Chapter 17

Efficiency Criteria for Environmental Evaluation of Power Technologies

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ABSTRACT

The potential of using efficiency as a criteria for the development of future power generation technologies is examined within the realm of pending CO_2 limitations. Efficiency measures of CO_2 per unit of net power available for sale and overall thermal efficiency along with their effects on direct environmental benefits are used to illustrate this concept. The results of this study indicate that improvements in efficiency provide greater environmental benefits than alternative emission reduction measures. However, significant improvements in the efficiency may be required if power generation facilities are to meet the 20 percent proposed reduction in CO_2 by the year 2000.

INTRODUCTION

Advanced technologies of coal and natural gas generated electricity are designated to produce power and meet present and anticipated environmental regulations at a minimum cost. However, many externalities exists in the price of this energy, as a result of its reliance on fossil fuels. Typical evaluations often overlook external cost like the cost of energy security, future gas scarcity, and carbon emissions. Although many economist agree that externalities should be included in the price of energy to obtain socially efficient pricing, their estimates of the dollar values for these costs vary significantly. If and when these costs are internalized, current selections of technologies targeted for development may not coincide with the optimal choices. As a means of accounting for these uncertainties this paper suggest that energy efficiency measures be included in the evaluation criteria for advanced power generation technologies. Specifically, this paper will analyze efficiency measures of CO_2 per unit of net power available for sale and overall thermal efficiency along with their effects on direct environmental benefits. These principles will be illustrated with examples which will make comparisons between conventional coal fired units and combined cycle using various primary fuels.

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POTENTIAL ENVIRONMENTAL BENEFITS FROM INCREASED EFFICIENCY

Efficiency improvements in power generation can produce environmental benefits in two ways. First, benefits can be directly related to declines in energy input requirements per unit of output which ultimately translate into a reduction in the quantity of pollution generated per unit of electricity produced. The levels of reduction, however, are dependent upon the pollutants under consideration. Pollutants such as CO_2 and SO_2, for example, are fuel dependent. Therefore, emissions of these pollutants will be in direct proportion to the type and quantity of fuel used in the on process. However, other pollutants such as NOx, CO and VOC's are technology dependent and the quantity of these pollutants emitted during the generation process depends more on the technology used rather than the amount and type of fuel used.

Second, improvements in efficiency may also generate ancillary benefits by reducing the environmental impacts caused by factors other than the combustion of fossil fuels at power generation facilities. The end use of energy at these facilities accounts for only a portion of the overall environmental impact for any given fossil fuel. Therefore, decreasing the fuel requirements for a given level of power production not only reduces the level of pollutants at the generation facility, it also reduces environmental degradation related to the production and processing of fossil fuels by reducing the need to carry out these activities. Energy efficiency can, therefore, have a strong cumulative effect on reducing environmental impacts associated with the use of fossil fuels as a result of this two fold effect.

EFFICIENCY MEASURES FOR SELECTING TECHNOLOGIES

The United States is one of a number of in of stabilizing CO_2 emissions at 1990 level by the year 2000. Some scientists, economists and environmentalists contend that this strategy is not aggressive enough and have proposed even more aggressive targets. With the increase of this attitude toward emissions, the regulation of CO_2 emissions appears to be inevitable. However, the level of abatement that will be required under these pending regulations, as well as the penalties for failure to meet these requirement have not been delineated. These pending regulations may be addressed in one of two ways either through curative or preemptive measures.

Curative measures reduce emission by treatingg and removing pollutants before they are released into the environment. Add on technologies of this nature generally reduce the overall efficiency of the facility thereby increasing fuel requirements and environmental degredation on through the ancillary effects discussed above. Depending upon the specific process and the level of CO_2 removal between 20 to 50 percent of the facility's electrical output could be consumed by the CO_2 control system [1] [2]. A summary of the effects of selected add on curative controls are presented in Table 1.

Table 1 Curative Emission Controls

<table>
<tr><td>FGD</td><td>SO_2</td><td rowspan="5">All have a negative impact on the overall energy efficiency of the power generation facility.

All have been demonstrated commercially either in power generation or petrochemcial facilities.</td></tr>
<tr><td>Combined do-SO_2/Nox FGD</td><td>SO_2/NOx</td></tr>
<tr><td>SCR</td><td>NOx</td></tr>
<tr><td>Econamine FG</td><td>CO_2</td></tr>
<tr><td>Selexol</td><td>H_2S/CO_2</td></tr>
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Notes:

(a) FDG (flue gas desulfurization), SRC (selective catalytic reaction), Econamine FG (amine flue gas scrubbing system), Selexol (flashing process – most CO_2 removed at medium pressure 50psia and the rest is removed at near atmospheric pressure)

(b) main pollutant marked for reduction

The only curative option currently available for CO_2 control would involve a tail-gas cleanup system that could be adapted from the acid-gas removal technologies used in the petroleum and petrochemical industries. A number of variations of this process are available. However, each is comprised of essentially four basic steps: recovery, concentration, liquefaction, and disposal. Research indicates that these-clean up measures would be quite expensive. Although there is a great deal of uncertainty associated with these costs, estimates for a 20 percent reduction in CO_2 emissions by the year 2000 range from $100 to $300 per ton of carbon reduced and an eventual GDP loss of 1 percent or more [3]. This represents an increase of 2.0 to 2.6 times the current cost of power from conventional coal fired facilities [2]. Similar reductions for IGCC plants are anticipated to increase the current cost of power by a factor approximately 1.7 [2]. Although the cost for CO_2 removal for IGCC facilities is less than that of conventional coal fired units, it is still an extremely expensive alternative method of reducing greenhouse gases when compared to preemptive options.

Preemptive options reduce emissions either by lowering the quantity of primary energy required to produce a unit of output or by substituting less polluting fuels. Fuel substitution has received considerable attention in light of mounting concerns over the effects of greenhouse gases. However, fuel substitution may provide only a temporary solution to these problems unless efficiencies are also enhanced. Because the amount of CO_2 emitted from a given facility is a linear function of the amount and type of fuel used, fuels with the lowest carbon to BTU ratio (see Table 2 for a comparison of fossil fuel properties) will be selected to reduce CO_2 emissions. Natural gas therefore provides the greatest potential for reducing CO_2 emission because it contains only 32 pounds of carbon per 10_6 BTU's (395 8 tons per MW-yr). These cleaner burning properties have lead natural gas advocates to push for regulations mandating its use. However, natural gas may not be the savior its proponents claim due the relative scarcity that would inevitably evolve from usage of this magnitude. To offset the effects of this anticipated demand efficiencies of current natural gas fired units would have to increase significantly. Current efficiencies of natural gas GCC units range between 40 and 50 percent although it has been suggested that an additional 10 percent gain may be achieved by modifying existing combustion turbines [4]. Even with the addition of this proposed increase in efficiency in natural gas fire GCC units, the ability of natural gas to meet anticipated demands remains questionable.

Table 2 shows that crude oil provides the second lowest carbon to BTU ratio (46 lbs per 10^6 BTU or 7231 tons per MW-yr), however, oil is plagued by a set of scarcity problems similar to those of natural gas. Issues of energy security must also be factored into any analysis involving the uses of oil due to the United States' heavy dependence upon foreign suppliers. These factors would likely overshadow any environmental benefits gained by using oil because of the small differences that exist between the carbon to BTU ratios of coal and oil. The difference in the efficiencies of conventional coal fired units and oil fired boilers are also small, further negating any apparent advantage oil may have in reducing CO_2 emissions.

Table 2: Fossil Fuel Characteristics

Coal (1 to 3% S)	1,307.00/ton	54
Crude Oil	6.18/gal	46
Natural Gas	33.0/mcf	32

Notes: (a) Units – lbs/10_6 BTU’s

Considering the scarcity issues surrounding oil and natural gas, coal is apparently the most logical fossil fuel for the interim until alternative energy sources may be developed. However, coal has the highest level of carbon per BTU of all fossil fuels and conventional coal fired units have the lowest efficiencies of all fossil fuel generating facilities. Efficiencies of coal fired units must therefore be increased if coal is to remain the predominate fuel for power generation in light of pending legislation limiting CO_2 emissions.

Results of research and development efforts in the 1970's indicate that development of the IGCC technology is a step in the right direction. The potential of this technology to advance energy and environmental objectives goes beyond the specific reduction in pollutant emissions and energy consumption and includes opportunities for increased flexibility and diversity as well. Efficiencies of these units are approaching those of GCC natural gas units as can be seen in Table 3. However, even with the most favorable coal fueled technologies, carbon emissions per MW-yr are approximately twice those of natural gas. Although it is possible to remove this CO_2 prior to combustion, the process is relatively expensive due to the costs of liquefaction and disposal [5] [2]. The only alternative is to increase the overall efficiency of the generation facility thereby reducing the fuel requirements and in turn CO_2 emissions. Decreasing the fuel requirement of coal fired units as a result of improved efficiency would not only reduce the level of CO_2 emissions, it would also decrease the environmental impacts of related activities previously described. These impacts can be significant for coal related activities. Improving the efficiency of IGCC coal units could make them competitive with their gas counterparts since the overall environmental benefits may be higher than those of natural gas when secondary environmental benefits are factored into the analysis.

A more detailed analysis is required before any definitive conclusions can be drawn with regard to the superiority of one fuel over another. It is evident that efficiency improvements provide the greatest potential for reducing the level of pollutants generated from the production of power using fossil fuels given the short term solution of fuel switching and high costs of curative measures.

While considerable efforts have been expended in making coal a more efficient fuel, the costs remain high relative to the current benefits. If CO_2 and other externalities are included in the price of coal, it is likely that additional ways to improve coal combustion technologies would emerge.

Table 3: Efficiency Summary

Coal (1 to 3% S)	Dry Bottom Wall Fired	34	198	8792
Coal (1 to 3% S)	IGCC	40	198	7807
Resid Fuel Oil	Boiler, Opposed Wall	35	169	7231
Natural Gas	GT, Combined Cycle	45	118	3958

Source: Adapted from *Energy And The Environment: Policy Overview*

CONCLUSIONS

This study indicates that increased efficiency provides the greatest potential for reducing pollutants given the uncertainty of pending limitations on CO_2 emissions. Although other CO_2 reduction measures may be implemented they are more costly and do not have the overall impact of increased efficiency. However, significant improvements in the efficiency of all power generation facilities may be required to meet the 20 percent proposed reduction in CO_2 by the year 2000. These reductions will undoubtedly place additional burdens on even the cleanest utilities. Therefore, those technologies with the potential to substantially increase the overall efficiency of power generation facilities should be targeted for development.

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