

# OPTIONS FOR AIR POLLUTION EMISSIONS PREVENTION AND CONTROL APPLICATIONS OF RAINS-ASIA MODEL

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## INTRODUCTION

A conventional view of the relationship between economic development and the emission of sulfur and nitrogen oxides suggests a relatively pessimistic view of the future in which developing nations face increasing pollution as their economic status and the well-being of their people increase. An argument is that this view is outmoded, inaccurate and short sighted. In the first place, there are a number of technologies that can control emissions of sulfur from power production and hence decouple primary energy consumption from acid emissions. Furthermore, according to the arguments presented, it is possible to decouple economic growth from primary energy consumption by investing in more efficient supply frameworks, improving energy efficiency amongst end-users, and substituting renewable energy technologies for primary fuels. It is clear from these examples that improving the well being of developing nations does not necessarily entail increased pollution of the environment. The key to future development lies in providing the services which people need by using the most efficient technologies, and consuming the lowest possible level of material resources.

### *Conventional worlds*

A conventional view of the relationship between acid emissions and economic development could be summarized as follows:

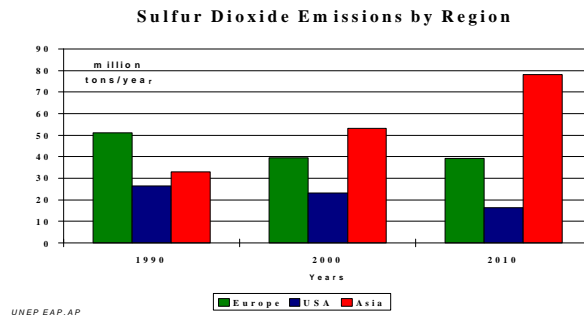
“Acid emissions are intrinsically linked to energy consumption; increasing energy consumption is essential to ensure economic growth; and economic growth is vital to improve human welfare.”

If these statements are all true, then it follows that improving people's welfare, which is a clear priority in developing countries, will lead to increased environmental damage from acidic deposition. The early history of conventional economic development, both in the so-called developed nations and in those still developing, would seem to bear out the truth of this viewpoint. Since the Industrial Revolution, economic development has been characterized by increasing energy consumption. The principal sources of energy have been coal and oil which both release acid rain precursors during combustion. Certainly in the early days of development little attempt was made to control emissions of these pollutants into the environment.

The implications of continuing this pattern of development in the world are quite profound. Globally, economic output is predicted to double between now and the middle of the next century with the fastest growth rates in China and South and South-East Asia (IPCC, 1992). Conventional development scenarios project a corresponding rise in energy demand from around 250 EJ in 1990 to almost 700 EJ in 2050 (Raskin and Margolis, 1995). [Note: 1

exajoule (EJ) =  $10^{18}$  Joules = 22.3 million tons of oil equivalent]. If the developing regions followed the conventional path with no mission control, there will be massive increase in sulfur due to increase in energy demand. This indicates that the conventional viewpoint described above, a viewpoint that can be, and is being, challenged on a number of grounds.

Firstly, increasing acid emissions are not the inevitable result of increasing energy consumption. In fact evidence from Europe shows that sulfur emissions reached its peak in the year 1980 and have subsequently declined steadily in spite of increasing energy consumption. Emissions are predicted to fall further in the next ten years or so as European countries fulfil their commitments under the UN-ECE sulfur protocol.



Secondly, there is increasing evidence of a decoupling of energy demand from economic growth in developed countries (Columbo, 1992). In fact, there is also clear evidence of lower energy intensity in countries with higher growth rates (Jackson, 1997).

In summary therefore, the conventional development path is relatively good description of the way in which most countries have progressed during the early stages of development. It is also a possible development path for the future. However, as a future option it carries with it adverse environmental consequences that could in themselves have long-term impacts on economic stability and human welfare. Moreover, there is clear evidence (e.g. from Europe) that this type of development path is unnecessary. There are number of different options for abating acid emissions without compromising economic development. In the following subsections the range of options available are elaborated for acid emission abatement in the energy sector. It should be recognized that acid emissions also arise from other sectors (principally agriculture); but investigation of the options for abatement from these other sectors will not be considered here.

## EMISSION ABATEMENT

The available abatement options can be characterized in a number of different ways, but fall broadly into two categories: technological options and socio-economic options. The main focus of this section is on technological options, but socio-economic and policy measures are also briefly reviewed. A rather broad view of what is meant by technological options is used here. In particular, there is an important distinction between emission control and emission prevention. Emission control operates mainly on the supply side of the energy sector and generally proceeds via the application of add-on treatments (such as coal washing) or end of pipe techniques (such as flue gas desulfurization). These technologies tend to increase the economic cost of supply, but installation, management and legislation with regard to these

technologies are relatively straightforward. Emission prevention, by contrast, operates as much on the demand side as it does on the supply side and can lead to economic savings in the economy as a whole. On the other hand, it has some profound implications, for the institutional arrangements under which the energy sector operates, and indeed for other sectors of the economy.

## **CONTROL OPTIONS**

Historically, the control option has tended to be the focus for environmental policy and regulation. It comprises a number of measures for removing sulfur and nitrogen from energy supply processes at various stages of the combustion cycle. Some methods remove pollutants from the combustion fuels in the pre-combustion stage; others inhibit the formation of acid gases during the combustion process; other again remove sulfur and nitrogen oxides from the flue gases after combustion.

### ***Pre-combustion methods***

These methods attempt to remove pollutants from the fuels prior to combustion. Generally speaking such methods are not applicable to nitrogen since the primary source of nitrogen oxides during combustion is the nitrogen content of the combustion air. Typically, the following methods are used to remove sulfur:

- Hard coal washing
- Gas-oil/diesel hydrosulphurization
- Heavy fuel oil desulphurization

### ***Treatment during combustion***

There are two principal methods of treatment during combustion. One of these methods is to use limestone to absorb the pollutants; the other is to modify the combustion process to reduce the formation of nitrogen oxides. The following are the most common limestone treatment methods:

- In-furnace limestone injection
- In-fuel limestone addition
- Fluidized-bed combustion (FGD)

Nitrogen oxides can be effected during the combustion by various modifications to the combustion process:

- Low excess air combustion
- Low nitrogen oxides burners

### ***Post-combustion methods***

The aim of the post-combustion methods is to remove sulfur and nitrogen from the flue gases, before they pass out of the stack in the atmosphere. There are a number of FGD methods. These include the following:

- Lime-gypsum FGD
- Wellman-Lord process

Post-combustion methods for removing nitrogen from flue gases include the following processes:

- Selective non-catalytic reduction
- Selective catalytic reduction
- 3-way catalytic converters (vehicles)

### *Technological and economic implications of control technologies*

Control technologies for sulfur and nitrogen have been widely applied in a number of developed countries and account for some of the reduction in sulfur emissions in Europe. In Japan, abatement levels for sulfur in different sectors are shown in Table 1 and the overall abatement level in 1985 was around 85 per cent.

**Table 1 Abatement levels in Japan in 1985 using control technologies**

Sector	Abatement level (%)
Power Production	85
Non-ferrous metal smelting	98.5
Other Industry	40
Domestic and commercial sectors	20

Source: Kato and Akimoto (1992)

Control technologies are generally straightforward to fit retrospectively to existing plant, or to incorporate into the design specification of new plant. However, there are some technical and economic implications. Firstly, add-on technologies reduce overall efficiency of plant (typically between 1 to 5 per cent) leading to slight increases in fuel consumption, and consequently to slight increases in emissions of carbon dioxide. Carbon dioxide is also released from fluidized bed combustion as a result of the breakdown of calcium carbonate in the process. There is therefore some trade-off between the reduction of acid emissions using control technologies and increasing greenhouse gases.

Secondly, control technologies can also incur environmental burdens elsewhere in the economy as they require material and energy inputs and give rise to outputs to the environment during construction and operation. For example, the main FGD technology uses limestone as an input, which must be quarried from geological deposits. This process is energy intensive and gives rise to environmental impacts from mining “overburden” and scarring of the landscape. The principal output from limestone-based FGD is gypsum, which is a usable commodity in industrial economies. However, due to fragility in market demand for gypsum, and because the quality of gypsum from FGD sources is not always high enough, some gypsum may require disposal in landfill sites. In addition to the routine operational emissions, control technologies also require energy and material input to build and install them, giving rise to additional environmental impacts in the manufacturing sector.

As might be expected from these remarks, there are also economic implications associated with using control technologies. Generally speaking, adding on another process which itself requires material inputs will also add to the cost of power and heat production. There are additional costs vary widely between different control options. For example, around a quarter of a million tons of sulfur can be abated in Belgium at an average cost of less than US \$ 2,000 per ton. However, beyond that point the cost of emissions reduction rises rapidly. These rising costs for emission control are one of the principal drivers for the move towards preventive emission abatement options.

## **PREVENTIVE OPTIONS**

The idea of preventive environmental management has arisen in response to the acknowledged limitations of emission control options. These options require add-on technologies that are costly to implement, and give rise to environmental impacts elsewhere in the economy. By contrast, preventive options aim to reduce emissions everywhere by lowering the energy and material throughput of conversion processes generally.

There are two general routes towards improved environmental performance in preventive environmental management. The first is through improved efficiency of conversion processes; the second is through substitution of polluting materials, processes and activities with those which are less polluting. In the energy sector, a number of examples of each of these different strategies for reducing sulfur and nitrogen oxide emissions can be found.

### ***Efficiency improvements***

It is useful to distinguish between supply-side and demand-side efficiency measures. Supply side efficiency measures improve the efficiency with which primary fuels are converted to delivered energy. Thus, the same energy demand is supplied by a smaller quantity of primary fuels. Since acid emissions are proportional to the quantity of primary fuel consumed, supply-side measures allow for reduction in acid emissions without any reduction in energy supplied. Demand-side efficiency measures improve the efficiency with which delivered energy is converted into useful energy services such as thermal comfort, motive power, lighting etc. By using less delivered energy to provide the same service, the demand for this energy is reduced. Fewer primary fuels are consumed, and again, the environmental impacts associated with primary fuel consumption are avoided.

### ***Supply-side efficiency measures***

Conventional coal- or oil- fired electricity generation typically has a primary fuel efficiency of between 30 and 35 per cent. Around 60-70 per cent of the energy content of the fuels is lost as waste heat. Although there are thermodynamic limits to the efficiency with which thermal energy can be converted into electrical energy, significant supply-side efficiency improvements are possible with newer technologies such as gas or oil-fired combined cycle gas turbines which can achieve fuel efficiencies approaching 50 per cent, fluidized bed technologies (efficiencies approaching 40 per cent), or IGCC technologies (efficiencies approaching 50 per cent).

It should also be noted that there is often some potential for improving the efficiency with which energy is transmitted and distributed, for instance by reducing leakage in transmission systems, and by optimizing electricity distribution grids. One of the ways in which this can occur is by matching local supply with local demand, thus reducing the distance over which electricity must be transmitted.

### ***Demand-side measures***

There is considerable potential for reducing primary fuel consumption through end-use efficiency improvements. For example, the EU's green paper on Energy Policy, published in 1995 suggested that between 10 and 30 per cent of primary energy consumption could be saved by implementing demand-side technologies, which are already on the market.

### ***Substitution***

The potential for reducing demand through improved energy efficiency is an important avenue for reducing the environmental impact of energy production and consumption. However, there are thermodynamic limitations to the efficiency with which energy services can be provided and, in the face of the rising demand for energy services in developing countries, meeting environmental targets requires some other means of reducing polluting emissions. The principal avenue for this is to substitute less polluting for more polluting supply technologies. Again, this trend is already visible in the developed nations.

The potential for substitutions by, for example, gas in developing nations on a similar scale to Europe will depend heavily on the development of gas supply markets and distribution infrastructures in those countries. However, there are some other technologies that could substantially reduce not only acid emissions but also emissions of greenhouse gases from the energy sector. These are the so-called non-fossil options; principally renewable energy technologies. The other main non-fossil option for electricity supply is nuclear power, but the risks associated with the development of the nuclear option and the problems associated with public acceptance are substantial.

### ***Renewable energy technologies***

Whereas fossil fuel technologies exploit the chemical energy locked into finite mineral reserves, the renewable energy technologies utilize the ambient energy flowing through the environment, mainly from solar sources.

Typical renewable energy technologies include hydropower, biomass, wind power, solar photovoltaics, solar thermal technologies, geothermal energy, tidal power, and wave power. In actual fact, the first two of these technologies already constitute around 20 per cent of the world's total commercial primary energy supply. Some renewable energy technologies, for instance wind energy, small-scale hydro, and the conversion of domestic and industrial wastes to energy, are already competitive with conventional sources of supply. Other technologies have considerable long-term potential, are still more expensive to operate. Perhaps the most significant of these long-short technologies is solar sunlight to electricity. Currently, photovoltaics are only economical in niche markets, usually involving locations isolated from the main electricity grid. But the costs of module production have been falling for two decades and are set to go on falling as conversion efficiencies rise. An increasing

interest in renewable energy technologies both from national governments and from multinational power companies suggests that the future landscape of energy supply will look very different from the past.

## **TECHNICAL, ECONOMIC AND INSTITUTIONAL IMPLICATIONS OF PREVENTION**

Several important features distinguish prevention options from control options. In the first place, reducing acid emissions by preventive options also reduces the emission of other pollutants that arise from fossil fuels combustion, most notably the emissions of GHGs such as carbon dioxide. Of equal importance, abatement proceeds in an integrated fashion with genuine savings in resources throughout, rather than reductions in one set of atmospheric emissions at the expense of increases in other emissions. This contrasts sharply with the control options, where acid abatement may lead to increased carbon dioxide emissions, increased emissions of sulfur to aqueous and solid waste streams and, inevitably, additional material throughout in the manufacture and operation of control devices.

In the second place, the efficiency options enable the same level of service to be delivered with fewer resource inputs. This means that they offer the potential for reduced costs. In other words, environmental protection which proceeds through improved efficiency does not cost money; it saves money. The truth of this remark is borne out by an increasing emphasis on the concepts of pollution prevention, waste minimization, and clean technology worldwide (Jackson, 1996).

In spite of the significant economic and technical advantages of the prevention options, they do have important institutional implications. For example, implementing energy efficiency amongst end-users implies intervening in a complex infrastructure involving a multitude of different social actors.

Among the most inventive ways of avoiding these difficulties are attempts to transform energy supplying companies into energy service companies (Jackson, 1997). Instead of basing their profitability on revenues from bulk sales of delivered energy, these new companies base their profitability on providing energy services.

## **POLICY FRAMEWORKS FOR PREVENTION AND CONTROL**

Conventionally policy frameworks have been seen as being based on two main types: regulatory measures and market-based instruments. Regulatory measures include the imposition of emission limits, the setting of appliance efficiency standards, and the requirement for best available process and end-of-pipe technologies. These types of measures are often called “command and control” instruments, and are portrayed by critics as inflexible and hence inefficient. However, well designed regulation is generally effective in ensuring that environmental standards are met, and there is evidence that appropriate legislation can promote technological improvement. Moreover, flexibility can be built into regulatory systems by notifying industry in advance of new standards, providing sliding scales of emission limits, and allowing emissions trading within emission “bubbles”.

Market based instruments include emission charges, taxes on resource use, subsidies for cleaner technologies, tax relief on new capital investments, and penalties for infringement of

environmental regulation. For example, in Sweden, a charge is levied on NO<sub>x</sub> emissions from all heat and power plants over 10MW in capacity, with production exceeding 50 GWh per year. A sulfur charge has also been levied at different rates on different types of sulfur containing fuels.

Generally speaking, it is argued that market-based instruments increase flexibility by allowing progressive shifts to less polluting fuels, and by encouraging abatement to be carried out where it is most cost-effective. However, their effectiveness in achieving environmental standards depends heavily on institutional factors such as the technical feasibility of removing pollutants, the elasticity of substitution between different types of fuels, the equitable availability of investment capital and the general responsiveness of the energy market to price signals.

In reality, the distinction between regulatory measures and market-based instruments is at best hazy. Effective legislation must be enforced in some way, and financial penalties are the most common type of instrument of enforcement. Equally, economic measures such as tradable permits operate as an effective means of abatement only under an emissions “cap”, requiring targets to be set, and limits to be observed. Any comprehensive environmental policy framework is likely to use both regulatory measures and market-based instruments.

## **SUMMARY**

Many developing countries are in the planning stage where strategies are being formulated and plants in the energy and industrial sectors are being constructed. If these are built according to conventional wisdom and technology then large increase in emissions will result in many regions. There are a number of alternatives, however, if implemented, can bring down the emission level substantially without compromising the well being and welfare of the people in developing countries.

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