Economics of Energy Efficiency in a CO_2 Constrained World

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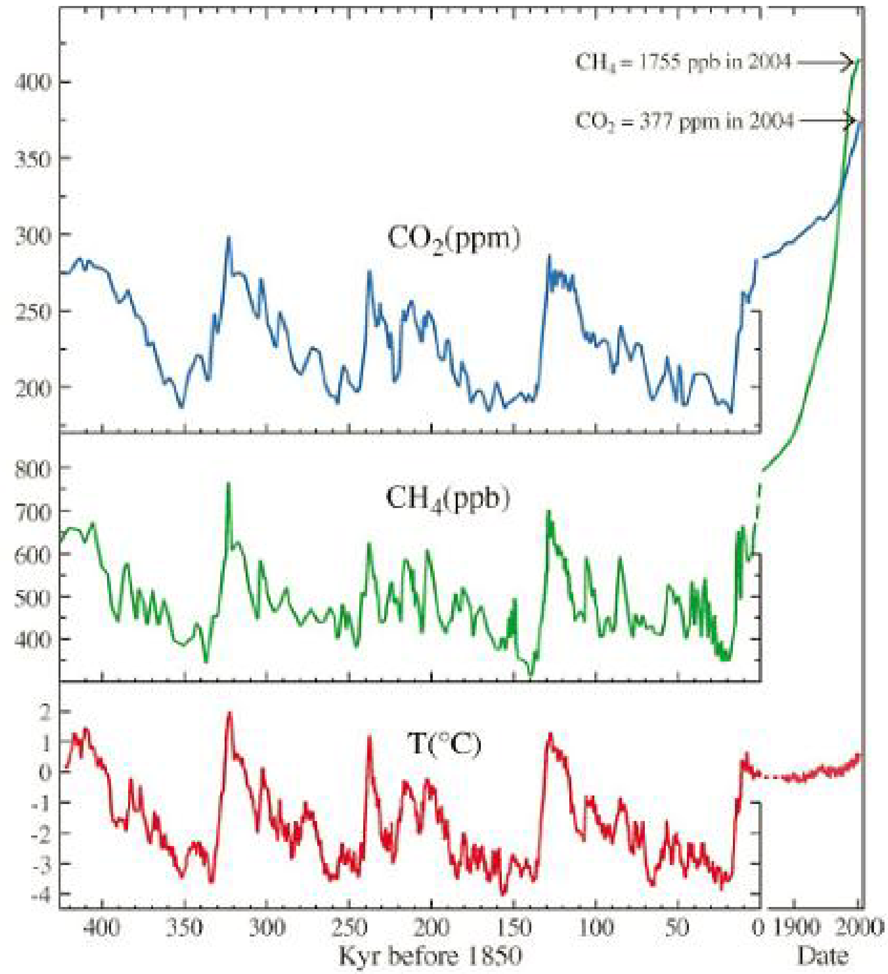
ABSTRACT

Greenhouse gas emission trading programs have been initiated in the European Union, Canada and the United States in an effort to harness market forces to efficiently reduce greenhouse gas emissions. Three major methods for reducing or offsetting greenhouse gas emissions are purchasing greenhouse gas emission reduction credits, purchasing renewable energy certificates, and improving energy efficiency on site. This paper investigates the economics of energy efficiency in comparison to purchasing renewable energy certificates or CO_2 emission reduction credits. The analysis considers three legislative scenarios: the current case with no CO_2 taxes or mandatory CO_2 emission reductions, a tax on CO_2 emissions, and mandatory CO_2 emission reductions with emission credit trading. A relation to quantify the cost of energy efficiency in terms of dollars per tonne of avoided CO_2 is proposed. Results show that at current prices, energy efficiency will remain more cost effective than purchasing renewable energy certificates or CO_2 emission reduction credits as long as the simple payback is less than the life of the energy efficiency project.

Introduction

Over the last 400,000 years, atmospheric temperature and greenhouse gas concentrations have been highly correlated, and Figure 1 shows that today's greenhouse gas concentrations are the highest ever recorded. This increase in atmospheric concentration of greenhouse gasses is a result of the exponential growth of fossil fuel use since the industrial revolution (Hansen 2005a; IPCC 2001). Because the mechanism of global warming is increasingly well understood, scientists predict that the earth's temperature will continue to rise in the 21^{st} century (Hansen, et al. 1997).

Figure 1. Long Term and Recent Global Temperature and Greenhouse Gas Concentrations



Source: Hansen 2005b

Expected impacts of global warming include mass extinctions, sea level rise, melting of the polar ice caps, and increasingly severe weather and droughts (IPCC 2001). In response to these threats, almost 90% of the countries in the world have ratified the Kyoto Protocol in an attempt to limit greenhouse gas emissions (UN 2007). The largest greenhouse gas emitter that did not ratify Kyoto is the United States. However, growing awareness of the threat of climate change is likely to spur the United States to take action to reduce CO_2 emissions. Possible actions include a CO_2 emission tax or mandatory CO_2 emission reductions with a carbon trading system.

The European Union has already enacted a carbon trading system called the Emission Trading Scheme (EU ETS 2007). In the EU ETS, carbon reductions are mandatory. Emission reduction credits were once as high as $40 per tonne, but have fallen because of excessive allowances granted for calculating baseline emissions.

Currently the only emission reduction and carbon trading system operable in the United States is the Chicago Climate Exchange (CCX 2007). Membership in the CCX is voluntary; however, all commitments are legally binding. Current members include Ford, Dow, Dupont, and IBM. Member companies commit to reducing greenhouse gas emissions from a year 2000 baseline. Emission reduction targets start at 1% in 2003 and grow to 6% by 2010.

Excess reductions beyond the specified targets can be sold as credits. Shortages in emission reductions can be compensated for by buying emission reduction credits from other companies. Six greenhouse gasses are traded: CO_2, Methane, Nitrous Oxide, Hydro-Fluorocarbons, Per-Fluorocarbons, and Sulfur Hexafluoride. To provide a common metric, the greenhouse warming potential of each gas is converted to the warming potential of CO_2, and the price is set in terms of dollars per tonne (1 tonne = 2,205 lbs).

This paper investigates how the economics of energy efficiency might change if a carbon trading system or CO_2 emission tax were instituted. It begins by quantifying the CO_2 intensity of electricity and natural gas using average prices for the industrial sector. Next, the representative economics of three major options for reducing CO_2 emissions are discussed. The options are emission reduction credits, tradable renewable certificates, and energy efficiency. The economics of energy efficiency in comparison to emission reduction credits and tradable renewable certificates are then explored for three possible legislative scenarios: the current case with no CO_2 taxes or mandatory CO_2 emission reductions, a tax on CO_2 emissions, and mandatory CO_2 emission reductions with emission credit trading.

CO_2 Intensity of Electricity and Natural Gas

In 2005, the average cost of electricity for the industrial sector was $0.057 /kWh and the average cost of natural gas for the industrial sector was $8.48 /mmBtu (EIA 2005). Average 2005 CO_2 emissions from the 100 largest power producers in the United States were 1.34 lb-CO_2/kWh, and average CO_2 emissions from natural gas were 117 lb-CO_2/kWh (NRDC 2006). Using these values, electricity has a carbon dioxide content of 0.011 tonnes-CO_2/$ and natural gas has a carbon dioxide content of 0.0063 tonnes-CO_2/$ (2,205 lb/tonne). Thus, on a unit cost basis, electricity results in almost twice the CO_2 emissions as natural gas.

Options for Reducing CO_2 Emissions

The three major options for reducing or offsetting greenhouse gas emissions are purchasing greenhouse gas emission reduction credits, purchasing renewable energy certificates, and improving energy efficiency on site. Each of these options, and the approximate cost of each option, is discussed below.

CO_2 Emission Reduction Credits

In a carbon trading system, companies would be obligated to reduce their CO_2 emissions. Companies that reduce emissions below the required level could sell the difference as CO_2 emission reduction credits. These credits could be purchased by another company to meet its emission requirements. Thus, the purchase of emission reduction credits subsidizes emission reduction efforts in other companies, and is a viable mechanism for reducing CO_2 emissions.

Historically, the cost of CO_2 emission reduction credits has ranged from about $4 /tonne, which is the current price on the Chicago Climate Exchange (CCX 2007), to about $40 /tonne, which was the peak price for emission reduction credits on the European Union Emission Trading Scheme (EU ETS 2007).

Tradable Renewable Certificates

Another option that reduces global CO_2 emissions is to invest in electrical power production from renewable energy technologies such as solar photovoltaic collectors or wind turbines. Currently, both solar and wind power are relatively expensive to install on site. However, it is now possible to purchase Tradable Renewable Certificates (TRC) that subsidize wind and solar power plants (Green-e 2006). The net effect is to displace traditional power from fossil fuels with power from non-CO_2 emitting renewable sources. Thus, through the purchase of TRCs, companies could completely offset all CO_2 emissions from electricity.

The current price for TRCs is about $0.015 /kWh for small purchases, and less for large purchases (Green-e 2006). This cost is paid as a premium, in addition to the cost of electricity. Thus, a $0.015 /kWh TRC would raise the average industrial cost of electricity by 26%. At this price and a carbon content of 1.34 lb-CO_2/kWh, the value of TRCs in dollars per tonne of avoided CO_2 emissions is $25 /tonne.

Energy Efficiency

Finally, perhaps the most direct method for companies to reduce CO_2 emissions is to invest in energy efficiency projects within the company. The cost of energy efficiency varies by project, but many industrial energy savings opportunities pay back within a just a few years. For example, U.S. Department of Energy funded Industrial Assessment Centers conduct one day energy assessments for mid-sized industries across the United States. Over 25 years, IACs have performed over 13,000 assessments and made over 99,000 individual energy saving recommendations (IAC 2007). On average, $110,000 per year of savings opportunities are identified at each plant with an average simple payback of 1.3 years. This represents an average of 19% of each plant's total energy use. About 50% of the 99,000 recommendations have been implemented.

A simple payback of 1.3 years represents an annual rate of return of about 77%, which dwarfs the rate of return of almost any alternative investment. Thus, energy efficiency is one of the most cost-effective investments that most companies can make, and a highly cost effective way to reduce CO_2 emissions.

In addition to simple payback, another important factor for energy efficiency projects is the measure life. Measure life is defined as "the median number of years that a measure is installed and operational" (ERS 2005). Figure 2 shows measure lives for common energy efficiency retrofit projects, as determined by multiple sources. The average measure life of energy efficiency projects reported in Figure 6 is about 13 years.

Figure 2. Measure Life for Common Energy Efficiency Measures

C&I Retro Common Measure Lives

Category	Measure	NSTAR	NGRID (MECO)	Unitil (FG&E)	Northeast Utilities (WMECO)	Cape Light Compact	MA Mean	National Mean	Technical Life	ERS Rec. Measure Life
Lighting										
	Fluorescent	17	20	15	5	13	14.0	15.6	15	13
	Hardwired CFL	17	8	15	15	13	13.6	15.7	15	13
	LED Exit Signs	16	20	15	20	13	16.8	16.9	>15	13
	HID	17	15	15	20	13	16.0	15.5	15	13
Lighting Controls										
	Occupancy Sensors	17	10	15	15	13	14.0	11.4	10	9
	Daylight Dimming	17	20	15	10	13	15.0	11.6	10	9
HVAC										
	EMS	8	8	15	15	25	14.2	12.3	16	10
Motors										
	Motors	17	20	15	17	15	16.8	15.0	22	15
VFDs										
	on HVAC Fans	8	15	15	15	NA	13.3	15.7	28	13
	on non-HVAC Fans	18	15	15	15	NA	15.8	15.8	28	13
	on CT/Chilled Water Discharge Pump	15	15	15	15	NA	15.0	15.0	28	13
Refrigeration										
	Vending	5	NA	NA	NA	NA	5.0	12.3	10	5
	Vending (non-refrig)	5	NA	NA	NA	NA	5.0	12.3	10	5
	Industrial Refrg. Compressors	NA	NA	NA	NA	NA	NA	NA	NA	18
	Refrigeration Controls	NA	NA	NA	NA	NA	NA	NA	NA	9
	Commercial Refrg. Compressors	NA	NA	NA	NA	NA	NA	NA	NA	13
Compressed Air										
	15-75 HP Efficient Compressor	10	15	15	20	NA	15.0	15.0	20	13

*NA indicates that the sponsors did not provide measure lives for the indicated measures.

**Industrial and commercial refrigeration measures were considered only in the final conference call between the sponsors and ERS, and measure life was decided without influence of a technical life. Due to the last minute addition of these measures, technical life was not researched.

C&I Retrofit Custom Measure Lives

Category	Measure	NSTAR	NGRID (MECO)	Unitil (FG&E)	Northeast Utilities (WMECO)	Cape Light Compact	MA Mean	National Mean	Technical Life	ERS Rec. Measure Life
Custom										
	O&M Projects	NA	2,5,10	NA	Varies	NA	5.7	2.0	NA	5
	Compressed Air	10	5,10,15	NA	20	NA	12.0	15.0	20.0	13
	EMS & HVAC Controls	8	5, 10	NA	15	NA	9.5	12.3	16.0	10
	HVAC Equipment or Systems	8	5,10,15	NA	Varies	NA	9.5	16.2	19.0	13
	Lighting Controls	17	5,10,15	NA	10,15	NA	12.0	12.1	10.0	9
	Lighting Systems	17,16	5,10,15	NA	20 new, 15 retro	NA	14.0	12.1	15.0	13
	Motors	17	5,10,15	NA	17	NA	12.8	15.2	22.0	15
	Process Cooling	NA	5,10,15	NA	18 air, 23 water	NA	14.2	20.0	23.0	16
	Process Equipment or Systems	NA	5,10,15	NA	Varies	NA	10.0	15.0	NA	5, 10, 13
	Industrial Refrg. Compressors	15	5,10,15	NA	Varies	NA	11.3	15.0	23.0	18
	Commercial Refrg. Compressors	15	5,10,15	NA	Varies	NA	11.3	13.2	15.0	13
	Refrigeration Controls	NA	NA	NA	NA	NA	NA	NA	NA	9
	Drives on HVAC Systems	8, 15	5,10,15	NA	15	NA	11.3	15.7	28.0	13
	Drives on non-HVAC Systems	18	5,10,15	NA	15	NA	12.6	15.0	28.0	13

*NA indicates that the sponsors did not provide measure lives for the indicated measures.

Source: ERS 2005

Summary

The three options discussed above are considered for three scenarios of Carbon legislation: no CO_2 emission taxes or mandatory reductions, a CO_2 emission tax, and mandatory reductions with a carbon credit market.

Scenario I: No CO_2 Emission Taxes or Mandatory Reductions

Currently, in order to maximize return on investment, companies consider energy efficiency projects only if the ROI for energy efficiency project is higher than for alternative investments. This view will not change if there remains no CO_2 emission tax or mandatory reductions. While there are other significant factors that impact the economics of energy efficiency, such as new methods, productivity improvements (Worrell et al. 2003), and learning curves (Laitner and Sanstad 2004), the method of calculating the economics of energy efficiency will remain the same. The energy, waste, and productivity savings generated by the energy efficiency project will be measured against the cost, and the project will be executed if the ROI is favorable. Although current market forces do generate energy efficiency projects, many economists believe that most companies under-invest in energy efficiency. This tends to slow overall CO_2 emission reductions (CERA 2007).

While energy efficiency projects clearly provide direct economic incentives, purchasing TRCs results in less direct incentives. For example, purchasing TRCs may help a company market itself as "green," which could help increase sales. Moreover, in the long term, purchasing TRCs reduces global warming and other pollution problems, which sustains an environment for long term business success.

Scenario II: CO_2 Emission Tax

Any fossil fuel energy used leads directly to CO_2 emissions. Therefore, if a CO_2 emission tax were enacted, the effect would be to increase the price of energy. However, the method of calculating the economics of energy efficiency would remain the same: an energy efficiency project would be considered only if the ROI was higher than the ROI of an alternative investment. The economic incentives for purchasing TRCs discussed above would still be in effect, but a CO_2 tax could drastically change the overall economics of purchasing TRCs, depending on the price of the tax.

In order to estimate the impact of a CO_2 emission tax on energy prices, consider costs similar to that of CO_2 emission reduction credits, which range from $4 /tonne to $40 /tonne. At $4 /tonne, a CO_2 tax adds $0.0024 /kWh to the average cost of electricity, which is an increase of 4.7%. At $40 per tonne, a CO_2 tax adds $0.024 /kWh, which is an increase of 47%. At $4 per tonne, a CO_2 tax adds $0.21 /mmBtu to the average cost of natural gas, which is an increase of 2.5%. At $40 per tonne, a CO_2 tax adds $2.1 /mmBtu to the average cost of natural gas, which is an increase of 25%. The increased cost of energy would result in increased savings from energy efficiency projects, and hence shorter payback periods. Thus, a CO_2 emission tax would improve the economics of energy efficiency projects.

These estimates suggest that CO_2 emission taxes could produce a wide range of relative impacts on energy costs. While a 5% increase in utility bills may be manageable, a 50% increase would have a more significant impact on most company's finances. However, it should also be noted that the average fraction of energy costs to total sales for U.S. industry is 2% (EIA 2002). Thus, even a 50% increase of 2% of total revenue only increases energy costs to 3% of total sales.

Similarly, a CO2 tax could affect the incentive to purchase TRCs. As discussed earlier, TRCs cost about $25 /tonne of avoided CO_2. For a CO_2 tax of $4 /tonne, the economic incentives for purchasing TRCs would be the same as discussed previously, but the cost of the

TRCs would be subsidized by the $4 /tonne tax, so the cost of TRCs would only be $21 /tonne. For a CO_2 tax of $40 /tonne, the economics change completely. Without changing its electricity consumption, a company could avoid a $40 /tonne charge by paying only $25 /tonne, for a net *gain* of $15 /tonne.

Scenario III: Mandatory CO_2 Reductions and Carbon Trading

In this scenario, it is useful to quantify the cost per tonne of CO_2 emission reductions from the three options listed above. As stated previously, the cost of CO_2 emission reduction credits ranges from $4 to $40 per tonne, and the cost per tonne of TRCs at $0.015 /kWh is $25 per tonne.

Cost per Tonne of Energy Efficiency

When carbon is sold on the open market, the price will be set according to levels of supply and demand. As shown above, the most viable alternative to buying CO_2 reduction credits is energy efficiency. No company would purchase CO_2 credits if they could achieve the same CO_2 reductions for less money with energy efficiency projects. Therefore, as markets such as the Chicago Climate Exchange develop, the maximum market price that a company would pay for CO_2 reduction credits will be largely dictated by the cost of energy efficiency for that company, as shown in the equation below:

$$\text{Cost of } CO_2 \text{ Emission Reduction Credits} \approx \text{Cost of Energy Efficiency Project}$$
$$\text{MMP (\$/tonne) x CO2 (tonne/year) x ML (years) = IC (\$) – CS (\$/year) x ML (years)} \quad (1)$$

Where MMP is the maximum market price that a company would pay for CO_2 emission reduction credits instead of the energy efficiency project being considered, CO2 is the amount of carbon dioxide saved by the energy efficiency project, ML is the measure life of the project, which describes how long the savings from the project will last, IC is the implementation cost of the energy efficiency project, and CS is the annual cost savings of the energy efficiency project. This can be simplified further if these individual terms are further defined in terms of CC (the carbon content of the fuel in tonnes/kWh or tonnes/mmBtu), ES (the energy savings in kWh/year or mmBtu/year), SP (the simple payback of the project in years), and EC (the energy cost in either $/kWh or $/mmBtu):

$$\text{CO2 (tonne/year) = CC (tonnes/energy) x ES (energy/year)} \quad (2)$$
$$\text{IC (\$) = SP (years) x ES (energy/year) x EC (\$/energy)} \quad (3)$$
$$\text{CS (\$/year) = ES (energy/year) x EC (\$/energy)} \quad (4)$$

Combining Equations 1-4 and solving for the maximum market price yields,

$$\text{MMP (\$/tonne) = EC / CC x [SP/ML – 1]} \quad (5)$$

Inspection of Equation 5 yields several useful observations about the cost of energy efficiency and the market price of CO_2 emission reduction. First, this equation shows that the economics of energy efficiency projects can be converted from standard energy efficiency economic terms, such as initial cost in dollars and cost savings per year, into terms of CO_2 prices ($/tonne). This makes it easy to compare energy efficiency with CO_2 emission reduction credits or TRCs when a certain reduction in CO_2 emissions must be met. For example, if the actual market price for CO_2 emission reduction credits is greater than the MMP for a certain energy efficiency project, then it is more economic to proceed with the energy efficiency project.

This equation also quantifies the relationship of simple payback to measure life. If the simple payback is less than the measure life, then the maximum market price is *negative.* This means a company would only favor CO_2 emission reduction credits over the energy efficiency project if someone *paid* them to take the credits. If an energy efficiency project pays back sooner than the measure life, it is always better to pursue the energy efficiency project. This provides a net monetary gain for the company. If the simple payback is greater than the measure life, then the maximum market price for CO_2 will be positive and determined by the equation above. The energy efficiency project will not recover the initial cost, but it still may be more economical than purchasing CO_2 emission reduction credits or TRCs.

By reworking the above equation, it can calculate the simple payback or simple payback to measure life ratio of an energy efficiency project that breaks even with a known market price for CO_2 emission reduction credits or TRCs. Using the average values for energy price and CO_2 content, the SP/ML ratio is shown in Table 1 for different energy sources and alternative CO_2 reduction prices.

Table 1. Ratio of Simple Payback to Measure Life to Produce Equivalent Costs for CO_2 Emission Credits and TRCs

SP/ML			
Alternative Price:	Market, Low $4/tonne	TRC $25/tonne	Market, High $40/tonne
Electricity	1.04	1.27	1.43
Natural Gas	1.03	1.16	1.25

When the alternative CO_2 reduction price is low, the benefits of energy efficiency drop off quickly as the simple payback becomes greater than the measure life. However, when the alternative CO_2 reduction price approaches the market's historic high, energy efficiency will still be comparable to the alternatives even when the simple payback is 40% and 25% higher than the measure life for electricity and natural gas, respectively.

Ideally, companies that purchase CO_2 emission reduction credits do not have energy efficiency opportunities with simple paybacks less than the measure life. However, the data suggests that not many companies should soon find themselves in this position, since the average simple payback for the first 19% of total a company's energy use is about 1.3 years and measure lives are typically about 13 years. This suggests that there should not be many companies initially seeking to purchase CO_2 emission credits and the market price of the credits should fall as a result. However, as CO_2 emission reduction targets increase, it will be harder to find energy efficiency projects with a maximum market price that is negative, or at least less than the actual CO_2 emission market price or the price of TRCs. At that point, emission credits, TRCs, and other CO_2 emission reduction strategies will be necessary to achieve necessary CO_2 emission reductions.

Decision Making

If mandatory CO_2 emission reductions are put in place in the U.S. and a carbon trading system is implemented, there are three primary ways to meet the reduction requirements: purchasing CO_2 emission reduction credits on the open market, purchasing Tradable Renewable Certificates to ensure electricity comes from non-CO_2 emitting renewable fuel, or investing in energy efficiency projects. Even though these three methods vary greatly in how they accomplish the task, they can be easily compared in terms of dollars per tonne of CO_2 reduced. A company need only use the methodology developed in this paper to determine the current cost of each option. CO_2 emission reduction credits on open markets range from $4 /tonne to $40 /tonne. Purchasing TRCs at $0.015 /kWh is equivalent to paying $25 /tonne to reduce CO_2 emissions. Finally, the company must assess energy saving opportunities and use the formula derived in this paper to calculate the price in $/tonne that a given energy efficiency project would cost. Then it is as simple as choosing the least expensive option.

Conclusion

Growing awareness of the threat of climate change is likely to spur the United States to take action to reduce CO_2 emissions. Possible actions include a CO_2 emission tax or mandatory CO2 emission reductions with a carbon trading system. Knowing how to effectively deal with these actions is vital for U.S. industries if they are to remain competitive in a global economy.

This analysis quantifies the various options for reducing CO_2 emissions in the common metric of $ per tonne of CO_2 emissions avoided. It shows that the cost effectiveness of energy efficiency at reducing CO_2 emissions is a function of the project simple payback to measure life. It also shows that energy efficiency projects are currently the most economical way to reduce CO_2 emissions under any CO_2 management scenario, and are likely to remain so as long as the simple payback is less than the measure life. Thus, this analysis provides a baseline from which to understand market prices for tradable renewable certificates and greenhouse gas emission reduction credits, and provides guidance to industries who may be considering options for reducing greenhouse gas emissions.

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