Chapter 6

THE ENVIRONMENT AND SOCIAL COSTS

As Chapter 2 points out, the 1990s witnessed a shift in the debate over the long-run availability of mineral commodities. Fears that the environmental and other social costs incurred in the extraction, processing, and use of mineral commodities might severely constrain their future availability pushed aside the more traditional concerns over mineral depletion. Even if new technology allows the exploitation of poorer deposits without any significant increase in the real price, the environmental damage inflicted on society and the other social costs that the producer and consumer do not pay, it is argued, may soon preclude the widespread use of mineral commodities.

Social costs cover all the costs associated with a particular activity. They include those costs for which the producing firm and in turn the consumer pay, such as the costs of labor, capital, and materials. These are called internalized costs, since the firm or party that uses these resources pays for them.

Social costs also include any external costs, or what are often referred to as simply externalities. These are costs that are borne by members of society other than the firm and the consumers who cause them. When the generation of electric power spews particulates and other pollutants into the air, unless the firm is charged or fined, it and ultimately consumers do not pay all the costs of power generation; some are inflicted on people who live down wind from the power plant.

Externalities create problems. Society in effect subsidizes goods with external costs, since their market price does not reflect their full costs of production. This results in greater production than is optimal. Producers, moreover, have no incentive to conserve on environmental and other resources for which they do not pay. So these valuable resources are overused. In addition, long-run trends in costs and prices are no longer reliable indicators of resource availability.

Figure 6.1 illustrates these distortions, and shows the optimal use of environmental resources from the perspective of society. The horizontal axis reflects the consumption of environmental resources, or alternatively the amount of environmental damage along with any other social costs incurred (E). These costs may in some instances be measured by an appropriate proxy. Mandonça (1998) and Mandonça and Tilton (2000), for example, contend that deforestation is a reasonable proxy for the environmental damage arising from iron ore mining in the Amazon region. If the use of environmental resources (deforestation) rises in direct proportion with output (iron ore production), the horizontal axis also reflects the output (Q) of the good causing the damage to the environment. When this is the case, a second line showing output (Q) can be drawn beneath the horizontal axis (E). The vertical axis measures benefits and costs associated with using the environmental resource measured in dollars or some other currency.

The MNB curve shows the additional or marginal net benefit derived from using one more unit of the environmental resource (the deforestation of one more hectare). This in turn depends on the extra profits the mining company can earn as a result (that is, on the difference between the firm’s costs and its revenues). Since profits per unit of output tend to fall as output increases, the curve slopes downward. The MEC curve shows the additional or marginal external costs—the environmental costs that society but not the mining companies must bear—as a result of using one more unit of the environmental resource (again, for example, from the deforestation of one more hectare). Since the unit value of the remaining environmental resource is likely to rise as its supply declines, this curve slopes upward.

For society, the benefits from mining in the Amazon are maximized when the additional costs of using one more hectare of land just equal the additional benefits. This occurs where the two curves cross at a mine output of Q_1 and land deforestation at E_1. In this situation some use of the environment, that is some environmental damage, is desirable. Of course, this need not be the case. In some instances, the curve MEC may lie above the curve MNB across all levels of output and environmental resource use. This means that the social costs of production exceed the social benefits for all outputs, and so any production would detract from, rather than add to, the well-being of society as a whole.

In either case, however, the mining company has an incentive to continue to produce until the MNB curve reaches zero, as it does not pay the environmental costs that the curve MEC reflects. Without some sort of government intervention it will continue to produce and pollute until output reaches Q_2 and environmental resource use E_2. The result is both too much output and too much pollution.

The remedy most policy analysts recommend for this problem is for the government to limit output or pollution to its optimal levels. For example, the government can regulate mining by permits and other means, and in the process either restrict the amount of output permitted to Q_1 or the amount of pollution to E_1. Since output is good, while pollution is bad, restricting pollution rather than output has the advantage that it encourages mining companies to increase output (the good) to the extent they can and still limit their pollution (the bad) to its socially optimum level (E_1).

Another possibility is for the government to impose a tax on companies, often referred to as a Pigovian tax, after Arthur Pigou, the British economist, who first recommended this solution to the problem of externalities. Placing a tax of OC dollars, for example, either on output or pollution would encourage producers to restrict their output and pollution to the desired levels. Again, a tax on pollution is preferable, since it is pollution not production that society wants to discourage.

Historically, governments have relied primarily on command and control regulations rather than on taxation and other economic incentives to correct the problems and distortions caused by environmental and other external costs. The past several decades, however, have seen growing support for economic incentives. By forcing companies to pay for the environmental resources they consume, they encourage companies to strive just as hard to reduce their pollution as to conserve on the labor, capital, and other inputs they employ. This is a big advantage, as over time it permits more production with less pollution and other social costs.

In the case of mining iron ore in the Amazon, for example, a tax of OC dollars per hectare of land deforested would encourage the socially desirable amount of pollution (E_1). It would also provide an incentive to find ways to reduce the environmental damage associated with mining, allowing iron ore output to increase with little additional deforestation. The price of iron ore would also reflect the full costs of production and so the true scarcity value of this resource.

The preceding suggests that the threat to the long-run availability of mineral commodities due to environmental and other social costs may be mitigated or completely eliminated by forcing producers and consumers to pay for these costs. Once this is done, new technology, just as it has reduced the labor, capital, and other internalized costs of resource production in the past, should reduce the erstwhile external costs associated with mining and mineral processing.

For this to happen, however, requires, first, that public policy has the ability and the will to force firms to pay the environmental and other social costs associated with their production. Then, once these costs are internalized, firms must possess the capability to generate the requisite technologies. This chapter examines these two necessary conditions, starting with the second.

Technology and Environmental Costs

A century ago, even 50 years ago, mineral producing firms faced few environmental restrictions. The environment was largely viewed as a free good, for firms and others to use as they wished. As a result, there was little or no incentive to reduce environmental costs. Sulfur dioxide, particulates, and other pollutants were pumped into the air. Other wastes were dumped on land or into nearby streams. Mines were abandoned with little or no reclamation.

This situation has changed greatly over the past several decades, as governments around the world have imposed regulations and other controls on mineral producers and other firms. One interesting byproduct of this development is the accumulating evidence indicating that firms can substantially reduce their environmental costs when they have the incentives to do so. Environmental costs, it appears, are just as amenable to the cost-reducing effects of new technology as capital and labor costs, perhaps even more so since efforts to reduce environmental costs were so modest until recently.

A comprehensive review of this evidence is to our knowledge not yet available, and in any case is not necessary here. Several examples should suffice. A particularly interesting case is the lead industry in the United States. Figure 6.2 provides a life cycle analysis for this commodity, first for 1970 and then for the years 1993-94. While consumption grew by about 15 percent over this period, primary domestic production and net imports declined as recycling and secondary production more than doubled. Despite rising consumption, lead discarded back into the environment fell by more than 50 percent. Government policies that regulated the recycling of motor vehicle batteries and that curtailed or eliminated for health reasons the use of lead in paints and gasoline deserve most of the credit for these favorable developments.

The aluminum industry in Canada provides another example. As Figure 6.3 shows, it managed between 1972 and 1995 to reduce its emissions of particulates, fluoride, and polycyclic aromatic hydrocarbons[1] (PAHs) by 67, 69, and 86 percent respectively, all while more than doubling its output.

Yet another interesting case is the Chuquicamata copper smelter in northern Chile. As Figure 6.4 illustrates, over the 1980-1999 period this smelter increased the amount of recovered arsenic emissions from 35 to 90 percent, and the amount of recovered sulfur dioxide emissions from zero to 80 percent. Codelco, the state enterprise that owns Chuquicamata, spent over $600 million to realize these improvements. While this is a formidable sum, Chuquicamata nevertheless managed to remain one of the world's largest and lowest cost copper producers over this period.

[1] Polycyclic aromatic hydrocarbons (PAHs) arise from the incomplete combustion of carbon compounds, and are largely the result of forest fires and the burning of wood. In the aluminum industry, the baking of pitch found in the anodes causes PAHs emissions. In newer smelters using Soderberg anodes, PAHS emissions are almost zero.

While the reduction in sulfur dioxide emissions at Chuquicamata is impressive, the technology exists today to capture more than 99 percent of these emissions. As a result, smelters in countries with very stringent environmental standards—in Japan, for example—remove all but one or two percent of their sulfur dioxide emissions. Unfortunately, at the other end of the spectrum a significant number of smelters still allow 100 percent of their emissions to escape into the atmosphere.

Thus, the impact of new technology on sulfur dioxide pollution is substantial where public policy internalizes these environmental costs and far less impressive elsewhere. Today the best smelters are producing a hundred tons of copper with less sulfur dioxide pollution than smelters generated in producing just a single ton several decades ago. In addition, about a fourth of the world's copper is now produced by a new hydrometallurgical process, solvent extraction electrowinning, which completely bypasses the smelting stage of the traditional process. As a result, the copper it creates generates no sulfur dioxide emissions.

There are instances where environmental or other concerns may preclude mineral exploitation, where mining is simply incompatible with preserving environmental resources and other assets that society values highly. Activities that diminish the natural beauty of national parks, the pristine wilderness of remote areas, the culture and mores of indigenous people, and biodiversity are often cited examples. Considering Figure 6.1 once again, these are situations where the MEC curve lies above the MNB curve across all possible outputs.

In these situations, no amount of technological change may reduce the costs to acceptable levels, and public policy may quite appropriately place certain sites off-limits to mineral exploitation.[2] This, in fact, has been the case for some time in most countries. While making it more difficult for the cost-reducing effects of new technology to offset the cost-increasing effects of depletion, such exclusions, even when growing in magnitude, are not incompatible with falling resource costs, as recent history shows. We will return to this issue in Chapter 7.

Internalizing the Externalities

According to the preceding section, the technology currently exists to capture all or almost all the sulfur dioxide emissions arising from copper smelting. Yet, this technology has diffused quite unevenly around the world, largely reflecting the success or failure of public policy in internalizing environmental costs. This brings us back to the first of the conditions necessary to avoid an environmental constraint on the long-run availability of mineral commodities: namely, that public policy must force firms to pay the environmental and any other external costs associated with their activities. This, in turn, requires (a) that governments are able to identify and measure these costs, and (b) that they possess the means and the will to force firms to pay them.

Valuing Environmental and Other Social Goods

Market prices provide a good starting point for assessing the value of the labor, capital, and the other inputs used in the extraction and processing of mineral commodities.

[2] It does not necessarily follow that exploration too should be excluded from all such sites. Exploration typically entails far less environmental damage than mine development and operation. It also provides information that permits a more accurate assessment of the potential benefits (the MNB curve) from mining in a particular area. While this point may trouble those concerned about preserving wilderness areas, the fact that

Unfortunately, many social goods, including clean water, wilderness, indigenous cultures, and biodiversity, are not traded on markets, and so alternative means are needed to assess their value. Over the past several decades, economists and others have devoted considerable effort to devising the necessary techniques.

One approach, a fairly recent social experiment, entails the actual creation of markets for environmental goods. For example, the government has for some years now allowed U.S. coal-powered electric power utilities to trade sulfur dioxide permits. Those companies that can reduce their sulfur dioxide emissions at a cost less than the going permit price have an incentive to sell their permits. Where the opposite is true, companies have an incentive to buy permits. So the market price for permits reflects the lowest possible cost to society of reducing sulfur dioxide emissions by one additional ton. Assuming the total number of permits reflects the optimum level of sulfur dioxide pollution, their price provides a good measure of the social costs associated with an additional ton of sulfur dioxide emissions, and of more importance forces firms to internalize these costs.

A second approach depends on inferences from actual consumer behavior. Hedonic pricing, for example, compares the value of similar houses close to and away from an airport to assess the social cost, measured by what people are willing to pay in additional housing costs, of the noise pollution created by arriving and departing airplanes. Travel cost studies measure the value users place on a lake, stream, or other recreational facilities from the travel and other expenses people incur to use these facilities.

A third approach, contingent valuation, arose primarily to value a class of environmental goods prized for their non-use or existence value. Many people, for

few if any private interests are likely to have an interest in conducting exploration where the probability of being permitted to develop a successful discovery is low or zero should provide some consolation.

example, may place a positive value on the rain forests of the Amazon, the pristine wilderness of Alaska, or the indigenous culture of the Bla'an people who live on the island of Mindanao in the Philippines.[3] This may be true even though they themselves never plan to visit the Amazon, Alaska, or the Philippines. Such non-use value has in practice proven particularly difficult to measure. Contingent valuation attempts to do so by asking people, typically in structured manner governed by recommended procedures, how much they would pay to preserve these resources. It has been used in the United States, particularly in legal cases for resource damage assessments, and elsewhere as well. It is generally considered the only available method for valuing environmental and other social assets with non-use value.

Contingent valuation is, however, controversial, in part because it is not based on or even related to actual behavior. Those polled do not actually have to pay what they say they would pay. Among the experts, there is widespread agreement that poorly designed contingent valuation studies—where, for example, the respondents are inadequately informed or the questions leading—can produce highly flawed results. There is much less agreement, however, over the reliability of well-designed studies.

In addition, public acceptance, or rather the lack of it, is a serious concern. Cox (1994) provides an interesting example in his analysis of the public dispute in Australia over the proposed gold, platinum, and palladium mine at Coronation Hill. Largely because this deposit lies within the Kakadu Conservation Zone in the Northern Territory, the Australian government carried out an extensive cost-benefit analysis of the proposal. The study used contingent valuation to estimate the value of preserving the area. The analysis

[3] For an interesting description of the efforts by a mining company to preserve the Bla'an culture, see Davis (1998).

was conducted with considerable care, with the assistance of experts from abroad, and in accordance with accepted procedures. It found that Australians feel strongly about the possible environmental damage from mining in the Conservation Zone, but the methodology created such a fierce backlash that the government removed all references to the contingent valuation effort from its final report.

Critics fault contingent valuation at two very different levels. First, many claim that the methodology (asking people what they would pay) simply does not produce reliable responses for a host of reasons. Here, the complaint is that contingent valuation does not produce the information it purports to, namely, true willingness to pay.

Second, several critics (Humphreys 1992 and 2000, Sagoff 2000, Soderholm and Sundqvist 2000) question the use of contingent valuation for more fundamental philosophical or ethical reasons. For them, even if contingent valuation does elicit reliable responses, adding the willingness to pay across all individuals in society is not the appropriate way for society to place a value on social goods.

They argue for an alternative approach, which recognizes that biodiversity, native cultures, pristine wilderness, and other social goods with substantial non-use value are public goods, just like national defense or safe municipal drinking water. Governments decide how much to spend on national defense through a political process that reconciles the various competing interests of society, not an artificially constructed simulation of the marketplace.

The political process allows a public debate. This provides individuals and organizations with the opportunity to make their own views known, as well as to become better informed about the issues and the views of others. The political process also more readily accommodates the fact that individuals may make decisions about the purchase of private goods in a different way using different criteria than the decisions about public goods. As citizens, for example, individuals may support policies (such as higher taxes for education) that have no impact or even a negative impact on their own well-being. The political process, it is argued, is much more likely to take into account and reflect such support than contingent valuation.

Finally, both approaches give the wealthy a greater say in the provision of public goods (since the rich have more dollars to spend on questions posed in contingent valuation studies and more dollars to spend influencing the political process). With the political process, however, every individual no matter how poor ultimately has one vote in electing public officials. This may leave the poor feeling less disenfranchised.

This review of various techniques for valuing environmental resources is far from comprehensive or complete, yet it suffices to show that measuring the full social costs associated with mineral exploitation is complex and difficult. While our tools in this area have advanced considerably over the past several decades, much progress is still needed before reliable measures of environmental resource values are available, particularly for those resources with non-use value.

The current debate over global warming and climate change, unfortunately, provides an excellent illustration of the need for progress in this area. After years of discussion, there is now a growing consensus that global warming is a reality, and that carbon dioxide and other greenhouse gases are largely responsible. Still hotly disputed are the pace of climate change, the consequences and costs, the contribution of people as oppose to nature, and the benefits of curtailing industries and other human activities that generate greenhouse gases. These uncertainties make it difficult, if not impossible, to assess the external costs associated with global warming that coal producers and other mineral commodity industries generate, which is necessary to determine suitable public policies to internalize these externalities by an appropriate carbon tax or other measures.

The Means and the Will

Once the environmental costs are known, governments need the means and the will to force producers to pay these costs. Clearly, the means exist. Indeed, as noted above, the on-going debate is over which set of tools or means governments should rely upon. Command-and-control regulations, probably the most common instrument, can require the use of certain technologies or equipment, and set ceilings on the permissible amounts of given pollutants. However, economic incentives, such as pollution taxes, have in recent years found increasing favor as they often lower the costs of reducing pollution. With both command-and-control regulations and economic incentives, there are enforcement problems, but these do not appear any greater than in many other areas of public policy, such as worker health and safety or taxation compliance.

The great differences noted earlier in the recovery of sulfur dioxide emissions found among copper smelters suggest the will of governments to internalize costs may be a more serious problem. Some of these differences may simply reflect the lower environmental costs associated with copper smelting in more remote and less inhabited regions. In addition, over time as old smelters are replaced, state-of-the-art environmental control technologies are likely to be used more widely. So some of the current discrepancies among smelters may be temporary, though given the long lives of many copper smelters, temporary may mean decades.

In addition, the sorry environmental legacy of state-owned mining enterprises in Russia and other former centrally planned states raises some troubling concerns. Clearly where the government has a conflict of interest, where it owns and operates mineral enterprises and is also responsible for ensuring that they adhere to acceptable environmental practices, the environment often suffers from a lack of will on the part of the government to internalize environmental and other social costs.

Another serious and possibly more permanent problem, given the recent trends away from central planning and toward the privatization of state-owned enterprises, entails artisanal or informal mining. This is very small-scale mining—often illegal—by individuals or groups using the simplest and most primitive equipment. According to the International Labor Organization (1999), some 13 million people along with 100 million dependents worldwide depend on small-scale mining for their livelihood. While some of these workers are engaged in small-scale mechanized mining, many are employed in the artisanal sector. The number of workers in small-scale mining rivals that of the formal mining sector, and has been growing at 20 percent a year over the past five years, a rate far faster than that for the formal mining sector.

The World Bank (Barry, 1996, p. 3) estimates that artisanal mining accounts for 20 percent of the gold, 40 percent of the diamonds, and nearly all the gemstones produced in Africa. Somewhat less than half of Brazil’s gold production comes from such operations, down from 70 percent just a few years ago. In addition to gold, diamonds, and gemstones, artisanal miners produce copper, silver, tin, zinc, and coal.

These mines are highly inefficient, often leaving in the ground ore that better-run operations would exploit. They are more dangerous, and often employ women and children. They are also far more damaging to the environment per unit of output. Many gold operations, for example, discharge mercury into the surface and ground water. Acid mine drainage, soil erosion, deforestation, and river silting are also common problems. Sites are typically abandoned with little or no reclamation.

In many respects, artisanal mining is resource exploitation at its worse, but it does provide a subsistence existence to millions of individuals with few if any alternatives. Governments as a result are reluctant to close down these operations or even in many cases to impose environmental and other regulations. In short, artisanal mining represents a major social and political problem whose resolution largely awaits major new initiatives to eliminate the poverty and the dearth of economic opportunities, which are largely responsible for these marginal activities so damaging to the environment.

Global warming provides one final illustration of the problems society can encounter in its struggle to deal effectively with externalities. Even without the uncertainties noted earlier, creating the political will on an international basis to curb greenhouse gases in a world of many independent nation states is daunting. Developing countries claim that they did not create the problem, and should not now have to slow their growth to reduce greenhouse emissions. The developed world argues that selective cutbacks by only a few countries will not be effective. Still other countries may benefit from a warmer climate, or believe they may benefit, and so are not greatly inclined to support efforts to abate or reverse global warming. And all countries are reluctant to bear more of the costs than they believe is their fair share, which invariable is less than other countries propose. The possibilities for stalemate are obvious.

Conclusions

The shift in the on-going debate over the long-run availability of nonrenewable mineral resources during the 1990s raises some interesting issues by focusing on the potential constraint that the environment and other external costs may impose of resource exploitation. In the past, scientists and engineers have successfully generated the new technology and other innovations needed to offset the cost-increasing effects of depletion.

In the future, if environmental and other social costs become a more important component of the total cost of mineral resource production and use, as seems likely, the favorable trend toward greater mineral resource availability can continue, as we have seen, but only if two conditions are satisfied. First, mineral producers with the assistance of science and technology must be able to continue to offset the upward pressure on their costs due to depletion. Second, public policy must internalize the environmental and other social costs of mineral production so that producers have the same incentive to reduce these costs as their other costs.

Of the two, the second condition appears the most challenging. The pursuit of this condition will involve policy analysts, economists, political scientists, and other social scientists in the struggle to ensure the long-run availability of mineral commodities. Indeed, their role could turn out to be even more difficult than that of their colleagues in engineering and natural sciences, for the problems of valuing environmental resources and the problems of ensuring that governments have the will to internalize all the social costs may prove more troubling, perhaps far more troubling, than the more traditional technical challenges.

References

Barry, M., Ed. (1996). Regularizing Informal Mining: A summary of the Proceedings of the International Roundtable on Artisanal Mining. Occasional Paper No. 6. Washington, DC, The World Bank, Industry and Energy Department.

Cox, A. (1994). Land access to mineral development in Australia. Mining and the Environment. R. G. Eggert. Washington, DC, Resources for the Future.

Davis, S. L. (1998). "Engaging the community at the Tampakan copper project: A community case study in resource development with indigenous people." Natural Resources Forum **22**: 233-243.

Humphreys, D. (1992). The Phantom of Full Cost Pricing, A paper given at the International Council on Metals and the Environment seminar on full cost pricing. London, The RTZ Corporation PLC.

Humphreys, D. (2000). "Taxing or talking: addressing environmental externalities in the extractive industries." Minerals & Energy **15**(4): 33-40.

International Labor Organization (1999). Social and Labour Issues in Small-Scale Mining. Geneva, International Labour Office.

Mendonça, A. (1998). The Use of the Contingent Valuation Method to Assess Environmental Cost of Mining in Serra dos Carajas: Brazilian Amazon Region, Unpublished PhD dissertation. Golden, CO, Division of Economics and Business, Colorado School of Mines.

Mendonça, A. and J. E. Tilton (2000). "A contingent valuation study of the environmental costs of mining in the Brazilian Amazon." Minerals & Energy **15**(4): 21-32.

Sagoff, M. (2000). "Environmental economics and the conflation of value and benefit." Environmental Science & Technology **34**(8): 1426-1432.

Soderholm, P. and T. Sundqvist (2000). "Ethical limitations of social cost pricing: An application to power generation externalities." Journal of Economic Issues **34**(2): 453-462.

Figure 6.1. The Optimal Use of Environmental Resources

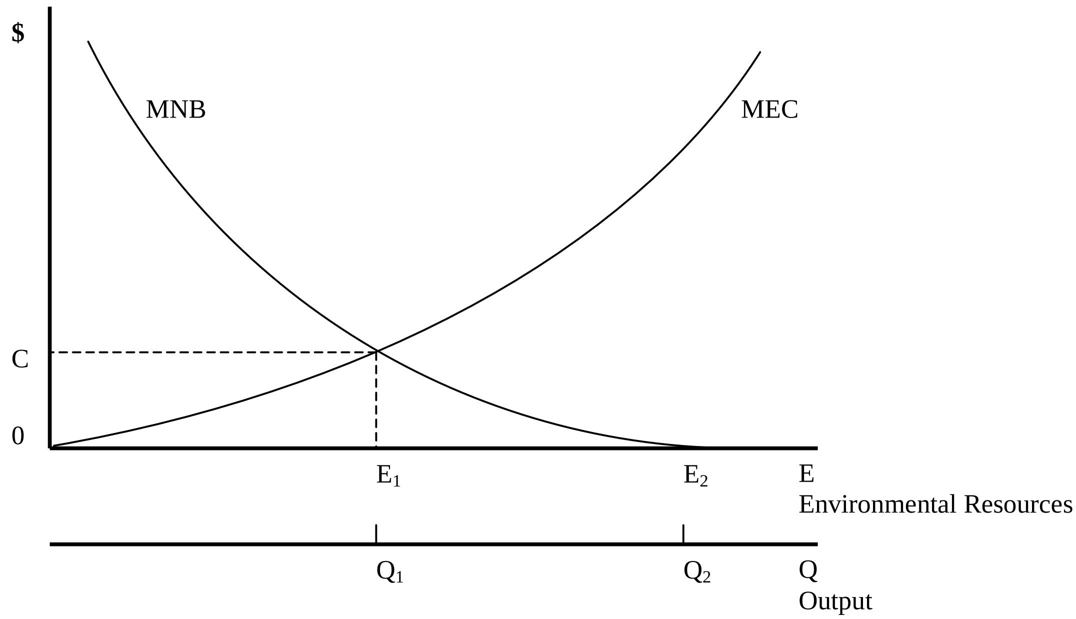
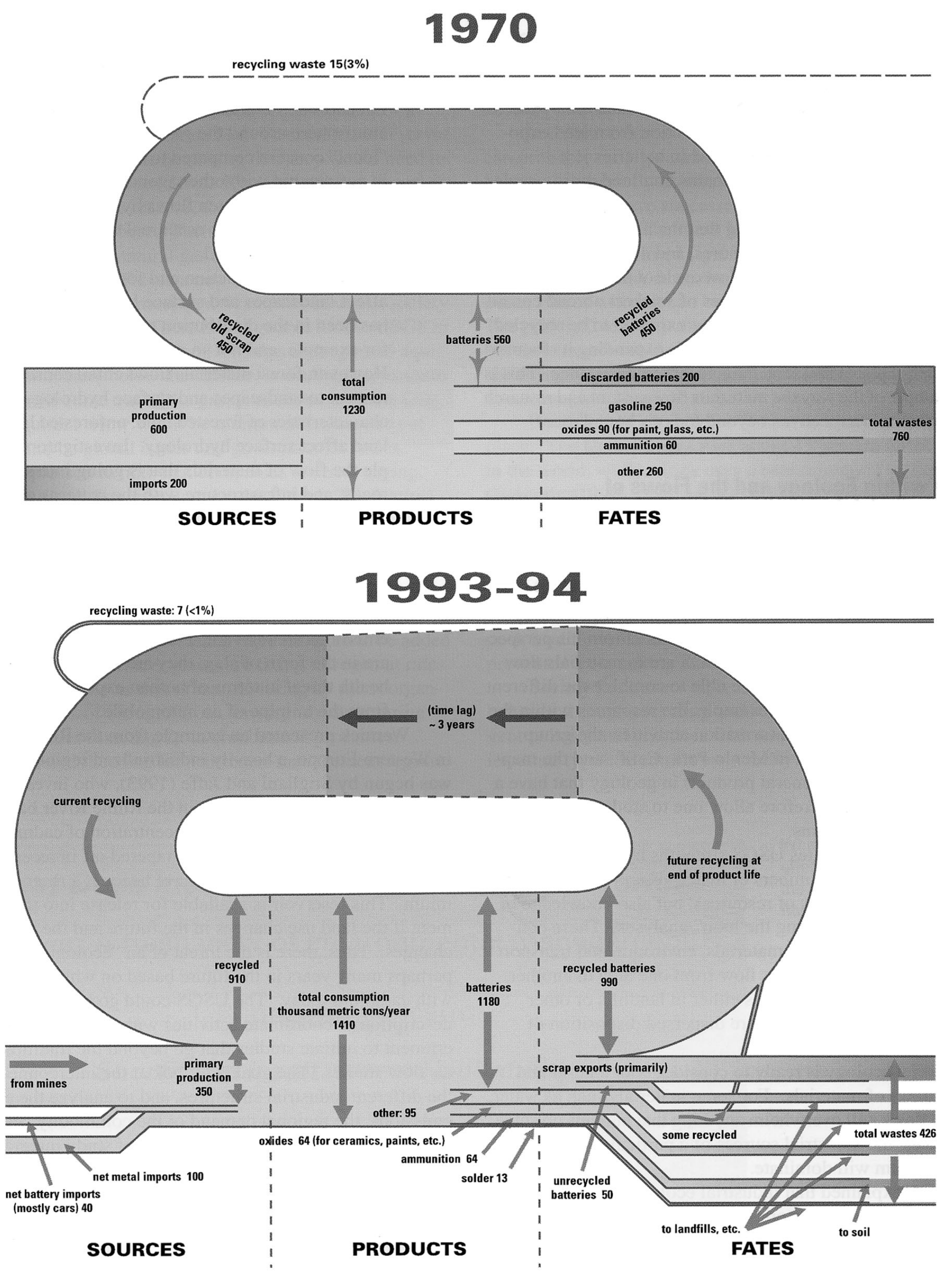
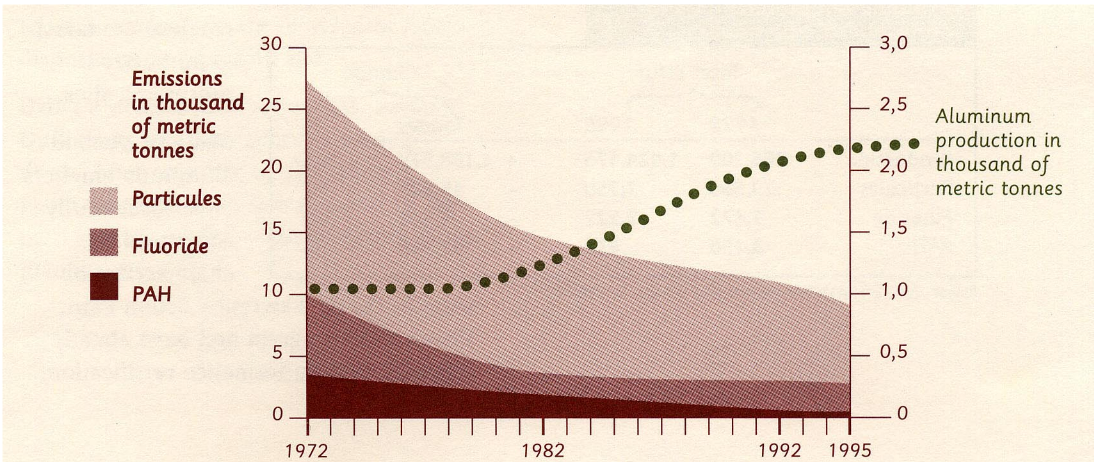


Figure 6.2. Lead Flows in the United States, 1970 and 1993-94.



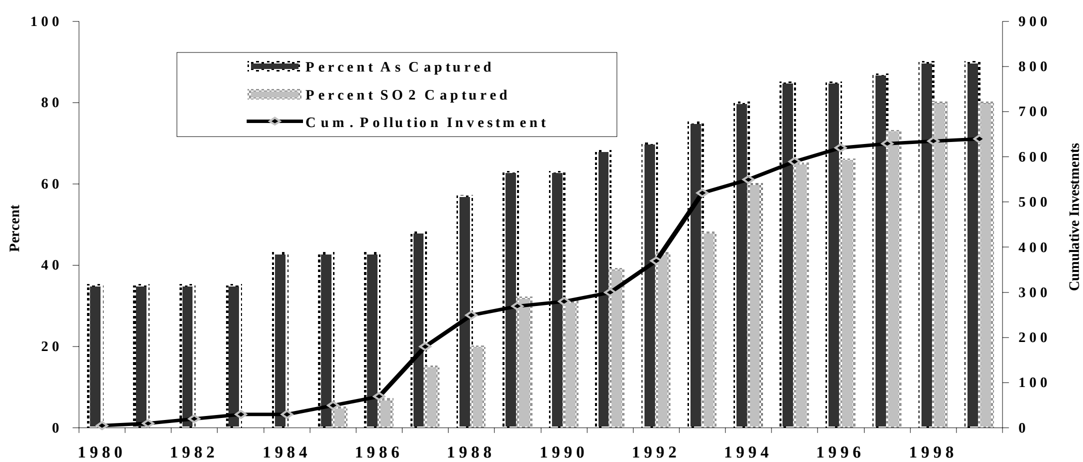
Source: The Interagency Working Group on Industrial Ecology, Material and Energy Flows as reproduced in U.S. Geological Survey (2000, p. 14).

Figure 6.3. Production and Air Emissions for the Canadian Aluminum Industry, 1973-1995



Source: Ministère de l'Environnement et de la Faune du Québec as cited in Aluminium Industry Association (1997).

Figure 6.4. Percentage of Arsenic and Sulfur Dioxide Emissions Captured and Cumulative Investment in Pollution Abatement at the Chuquicamata Smelter, 1980-1999



Note: Figures for the years after 1995 are projections.
Source: Corporacion Nacional del Cobre de Chile (Codelco).