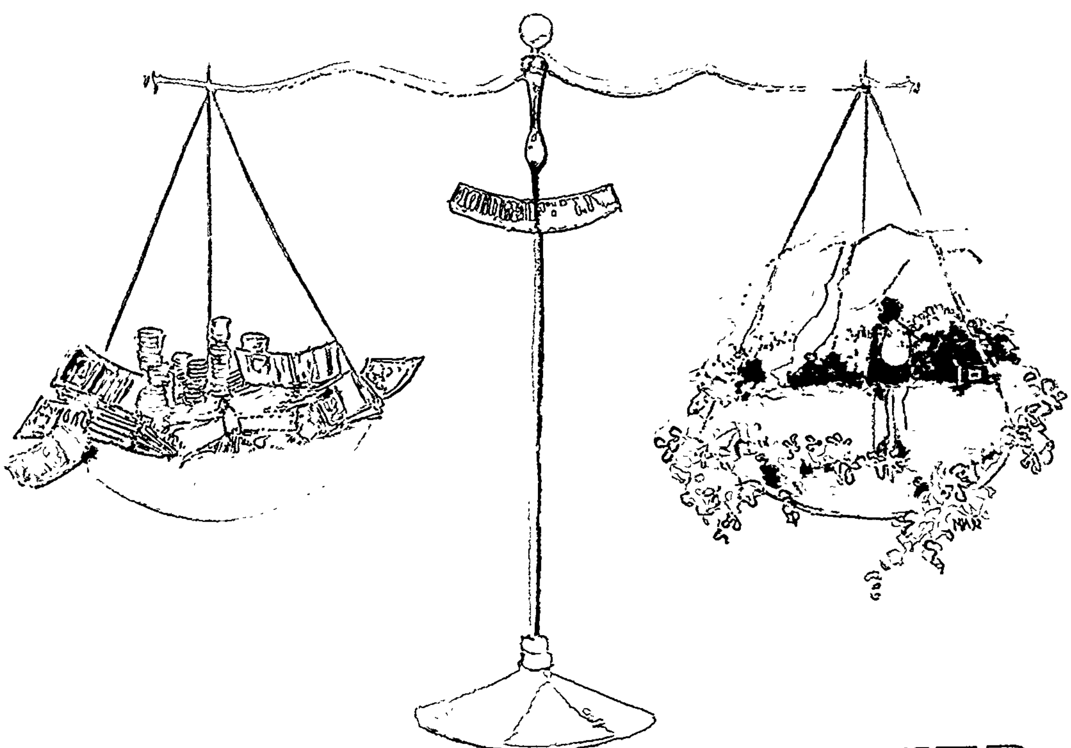
NVE
NORWEGIAN
WATER RESOURCES AND
ENERGY ADMINISTRATION

NVE-E-PUB--03/1994

PUBLICATION

QUANTIFICATION OF ENVIRONMENTAL IMPACTS OF VARIOUS ENERGY TECHNOLOGIES

Final report



MASTER

No. 03

ENERGY DEPARTMENT 1994

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NVE
NORGES VASSDRAGS-
OG ENERGIVERK

TITLE **QUANTIFICATION OF ENVIRONMENTAL IMPACTS OF VARIOUS ENERGY TECHNOLOGIES**	**PUBLICATION** No. 03
EDITOR Asle Selfors	DATE October 1st 1994
COMMISSION AGENT Norwegian Water Resources and Energy Administration	ISBN 82-410-0215-7 ISSN 0804-6263

ABSTRACT
This report discusses problems related to the economic assessment of the environmental impacts and abatement measures in connection with energy projects. Attention is called to the necessity of assessing environmental impacts both in the form of reduced economic welfare and in the form of costs of abatement measures to reduce the impact. In recent years, several methods for valuing environmental impacts have been developed, but the project shows that few empirical studies have been carried out. The final report indicates that some important factors are very difficult to evaluate. In addition environmental impacts of energy development in Norway vary considerably from project to project. This makes it difficult to obtain a good basis for comparing environmental impacts caused by different technologies, for instance hydro-electric power versus gas power or wind versus hydro-electric power. It might be feasible, however, to carry out more detailed economic assessments of environmental impacts of specific projects.

SUBJECT TERMS	RESPONSIBLE
Energy Environmental Impacts Economic Valuation	Erling Diesen Director General

Kontoradresse: Middelthunsgate 29
Postadresse: Postboks 5091, Maj.
0301 Oslo
Telefon: 22 95 95 95
Telefax: 22 95 90 00
Postgiro: 0803 5052055

Illustrator: Mia Brambani

CONTENTS

PREFACE

This report presents the results of the investigative programme: "Quantification of Environmental Impacts of Various Energy Technologies". The programme was commissioned by the Norwegian Water Resources and Energy Administration during the period 1990-92 and was funded by NVE and NTNF, the Royal Norwegian Council for Scientific and Industrial Research. It seeks both to summarize the different subreports which was prepared in the course of this programme and to provde extensions to the major issues involved. This final report was prepared by ECON Energi with authors Kjell Roland, Per Schreiner and Olvar Bergland. The last author is also responsible for Appendix 1. NVE's programme manager for this programme, Asle Selfors, assisted with the writing and was responsible for editing the report.

1. SUMMARY

An overriding objective in the Norwegian energy policy is economic efficiency in the development and operation of the energy sector. Production, transportation and use of energy places burdens of many kinds on the environment. Since hydro-electric power has such a prominent position in Norway, one key issue in Norwegian energy supply is the land use conflicts (including use of water courses) when building power plants and transmission lines. Another important energy related environmental issue is atmospheric emissions from stationary combustion of fossil fuels.

A prior condition for a socially rational energy sector is that the players in the sector account for environmental impacts when making their investment and operation decisions. In order that they shall do so, it is necessary to find methods of valuing the environmental impacts that allow the benefits of greater energy consumption to be compared with the total social cost. It must also be possible to select the energy projects with the lowest costs, including environmental costs.

This was the thinking behind the initiative taken by the NVE for this investigative programme: "Quantification of Environmental Impacts of Various Energy Technologies". The aim was to promote a rational energy sector by factoring environmental impacts into social assessments of benefits and costs of energy projects.

Identifying the optimal abatement level of environmental impacts requires *not only* knowledge of abatement costs *but also* knowledge of the environmental damage costs, which often take the form of reduced economic welfare. This is necessary in order to determine the optimal level of environmental taxes and to decide whether to award a licence and, if so, under what licence conditions, for instance for hydro-electric power developments. The optimal social level og environmental impacts is determined by setting the marginal abatement costs equal to the marginal environmental damage costs.

In order to quantify the environmental impacts that commonly occur in the energy sector a range of subprojects were initiated, see Appendix 2. The reports of these were generally literature reviews providing surveys of previous studies that sought to put a price on environmental impacts, or studies which were important in developing a planning method or analysis model. In designing the subprojects a main consideration was not just to describe the problem but, if possible, also to quantify it.

In this context it was important to distinguish between three levels of ambition in describing the environmental impacts:

- *Survey of potential impacts*
- *Quantification in physical (as opposed to monetary) units*
- *Quantification in economic (monetary) units.*

As a rule one should at least require a summary of all environmental impacts to be submitted for all projects of a certain minimum size. How much further one goes must be evaluated on a case by case basis depending on initial estimates about the importance of the effects and the project's assumed sensitivity to the magnitude of the impacts.

Costing an action to abate environmental impacts is often a straightforward commercial calculation that is relatively easy to perform. Finding the damage cost of an environmental impact on the other hand is often anything but straightforward. Recent developments in economic theory has produced a raft of methods whereby to measure the cost of environmental impacts. The methods for economic valuation of environmental effects can be divided into three main categories:

- *Direct valuation*

- *Indirect valuation*
- *Political valuation.*

Moreover it is possible to transfer valuation estimates from one problem situation to another by using analogies. In Appendix 1 and Subreport 7 the key methods of doing so are explained and assessed.

The valuation of environmental effects is typically both time-consuming and expensive if convincing quality is to be attained. Often it is preferable therefore to simply list and physically describe the impacts.

Factors that should be considered in deciding how far the potential licensee should go in his preliminary valuation analysis are the following:

- *Magnitude scope of environmental issues*
- *The significance of environmental impacts on project evaluation*
- *The assumed significance of the economic valuation on the assessment of the environmental impacts*
- *Opportunity to rely on previous studies and prior knowledge*
- *Whether environmental impacts are unique or more general in character*
- *Status of the knowledge produced by any further analyses*

The subreports available here provide first and foremost a useful survey of possible environmental effects of various energy technologies. Moreover, they also provide some numbers for physical magnitudes and a summary of feasible abatement measures, sometimes with cost estimates. The treatment of the economic valuation is limited by and large to a discussion of available methods and a search and review of the literature. It is evident that very few valuations of the environmental effects of energy projects have been undertaken.

The utility of the projects is principally that they lay a foundation for further work and provide a useful assessment of the economic valuation of energy projects. In combination with this final report they:

- *Offer a survey of relevant methods of economic valuation of environmental effects*
- *Make it clear that experience in using these methods in the energy sphere is largely limited to recreation, hunting and angling, while the effects on nature, health and agricultural production are poorly elucidated*
- *Provide an indication of the extent to which the results of economic valuation can be precise and relatively uncontroversial.*

They thus provide a basis for evaluation of:

- *If and how far an economic valuation can assist the rational processing of projects with defined environmental side effects, in other words act as a conflict resolver in decisions that are environmentally controversial.*

The subreports provide little basis for assessing what it will cost to implement an economic valuation study. Therefore they will also provide a limited basis for deciding whether it is worth undertaking a study of the economic value of the environmental effects of specific projects. The review of various methods in Appendix 1 indicates none the less that the costs of the valuation exercise are often substantial.

An important lesson that is developed in this final report is that very many environmental effects are local in scope and project-specific. Variations from project to project in the same technology can be greater than the variations between technologies. Therefore it may not be particularly meaningful to compare average environmental impact values, for instance between hydro-electric power and gas power.

2. MORE ABOUT THE QUANTIFICATION PROJECT

2.1 *BACKGROUND AND AMBITIONS*

The investigative programme "Quantification of Environmental Impacts of Various Energy Technologies" was instigated by the NVE in 1989. Its background was in part the discussions flowing from the Brundtland Commission report, particularly as they concerned environmental impacts related to obtaining and using energy. In part the background was the projected introduction of gas power in Norway and the need to evaluate the pros and cons of gas power compared to hydro-electric power. At the same time interest in energy efficiency was growing and there was considerable discussion regarding whether the potential environmental benefits of the purportedly new, renewable energy sources could offset the added costs of producing electricity that way. In the National Budget for 1989 it was pointed out that there was a need to "take up the issue of ... how environmental costs could be factored into the energy price".

Based on this an investigative programme was devised aiming to:

> *"lay the foundation for socially rational energy planning by incorporating environmental impacts into the cost-benefit analysis of energy projects at the regional and national level."*

This was to be achieved by quantifying the environmental impacts in monetised units and by supplementing the planning methods and analysis models so that environmental impacts and their costs were included in any evaluation of energy projects.

The aim was to produce information concerning both the welfare effects of impacts on the environment caused by production, transport and use of energy; and the costs of reducing these impacts. All this was to be done for all likely energy technologies: hydro-electric power, thermal power, new renewable energy sources, and various types of energy transmission and transport. In practical terms it was intended to achieve the aim by reviewing the literature on each particular theme.

In designing the subprojects the emphasis was not just on describing the issues, but also as far as possible quantifying them. What quantification implied was not expressly stated; but the main thing was an economic valuation. But also other numbers, for example the magnitude of the impact, were of interest. It was expected that the necessary data already existed in the extant studies. Following a literature search and compilation of data, the aim was to establish a model or data bank containing all relevant information on environmental costs of different technologies.

The cost budget for the investigation was set at two million kroner and the project was launched with a project coordinator, steering group and user and reference groups, the last comprising the Norwegian Water Resources and Energy Administration, Ministry of Industry and Energy, Directorate for Nature Management, Norwegian Pollution Control Authority (SFT), Norwegian Electricity Federation and Statistics Norway.

2.2 *ROLES AND INFORMATION NEEDS*

The investigative programme "Quantification of Environmental Impacts of Various Energy Technologies" was instigated before the new Energy Act had been passed and implemented. The roles in energy development remained as before, however.

Responsibility for financing and implementing the projects lies with each individual developer. In a market-based power system a developer has no guarantee of sales at a viable price. It is therefore more important than before to choose power development projects based on profitability, whether they involve hydro-electric power, thermal power, alternative renewable energy sources or energy efficiency measures.

A licence is required for each power project and certain specific aspects of it, such as construction work and transmission lines. One of NVE's tasks is to evaluate the technical content of applications and decide what details such applications should contain. NVE must also, as the central technical office, monitor and ensure that development in the energy sector takes place rationally; and also act as advisor to the competent ministry in energy matters. The acts and regulations defining NVE's role make it clear that the institution must promote an environment-friendly administration of water and energy resources.

The present information needs in the energy sector are not substantially different from those that were required before the new Energy Act was passed. Developers, involved parties (land owners, local communities, nature conservation organisations and so on), NVE and other central agencies require information about environmental problems. When considering licence applications there is a need for expertise in evaluating the quality of the reports submitted. An important task is to know what reports are required under changing circumstances and what they need to — or need not to — contain. With this in mind a review of the options for quantification of environmental impacts will be useful for all concerned. Such quantification is also interesting in connection with long-term analysis of energy development and as a baseline for the authorities' deliberations on energy taxes.

3. ENVIRONMENTAL IMPACTS OF NORWEGIAN ENERGY SECTOR

3.1 DIFFERENT ENVIRONMENTAL IMPACTS FROM DIFFERENT ENERGY TECHNOLOGIES

All energy production and almost all energy use affects the natural environment in some way or another. Few other sectors raise such complex and far-reaching environmental issues as the energy sector. The environmental problems stretch from local, temporally limited impacts such as noise and scenic encroachment; to regional problems lasting many decades as the result of acid rain; to global climatic change lasting one supposes up to several hundred years or more; to stockpiling of waste from nuclear power that will remain active in a geological time scale. The problems that attract most attention have become geographically larger and temporally longer. Our interest has been turned from local pollution to issues of climatic change and ozone depletion.

Environmental problems connected with energy supply and energy use vary from one country to the next. Most OECD countries have a broad range of environmental problems associated with emissions from fossil fuel thermal power stations or with waste from nuclear power stations. This investigative programme aimed to quantify the environmental impacts in the hydro-electric power sector and in stationary energy consumption on the Norwegian mainland. The environmental problems linked to energy consumption offshore, in the merchant shipping fleet, in the fishing fleet, on ferries and by other means of transport are therefore not discussed. Nuclear power has not been evaluated.

The most common environmental problems caused by the power sector in Norway are associated with different forms of land use conflicts to do with hydro-electric power developments (dams, embankments, changes in water flow, etc) and transmission of power and heat (transmission and distribution lines). Other factors are possible health impacts due to electromagnetic fields from transmission lines. Stationary uses of fossil fuel for space heating and process heating are of lesser importance in Norway than elsewhere. They none the less cause problems of noise from the combustion process and atmospheric pollution (emission of SO_2, CO_2, NO_x and particulate matter).

In the future this pattern may change if gas or biomass power stations are built (causing atmospheric pollution), or windmills are erected (which cause noise). Other environmental problems associated with alternative energy sources (wind, wave and solar energy) are land use conflicts similar to those encountered with hydro-electric power.

The original brief that describes the programme "Quantification of Environmental Impacts of Various Energy Technologies" explains the large variety of potential environmental consequences of the energy sector that need to be analyzed and if possible quantified. Table 3.1 provides a summary of all relevant technologies and indicates the extent to which they cause local, regional or global environmental problems.

Table 3.1 ***Environmental impacts of various energy technologies***

ENERGY TECHNOLOGY	Environmental impact		
	Local	**National**	**Global**
Power production			
Hydro, solar, wind and wave power	X		
Coal, oil and gas power	X	X	X
Other fuels: biomass, waste etc	X	X	?
Other fossil stationary energy processes			
Production of steam or heat	X	X	X
Space heating (oil)	X	X	X
Transport and storage of energy			
District heating, power and gas lines, road transport of fossil energy	X	?	?

3.2 SOCIAL ECONOMIC EFFICIENCY IN ENERGY SECTOR

A socially economic efficient energy system is characterised by the costs of increasing production by one kWh equalling the consumers' willingness to pay (WTP) for one more kWh. This means, in practice, that there has to be equality between marginal production costs, inclusive environmental costs, and the marginal costs of energy conservation measures taken by the consumers. It is wasteful to spend more on saving one kWh than producing it, provided all costs are included in the calculation. By the same token it is wasteful to increase production if to do so costs more than reducing consumption by the same amount.

In an efficient market economy there should be a balance of supply and demand at the prevailing price. Therefore production capacity must be adjusted so that investment costs correspond to the market price. This is naturally an ideal situation, and in practice fluctuations occur in both supply and demand that are not always balanced by the fluctuations in market price. In the electricity market the demand fluctuates by the hour, day and year. Moreover, production depends on precipitation, production capacity is increased by large increments, and it takes many years to complete a development. Key constraints and key decisions in the power market are also subject to political intervention.

Altogether therefore it is impossible in practice to achieve a price that clears the market at all times. Still, the model does provide support in devising energy policy. One should aim for development that over time largely assures correspondence between the various development and transport costs and the prices the users are ready to pay for various types of power delivered. All this assumes of course that the authorities have established measures that ensure that power suppliers are charged all costs of indirect effects, including environmental impacts.

3.3 ENVIRONMENTAL POLICY IN THE ENERGY SECTOR

An environmental policy towards the energy sector must ensure that all environmental impacts of production, transportation and use of energy are included in the total development and usage costs. Environmental impacts are often reckoned as side effects or indirect effects (external effects) since they are not normally subject to purchase and sale. Damage and disadvantage is caused to society as a whole or groups in society who are unable to claim compensation or payment.

If energy producers or energy users can impose environmental costs on society without being held responsible for those costs, the volume of energy produced and consumed will be greater than is optimal from a social efficiency perspective. That is why we have political and administrative regulations in the form of licensing rules, directives, taxes and so forth to force those causing the impact to be accountable for it. The difficulty for the authorities whose job it is to monitor and set the regulations for the energy sector is in reaching a balance between the advantages of increased energy consumption and the disadvantages of its accompanying environmental disturbance.

From the above it will be clear that even if environmental disturbances like emissions to air or discharges to water or scenic encroachments are undesirable, the aim is not maximum reduction whatever the cost. The goal of energy policy is to strike a balance between the benefits achieved by increasing energy consumption on the one hand, and the disadvantages due to environmental impacts and the effort spent in rectifying those impacts on the other. Increased attention to the environmental impacts may lead to efforts toward reducing energy consumptions and redesign of the energy system.

Establishment of planning constraints

Development of the energy system should be made within constraints that offer incentives for energy producers and energy users to act in the best interests of society. Where markets can be established that are efficient, there is no problem. But on the environmental side the issue is not usually so simple. Here constraints must be established that induce the players to act in a socially rational way. That can happen in several ways, using anything from a direct order or prohibition, to subsidy and tax arrangements, to rules ensuring that all considerations are illuminated and all interested parties heard.

The formal rules that are needed already exist. An environmental impact analysis that meets the requirements of the Planning and Building Act (Chapter VII-a dealing with impact statements for projects) is intended to produce the information needed. The task then is to ensure that the level of information detail is correct and that the information is evaluated and applied in a suitable manner.

3.4 COST-BENEFIT ANALYSIS

When a reasonable long-tun equilibrium exists in the energy sector, the benefits of energy utilisation can be expressed in terms of the price the consumer pays for the energy. Many of the social costs of producing and transporting energy can be valued in money. It therefore simplifies the decision process if environmental costs can also be expressed in money. But just as there is often much controversy regarding the significance of different environmental impacts, so it is difficult to put an uncontroversial monetary value on them. There are no neutral or objective methods for determining the value of the environment. But there are methods that may help us organise and clarify the environmental concerns in the decision process.

Criticism of cost-benefit analyses

Cost-benefit analysis as a project evaluation tool has been much criticised. The method has been and still is under continuous development. Earlier cost-benefit analyses highlighted the project consequences that could be easily priced in monetary units. The conclusions were presented as final and indisputable. Particular attention was given to goods and services sold in markets, while goods and services not usually sold in markets (nonmarket goods and services) were only mentioned in passing or completely ignored. Often the claimed objectivity of the cost-benefit analysis was used to ward off criticism and to argue for a particular standpoint, in most cases in favour of development and construction.

The variations on cost-benefit analyses that are recommended for use in environmental and resource economics also stress the point that nonmarket goods and services are important and that they should be treated on a par with marketed goods. A number of methods have been developed for valuing environmental goods which use a value concept that is much broader than that underlying commercial market values of a good. At the same time it is accepted that not everything can be valued, and that much valuation is controversial. The aim of valuation is not to reach a final figure that is totally indisputable, but rather to focus on the problems and thereby ensure that they are taken into account and not forgotten.

Among economists there has been a tendency to use cost benefit analysis as a mechanistic decision tool. Worthwhile projects are those, and only those, that pass a cost-benefit test: that the present value of the project's benefits should exceed the present value of the project's costs. Such a technocratic use of cost-benefit analyses only serves to alienate the decision process from the population and hide important political trade-offs and value choices behind a vail of expert assumptions, calculation and figures.

The view of cost-benefit analyses that appears in environmental and resource economics assigns the cost-benefit analyses a different role. The aim here is to obtain information, illuminate complex and controversial problems, ensure that all aspects and sides of a project are discussed, and ensure that the final political decision is made in the basis of the best possible information.

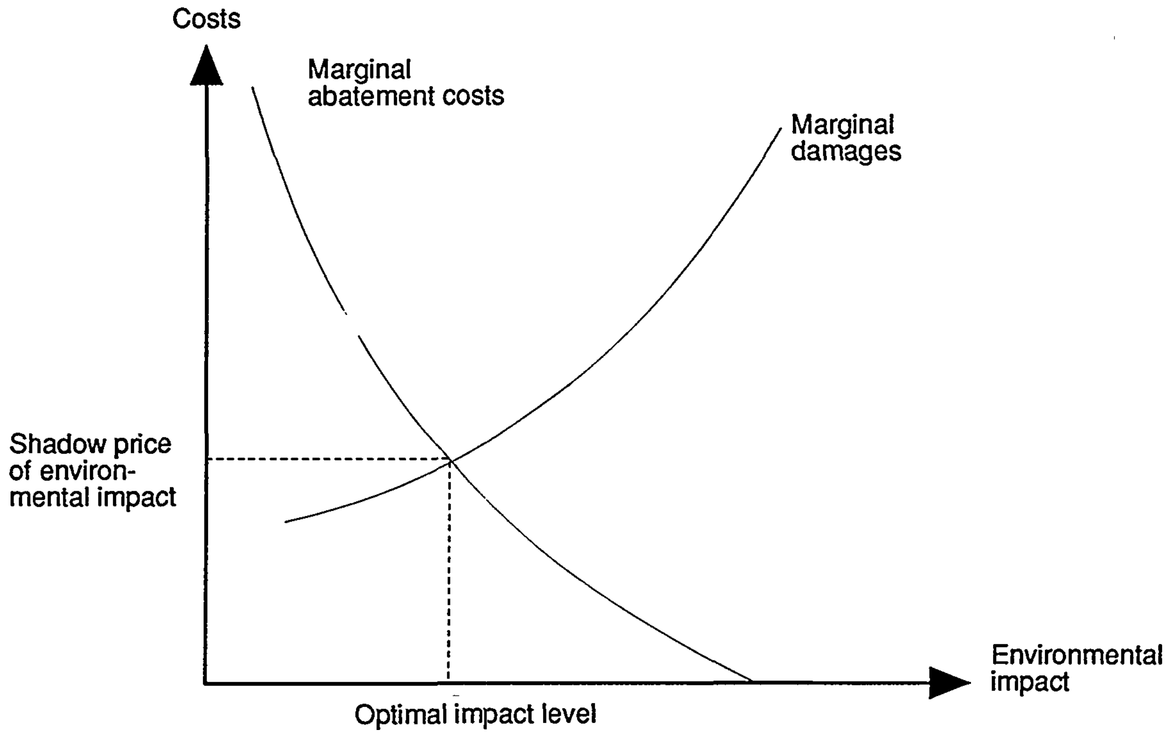
Much of the criticism coming from conservationists has been accomodated in the design and development of the various valuation methods, but there is also the criticism that says that assigning any monetary value at all to nature and the environment is a sacrilege.

Discounting in cost-benefit analyses are often controversial. For small projects with a limited commercial life the matter is often clear enough. But for long life-span projects where the potential environmental consequences are catastrophic, discounting offers less satisfactory results since future potential consequences are marginalised. Discounting solves some problems relating to allocation of resources over time, but does not solve problems relating to the just allocation of resources and risk.

Optimal environmental effect

The principle behind a social evaluation in this field is illustrated in Figure 3.2. The marginal abatement cost curve represent the cost of the undesirable environmental impacts by an incremental amount, depending on how large the environmental impacts are to begin with. The larger the environmental impact, the cheaper is the achievement of a small environmental improvement. When abatement action is taken, the environmental impact is lessened and we move toward the left in the figure. Gradually the abatement costs rise for achieving a given environmental improvement.

Figure 3.2 ***Principle used to identify efficient levels of environmental impacts***



The graph marked marginal damages indicates the cost of the impact that a small additional development causes society. The increasing marginal damage function expresses society's estimated increasing aversion to further environmental degradation. Gradually as we have developed more hydro-electric power, the value of the remaining undeveloped waterfalls and watercourses has appreciated.

The efficient level of environmental measures in a development project, is given by the intersection of the marginal abatement cost curve with the marginal damages curve. At that point, whatever is saved by cutting environmental measures slightly, will be less than the increased loss of environmental benefits. Put another way, if from this point a slight increase in environmental abatement measures is made so as to slightly reduce the environmental impact, the environmental benefit that we gain will be less than the cost of the additional measures necessary to achieve that reduction.

The optimal impact level, which is simultaneously the optimal abatement level, is the point at which the marginal abatement costs are equal to the marginal damage costs. The magnitude of the marginal damage costs (or the marginal abatement costs, since these are equal by definition) at this point is called the shadow price of environmental impact. If environmental taxes are being considered as a policy instrument, the environmental tax must be set equal to the shadow price in order to achieve the optimal result. If the policy instrument consists of licensing conditions or injunctions by the authorities, the licensee can be ordered not to develop, or to implement abatement measures, so that the environmental impact is limited to the optimal level.

It is difficult in practice to determin the shape of the curves for marginal abatement costs and damages. Usually, too, it is expensive to do so. In practice therefore one has to strike a balance by adjusting the scope of the optimisation process. In this context it is important to distinguish between determining the full shape of the curve, and being content with identifying certain of its properties. Subreport 1 discusses how for each of the curves three levels of ambition can distinguish between:

- *Complete description (catalogue) of environmental impacts and possible measures*
- *Qualitative evaluation of their significance*
- *Complete valuation of marginal abatement cost curves and environmental damage curves.*

As a general rule a qualitative description must be required of the environmental impacts of all projects of any size. How far one should go from there should be assessed in each case based on assumptions of how sensitive the project design will be with regard to valuation of the environmental costs (or benefits). In what follows we will use the term impact analysis for an analysis of the environmental impacts of a project regardless of how far the analysis goes in fulfilling the three levels of ambition.

3.5 CHOICE OF INSTRUMENTS

Local, national and global environmental problems

It is customary to distinguish between economic instruments, regulations and tradeable emission rights. There are also information measures.

National environmental problems where the impact is not dependent on geographical location should normally be handled by establishing common constraints at the national level. For such environmental impacts it will not be useful if all polluters are ordered to implement the same impact analyses (for example to determine the effects of emitting greenhouse gases). If the instruments applied generally in the sense that all emissions are subject to the same instruments (such as a tax on CO_2 emissions) then it is not necessary for the polluter to analyze the costs of limiting emissions. The players already have an incentive to use their best efforts to take into account the social effects of their emissions.

Environmental impacts of regional and global character (such as the emission of SO_2 and CO_2) can normally be limited by establishing a set of measures at the national level. Since the environmental target concerns a geographical area that is larger than Norway, it will not always be useful to present all Norwegian polluters with the same incentives unless they are coordinated internationally. An important distinction is drawn between the polluters who are able to divert their clean-up costs and tax charges to the consumer, and those who cannot do so, but who can emigrate to some other country. The policy must be designed with the aim to reduce regional or global emissions, not Norwegian emissions. It is not obvious, therefore, that a gas power station in Norway should necessarily pay the same CO_2 tax as the transport sector in Norway. The result might be that a development that would otherwise be cheapest in Norway, is relocated elsewhere without any reduction in CO_2 emissions.

Environmental impacts of a local nature mean that the environmental consequences vary with the location and design of the project. Therefore the environmental costs, and normally also the costs of measures to reduce the scope of the impact, will be project dependent. Variations in costs are due in part to variations in the natural environment between different locations, and in part to different uses and perceptions of the natural environment in various parts of the country. The constraints that are enacted should reflect the fact that a seemingly similar impact (say, dam building) may have wildly different consequences, depending on the location.

By tailoring the constraints — in other words adjusting the licensing conditions, environmental regulation and environmental taxes, etc — to the local and project-specific impacts, the disparity between private and social benefits of the projects will be minimised. But it is a complex and costly matter to tailor all measures to each activity causing environmental problems. Therefore it is often useful to establish more general arrangements or rules of thumb even for problems that are specifically local.

In the choice of instruments it is also important to distinguish between environmental impacts whether they have local, national or global consequences. The environmental problems in the Norwegian energy sector are special in the sense that it is the local, project-specific land use conflicts that are predominant. In other countries the energy sector is to a greater degree presented with local, regional and global consequences of emissions to air.

3.6 INFORMATION NEEDS

Global and regional air pollution

In facing national and regional environmental problems, which in practice means air pollution by such gases as SO_2, CO_2 and CFCs, the general rule should be that one uses economic instruments. This complies with the recommendation by the Environmental Tax Committee (Norwegian Public Reports NOU 1992:3) and with the arguments outlined above. The environmental effects per unit of emission to air are independent of the source of the emission and often almost independent of the emission location. When the emissions from each source can be metered and verified, the information needed by the authorities is limited to determining the costs that CO_2, SO_2 and CFC emissions impose on society. There is no need to carry out investigations for all emission sources or all technologies.

Quantification of the environmental impact that follows from emissions to air demands extensive studies of the physical processes in nature (like the effect on forest growth of acid rain) or the impacts on social infrastructure (like corrosion caused by acid rain on buildings and equipment). Even more complex are the relationships that seem to underlie the greenhouse effect and its feedback on society. It is difficult to estimate with any accuracy the costs that society will have to bear as the result of such environmental problems.

Norway has none the less signed binding agreements to limit its atmospheric emissions of a list of harmful substances that have an effect beyond national boundaries. The obligations we have taken on in such situation are political decisions. Therefore the energy sector does not have as much need to evaluate the environmental costs involved. But it is necessary to clarify the costs of limiting emissions from the various sources, so that the political emission targets can be achieved at the lowest possible cost. Moreover, the competent authority is responsible for informing about the linhenges between net abatement costs and reduced environmental damages.

The costs are lowest when the marginal cost of limiting emissions is the same for all emission sources.

The comparison of abatement costs for individual projects provides a basis for checking that one is close to the cost minimum. At the same time an estimate will be made of the marginal costs needed to achieve the stated target. The estimate should be used as the level of the emission tax or as a reference point for other instruments, so that they are suitably sized relative to the environmental targets. If we set the emission tax according to this formula and enact other measures well knowing that they will result in equal marginal abatement costs, the individual decision-makers do not need to undertake a specific valuation of the environmental effects.

Land use conflicts

The environmental effects in the hydro-electric power sector are generally project-specific and the social welfare effects will often depend on evaluations that can vary a lot. The use of instrument for project-specific and local environmental impacts should normally involve licensing and other direct regulation. Such measures should be made project or area specific. Basically this means that one has to rely on studies being made for each project or area to elucidate both the abatement costs and the impact costs. There are various methods of making such a valuation of the environmental effects. For some problems one may arrive at reasonably sound knowledge about the environmental costs, but for others the methodological obstacles in doing so remain formidable.

When deciding to require an impact analysis for an energy project, it is essential to weigh the costs of the actual analysis against the anticipated benefits of the information that can be expected to transpire. Assigning a price to losses of scenic or recreational value due to nature encroachment is difficult and costly and there is substantially uncertainty surrounding the results. In such situations it is important to consider carefully what one hopes to achieve before ordering the licence applicant to do far-reaching quantification studies.

Whether one decides to require a complete assessment of the impact and abatement costs for each project, or to pursue a simplified method, should be determined on the basis of the size of the anticipated error that the simplified method would entail compared with the costs to the developer of doing the full analysis. The competent energy authorities are also required to make sure that society does not spend more resources on the impact analysis than are reasonable in view of the social benefits that will result as the improved information obtained permits a more socially optimal decision to be made.

4. VALUATION OF ENVIRONMENTAL EFFECTS

4.1 WHY VALUE ENVIRONMENTAL EFFECTS?

The difficulties of valuing environmental impacts must not cause them to be ignored. Even in overall models and system studies for all or parts of the energy sector we must seek to take into account all environmental impacts in the energy sector, including those that are not so easily quantified or valued.

The environmental impacts may appear rather intangible: they often hit scattered, poorly organised groups and public opinion is often divided. Therefore it is not always an easy matter to gain a hearing for environmental concerns unless they are put on the agenda following some kind of campaign. When weighing the many different impacts on different groups, it becomes apparent that considerable social interests may be affected. Valuation makes it easier to collate many individual effects, and compare them to ordinary revenues and costs. Even though such valuation is often speculative and different methods can result in different numbers, it will generally lead to better understanding of environmental concerns in the decision process.

The aim of valuing environmental impacts is two-fold. In the first place, valuation should generally help reinforce environmental concerns in a decision process that often involves major economic interests. In the second, valuation should provide a basis for choosing from among alternative measures, and for applying them in the proper proportion to each other. Environmental protection is not often a case of either-or, but a matter of degree. There must be compatibility of costs taken on in protecting the environment, and the environmental benefits one seeks to achieve. This is true of both the total resource input and of how the resources are divided between various measures.

One cannot count on finding clear, uncontroversial methods of valuation for all imaginable environmental impacts. In practice one must build on estimates of the key environmental effects and then, in interpreting and evaluating the results, take into account the fact that not all factors have been considered. It is better to systematically incorporate qualitative reasoning linked to limited estimates than just to offer a description of the supposed environmental impacts.

The aim of the valuation is not to produce a single figure that represents the ultimate solution: valuation results for relevant environmental amenities should be presented with an account of the uncertainties in the valuation estimates. The economic valuation of environmental benefits is an extension of impact analyses where the consequences of the project are described quantitatively in monetary terms in so far as it is technically feasible to do so.

4.2 VALUATION OF ENVIRONMENTAL IMPACT

In determining the optimal level of environmental impact there is, as already noted, a need for knowledge of both the behavior of the abatement costs, and the costs of environmental impact. The abatement cost curve can be derived from the private investment analysis for the project. It is often a relatively simple matter to calculate what a fish ladder will cost or how much production capacity will be lost if minimum in-stream flow requirements and restrictings on reservoir run-down in imposted on a power plant. Determining the environmental costs as a function of the scope of the impact is more complicated.

In order to estimate the environmental costs one starts, in environmental and resource economics, with the various methods of measuring the members of the society's willingness to pay for changes in the environment (a summary of such methods is given in Appendix 1). Basically what one wants to discover is how much society is willing to pay to limit alterations in the environment. Another way to say the same thing is that the valuation studies attempt to numerically determin welfare changes resulting from environmental disturbanses.

As already noted, there are a number of methods of valuing environmental impacts, and no one method, or set of methods, is generally accepted. Economic valuation of environmental amenities must be based on the aim of bringing together a consensus and creating a legitimate balance between environmental concerns and other social objectives. It is therefore no small problem that there seems to be a tendency for different methods to produce systematically differing results. Often it is not possible to reach an exact and generally accepted numerical estimate of the environmental costs. When valuation analyses are used and presented, it must be made clear that valuation does not provide an ultimate and exact estimate, but that the result depends on the valuation methods and the time at which the study was performed.

4.3 VALUATION METHODS

The reports prepared, see in particular Appendix 1 and Subreports 1, 5 and 7, start with the premise that in the literature on valuation of environmental impacts it is customary to divide the total economic value of a good or a service into its use value and its value. Use value means here the value of using a good, either today or some time in the future; nonuse value means here the pleasure we derive from the resource regardless of whether we actually use it personally. The use value embraces the value one ascribes to safeguarding the resource so that we can use it in the future. This element in the use value is the resource's option value. In many empirical studies it has been found that the nonuse value is many times greater than the use value and that the option value often accounts for a large part of the use value.

The methods available for economic valuation of environmental impacts can be divided into three categories:

- *Direct valuation methods*
- *Indirect valuation methods*
- *Political valuation methods.*

It is also possible to transfer existing valuation estimates from another place and study.

In the *direct valuation methods* the aim is to measure the monetary value of the change in the environmental factor directly, which is done either using experimental markets or by drawing conclusions from markets for other goods, in other words surrogate markets. In experimental markets one simulates the market by creating a situation where individuals have an opportunity to express their willingness to pay for an environmental amenity. Of the methods that build on experimental markets, contingent valuation is the most common and most sophisticated method. In the surrogate market methods one looks at markets for goods and services that are technologically or behaviourally related to the environmental amenities.

In the *indirect valuation methods* one does not seek to measure the preferences for environmental benefits directly, but instead to build on the connection between a given change in a primary environmental factor and its effects on production, health etc (dose response, production function, and impact function are all terms used). When such connections have been identified, the derived effects are valued using one of the indirect valuation methods.

In the *political valuation methods* one reviews previous decisions by political bodies and draws conclusions from them regarding the value the various environmental benefits have been assigned. Since political representatives are democratically elected, the method assumes that their decisions are an expression of the will of the people. Another underlying assumption is that politicians are better informed and more mature in their decision making than most people and that they try to do what is best for the electorate or the population.

Contingent valuation

Contingent valuation is generally done by polling a sample of individuals more or less directly about the value they put on a well specified but hypothetical change in the environment. The valuation that is found, is contingent on the interviewee assuming that the stated environmental change will actually take place and that payment will be demanded (or compensation paid out) as described in the poll survey.

The actual valuation procedure can be designed in many ways. Direct questions about maximum willingness to pay or minimum compensation have been employed. They make for straightforward interviews and the results are readily analyzed. The problem is that the respondent has no incentive to answer honestly, and there is the chance that an answer is adjusted with the express intention of biasing the poll result, for example. This problem can be avoided by offering a clear description of how payment will be obtained (or compensation paid), and the actual amounts involved. The interviewee is then faced with the choice of accepting or rejecting such a proposal. By adjusting the size of the amounts from one participant to the next, it is possible to estimate a distribution curve for willingness to pay. It is also possible to ask the same question once more to the same respondent, using different amounts. In this way the statistical uncertainty can be substantially reduced.

Little is known of the significance of the information given to interviewees and how it affects their estimated willingness to pay. Certain tendencies have been demonstrated that interviewees in contingent valuation studies report a higher willingness to pay than they actually have, because they want to be generous or because they believe that it is the politically or socially correct thing to do.

Surrogate markets

The surrogate market methods look for markets of goods and services that are technically or behaviourally linked to the environmental benefits of interest to the pollster. The changes in supply of environmental benefits lead to changes in behaviour in the markets for the related goods. It is these changes that provide the basis for valuation of the environmental changes.

One such surrogate market method is the hedonic housing price method. Changes in the neighbourhood environment bring about changes in property prices. Based on covariation of locality specific environmental amenities and property prices it is possible to determine the willingness to pay of property buyers for environmental goods.

Another approach is the travel cost method which assumes that users of recreation at site make use of travel and transport services in order to visit the recreation at site. By looking at the demand for such services it is possible to derive the willingness to pay that people have for the natural resources at the recrutional sites.

Recommended methods

Of the methods available, contingent valuation, property prices, travel costs and dose-response are the most suitable for economic valuation of environmental effects of energy projects. The choice of economic valuation method is discussed in Subprojects 1, 5 and 7, and in Appendix 1. It may be useful to relate these valuation methods to the various environmental categories and user interests linked to them. The applications of each method are tabulated in Table 4.1.

Table 4.1 ***Environmental categories and valuation methods***

Category	Contingent valuation	Hedonic housing price	Travel cost	Dose response
Nature conservation	Used	Not used	Not used	Not used
Cultural heritage	Used	Not used	Possible	Not used
Aesthetic interest	Little used	Little used	Possible	Not used
Recreation, hunting, fishing	Used	Not used	Used	Not used
Farming, forestry and reindeer herding	Not used	Not used	Not used	Used
Water supply, recipients	Used	Possible	Not used	Used
Noise, dust	Used	Used	Not used	Little used
Material damage	Not used	Possible	Not used	Used

Farming, forestry and reindeer herding are all industries with direct connection to the productivity of the natural environment. The valuation of environmental consequences is therefore based on the changes in production and market values of the produced goods. A complicating factor is the subsidies and direct payment made to primary industry which may render the product and factor prices unsuitable for evaluating the social value of the goods produced.

Nature conservation concentrates on protecting the natural environment. Therefore the value of the goods produced from the environment make up only a small part of the value of the natural environment. Accordingly any attempt to value environmental protection must be based on some sort of willingness to pay survey, such as contingent valuation.

Cultural heritage is difficult to value. The travel cost method can estimate the value of visiting a cultural monument and thereby experiencing the place. The non-use value that resides in a cultural monument can only be found by willingness to pay studies, but such studies will be fraught with uncertainty and can only be expected to give a very rough indication of the magnitude of the monument's value.

Each valuation method looks at different types of economic value. Contingent valuation can, at least in principle, measure the total economic value. It is important in a situation where one expects that the option value or existence value is substantial. The property price and travel cost methods only look at the present use value of the resource, and do not take into account the option value or non-use value.

One problem in focusing on interest groups and detailed impact categories in willingness to pay studiesis is the confounding of the project at large with the specific aspects to be measured. Thus it may be difficult to a value protection of a cultural monument without simultaneously knowing the context in which the question has arisen.

The conclusions that are made here and in other reviews of valuation methods indicate that contingent valuation is often the only available valuation method. By careful and precise use the method may provide useful estimates of the social cost of environmental impacts. But one must remember the uncertainties and weaknesses involved in the method and take them into account in the full social cost-benefit analysis of the project.

4.4 *COSTS OF VALUATION STUDIES*

It is difficult to make unequivocal statements about the magnitude of the resource input that is required to undertake a valuation. But economic valuation of environmental changes does require both time and money. In those cases where baseline data are not available, it is necessary to draw up plans, collect the data, statistically process the data, estimate results and then test relevant models. The researchers must be familiar with the methods and have a sound basis in economics and statistics. The valuation methods are all new, and only a small number of economists can be expected to be proficient in them at present. This in itself may impose limits on how feasible it is to implement non-market valuation studies.

There are a number of factors that have an important bearing on the cost of a valuation analysis:

- *The type of environmental problem one wishes to value*
- *The method of conducting the interview survey*
- *The size of the sample*
- *The experience and expertise of the analysts.*

Very roughly it can be assumed that a valuation study based on contingent valuation or travel cost will require from four to ten months of work by the analysts. Additional to that are the costs of doing the interviews. A contingent valuation study may demand considerably more time if the questionnaire has to be designed and tested in several stages before it is ready for the actual interviews.

Regarding the population sample then of course the larger the sample, the better the results, and the greater the cost. As a rule of thumb the sample should be at least 500 persons, both for contingent valuation and for travel cost. For contingent valuation the design of the valuation segment of the survey will help decide the size of the sample. If the contingent valuation question is combined with a follow-up question, then much fewer participants are needed in the survey to achieve the same statistical precision as an interview that restricts itself to a round of yes-no questions. If contingent valuation is intended to test the different effects of questionaire design, then a larger sample is necessary.

The type of travel cost model that one plans to carry out will largely decide the size of the population sample. A simple travel cost model based on a few aggregated zones can manage with a few hundred observations from users, while a multinominal model can require many thousand observations from both users and non-users.

The property price method may require several months of work for collection, coding and checking of data. If the data are already in place, a valuation study based on property prices will require a few months. Most property price studies have used huge data bases often containing many thousand observations. A valuation study based on the property price method can be done with far fewer observations, though at the expense of statistical precision.

Transfer of value estimates from one place of study to another is the least resource intensive method. Where comparable studies have already been done it is often feasible to transfer the economic values found to other areas. Such transfer cannot be made mechanically; it must take into account the factors that are unique to the place where the valuation was done and the place where the valuation results will be applied. And while such transfers take little time they do require considerable insight and skill in valuation methods and problems by the persons doing the work.

4.5 *WHAT CAN AND SHOULD BE VALUED?*

The valuation of environmental impacts is usually both time consuming and expensive if sufficient quality is to be achieved. Often one should content oneself therefore with a list and physical description of the environmental impacts. This sort of non-quantitative impact analysis may have a large effect on public opinion and help clarify the decisions facing the community. But when it comes to large projects with many alternative environmental impacts, or where the environmental impacts are common for many projects, the utility of an economic valuation study can be seen more fully to justify the costs of the study.

Environmental analyses should be applied first and foremost to issues of significance for the decisions that have to be made. It is possible to estimate in advance how decisive an environmental evaluation study will be. Some projects are so profitable that it is difficult to imagine that environmental concerns can offset the advantages. Other projects are less obvious, and here environmental concerns may sway the issue. One should always carry out sensitivity tests to examine the variability in the social profitability of the project to the price put on environmental impact.

Traditionally certain environmental concerns have been addressed by strict regulations, protection, building bans, etc. It is possible to work out what a regulation or building ban means in terms of extra costs. These provide an estimate of the implicit value of the environmental good that is protected. In some cases it may turn out, when the bill is finally known, either that the price was unduly high, or that since the price was not higher, more protection is feasible.

Subreport 7 (Supplement) is an analysis of the implicit willingness to pay for environmental benefits built into the governmental consideration of the "Master Plan for Water Courses". Based on the projects in Category I, the implicit willingness to pay for environmental goods was estimated for the various interest groups. The report shows that environmental goods are accorded considerable value and that environmental costs in many cases exceed the development costs.

Implicated parties such as landowners and nature conservation interests may find it advantageous to demand a valuation, depending on what they believe in advance about the outcome. Generally one must assume that a valuation will be asked for by the licensing or regulation authorities. There are good reasons to avoid formal rules that list exhaustive requirements for impact analyses and valuation of environmental impacts without allowing for an evaluation of the value to the decision process of further analyses. The aim must be to deploy the analysis resources where they are likely to give the greatest benefit, and to draw on the knowledge and competence that has already been recorded in reports from similar projects. The factors that should count when deciding how far to go in deciding whether an applicant should carry out a valuation are:

- *Scope of environmental issues:*
  If major social values are believed to be at stake then extensive analyses are indicated.

- *The environmental impact's significance for project evaluation:*
  If the environmental impact can be expected to be crucial for the evaluation of the entire project then this indicates much effort should be made in the analysis stage.

- *Valuation's estimated significance for weighing environmental impacts:*
  If a summary is expected to be sufficient, then no further work should be done on the valuation.

- *Opportunity to rely on previous studies and prior knowledge:*
  In the energy sector as well as in other sectors certain valuation studies have already been performed and an extensive literature is available. Wherever possible this information should be exploited directly or by transfer before undertaking a new study.

- *Whether environmental impacts are unique or more general in character:*
  If the environmental impacts are quite specific for the particular project it may be too expensive to carry out a special analysis. If on the other hand the problem is general in the sense that there are many parallel or similar projects, then the increased utility may justify the costs of a valuation study. If a thorough valuation is carried out for a specific project because one expects to develop generally applicable results, then allocating the costs across a number of projects should be considered.

- *Status of the knowledge produced by further analyses, if undertaken:*
  One should make a bigger commitment if one expects to determine exact and reliable information than if the results are expected to be tenuous.

4.6 VALUATION FOR COMPARISON OF TECHNOLOGIES

So far we have considered valuation of the environmental effects primarily as a potential aid in impact analyses of a given development project. However, our point of departure for the quantification project was largely a wish to obtain a better basis for comparison and selection of different energy technologies:

- *Does gas power entail larger negative environmental impacts than hydro-electric power?*
- *Do the so-called new, renewable energy sources have such small environmental consequences that they more than compensate for their high production costs?*

Such problems are relevant for long term planning of energy questions and when the authorities evaluate principal issues of energy policy. Concrete questions in Norway might be when to phase in gas power, or how much should be allocated by the government to new, renewable energy sources.

In this project we opted to take a broad view and attempted to quantify the environmental impacts of the most likely technologies, and we did so from a desire to be able to compare all environmental impacts caused by each technology. We hoped to gain an idea of the net social costs linked to each technology by adding the value of the environmental impacts — expressed as price per kWh for instance — to the production costs.

A good estimate of the typical environmental costs for individual technologies must meet the following three requirements:

- *All key environmental consequences must be valued*
- *The valuation must be accepted by all interested parties*
- *A complete valuation must be made for many individual projects in each technology.*

It is difficult to meet all these requirements. Many interests, such as cultural heritage and conservation-worthy natural environment, are obviously of great value to many people, but it is hardly feasible to give them an economic value that everyone would accept. The negative social value (i.e. the social cost) of CO_2 emissions may be large, but we know too little about the climatic effects to be able to quantify the impact. We have no evidence to say whether damage from emissions from generation of gas power would represent 0.01, 0.15 or 0.30 kroner per kWh.

If it were possible to create a complete valuation of the environmental effects of a given project, the problems would not stop there. Most effects are project-specific. The variations between individual projects in one and the same technology may be larger than the variations between technologies. If we were able to carry out complete valuations for many different individual projects in the same technology, we might find that the value of the negative environmental impacts of hydro-electric power projects varied between 0.02 and 0.40 kroner per kWh. In that case there is little sense in applying an average impact factor for hydro-electric power and comparing it with a similar average factor for gas power.

In addition to these problems, there are large costs involved in implementing an extensive valuation of many projects in each technology. The environmental valuations that have been done show that there is a long way to go even to achieve a reasonably complete evaluation of a given development project. At the same time we must expect that the environmental values will change a great deal over time as a result of new knowledge and changed preferences.

The fact that we lack a foundation for comparison of the various energy technologies based on complete valuation of all environmental consequences does not mean that such comparisons cannot or should not be undertaken. One must continually make decisions that are based on comparisons of disparate technologies. In such decisions it is right and proper to stress environmental impacts as well as production costs.

5. OVERALL ASSESSMENT OF THE PROJECT

The object of the project was to "lay the foundation for socially rational energy planning". The aim was to obtain information both about the value of the environmental impacts of production and use of energy and the costs of reducing those impacts. The benefit of the project must be evaluated based on whether it can lead to decision processes in the energy sector where:

- *Environmental concerns are less prone to being forgotten or underestimated*
- *The measures implemented to protect the environment give the maximum benefit per money unit spent*
- *There is a reasonable balance between the total costs of the environmental measures, alternativly, the foregone economic gains if the project is left unrelized, and the value of the environmental impacts thereby avoided.*

The information basis necessary to take reasonable account of the environment in the management of hydro-electric power and other energy resources contains three types of information:

- *Summary (catalogue) of potential environmental effects and measures that can counteract them*
- *Impact analyses that quantify (in physical units) each particular environmental effect, discuss the degree of certainty/uncertainty in each effect, and specify in concrete terms the measures that can counteract them.*
- *Economic valuation of the environmental impacts combined with a description of the methods used to do the valuation, and the costs of countermeasures.*

The reports that were raised and presented in Appendix 2 provide primarily a summary of the potential environmental impacts of the various energy technologies. Moreover they provide some physical quantities and offer a summary of potential abatement measures, sometimes with cost estimates. The economic valuation is largely limited to a description of methods and a summary of the valuation studies actually carried out. It is apparent that very few valuations of the environmental impacts of energy projects have been undertaken. Subreport 1 refers to nine such studies in Norway.

The reports provide scant basis for evaluating what it will cost to implement economic valuations. Therefore the reports also provide little guidance for deciding the usefulness of valuing the environmental impacts of individual projects. The review of the various methods in Appendix 1 does indicate none the less that the costs of making such valuations can be substantial.

In the project plan the intention was to present detailed numbers for the environmental impacts of all relevant energy technologies. It was hoped to make so much progress that environmental impacts could be factored directly into the cost evaluations, thereby in part providing a basis for evaluating the various technologies against each other. The aim was to obtain information both about the value of the welfare losses that follow from environmental impacts and the costs of abating these environmental impacts. In other words one wished to provide a basis for drawing curves showing how welfare losses depend on the degree of environmental impact and how costs of abatement measures increase as a result of stricter rules designed to limit environmental impacts.

This was a very ambitious and perhaps unrealistic aim. A more moderate aim would have been to examine what has been done, and how far it is possible to go, in regard to valuation of environmental impacts in the energy sector. A substantial improvement has been made in methods of estimating environmental costs in recent years. But still, as noted above, it is unrealistic to try to build up a data base of all the necessary data about how social welfare is influenced by environmental impacts deriving from the energy sector, or indeed to attempt to estimate the entire abatement costs curve.

In a number of areas, particularly for project and locality specific problems, the costs of producing this type of information far exceed the benefits of improved economic efficiency. In some areas it is not even practicable to produce such information. The work of economic valuation of environmental consequences should for the time being be limited to concrete development projects. Our efforts must be concentrated where it is possible to obtain knowledge of direct benefit to the licensing authorities, developers, nature conservationists, and others.

What may be a key task centrally is to establish a practice whereby an evaluation of the environmental impacts of energy projects is carried out so that environmental measures are introduced in sufficient and reasonable degree. At the same time there should be central guidance, experience gathering and method development.

The utility of the reports is principally to be found in the basis they lay for further information gathering and methodological development. In conjunction with this final report they:

- *Offer a survey of relevant methods of economic valuation of environmental effects*
- *Make it clear that experience in using these methods in the energy sector is largely limited to recreation, hunting and angling, while the effects on health and other industry are poorly elucidated*
- *Provide an indication of the extent to which the results of economic valuation can be exact and relatively uncontroversial.*

They thus provide a basis for evaluation of:

- *If and how far an economic valuation can assist the rational processing of projects with definite environmental effects, in other words act as a conflict resolver in decisions that are environmentally controversial.*

An important lesson is that very many environmental effects are locality specific and often depend on an evaluation that may vary from place to place. That means that, except for air pollution where a general emission tax can be levied, the Norwegian energy sector must account for the environmental effects by ensuring that environmental costs are integrated into each individual project evaluation. For one thing, therefore, one must make project-specific evaluations in order to compare such different energy technologies as hydro-electric power and gas power.

The most visible result of the project is the eight subreports that are presented. But the project cannot be evaluated on the basis of the subreports alone. This final report reviews the principal issues which are only occasionally discussed in the other reports. Another important point was the interdisciplinary contact during work on the reports, and the fact that the reports will be discussed and evaluated in the established circles. Through this process competence are built up and, not least, an understanding of how complex the problems are. An important result of the project is probably that many individuals have acquired and will continue to develop competence and insight.

A follow-up of this investigative programme could be envisaged along three lines:

- *The insights discovered should be applied to further shape the impact analyses that are now being presented for development projects. Criteria should be worked out for determining the useful scope of the analyses, emphasize should be given to utilising already completed studies, and work should be done on methods to summarize large volumes of investigative data.*

- *In special cases one can consider requiring a valuation study of certain environmental consequences, in which case one should later evaluate the utility of the valuation*

- *One should continue to develop modelling tools and analysis methods for use in energy policy.*

APPENDICES

APPENDIX 1: *METHODS OF ECONOMIC QUANTIFICATION OF ENVIRONMENTAL CHANGE*

CONTENTS:

1. INTRODUCTION

The purpose of this Appendix is to provide a summary of the various methods available for the economic valuation of environmental impacts.

Over the past two or three decades many methods have been developed for valuation of nonmarket resources (resources that are not traded directly in any market). A great research effort led to improvements in the methods and they are now considered a part of the economic analyst's toolbox.

Chapter 2 examines how economic valuation of environmental change fits in with the evaluation of energy projects. Chapter 3 looks at the welfare economic basis for economic valuation and the economic value concept is more closely specified and discussed. Chapter 4 examines the most pertinent methods of valuation of environmental change while Chapter 5 is a brief summary of ways of using already estimated social costs of environmental goods in new contexts.

2. QUANTIFYING ENVIRONMENTAL CHANGE

Production, transport and use of energy impact the natural environment and have consequences for the interests associated with it. Under the Planning and Building Act an impact study must be carried out before major projects can be endorsed. For hydro-electric power projects and transmission lines it is also necessary to go through a licensing process.

The impact analysis is intended to illuminate all consequences of a project and to identify the impacted interest groups. The various consequences should be described qualitatively and wherever possible also quantified in relevant physical units. Based on the identification an evaluation can be made of the economic value that the consequences have for each group. A rational social evaluation of projects must take into account all costs and all benefits, both for the individual project and for the development as a whole.

> **Economic valuation** of environmental change quantifies in monetary terms the economic value of the environmental impacts that implementation of a project will cause members of society.

The natural environment produces a range of different goods and services, and the environmental consequences of projects can be seen as an impact on the production of these goods. For the goods that are traded in a market, the market price is a suitable basis for valuation of the consequences.[1] A great many of the environmental goods and services that people enjoy are nonmarket goods and services. For these we must define other ways of estimating the value of a change. In order to make a complete analysis of how energy projects impact on welfare it is necessary to quantify the physical consequences that the projects may entail for the environment and to determine a price for the various environmental goods that are affected.

Below we will discuss some of the available valuation methods that can quantify the economic value of environmental *changes* resulting from the implementation of projects.

> **Sequence for valuation of environmental consequences:**
> 1. Qualitative description
> 2. Quantitative description
> 3. Economic valuation

3. ECONOMIC VALUE

3.1 WELFARE THEORY

The basis for the value concept in economic welfare theory is the individual's *utility function*, which describes how individuals, based on given prices, income and available quantity of public goods, prioritise the various goods they can choose among.[2]

Public goods are those that are available to all members in a community. Thus environmental goods can also be seen as public goods. Environmental goods may be available locally, regionally, nationally or globally. An important feature of public goods and environmental goods is that individuals in the short run cannot influence the amounts of them.

Where income, prices, or the quantity of a public good changes, the individuals will adjust to the new situation. This adjustment will take place in market goods. The utility function indicates whether the changes led to an improvement in welfare for an individual (higher utility level) or a decrease (lower utility level).

The utility function can be used to evaluate the consequences of a project on a person. Before the project is initiated the person enjoys a given utility level. The implementation of the project will affect prices, incomes and the availability of public goods, and lead to a new adjustment and thus a new utility level. The change in utility level can be *measured* in monetary units as the change in income after implementation that buys the same utility level as the person enjoyed before the project. This value, the *compensating variations*, is positive when the implementation of a project leads to an increase in utility value, and negative when the utility level is reduced by the project.

Compensating variations is that change in income an individual require in order to be on the same utility level after the project is implemented as before the change.

Where the project results in an improvement in utility level for a person, the compensation pay expresses the *maximum willingness to pay* to carry the project through. If the project, on the other hand, leads to a reduction, then the compensation pay is the *minimum compensation* that is necessary in order for it to be acceptable to implement the project. Often the willingness to pay is used as a synonym for compensating variation, but it must be kept in mind that the willingness to pay may sometimes be negative.

The principle behind social cost-benefit analysis is that if the sum of compensating variation for all members of the community is positive, then it is socially desirable to carry through the project. The members of the community who suffer a worsening, can be compensated from the aggregate compensating variation, and the remainder can be distributed to all the other members of society so that *all* members are lifted onto a higher utility level than before the project.

The social value of an environmental change is equal to the willingness to pay for it summed over all members of the society.

The aggregate compensation variation identifies the Pareto improvements that are available to the society. A Pareto improvement is one that leaves some people better off and nobody worse off. There has been some discussion whether compensation should be made to those made worse off after a project implementation so that implementation will result in a higher welfare level for society.[3] But in practice it is unusual for full compensation to be made to all parties. Just what compensation should be given is usually determined in principle by constitutional law.

The conceptual point of departure for economic valuation is the *total economic value*, or simply *total value* (TV). The TV of a resource is the perceived value of its availability and utility to the individual. A change in resource availability changes the total value of the resource, and the change can be measured, for instance by working out the compensating variation. The aggregate sum of individual compensating variation forms the basis for the social value.

In the total value of a resource there are two main components: use and non-use values.[4]

Total value = total use value + non-use value

In valuing the environmental consequences of a project one looks at the change in TV that occurs due to project implementation. This change can be gauged in monetary units using the compensating variation,[5] which makes it possible to compare the measured economic value of the environmental change with other costs and benefits of the project.

3.2 USE VALUE

Use value is the value of people's use of the natural environment. A person's use of the natural environment may consumptive, which prevents others from enjoying the same resource. Examples are hunting and sports fishing. The use of nature can also be non-consuming, examples being nature photography and bird-watching.

The utility value of a resource is made up of contributions from a number of sources:

1. ***Current use value** is the value of the current use of the resource*
2. ***Future use value** is the value we now expect future use of the resource to have.*

Direct use value = current use value + future use value

The distinction between current and future use value influences the quantification method employed. Current and former use value are ex post. For many usage types statistics are kept on a routine basis. Future use is ex ante and therefore unknown. The plans for future use change as unforeseen events unfold. Future use can be extrapolated from historical data or from studies of explicit assumed intentions regarding future use.

The uncertainties of future use and availability result in different types of *option value* for a resource:

3. ***(Ordinary) option value:** Persons wishing to use a resource in the future are willing to exchange a part of today's income for an option (purchase entitlement) that ensures the availability of the resource for future use. The option value is positive in situations where a person is sure of his desire to use a resource in the future and there is simultaneously*

uncertainty about its future availability. In a situation where an individual is uncertain about his own future preference for a good and the availability of the good is not in doubt, the option value may be negative. The option value can thus be either positive or negative.[6]

4. ***Quasi-option value** expresses the value of avoiding or delaying the decision to irreversibly change the natural environment or eco-system. This value arises due to the chance that information may become available in the future upon which to base a better decision.*[7]

The four value categories outlined above together make up the total use value of a given resource.

Total use value = current use value + future use value + option value + quasi-option value

3.3 *INTRINSIC VALUE*

The nonuse value of a resource is that part of the TV that is not motivated on the basis of actual or potential use of the resource either today or in the future. Distinctions are often drawn between three types of nonuse value:

1. ***Existence value** which is the value of knowing that the resource exists*
2. ***Bequest value** which is the value of knowing that the resource will be available to future generations*
3. ***Preservation value** which is the value associated with knowing for sure that a resource is protected.*

The three categories are evidence of three different *motives* why people have positive value perceptions of resources apart from the use value. As they are presented here the categories complement and overlap each other. There is also the difficulty of drawing a line between option value on the one hand and bequest and preservation value on the other. Without looking more deeply into the problem it can be said that the nonuse value of a resource is motivated by and composed of the existence, bequest and preservation values.[8]

Intrinsic value = existence value + bequest value + preservation values.

4. VALUATION METHODS

4.1 INTRODUCTION

This section will look more closely at the most important methods for economic valuation of environmental change.[9] The methods can be gathered into three main groups:[10]

1. ***Direct** valuation methods*
2. ***Indirect** valuation methods*
3. *Methods based on **political** processes.*

4.2 DIRECT METHODS

The direct valuation methods seek to measure by direct means the economic value of changes in environmental factors. It can be done either by observing the behaviour of *constructed markets* or in markets for other, related goods, *surrogate markets*.

Construction of markets for environmental goods can be made by simulating market-like situations for environmental goods. The simulated market creates a *hypothetical* situation where individuals have an opportunity to show their willingness to pay for changes in environmental goods. This valuation process is called contingent valuation.[11]

It is also possible to introduce *experimental markets* where no market existed before. Where contingent valuation is an oft-used method there are few recorded applications of experimental markets for valuation of environmental goods.[12] The reason is that valuation based on experimental markets is difficult to carry out and a very costly valuation method. The method is thus inherently limited and cannot be recommended as a general valuation model (Mitchell and Carson 1989).[13]

The surrogate market methods look for markets for goods and services that are either *technically* or *behaviourally* related to the environmental goods one is interested in. The changes in availability of environmental goods lead to a change in behaviour in the markets for the related goods. It is these changes that form the basis for valuation of the environmental changes. Such a derived market method is the *hedonic property price method.* Variations in neighbourhoods are reflected in varying property prices; and based on the covariance of specific local environmental goods and property prices it is possible to estimate the willingness to pay that property buyers exhibit for environmental goods.

The *travel cost method* takes the starting point that users of recreation areas use travel and transport services to visit those areas. By examining the demand for such services it is possible to derive the willingness to pay that people have for the natural resources that are at the heart of the recreation areas.

Of the direct valuation methods the hedonic property price, travel cost and contingent valuation methods are the most interesting in connection with evaluation of the environmental consequences of energy projects.

Hedonic property price method

Introduction

The idea behind the hedonic price method is that the price of housing reflects the local environmental conditions. View, noise, traffic and air pollution are all examples of local environmental factors that influence the buyer's willingness to pay for a place to live. Assuming that environmental factors vary from place to place, then the prices of housing will reflect these variations.

Description

The main features of the property price method are:[14]

1. *Using statistical methods the effects on housing prices of environmental factors are isolated from the effects of factors related to the actual house and its neighbourhood.*

2. *Based on the statistical model for housing prices the willingness to pay is derived for changes in environmental qualities. There are many aspects of the actual house (such as size, quality, furnishing and lot size), its location (convenience for schools, shops and public transport) and its neighbourhood (playgrounds, clubs and associations) which determine the price of the house in conjunction with the environmental factors. If the statistical model of property prices is to reflect the effect of any of these factors then it must include them all. If any of the variables are omitted from the analysis then the estimated effects of the included variables will deviate from*

their true value (will be biased). Therefore it is extremely important that data are complete and detailed in describing both the actual house and the surroundings.

An estimate of the property price function is just the first step in the analysis. The hedonic price function tells us how the equilibrium price for the property will vary. Based on the hedonic price function the marginal willingness to pay can be calculated for environmental factors and other relevant characteristics of the house. The marginal willingness to pay then forms the basis for estimation of the inverse demand function for environmental goods. When the demand function is known the analyst has a basis for calculating the willingness to pay (compensating variation) for change in the environmental factors.

The property prices will reflect the willingness to pay that house buyers have for environmental goods to the extent they are aware of them and their variation. Environmental factors that were unknown to the buyer when making the purchase are not reflected in the price.

Discussion

Data: Implementation of the property price method requires very detailed synopses of transactions in the housing market:

- *Property*
- *Locality*
- *Buyer.*

Sadly this type of data is not generally available for ordinary transactions in the housing market. Therefore the primary data must be specifically collected in each case if one is to use the hedonic price method. In addition to detailed information there will also be a need for a large number of observations, which means data collection will be costly or even impossible due to lacking information.

Statistical method: Both the estimation of the property price function and the demand function for the environmental good make use of regression analysis. It turns out that the results are very sensitive to selection of function form and variables in the model, so a high level of statistical skill is required in carrying out property price studies as well as care and insight in interpreting the results.

Result: Once suitable data are found, the property price method will produce estimates of the social value (cost) of the impact on the local environment. Where data availability is limited, the method will define a lower limit for the social cost. The method estimates parts of the use value, and ignores the option value and any nonuse value components in its evaluation of the environmental good.

Precision: The hedonic property price method has been shown to have relatively low precision. Pearce and Markandya (1991) believe that the method itself is to blame and that one cannot therefore expect an increase in precision as a result of better measurements of variables or improved statistical methods.

Assumptions: The basic assumption underlying the hedonic property price method is that house buyers are aware of the environmental variations between alternative home locations, and that they choose the location that gives them the optimal combination of environmental goods. The prices in the housing market must be such as to reflect the variations in the environment and the sales price for the property must always be the equilibrium price in the property market.

Resource input: Analyses based on the property price method demand personnel having competence in economics and statistics as well as knowledge of the property market. The time needed is difficult to judge,[15] but from six months and up is a reasonable estimate. The time spent depends mostly on the availability of data and how long it will take to collect, prepare and finalise data for the analysis.

Applications
The property price method is generally applicable to the valuation of environmental conditions which one assumes *a priori* are reflected in the prices of houses. Local environmental consequences like noise, dust and smell are relevant impact categories.

Travel cost method

Introduction
The other behavioural valuation method we will examine here is the travel cost method, which has its roots in the need to determine a value for recreational areas, which is where the method has found most use.

The theory behind the method is to consider costs of travelling to a recreational area as a price of the visit to the area. This price is different for different people with different journey distances. The assumption is that the relative visitation frequency from the different geographical areas at different journey distances from the recreational area would have been the same if the journey distance had been equal for all areas.

This provides a starting point for estimating a demand function for visits to the recreational area. The demand function then provides a basis for estimating the use value of the recreation area.

If the travel cost method is to be used to value the *change* in the quality of a recreation area, the relevant quality traits of the area must be included in the demand functions. The most straightforward model of the travel cost method is outlined here, but in practice there are many variations on the travel cost theme.

Description
Very roughly the procedure for applying the travel cost method is as follows:[16]

1. *Draw up questionnaire containing, among other things:*
   - *Address*
   - *Visitation frequency*
   - *Information on last trip*
2. *Carry out questionnaire survey*
3. *Calculate travel costs*
4. *Create quantitative measures of environmental quality in each area*
5. *Estimate statistical model of demand for trips*
6. *Calculate willingness to pay to bring about change in environmental quality.*

Discussion
Data: The travel cost method can be built on studies among users of a recreational area or studies of the entire population. For user studies it is common to use direct interviews with the user at the site. Otherwise telephone or postal polls can be taken to study both users and non-users.

In some cases already collected data can be used, for example data on sales of fishing licences and hunting licences for specific areas.

A critical element in the most common formulations of the travel cost method is the value of the estimated alternative cost of the journey time.[17] By using different alternative costs the results may vary a great deal. Experience with attempts to obtain the alternative cost by questionnaires has been mixed and it is generally not worth the additional cost (Anderson and Bishop 1986).

Statistical method: Regarding the use of statistical methods a great deal of progress has been made in the past 5-10 years.[18] The choice of statistical method depends on what kind of sample the data is based on (user sample or population sample), what sort of model will be used (based on zone or single observations) and whether it is a matter of visiting one or several areas.

When the sample is of users, then information on non-users is lacking from the model. Estimation of a regression model without taking this fact into account leads to bias in the model parameters and thus to bias in the resulting economic value (Pearce and Markandya 1989, p. 45-46).

Models based on single observations are generally of the discrete choice type demanding an estimation of the logit/probit models (for trips to an area) or multinominal logit models (for several areas).[19]

Result: The different variations on the travel cost method estimate the demand functions for the recreation areas. The method, in principle, values the actual area, not the quality traits of the area. Some of the newer methods based on single observations are, in principle, able to estimate the value of quality traits of a recreational area (Bockstael, McConnell and Strand 1991).

Precision: In applying the travel cost method, value estimates have been found that seem commonsensical. Despite this, Anderson and Bishop (1986) claim that when evaluating assumptions and statistical problems, it is hard to say how good the value estimates from the travel cost method really are.

Assumptions: The travel cost method builds on two main assumptions:

1. *The environmental good that we wish to value must be used in conjunction with some other good that is traded in a market, such as visits to the area which depend on travel or transport services*
2. *The quality of the environmental good must not affect the utility level of people not using the recreational area.*

One consequence of the second assumption is that the travel cost method is only capable of estimating the use value and none of the other value components.

There are also assumptions that must often be made when using the travel cost method:

1. *The alternative cost of the travel time must be estimated*
2. *Alternative recreation areas must be elucidated (i.e. substitution possibilities).*
3. *The trip to and from the recreation area must have a single purpose and a single destination.*

Resource input: The resource input for using the travel cost method is expected to be less than when using the property price method. An estimated 3-4 months or more seems reasonable for a straightforward travel cost model with modest data requirements. Complex models that take into account many alternative visitation areas and travel routes are more time-intensive and place increasing demands on statistical analysis methods and data processing. The collection of data can take a lot of effort during certain parts of the analysis depending on how the process is devised.

Applications

Despite many examples of the travel cost method there are still reservations in making use of it (Pearce and Markandya 1989, p. 47). The costs of obtaining data can be high. Certain of the assumptions behind the model may be suspect and it is not at all evident which statistical estimation methods should be used.

The travel cost method is useful for estimating the use value of a recreational area and the environmental goods that are associated with it. All in all, considering the costs of collecting data and the costs and pitfalls of the analysis process, the method is best suited to valuation of public goods at a specific recreational area. For valuation in a case where there are several likely visitation areas, the costs and complexities of the method increase with increasing number of areas, while at the same time the level of precision decreases.

Contingent valuation

Introduction

The idea of contingent valuation of environmental goods is to ask a sample of individuals more or less directly about their valuation of a well-defined but hypothetical change in the environment. The valuation that transpires is contingent on whether the interviewee believes that the environmental change will actually take place and payment will be demanded (or compensation paid out) as described by the interviewer.

The actual valuation procedure can be designed in many ways. Direct questions about maximum willingness to pay or minimum compensation have been employed. They make for straightforward interviews and the results are readily analyzed. The problem is that the respondent has no incentive to answer honestly. This pitfall can be avoided by offering a clear description of how payment will be obtained (or compensation paid), and the amounts involved. The interviewee is then faced with the choice of accepting or rejecting such a proposal. By adjusting the size of the amounts from one participant to the next, it is possible to estimate a distribution function for willingness to pay. It is also possible to ask the same question once more to the same respondent, using different amounts. In this way the statistical uncertainty can be substantially reduced.

Description

The main elements in contingent valuation are schematically as follows:[20]

1. *Collection of data by interview surveys (direct interview, telephone interview or postal poll) or using computerized experiments*
2. *Design of questionnaire containing several parts for collection of background information for use in contingent valuation*
3. *Valuation segment comprising:*
   - *explanation of the base-situation: What is the environmental good, how much is available, and how is it made available*
   - *definition and explanation of the change in the availability of the good*
   - *establishing the condition under which the choice will be made*
   - *component for elicitation of valuation*
4. *Statistical analysis of collected data leading to estimate of value of environmental good.*

When it comes to the valuation elements there are several options:[21]

1. *Direct question about maximum willingness to pay*
2. *Payment-card with several payment alternatives*
3. *Repeated (iterative) bidding procedure*
4. *Yes-no questions with a simple alternative*
5. *Yes-no questions with a simple alternative with follow-up.*

The first two options are plagued by the possibility of strategic responses. Repeated (iterative) bidding procedures are often a long-winded examination of whether willingness to pay is larger or smaller than a bid. One has wondered if the first bid generally determines the final outcome of the bid procedure (anchor effect). Yes-no questions offer a lower statistical precision than the other methods, but avoid the problems of strategic responses. Yes-no questions with a *single* follow-up increase the statistical precision considerably without opening the pandora's box of strategic response. In some applications of the method it seems that the persons taking part in the survey answer *yes* to be polite or agreeable, or because they consider it the expected answer, in other words the politically correct or socially acceptable answer.

It is difficult to say generally what type of procedure is preferable, but a procedure based on a yes-no-format with a follow-up has some advantages.

Discussion

Assumptions: Contingent valuation builds principally on two assumptions:

1. *Interview participants understand and believe in the hypothetical situation they are presented with*
2. *Interviewees respond honestly to the valuation procedure.*

Result: Contingent valuation estimates the willingness of people to pay for environmental change. The method can be used to arrive at the total value of the environmental change, or elements of it such as direct use value, option value and nonuse value. Although in principle it is possible to determine the different elements of the total value using contingent valuation, researchers are warned against doing so since respondents often have difficulty distinguishing properly between differently formulated questions about value elements. Moreover the uncertainties of taking the issue apart into its elements are believed to be very great. The results are contingent, not only on the hypothetical description, but also the mode of payment described and the context in which the valuation is made.

Precision: In applying contingent valuation there are a number of matters that affect the precision of the value estimates. Both the type of information that is provided and the way the questionnaire is designed can influence the outcome of the valuation (Mitchell and Carson 1989, Strand and Wenstrøp 1991). In this context the design of the questionnaire is important. By varying its design in a systematic manner it is possible to test and verify any bias that the design may induce.

Both the statistical precision and the stability of the value estimates depend on the public goods that are being valued: in those cases where a realistic and credible account of the environmental goods and the impacts that may arise is given, the value estimates are precise and relatively stable. This is particularly true for environmental issues that are well known and which the participants are well aware of. For unfamiliar or hypothetical environmental issues the value estimates are uncertain and often superficial. This means that contingent valuation provides the best results in the case of concrete, relevant and credible environmental impacts.

Resource input: Studies based on contingent valuation demand the collection of data from interview surveys. They can be time-consuming and costly depending on the design of the study. Apart from data collection it is reasonable to expect 4-6 months to be spent on the project, or more, depending on the subject of the valuation and how much effort is necessary and desirable to finalise the design of the actual questionnaire form.

Applications

Contingent valuation has been used to value many environmental goods that were formerly considered impossible to value. In many situations the contingent valuation is often the only available valuation method (Pearce and Markandya 1991). This is particularly true of value elements apart from use value, such as option value and non-use value, and for the non-market environmental consequences.

Many of the applications of contingent valuation have been severely criticised. In connection with evaluation of environmental consequences of energy projects the method is none the less a useful one. The environmental problems and their backgrounds are already familiar, and if the information in the valuation study is based on knowledge that is already set out in the impact analysis, the admittedly hypothetical situation that the valuation is contingent on will have a very real ring. Thus several of the prerequisites for a successful study are in place. In the design of the valuation one should avoid too fine a focus on simple project impacts as it is then difficult to distinguish clearly between specific impacts and the whole project.

4.3 INDIRECT METHODS

Indirect valuation methods do not attempt to measure preferences for environmental goods directly: instead the methods build on a dose-response relation between the primary environmental factor and a consequence of it (Pearce and Markandya 1991). Examples of dose-response relation are those between air pollution and health, or between air pollution and corrosion of buildings and materials, or damage to vegetation. When such relation have been found, the valuation of the derived effects can be done either using one of the direct valuation methods already described or using estimated damage functions.

Damage functions

Description
Valuation of environmental change using impact functions will be only briefly described here.[22] The procedure is schematically:

1. *Description of how the environmental change will affect production possibilities geographically and temporally*
2. *Determination of effect on factor and product prices of changes in production possibilities*
3. *Identification of adjustments that the implicated producers and consumers can make to minimise losses or maximise profits as a result of the changes in possibilities and prices.*

The experience in damage such valuation models indicates that it is important to use relevant models of the physical and biological relationships that underlie the valuation. The models must be sufficiently flexible to handle considerable substitution among production factors.

Resource input
Analyses based on damage functions demand access to personnel who have both knowledge of economics and of the relevant physical and biological relationship. In the situations where already developed models can be deployed, the number of months of work needed will be relatively modest. If physical or biological models of any size need to be developed, the time required can multiply many times. It has turned out that in many situations relatively simple models are fully adequate to provide a first estimate of the value of environmental change (Adams and Crocker 1991).

Applications
Valuation of environmental change using impact functions is particularly apt where the changes have consequences for production of marketable goods. The effects of pollution and changes in water courses on agriculture, forestry and commercial fisheries are examples where such studies have been performed. Even damage to buildings and landmarks resulting from air pollution can be quantified using the method.

4.4 VALUATION THROUGH POLITICAL PROCESS

Political decisions made by democratically elected representatives can be expected to address two pertinent valuation problems in two different ways.[23] The first is that since the representatives are democratically elected, their decisions should be valid as an expression of the "will of the people" in the particular valuation matter. But there are many issues that decide whether a voter chooses one party or the other, and therefore many minor environmental cases may have little significance for voting in an election. The politicians' decisions will then ideally provide an approximate expression of the population's valuation of the issue in question (Strand and Wenstrøp 1991).

The second is to imagine that politicians aim to do what is best for the electorate or population, and that their decisions are based on better information and more "mature" judgment than the population at large would be able to muster for decision making. The so-called *costs method* (Hervik and Risnes 1983) starts with this reasoning. The idea is to study how much added cost the authorities are willing to accept in addressing specific environmental concerns in connection with a project. Based on decisions to go ahead with projects having different commercial profitability and different environmental consequences, it is possible to calculate the value the authorities implicitly placed on the respective environmental impacts.

The costs method provides an estimate of the value of the environmental consequences of given projects. Where the value of the environmental consequences of new projects needs to be quantified, earlier value estimates can be *transferred* from one project to the other, or from one geographical area to another, or from one point in time to another. Such transfers of value estimates raise a number of methodological issues that will be illuminated in Chapter 5.

4.5 RELEVANT METHODS

The methods that are the most pertinent will depend largely on the environmental consequences that need to be valued. In general the hedonic property price method, travel cost method and damage function method will use only catch the direct value of the environmental good. In order to value environmental goods that are believed to have a considerable option or nonuse value, the contingent valuation approach is the only viable one. All methods if properly applied will produce sensible estimates of the economic value of environmental goods.

Within each of the methods there are many opportunities for designing analyses for application to specific projects. Previously completed studies and evaluations of them will provide points of reference for the design of new studies.

If we look at the types of study that have been carried out[24] and at the technical literature in the field, we see that some valuation methods are especially popular for a given problem, but not others. Table 4.1 summarises the valuation methods that have been used for the various categories of environmental goods.

Table 4.1 Environmental categories for impact costing methods

Category	Contingent valuation	Hedonic property price	Travel cost	Dose response
Health benefits	Used	Used	Not used	Used
Material damage	Possible	Not used	Not used	Used
Vegetation	Possible	Not used	Not used	Used
Aesthetics interest	Used	Used	Used	Not used
Recreational value	Used	Not used	Used	Not used
Noise impact	Little used	Used	Not used	Not used
Bio-diversity	Little used	Not used	Possible	Possible

5. TRANSFER OF ESTIMATED ENVIRONMENTAL COSTS

The transfer of value estimates from one study area to another is the least resource intensive method available. Where comparable studies have already been carried out, then it should often be possible to transfer the available economic values to other, new study areas. Such a transfer cannot be made mechanically, but must take into account the factors that are unique in the area where the valuation was performed and the area where the valuation result will now be applied.[25] Although such transfer demands little time it is necessary for the analyst to understand the valuation methods and problems involved.

It is important to stress that sensitivity analyses should always be performed in connection with transfer of a value estimate in order to see how sensitive the estimated social costs and benefits of the project is to the environmental costs one intends to transfer. In situations where it turns out that the social outcome is very susceptible to the estimated environmental costs that are transfered from another place, special valuation studies should be performed to lessen the uncertainty in the environmental cost figures.

6. ENDNOTES

1. Methods for economic evaluation of environmental impacts in the case of marketable goods are discussed in Mattson (1977) and Freeman (1977).

2. See Johansson (1987) or Kolstad and Braden (1991) for a technical description of the economic theory that underlies the utility function and consumer's surplus in the valuation of environmental goods. A less technical account is given in Pearce, Markandya and Barbier (1990) and Pearce and Turner (1990). Boadway and Bruce (1984) offer a general account of the economic welfare theory.

3. See for example Graaff (1957), Boadway and Bruce (1984), and Mattson (1977).

4. The technical literature contains a lively debate on the most suitable breakdown of Total Value and the contributing elements that make up TV. The presentation here builds principally on Randall and Stoll (1983). For similar treatments see for example Mitchell and Carson (1989), Pearce et al (1990), Pearce and Markandya (1989) or Randall (1991). Mitchell and Carson (1989, Ch. 3) look in particular at the connection between the various value components and the valuation method.

5. A good example of a study that estimates the various value components is Brookshire, Eubanks and Randall (1983).

6. Bishop (1982) gives a detailed discussion of option value and a survey of the relevant literature.

7. Fisher and Hanemann (1987) discuss the quasi-option value in more detail.

8. The literature does not always clearly distinguish between nonuse value and existence value since the terms are often used to define each other. For further discussion of nonuse value and total value, see for example Randall and Stoll (1983).

9. There are now many surveys of the economic valuation methods for environmental goods. In connection with this project a report (Strand and Wenstrøp 1991) was raised to summarise the methods and their applications. Also worthy of mention are Pearce and Markandya (1991), Mitchell and Carson (1989, Ch. 3), Johansson (1987), and Anderson and Bishop (1986). Bentkover, Covello and Mumpower (1986) give a summary of the field as it was understood in the mid-eighties. A new compendium of articles (Braden and Kolstad 1991) discusses the various valuation methods at a high level of technicality and is important reading for the practitioners who do the valuation studies.

10. This division builds on Pearce and Markandya (1991), but there are also other ways of grouping valuation methods. See for example Strand and Wenstrøp (1991), Braden, Kolstad and Miltz (1991) or Smith and Krutilla (1982).

11. The name "contingent valuation" is also often used in Norwegian. Other names are "survey method" and "interview method".

12. A well known study that uses experimental markets was carried out by Bishop and Heberlein (1979). In Norway the method has been used for sale of fishing rights in certain salmon rivers, see Strand and Wenstrøp (1991, p. 26-27).

13. Mitchell and Carson (1989) make the point that the method is an important tool for gauging the validity of the results that are produced using contingent valuation.

14. For detailed discussions of the method, see Pearce and Markandya (1989, Ch. 4.2), Anderson and Bishop (1986), Freeman (1979, Ch. 6), and Johansson (1987, Ch. 7.3). The theory behind the method is presented by Freeman (1979) and Palmquist (1991).

15. The time required to carry out a given valuation study depends on how much of the preparatory work has already been done and how much experience the personnel have with this type of analysis.

16. For detailed accounts of the method, see Pearce and Markandya (1989, Ch. 4.5), Anderson and Bishop (1986), Freeman (1979, Ch. 4), and Johansson (1987, Ch. 7.7). The theory underlying the method is given by Mäler (1974, Ch. 5.6), and Bockstael et al (1991).

17. See the discussion in Anderson and Bishop (1986) and Strand and Wenstrøp (1991).

18. See Bockstael et al (1991) and Smith (1991).

19. See Hanemann (1984) for a theoretical presentation; and Wegge, Carson and Hanemann (1988) and Bergland and Brown (1988) for examples of practical applications.

20. For detailed accounts of the method, see Pearce and Markandya (1989, Ch. 4.4), Anderson and Bishop (1986), and Carson (1991), and in particular Mitchell and Carson (1989) for guidance in using the method. A critical evaluation of the method and its limitations is given in Cummings, Brookshire and Schulze (1986).

21. See Mitchell and Carson (1989) for a detailed discussion and references to the empirical literature.

22. For detailed accounts of the method see Pearce and Markandya (1989, Ch. 5), Freeman (1979, Ch. 4), and Adams and Crocker (1991).

23. Our presentation here builds on Strand and Wenstrøp (1991).

24. Strand and Wenstrøp (1991) offer a comprehensive summary of valuation studies that have been carried out.

25. Only in recent years have the problems of transferring valuation results been examined in their full breadth. See the special edition of *Water Resources Research*, June, 1991.

7. LITERATURE

Adams, R.M. and Crocker, T.D. (1991), 'Materials damages', in J.B. Braden and C.D. Kolstad, Ed., *Measuring the Demand for Environmental Quality*, North-Holland, Amsterdam, p. 271-302.

Anderson, G.D. and Bishop, R.C. (1986), 'The valuation problem', in D.W. Bromley, Ed., *Natural Resource Economics: Policy Problems and Contemporary Analysis*, Kluwer-Nijhoff Publishing, Boston, MA, p. 89-137.

Bentkover, J.D., Covello, V.T. and Mumpower, J., Ed. (1986), *Benefit Assessment: The State of the Art*, D. Reidel, Dordrecht.

Bergland, O. and Brown, W.G. (1988), Oregon recreational ocean salmon fishing, paper presented at the AERE workshop, Seattle, WA.

Bishop, R.C. (1982), 'Option value: An exposition and extension', *Land Economics* 58(1): 1-15.

Bishop, R.C. and Heberlein, T.A. (1979), 'Measuring values of extramarket goods: Are indirect measures biased?', *American Journal of Agricultural Economics* **61**: 926-930.

Boadway, R.W. and Bruce, N. (1984), *Welfare Economics*, Basil Blackwell, Oxford.

Bockstael, N.E., McConnell, K.E. and Strand, I.E. (1991), 'Recreation', in J.B. Braden and C.D. Kolstad, Ed., *Measuring the Demand for Environmental Quality*, North-Holland, Amsterdam, p. 227-270.

Braden, J.B. and Kolstad, C.D., Ed. (1991), *Measuring the Demand for Environmental Quality*, North-Holland, Amsterdam.

Braden, J.B., Kolstad, C.D. and Miltz, D. (1991), 'Introduction', in J.B. Braden and C.D. Kolstad, Ed., *Measuring the Demand for Environmental Quality*, North-Holland, Amsterdam, p. 1-15.

Brookshire, D.S., Eubanks, L.S. and Randall, A. (1983), 'Estimating option prices and existence values for wildlife resources', *Land Economics* 59(1): 1-15.

Carson, R.T. (1991), 'Constructed markets', in J.B. Braden and C.D. Kolstad, Ed., *Measuring the Demand for Environmental Quality*, North-Holland, Amsterdam, p. 121-162.

Cummings, R.G., Brookshire, D.S. and Schulze, W.D. (1986), *Valuing Environmental Goods: An Assessment of the Contingent Valuatio' Method*, Rowman and Allanheld, Totowa, NJ.

Fisher, A.C. and Hanemann, W.M. (1987), 'Quasi-option value: some misconceptions dispelled', *Journal of Environmental Economics and Management* 14(2): 183-190.

Freeman, III, A.M. (1979), *The Benefits of Environmental Improvement: Theory and Practice*, Johns Hopkins University Press, Baltimore, MD.

Graaff, J.d.V. (1957), *Theoretical Welfare Economics*, Cambridge University Press, Cambridge.

Hanemann, W.M. (1984), 'Discrete/continuous models of consumer demand', *Econometrica* 52(3): 541-561.

Hervik, A. and Risnes, M. (1983), Økonomiske metoder for å måle miljøkonsekvenser av vannkraftutbygging (Economic methods of measuring the environmental consequences of hydro-electric power development), MVU-rapport 2, NVE, Oslo.

Johansson, P.-O. (1987), *The Economic Theory and Measurement of Environmental Benefits*, Cambridge University Press, Cambridge.

Kolstad, C.D. and Braden, J.B. (1991), 'Environmental demand theory', in J.B. Braden and C.D. Kolstad, Ed., *Measuring the Demand for Environmental Quality*, North-Holland, Amsterdam, p. 17-39.

Mäler, K.-G. (1974), *Environmental Economics: A Theoretical Inquiry*, Johns Hopkins University Press, Baltimore, MD.

Mattson, K. (1977), *Lönsamhet från samhällets synspunkt* (Profitability from society's point of view), Akademiförlaget, Stockholm.

Mitchell, R.C. and Carson, R.T. (1989), *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Resources for the Future, Washington, D.C.

Palmquist, R.B. (1991), 'Hedonic methods', in J.B. Braden and C.D. Kolstad, Ed., *Measuring the Demand for Environmental Quality*, North-Holland, Amsterdam, p. 77-120.

Pearce, D., Markandya, A. and Barbier, E.B. (1990), *Blueprint for a Green Economy*, Earthscan, London.

Pearce, D.W. and Markandya, A. (1989), *Environmental Policy Benefits: Monetary Valuation*, OECD, Paris.

Pearce, D.W. and Turner, R.K. (1990), *Economics of Natural Resources and the Environment*, Johns Hopkins University Press, Baltimore, MD.

Randall, A. (1991), 'Total and nonuse values', in J.B. Braden and C.D. Kolstad, Ed., *Measuring the Demand for Environmental Quality*, North-Holland, Amsterdam, p. 303-321.

Randall, A. and Stoll, J.R. (1983), 'Existence value in a total valuation framework', in R.D. Rowe and L.G. Chestnuts, Ed., *Managing Air Quality and Scenic Resources at National Parks and Wilderness Areas*, Westview, Boulder, CO, p. 17-39.

Smith, V.K. (1991), 'Household production functions and environmental benefit estimation', in J.B. Braden and C.D. Kolstad, Ed., *Measuring the Demand for Environmental Quality*, North-Holland, Amsterdam, p. 41-76.

Smith, V.K. and Krutilla, J.V. (1982), *Explorations in Natural Resource Economics*, Johns Hopkins University Press, Baltimore, MD.

Strand, J. and Wenstrøp, F. (1991), Miljøkostnader og samfunnsøkonomi (Environmental costs and social economy), Subproject 7, NVE, Oslo.

Wegge, T.W., Carson, R.T. and Hanemann, W.M. (1988), Site quality and the demand for sportfishing in south-central Alaska, paper presented at Sportfishing Institute Symposium, Charleston, S.C.

APPENDIX 2: *SUMMARY OF SUBREPORTS IN INVESTIGATION PROGRAMME*

CONTENTS:

INTRODUCTION

Within the framework of the investigative programme "Quantification of Environmental Impacts of Various Energy Technologies" a number of subreports were commissioned from research institutes and firms of consultants. This Appendix is a brief discussion of each report. The discussions do not seek to be exhaustive and the emphasis has been on indicating the purpose of each subproject and reviewing its principal results. It should also be noted that the programme did not seek to reveal new knowledge and all the reports were essentially literature studies. The resources available to each study were thus limited.

All subreports are available (in Norwegian) upon request to the NVE.

In order to provide a foundation for socially rational energy planning three subordinate objectives for the reports were established. The projects should:

1. *Analyze the environmental impacts of various energy technologies and seek to quantify them*
2. *Supplement the planning methodology so that environmental impacts and environmental costs can be factored into the individual project evaluations*
3. *Form a basis for determination of optimal environmental taxes where environmental costs are not otherwise reflected in today's system.*

The three sub-objectives placed rather different demands on the implementation of the subreports, and not all subprojects attempted to satisfy all partial objectives. The table below indicates which objectives and questions each of the subprojects sought to address and answer.

In order to determine the level of environmental impact that coincides with economic efficiency one needs to know both the social costs of the abatement measures and the social costs of the environmental impact. For instance it is important in order to set the optimal environmental taxes or set the optimal standards when processing licence applications for energy projects. Only when we know both of these functions are we able to estimate the level of environmental impact that is commensurate with the social optimum, and the shadow price of the impact at the optimal level. One aim in the project has been to move from a general description of the abatement and impact curves, to a quantitative treatment of the same curves. It is possible to identify three levels of ambition in seeking to achieve the aim of quantifying both the costs abating the environmental impacts and the costs to society of living with those impacts:

1. *Identification of potential environmental consequences and potential abatement measures*
2. *Physical quantification of the measures and environmental impacts identified*
3. *Economic evaluation of identified and physically quantified abatemen measures and environmental damages.*

It is probably safe to say that none of the subprojects quantify both the costs of abatement measures and the costs of environmental impacts. A number of the studies offer estimates of the abatement costs. As for the damages costs, many of the literature studies contain the results of valuation studies, in most cases from abroad.

Table 1 Themes of subreports

Subproject number[1]	Project theme and objective			
	Quantify environmental impacts		Planning methods	Set environmental taxes
	Physical units	Money units (Nkr)		
1 Environmental impacts of hydro-electric power	X		X	
2A Environmental impacts of wind, wave, solar power	X			
2B Environmental impacts of bioenergy			X	
3 Pollution and noise from incinerators and heat pumps	X	X		X
5 Environmental impacts of energy transport			X	
6 Environmental costs of energy efficiency measures	(X)		X	
7 Environmental costs and social economy	X	X	X	
10 Use of MARKAL			X	

[1] Projects are numbered as in the original brief. Plans for 4, 8 and 9 were not realised.

SUBREPORT 1: ENVIRONMENTAL IMPACTS OF HYDRO-ELECTRIC POWER

Executive institute:
Norwegian Institute of Water Research (NIVA) and Norwegian Institute for Nature Research (NINA).

Objective:
Create summary of environmental impacts and abatement measures for hydro-electric power production and develop principles for how consequences can be gauged in physical units and then in monetary units. Also evaluate suitable methods for valuation of environmental impacts.

Principal results:
The project is limited to evaluating local environmental effects during construction and operational phases of hydro-electric power projects. More specifically the aim was to examine what environmental impacts can be anticipated, how they can be reduced, and the methods that can be used to quantify and value the environmental impacts. The ambition is thus to illuminate methodological issues, not to carry out a physical or economic quantification of interesting projects.

The report first offers a brief account of the most important forms of nature encroachment by hydro-electric power projects and their significance for water quality, biotopes, and scenic factors. Also a brief account is given of possible measures to abate the impacts identified. The consequences of the encroachments for each group of interested parties are also briefly described and flow charts have been worked out showing the relation between the type of encroachment and the physical and biological consequences for each interest group.

Then relevant methods are discussed to quantify and value the environmental impacts. The methods reviewed belong to several categories:

- *Methods to clarify causes and effects of encroachment, primary environmental consequences, side effects, and impact on user interests*
- *Methods for systematic comparison of consequences*

- *Quantification and valuation methods.*

The methods are reviewed and evaluated in relation to the following criteria:

- *General presentation*
- *Dealing with consequences*
- *Testability*
- *Data basis.*

The discussions and evaluations of the various methods lead to a selection of recommended methods and procedures for investigating and evaluating the environmental consequences of hydro-electric power projects.

It is worth noting that the criteria for basic data contain a note that the methods should be based on information obtained during the regular licensing process. At least in principle, therefore, the method should not presuppose the collection of data beyond that already in place.

In terms of information needs for hydro-electric power developments the subreport provides clear recommendations for how the impact analyses should be carried out. Various methods and techniques for measurement and estimation are evaluated, and reasoned suggestions are made as to which are most useful and acceptable.

The subproject has a theoretical basis and draws on established Norwegian methods of investigating environmental consequences. The recommended method consists of an evaluation of the consequences for each user group in turn. Then the effects are divided into three categories depending on whether they are quantifiable economically, quantifiable in physical units, or can be qualitativly described but not quantified.

The recommended valuation method for environmental impacts is "wherever possible to base the economic valuation on evaluations of changes in existing production factors", the latter being the factors associated with the production of a good. In order for the valuation method to work the good must be traded in a functioning market. A clear disadvantage of this type of valuation is that the observed values will be closely connected with the goods that are produced and traded commercially. When valuing the various user interests, however, it is noted that valuation in many cases can only be done using nonmarket (contingent valuation) methods.

SUBREPORT 2A: *QUANTIFICATION OF ENVIRONMENTAL IMPACTS OF VARIOUS ENERGY TECHNOLOGIES — WIND POWER, WAVE POWER AND SOLAR POWER*

Executive institute:
Institute for Energy Technology (IFE) and Centre for Contract Research (SEFO).

Objective:
The aim of the project is to analyze the environmental impacts of various energy technologies and attempt to quantify them. This subproject concentrates on wind energy, though also solar power and wave power are briefly discussed in an annex. Basically the ambition is to obtain an estimate of the costs of the environmental impacts.

Principal results:
The report concentrates mainly on a review of the environmental impacts of wind power. But it includes a summary discussion on wave and solar power. The discussion of wind power starts by evaluating the potential for wind power in Norway. The various environmental consequences that

can be anticipated from wind power installations are described as well as measures that could help abate them. The environmental consequences of wind power are first and foremost scenic, the generation of noise, interference with electromagnetic communications, and disturbance of birdlife.

For each environmental consequence, possible abatement measures are examined. Experience from other countries shows that thoughtful project planning can reduce the environmental impacts significantly. The costs of carrying out the various abatement measures are estimated. The report notes that this does not provide a complete picture of the environmental impact. An evaluation of the optimal level of abatement measures is only possible if the social costs of the environmental impacts are known as well as the abatement costs. Only after having evaluated and quantified the local environmental impact is it possible to say something about the environmental costs and the least damaging (i.e. optimal) social impact. Since the environmental drawbacks of windmills are local in nature, the social cost will depend on the particular project and location.

The subreport contains no references to studies that examine the valuation of the environmental impacts of wind, wave or solar energy.

SUBREPORT 2B: ***ENVIRONMENTAL CONSEQUENCES OF VARIOUS BIOENERGY TECHNOLOGIES***

Executive institute:
Department for Economics and Social Sciences (NLH).

Objective:
The aim of this subproject was to review and summarise studies of the environmental consequences of using biofuels for energy production. The ambition was to reach a determination of both the clean-up and environmental costs of using bioenergy. The project was limited to a review of the literature.

Principal results:
The report first explains what bioenergy is and the raw materials that are used to generate bioenergy. The scope and potential for bioenergy in Norway are also reviewed.

The valuation of environmental consequences is seen in a wider context and a model of the energy sector is sketched that stresses the choice of energy technology and scope of energy production. The discussion is relevant for the entire investigative programme when it concerns the interaction of the markets, environmental policy measures and choice of technology. The model provides a method for how development of one energy carrier (in this case bioenergy) can be compared with other potential energy carriers in a decentralised, market-oriented energy sector.

The use of bioenergy has various environmental consequences, including both local and global or national effects. These environmental consequences are discussed and the production costs of some of them are estimated. No studies directly examining the environmental costs of bioenergy are referenced. The subreport does not discuss how the environmental costs can be estimated or what methods might be at hand or can be recommended.

The report raises one point that it is worth stressing, that bioenergy as a fuel is often based on waste and low-value by-products from other production. Alternative uses and disposal also may have important environmental consequences. Even though production of bioenergy has an environmental impact, it may be that overall the production of energy from biofuel is advantageous. Any cost-benefit analysis of the net environmental impacts and benefits requires great care to avoid double counting. This problem is a potential stumbling block in assessing both bioenergy and energy-efficiency.

The subreport concludes that there is little information available regarding the costs of reducing emissions from bioenergy plants and the costs of environmental impacts. The best studies go no further than to describe in qualitative terms the various environmental impacts.

SUBREPORT 3: *COSTS OF REDUCING POLLUTION AND NOISE LEVEL FROM INCINERATORS AND HEAT PUMPS*

Executive institute:
Hafslund Engineering, Berdal Strømme A/S

Objective:
This project aimed to evaluate the costs linked to reduction of atmospheric emissions and noise from combustion of fossil fuels, biofuels and waste, and heat pumps. As the aim suggests the focus was entirely on pollution clean-up and noise reduction costs.

Principal results:
The environmental impacts considered are partially local (noise) and partially national or supernational (greenhouse gases). The report gives a summary review of the clean-up requirements made, or expected to be made, by Norway's State Pollution Control Authority (SFT) for each emission. Then the costs of meeting these clean-up requirements are estimated, based on current technology and certain assumptions about useful life, depreciation, interest payments and efficiency of the cleansing plant.

A supplementary report looking into production and clean-up costs of specific installations was also prepared. Here the investment, usage and operating costs were estimated for running the plants with and without cleansing.

The report provides estimates of the clean-up costs for various types of emissions from combustion plant and noise abatement costs for heat pumps. The estimates build on the established emission and noise standards.

SUBREPORT 5: *TRANSPORT OF ELECTRICITY, HEAT AND NATURAL GAS*

Executive institute:
ENCO Environmental Consultants A/S

Objective:
The aim of this subproject was to estimate in montary units the environmental impacts of power transmission, natural gas transport, and district heating systems.

Principal results:
The report starts by describing the environmental consequences of transporting electricity, heat-carrying media, and natural gas. The consequences are described qualitatively for each group of users identified in the "Master Plan for Water Courses" (including, for example, forestry, recreation, etc). The consequences for each group of users are summarised in tables for electricity, natural gas and district heating. In the same way compensatory measures are discussed and evaluated for each energy form and each user group.

The section on economic quantification looks at the abatement issues and the impact issues. Abatement costs are generally the additional costs of implementing the compensatory measures. The various components that are believed to make up these costs are described.

In the case of environmental costs the use of methods for economic quantification of environmental consequences is suggested. The report contains a short description of the relevant methods, and this section of the report leads to a proposal for application of the methods for scenic and recreational interests.

The environmental consequences of transporting energy are usually limited to local impacts. Therefore it is difficult to state how great the costs of abatement measures are generally likely to be or, indeed, the reduction in environmental costs that might result from such measures.

The literature provides insufficient information about the physical and economic aspects of environmental impacts from transporting electricity, natural gas and district heat. The report makes no attempt to quantify the results and no references are made to literature containing any discussion of actual valuation studies. Methods for such studies have been devised, however, and the studies are feasible, though few if any have been implemented to date.

SUBREPORT 6: ***ENVIRONMENTAL CONSEQUENCES OF ENERGY EFFICIENCY MEASURES***

Executive institute:
Institute for Energy Technology (IFE).

Objective:
This subproject aimed to analyze and quantify the environmental impacts associated with energy efficiency.

Principal results:
The study looks at life-cycle costs of various energy saving measures. A life-cycle analysis evaluates a technology, in this case energy conservation, over the useful life of the technology: starting with the manufacture of the products and components, continuing through the operating phase and ending with disposal. The reason this method of analysis was chosen was to try to identify what lies in the concept of "cleaner technology".

The report did not attempt to estimate the costs to society of the emissions (impact costs) since there is insufficient data to do so. The report therefore had to concentrate on estimating the costs of energy conservation.

The report provides a summary of the various environmental consequences that can be expected from the various energy conservation measures. The cost estimates are sometimes based on little evidence and the results are therefore at best considered as tentative. An example is the environmental cost of using low-energy light tubes, which is estimated as the cost of disposing used light tubes to the Oslo Municipal Refuse Service. In the language of economics, the disposal fee must therefore be equal to the social cost of waste treatment if the analysis is to be valid.

The problems of indoor climate that result from certain energy efficiency measures, particularly the entrapment of radon gas, are relatively exhaustively dealt with. Much research has been done on the issue in the United States and many studies have examined the willingness to pay to reduce radon incidence. The estimated willingness to pay is often quite high.

The subreport gives an idea of the energy efficiency measures that will have national or supernational environmental consequences and those that will have local consequences, and can offer a first approximation for evaluating the environmental impacts of future energy efficiency measures.

SUBREPORT 7: ***ENVIRONMENTAL COSTS AND ECONOMICS***

Executive institute:
Institute of Economics at University of Oslo and Institute of Economics at Norwegian School of Management (BI).

Objective:
The aims of this subproject were to:

- *Provide a summary of the actual environmental costs to the Norwegian population of energy use*
- *Clarify how identified environmental impacts can be valued in economic terms.*

Principal results:
This subproject starts by reviewing the economic theory that underlies a rational environmental policy. One basic premise must be that environmental measures are implemented until their social benefit as accurately as possible balances the social costs of further environmental abatement measures. For that to be possible, then of course one needs to know the social benefits of the measures. A large part of the report is a review of methods to quantify the benefits in economic terms, of reduced environmental impacts. The report therefore, unlike most of the other reports, primarily aims to describe the environmental damage function.

The main report has two parts: In the first the principles and alternative methods of economic valuation are reviewed; In the second the valuation of defined categories of impact is examined. Both parts are literature studies.

The report provides a summary review of the various availablevaluation methods. A distinction is drawn between indirect methods, direct methods and political processes (management-oriented decision methods). Indirect methods make their valuation either by observing physical connections between environmental variables and the impact on man or physical values, or by observing changes in behaviour in a market in response to environmental changes. The latter method is often based on the hedonic property price model or the travel cost method. Direct methods are based on the individual's stated preferences for environmental goods. This type of valuation can be done by contingent valuation (interview surveys where individuals account for their willingness to pay), market or auction mechanisms, or referenda. The third alternative, political processes and management-oriented decision methods, assumes that decision makers act on behalf of the population and loyally embody their preferences.

For all the various methods the theoretical grounding is sketched out and the most important advantages and drawbacks of each are described. The discussions are firmly based on theory and the literature references make it possible to use the report as the starting point for further studies of the method. For a review of the valuation methods, see Appendix 1 above.

In a supplementary report the authors examine in greater detail the implicit valuation of various user interests that underlies the ranking of hydro-electric power projects in the "Master Plan for Water Courses". The study seeks to clarify the extent to which various user interests (heritage protection, recreation, agriculture, water supply and nature conservation) affect the ranking of projects in the Master Plan. With that basis established the implicit environmental costs of the projects are calculated. The authors conclude that the total user interest costs are of the same order of magnitude as the project development costs. This implies that the total direct and indirect costs of a hydro-electric power development are twice as large in practice as the purely private development costs.

SUBREPORT 10: PLANNING METHODS — TESTING ENERGY AND ENVIRONMENTAL PLANNING MODEL MARKAL

Executive institute:
Profu (Gothenburg) and Energidata (Trondheim).

Objective:
This project aimed to test the MARKAL model as an aid in local energy and environmental planning.

Principal results:
The MARKAL model is a dynamic, linear programming model that optimises the supply and use of energy in a geographical region. In the report the Larvik-Lardal area is taken by way of example. The model integrates the environmental concerns with the energy market and simultaneously makes it possible to optimise not only supply and use of all primary energy, but also transportation and distribution of energy, and also the large and small scale transformation of energy at the end user, and even energy efficiency measures. The model does not offer prognoses for the evolution of the energy market, though it does provide a normative guide to how the system should be designed to function optimally. On the other hand, prognoses do show how the market is expected to evolve. MARKAL can be used to estimate how an optimal energy system can and ought to be designed given certain technological feasibilities, energy prices, availability of suitable energy carriers, and final demand for energy. MARKAL is thus a useful tool for analysing how key aims of the energy and environmental policy can be achieved at the lowest possible cost.

This series is published by Norwegian Water Resources and Energy Administration (NVE)
Address: P.O. Box 5091, Majorstua, 0301 OSLO

PUBLISHED IN THIS SERIES:

No. 1 Torstein Herfjord, Haavard Østhagen, Nils Roar Sælthun: The Water Hyacinth with focus on distribution, control and evapotranspiration. Office of International Cooperation, 1994. (39 pp.)

No. 2 Jon Eilif Trohjell, Inge Harald Vognild: Underground cables as an alternative to overhead lines. A comparison of economic and technical aspects of voltages over 22 kV.
Energy Department, 1994. (65 pp.)

No. 3 Asle Selfors (red.): Quntification of environmental impacts of various energy technologies. Final report.
Energy Department, 1994. (52 pp.)