Environmental Assessment Policy (The EAP)
Environmental Screening and
Developmental Projects

Introduction

Environmental screening is intended to ensure that proposed projects are subject to the appropriate extent and type of environmental assessment (EA). The World Bank's EA process generally begins with screening at the time of project identification. At this stage, the project is classified into one of three categories prior to issuance of the Project Concept Document. The chosen category signals the appropriate level of EA required. Environmental screening also helps determine the choice of EA instruments, depending on the needs of the project.

What is an EIA?

EIA is the process of identifying, predicting, evaluating, and mitigating the biophysical, social, and other relevant effects of development proposals prior to major commitments being made. Through this process, information about environmental effects, including any harmful effects on humans and the biophysical environment, of a project are collected, assessed and taken into account.

EIA process generally begins with screening at the time of project identification. The screening process helps the study investigator determine if a project has a negative or positive significant environmental impact and the eligibility for applying the project. Thus, it is important to decide if project requires an EIA with or without consultation with the Local Planning Authority.

What are objectives of EIA?

The role of EIA is to identify environmental limits and constraints on the project, not just its impacts on the environment; to ensure that environmental considerations are explicitly addressed and incorporated into the development decision making process; to anticipate and avoid, minimize or offset the adverse significant biophysical, social and other relevant effects of development proposals; to protect the productivity and capacity of natural systems and the ecological processes which maintain their functions; to promote development that generates less destruction and optimizes resource use and management opportunities.

Determining the level of EA

It is important to determine the level of EA for any given developmental project prior to issuance of the Project Concept Document[1]. The Bank uses the following three categories to signal the appropriate level of EA for any given project:

Category A: A full EA is needed in accordance with the specific requirements of the Bank's EA policy and procedure for Category A projects.

Category B: EA is required, but its scope corresponds to the limited environmental impacts of the project.

Category C: No EA is required.

It should be noted that: category (A) and category (B) projects are those projects with high and medium potential environmental impacts. They are called black listed projects.

The selection of the category should be based on professional judgment and information available at the time of project identification. If the project is modified or new information becomes available, Bank EA policy permits the reclassification of the project. For example, a Category B project might become Category A if new information reveals that it may have diverse and significant environmental impacts when they were originally

[1] In the Project Concept Document, it is important to present the current situation of the developmental project; describe the project objectives; describe all parties that will benefit from the project; discuss the project results, or what is expected to be accomplished throughout the project; describe the type of activities that are planned within the project; state the amount of funding requested from the grants programme.

thought to be limited to one aspect of the environment. Conversely, a Category A project might be reclassified as B if a component with significant impacts is dropped or altered. The option to reclassify projects relieves some of the pressure to make the initial decision the correct and final one. However, reclassification is not free of cost. For example, if a Category B project is later changed to Category A, additional resources will be required for environmental studies, public consultation, and report preparation. The schedule for project preparation will almost certainly be adversely affected.

Criteria for making the classification decision

The selection of the category should be based on professional judgment and information available at the time of project identification.

Projects are classified into Category A if they are "likely to have significant adverse impacts that are sensitive, diverse, or unprecedented, or that affect an area broader than the sites or facilities subject to physical works."

The impacts of Category B projects are "site-specific in nature and do not significantly affect human populations or alter environmentally important areas, including wetlands, native forests, grasslands, and other major natural habitats. Few if any of the impacts are irreversible, and in most cases mitigatory measures can be designed more readily than for Category A projects."

In order for a project to classified into Category C, it must be considered likely to have no adverse impacts at all, or the impacts would be negligible.

In practice, the significance of impacts, and the selection of screening category accordingly, depends on: (1) the type and scale of the project, (2) the location and sensitivity of environmental issues, and (3) the nature and magnitude of the potential impacts. These dimensions are discussed below.

(1) Project type and scale

Category A.

Certain types of projects such as aquaculture and mariculture, irrigation, drainage, and flood control, are likely to have adverse impacts that normally warrant classification in Category A. Category A includes projects which have one or more of the following attributes that make the potential impacts "significant": (1) direct pollutant discharges that are large enough to cause degradation of air, water or soil; (2) large-scale physical disturbance of the site and/or surroundings; (3) extraction, consumption, or conversion of substantial amounts of forest and other natural resources; (4) measurable modification of hydrologic cycle; (5) hazardous materials in more than incidental quantities; (6) and involuntary displacement of people and other significant social disturbances.

Examples of Category A projects
– Aquaculture and mariculture – Dams and reservoirs – Forestry production projects – Hazardous waste management and disposal – Industrial plants (large-scale), Manufacture, transportation, and use of pesticides – Irrigation, drainage, and flood control (large-scale) – Mineral development (including oil and gas) – New construction or major upgrading of highways – Ports development – Reclamation and new land development – River basin development – Thermal power and hydropower development – Water supply and wastewater collection, – Treatment and disposal projects (large-scale)

Category B.

Certain types of projects such as electrical transmission, energy efficiency, energy conservation, and tourism may have environmental impacts for which more limited EA is appropriate.

Projects in Category B often differ from A projects of the same type only in scale. Large irrigation and drainage projects are usually Category A; however, small-scale projects of the same type may fall into Category B. Similarly, a 50-meter hydroelectric dam is clearly large in scale and will usually require Category A classification, while low-head power dams may be Category B. Construction of a 50-km expressway would also require Category A due to scale, while rural road rehabilitation will tend to raise only minor environmental issues (Category B).

Projects entailing rehabilitation, maintenance or upgrading rather than new construction will usually be in Category B. A project with any of these characteristics may have impacts, but they are less likely to be "significant". However, each case must be judged on its own merits. Many rehabilitation, maintenance and upgrading projects—as well as privatization projects—may require attention to existing environmental problems at the site rather than potential new impacts.

Examples of Category B projects
– Electrical transmission – Energy efficiency and energy conservation – Irrigation and drainage (small-scale) – Protected areas and biodiversity conservation – Rehabilitation or maintenance of highways or rural roads – Renewable energy (other than hydroelectric dams) – Rural water supply and sanitation – Tourism

Category C.

These projects are likely to have negligible or no environmental impacts. EA is normally not required. However, it should be noted that before classifying a project in this category it is important to consider potential adverse impacts, some of which may not immediately spring to mind. For example, disposal of medical wastes may be an issue in many health projects. Likewise, while most technical assistance (TA) projects should fall into Category C since they involve no physical works, certain (TA) operations are designed to pave the way for major investments or privatization (often in a particular sector). In such cases, it is appropriate to undertake a limited review of the environmental institutional and regulatory framework for the sector and recommend improvements (as needed). In these later cases, Category B is normally the correct classification for such projects.

Examples of Category C projects
– Education – Family planning – Health – Institution development – Most human resources projects – Nutrition

(2) Project Location Sensitivity of Environmental Issues

Project location

The selection of a screening category often depends substantially on the project setting, while the “significance” of potential impacts is partly a function of the natural and sociocultural surroundings. Experience to date shows that precise identification of the project’s geographical setting at the screening stage greatly enhances the quality of the screening decision and helps focus the EA on the important environmental issues. A map of the project area that includes key environmental features (including cultural heritage sites) is invaluable for this purpose. Information on the project setting may be available from colleagues in country departments, or in-country environmental profiles or Bank reports on other projects in the vicinity. Local institutions and NGOs are also valuable sources. In the absence of any such information, the TM should consider sending a reconnaissance mission to provide the basis for proper screening. Often a product of this mission is a draft of the Terms of Reference (TOR) for the EA.

There are a number of locations which should be considered for “A” classification:

- In or near sensitive and valuable ecosystems — wetlands, wildlands, coral reefs and habitat of endangered species;
- in or near areas with archaeological and/or historical sites or existing cultural and social institutions;
- in densely populated areas, where resettlement may be required or potential pollution impacts and other disturbances may significantly affect communities;
- in regions subject to heavy development activities or where there are conflicts in natural resource allocation;
- along watercourses, in aquifer recharge areas or in reservoir catchments used for potable water supply; and
- on lands or waters containing valuable resources (such as fisheries, minerals, medicinal plants, prime agricultural soils).

Sensitivity of issues

The project may involve activities or environmental features that are always of particular concern to the Bank as well as to many borrowers. These issues may include disturbance of tropical forests, conversion of wetlands, potential adverse effects on protected areas or sites, encroachment on lands or rights of indigenous peoples or other vulnerable minorities, involuntary resettlement, impacts on international waterways and other transboundary issues, and toxic waste disposal.

The best way to ensure proper treatment of such issues is to classify the project as Category A, so that the level of effort will be adequate in terms of analytical expertise, decision-making, interagency coordination, and public involvement.

(3) The Nature and Magnitude of the Potential Impacts

Nature of impacts

The TM should take into consideration the following examples of impacts that warrant Category A attention:

– Irreversible destruction or degradation of natural habitat and loss of biodiversity or environmental services provided by a natural system;
– risk to human health or safety (for example, from generation, storage or disposal of hazardous wastes, or violation of ambient air quality standards); and
– absence of effective mitigatory or compensatory measures.

Magnitude of impacts

The magnitude of a specific impact and the cumulative impact of the proposed action and other planned or ongoing actions may need to be considered. There are a number of ways in which magnitude can be measured, such as: (1) the absolute amount of a resource or ecosystem affected, (2) the amount affected relative to the existing stock of the resource or ecosystem, (3) the intensity of the impact and its timing and duration.

For example, the resettlement of 5,000 families is a large impact, in absolute terms. Conversion of 50 hectares of wetland, however, differs markedly in significance depending on its size relative to the total area of wetlands in the country or region. An average decrease in dissolved oxygen concentration of 0.05 mg/l in a receiving water is unlikely to have serious biological or chemical implications, while a decrease of 3.0 mg/l will in many circumstances.

The effect of either decrease on the aquatic ecosystem will be different depending on its duration and frequency of occurrence—continuous or permanent, seasonal, intermittent or accidental. Where it is possible to assign probabilities to potential impacts, which often cannot be done without detailed analysis, the risk of occurrence becomes an aspect of magnitude.

One of the requirements of a full EA is that other current and proposed development activities within the project area and more spontaneous activities spurred by a project (such as migration of people into an area opened up by a road project) must be taken into account. Such cumulative or induced impact may sometimes be the primary determinant of the appropriate level of EA.

Screening of operations with multiple subprojects

During screening an investment loan, the details of sub-projects are usually not known at the time of project identification. One of the TM's responsibilities is to see that the loan includes a mechanism for conducting environmental screening of subprojects. In addition, the entire loan must also be assigned to a category that is appropriate for subprojects. If it becomes evident that one or more subprojects will require full EA, the entire loan should be classified as Category A. Moreover, when screening a sector investment loan, the need for undertaking a sectoral EA should be considered.

Outputs of screening

The screening results are recorded and explained in the Project Concept Document and the Environmental Data Sheet. The Bank reviews the results with the borrower, especially with regard to the type of EA instruments required and the general scope of the EA.

After screening, the borrower should prepare the Terms of Reference (TORs) for any EA required. The Bank assists as necessary in preparing the TORs and always reviews their contents.

Case Study: Industrial Pollution

Industry plays an important role in the process of economic development in the world. It enhances the economic welfare of citizens and supplies the material goods they consume. The way in which society will develop in the future is largely dependent on how the growth which industry generates is distributed. Industry is also a major consumer of natural resources and a major contributor to the overall pollution load. Based on OECD (Organization for Economic Cooperation and Development) estimates, it accounts for about one-third of global energy consumption of their member states, and for about 10 percent of the total water withdrawal. The relative contribution to the total pollution load is obviously higher for industry-related pollutants. The industrial sector generates both traditional pollutants (e.g., organic substances, sulfur dioxide, particulates and nutrients) and newly-recognized pollutants (e.g., specific toxic substances). The industrial sector includes a number of diverse activities. As a result, there is a wide range of different resource and environmental impacts created by industry. Thus, industry has particular environmental responsibilities in terms of such factors as plant location and design, environmental pollution, vibration and noise controls, waste disposal, occupational health and safety aspects, and long-range planning. Generally, the pollutants from industries are divided into three major categories namely gas, solid and water. There are also some other pollutant forms such as noise and odor.

Industrial pollution control has been paid a lot of attention. Increasing efforts have been made to protect the environment, both in terms of reducing point-source emissions, risk management during chemical use and handling of hazardous waste. New legislation, more stringent emission standards, stricter controls and growing consumer demands for environmentally-sound products have been promoting the implementation of environmental friendly technologies and integrated pollution management strategies. Recent practices in pollution control tend to move towards the core of industrial operation. Nevertheless, end-pipe treatments played and still play an important role in industrial pollution control.

The industrial pollution problems faced by different countries worldwide are different. Generally speaking, in developed countries, the pressures created by industrial activates (i.e., the emission of traditional pollutants from iron and steel, metal fabrication and petrochemicals) has grown slowly in recent decades. Other types of environmental problems, e.g., contamination of soil and buildings at closed sites, with subsequent high costs for remedial treatments have received growing attention. In developing countries, the environmental pressure coming from the traditional pollutants created by industries is still very heavy. For both developed and developing countries, the growing technology-based industries, created new problems due to the use of toxic material in their production processes, which can cause soil and water contamination.

In developed countries, early in the twentieth century, pollutant emissions to air and water were considerable at production sites, and large volumes of waste material were often dumped in the immediate surroundings of the factories. A classic example is the industrial districts in Northern England, where the fallout of soot put a dark coating cover over the whole landscape. In the Ruhr area in Germany, undesirable amounts of dust fallout from the steel industry as well as large amounts of sewage effluents transformed the river Ruhr into an industrial sewer. In the United States and in Japan, similar situations occurred. The pollution situation in the OECD countries is now quite different from the previous decades. Treatment measures have been introduced to treat much of the pollution. Wastewater tubes do not end up any more at dead bottoms, trees and vegetation surrounding factories are alive and green, and the surrounding air has cleared up substantially. The efforts in many OECD countries to reduce pollution started in the 1980s, after the need for such efforts became apparent. The discharges of early identified pollutants have been reduced to a large extent since the beginning of the 1970's, and many environmental problems have been solved.

Industrial growth is commonly regarded as being accompanied by an increase in consumption of energy and raw materials. However, industrial experiences in many countries show that the opposite situation can prevail. Industrial growth may favor environmental protection work and govern research and development, thereby promoting new technologies in industry to further minimize environmental risks. It also provides the necessary financial conditions under which large investments in new technology, necessary for further reducing environmental effects, can be made. As a result, the prerequisites are created for a sustainable industrial development of products with lower requirements for natural resources, and enhanced waste recycling and minimization. However, the environmental problems have not disappeared in many OECD countries. The local, intense industrial pollution has merely been replaced by regional or global diffuse pollution. Local sources and individual contaminants may be found and identified. Clean, non-contaminated reference areas are still difficult to find. The environmental accidents erupt sometimes. The environmental problems in using the industrial products and used up products are absorbing more concern.

The situation with regard to industrial pollution is more heterogeneous and complex in developing countries. The process of industrialization in these countries is far less advanced. Typical industries in these countries are steel mills, mining activities, textile industries, tanneries and pulp and paper industries. Many of these industries are linked to multinational industrial enterprises supplying important raw materials on the world market, to some extent favored by low-paid labor. A large number of the more traditional, small-scale industries are also typical of developing countries. They typically induce severe environmental pollution. On the other hand, technology-based industries have sprouted in some of the developing countries too. Both the traditional pollutants and newly-recognized pollutants function together, which makes environment protection more difficult. Many developing countries have set aside areas called “industrial free zones” or “export processing zones”. These zones are regarded as extra-territorial land from perspectives of, custom regulations, taxation, rules for employment, salaries, working hours, occupational safety and even environmental protection. During the 1980’s, some industries unable or unwilling to meet more stringent environmental standards in the OECD countries have moved to “industrial free zones” in many developing countries, which makes the environmental pollution situation in these countries more complex.

Externalities and the Environment

What is an Externality?

In general externalities occur when a person/firm does something that affects the interests of another person or firm without affecting prices; or when an exchange between a buyer and seller has an impact on a third party who is not part of the exchange.

Environmental externalities refer to the economic concept of uncompensated environmental effects of production and consumption that affect consumer utility and enterprise cost outside the market mechanism. As a consequence of negative externalities, private costs of production tend to be lower than its "social" cost. This means, markets cannot be used to give people incentives to produce social desired quantities. For example, flat-screen TVs causes negative externality[2].

Consider, for example, the automobile industry. The market demand schedule for automobiles shows how many automobiles consumers are willing to purchase, generally indicating that more will be purchased at lower prices. The market supply schedule shows how many automobiles the producers will be willing to put on the market at various prices, reflecting their costs of production. Combining the two schedules gives a market equilibrium, showing the price and quantity traded. So far so good. But, as we know, the production and operation of automobiles has significant environmental effects[3]. Where do these appear in economic analysis? The answer is that they do not appear in basic supply and demand analysis, nor are they reflected in the real-world market equilibrium of automobile price and quantity produced, unless specific laws and institutions are created

[2] The rising demand for flat-screen televisions could have a greater impact on global warming than the world's largest coal-fired power stations. As, manufacturers use a greenhouse gas called nitrogen trifluoride, more toxic than carbon dioxide, to make the televisions, and as the sets have become more popular, annual production of the gas has risen to about 4,000 tonnes.

[3] Automobiles are a major contributor to air pollution, including both urban smog and regional problems such as acid rain. In addition, their emissions of carbon dioxide contribute to global warming, and coolants escaping from automobile air conditioners contribute to depletion of the ozone layer. Automobile oil is a significant cause of groundwater pollution. The production of automobiles involves toxic materials which may be released to the environment, or may remain as toxic wastes.

to address them. They are what economists call environmental externalities. Neglecting these costs (externalities) will give us a distorted picture of reality.

Thus, in thinking about addressing pollution externalities, economists are interested in two issues: (1) What should be the target level of pollution? (2) What is the best (cost-effective) method of achieving that level (i.e., the cost-effective pollution control system)?

(1) What should be the target level of pollution?

Pollution is bad, but prevention is costly. Thus, it is important to balance benefits from and costs of preventing pollution. Abatement of pollution is costly for the polluter. Since the polluter should pay for the purchase and installation of pollution control equipment. In addition, the polluter encounters more radical changes of the production process towards cleaner production processes. Moreover, the polluter faces a reduction in the level of production.

Identifying the target level of pollution requires a comparison between the social marginal benefits and social marginal costs of pollution.

What is the social marginal cost (damage) of pollution (MSD)?

It identifies the extra cost arising from additional unit of pollution (emissions). It is an increasing function in level of emissions. Pollution includes any type of damage caused by:

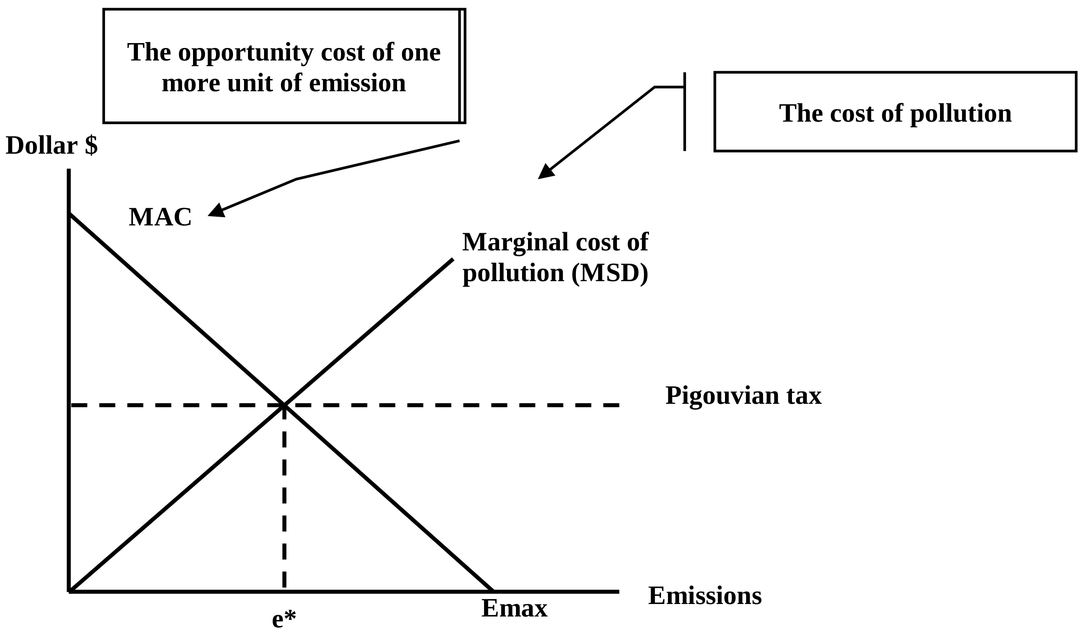
- A decrease in the value of other activities due to the pollution;
- Estimated value of health effects.
- Value of a less beautiful landscape

What is the marginal abatement cost (MAC)?

It represents the cost of reducing pollution (emissions), i.e. increase in abatement costs caused by lowering emissions by one unit. Thus, it reflects the cost of one additional unit of pollution that is abated, or not emitted. It is an increasing function in the firm’s production resulting from efforts to reduce pollution (e.g., costs of a recycling program and costs due to a change in technology, *etc*.). Thus, the MAC of each additional unit is always increasing.

MAC curve slopes downward in emission level (pollution). This implies low marginal cost of abatement for the first reductions in emissions and MAC rises with more abatement activity.

The Efficient level of Abatement of Pollution



- **Start at the level of emissions with no abatement activity (Emax):**

In this case, marginal social costs are too high (i.e., no abatement reductions). Emax is considered as the maximum level of pollution that occurs if the costs of pollution are ignored in the society.

- **If MSD >MAC:**

In this case, emissions should be reduced. It is better to keep reducing emissions until level where MSD = MAC. The resulting level of emissions is e* (the efficient level of emissions). Any further reductions cost more than the damages avoided (MSD<MAC), which creates a loss to society.

In general, we can say that:

- The greater the level of pollution the greater the level of damages and the greater the abatement costs required.
- More pollution (emissions) is desirable as long as its marginal abatement cost outweigh its marginal social costs.
- Less pollution (emissions) is desirable whenever its marginal social costs outweigh its marginal abatement cost.

(2) What is the best (cost-effective) method of achieving that level (i.e., the cost-effective pollution control system)?

The choice of pollution control instrument is a crucial environmental policy decision in order to control greenhouse gases. The choice is inherently difficult because competing criteria are involved. A number of criteria are used for the selection of pollution control instruments:

- **Cost-effectiveness:** does the instrument attain the target at least cost?
- **long-run effects:** does the influence of the instrument strengthen, weaken, or remain cost over time?
- **Dynamic efficiency:** does the instrument create continual incentives to improve products or production processes in pollution-reducing ways?
- **Ancillary benefits:** does the use of the instrument allow for a double dividend to be achieved?
- **Equity:** what implications does the use of an instrument have for the distribution of income or wealth?
- **Dependability:** to what extent can the instrument be relied upon to achieve the target?
- **Flexibility:** is the instrument capable of being adapted quickly and cheaply as new information arises, as conditions change, or as targets are altered?

- **Costs of use under uncertainty:** how large are the efficiency losses when the instrument is used with incorrect information?
- **Information requirements:** how much information does the instrument require that the control authority possess, and what are the costs of acquiring it?

Some Solutions to the Environmental Externalities

Four common regulatory and non-regulatory approaches used in environmental policy making:

(1) Command and Control (CAC) Regulation

(2) Market-Based Policies

(3) Hybrid Approaches

(4) Voluntary Initiatives

(1) Command and Control (CAC) Environmental Regulation

The key characteristic of command and control (CAC) regulation is that the regulator specifies what individual firms can and cannot do (enforced by the threat of penalties for non-compliance). Thus, it is a prescriptive regulation; or, more specifically, a policy that prescribes how much pollution an individual source or plant is allowed to emit and/ or what types of control equipment it must use to meet such requirements or standards. Most CAC standards are uniform. That is, the same standard applies to all firms. Such standards are often defined in terms of a source-level emissions rate. Uniform standards have an important shortcoming: they generally do not achieve a given aggregate emissions target at least cost. It should be noted that the problem with uniform standards is not that they are implemented through CAC. The problem is that they are uniform. Thus, it is possible for a CAC approach to implement an aggregate emissions target at least cost if the regulator assigns to each firm an emissions target such that marginal abatement costs (MACs) are equated. However, in practice it is difficult, since the regulator generally does not know the MACs for all the sources under its regulation.

Despite the introduction of potentially more cost-effective methods for regulating emissions, this type of regulation is still commonly used and is sometimes statutorily required. This is the dominant regulatory regime in most countries. It should be noted that regulators can at least partially account for some variability in costs by allowing prescriptive standards to vary according to: (1) size of the polluting entity, (2) production processes, (3) geographic location. The different forms of CAC regulation can be classified into two main types:

I. **Performance standards**: Performance standards place restrictions and conditions on the day-to-day performance of the firm. They include restrictions on: the volume of emissions, the volume of emissions per unit of output, the volume of emissions per unit of a particular input, the use of polluting inputs (or mandated use of non-polluting inputs).

II. **Design standards (or technology standards):** design standards impose requirements for the use of particular pollution control equipment, or a particular production technology. The regulator might impose one of the following:

   a. The best available technology **(BAT)**: This regulation requires that firms adopt the cleanest technology available. Thus, the polluting firms will encounter excessive cost.
   b. The best commercially available technology **(BCAT)**. This regulation requires that polluting firms adopt the technology only if it is "commercially" available.
   c. Best Available Technology Not Entailing Excessive Costs **(BATNEC)**. This regulation requires adoption of the BAT (not involving excessive cost).

(2) Market-Based Policies

In order to improve the supply and demand analysis, it is important to include externalities in such analysis (or to internalize the externalities, i.e., bringing these environmental costs into the market analysis). This can be done by creating an incentive for the private sector to incorporate pollution abatement into production or consumption decisions and to innovate in such a way as to continually search for the least costly method of abatement.

Environmental economists generally **favor market-based policies** because: (1) this allows firms **more flexibility** than more traditional regulations; (2) they tend to be **least costly**; (3) they place **lower information burden** on the regulator; (4) and they provide incentives for **technological advances**. In general, we can identify four classic market-based approaches: Marketable permit systems, Emission taxes, Environmental subsidies, and Tax-subsidy combinations. We will focus on marketable permit system.

Marketable permit systems

These systems allow for emission trade. Marketable permits are quantity-based approach. Several forms of marketable permit (emissions trading) systems exist: (A) Cap-and-Trade systems, (B) Project-Based Trading Systems, and (C) Emissions Rate Trading Systems.

(A) Cap-and-Trade Systems

The **cap** on greenhouse gas emissions is a limit. Companies pay penalties if they exceed the cap, which gets stricter over time. The **trade** part is a market for companies to buy and sell **allowances** that permit them to emit only a certain amount. Trading gives companies **a strong incentive to save money by cutting emissions.**

E.g. **The Acid Rain Program** by **EPA** (The program is an implementation of emissions trading that primarily targets **coal-burning power plants**, allowing them to buy and sell emission permits (called "allowances") according to individual needs and costs)

(B) Project-Based Trading Systems

Plant managers can propose their **own emission standards--tightening them** in places where it is least costly, and **relaxing or even eliminating them** where pollution control costs are high.

(C) Emissions Rate Trading Systems

The regulatory authority establishes **a performance standard** or **emissions rate**. Sources with emission rates below the performance standard can **earn credits** and **sell them to sources** with emission rates above the standard.

(3) Hybrid Approaches

These approaches combine aspects of **command-and-control** and **market-based incentive** policies. Such approaches are appealing to policy makers because they often combine **the certainty associated with a given emissions standard** with **the flexibility** of allowing firms to pursue the least costly abatement method.

(4) Voluntary Initiatives (Non-Regulatory Approaches)

Voluntary programs can use the following five general methods to achieve environmental improvements:

a. Require firms to set **specific environmental goals**;
b. Promote firm **environmental awareness**;
c. Publicly recognize **firm participation**;
d. Support advertising campaigns that support environmental issues.
e. Use labeling to identify environmentally responsible products.

The EU Emissions Trading System- (EU ETS)

Background

The Kyoto protocol to the united nations framework convention on climate change

The Kyoto Protocol was adopted in Kyoto in 1997. The Protocol shared the objective and institutions of the 1992 UN Framework Convention for Climate Change. The major distinction between the two, however, is that while the Convention encouraged industrialized countries to stabilize GHG emissions, the Protocol commits them to do so. The Protocol places a heavier burden on developed nations under the principle of common but differentiated responsibilities. The Kyoto Protocol entered into force in 2005.

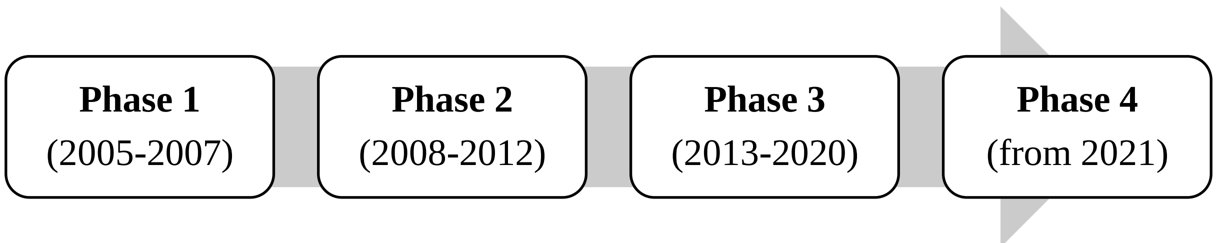
Under the Protocol 37 industrialized countries and the European Community have committed to reducing their emissions by an average of 5 percent against 1990 levels over the five-year period 2008-2012. These countries will also have to make use of the Protocol flexible mechanisms in order to reach their collective emission reduction goal. This led to the need for policy instruments by EU to meet the Kyoto commitments. The first step was in 2000, when a green paper with some first ideas on the designs of the EU ETS was presented by the European Commission. The green paper served as a basis for numerous stakeholder discussions that helped shaped the EU ETS in the first phases. This led to the adoption of the EU ETS Directive in 2003 and the introduction of the EU Emissions Trading System (EU ETS) in 2005.

What is the EU ETS?

The EU ETS is a major tool, first introduced in 2005, of the European Union in its efforts to meet emissions reductions targets proposed in the Kyoto Protocol. It is a ‘cap and trade’ system. As, it caps the total volume of GHG emissions mainly from installations and aircraft operators that are responsible for around 50% of EU GHG emissions. The EU ETS covers more than 11,000 power stations and industrial plants in 31 countries, and flights between airports of participating countries. The system allows trading of emission allowances so that the total emissions stays within the cap and the least-cost measures can be taken up to reduce emissions. The adoption of the trading approach helps to combat climate change in a cost-effective and economically efficient manner.

The implementation of the system has been divided up into distinct trading periods over time, known as phases, as shown in the following figure.

EU ETS-Phases



Why did the EU choose a "cap-and-trade" structure?

A traditional command-and-control approach may mandate a standard limit per installation, but provides little flexibility to companies. A tax does not guarantee that the GHG emissions reduction target will be achieved; and moreover, in a multi-national system, agreement would be required across all countries on the right price for carbon. Thus, there is a difficult to determine the "right price" to obtain the cut in emissions required without under- or overcharging companies. On the other side, "cap-and-trade" allows a set environmental outcome to be achieved. Trading allows companies to determine what the least-cost option is for them to meet a fixed cap. The carbon price is then set by the market through trading. In addition, cap-and-trade provide: (1) certainty about quantity, (2) cost-effectiveness, (3) revenue, and (4) minimization of budget risks to member states.

(1) Certainty about quantity

Emission Trading directly limits GHG emissions by setting a system cap that is designed to ensure compliance with the relevant commitment. There will be certainty about the maximum quantity of GHG emissions for the period of time over which system caps are set. This is relevant for supporting the EU's international objectives and obligations and achieving environmental goals.

(2) Cost-effectiveness

Trading reveals the carbon price to meet the desired target. The flexibility that trading brings means that all firms face the same carbon price and ensures that emissions are cut where it costs least to do so.

(3) Revenue

If GHG emissions allowances are auctioned. This creates **a source of revenue** for governments at least 50% of which should be used to fund measures to tackle climate change in the EU or other Member States.

(4) Minimization of budget risks to member States

The EU ETS provides certainty to emissions reduction from installations responsible for around 50% of EU emissions. This reduces the risk that member states will need to purchase additional international units[4] in order to meet their international commitments under the Kyoto Protocol.

How does the EU ETS contribute to meeting the EU's climate policy goals?

The international community has agreed that global warming should be kept below a 2ºC increase, as compared to the temperature in pre-industrial times. In 2008, the EU set a series of climate and energy targets to be met by 2020 in its pathway towards a low-carbon competitive economy, known as the "20-20-20" targets, which are:

– A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels.
– 20% of EU energy consumption to come from renewable resources.
– A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

[4] Emission Reduction Unit (equipment).

How does the EU ETS contribute to a competitive economy?

EU leaders envisage that the European economy can cut most of its GHG emissions by 2050 through smart, sustainable and inclusive growth. The Commission's roadmap for moving to a low-carbon economy by 2050 includes a key role for the EU ETS in promoting decarbonization (i.e. reducing its carbon intensity) throughout the European economy. The EU ETS contributes to the creation of jobs, generation of green growth and strengthening long-term competitiveness of the European economy by putting a price on carbon. specifically:

– It stimulates investments in energy efficiency measures, reducing energy costs and financial risks associated with increasing energy prices
– It offers an incentive to invest in renewable energy technology, reducing the energy dependency on fossil fuel imports and enhancing energy security
– It strengthens the EU ambition to decarbonize the European economy, providing a long-term stable policy environment for low carbon investments and clean technology.

Case Study: Advantages of Green Technology

As the name implies green technology is one that has a "green" purpose. By green we do not mean the color. Green inventions are environmentally friendly inventions that often involve - energy efficiency, recycling, safety and health concerns, renewable resources, and more. The world has a fixed amount of natural resources, some of which are already depleted or ruined. For example - household batteries and electronics often contain dangerous chemicals that can pollute the groundwater after disposal, contaminating our soil and water with chemicals that cannot be removed from the drinking water supply and the food crops grown on contaminated soil. The risks to human health are great. Therefore, the need of the hour is that every investor should think green. They should know that green inventions and clean technologies are good business. These are fast growing markets with growing profits. From the view point of consumers they should also know that buying green inventions can reduce their energy bill and that green inventions are often safer and healthier products.

Different Types of Green Technology

Green technology covers a broad area of production and consumption technologies. The adoption and use of green technologies involves the use of environmental technologies for monitoring and assessment, pollution prevention and control, and remediation and restoration. Monitoring and assessment technologies are used to measure and track the condition of the environment, including the release of natural or anthropogenic materials of a harmful nature. Prevention technologies avoid the production of environmentally hazardous substances or alter human activities in ways that minimize damage to the environment; it encompasses product substitution or the redesign of an entire production process rather than using new pieces of equipment. Control technology renders hazardous substances harmless before they enter the environment. Remediation and restoration technologies embody methods designed to improve the condition of ecosystems, degraded through naturally induced or anthropogenic effects.

Green technology products are items which factor environmental awareness into their design and use. Green technologies products aim to reduce waste, cut pollution, and even diminish fossil fuel use. Some of the major types of green technology products include energy creation products, green chemicals, sustainable or recyclable products, and technology that run on alternative energy. Products that help create alternative energy, such as solar panels and thermal heating discs, are some of the most important green technology products used in everyday life. Solar panels, which can be installed on homes, apartments, and commercial buildings, use the sustainable heat of the sun to charge solar batteries, which can be used for electricity instead of traditional, non-sustainable sources like gas. Thermal heating discs, which are used in swimming pools, suck the sun's rays in and radiate them over the pool's surface, providing an alternative means of heating that avoids fossil fuel use. Green chemicals are important in many green technology products. These products aim to create the same effects as toxic, polluting chemicals, while reducing risk of poisoning and environmental harm. Green chemical products include home cleaning agents made out of coconut and glycerin, insecticides that use orange or peppermint oil instead of toxic chemicals, and even green laundry detergent that can reduce water pollution. Sustainable and recyclable green technology products help increase the life cycle of consumer material. These products may include cell phones made from plastic water bottles, appliances rebuilt from scrap metal, and even recyclable laptops. Green technology products that use sustainable and recyclable materials often advertise their involvement in recycling initiatives; consumers shopping for a new cell phone or laptop may wish to inquire about specific models that use recycled materials. Solar powered charging devices for phones, laptops, and portable appliances are also popular green technology products. By converting everyday products to alternative energy power sources, green technology can help reduce fossil fuel use and help users cut energy bills.

Applications of Green Technology in Our Life

Solar Array

One of the best known examples of green technology would be the solar cell. A solar cell directly converts the energy in light into electrical energy through the process of photovoltaics. Generating electricity from solar energy means less consumption of fossil fuels, reducing pollution and greenhouse gas emissions.

Reusable Water Bottle

Another simple invention that can be considered green is the reusable water bottle. Drinking lots of water is healthy. Reducing plastic waste is great for the environment. Hence, trendy reusable water bottles that you can refill yourself are health-promoting, eco-friendly, and green.

Solar Water Heater

Installing a solar water heater can be a great way to cut down on energy costs at a much lower initial expense. The costs associated with the installation of a solar water heater are actually recouped much faster than the costs associated with photovoltaic technology for power generation. This is due to the increased efficiency of solar water heating systems, as well as their reduced expense when compared to the large solar array required for powering a home.

Wind Generator

The costs of a home wind generator vary greatly. Some have built their own wind generators with off-the-shelf parts from their local hardware stores. Others have purchased kits or paid for professional installation to supplement the power purchased from their local electrical grid. The power production capability of a home wind generator varies about as much as the initial expense. Many kit based generators will produce only enough power to offset 10-15% of your home energy costs.

Rainwater Harvesting System

Rain collector systems are extremely simple mechanical systems that connect to a gutter system or other rooftop water collection network and store rain water in a barrel or cistern for later non-potable use (like watering plants, flushing toilets, and irrigation). These systems are extremely inexpensive.

Insulate Our House

Based on EPA estimates, 10% of household energy usage a year is due to energy loss from poor insulation. We will get an excellent return on investment from sealing our home to prevent energy escape.

Building With Green Technology

Green buildings use a variety of environmentally friendly techniques to reduce their impact on the environment. Reclaimed materials, passive solar design, natural ventilation and green roofing technology can allow builders to produce a structure with a considerably smaller carbon footprint than normal construction. These techniques not only benefit the environment, but they can produce economically attractive buildings that are healthier for the occupants as well. The chief benefit of building green is reducing a building's impact on the environment. Using green building techniques can also reduce the costs associated with construction and operation of a building. Green ventilation techniques involve open spaces and natural airflow, reducing the need for traditional air conditioning and preventing many of these problems.

National Benefits for Energy Generation

Power generation is another sector where green technology might create wonders. Distributed generation technologies e.g. solar PV, biogas production, wind power etc. have practically proven that they can provide more employment opportunities to people and can be applied to provide energy solutions to communities in remote areas successfully. Live examples exist in India where people have used alternative green power generation technologies and have not only fulfilled their own energy needs but have also sold their energy to the grid thereby making significant income. Same is in countries like Germany, where people sell the electricity generated by their household Photovoltaic panels to the national grid and in rare cases may end up charging money from the utility instead of paying! In this way a person not only helps himself or herself but also helps the nation by actually contributing to the national power generation and thus proves to be an asset rather than a liability to the society.

Benefits to The Rural Areas

Green technologies have had great impact on communities of the areas where they have been implemented. Provision of bio-gas plants to rural households has empowered communities and has increased their productivity. Same has been the case with distribution of solar lanterns through certain programs. It is clear that people have benefited from it by not only using the outputs personally but also by trading it. Initiatives such as the barefoot college in Rajasthan empower villagers by teaching them how to use eco-friendly technologies like solar cookers, mud refrigerators, and sustainable farming practices.

Villagers have built their own water storage and rainwater harvesting techniques and are not dependent on outside help. This has raised the standard of living in the participating villages.

Benefit to the Urban Areas

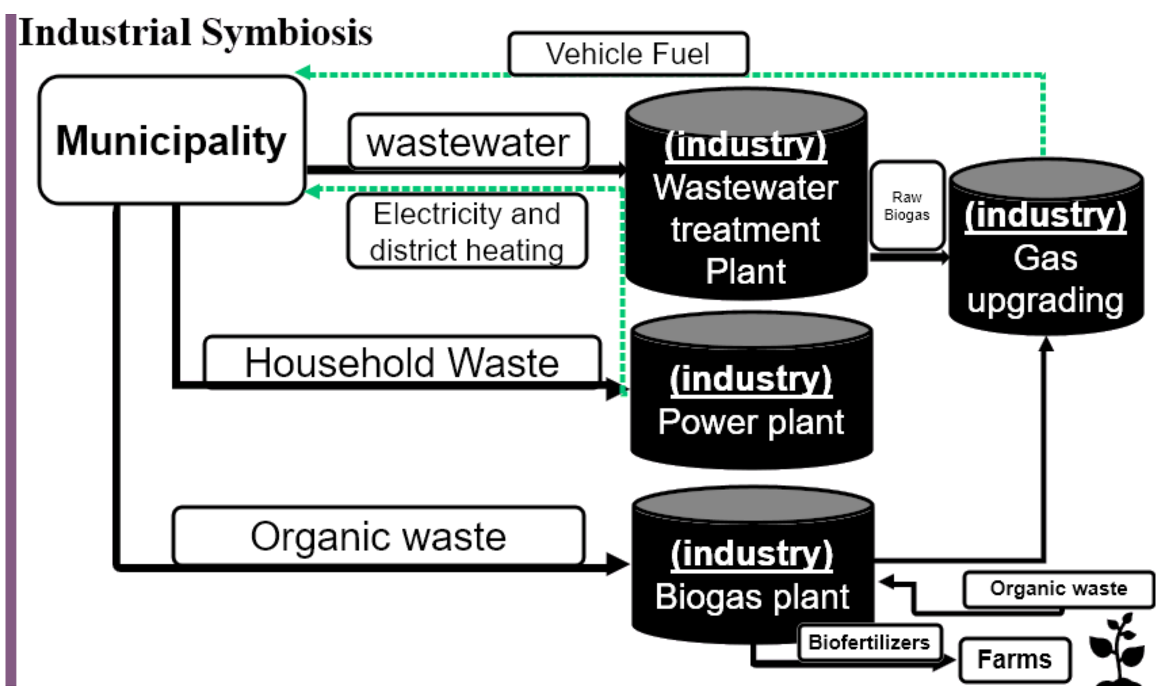
Cities which actively pursued their environmental concerns in the last ten years are showing a marked improvement in their environment quality parameters. For example Delhi launched CNG fueled public transport in a phased manner. This was done as measures to improve air quality of Delhi where the toxic gas levels were off the charts, sometimes exceeding 5-12 times the normal values. Since then Delhi has shown steady improvement in the air quality.

Industrial Ecology: Material and Energy Flows

Introduction

Industrial ecology is an interdisciplinary and an emerging field aims to analyze industrial systems with the goal of finding ways to minimize their environmental impact. It shows the interactions between the use of natural resources and the world of enterprises. It the study of the physical, chemical, and biological interactions and interrelationships both within and between industrial and ecological systems. One goal of industrial ecology is to change the nature of our industrial system, where raw materials are used and products, by-products, and wastes are produced, to a cyclical system where the wastes are reused as energy or raw materials for another product or process. The was an introduction to the concept of industrial symbiosis, which shows the association between two or more industrial facilities or companies in which the wastes or byproducts of one become the raw materials for another. The following figure demonstrates the idea of industrial symbiosis.

<u>Figure: Industrial Symbiosis</u>



Fundamental to industrial ecology is identifying and tracing flows of energy and materials through various systems. This concept, sometimes referred to as industrial metabolism[5], can be utilized to follow material and energy flows, transformations, and dissipation in the industrial system as well as into natural systems. The mass balancing of these flows and transformations can help to identify their negative impacts on natural ecosystems.

Goals of Industrial Ecology

Industrial ecology aims at achieving three main goals: (1) Sustainable Use of Resources; (2) Considering Human Health; (3) Achieving Environmental Equity.

Sustainable Use of Resources

The primary goal of industrial ecology is to promote sustainable development at the global, regional, and local levels. Sustainable development aims at meeting the needs of the present generation without sacrificing the needs of future generations, which can be achieved by the sustainable use of resources, preserving ecological and human health (e.g. the maintenance of the structure and function of ecosystems), and the promotion of environmental equity (both intergenerational and intersocietal). Industrial ecology should promote the sustainable use of renewable resources and minimal use of nonrenewable ones. Industrial activity is dependent on a steady supply of resources and thus should operate as efficiently as possible. Although in the past mankind has found alternatives to diminished raw materials, it can not be assumed that substitutes will continue to be found as supplies of certain raw materials decrease or are degraded. Besides solar energy, the supply of resources is finite. Thus, depletion of nonrenewable resources and degradation of renewable resources must be minimized in order for industrial activity to be sustainable in the long term.

[5] ***Industrial Metabolism*** is the use of materials and energy by industry and the way these materials flow through industrial systems and are transformed and then dissipated as wastes.

Ecological and Human Health

Human beings are only one component in a complex web of ecological interactions: their activities cannot be separated from the functioning of the entire system. Because human health is dependent on the health of the other components of the ecosystem, ecosystem structure and function should be a focus of industrial ecology. It is important that industrial activities do not cause catastrophic disruptions to ecosystems or slowly degrade their structure and function, jeopardizing the planet's life support system.

Environmental Equity

A primary challenge of sustainable development is achieving intergenerational and intersocietal equity. Depleting natural resources and degrading ecological health in order to meet short-term objectives can endanger the ability of future generations to meet their needs. Intersocietal inequities also exist, as evidenced by the large imbalance of resource use between developing and developed countries. Developed countries currently use a disproportionate amount of resources in comparison with developing countries. Inequities also exist between social and economic groups within a country. Several studies have shown that low income and ethnic communities, for instance, are often subject to much higher levels of human health risk associated with certain toxic pollutants.

Case Study: Differences between Ecological and Environmental Economics

First of all, there is an explicitly long-term focus in ecological economics; it has multiple time scales, but because sustainability is a dynamic long-term phenomenon, we need to concentrate on the long-term issues of resource use, accumulation of emissions, technological transformations, and evolutionary perspectives. The prioritizing of sustainability in ecological economics corresponds to the prioritizing of efficiency in environmental economics. The meeting of needs and equitable distribution in ecological economics is opposed to the optimal welfare and Pareto efficiency in environmental economics.

Ecological economics focuses on physical and biological indicators whereas environmental economics emphasizes monetary measures. The principle of multicriteria evaluation of ecological economics contrasts with the idea of cost-benefit analysis in environmental economics. The environmental ethics of ecological economics is a response to the utilitarianism and functionalism of environmental economics.

Ecological Economics	**Environmental and Resource Economics**
Optimal scale	Optimal allocation and externalities
Priority to sustainability	Priority to efficiency
Needs fulfilled and equitable distribution	Optimal welfare to Pareto efficiency
Sustainable development, globally and North/South	Sustainable growth in abstract models
Growth pessimism and difficult choices	Growth optimism and "win-win" options
Unpredictable co-evolution	Deterministic optimization of intertemporal welfare
Long-term focus	Short to medium term focus
Complete, integrative and descriptive	Partial, monodisciplinary and analytical
Concrete and specific	Abstract and general
Physical and biological indicators	Monetary indicators
Systems analysis	External costs and economic valuation
Multidimensional evaluation	Cost-benefit t analysis
Integrated models with cause-effect relationships	Applied general equilibrium models with external costs
Bounded individual rationality and uncertainty	Maximization of utility and profit
Local communities	Global market and isolated individuals
Environmental ethics	Utilitarianism and functionalism

Climate Change and Economic Growth

Introduction

There is no question that the continued buildup of greenhouse gases will cause the earth to warm. However, there is considerable debate about what is the sensible policy response to this problem. Economists, weighing cost and damages, advocate a balanced mitigation program that starts slowly and gradually becomes more severe over the century. Scientists and environmentalists, in contrast, advocate more extreme near-term mitigation policies. Which approach is followed will have a large bearing on economic growth. The balanced economic approach to the problem will address climate change with minimal reductions in economic growth. The more aggressive the near-term mitigation program, however, the greater the risk that climate change will slow long-term economic growth.

It should be understood that climate is not a stable unchanging phenomenon even when left to natural forces alone. The cold periods, throughout history of earth, have been quite hostile, discouraging humans from living in much of the northern parts of the northern hemisphere. These natural changes have had major impacts on past civilizations causing dramatic adaptations and sometimes wholesale migrations. Climate change is not new. Human-induced climate change is simply an added disturbance to this natural variation.

The heart of the debate about climate change comes from a number of warnings from scientists and others that give the impression that human- induced climate change is an immediate threat to society. Millions of people might be vulnerable to health effects, crop production might fall in the low latitudes, water supplies might dwindle, precipitation might fall in arid regions, extreme events will grow exponentially, and between 20–30 percent of species will risk extinction. Even worse, there may be catastrophic events such as the melting of Greenland or Antarctic ice sheets causing severe sea level rise, which would inundate hundreds of millions of people. Proponents argue there is no time to waste. Unless greenhouse gases are cut dramatically today, economic growth and well-being may be at risk.

These statements are largely alarmist and misleading. Although climate change is a serious problem that deserves attention, society's immediate behavior has an extremely low probability of leading to catastrophic consequences. The science and economics of climate change is quite clear that emissions over the next few decades will lead to only mild consequences.

In fact, the mitigation plans of many alarmists would pose a serious risk to economic growth. The marginal cost function of mitigation is very steep, especially in the short run. Dramatic immediate policies to reduce greenhouse gas emissions would be very costly. Further, by rushing into regulations in a panic, it is very likely that new programs would not be designed efficiently. The greatest threat that climate change poses to economic growth is that the world adopts a costly and inefficient mitigation policy that places a huge drag on the global economy.

Climate Change Impacts

Economic research on climate impacts has long revealed that only a limited fraction of the market economy is vulnerable to climate change: agriculture, coastal resources, energy, forestry, tourism, and water. These sectors make up about 5 percent of the global economy and their share is expected to shrink over time. Consequently, even if climate change turns out to be large, there is a limit to how much damage climate can do to the economy. Not all sectors of the global economy are not climate sensitive.

Of course, the economies of some countries are more vulnerable to climate change than the global average. Developing countries in general have a larger share of their economies in agriculture and forestry. They also tend to be in the low latitudes where the impacts to these sectors will be the most severe. The low latitudes tend to be too hot for the most profitable agricultural activities and any further warming will further reduce productivity. Up to 80 percent of the damages from climate change may be concentrated in low-latitude countries.

Some damages from climate change will not affect the global economy, but will simply reduce the quality of life. Ecosystem change will result in massive shifts around the planet. Some of these shifts are already reflected in agriculture and timber but they go beyond the impacts to these market sectors. Parks and other conservation areas will change. Animals will change their range. Endangered species may be lost. Although these impacts likely lead to losses of nonmarket goods, it is hard to know what value to assign to these effects.

Another important set of nonmarket impacts involve health effects. Heat stress may increase. Vector-borne diseases may extend beyond current ranges. Extreme events could threaten lives. All of these changes could potentially affect many people if we do not adapt. However, it is likely that public health interventions could minimize many of these risks. Many vector-borne diseases are already controlled at relatively low cost in developed countries. Heat stress can be reduced with a modicum of preventive measures. Deaths from extreme events can be reduced by a mixture of prevention and relief programs. As the world develops, it is likely that these risks may involve higher prevention costs, but not necessarily large losses of life. Further, winters lead to higher mortality rates than summers so it may well be that warming has little net effect on health.

Agricultural studies in the United States suggest that the impacts of climate change in mid-latitude countries are likely to be beneficial for most of the century and only become harmful towards the end of the century. In contrast, there will be harmful impacts to agriculture in African countries, Latin American countries, and China starting almost immediately and rising with warming. The overall size of these impacts is lower than earlier analyses predicted because of the importance of adaptation. Irrigation, crop choice and livestock species choice all play a role in reducing climate impacts. Studies show that current farmers are already using all of these methods to adapt to climate today in Africa, Latin America, and China.

Other sectors that were originally expected to be damaged include timber, water, energy, coastal, and recreation. Forestry models are now projecting small benefits in the timber sector from increased productivity as trees respond positively to a warmer, wetter, CO2 enriched world. Water models tend to predict there will be damages as flows in major rivers decline. However, the size of the economic damages can be greatly reduced by allocating the remaining water efficiently. Energy models predict that the increased cost of cooling will exceed the reduced expenditures on heating.

Several geographic studies of sea level rise have assumed there would be large coastal losses from inundation. However, careful economic studies of coastal areas suggest that most high-valued coasts will be protected. The cost of hard structures built over the decades as sea levels rise will be less than the cost of inundation to urban populations. Only less-developed coastal areas are at risk of inundation.

Initial studies of recreation measured the losses to the ski industry of warming. Subsequent studies of recreation, however, noted that summer recreation is substantially larger than winter recreation and would increase with warming. The net effect on recreation is therefore likely to be beneficial. As economic research on impacts has improved, the magnitude of projected damages from climate change has fallen. Early estimates projected that a doubling of greenhouse gases would yield damages equal to 2 percent of GDP by 2100. More recent analyses of impacts suggest damages are about an order of magnitude smaller (closer to 0.2 percent of GDP).

The reason that damages have been shrinking is that the early studies (1) did not always take into account some of the benefits of warming to agriculture, timber, and tourism; (2) did not integrate adaptation; and (3) valued climate change against the current economy. At least with small amounts of climate change, the benefits appear to be of the same magnitude as the damages. Only when climate change exceeds 2 degrees Celsius are there net damages. Many early studies assumed victims would not change their behavior in response to sustained damages.

More recent studies have shown that a great deal of adaptation is endogenous. If government programs also support efficient adaptations, the magnitude of damages falls dramatically. Finally, by examining the effect of climate change on the current economy, early researchers made two mistakes. First, they overestimated the relative future size of sectors that are sensitive to climate such as agriculture. Second, they underestimated the size of the future economy in general relative to climate effects. Economic analyses of impacts also reveal that they follow a dynamic path, increasing roughly by the square of temperature change. The changes over the next few decades are expected to result in only small net effects. Most of the damages from climate change over the next hundred years will occur late in the century. These results once again support the optimal policy of starting slowly with climate change and increasing the strictness of regulation gradually over time. In contrast to the literature on economic impacts, the Stern Report predicts large damages. However, most of the losses in the Stern Report occur in the twenty-second century. Stern tries to argue that these damages are equivalent to losing 5 percent of GDP a year starting immediately. However, the argument is based on a false assumption that the discount rate is near zero. He argued that the only reason to discount for time at all is because there is a possibility that the earth would be destroyed by an asteroid. This assumption has been heavily criticized in the economics literature since it makes no economic sense. Stern also talks about the importance of adaptation but gives little credence to any impact studies that included adaptation. In Stern's defense, he does take into account of uncertainty and low- probability, high-consequence events. However, in general, he tends to overestimate the expected value of these impacts. For example, he assumes that climate change will cause extreme events to grow exponentially. This is a misinterpretation of data on historic damages from extreme events that are due to economic growth, not climate damages. The consequences of catastrophic events are possibly quite severe. If there is large-scale melting of the Greenland ice sheets or West Antarctica, it could lead to dramatic sea level rise especially after several centuries. There is no question that this would force mankind to retreat from rising seas and build new cities inland. However, given the long-time frame involved, it is not clear that the cost of such a relocation is as dramatic as it might at first seem. There is no question that the land along the coast would be lost. But new coastal land would appear so that what is actually lost is interior land. Buildings would not really be lost as new cities would be built in anticipation of rising seas. Older cities along the old coast would gradually be depreciated until they are abandoned. Although this may seem like a huge loss, most of the buildings built 500 years ago no longer exist. Finally, it is uncertain whether catastrophic events will occur. These damages must consequently be weighed by the low probability they will occur.

Case Study: Climate Change and Industries

Introduction

In the United States, oil and natural gas supply 66 percent of the energy Americans use today, and the U.S. Energy Information Administration projects that these fuels will continue to furnish more than 66 percent of the energy we use through 2040 and beyond. Without modern fuels, our world would be harsher, less healthy and less convenient – an existence far removed from what we often take for granted living in the 21st century. We know this is true because, unfortunately, more than a billion people across the planet are living that existence right now, often with little or no opportunity to hope for anything better – largely because they lack access to energy. Right now, the United States is leading the world in the production and refining of oil and natural gas, as well as in the reduction of GHG emissions. CO2 emissions from power generation in 2016 were near 30-year lows, in large part due to greater use of natural gas. And increased use of natural gas in the power generation sector has helped to reduce total CO2 emissions to their lowest level in nearly 25 years. This proves that Americans do not have to make the false choice between utilizing our nation’s energy resources and protecting the environment. The oil and gas industry considers climate change a very important issue and is engaging constructively to address this complex global challenge. United States climate policy must recognize the vital role of petroleum products in modern society, and the many benefits that oil and natural gas provide our nation and the world. Affordable energy helps to secure life's basic needs: clean water and sanitation; food production and storage; lighting, heating and cooling of homes; and transportation. Beyond their uses as fuels, oil and natural gas serve as the feedstocks for thousands of products like medical devices, cellphones, clothing, building materials and pharmaceuticals. Domestic production, refining and delivery of oil and natural gas strengthens the American economy, enhances national security and reduces our trade deficit, thus maintaining the competitive position of the United States in the global marketplace. Modern life as we know it would be impossible without the fuels and products derived from oil and natural gas. As such, policy proposals must balance environmental, economic and security concerns.

When you compare the top 20 economies in the world, the United States is second to none in reducing greenhouse gas emissions from energy consumption since 2005. For many countries, GDP growth is associated with emissions growth, but this is not true for the United States. Natural gas is enabling this rare combination of increased economic growth and falling emissions. Thanks in part to big investments in production and innovation by U.S. oil and natural gas companies, the U.S. economy is growing while simultaneously reducing emissions. Nine of the top twenty economies in the world lowered carbon emissions between 2005 and 2014 (the last year for which full data is available). And, from 2013 to 2014, the U.S. oil and natural gas industry directly reduced emissions by the equivalent of 55.5 million metric tons of CO2 6 – equal to the carbon sequestered by 5.27 billion trees over 10 years.

The United States is leading the world in the production and refining of oil and natural gas. And due primarily to greater use of natural gas, 2016 carbon dioxide emissions from power generation were at nearly 30- year lows. Industry places a high priority on the capture of methane during oil and natural gas development and production. And because methane is the major component of natural gas, containing it means that more product can be delivered to customers. Methane emissions from 1990-2015 associated with the natural gas industry declined by 18.6 percent as U.S. natural gas production increased by more than 50 percent, according to EPA and EIA data.8,9 This shows U.S emissions of methane from the natural gas sector decreased noticeably during one of the largest increases in natural gas production in the nation's history.

Natural gas availability and use are direct products of an American energy renaissance built on shale reserves and safe hydraulic fracturing and horizontal drilling. The availability of affordable, clean-burning natural gas is directly impacting the power sector in positive ways – among them, helping to drive down CO2 emissions. The inescapable climate point here is that while many talk about ways to reduce emissions, the United States already is achieving results largely due to increased use of natural gas. From 2005 to 2016 natural gas consumed by the electric power sector for generation grew 76.6 percent. During that same period carbon dioxide emissions from electrical generation fell 24.7 percent.

The dramatic resurgence of the United States as an energy superpower has provided tremendous economic and environmental benefits. Even as America is leading the world in oil and natural gas production, methane emissions have fallen, thanks to industry leadership and investment in new technologies. U.S. carbon emissions from power generation are now at nearly 30-year lows due to increased use of natural gas. The U.S. energy renaissance reduces fuel costs for drivers, estimated to be a savings of $550 in lower fuel costs in 2015, according to the AAA.11 In addition, American households saved an average of $1,337 in lower home energy costs and other related expenditures in 2015.12 Methane emissions from 1990-2015 associated with the natural gas industry declined by 18.6 percent while U.S. natural gas production increased by more than 50 percent, according to EPA and EIA data. This shows U.S. emissions of methane from the natural gas sector decreased noticeably during one of the largest increases in natural gas production in the nation's history. Furthermore, America's oil and natural gas industry continues to lead all other industries in zero and low-carbon investments. Between 2000 and 2014, the oil and natural gas industry invested $89.9 billion in such investments, more than double that of the next largest private sectors (automotive at $38.2 billion and electric utilities at $37.1 billion) and nearly as much as the federal government ($110 billion).13 In a dynamic, innovation-driven industry like energy, the U.S. should be careful not to adopt prescriptive regulations that prevent technological improvements or shrink opportunities for investments that could deliver environmental benefits and consumer savings for years to come. Moving forward, our government leaders should embrace our nation's energy renaissance that has lowered costs for consumers, benefited American workers and improved the environment.

The White House's October 2016 report is in addition to two EIA reports showing that American consumers are paying less in electricity costs due to abundant natural gas15 and that carbon dioxide emissions for power generation dropped to near 30 year lows in 2016,16 due in large part to cleaner-burning natural gas Market forces and environmental policy are driving the ongoing shift in our nation's power generation mix. The challenge of ensuring environmental compliance, reliable generation and affordable electricity rests on states and regional transmission organizations that must consider the interests of electricity consumers as well as the overall well-being of the state economy. The final U.S. Environmental Protection Agency's (EPA) Clean Power Plan (CPP) is a sweeping and complex rule affecting most power generation in the country. The fate of the CPP is uncertain, given both legal challenges and the forthcoming EPA review of the rule.17 Nevertheless, grid operators must balance their goals to reduce emissions, maintain reliability and reduce costs. Natural gas generation meets all three objectives, providing a generation solution that is clean, reliable and affordable. America's energy revolution continues to deliver broad economic benefits while helping to reduce emissions of carbon dioxide (CO2) from electricity generation to nearly 30-year lows. These reductions are the result of market forces. They have little to do with government programs and everything to do with the affordability of the United States' natural gas resource. With such an abundant supply of affordable fuel on hand, power plants already have an incentive to use cleaner-burning natural gas without government interference. The challenge to provide more energy while lowering greenhouse gas emissions is clear. Government mandates like the Clean Power Plan are not the most cost-effective means to lower greenhouse gas emissions; the market demand for natural gas is doing that on its own. And a market-based, all-of-the above energy policy that encourages innovation and meets demand is the best combined economic and environmental option for our future.

Case Study: Renewable energy and climate change

Demand for energy and associated services, to meet social and economic development and improve human welfare and health, is increasing. All societies require energy services to meet basic human needs (e.g., lighting, cooking, space comfort, mobility and communication) and to serve productive processes. Since approximately 1850, global use of fossil fuels (coal, oil and gas) has increased to dominate energy supply, leading to a rapid growth in carbon dioxide (CO2) emissions. Greenhouse gas (GHG) emissions resulting from the provision of energy services have contributed significantly to the historic increase in atmospheric GHG concentrations. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report concluded that "Most of the observed increase in global average temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. Recent data confirm that consumption of fossil fuels accounts for the majority of global anthropogenic GHG emissions. Emissions continue to grow and CO2 concentrations had increased to over 39% above preindustrial levels, by the end of 2010.

There are multiple options for lowering GHG emissions from the energy system while still satisfying the global demand for energy services. Some of these possible options, such as energy conservation and efficiency, fossil fuel switching, nuclear and carbon capture and storage (CCS) were assessed in the Fourth Assessment Report of IPCC. A comprehensive evaluation of any portfolio of mitigation options would involve an evaluation of their respective mitigation potential as well as their contribution to sustainable development and all associated risks and costs. As well as having a large potential to mitigate climate change, RE can provide wider benefits. RE may, if implemented properly, contribute to social and economic development, energy access, a secure energy supply, and reducing negative impacts on the environment and health. Under most conditions, increasing the share of RE in the energy mix will require policies to stimulate changes in the energy system. Deployment of RE technologies has increased rapidly in recent years, and their share is projected to increase substantially under most ambitious mitigation scenarios. Additional policies would be required to attract the necessary increases in investment in technologies and infrastructure.

Renewable energy technologies and markets

RE comprises a heterogeneous class of technologies. Various types of RE can supply electricity, thermal energy and mechanical energy, as well as produce fuels that are able to satisfy multiple energy service needs. Some RE technologies can be deployed at the point of use (decentralized) in rural and urban environments, whereas others are primarily deployed within large (centralized) energy networks. Though a growing number of RE technologies are technically mature and are being deployed at significant scale, others are in an earlier phase of technical maturity and commercial deployment or fill specialized niche markets. The energy output of RE technologies can be (i) variable and—to some degree—unpredictable over differing time scales (from minutes to years), (ii) variable but predictable, (iii) constant, or (iv) controllable.

On a global basis, it is estimated that RE accounted for 12.9% of the total 492 Exajoules6 (EJ) of primary energy supply in 2008. The largest RE contributor was biomass (10.2%), with the majority (roughly 60%) being traditional biomass used in cooking and heating applications in developing countries but with rapidly increasing use of modern biomass as well. Hydropower represented 2.3%, whereas other RE sources accounted for 0.4%. In 2008, RE contributed approximately 19% of global electricity supply (16% hydropower, 3% other RE) and biofuels contributed 2% of global road transport fuel supply. Traditional biomass (17%), modern biomass (8%), solar thermal and geothermal energy (2%) together fueled 27% of the total global demand for heat. The contribution of RE to primary energy supply varies substantially by country and region.

Renewable energy sources and technologies considered

Bioenergy can be produced from a variety of biomass feedstocks, including forest, agricultural and livestock residues; short-rotation forest plantations; energy crops; the organic component of municipal solid waste; and other organic waste streams. Through a variety of processes, these feedstocks can be directly used to produce electricity or heat, or can be used to create gaseous, liquid, or solid fuels.

The range of bioenergy technologies is broad and the technical maturity varies substantially. Some examples of commercially available technologies include small- and large-scale boilers, domestic pellet-based heating systems, and ethanol production from sugar and starch.

Advanced biomass integrated gasification combined-cycle power plants and lignocellulose-based transport fuels are examples of technologies that are at a pre-commercial stage, while liquid biofuel production from algae and some other biological conversion approaches are at the research and development (R&D) phase. Bioenergy technologies have applications in centralized and decentralized settings, with the

[6] 1 Exajoule =24 million tonnes of oil equivalent (Mtoe)

traditional use of biomass in developing countries being the most widespread current application. Bioenergy typically offers constant or controllable output. Bioenergy projects usually depend on local and regional fuel supply availability, but recent developments show that solid biomass and liquid biofuels are increasingly traded internationally.

Direct solar energy technologies harness the energy of solar irradiance to produce electricity using photovoltaics (PV) and concentrating solar power (CSP), to produce thermal energy (heating or cooling, either through passive or active means), to meet direct lighting needs and, potentially, to produce fuels that might be used for transport and other purposes. The technology maturity of solar applications ranges from R&D (e.g., fuels produced from solar energy), to relatively mature (e.g., CSP), to mature (e.g., passive and active solar heating, and wafer-based silicon PV). Many but not all of the technologies are modular in nature, allowing their use in both centralized and decentralized energy systems. Solar energy is variable and, to some degree, unpredictable, though the temporal profile of solar energy output in some circumstances correlates relatively well with energy demands. Thermal energy storage offers the option to improve output control for some technologies such as CSP and direct solar heating.

Geothermal energy utilizes the accessible thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs using wells or other means. Reservoirs that are naturally sufficiently hot and permeable are called hydrothermal reservoirs, whereas reservoirs that are sufficiently hot but that are improved with hydraulic stimulation are called enhanced geothermal systems (EGS). Once at the surface, fluids of various temperatures can be used to generate electricity or can be used more directly for applications that require thermal energy, including district heating or the use of lower-temperature heat from shallow wells for geothermal heat pumps used in heating or cooling applications. Hydrothermal power plants and thermal applications of geothermal energy are mature technologies, whereas EGS projects are in the demonstration and pilot phase while also undergoing R&D. When used to generate electricity, geothermal power plants typically offer constant output.

Hydropower harnesses the energy of water moving from higher to lower elevations, primarily to generate electricity. Hydropower projects encompass dam projects with reservoirs, run-of-river and in-stream projects and cover a continuum in project scale. This variety gives hydropower the ability to meet large centralized urban needs as well as decentralized rural needs. Hydropower technologies are mature. Hydropower projects exploit a resource that varies temporally. However, the controllable output provided by hydropower facilities that have reservoirs can be used to meet peak electricity demands and help to balance electricity systems that have large amounts of variable RE generation. The operation of hydropower reservoirs often reflects their multiple uses, for example, drinking water, irrigation, flood and drought control, and navigation, as well as energy supply.

Ocean energy derives from the potential, kinetic, thermal and chemical energy of seawater, which can be transformed to provide electricity, thermal energy, or potable water. A wide range of technologies are possible, such as barrages for tidal range, submarine turbines for tidal and ocean currents, heat exchangers for ocean thermal energy conversion, and a variety of devices to harness the energy of waves and salinity gradients. Ocean technologies, with the exception of tidal barrages, are at the demonstration and pilot project phases and many require additional R&D. Some of the technologies have variable energy output profiles with differing levels of predictability (e.g., wave, tidal range and current), while others may be capable of near-constant or even controllable operation (e.g., ocean thermal and salinity gradient).

Wind energy harnesses the kinetic energy of moving air. The primary application of relevance to climate change mitigation is to produce electricity from large wind turbines located on land (onshore) or in sea- or freshwater (offshore). Onshore wind energy technologies are already being manufactured and deployed on a large scale. Offshore wind energy technologies have greater potential for continued technical advancement. Wind electricity is both variable and, to some degree, unpredictable, but experience and detailed studies from many regions have shown that the integration of wind energy generally poses no insurmountable technical barriers.

Economic Growth and the Natural Environment

Natural Limits to Growth

Many stocks of natural resources are components of an economy's productive potential. **For a country like Norway**, exhaustible natural resources, namely the deposits of fossil fuels below the Norwegian sea, belong to its productive capacity, as well as renewable natural resources like the famous Norwegian wood and water resources used in energy production. **For agriculturally structured regions** like the United States Mid-west, the quality of the soil and the availability of water resources are of great productive importance. In **a country like Austria**, engaging heavily in the tourist sector, climate stability may be considered an important component of the productive capacity because, on the one hand, global warming may reduce the snowfall in skiing areas in winter and, on the other, it may endanger mountaineers by causing rockfall and mudflows in summer. From **a Caribbean point of view**, the cleanliness of the sea water is a precondition for generating income by attracting spa visitors, and for China, rare earths become an increasingly important component of the productive capacity.

However, in **the basic model of neoclassical growth theory**, the productive contribution of natural resources is neglected completely. The question arises as to whether the conclusion of neoclassical growth theory – that **infinite economic growth is feasible** – is invalidated by the presence of **productive natural resources**, in particular non-renewable natural resources. In 1972, the optimistic perspective of the Solow-Swan model was challenged by **the Club of Rome's report** "**The Limits to Growth**". In this report it was predicted that, in just a few decades, some essential non-renewable natural factors of production would be exhausted. As a consequence, the global economy would collapse, and the standard of living would fall significantly all over the world. **As early as 1973**, the first oil crisis, though not caused by natural scarcity but by the market power of the Organization of the Petroleum Exporting Countries (OPEC), gave people a realistic impression of the scenario delineated by the Club of Rome's report.

Sustainable Development

In economic theory and growth theory in particular, the challenge posed by the Club of Rome led to the emergence of natural resource economics. Economists tried to examine the pessimistic theses of the Club of Rome within the context of a neoclassical growth model supplemented by a non-renewable natural factor of production. A number of economists tried to demonstrate that unlimited economic growth would be possible, even if production relied on non-renewables. For them, the predominant goal became the achieving of the highest possible constant per capita level of consumption of produced commodities and services for all times to come, irrespective of the dependence of production on an exhaustible natural factor of production. They showed that the economic collapse predicted by the Club of Rome could be prevented if, at any point in time, the inevitable decline in the stock of the non-renewable factor of production (e.g., fossil fuels) were offset by "sufficient" investment in other productive assets. Those other productive assets could be man-made capital goods (like wind energy plants), as well as human capital (increased knowledge concerning energy saving technologies) or renewable natural resources (firewood from forests). There are many ways to invest in various productive assets. Investment can be both quantitative and qualitative in nature. The labour potential depends both on the number of workers available and on their level of education, health, and motivation. The quantity of an economy's labour force can be enhanced by a rising number of births or by immigration. It can also be increased by a rise in labour market participation, e.g., on the part of parents with young children or by extending the working lifespan by attaining an earlier entry into work (perhaps via shortening the education period) or delaying entry into retirement. The quality of labour can be improved by education and training, improved health care and measures to enhance employee motivation.

With regard to man-made capital, its quantity can be enhanced by installation of additional machines, tools and buildings, by building infrastructure like highways, railroads, harbours, and airports. The quality of the man-made capital stock rises if new capital goods are more productive than the older ones, owing to, for example, the embedding of a more advanced level of technical knowledge.

Investments in the stock of knowledge can be made by research and development activities. In this context the special feature arises that new knowledge stored in books, on DVDs, or on web servers is not productive on its own. However, it must be incorporated into the labour force by education, training, and/or into a new generation of machines by construction activities.

But, of course, the idea and nature of investment activities carries over to natural resources as well. In analogy to man-made and human capital, the stocks of productive natural resources can be enlarged by investment activities. In the case of renewable natural resources like forests, stocks may be enlarged actively by afforestation (which, incidentally, has positive effects on climate stability as well). A “passive” form of investment would be a (temporary) renunciation of harvesting renewable natural resources in order to allow for a regeneration of the stocks of endangered plants (tropical wood) or animals (sea fish). Finally, the stocks of endangered species can be protected by the establishment of protected areas where human activities are regulated. With regard to non-renewable natural resources like fossil fuels, investments are possible as well, although the stock of the resource existing on earth, by definition, cannot be enlarged. Investments can take the form of exploration activities which add former unknown resource deposits to the reserves. At present, there are significant exploration activities being carried out in the North Pole region which bear a significant potential for conflict, namely between Russia and Canada. In the special case of fossil fuels, however, one should bear in mind that investment in reserves through exploration activities implies a negative investment as regards another stock of natural resources, namely the cleanliness of the atmosphere and climate stability: the productive use of the newly explored fossil fuels will inevitably raise the atmospheric concentration of greenhouse gases.

Another “roundabout” method of investing in non-renewable natural resources may take the form of developing new techniques of depletion or utilization. On the one hand, new depletion techniques can make already known but formerly unattainable deposits workable. On the other hand, more efficient techniques of using non-renewable natural resources may extend the time span over which the resource remains available.

To summarize, the basic idea developed in neoclassical resource economics in order to avoid the Club of Rome’s “doomsday” scenario was to substitute for the decline in some of the productive natural resources by investing in both other natural resources and in man-made capital, human capital, and knowledge. Apparently, this strategy depends crucially on the assumptions, firstly, that substitution for natural resources is possible at all and, secondly, that substitution possibilities are sufficiently “good”.