants clearly imply different economics than loans.

7.3 Energy Efficiency Investment Behaviour

The nature of energy efficiency investment in the Czech Republic since 1996 has been chiefly government oriented and supported. Large government sponsored programs are underway aimed at promoting both higher levels of efficiency and fuel switching to cleaner fuels (i.e. off coal). These programs receive both local (federal) and international funding through agencies such as the World Bank, the European Bank for Reconstruction Development (EBRD) and USAid. Much of this effort is driven by the Czech Republic’s need to both lower emissions levels, and by the desire to meet the environmental standards of the European Union.

Current investments in energy efficiency through the state - supported programs focus on specific sectors of the economy – notably institutional, large industrial and district energy. These sectors are viewed as the primary contributors to emissions. They are also sectors where significant numbers of coal fired boilers are still in use. Efforts aimed at lowering energy use in homes and other sectors (e.g. commercial and small industrial) have not been explored much to date. The potential for indirect impacts from lowering electricity use is still largely un-tapped. However, it is important to stress that the business as usual energy use for these other sectors and their electricity based end uses is likely significantly lower than in North America. While ESCOs have built their business around managing specific electric end uses in the commercial and institutional sectors in North America, it is premature to suggest that the same potential exists in the Czech Republic.

The use of district energy in the Czech Republic, and in much of Europe, has its origins in the use of fossil fuels such as coal which require storage and high maintenance, the historical preference for “wet heat” over forced air (also aided by a lack of perceived need for air conditioning), a need for low or even subsidized costs for the end user, and a general preference for state owned and operated utilities. As a consequence, the development of heating appliances in small capacities using fuels other than electricity was delayed compared to North America. With the introduction of natural gas to the European market, combined with the development of regional and local transmission facilities, there has been some movement towards in situ heating plants. Countering this trend is the efficiency advantage of cogeneration, the development of low-loss pre-insulated piping systems, and the move to high temperature hot water systems which offer considerable efficiency advantages over steam. Countries such as Denmark and Sweden, neither of which has any indigenous source of fossil fuel, have made an almost total commitment to district energy systems. Countries such as the Czech Republic are currently applying both district and local energy systems.

7.4 Parameter Estimation

Model calibration focused on testing the various model parameters with the Czech data provided for the 18 projects reviewed. Project data was input as per the model requirements and IRR results were reported and compared to those provided by SEVEn. Table 7.1 shows project IRR, payback and Life Cycle Savings for The 18 projects reviewed.

While 18 projects may not be a large enough sample, some conclusions can be drawn from the data. Removing the outliers, the average IRR seen is in the 40% range – not unlike what could be anticipated for North American energy projects. However, the range of the various IRRs is large, and in at least one case – non-intuitive. There were a number of projects that had very high IRRs, suggesting that the combination of the savings and the financing arrangements made these projects extremely cost effective. An examination of these projects revealed that they did receive grants from a variety of funding agencies. Some projects in the sample plus a number that were reviewed but were not included in the analysis (due to data limitations) had abnormally low IRRs. Discussions with SEVEn and CEA staff suggested that these projects went ahead irrespective of their energy savings. The main reason given for these related to their huge emissions reductions potential – thus implying a very high emissions credit. In at least two cases, negative IRRs were reported for projects that went ahead. These were projects specifically designed to convert coal burning boilers to natural gas.

Based on the sample, and discussions with professionals in the energy community in the Czech Republic, it is expected that there will not be a large number of projects with abnormally low IRRs in the future. This relates both to the fact that the immediate emissions reductions projects have already been done and to the general sense of an increasing focus on project economics for these kinds of investments.

Finally, discussions with active ESCOs in the Czech Republic indicated the funding is not the challenge for implementing projects. Rather, since many of the investments are made in the public sector environment, there is an element of conservatism among decision-makers in this sector that needs to be overcome. This is especially true for investments that require municipal sector involvement. Decision-makers in this sector tend to be wary of energy performance contracting and the notion of return on investment for energy efficiency improvements. This likely relates to the pre-revolution nature of compensation in this sector.

Table 7.3
Project IRRs

Project Name	IRR	Payback	SEVEn Payback
Hospital Ivancice	36%	2.93	
Wind Mill Jeseník	1%	18.09	
Hodonin	170%	0.61	
Utilization of Natural Gas for Heating of Housing Structure Decin - Bynov, City of Decin	10%	9.31	
Horni Podluzi Town[10]	49%	2.17	
Elementary School, Velky Senov Village	14%	7.40	
Primary School, Velhartice Village	31%	3.41	1.4
AURORA Baths, City of Trebon	44%	2.41	
Primary School in Litvinov, City of Litvinov[11]	130%	0.79	
Borova Lada Village	60%	1.75	
Secondary School Chomutov, City of Chomutov	43%	2.47	4.1
Secondary nursery school, City of Most	59%	1.76	4.6
Masaryk`s City Hospital, Jilemnice Town	41%	2.60	5.3
3. Primary School Chomutov, City of Chomutov	34%	3.09	4.3
Factory Power and Heating Plant Kyjov [12]	250%	0.42	
ECKG Kladno Power Plant, Kladno	#N/A*	#N/A	

* Model did not find savings over the baseline

As shown, the project IRRs had significant variation. As discussed earlier, this may relate to the “other” reasons for project investment. Also, the existence of grant funding decreases the initial capital cost by 75% in some cases. Further, in some cases, in spite of the data cleaning exercise, the quality of data provided was not robust enough for a full life-cycle cost analysis. Many fields remained blank for the analysis, so some relevant facts were not taken into account. In particular, data on maintenance costs were not available in several cases, effectively reducing non-energy direct benefits to zero. As well, the current age and remaining life of existing equipment, and replacement cost with the lowest available energy efficiency were not available for most projects.

[10] This site replaced oil and electricity from the grid usage with a cogeneration unit resulting in significant energy savings from the reported usage values.
[11] For a small capital investment, this site reduced lignite consumption by nearly a third.
[12] This facility replaced electric usage with a combined-cycle combustion turbine, reducing energy usage significantly.

7.5 Test Case

The following section provides details of the modelling exercise for one project. The project was selected at random from the list of 18 projects reviewed. The Project Primary School, Velhartice Village. All data gathered for the CR are considered “client” models, so the ESCO example below is shown for demonstration purposes only.

First, the potential barriers for the client case and ESCO case are idnentified. Again, the answers and impact on IRR are based on the Project Team’s experience, not on observations in the Czech Republic. The client barrier model is shown below.

Implied IRR with Barriers- Client

40%

	Is this a barrier for you?	Impact on Client IRR:
Client uncertainty about the savings associated with efficient equipment	yes	10%
Uncertainty about future energy prices and associated returns	yes	10%
Lack of awareness and information	yes	10%
Private Firm rather than Institution:	no	0%
Other	no	0%

For the ESCO case, it is assumed that the uncertainty related to savings and lack of awareness and information were both improved, therefore the implied IRR for the ESCO case was 20%.

For the quantitative model, the client case had a financing mix of 30% grant and 70% self-contribution. The technology costs were CZk 3.2 million and savings in operational costs were identified. The original technology used lignite coal while the new technology used gas. Modelled IRRs concur with data reported by SEVEn and the CEA (shown in section 7.4 above). For the ESCO case, the project team used artificial data to show the functionality of the model. In this case the a portion of the grant funding was transferred to debt funding at the ESCO cost of capital, the technology costs were decreased by 50%, and the energy costs were reduced by 50%.

The project parameters provide an overall results summary:

Table 7.4
Complete Project Summary Costs

Complete Project Summary Costs			
Overall (mil CZK)			
Present Value of Costs	**Business-as-Usual**	**Client**	**ESCO**
Equipment Costs	CZK 0.0	CZK 0.9	CZK 0.9
Maintence Costs	CZK 0.0	CZK 0.0	CZK 0.0
Energy Costs	CZK 1.1	CZK 0.4	CZK 0.2
Pollution Penalties	CZK 0.8	CZK 0.3	CZK 0.3
Other Savings	CZK 0.0	CZK 0.0	CZK 0.0
Carbon Credits	CZK 0.0	(CZK 0.0)	(CZK 0.0)
Total	**CZK 2**	**CZK 1.6**	**CZK 1.4**
Annual Life Cycle Cost	**CZK 0**	**CZK 0.2**	**CZK 0.2**
Carbon Saved (tons)		**11.66**	**459.99**
Total Savings (difference in life cycle costs)		**CZK 0.3**	**CZK 0.5**
PV of Initial Investment above Baseline		**CZK 0.9**	**CZK 0.9**
Payback Period (yrs)		**7.40**	**6.30**
Internal Rate of Return		**13.6%**	**16.4%**
IMPLIED IRR		**40%**	**20%**

As shown, because of the ability for an ESCO to positively influence energy savings and technology costs, the ESCO case experiences the higher IRR. The implied versus actual rates of return are significantly different for the two cases. This means that the ESCO project will have a higher likelihood of making the appropriate adjustments to the various parameters or to the value of emissions reductions to meet the project IRR.

7.6 Aligning Implied IRR with Project IRR

Using the goal-seek function, there are three potential parameter changes that allow the expected IRR to match the Implied IRR. A message box will show the options available to the ESCO case above:

Goal seek solutions

Given an ESCO Project IRR of 16.43%, to achieve an Implied IRR of 20.00%, you can: 1. Change loan rate to 1.40%, or2. Change the grant proportion to 52.96% with self-contribution proportion of 33.25%and a loan proportion of 13.79%, or 3. Change the carbon offset value to [Significantly Larger than Accepted Range of $2-$10 per ton] 1404.85 czk/ton
----

The first option shows that, keeping the loan proportion the same, reducing the loan rate to 1.4% will bring the Project IRR to the Implied IRR. The Second option indicates that reducing the loan percentage to 13.8%, increasing grant to 53.0% and self-contribution to 33.3% will increase the IRR. For the third option the value of an emission trade is calculated using the goal seek feature of the model. For this example, an emission value of CZk 1404 is required to make the project meet an expected IRR of 20%. Note that the message box states that this is much larger than the currently accepted range of $2 - $10 per ton, making this particular option unlikely.

8. Conclusion

At the outset, the intent of this project was to review and evaluate the various approaches for delivering GHG emissions reductions through third party energy efficiency projects focused on economies in transition. To accomplish this, the Project Team set out to first characterize the marketplace and general approaches and then develop a modeling framework for assessing specific third party projects. The modeling framework needed to accommodate a typical discounted cash flow assessment for cost effectiveness for three cases: business as usual, client case and ESCO case where ESCO is used as a proxy for third party EE investments. Since it was anticipated that there would be specific barriers to implementation in the various EITs, it was established that a model which could also address the various barriers would also be useful.

As part of the development of the modeling framework, a review of the literature with respect to the nature of barriers to energy efficiency improvements was undertaken. Based upon the results of the research, five basic barriers were identified. These formed the basis for the development of the barriers model.

The goal for the development of the model was to use "real world" data and information from the various EITs to develop, validate and test the model. To facilitate this, a portion of the Project Team prepared a detailed review of EE projects in EITs using secondary sources. Based upon this information, and the development of contacts with the Czech Energy Efficiency Association (SEVEn), it was determined that a review of EE projects in the Czech Republic would likely yield the best data and qualitative information on EE projects in an economy in transition. As well, it was expected that a better understanding of the experience to date with third party delivery of EE, in particular, energy performance contracting would be developed. In the summer of 2001, the Project Team spent one week in the Czech Republic collecting data and interviewing the various energy professionals. The interviews included meeting with the major ESCOs currently active in the marketplace and members of both SEVEn and the Czech Energy Agency.

The results of the interviews helped to establish the expectations with respect to the IRRs for the various projects. Equally important was the feedback received regarding the nature of the ESCO marketplace in the Czech Republic and the challenges currently faced – one of which was an institutional barrier related to decision-makers in the municipal sector.

Model development was undertaken concurrently with the data collection process in the Czech Republic. A standardized DCF model was developed allowing for cost effectiveness assessments from the client and ESCO perspective. The model also includes a qualitative barriers component which directly adjusts the implicit IRR. This is in keeping with the literature which suggests that most barriers and "other" factors can be accommodated through adjustments to required IRRs. Finally, the model employs a unique "goal-seek" feature which tells the user how much certain parameters (financing, emissions values) would need to change to make the project meet its required IRR. The model is configured in manner where a user-friendly front end can be used to input the various data. Both detailed and summarized output options are available.

Without employing the model's probability features, a standard assessment can be done which will provide the basic information regarding the economics of a potential investment. Many would recognize that the standard assessment of the economics of energy-efficiency projects (comparing the project IRR to the cost of capital) is not an accurate predictor of which energy-efficient projects will be undertaken. Use of the qualitative aspects can be used to better predict which projects will proceed (or not) by comparing project IRRs to the implicit IRR calculated for clients or for ESCOs.

Using data from the Czech Republic, the Project team verified that the model calculates project economics, however only quantitative data from client projects that were implemented was available. Rigorous testing of the model's more sophisticated capabilities would require the availability of a broader range of quantitative data from client and ESCO projects and the collection of qualitative data regarding the evaluation and assessment of project opportunities. This is beyond the scope of this effort, and the data necessary for this purpose should be obtained from the United States and Canada where there is a long, varied history of third party/ESCO experience with energy efficiency investments. Since the data can differ significantly from the Central and eastern Europe experience, the US and Canada data should be compared with several projects from CEE, such as old Wind power projects from the previous years or Biomass projects.

As a result, at this point the primary limitation of the model is the availability of robust, verified data to test both the barrier and the financial model fully. Further, the Project Team used its current experience to create the barrier model using the implied IRR approach, but data has not been collected and studied to make this a tested approach. To our knowledge, this research has not been done in US or Canada and therefore would require a study using primary research to collect data on projects and expectations of ESCOs in North America. Section 6 provided guidelines on the type of information that would need to be collected to facilitate a more robust set of model parameters.

GLOSSARY

^{0}C	Degrees Celsius
AAU	Assigned Amount Unit, units issued by Annex B Parties to track compliance with their emissions limitation commitments under the Kyoto Protocol
Annex B	Countries listed in Annex B to the Kyoto Protocol as of May 2002
ASHRAE	American Society of Heating, Refrigerating & Air Conditioning Engineers
CACI	Clean Air Canada Incorporated
CDM	Clean Development Mechanism, emission reduction or sink enhancement projects in developing countries under Article 12 of the Kyoto Protocol
CEA	Czech Energy Agency
CEE	Central and Eastern Europe
CER	Certified Emission Reduction, credit issued for an emission reduction achieved by a CDM project (Kyoto Protocol
CEZ	Ceske Energeticke Zavody (Czech) National Power Utility
CH_4	Methane, a greenhouse gas
CHP	Combined Heat and Power
CO_{2E}	Carbon Dioxide, a greenhouse gas
COP	Conference of Parties (UNFCCC)
CZK, CZH	Czech Republic Koruna (Currency Unit)
DCF	Discounted Cash Flow, used to determine Net Present Value
DER	Discrete Emission Reduction, credit issued for a NOx or VOC emission reduction achieved by a source under programs in some states in the US
DET	Domestic Emission Trading, an emissions trading program implemented in a single country
DSM	Demand-Side Management, actions to change the quantity or timing of energy use by customers of a utility
EBRD	European Bank for Reconstruction & Development
ECMs	Energy Conservation Measures
EE	Energy Efficiency
EIT	Economy In Transition, former eastern block countries
EMCS	Energy management control system
EPA	Environmental Protection Agency (USA)
EPC	Energy Performance Contract
ER	Emission Reduction
ERC	Emission Reduction Credit (US, Canada)
ERU	Emission Reduction Unit, credit issued for an emission reduction or sink enhancement achieved by a JI project (Kyoto Protocol)
ESCO	Energy Service Company
ET	Emissions Trading
ETP	Emissions Trading Program
EU	European Union
FCCC	Framework Convention on Climate Change (United Nations)
GDP	Gross Domestic Product
GEF	Global Environment Facility (World Bank)
GHG	Greenhouse Gases
GJ	Gigajoule (10^9 Joules)
Gtoe	Giga tonnes of oil equivalent
GUM	Guideline to the Expression of Uncertainty in Measurement (ISO)
HOS	Hospital

IET	International Emissions Trading, trading of AAUs under Article 17 of the Kyoto Protocol
IETA	International Emission Trading Association
IPCC	Intergovernmental Panel on Climate Change
IPMVP	International Performance Measurement and Verification Protocol [21]
IRR	Internal rate of return
ISO	International Standards Organisation
JA	Joint Attainment, voluntary redistribution of emissions limitation commitments by Annex B Parties under Article 4 of the Kyoto Protocol [I think this may have been deleted from the report]
JI	Joint Implementation, emission reduction or sink enhancement projects in Annex B countries under Article 6 of the Kyoto Protocol
kW	Kilowatt
kWh	Kilowatt hour
M&V	Monitoring and Verification
Mg	Megagrams
MWh	Megawatt Hours
NEK	Norsk Electroteknisk Komite
NGO	Non-governmental organization
NO_x	Nitrogen oxides
NPV	net present value
P	Power
PCF	Prototype Carbon Fund, a fund to invest in CDM and JI projects (World Bank)
PER	Per Capita Energy Consumption
PES	Primary Energy Supply
POI	Point of Impingement Standard (Ontario)
PPP	Purchasing Power Parity, an exchange rate that reflects the ability to purchase the same mix of products in two countries
PRISM	Princeton Scorekeeping Method
RMU	Removal Unit, a credit for eligible sink enhancement actions implemented b Annex B Parties during 2008-2012 under the Kyoto Protocol
ROI	Return on Investment
SCH	School
SE	National Power Generation Company of the Slovak Republic
SEVEn	Stredisko Pro Efektivni Vyuzivani Energie (The Energy Efficiency Center, Czech Republic)
SO_2	Sulphur Dioxide
TPES	Total Primary Energy Supply
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
VBA	Visual Basic for Applications
VBDD	Variable-base degree-day
VER	Verified Emission Reduction
WMO	World Meteorological Organization

Appendices

Appendix A

Czech Project Data

Project Descriptions (millions CZK)

No	Class/Name	Sector	Description	Financing Participants	Financing Amount	Financing Type
Cogeneration						
1	Factory Power and Heating Plant Kyjov	IND	construction of power and heating plant and waste heat utilization	Own contribution	250.0	Equity
				GEF	198.0	Grant
				Commercial loan	370.0	Debt
2	ECKG Kladno Power Plant, Kladno		construction of power and heating plant	Matra (private consortium)	12,460.0	Equity
				Středočeská energetická, a.s.	1,540.0	Equity
3	Liberec Pool	MUN	cogeneration at indoor swimming pool	Own contribution	10.0	Equity
				Phare	3.3	Grant
Steam Utilities						
4	Ivancise Hospital	MUN/HOS	hospital steam system efficiency retrofit: boilers, distribution, controls	Local Government	8.3	Debt
				CEA	2.5	Grant
				Commercial loan	1.0	Debt
				USAID	0.7	Grant
5	Bulovka Hospital	NAT/HOS	hospital steam system efficiency retrofit: boilers, distribution, controls - EPC contract, guaranteed savings	EPS-ČR (ESCO)	67.0	Debt
				CEA	5.0	Grant
District Heating						
6	Decin DHS	MUN	municipal district heating system upgrade: gas conversion, boiler replacement, distribution upgrade	SFZP	86.5	Debt
				Danish government	20.2	Grant
				3 US utilities	18.6	Loan
				City of Decin	15.0	

No	Class/Name	Sector	Description	Financing Participants	Financing	
					Amount	Type
7	Bohumin DHS	MUN	municipal district heating system upgrade: gas conversion, distribution upgrade	City of Bohumin	4.7	Equity
				CEA	0.4	Grant
8	Jesenik DHS	PRI	private district heating system upgrade: boiler reconstruction and distribution system replacement	Jesenická tepelná společnost	7.4	Equity
				CEA	0.8	Grant
				Other-not specified	3.0	
9	Jihlava DHS	PRI	private district heating system upgrade: fuel switch and distribution system replacement	CEA	0.3	Grant
				Jihlavske kotelny	1.9	Equity
Alternative and Renewable Energy						
10	Jesenik Wind	RES	Wind Mill	Commercial loan	93	Debt
				Energovars	14.5	Equity
				CEA	17.5	Grant
11	Hodonin LFG	MUN	Landfill gas plant	SFZP	5.7	Grant
				Commercial loan	1.4	Debt
Thermal Rehabilitation						
12	Horni Podluzi town	MUN	thermal rehabilitation of a residential building	Phare	4.1	Grant
				Own contribution	1.2	Equity
13	Elementary School, Velky Senov Village	MUN/SCH	gasification and thermal rehabilitation of an elementary school	Phare	2.32	Grant
				Own contribution	0.89	Equity
14	Primary School, Velhartice Village	MUN/SCH	thermal rehabilitation of an primary school	Czech SEF	1.988	Grant/Debt
				Velhartice Village	0.497	
15	AURORA Baths, City of Trebon	MUN/HOS	local heating and hot utility water preparation system	Own contribution	16.415	
				Czech SEF	6	
				CEA	1.5	
16	Primary School in Litvinov, City of Litvinov	SCH-EPC	EPC contract, Shared Saving	Stredisko pro uspory energie, s.r.o. (ESCO)	0.342	Debt
				Own contribution	0.114	Equity

No	Class/Name	Sector	Description	Financing Participants	Financing	
					Amount	Type
17	Terrestrial heat utilization for heating of municipal buildings	MUN/RES	Terrestrial heat utilization for heating of municipal building	Phare	13	Grant
				Own contribution	1.75	Debt
				CEA	2.18	Grant
				SouthBohemia Power Distributor (Jihoceska energtika)	0.07	Grant
18	Secondary School Chomutov, City of Chomutov	SCH-EPC	EPC contract, Shared Savings	Stredisko pro uspory energie, s.r.o. (ESCO)	1.12	Debt
19	Secondary nursery school, City of Most	SCH-EPC	EPC contract, Shared Savings	Stredisko pro uspory energie, s.r.o. (ESCO)	1.46	Debt
20	Masaryk's City Hospital, Jilemnice Town	HOS-EPC	EPC contract, Cost Cutting Guaranteed	EPS ČR, Ltd., now MVV EPS, s.r.o. (ESCO)	19	Debt
				CEA	2	
21	Primary School Chomutov, City of Chomutov	SCH-EPC	EPC contract, Shared Savings	Stredisko pro uspory energie, s.r.o. (ESCO)	1.591	Debt

Economic Details (millions CZK)

No	Class/Name	Investment			Debt Rate	Annual Operate (after)	Energy Revenue	IRR	NPV	Capital Costs
		Total	Equity	Debt						
Cogeneration										
	Local Indoor Swimming Pool, City of Liberec	13.3	10	0	NA	5.2	1.28	NA	NA	13.3
District Heating										
	Hospital Ivancise	12.5	0	8.3 1	0% 13%	3.065	3.49	NA		12.5
	Utilization of Natural Gas for Heating of Housing Structure Decin - Bynov, City of Decin	226.8	0	105.1	0%	NA				226.8
	Bohumin	5.125	4.725	0	NA	2.1901	-0.84	NA	NA	5.125
	Jesenik	11.24	7.44	0	NA	2.2432	1.07	NA	NA	11.24
	Jihlava	2.2	1.88	0	NA	1E+06		NA	NA	2.2
Renewable										
	Wind Mill Jesenik	125	14.5	93	13%	1.02	1.84	NA	-117.5	125
	Hodonin	7.1	0	1.4	11%	1.86	0.96	NA	NA	7.1
Thermal Rehabilitation										
	Horni Podluzi town	5.3	1.2	0	NA	0.2463	0.23	NA	NA	5.3
	Elementary School, Velky Senov Village	3.2	0.89	0	NA	0.081	0.07	NA	NA	3.2
	Primary School, Velhartice Village	2.5	0	0.994	0%	0.212	0.52	NA	3.8	2.5
	AURORA Baths, City of Trebon	23.9				4.225	4.10	NA	NA	23.9

No	Class/Name	Investment			Debt Rate	Annual Operate (after)	Energy Revenue	IRR	NPV	Capital Costs
		Total	Equity	Debt						
	Primary School in Litvinov, City of Litvinov	0.457	0.114	0.342	NA	0.609	0.32	NA	NA	0.457
	Terrestrial heat utilization for heating of municipal buildings	17	0	1.7	NA	0.21		NA	NA	21.2
	Secondary School Chomutov, City of Chomutov	1.12	0	1.12	NA	0.458	0.27	NA	NA	1.12
	Secondary nursery school, City of Most	1.46	0	1.46	NA	1.026	0.32	NA	NA	1.46
	Masaryk's City Hospital, Jilemnice Town	21		19	NA	1.943	5.92	NA	NA	21
	Primary School Chomutov, City of Chomutov	1.591	0	1.591	NA	0.861	0.37	NA	NA	1.591
Power & Heating Plant										
	Factory Power and Heating Plant Kyjov	818	250	370	7%			NA	NA	818
	ECKG Kladno Power Plant, Kladno	14,000	14,000	0	NA	NA		NA	NA	14000
	Teaching Hospital Bulovka, Prague	72	0	67	NA	23.884	15.44	NA	NA	72

Energy & Environmental Details

No	Class/Name	Capacity	Before		After		Saving GJ/y	Emission Reduction, Mg/y		
			Fuel	Demand GJ/y	Fuel	Demand GJ/y		CO_{2E}	NO_X	SO_2
Cogeneration										
	Liberec			18,028			439.6	10,819	13.1	42.7

Appendix B

Energy Efficiency Investment Model User Guide

Energy Efficiency Investment Model User Guide

I. Introduction and Overview

To analyze and predict behavior, separate client and energy service company (ESCO) spreadsheet models that contain both qualitative and quantitative aspects have been created. The qualitative section addresses barriers that are not accounted for in the financial model. The barrier model examines the barriers that tend to prevent companies from investing in energy efficiency technologies that would seemingly be cost-effective using a firm's cost of capital. These barriers tend to be more difficult to quantify, such as uncertainty about energy savings and prices or lack of awareness or information about energy savings technologies. It is recognized that many firms/organization have an Implied internal rate of return (IRR) requirement for energy efficiency investments that exceeds the standard cost of capital. The model attempts to quantify the impact of various barriers faced by clients or ESCOs and calculates the Implied IRR that serves as the investment threshold.

With detailed quantitative information on the project technologies and energy use, the quantitative section of the model calculates IRR, payback and life-cycle costs and creates a summary table that compares the following three cases:

- ➜ ***Business as usual case.*** The business as usual reflects the existing technology state and energy consumption levels for a firm/organization. The model allows for remaining technology life to expire and then the technology will be replaced with a similar technology. Yet, the model accounts for additionality by allowing energy consumption to decline over the planning horizon. This allows for "naturally occurring" conservation—increases in energy efficiency as equipment fails, either through mandatory codes and standards or because the new equipment is more efficient than the old equipment[13].
- ➜ ***Client case***. A firm or organization makes investment in energy-efficient technologies, accelerating the replacement of existing equipment with technology that exceed minimum efficiency standards. There are several financing options available.
- ➜ ***ESCO case.*** The term ESCO is used as a proxy for any third-party intermediary that may deliver energy efficiency. In this case an ESCO makes the investment in energy-efficient technologies for a firm or an organization. The ESCO may be able to deliver additional energy savings by installing efficient technologies (with different costs) over and above what the client may consider. Again, the ESCOs can have different costs of capital, funding sources and loan rates than both the client and business as usual case. Presumably, the cost of financing will be lower for the ESCO's due to their availability of funds. Note that the ESCO and client model structure is exactly the same, allowing the ESCO case to represent any third option.

For projects that would not meet the Implied IRR investment threshold revealed for a client or and ESCO in the barrier section, the model will attempt to reach the expected IRR through either changing the mix of financing, decreasing the financing rate on the loan or increasing the carbon credits given.

[13] The naturally occurring energy reductions happen only when a technology is retired. Therefore, if energy efficiency naturally happens at 1% and the current measure has 5 years of life left, the next measure will use 5.1% less energy.

Barrier Model

The barrier model attempts to address the major issues confronting the client and ESCO for the decision whether or not to invest. Research has shown that non-financial barriers raise the implied IRR for organizations. Implicit discount rates for energy-efficiency projects have been shown to be often far higher than the cost of capital. The barrier model roughly estimates the impact of barriers on the return required for either a Client project or an ESCO project to be pursued.

Starting with the cost of capital for a Client or an ESCO, an Implied IRR is calculated considering the various barriers. While the model explicitly lists the following barriers, other barriers facing specific clients or ESCOs can also be considered.

Client	ESCO
Uncertainty about technology performance and energy savings	Uncertainty of energy savings or industry specific operational concerns
Uncertainty of energy prices	Uncertainty of energy prices
Lack of awareness and information	Firm/Organization longevity uncertainty
Firm/Organization longevity uncertain	Pre-decisional investment of resources required by the ESCO

Thus, the financial model output of project IRR can be compared to the Implied IRR from the barrier model to see if the project makes economic sense for either the Client or the ESCO. It should be stressed that the barrier section of the model can be by-passed by zeroing out the values. This results in the model operating as a standard Discounted Cash Flow (DCF) model.

Financial Model Parameters and Data Collection

The model utilizes the data reported from the Czech Republic, yet it also allows for flexibility and complexity in future situations. Therefore, the model asks for data beyond what has been reported by the projects in the Czech Republic. These can be left blank if information is not available, but will provide for more comprehensive modeling capability for future efforts in this area.

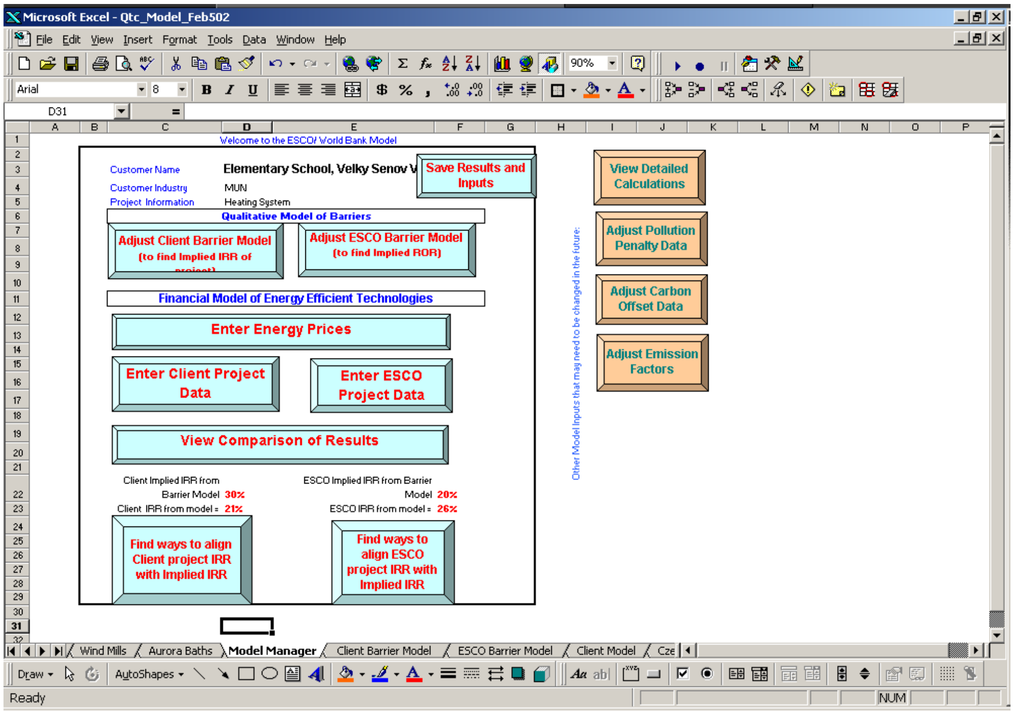
The model analyzes three cases—business as usual, client and ESCO, as discussed above. Because energy-efficiency projects often include multiple measures, this model allows for up to three technologies to be analyzed within a project. The model uses the CZK as the default currency for expressing costs, savings, and energy prices, however any currency can be used.

Overview

The following section provides a description of the various modules and outputs in the model. The model employs a “Model Manager” to navigate through the different aspects of entry and analysis. Due to the complexity of inputs and outputs, users are encouraged to use this feature of the model[14]. The Manager employs Visual Basic for Applications (VBA) buttons that hide and unhide the relevant sheets. For example, by pressing the “Adjust Energy Rates” button on the Manager, you are immediately taken to the “EnergyRates” tab of the worksheet. Once you are done inputting information, use the “Back” button in the top left corner to hide the current sheet and bring you back to the Manager. If users wish to by-pass this feature, they can use the Format, Sheet, Unhide Feature on Excel to unhide the sheets and proceed with model inputs.

The figure below shows the Manager with one project example.

[14] If users wish to by-pass this feature, they can use the Format, Sheet, Unhide Feature on Excel to unhide the sheets and proceed with model inputs.



There are two different types of buttons. The blue buttons direct the user to the model's required input sheets. The orange buttons to the right direct the user to background information that may require adjustment in the future. For example, in the future, the pollution penalty may change necessitating adjustments within the model.

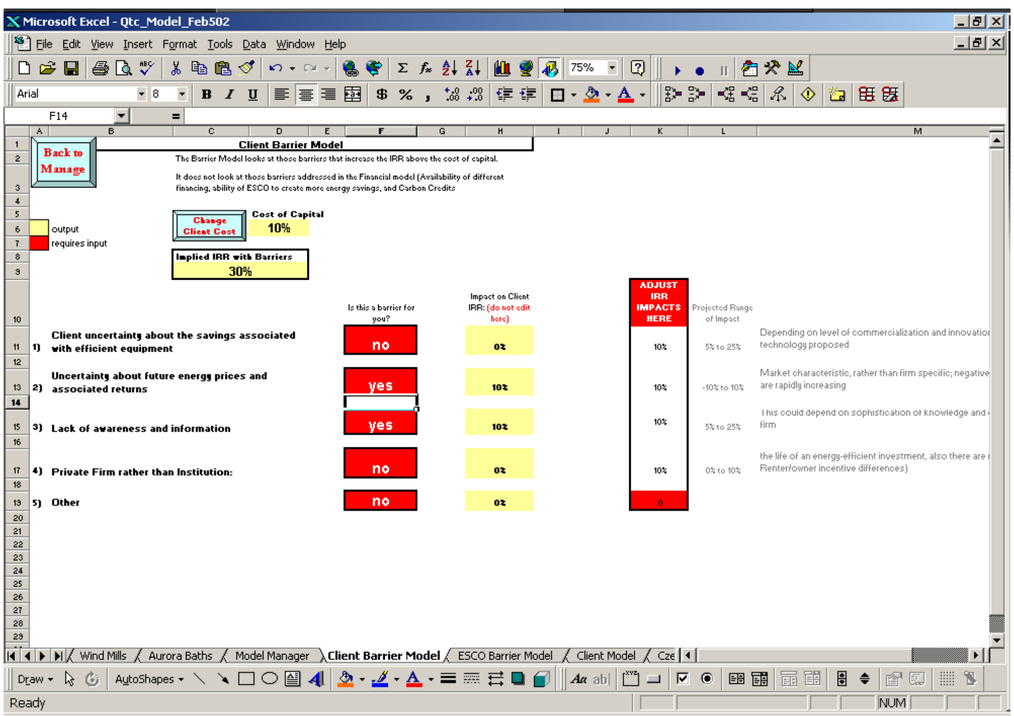
1) The first step in establishing a project analysis is to input the project name, industry and information. These fields are at the top of the "Model Manager".
2) The user then completes the Barrier Model for at least the Client Project and the ESCO project if relevant (see Section II for Barrier Model discussion and Section V for cell-level detail of model inputs).
3) Next, the user completes the relevant Project Models for the Financial Model (see Section III for Financial Model discussion and Section V for cell-level detail of model inputs).
4) The user can then view a summary of results, and save the project inputs and outputs into a new sheet.
5) The model will also attempt to align the project IRR from the financial model with the Implied IRR from the Barrier model (see Section IV for discussion of above topics).

II. Barrier Model

From the "Model Manager", the Barrier Model has two options: "Adjust Client Barrier Model" or "Adjust ESCO Barrier Model". Each page will calculate the Implied IRR. It begins with the Cost of Capital (from the Financial Model) and adds relevant required returns given certain barriers. It should be stressed that the barrier section of the model can be by-passed by zeroing out the values (or entering "No"). This results in the model operating as a standard Discounted Cash Flow (DCF) model.

The Implied IRR result for each case guides the investment decision for a Client or ESCO. Specifically, if the project financial IRR returned by the financial model is less than the Implied IRR then the project will likely not be accepted. This model allows the ESCO and Client Implied IRRs to be different allowing the ESCO to invest in projects where the project IRR is less than the Client Implied IRR but greater than the Implied IRR for an ESCO. This accommodates the notion that ESCOs will undertake energy efficiency investments beyond those that the client would typically consider.

The following sheet appears when the "Adjust Client Barrier Model" is selected:



A similar spreadsheet appears when the "Adjust ESCO Barrier Model' model is selected. The Cost of Capital in the top middle of the sheet is taken from the financial model. This can be updated by pressing the button labeled "Change Client (or ESCO on the ESCO barrier model) Cost of Capital which takes you to the financial model input fields. The Implied IRR shown directly below the cost of capital is calculated by the model by adding the barrier impacts to the original cost of capital.

The barriers are listed in "Yes" or "No" question format. If a question is answered "Yes", then the yellow cells to the right will return the IRR impact level. The level of impact to the IRR of each of the identified barriers can be adjusted to the right, under the heading

"Adjust Impacts Here". To the right of the adjustments are projected ranges of impact and a description of the factors that would influence the level of impact a barrier may have on the Implied IRR required for a project. There is an "Other" barrier space for those specific project barriers that are not addressed here. Users must input impact values.

Please refer to Appendix a for cell-level detail of Barrier Model inputs.

III. Financial Model

The financial models for the Client Project and ESCO project are DCF models using Energy Rate Inputs as well as Project specific information. Both of these cases are analyzed relative to the Business as Usual Case, therefore information is required for this case and it is assumed that the business as usual case is the same whether a client or and ESCO makes the investment. Please refer to Section 1 for a more detailed discussion of the Business as usual, Client and ESCO cases.

After entering the requisite Business as Usual information, Client Project data and/or ESCO Project Data, the model then allows for a comparison of results. The Implied IRRs from the Barrier Models are shown versus the output for the financial models . The input and output for a specific project can be saved using the “Save Results and Inputs” button. The model also attempts to bring the actual project IRR to the level of IRR required by a Client or an ESCO to pursue a project using certain specific adjustments.
The process for entering data and utilizing the model features is described in more detail below. Actual cell numbers and numeric details are found in Section V.

Enter Energy Prices

The first step in using the model is to input the various energy prices. The model allows for three types of fuels to be analyzed for each case within each project. There are two ways to approach this data input. In the first approach, the user inputs the expected energy inflation rate relative to the general rate, and the current energy price, and the data will change accordingly. The current cost is inflated by expected energy price increases plus the general inflation rate. Therefore, the energy inflation rate input must be an energy specific inflation beyond the overall price increases[15]. The model expects all inputs in CZKs. The second approach is applicable when the user has specific estimates of future energy costs. One can override the calculation of future energy prices by simply entering the current and future expected price values.
The model is provided with default factors for coal, electricity, gas, oil, steam and lignite to convert prices from standard units to giga-joules as used by model. It also contains space for the addition of two energy types: Other1, and Other2. The names listed above must be used as the energy names in the quantitative portion of the model for accurate cost calculations.

Enter Project Data

There are three cases: Business as Usual, client and ESCO. These cases are presented in two distinct modules: the Client Project and the ESCO Project. In both modules, the business as usual case is the same. The model assumes that the Client Project information will be input first, so the Business as usual information on ESCO Project case is linked to the Client Case. To compute savings, payback, and IRR, the business as usual case must be input as well either the ESCO or the Client case. For the Czech sample data, business as usual operating and energy costs were provided but the natural rate of re-investment was not, therefore the cost of investing in the client/ESCO cases will be overstated, thus understating their respective payback and IRR values.

The ESCO case allows for additional energy savings, improved financing strategies and different technologies that may be applied by ESCOs. While the model accommodates investments by ESCOs, the project data collected in the Czech Republic did not include any projects undertaken by ESCOs.

[15] This inflation is the rate of energy cost inflation beyond the general inflation rate. Therefore, if the general inflation rate is 4% and electricity inflation is 2%, the initial energy cost will be inflated by 6% each year.

The figures below show the Client Cost Model page. As indicated, the structure of the ESCO Cost Model is the same.

Back to Manager

Input Sheet for Client Cost Model

To Summary Results | To Summary Results

Clear Project (make all zeros)

	Requires Input in Yellow	**Business-as-Usual Case** Replacement of retiring technologies at new minimum efficiency standards		**Client Project** Accelerating replacement of inefficient technologies and exceeding minimum efficiency standards	
Rates		General Inflation Rate	3%		
		Baseline Cost of Capital	10%	Client Cost of Capital	10%
Funding Types				type	Funding by source / rate
				Grant	10%
				Self-contrib	10%
				Debt	80% / 15.00%
Technology Life	**Tech 1**	Current technology life remainin	0		
		Expected Service Life (new) (yrs	0	Expected Service Life (new) (yrs):	20
	Tech 2	Current technology life remainin	0		
		Expected Service Life (new) (yrs	0	Expected Service Life (new) (yrs):	0
	Tech 3	Current technology life remainin	0		
		Expected Service Life (new) (yrs	0	Expected Service Life (new) (yrs):	0
Equipment Costs	**Tech 1**	**Technology Cost** (mil.CZK)	CZK 0.00	**Technology Cost (mil.CZK)**	CZK 0.99
		Technology Inflation	0%	**Technology Inflation**	0%
		Operational Costs (mil.CZK)	CZK 0.16	**Operational Costs (mil.CZK)**	CZK 0.08
		Life End Salvage Value (mil. CZ	CZK 0	Life End Salvage Value (mil. CZK)	CZK 0
	Tech 2	**Technology Cost** (mil.CZK)	CZK 0.00	**Technology Cost (mil.CZK)**	CZK 0.00
		Technology Inflation	0%	**Technology Inflation**	0%
		Operational Costs (mil.CZK)	CZK 0.00	**Operational Costs (mil.CZK)**	CZK 0.00
		Life End Salvage Value (mil. CZ	CZK 0	Life End Salvage Value (mil. CZK)	CZK 0
	Tech 3	**Technology Cost** (mil.CZK)	CZK 0.00	**Technology Cost** (mil.CZK)	CZK 0.00
		Technology Inflation	0%	**Technology Inflation**	0%
		Operational Costs (mil.CZK)	CZK 0.00	**Operational Costs** (mil.CZK)	CZK 0.00
		Life End Salvage Value (mil. CZ	CZK 0	Life End Salvage Value (mil. CZK)	CZK 0
Energy Use * if you use Electriciy, enter as Tech 1	**Tech 1**	Fuel Type Used	lignite	Fuel Type Used	gas
		Annual Energy Use in GJ	770	Annual Energy Use in GJ	426.6
	Tech 2	Fuel Type Used	none	Fuel Type Used	none
		Annual Energy Use in GJ	0	Annual Energy Use in GJ	0
	Tech 3	Fuel Type Used	none	Fuel Type Used	none
		Annual Energy Use in GJ	0	Annual Energy Use in GJ	0
Additionality	**Tech 1**	Baseline Energy 1 % Reduction	0%		
	Tech 2	Baseline Energy 2 % Reduction	0%		
	Tech 3	Baseline Energy 3 % Reduction	0%		
Pollution Penalties		**Pollution Penalties**		**Pollution Penalties**	
	Tech 1	Penalty Applies?	yes	Penalty Applies?	yes
	Tech 2	Penalty Applies?	no	Penalty Applies?	no
	Tech 3	Penalty Applies?	no	Penalty Applies?	no
OtherSavings		**Non-energy Benefits**		**Non-energy Benefits**	
		Savings/yr (mil.CZK)	CZK 0	Savings/yr (mil.CZK)	CZK 0
Carbon Offset				**Carbon Credits**	
	Tech 1			Avail carbon credit?	yes
	Tech 2			Avail carbon credit?	no
	Tech 3			Avail carbon credit?	no
	This applies only to Electricity		**Share produced by:**		**Share produced by:**
		Oil	0%	**Oil**	0%
		Gas	0%	**Gas**	0%
		Nuclear	0%	**Nuclear**	0%
		Coal	0%	**Coal**	0%
		Hydro	0%	**Hydro**	0%
		total	0%	**total**	0%

The very top left shows the "Back" button that will return the user to the Manager. The user can also choose the "To Summary Results" located above the inputs for each of the cases which bypasses the Manager and calculates the changes and brings the user directly to the results. If a new project is being started, the user can use the "Clear Project" button that will make all fields zero.

Along the column A, the category of inputs is highlighted in blue. These include energy costs, capital costs and carbon offsets. The next column, highlighted in purple, details the technology associated with that specific input. This model accommodates three types of technology investments within one overall project, which allows for synergistic effects from installing more than one type of energy-saving technology at a time. Each data input category therefore has up three inputs; one for each technology.

A brief description of the quantitative inputs and their calculation uses follows. These descriptions complement the general data input discussion and provide further details showing how data need to be input into the model. A more detailed table of the inputs is contained in Section V.

➜ ***General Inflation Rate.*** The regional general rate of price inflation must be input The model will also ask for the rate of energy price inflation and technology cost inflation relative to the general rate of inflation.

➜ ***Cost of Capital*** - the average cost of capital required for the investment in new technologies, the cost of capital for the business as usual case and the client case are likely to be the same (as capital for both comes from the firm/organization). The ESCO cost of capital my reflect access to more innovative funding sources.

➜ ***Funding Types.*** The data collected in the Czech Republic indicated various types of funding were available with correspondingly different impacts on the cost and savings of a project. The model allows for the client and ESCO cases to vary their funding sources between grants, self-contributions, and loans. Grant values are treated as a reduction in technology cost. Self-contribution is treated as an initial investment, requiring no additional loan-type funding. The model assumes that the business as usual case is funded by 100% self-contribution. Equity is treated as a self-contribution. Loans are treated as a standard loan and require an annual interest rate on debt. The loan rate is assumed to be either the life of the technology or ten years, which ever is smaller.

➜ ***Technology Life.*** All cases with investment are required to input the new technology expected service life. For the business as usual case, the model asks for the outstanding service life on a current technology. Therefore, the model allows for the business as usual case to expire the unused portion of life on the current technology before re-investing. In contrast, the client and business as usual cases invest immediately in a new technology. The minimum service life is 5 years. Because of the varying lifetimes of the projects seen in the Czech Republic, this 20-year model accommodates shorter life-spans by assuming re-investment.

➜ ***Equipment Costs***. There are four details required for this category: Technology capital cost, technology inflation, maintenance cost per year and salvage value. The technology cost is the total initial investment including installation costs. Note that for the business as usual case this will not occur until the life of the current technology expires. In the business as usual case, the technology cost is the current cost of replacing an existing technology at the end of its useful life with a technology with a similar efficiency level (or the minimum standard of efficiency). For the Client and the ESCO cases, the capital costs are the initial capital cost, including installation, of the proposed technology solution(s).

The technology inflation rate to be input is the rate of technology price increases relative to the general rate of inflation (e.g., if general inflation is 4% and price of technology are increasing 5% each year, the user would enter a technology inflation rate of 1%). Operational costs are the annual non-energy operating and maintenance costs associated with a technology. Salvage value is the value of a technology, if any, at the end of its useful life.

In calculating total investment, the model assumes that if a service life is less than 20 years, there will be reinvestment in another similar technology. General inflation plus the technology will inflate this cost. Further, the model assumes that the mix of funding stays constant.

The salvage value is also inflated by both general inflation and technology costs, yet maintenance costs inflate only with the general rate of inflation. Further, at year 20 of the model, each technology is credited its straight-line depreciation value on the remaining service life plus the salvage value. For example, a technology with a service life of 6 years will be purchased four times: immediately, year 6, year 12 and year 18. At each of these years, it will receive the inflated salvage value and at year 20 it will receive the remaining 4? (6-2) years of value plus salvage value.

In the Czech data, business as usual capital costs, or the cost of replacing existing equipment at the end of its useful life, were not reported. Without this information, the model understates the actual cost of the business as usual case, or overstates the investment cost of the client or ESCO case above the business as usual. In turn, this will overstate the payback and IRR for the non-business as usual cases.

➜ ***Annual Energy Use.*** The model requires a type of energy and quantity used for each technology. The types of energy currently in the model are Electricity, Steam, Gas, Oil, Lignite and Coal. For non-standard energy types, the names Other1, and Other2 are used. Energy use is the annual energy used to operate the business as usual, Client or ESCO set of technologies. Annual energy use is converted to and input as giga-joules (GJ) for each technology input for the each case. A conversion table from standard energy units (e.g., kWh or therms) to GJ is provided here for the convenience of the user.

To Convert From	To Giga-Joules multiply by:
Btus	1.0548×10^{-6}
KWh	3.6×10^{-3}
Therms	1.0548×10^{-1}
Gallons Oil	1.4524×10^{-1}
Lbs. Coal	1.1392×10^{-2}
Lbs. Steam	1.2394×10^{-3}
Lbs. Lignite	7.807×10^{-2}

➜ ***Additionality.*** Additionality refers to the “naturally occurring” efficiency improvements in the business as usual case as existing technologies are replaced with new, more efficient technologies meeting updated efficiency standards. The input is the percent of expected efficiency increase (or expected consumption decrease) when existing equipment is replaced at the end of its life. Annual energy consumption for the specified technology is reduced by that percentage beginning the year of replacement.

➜ ***Pollution Penalties.*** Given the emission factors reported by the Czech data and the penalty levels[16], the model computes pollution penalties on NOx, SO2 and CO2. It treats pollution penalties as a cost and no savings are available for reducing emissions

[16] http://www.rec.org/REC/Publications/EcInstruments/Czech.html

below the prescribed level. Therefore, a reduction in energy use for a project a may lead to a savings in pollution penalties.

The model asks for "yes" or "no" for the application of pollution penalties by technology and case. The detailed penalty information including levels, costs and emission factors are entered on sheet "PollutionPenaltyData", which can be easily accessed by the Manager. Current Czech information is given, but this may need to be changed throughout the years. This is an annual cost inflated by general inflation.

➜ ***Other savings.*** Although no data was reported from the projects reviewed, it is an important factor to consider and input in a DCF model. Non-energy benefits may be difficult to quantify, but the factors such as societal benefits and productivity gains may push a project into cost-effectiveness and drive an investment decision by a client or and ESCO.

➜ ***Carbon Credits.*** To allow for more emission-reducing incentives, the model allows for carbon offsets to be offered. Current Czech information as reported by the Czech Energy Agency is provided in the model. These values can be changed in "Carbon Credit Data", accessed through the Manager. This is an annual savings inflated by general inflation.

Additionally, the model allows for fuel-type variation between the business as usual, client and ESCO cases. For example, the business as usual Technology 1 may be a lignite heating system, but the client Technology 1 may be a more efficient gas heating system.

IV. *Results, Save Projects and Alignment Analysis*

Results Comparison

After entering Business as Usual, Client and ESCO data, the output can be accessed from the Model Manager as "View Comparison of Results" or Financial Model pages as "To Summary Results". The Results page shows a breakdown of the relevant input costs by overall project and technology. It also returns IRR and payback period for the financial model. To compute IRR, the Client and ESCO total investment and savings is computed relative to the business as usual. All results are calculated in present values, using the corresponding discount rate by case. The summary results also return total carbon savings in tons of carbon.

The figure below shows an example of the overall project results and one technology. Notice that the Implied IRR returned from the Barrier Model is listed below the overall Project IRRs to allow for easy comparison.

Back to Manager

To Client Data

To ESCO Data

Summary Life Cycle Cost By Case

entary School, Velky Senov Village

Complete Project Summary Costs			
Overall (mil CZK)			
Present Value of Costs	**Business-as-Usual**	**Client**	**ESCO**
Equipment Costs	CZK 0.0	CZK 1.1	CZK 0.8
Maintence Costs	CZK 1.6	CZK 0.8	CZK 0.8
Energy Costs	CZK 1.1	CZK 0.4	CZK 0.4
Pollution Penalties	CZK 0.8	CZK 0.3	CZK 0.3
Other Savings	CZK 0.0	CZK 0.0	CZK 0.0
Carbon Credits	CZK 0.0	(CZK 0.0)	(CZK 0.0)
Total	**CZK 3**	**CZK 2.5**	**CZK 2.3**
Annual Life Cycle Cost	**CZK 0**	**CZK 0.3**	**CZK 0.3**
Carbon Saved (tons)		**405.21**	**405.21**
Total Savings (difference in life cycle costs)		**CZK 1.0**	**CZK 1.2**
PV of Initial Investment above Baseline		**CZK 1.1**	**CZK 0.8**
Payback Period (yrs)		**5.16**	**4.11**
Internal Rate of Return		**20.5%**	**26.0%**
IMPLIED IRR		**30%**	**20%**

Tech 2 Summary Costs			
Technology 2 (mil CZK)			
Present Value of Costs	**Business-as-Usual**	**Client**	**ESCO**
Equipment Costs	CZK 0.0	CZK 0.0	CZK 0.0
Maintence Costs	CZK 0.0	CZK 0.0	CZK 0.0
Energy Costs	CZK 0.0	CZK 0.0	CZK 0.0
Pollution Penalties	CZK 0.0	CZK 0.0	CZK 0.0
Other Savings	-	-	-
Carbon Credits	CZK 0.0	CZK 0.0	CZK 0.0
Total	**CZK 0**	**CZK 0**	**CZK 0**
Total Savings (difference in life cycle costs)		**#N/A**	**#N/A**
Total PV investment above Baseline		**#N/A**	**#N/A**
Payback Period (yrs)		**#N/A**	**#N/A**
Internal Rate of Return		**#N/A**	**#N/A**

Tech 1 Summary Costs			
Technology 1 (mil CZK)			
Present Value of Costs	**Business-as-Usual**	**Client**	**ESCO**
Equipment Costs	CZK 0.0	CZK 1.1	CZK 0.8
Maintence Costs	CZK 1.6	CZK 0.8	CZK 0.8
Energy Costs	CZK 1.1	CZK 0.4	CZK 0.4
Pollution Penalties	CZK 0.8	CZK 0.3	CZK 0.3
Other Savings	-	-	-
Carbon Credits	CZK 0.0	CZK 0.0	CZK 0.0
Total	**CZK 3**	**CZK 2.5**	**CZK 2.3**
Total Savings (difference in life cycle costs)		**CZK 0.9**	**CZK 1.2**
Total PV investment above Baseline		**CZK 1.1**	**CZK 0.8**
Payback Period (yrs)		**5.16**	**4.11**
Internal Rate of Return		**20.5%**	**26.0%**

Tech 3 Summary Costs			
Technology 3 (mil CZK)			
Present Value of Costs	**Business-as-Usual**	**Client**	**ESCO**
Equipment Costs	CZK 0.0	CZK 0.0	CZK 0.0
Maintence Costs	CZK 0.0	CZK 0.0	CZK 0.0
Energy Costs	CZK 0.0	CZK 0.0	CZK 0.0
Pollution Penalties	CZK 0.0	CZK 0.0	CZK 0.0
Other Savings	-	-	-
Carbon Credits	CZK 0.0	CZK 0.0	CZK 0.0
Total	**CZK 0**	**CZK 0**	**CZK 0**
Total Savings (difference in life cycle costs)		**#N/A**	**#N/A**
Total PV investment above Baseline		**#N/A**	**#N/A**
Payback Period (yrs)		**#N/A**	**#N/A**
Internal Rate of Return		**#N/A**	**#N/A**

Save Project Function

From the "Model Manager", the button "Save Results and Inputs" will save the Business as usual, Client and ESCO inputs as well as the results from the summary results tables. This will automatically create a new sheet with the name of the project as specified at the top of the "Model Manager" page.

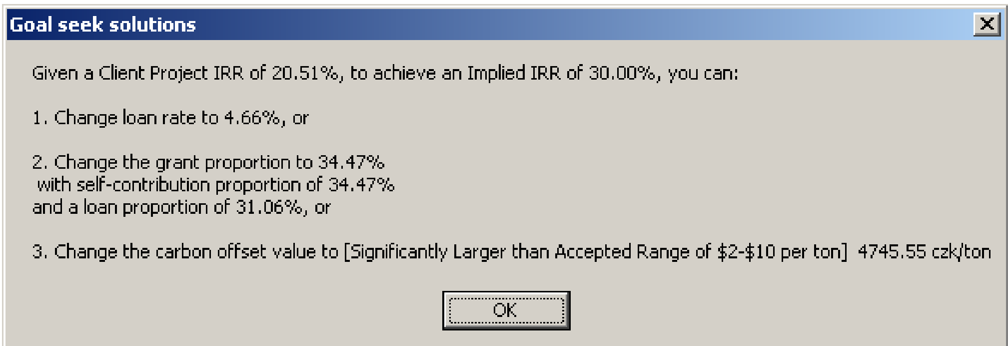
Align Implied IRRs from Barrier Model with project IRRs from Financial Models

This function works when a user has completed the Barrier section of the model and the implied IRR is higher than the Project IRR from the financial model. The function uses the Excel GoalSeek feature to attempt to bring the actual IRR to the expected value. Note that this function is highly sensitive to the data inputs and certain constraints are required to allow this function to work. There are cases where no solution can be returned.

There are three potential adjustments that can allow the Actual IRR to match the Expected. First, the GoalSeek function adjusts the mix of financing. Second, it decreases the cost of financing the loans (i.e. if a third-party can offer a lower cost of borrowing, it may make a project cost-effective for the Client Case). Finally, the function will increase the carbon credit level to increase the actual IRR. These results are given in a message box format and not saved within the model. The model assumes that the client or ESCO will choose one of the three strategies to pursue to improve the project's potential financial performance, and gives results as follows:

- ➜ ***Change the Mix of Financing*** – by how much would the mix of financing need to change need to increase to make the Project IRR meet the Implied IRR
- ➜ ***Decrease the Cost of Financing*** - by how much would the cost of financing (the interest rate on debt used to finance the project) to make the Project IRR meet the Implied IRR

Increase Carbon Credit Level – by how much would the value of carbon credits need to increase to make the Project IRR meet the Implied IRR. The follow diagram provides an example:



These results could be taken for the Client Case and used as scenarios for third-party or ESCO options.

V. Appendix A

Tab: "EnergyRates"			
Category	**Type**	**Cell Reference**	**Description**
Energy Units (i.e kWh): Other1, Other2	Non-standard energy source unit for cost	I2 to J2	Optional input User must input the unit of energy for the current cost calculation.
Inflation Rates	By Energy	D4 to K4	Requires input Expected rate of annual energy inflation over the next 20 years. This rate is in addition to the general inflation rate. Therefore, the calculation inflates the current rate by general inflation and energy inflation
Name of Other Energy Sources	Energy Type	I6 to J6	Optional input This is for the user only in order to document Other energy sources. The quantitative section requires a name input of Other1, Other2.
Current Cost	Cost per unit of Energy	D11 to K11	Requires input Enter current cost of energy in CZK.
Future Cost	Cost per unit energy for future costs	D12:K31	Optional input Override the calculation using expected energy inflation rates and enter forecasted values of energy costs
Conversion Rates	Conversions for Other1, Other2, cost units into GJ	T7 to U7	Optional input Because the model uses GJs as the input for energy use, the conversion rates must be entered to allow for accurate cost calculations for non-standard energies

Tab: "Client Model" or "ESCO Model"			
Category	**Type**	**Cell Reference**	**Description**
Rates	General Inflation	D6	Requires input Expected rate of annual inflation over the next 20 years in the project's region
	Cost of Capital	D7 G7	Requires input Input of Cost of Capital for each case
Funding Types	Grant, % of total funding	G10	Requires input, default 0% The percentage of funding available as a grant. A grant requires no return of money and is assessed as a reduction in the cost of the technology.
	Self-contribution, % of total funding	G11	Requires input, default 0% The percentage of funding available as self-contribution. This is an immediate cost to the organization, but does not require future payments. Equity payments are considered to be self-contributions.
	Debt, % of total funding	G12	Requires input, default 0% The percentage of funding available as debt. This is calculated as a standard loan.
	Debt, Annual rate	H12	Requires input, default 0% The average annual percentage rate on the debt. Therefore, if there are more than one sources of debt, create a weighted average of the financing cost.
Technology Age	Current Technology Age Remaining	D14, D16, D18	Requires input, default 0 In the business as usual case, the model assumes that the current technology will be used to the end of its life before replacement. Therefore, enter the years remaining on the life of the technology
	New Technology Age	D15, D17, D19 G15, G17, G19	Requires input Enter service life of new technology. The model allows for different new technologies to be adopted by the business as usual, client and ESCO case. Note: the minimum service life is 5 years
Equipment Costs	Technology Capital Cost	D21, D25, D29 G21, G25, G29	Requires input Cost of technology, including installation in millions of CZH.
	Technology Inflation	D22, D26, D30 G22, G26, G30	Requires input, default 0% Technology inflation in addition to the general rate of inflation.
	Annual Operational Costs	D23, D27, D31 G23, G27, G31	Requires input Expected maintenance costs per year in millions of CZH.

Tab: "Client Model" or "ESCO Model"			
Category	**Type**	**Cell Reference**	**Description**
	End life salvage value	D24, D28, D32 G24, G28, G32	Default setting 0 Salvage value at end of technology life. The model separately accounts for depreciation of an unused portion of life at the end of the model life in CZH. This model only allows for salvage value on new technologies.
Energy Use	Fuel Type Used	D34, D36, D38 G34, G36, G38	Requires input The fuel type by technology will stay the same across the cases. The choices here are Electricity, Oil, Gas, Coal and Steam. NOTE: If electricity is used as a technology energy, it must be entered in Technology 1 NOTE: If non-standard energies are used, the input must be Other1 or Other2 that corresponds to the entered energy rate information
	Annual Energy Use by GJ	D35, D37, D39 G35, G37, G39	Requires input This is the annual energy use by the business as usual case, by GJ.
Additionality	Business as usual % Energy Savings	D41, D42,D43	Default setting 0% In the business as usual case, the model allows for normal annual increases in energy efficiency that would be adopted regardless of additional funding or incentives. This should be an average annual number over 20 years.
Pollution Penalties	Penalty Applies?	D46:D48 G46:G48	Requires Yes or No The model allows for pollution penalties as a cost. Therefore, a reduction in energy use will lead to a savings in pollution penalties. The penalty levels, costs and emission factors are entered and can be adjusted on sheet "PollutionPenaltyData", but does not require input. General Czech information is given.
Other savings/ Non-energy Benefits	Savings/ yr (mil CZK)	D52 G52	Default setting 0 Model allows for other savings to come from installation of energy efficient technologies such as increased productivity. Enter value in mil CZH.
Carbon Offsets	Credit Available	G55:G57	Requires Yes or No The model allows for carbon offsets to be offered as incentives for less emissions. The credit levels, costs and emission factors are entered on sheet "Carbon Credit Data". Current Czech information is given, so it does not require input but these values can be changed. Note: if electricity is one of the fuel types, see below.

Tab: "Client Model" or "ESCO Model"			
Category	**Type**	**Cell Reference**	**Description**
	Share of Electricity produced by	D61:D66 G61:G66	Default setting 0% The model allows for carbon credits in reductions of electricity creating other fuel emissions. Enter share of other energy types used to produce electricity. This should total 100%.

Qualitative Input

Tab "Client Barrier Model" or "ESCO Barrier Model"		
Type	**Cell Reference**	**Description**
Yes or No	F11, F13, F15, F17, F19	Requires Yes or No If yes, the model takes the associated value in Column K.
Adjustment of IRR Impacts	K11, K13, K15, K17, K19	Optional Input Use the suggested ranges to decide what is appropriate for the specific project. This will change the values in Column H which are added to the Cost of Capital to create the Implied IRR.