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Proceedings of Workshop (June 9-10)

ON THE SOCIAL CONSEQUENCES OF WASTE HEAT DISCHARGE ALTERNATIVES*

by

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PREFACE

The United States Energy Research and Development Administration (ERDA) has funded the Energy and Environmental Systems Division (EES) of Argonne National Laboratory to analyze the Social Consequences of Waste Heat Discharge Alternatives. The study, which began during fiscal year 1975, focuses on heat discharges emanating from steam-electric power plants located near rivers, large lakes, estuaries, or oceans.

On June 9-10, 1975 a Workshop was held at Argonne to determine what social consequences are and how they should be measured. Individuals representing federal regulatory and research agencies, universities, private industry, and citizen interest groups were invited to attend the Workshop to help the Social Consequences program staff organize a meaningful and effective program plan. This report describes what happened at the Workshop, what ideas were generated, and what the participants recommended to the Social Consequences program staff.

The principal recommendations and comments received were that

1) site specific cases be analyzed,

2) following site-specific analyses, careful extrapolation of the results be made region by region,

3) generic impact matrices be handled very carefully or avoided, and

4) methodology development be initiated.

For their help and encouragement throughout the project as well as the Workshop, I thank the program staff: H. Paul Friesema, Albert N. Halter, Kay Marie Holub, Barbara-Ann Lewis, and Richard Stanek. Special thanks goes to Phyllis Raschke for her assistance in arranging the Workshop and to Olga Skala for editing these Proceedings.

Brian P. Butz
July 30, 1975

INTRODUCTION: The Social Consequences Program

The public has displayed an increasing concern with regard to the environmental impact of power plants, the subject of thermal discharges receiving particular attention. This increasing public concern manifested itself in Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972. Specifically, PL 92-500 requires the Administrator of the Environmental Protection Agency (EPA) to establish effluent guidelines and standards for the steam-electric power generating industry. The Administrator published EPA's effluent guidelines and standards for the steam-electric power industry in the Federal Register on October 8, 1974 and they became effective on November 7, 1974. Essentially, the guidelines identify closed cycle cooling systems as the best available technology economically achievable to control thermal discharges and at the same time decree which plants in existence are subject to thermal controls and which are not. Additionally, Section 316(a) of PL 92-500 allows power plants to demonstrate that they should be exempt from thermal controls if they meet certain criteria established by EPA.

What all of this means is that both open and closed cycle cooling systems will be used by the power industry for the forseeable future. While many individuals are convinced that closed cycle cooling systems, especially cooling towers, embody society's hopes for a cleaner total environment, others are not sure. Some of the comments on EPA's proposed rulemaking* on the steam-electric power industry evoked the following interesting response by Administrator Train:

> The most fundamental criticism of the (Environmental Protection) Agency's approach was that it had not estimated the improvement in national water quality attendant on conversion to closed cycle evaporative cooling and had not attempted to assign a monetary value to that improvement. A related contention frequently advanced was that had this been done, the economic benefits of requiring most existing units to retrofit closed cycle cooling systems would be shown to be substantially less than the costs.

*The notice of proposed rulemaking appeared in the Federal Register on March 4, 1974.

> The law under which the Agency has promulgated this regulation (and has or will promulgate over 50 additional regulations for other industries) does not require that the ultimate social benefits which reduction in industrial pollution of the Nation's waters will produce be quantified in economic terms.*

The emphasis has been added. Continuing to comment on the notion of balancing benefits against costs, he adds:

> An industry group did conduct such an exercise, the results of which were submitted to the agency as a portion of its comments. On the basis of those results, the group recommended that the agency subcategorize the industry so as to exclude all units for which the cost of closed cycle cooling exceeded 1 mill per kilowatt hour. This decision rule, which would exclude virtually all existing units from thermal control while requiring most new plants to employ closed cycle cooling, was derived from the industry's cost-benefit analysis and represented what the commentors concluded was the maximum reasonable cost which was justified by its calculation of the benefits to the aquatic environment resulting from closed cycle cooling.*

As Administrator Train notes, EPA is not required to evaluate the social consequences in economic terms. Perhaps it is not even possible or desirable to quantify social consequences of alternative cooling technologies in pure economic terms, but it is possible -- even desirable -- for an impartial agent to assess the social consequences of alternative cooling technologies. The United States Energy Research and Development Administration has funded the Argonne National Laboratory to undertake that kind of thorough and impartial assessment.

The purpose of Argonne's "Social Consequences of Waste Heat Discharge Alternatives" program is to define and to relate the consequences of various methods of waste heat disposal from power generating plants to their impacts on society. This program will compare the environmental, economic, and social impacts of once-through cooling to impacts of closed cycle cooling systems including (1) cooling towers (natural draft, forced draft, and dry), (2) cooling ponds, and (3) spray canals for sites adjacent to (a) rivers, (b) large lakes, (c) estuaries, and (d) oceans.

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*These remarks appeared in the October 8, 1974 Federal Register, in Part III, "Steam Electric Power Generating Point Source Category - Effluent Guidelines and Standards."

In particular, this program will focus on the alternative cooling technologies and their effects on the environment and economic and social sectors, as shown in Fig. 1. Environmental effects include, but are not limited to, changes in aquatic biota induced by water quality and temperature changes, changes in air quality caused by cooling towers and ponds, changes in noise levels; economic effects include, but are not limited to, electricity supply costs, tax revenues, demand for funds, dividends, electricity demand, input-factor demand, including raw materials and labor and other natural resource requirements; and social effects include, but are not limited to, potential health benefits or hazards, land use changes, esthetics, displacement, and changes in attitudes and opinions. As Fig. 1 indicates, these three effects are interdependent.

Since this program has so broad a scope, an intense, concentrated research effort will not be attempted in any one area. Rather, the program will concentrate on available state-of-the-art methodologies to measure the social consequences of the three effects just described. A result of the program will be a document that will aid decision-makers in estimating the social consequences of alternative cooling water technologies.

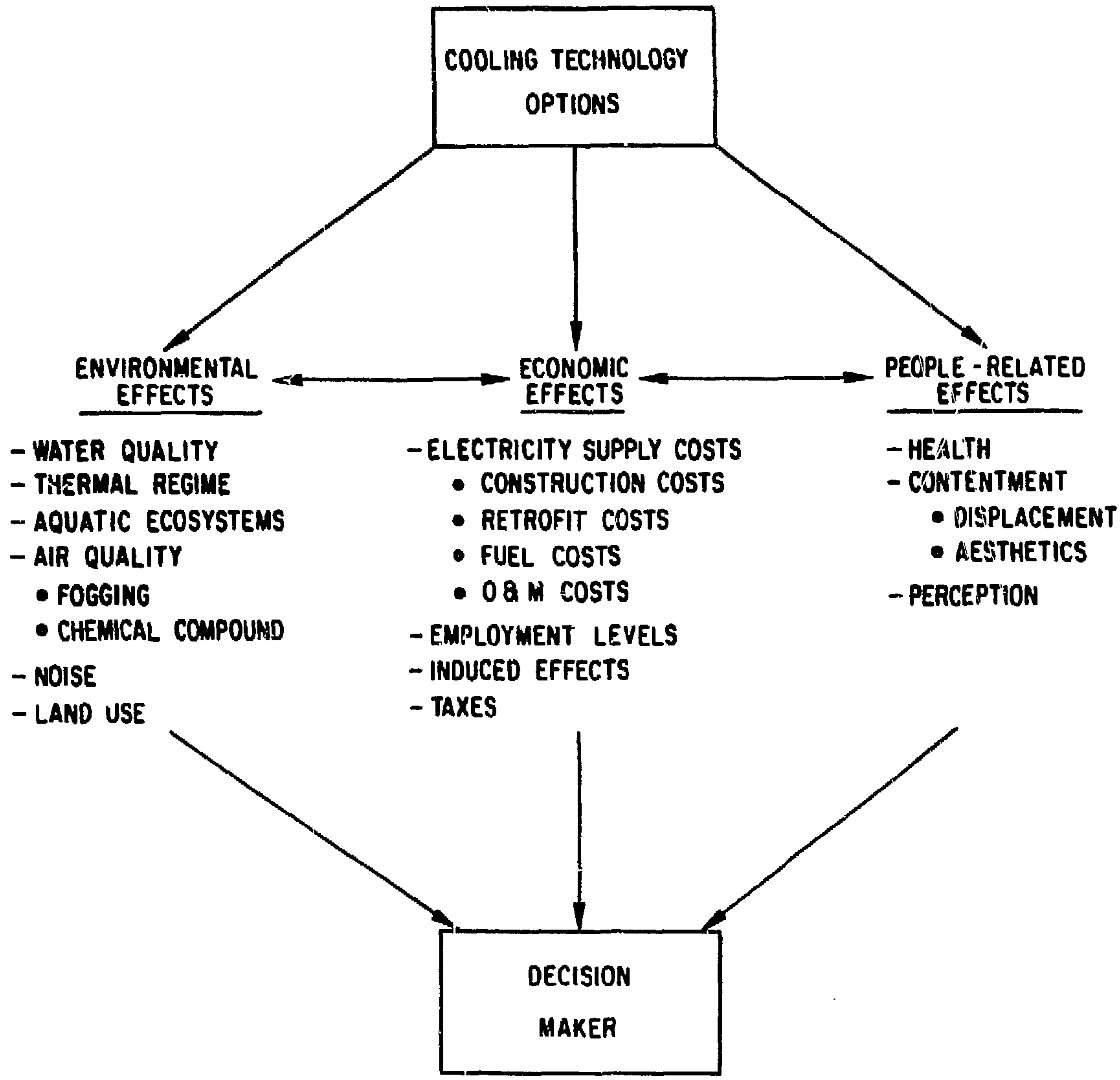

Fig. 1. Scope of the Program

THE WORKSHOP

I. THE SOCIAL CONSEQUENCES WORKSHOP

A workshop was held on June 9-10, 1975 at Argonne National Laboratory (ANL) to discuss the objectives and scope of the Social Consequences of Waste Heat Discharge Alternatives Program and to address techniques to identify and quantify the costs or benefits resulting from the various technologies. The two-day session was attended by over 25 representatives from government, university, industry, and special interest groups. A list of attendees is presented in Appendix A.

During the first half of the first day of the workshop, the participants heard five short speeches that described previous and ongoing ANL programs as well as the Social Consequences Program. Mr. Edward J. Croke, Director of the Energy and Environmental Systems Division of ANL, described the background of ANL programs that provided for the undertaking of multidisciplinary programs such as the Social Consequences Program. Dr. Brian P. Butz, the Argonne Social Consequences Program Director, described the definitions, goal, and scope of the program and gave a brief lecture on the problems of and some techniques for quantifying social costs and benefits. Additional brief talks regarding environmental, social, and economic consequences of alternative cooling technologies were given by Drs. Barbara Ann G. Lewis, H. Paul Friesema, and Albert N. Halter, respectively.

The attendees were then grouped into three panels, which held sessions. Each panel was composed of individuals representing a cross section of interests, and had as its purpose the identification of techniques and issues that should be employed and addressed by the Social Consequences Program. On the second day, the panels reconvened and drew up statements reflecting their views, after which they met at a general session where each statement was read and discussed before a consensus was reached.

The lectures given by the Social Consequences staff are summarized in Section II, and the workshop participants' recommendations are given in Section III. Section IV concludes this report and describes the path that the Social Consequences Program will follow.

II. STAFF PRESENTATIONS

A. Quantification of Social Consequences (B. P. Butz)

The benefits associated with the generation of electricity are well known and have contributed to a quality of life that is taken for granted by most Americans. Since electricity was first commercially produced, it has steadily become more important in the nation's total energy picture. Electric generation has doubled every ten years for the last forty years. The use of electricity since 1940 has constituted from 12-26% of total energy consumed and this figure is anticipated to increase by 1990 to 40%.* Electricity's rapid growth is most likely attributable to its attractiveness relative to other energy sources -- it is a very flexible energy source. Electricity is fully substitutable for other fuels in applications where stationary heat is required and, moreover, most fuels can be used to generate electrical power.

However, besides providing society with an unquestioned assortment of benefits, electricity generation has certain external disadvantages that include environmental damage, adverse economic impacts, and unfavorable social consequences. More unfortunate is the fact that instances exist where those who receive the electrical benefits are distinct from those who are saddled with electricity's external costs. The term "social consequences" is meant to include costs to the utilities that are passed on to the user in the form of electric rates (internal) as well as costs not borne directly by the electricity producer or consumer (external).

One source of external costs is the mechanism used by steam-electric power plants to cool the steam entering the plant's condenser. The steam is usually cooled by transferring heat to cooler water that flows around the outside of the condenser. The cooling water may be discharged directly to a water body (open cycle cooling) or, by means of closed cycle techniques, it may be recycled and not discharged directly into a waterbody. External costs include thermal, entrainment, and impingement effects caused by open cycle cooling as well as the esthetic and health effects caused by the closed cycle systems.

*These figures are from the Federal Energy Administration's "Project Independence Report," 1974.

In evaluating the true costs and benefits of the several cooling technologies, the problem reduces to one of social consequence identification and quantification for cooling technology alternatives at different types of steam-electric power plants in various regions of the country. Although social consequences tend to be site specific, general statements concerning the most prominent social consequences usually can be identified on a nationwide basis. Social consequences quantification is a most difficult process and it is probable that no quantification scheme will ever be devised that will satisfy all interested parties.

Presented below are three techniques that have been proposed and used for the identification and quantification of social costs. A brief description of each technique is presented along with the pros and cons of employing that technique within this particular program.

1. The Impact Matrix Concept

One technique for evaluating tangible and intangible aspects of social costs is the impact matrix concept. Used primarily in the past to evaluate environmental impact, impact matrices are being advanced for the evaluation of the environmental, economic, and social impacts that comprise social consequences. The matrix usually has two dimensions, one enumerating the possible causes of the impact and the other listing the characteristics that may receive the impact. Some weight, either arbitrary or fixed, is assigned each combination of possible causes and effects, resulting in an impact index or coefficient.

One type of environmental impact matrix, a portion of which is shown in Fig. 2, has been developed by Leopold et al.* for the Department of the Interior; however, the system is more of a checklist than an overall evaluation system. The matrix consists of 100 columns and 88 rows. The columns contain 100 types of proposed actions that can result in an environmental impact, and the rows represent 88 existing characteristics and conditions of the environment that may be impacted. Hence, the matrix has 8800 possible entries, each of which consists of two numbers. The matrix is used as follows.

*L. B. Leopold, F. E. Clarke, B. B. Hanshaw, and J. R. Balsley, "A Procedure for Evaluating Environmental Impact," Geological Survey Circular 645, U.S. Geological Survey, Washington, D.C., 1971.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

INSTRUCTIONS

1- Identify all actions (located across the top of the matrix) that are part of the proposed project.
2- Under each of the proposed actions, place a slash at the intersection with each item on the side of the matrix if an impact is possible.
3- Having completed the matrix, in the upper left-hand corner of each box with a slash, place a number from 1 to 10 which indicates the MAGNITUDE of the possible impact; 10 represents the greatest magnitude of impact and 1, the least, (no zeroes). Before each number place + if the impact would be beneficial. In the lower right-hand corner of the box place a number from 1 to 10 which indicates the IMPORTANCE of the possible impact (e. g. regional vs. local); 10 represents the greatest importance and 1, the least (no zeroes).
4- The text which accompanies the matrix should be a discussion of the significant impacts, those columns and rows with large numbers of boxes marked and individual boxes with the larger numbers.

SAMPLE MATRIX

	a	b	c	d	e
a		2/1			8/5
b		7/2	8/8	3/1	9/7

...S AND CONDITIONS OF THE ENVIRONMENT

PROPOSED ACTIONS	A. MODIFICATION OF REGIME: a Exotic flora or fauna introduction	b Biological controls	c Modification of habitat	d Alteration of ground cover	e Alteration of ground water hydrology	f Alteration of drainage	g River control and flow modification	h Canalization	i Irrigation	j Weather modification	k Burning	l Surface or paving	m. Noise and vibration	B. LAND TRANS...: a Urbanization	b Industrial sites and buildings	c. Airports	d Highways and bridges	e Roads and trails	f Railroads
A. PHYSICAL AND CHEMICAL CHARACTERISTICS — 1. EARTH — a Mineral resources																			
b Construction material																			
c Soils																			
d Land form																			
e Force fields and background radiation																			
f Unique physical features																			
2. WATER — a Surface																			
b Ocean																			
c. Underground																			
d. Quality																			
e. Temperature																			
f Recharge																			
g Snow, ice, and permafrost																			
3. ATMOSPHERE — a Quality (gases, particulates)																			
b. Climate (micro, macro)																			
c Temperature																			
4. PROCESSES — a Floods																			
b Erosion																			
c. Deposition (sedimentation, precipitation)																			
d Solution																			
e Sorption (ion exchange, complexing)																			
f. Compaction and settling																			
g. Stability (slides, slumps)																			
h Stress-strain (earthquake)																			
i Air movements																			
BIOLOGICAL CONDITIONS — 1. FLORA — a. Trees																			
b Shrubs																			
c Grass																			
d Crops																			
e Microflora																			
f Aquatic plants																			
g Endangered species																			
h Barriers																			
i Corridors																			
2. FA... — a Birds																			
b. Land animals including reptiles																			
c Fish and shellfish																			
d Benthic organisms																			

Fig. 2. A Portion of the USGS Impact Matrix

For each entry for which an impact occurs, the evaluator first indicates, using a scale from 1-10, the magnitude of the impact in question with a plus before the number if the number is beneficial. Next, on a scale from 1-10, the evaluator indicates the importance of the impact and incorporates this into the entry. Finally, a discussion is used in conjunction with the matrix to explain the more significant impacts identified by the matrix. The main difficulties with this technique are (1) the evaluation is subjective and (2) the matrix can contain as many as 17,600 numbers, which makes impact assessment by matrix inspection cumbersome. However, the value of the use of the matrix as a systematic environmental impact checklist cannot be denied.

Another type of impact matrix scheme is the environmental evaluation system developed by Battelle-Columbus* for the Bureau of Reclamation. This scheme shown in Fig. 3 is based upon a hierarchical arrangement of environmental quality indicators -- an arrangement that classifies the major areas of environmental concern into major categories, components, and, finally, parameters and measurements of environmental quality. Four major categories: ecology, environmental pollution, esthetics, and human interest are evaluated. The significant feature of the Battelle scheme is that the impact is evaluated by actual physical measurement coupled with its preassigned weight, a weight that has been determined by Battelle. The environmental evaluation system is used to ascertain the environmental condition of the local area before and after planned project has been developed. The environmental condition is shown in environmental impact units (by number), obtained through a series of simple calculations. Since all the weights are predetermined, the number of environmental impact units attributed to a project will be the same regardless of the evaluator, hence, in that sense, the evaluation system is "objective." The main objections to this system are (1) it is subjective -- somebody developed the weights, (2) even though the weight developers are knowledgeable, it is difficult to apply a single weighting scheme nationwide, and (3) there is a danger of such a scheme being used mechanically since it automatically results in an impact evaluation index.

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*N. Dee, et al., "Final Report on Environmental Evaluation System for Water Resource Planning," Battelle-Columbus Laboratories, Jan. 1972.

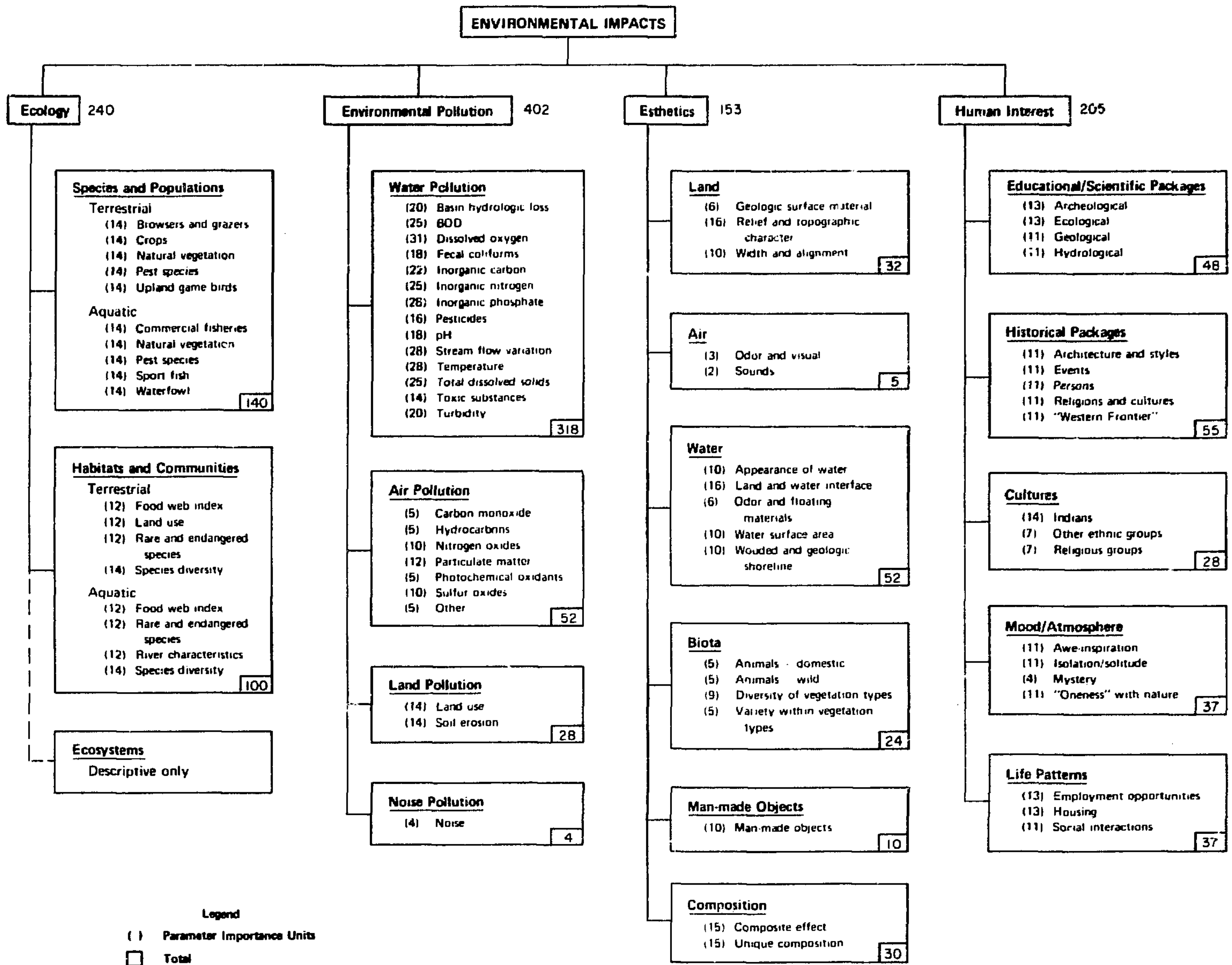

Fig. 3. Chart of Environmental Evaluation System

Several other techniques to quantify esthetics have been attempted, including those of Battelle-Northwest* and the Nuclear Regulatory Commission,** that show some promise. Perhaps the main advantages that matrix techniques offer are (1) they provide an exhaustive and systematic checklist for the evaluator, and (2) the numerical rating of alternatives may provide insights to the relative social costs and benefits.

2. The Social Assessment Technique

A second technique that can be used to analyze social costs is through the use of an assessment of alternatives. This technique was used by Hub, et al.*** to assess the social risks, costs, and benefits of generating electrical energy using alternate means. The study compared alternative electrical generating systems, such as various nuclear reactors and coal-fired, oil-fired, and gas-fired power plants, on the basis of both internal and external costs. The external costs treated included: land despoliation during mineral fuel extraction; damages to health, property, and the environment, resulting from the release of air and water pollutants; esthetic damage; and many others. These were then added to the internal costs (construction, operation, and maintenance) and converted to yield the total dollar cost of the option under consideration. Thus, the total dollar figure included social costs as well as the conventional internal costs, so that an alternative could be selected based on its total impact.

The advantages of this type of study are (1) it permits a nationwide examination of an industry that results in a list containing the identity and probable magnitudes of selected environmental, economic, and social impacts; (2) it is manageable and can be done on a limited time scale and a limited budget; (3) it forms a good basis for future study. Some of the failings of the techniques are (1) the resolution of impact magnitude is such that only

*J. B. Burham, et al., "A Technique for Environmental Decision Making Using Quantified Social and Aesthetic Values," BNWL-1787, Feb. 1974.

**D. P. Cleary, et al., "A Preliminary Matrix Model for Quantifying and Balancing the Socio-Economic Impact of Alternative Cooling System Technologies for Nuclear Power Plants," Short Course on Energy and the Environment - Cost-Benefit Analysis, Georgia Institute of Technology, June 1975.

***K. A. Hub, et al., "A Study of Social Costs for Alternate Means of Electrical Power Generation for 1980 and 1990," ANL-8092, Feb. 1973.

large relative differences are meaningful, (2) the results of this technique give no clue as to what control actions might significantly affect the results. Specifically, for the Social Consequences of Waste Heat Alternatives Program, this technique could be useful when discussing alternative cooling technologies in various regions of the country. The danger of this technique is that the results obtained will be so general or so well known that the results of the program might not be able to justify the effort expended.

3. Methodology Development and Analysis

The third technique for analyzing social consequences consists of simulating the system under study, applying alternatives to the system, and estimating the impact of each, several, and all alternatives on the system as shown in Fig. 4. Inherent in this approach is the ability not only to discover what the impact of an action is, but why that impact occurs and how to modify it. Russell G. Thompson leads a group at the University of Houston, which uses this technique to investigate certain impacts of various effluent guidelines on several industries.* The advantages of this technique are (1) one learns what the impact is and has at one's disposal the opportunity to observe how to modify the impact without changing the project and (2) theoretically, an analysis with a high degree of resolution can be obtained. Some objections are (1) a large amount of data is needed, (2) individuals with rather specialized training are needed to use and modify the methodology, and (3) this technique requires more time and money than the previous two techniques.

4. Conclusions

Quantifying social consequences is a most difficult task, yet those parameters that are so difficult to quantify may well be the ones that are the driving forces that might be critical in the final analysis. The question before the Workshop is: How should we quantify and/or account for all the likely social consequences of alternative cooling technologies?

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*See, for example, H. P. Young and R. G. Thompson, "Forecasting Water Use for Power Generation," Water Resources Research, 1973, or G. Otto and K. Inoue, "Industrial Economic Models of Water Use and Waste Treatment," Working Paper No. 4, NSP Project GI-34459.

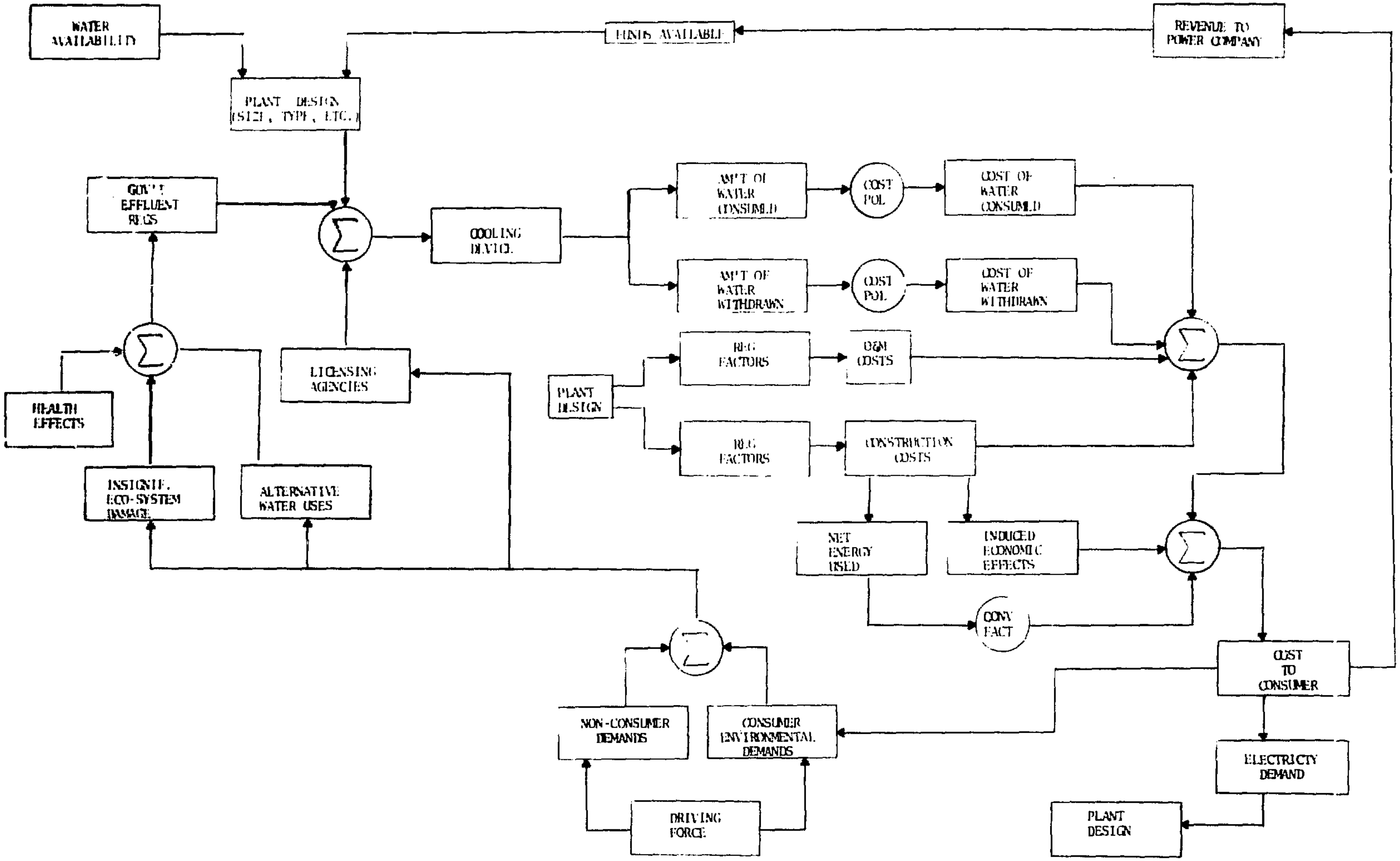

Fig. 4. Methodology Development and Analysis

B. Environmental Considerations (B. G. Lewis)

Briefly, there are three major cooling alternatives currently in use: once-through (open cycle) systems, closed cycle with cooling ponds, and closed cycle with wet cooling towers. The "closed cycle" systems are not completely closed; a certain proportion of the water in the closed system must be discharged (blowdown) to prevent excessive accumulation of salts in the circulating water, and another proportion of fresh water (makeup) must be drawn into the system to replace blowdown, evaporation losses, and seepage (in the case of cooling ponds). There are other alternatives, e.g., dry cooling towers, spray ponds, and various combinations such as wet-dry towers, cooling ponds, but these will not be discussed here. Some of the major effects of the three types of cooling mentioned above are listed in Table 1. There are a variety of other effects, real and postulated, that have not been included for the sake of brevity.

Table 1. Some Environmental Effects of Three Cooling Alternatives

Once-Through	Cooling Ponds	Cooling Towers
Aquatic Effects:	Land use	Esthetics:
Entrainment	Fogging	Noise
Impingement	Noxious growths	Visual intrusion
Thermal Effects:	Aquatic effects	Chemical deposition into the aquatic, atmospheric, and terrestrial environments
Cold shock Thermal death Shifts of aquatic organism species and population density Interference with spawning and migration Synergisms		Aquatic effects

The major objection to once-through cooling is the fact that relatively large volumes of water are drawn into the power station, i.e., about 1 billion gallons per day for a 1000-MWe nuclear plant compared to 0.1 billion gallons or less per day, depending on water quality, makeup water for a closed cycle system. The water passing through the power plant's condensers will contain biota that are present in the water source, and these organisms are subjected to chemical, mechanical, and thermal stresses that may or may not destroy them (entrainment effects). Additionally, organisms such as adult and juvenile fish too large to pass through the intake screens are impinged upon these screens, are injured, and eventually die (impingement effects). The discharge of the large volumes of heated water produces adverse effects at the discharge area and more subtly further downstream (thermal effects). These aquatic impacts also occur in closed cycle systems due to withdrawal of makeup and discharge of blowdown, but the magnitudes are less due to the smaller volumes of water involved.

The major impact of a cooling pond is change in the land use of a large area; roughly, about 1000-2000 acres of pond is required per 1000 MWe. If the land is of poor quality (e.g., an abandoned quarry or strip mine), the use of such acreage for a cooling pond is perhaps appropriate. More often, however, the land is producing agricultural crops or providing habitat for diverse wildlife. In such cases, taking the land out of agricultural and wildlife productivity for decades can have long-term effects that may not be fully predictable or reversible. Recreational use of power station cooling lakes has been touted as a benefit of such a project. However, unless the cooling lakes are well managed, esthetic and health problems may arise due to enhanced growth of noxious aquatic organisms under the warm water conditions.

A major objection to the use of wet cooling towers is the esthetic impacts of noise (fans and falling water) and visual intrusion of the structures and vapor plumes upon the landscape. In areas where the water is brackish, salt deposition on surrounding vegetation, due to drift from the towers, may be adverse. Additionally, chemical treatment of the circulating water to protect tower surfaces from degradation results in discharge of such chemicals to the receiving water in the blowdown.

The choice of a particular cooling alternative is generally made by a utility on the basis of economics and satisfaction of legal requirements, such as the effluent regulations recently promulgated by the Environmental Protection Agency. Cooling alternatives need to be evaluated from a greater variety of viewpoints.

C. Social Considerations (H. P. Friesema)

There are many ways in which matrices can be used and abused in assessing the social impacts of alternate waste heat discharge systems. While we will be assessing a matrix that essentially tries to compare the impact of alternate cooling technologies this afternoon (once-through, cooling towers, cooling ponds, spray canals), it may also be useful to order a matrix in a different way. In Fig. 5, I am not trying to compare cooling technologies, *per se*, but instead I attempt to isolate those elements of the cooling technologies that can vary and then identify some social impacts that may be affected by variance in those cooling technology elements.

From a preliminary survey of environmental impact statements concerning power plant developments, it appears that alternate cooling systems vary on a number of dimensions that will, in turn, lead to differential social impacts. Some of the variables in cooling systems that may lead to social consequences include:

1. Noise (e.g., mechanical draft)
2. Esthetic alterations (e.g., tower and plume)
3. Use of land (e.g., for spray canals of cooling ponds)
4. Weather modification (e.g., reduction of sunshine, fog, rainfall, snow, etc.)
5. Fallout of salts and solids from plumes
6. Use of water that would otherwise be available for other consumptive or nonconsumptive uses
7. Heated water discharges

It has already been suggested this morning that another element differentially associated with alternate cooling systems, which may lead to social impacts is delay in installation -- whether induced in the permit process or the construction phase. That seems an intuitively important variable that could have identifiable social consequences. It deserves more thought.

These factors that occur and vary, depending upon the waste heat discharge alternative that is considered, can have many social consequences.

SOCIAL CONSEQUENCES

COOLING SYSTEM VARIABLES	Psychological Well Being	Recreational Opportunities	Use of Land	Occupational Opportunities	Community and Cultural Patterns	Health	Family Life	Public Safety	
Noise									
Aesthetic Alterations									
Use of Land									
Weather Modifications									
Fallout of Salts and Solids									
Use of Water									
Heated Water Discharges									

Fig. 5. An Impact Matrix

To illustrate:

1. Noise from mechanical draft cooling towers can, under some circumstances, affect health, psychological well being, the use and value of adjoining lands, etc.

2. Esthetic alterations, due to towers and/or plumes, can affect psychological well being, the use and value of adjoining lands, etc.

3. The use of large amounts of land for cooling ponds can remove land from agriculture or other productive use, affecting community and cultural patterns, occupational opportunities, and may provide recreational benefits.

4. Weather modification from cooling towers or cooling ponds can affect public safety, psychological well being, uses of adjoining lands, etc.

5. Fallout of salts and solids from plumes can affect health, the uses of affected land, etc.

6. The consumptive use of water for cooling, eliminating the prospect for other uses of that water, can alter occupational opportunities, recreational opportunities, and some uses of land.

7. Discharged heated water from once-through cooling can affect recreational opportunities, some occupational opportunities (irrigation, year-round navigation).

It seems worth noting that the distinction I have made between elements or characteristics that vary depending on the cooling mode, on the one hand and social consequences or impacts on the other hand, has not always been followed in other attempts to develop a matrix of social impacts. But note that neither noise nor esthetic alterations are social impacts. Rather, it seems more useful to think of noise and esthetic alterations as things that may occur and vary, depending on cooling mode, and that may affect people in turn in a variety of ways, hopefully captured among the identified "social consequences."

There are some types of social consequences that are probably associated with some power plants. It is probable for example that new power plants may affect the distribution of power and social differentiation in adjoining communities. A major power plant development will, or may, affect the patterns of crime and social disorder in the area. While the cooling mode that is adopted will affect the scale of power plant development (numbers of new workers, length of construction, etc.), the incremental affect that the cooling system might have upon the social impact of the total power plant development is probably too subtle and undifferentiated to be easily isolated and measured.

So the matrix in Fig. 5 presents a list of variables specifically associated with alternate cooling systems, and a broad set of social consequences that may be affected by variation in cooling system characteristics. This list is tentative and heuristic. While the list of social impacts was generated from a survey of some 25 final environmental statements (AEC, REA, TVA), many of the social consequences that appear in the matrix could only be inferred from the EISs.

As with similar matrices, this one seems to suggest that all social consequences are equivalent and all that are listed are serious. This may be a distortion. But this matrix may be of use for the limited purpose of identifying research priorities and areas of concern about the social consequences of heat discharge systems.

The value of a matrix like this as a guide to decision-makers needs to be considered. It undoubtedly serves as a checklist. That may be its chief value. But a checklist is no substitute for critical intelligence. While the social consequences listed may be of general use, the application of this list to some specific site could lead to omitting the consideration of some locally important social impacts.

A matrix is essentially a device of simplification. This one, for example, is unable to deal with weightings when the social costs of a project may be borne by a different population than will receive the benefits of the effort -- not an uncommon occurrence.

While there are serious limitations to using matrices for purposes beyond checklists, in one way this matrix may have a use beyond helping decision-makers select some particular cooling mode. Once the analysis is made upon the basis of the elements in a cooling mode that can vary, it is quite clear that many of the cooling mode elements that may have social consequences are not inherent or immutable with some particular cooling tower!

So a matrix may be useful in identifying areas in which ameliorative or mitigative strategies to reduce social impacts may be appropriate; and not just to decide about the cooling alternative.

No matrix or other shorthand is going to solve the very real epistomological difficulties and limits that social scientists have in anticipating even in very broad sweeps, the consequences of some technical development upon a moving, interactive social system.

D. Economic Considerations (A. N. Halter)

Economic consequences are always included among the impacts of new technologies and can be listed in a matrix along with the environmental and other social consequences. Economic costs and benefits of new technology can be enumerated at three levels of specification. These are: (1) site specific, (2) region, and (3) national.

At the site-specific level, economic impacts include (1) costs of production, (2) prices of the final product, (3) profits or the return on investment, (4) employment, (5) tax revenues, (6) demands for nonlabor inputs, and (7) sales of the final product. The regional level is the aggregation across the various specific sites and the economic impacts include: (1) industry and interindustry outputs, (2) labor employment, (3) regional income effects, (4) prices of goods and services, and (5) tax revenues. At the national level, which is the aggregation across regions, the economic impacts include: (1) growth of GNP or output effects, (2) inflation or price effects, (3) employment and unemployment, (4) interest rates and fund demands, (5) income distribution effects, and (6) balance of trade and payment effects.

The cost of pollution abatement technologies, including waste heat control alternatives, may affect the total economy in a number of more subtle ways than enumerated above. The efficiency of capital may be reduced in the aggregate production function, which means the cost of capital per unit of output increases. These changes then lead to price increases for consumer goods and capital equipment. Consumer demand may then shift to products that are produced by relatively less polluting processes. Some of the positive impacts of pollution abatement are the increased profits and employment in industries producing the abatement equipment and services. However, the higher costs of abatement may stimulate technological developments that are more productive of desirable outputs and less of pollution. This then stimulates profits and employment in entirely new industries.

While the list of economic impacts of pollution abatement technologies can be extended to include the most subtle of effects, the objectives of this talk are to show (1) that whatever economic outcomes are listed, there is always some degree of uncertainty associated with estimating the outcomes, and (2) that although the total economic impact of waste heat control from electric generating processes appears small, that in combination with other pollution abatement and new energy technologies, the economic impact may indeed be quite significant.

1. Uncertainty of Estimating Economic Consequences

In showing the uncertainty of estimating economic consequences, I have drawn on a number of studies that have appeared in the literature. Most of the studies were done before the current period of inflation, and hence the levels of costs and prices are probably outdated; however, the range of figures that are shown demonstrate the uncertainty in the estimation procedures, whatever the magnitude of the numbers.

The major driving force behind capacity planning in the electricity generating system is the demand for electricity. Also as the costs of producing electricity increase, prices of electricity to consumers may increase and the quantity consumed or used by industry may change, which could be one of the major economic impacts of imposing pollution abatement technologies. The upper portion of Table 2 shows the demand and income elasticities of electricity estimated by a number of investigators for short-run and long-run periods. The short-run period refers to a period of time for which the stock of electric-consuming appliances and equipment are fixed. Whereas the long-run allows the stock of electric durable goods tc be variable.

Projections of electricity consumption for a 25-year period are shown in the lower portion of Table 2. The variance in estimates demonstrates the uncertainty in economic forecasting that is the foundation of planning for generating capacity and hence the expected demand for pollution abatement equipment. The estimates vary from 2.01 to 10.25 trillion kilowatt hours depending upon the price assumptions that are made for the year 2000. One should recognize that all of these studies used historical data to make these

Table 2. Price and Income Elasticities of Electricity Demand Summary of Econometric Estimates

Type of Demand	Type of Price	Price Elasticity Short-Run	Price Elasticity Long-Run	Income Elasticity Short-Run	Income Elasticity Long-Run	Type of Data
Residential						
Houthakker (27)	M	-0.89	NE	1.16	NE	CS: Cities (U.K.)
Fisher & Kaysen	A	≈-0.15	≈0	≈0.10	SMALL	CS-TS: States
Houthakker & Taylor	A	-0.13	-1.89	0.13	1.94	TS: Aggregate U.S.
Wilson	A*	NE	-2.00	NE	≈0	CS: SMSA's
Mount, Chapman, & Tyrrell	A	-0.14	-1.20	0.02	0.20	CS-TS: States
Anderson (1)	A*	NE	-1.12	NE	0.80	CS: States
Lyman	A	(≈-0.90)		(≈-0.20)		CS-TS: Areas Served By Utilities
Houthakker, Verleger, & Sheehan	M	-0.90	-1.02	0.14	1.64	CS-TS: States
Commercial						
Mount, Chapman, & Tyrrell	A	-0.17	-1.36	0.11	0.86	CS-TS: States
Lyman	A	(≈-2.10)				CS-TS: Areas Served By Utilities
Industrial						
Fisher & Kaysen	A	NE	≈-1.25			CS: States
Baxter & Rees	A	NE	≈-1.50			TS: Industries (U.K.)
Anderson (2)	A	NE	-1.94			CS: States
Mount, Chapman, & Tyrrell	A	-0.22	-1.82			CS-TS: States
Lyman	A	(-1.40)				CS-TS: Areas Served By Utilities

Note:

NE: Not Estimated.
CS: Cross-Section
TS: Time-Series
M: Marginal Price
A: Ex Post Average Price
A*: Average Price for A Fixed Amount of Electricity Consumed Per Month.

Alternative Forecasts of U.S. Electricity Consumption
(Trillion Kilowatt Hours)

Projection*	1970	1975	1980	1985	1990	2000
Cornell-NSF	1.57	2.15	2.92	3.96	5.38	10.25
CMT-High	1.53	2.14	3.05	--	5.66	9.89
-Medium	1.53	1.98	2.38	--	3.01	3.45
-Low	1.53	1.88	2.07	--	2.11	2.01
DW	1.53	2.13	3.00	4.14	--	9.01
FPC	1.53	--	3.07	--	5.83	--
HJ	1.53	1.94	2.59	3.36	--	6.98
NPC	1.59	2.29	3.29	4.54	--	--

*Cornell-NSF is Cornell-National Science Foundation Workshop; CMT is Chapman Mount, and Tyrrell; DW is Dupree and West; FPC is Federal Power Commission; HJ is our projection; NPC is National Petroleum Council

Sources: Cornell-NSF, FPC, NPC Forecasts are given in Chapman, Mount, and Tyrrell (1972), Table 1, Page 3.
The CMT "low" forecast assumes that the real electricity price doubles by 2000. The "medium" forecast corresponds to the FPC estimates of a 19-percent real price increase over 1970-1990. "High" corresponds to a 24-percent real price decline over 1970-1980 and a 12-percent decline over each of the 1980-1990 and 1990-2000 intervals.

Source: Taylor, Lester D., "The Demand for Electricity: A Survey," The Bell Journal of Economics, Vol. 6, No. 1, Spring, 1975.

forecasts, which did not include the recent period of rapidly increasing fuel prices. Since these estimates were made from data generated during a period of relatively stable economic conditions, it is very likely that they do not describe the current situation of rapid changes.

Another major component of planning for capacity and pollution abatement is the capital equipment and operating costs of the various alternative heat waste control technologies. A number of studies* have been carried out on this aspect of thermal pollution control and show a wide dispersion in estimates.

While costs vary between alternative cooling systems by type of generating plant and specific site, there still is a wide range of costs between studies. For example, capital costs, above once-through cooling, of cooling ponds vary between $2-$5/kwh for fossil-fuel plants and from $2-$7/kwh for nuclear plants. When operating costs are included with capital costs, power costs for fossil-fuel plants are increased above once-through cooling by .14-.20 mills/kwh for wet natural draft towers and .06-.10 mills/kwh for cooling ponds.

From nuclear plants, power costs are increased from .03-.10 mills/kwh for cooling ponds and from .14-.23 mills/kwh for wet natural draft towers. To make realistic comparisons between waste heat control alternatives, one must recognize the uncertainties in making estimates of costs and prices for long periods of time into the future and then to account for this variability in the decision-making process.

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*For example:

R. D. Woodson, "Cooling Towers for Large Steam Electric Generating Units," Electric Power and Thermal Discharges, M. Eisenbud and G. Gleason, eds. (New York: Gordon and Breach Science Publishers, Inc., 1969).

Oak Ridge National Laboratory, Interdisciplinary Research Relevant to Problems of our Society, Progress Report to the National Science Foundation on Summer Study of 1970, Report ORNL-4632, Dec. 1970.

John P. Rossil and Edward A. Cecil (of R. W. Beck and Associates, Denver, Colorado), Research on Dry-Type Cooling Towers for Thermal Electric Generation: Part I, prepared for the Water Quality Office of the U.S. Environmental Protection Agency (Washington, D.C.: USGPO, Nov. 1970).

R. M. Jimeson and G. G. Adkins, "Waste Heat Disposal in Power Plants," Chemical Engineering Process, 67(7):58, 1971.

G.O.G. Löf and J. C. Ward, "Economics of Thermal Pollution Control," Water Pollution Control Federal Journal, 42(12):2102-2116, Dec. 1970.

2. Economic Impacts of Thermal Pollution Abatement Appear Small

When thermal pollution abatement is considered by itself, as was done by EPA in the study of economic impacts of the proposed effluent guidelines and standards for the steam electric industry,* the economic impacts in percentage terms seem small for imposing closed cycle cooling systems on the U.S. electricity generating industry. For example, the capital requirement of abatement equipment to meet the standards is only 2-3% of the 1970 capital requirement of the industry. Expected price increases of electricity due to the increased costs of generating electricity from meeting the abatement standards are only 0-5%, even with exemptions. Fuel and capacity penalties are also small as a percentage of the national fuel demand and total national capacity, respectively.

The impact on consumers' electricity bills, whether residential or industrial, is expected to be only an increase of 1.6% by 1977 and 2.5% by 1983. This assumes that all the costs of abatement technologies are passed on uniformly to all types of users, that the consumption of electricity continues to grow at 7% per year, and the number of consumers increase at 2% per year. Thus, when abatement of waste heat from electricity generation is considered by itself, it appears that most of the economic consequences are small relative to the existing situation. However, in a study by Anne Carter** in which pollution abatement of all types and new energy technologies are considered, the impacts on economic growth and the industrial structure of the U.S. economy are significant over a projected 10-year period.

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*James M. Speyer, Economic Impact of Proposed Effluent Guidelines -- Steam Electric Power Plants, EPA 230/1-73-006, Wash. D.C., Sept. 1973.

**Anne P. Carter, "Energy, Environment, and Economic Growth," The Bell Journal of Economics and Management Science, 5(2), Autumn 1974.

The upper table in Table 3 shows the various scenarios that were specified in a macrocomputer model of the U.S. economy.*

The assumptions made for consumption structures are shown across the top of the table and the technology assumptions down the left-hand column. The second table shows a comparison of growth rates for the base year run and for (1) all pollution abatement and (2) electric, coal gasification, and all pollution abatement. Under the four consumption structures assumed, the growth rate is reduced for all the pollution abatement alternative by .5 to .6 per year or a percentage reduction of approximately 10-14% from the base year. When the entire package of pollution abatement and new energy technologies are considered, the growth rate is reduced .9 to 1.0 per year or a percentage reduction of approximately 17-26% from the base year.

The third table of Table 3 shows the sectoral shares of the total gross national output for the various scenarios. The columns headed 1 and 1 (i) are the base year runs for the low growth and high growth consumption assumptions. The other columns can then be compared with these two to ascertain the shifts in output of the various sectors. For example, it can be seen that construction's share of output would be double by the all pollution abatement scenario. Electric utilities' share of output would be increased most by the 1980 electric generating technology with coal gasification and high electricity consumption coefficients.

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*Technology assumptions: 1980 electric power generation, transmission and distribution input coefficients reflect the increase in nuclear generation, addition of pollution abatement equipment, extra high voltage transmission and underground distribution lines; 1980 electric with coal gasification means the increment over present fossil-fuel consumption would come from gasified coal from the Hygas process; All pollution abatement includes particulate air pollution, industrial water pollution, thermal pollution, municipal sewage disposal, strip mining pollution, and municipal solid waste disposal to the 1971 Clean Air Act standards.

Consumption assumptions: 28% increase in real income means labor productivity increases by 2.5% per year for 10 years giving rise to a 28% rise in real income and a tripling of percentage rate of savings; 1% increase in savings instead of tripling of savings rate over base period to be consistent with historical trends; Energy saving changes reflects substitution in favor of less energy intensive products induced by rising energy prices over the next 10 years.

Table 3. Scenarios Computed in This Study

Consumption Structure	(i) 1970		(ii) Income-Specific Consumption Structures Reweighted for 28-Percent Increase in Real Income	(iii) One-Percent Increase in Savings Over 1970	(iv) Energy Saving Changes
Electricity Consumption Coefficients	(a) 1970	(b) 1970 x 1.4			
Technology					
1. Base Year	X	X	X	X	X
9. Air Pollution Abatement	X		X	X	X
10. 1980 Electric	X				
11. 1980 Electric With Coal Gasification	X	X			
12. All Abatement, 1980 Electric And Coal Gasification	X	X	X	X	X

Long Term Growth Potential (λ) With Varying Technologies and Consumption (Percent Per Annum)

Technology	Consumption Structure			
	(i)	(ii)	(iii)	(iv)
1. Base Year	3.5	5.7	3.8	3.6
9. All Pollution Abatement	3.9	5.1	3.3	3.1
12. Electric, Coal Gasification And all Pollution Abatement	2.6	4.7	2.9	2.7

Sector Shares of Total Gross Output With Various Technologies And Consumption Patterns (Percent of Total Gross Output)

	Scenario Number							
	11b	12	9	11	10	1	9(ii)	1(i)
λ	2.1	2.6	3.0	3.1	3.3	3.1	5.1	5.7
Producing Sector								
New Construction	2.5	2.7	2.9	2.9	3.0	3.1	3.9	4.1
Maintenance Construction	2.2	2.1	4.4	2.1	2.1	2.2	2.1	2.1
Food	4.4	4.3	4.4	4.4	4.3	4.4	3.8	3.8
Iron & Steel	1.6	1.6	1.6	1.6	1.6	1.6	1.8	1.8
Automobiles	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Electric Utilities	2.8	2.2	2.0	2.1	2.2	2.0	1.8	1.8

Source: Carter, Anne P., "Energy, Environment, and Economic Growth" The Bell Journal of Economics and Management Science, Vol. 5, No. 2, Autumn, 1974.

The upper table on Table 4 shows the comparative growth rates for various structural changes including thermal pollution control using cooling towers. The imposition of cooling towers reduces the growth rate from the base year by only .02 per year or .5%. However, when all pollution abatement and energy technologies are included, the growth rate is reduced .95 per year or 26.8% per year.

The second table on Table 4 shows the capital/output ratios and percent of total capital investment in utilities and in pollution abatement equipment under the various scenarios. The capital investment in utilities could be increased over the base year by 54% when the 1980 electric generating technology is combined with coal gasification. The total pollution abatement investment for the base year was not estimated and hence the increase in capital cannot be deduced. However, under some scenarios the capital invested in all pollution abatement could make up 36% of the capital invested in all utilities.

One hardly needs to repeat that abatement of waste heat from electricity generation by itself has a small economic impact; however, when combined with all pollution abatement and new energy technologies the economic impacts are significant. What this means for national decision-makers is that the choice among heat waste abatement alternatives is not independent of the total energy policy and the pollution abatement standards and regulations contemplated for the entire economy. Thus, when viewed in the context of the entire energy-pollution problem, we see that there are economic tradeoffs between national policies on energy and environmental pollution abatement of which waste heat control is a part. In conclusion, impact methodologies that account for the incremental impacts of specific technologies may overlook the simultaneous and synergistic effects of other possible and related actions, policies, and technologies.

III. PARTICIPANT RECOMMENDATIONS

Following the staff presentations, the workshop attendees were divided into three panels. Each panel consisted of members having an interest in each of the three areas (environmental, economic, social) comprising social consequences and was asked to consider the items shown in Table 5. This section contains the results of the panel discussions and the subsequent recommendations of the workshop participants.

Table 4. Long-term Growth Potential (λ) with New Energy and Abatement Technologies

Structural Change	λ Percent Per Annum
1. None (Base Year Structure)	3.54
Pollution Abatement	
2. Particulate Air Pollution (=99 Percent)	3.44
3. Industrial Bod and Suspended Solids (Primary Treatment)	3.47
4. Municipal Bod and Suspended Solids (Primary Treatment)	3.45
5. Acid Mine Drainage	3.49
6. Thermal Pollution (Cooling Towers)	3.52
7. All Water Pollution	3.33
8. Solid Waste Disposal	3.33
9. All Pollution	3.03
New Energy Technologies	
10. 1980 Electric Power Technology	3.32
11. 10+ Coal Gasification	3.06
12. Energy and Pollution Control (9+11)	2.59

Economy-Wide Capital/Output Ratios and Proportion of Investment in Utilities and Abatement with Varying Structures (Dollars Per Dollars of Total Gross Output)

Scenario Number	Growth Rate (λ) (% Per Annum)	Capital/ Output Ratio	Percent of Total Investment In	
			Utilities	Pollution Abatement
11b	2.1	0.84	15.3	.
1b	2.9	0.81	12.1	.
9i	3.0	0.80	9.8	3.2
11a	3.1	0.81	11.8	.
1	3.5	0.79	9.9	.
12ii	4.7	0.82	10.8	2.5
9ii	5.1	0.80	8.9	3.2
1ii	5.7	0.78	9.1	.

*Pollution Abatement Costs are not estimated for these scenarios.

Source: Carter, Anne P., "Energy, Environment, and Economic Growth" The Bell Journal of Economics and Management Science, Vol. 5, No. 2, Autumn 1974.

A. The Impact Matrix Technique

Item number one in Table 5 deals with the use of impact matrices to identify and, perhaps, quantify the social consequences of implementing each alternative cooling technology. All three panels felt that the major usefulness of the impact matrix technique appears to be that it provides an organizational framework for providing insight and a feel for the problem of environmental, social, and economic impacts. It is a good stimulant to discussion at the initiation of the problem statement and again at the end of the process of alternative evaluation in communicating in a summary way with interest groups.

The technique should be used in organizing one's thoughts about impacts and as a checklist of items to be considered. It could be improved by including quantitative measures of the various impacts, their probability distributions giving the likelihood of the impact occurring, and the decision-maker's or evaluator's preferences (and/or tradeoffs) among the impacts. It could also be improved by categorizing the impacts in different hierarchial levels to illustrate and to sort out the interdependencies among the impacts.

Assigning weights to the impacts may be a useful extension of the simple alternative-impact matrix, since it forces the weighers to make their value preferences explicit. If the assignment is done with meaningful weights the outcome should aid in arriving at a ranking of the alternatives. If likelihood weights are assigned, then some reflection of the degree of confidence one has about the available information is made explicit.

The group discussions show agreement that the weighting would have to be a combination of both objective and subjective evaluations. In the final analysis, the decision-maker will make a subjective judgment among the alternatives so there is no need to try to make something subjective appear more objective than it ultimately is. Additionally, the groups pointed out that one danger of any impact matrix is that it tends to neglect interactions and feedbacks. Moreover, matrices can hide or oversimplify important, complex issues. For matrices to be of any value, the basic structure of the matrix, as well as any weights given to a particular cell within the matrix, needs to be updated to keep abreast with society's changing values.

Table 5. Questions Addressed by Workshop Participants

1. Impact Matrix Technique

   a) How useful is it?
   b) What should it be used for?
   c) How can it be improved?
   d) What value does weighting have?
   e) Subjective weighting vs objective weighting: which is better?
   f) Who, in the group, uses it?

2. The Sample Impact Matrix

   a) Is it complete?
   b) What should be added?
   c) Should weights be assigned?
   d) If the answer to 2c is yes, assign weights.

3. Technology Assessment Technique

   a) Should this technique be used in the program?
   b) If so, how?

4. Methodology Development

   a) Does a methodology exist at present for assessing the impact of a technology?
   b) Which one?
   c) Should this technique be pursued?

5. The Social Costs Program

   a) What are "social costs"?
   b) What should be the philosophy of the program?
   c) How would each member use the results of the program?
   d) How would ERDA use the results of the program?

6. Any Other Items of General Interest

Many of the panelists had used matrices in the past to help them in their decision-making process. However, previous matrix users had used the devices as checklists and as decisional tools to pinpoint which issues needed more detailed examination.

B. Discussion of the Sample Impact Matrix

A sample social consequences matrix, shown in Fig. 6, was given to all the panel members prior to the Workshop. During the panel sessions, each panel analyzed and discussed this sample matrix. It became clear almost immediately that the panel members disliked "generic weighting" and felt that weights could be given for possible impacts only for a site-specific project. Even though no specific site was given, one panel did evaluate the sample matrix in detail as is described below.

> The sample impact matrix for the six alternative cooling technologies was examined and a number of additional impacts (4) and technologies (2) were added. Also, 62 additional cells were checked to indicate impacts that could occur but were previously not checked. We also recognized that a single requirement of an alternative cooling technology could eliminate it from further consideration. Such a 'red tag' item might be the land requirement for cooling ponds. The additional impacts that were added are: (1) aviation hazard, (2) technology and engineering design feasibility and the uncertainty of implementation, (3) visual esthetics, (4) costs of hearing and court cases (this may have been included under induced impacts). The additional technologies included: (1) waste heat utilization alternatives, and (2) new technologies in the design stage, e.g., circular mechanical draft. The revised matrix is attached (Fig. 7), with the impacts categorized in groups according to the order of preference for avoiding or enhancing the group of impacts from highest to lowest as indicated by the members of the workshop session.
>
> The group agreed that weights should be assigned provided that (1) a careful definition of the quantitative measures of the impacts is given; (2) a clear definition of the meaning of importance is specified; (3) time and resources permit; and (4) a specific set of sites has been designated.

Each individual in that panel tried to rank his preferences for categories of impacts that each would want to avoid or enhance. The list of possible impacts were grouped into seven categories as follows: (1) aquatic life,

Cooling Technology	Entrainment	Impingement	Thermal Death	Cold Shock	Increased Predation	Disease Susceptibility	Gas Bubble Embolism	Insect Pre Emergence	Migration	Species Shift	Loss of Species Diversity	Spawning	Scouring Effect	Chlorine Discharge	Other Chemical Discharge	Increased Concentration of Dissolved Solids	Salt Deposition	Misting	Fogging	Icing	Noise	Consumptive Water Use	Shading	Asbestiform Particles	Dispersion of Pathogens	Algal Blooms	Health Hazard	Land Use	Acid Rain	Weather Modification	Psychological Well-Being	Recreation	Occupational Opportunities	Community & Cultural Patterns	Family Life	Construction Cost	O&M	Induced Economic Effects	Power Penalty	Regulatory Induced Costs	Retrofit Costs
Once-Thru	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																	X	X			X					
Wet, Natural Draft Cooling Tower	X	X	X										X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X
Wet, Mechanical Draft Cooling Tower	X	X	X										X	X	X	X	X	X	X	X	X	X		X	X			X			X	X	X			X	X	X		X	X
Dry Cooling Tower																												X		X	X	X	X			X	X	X	X	X	X
Cooling Pond	X	X											X	X	X	X			X			X				X	X	X			X	X	X	X	X	X					
Spray Canal	X	X											X	X	X	X			X			X				X	X	X			X		X	X	X	X	X	X	X	X	

Fig. 6. Sample Impact Matrix

Cooling Technology	Social Impacts						Economic Impacts									Water Quality						Air Quality								Health and Safety				Aquatic Life											
	Psychological Well-Being	Recreation	Occupational Opportunities	Community & Cultural Patterns	Visual Aesthetics	Family Life	Construction Cost	O&M	Induced Economic Effects	Power Penalty	Regulatory Induced Costs	Retrofit Costs	Engineering Feasibility	Costs of Court Cases & Hearings	Land Use	Increased Concentration of Dissolved Solids	Scouring Effect	Chlorine Discharge	Other Chemical Discharge	Algal Blooms	Consumptive Water Use	Acid Rain	Weather Modification	Salt Deposition	Misting	Fogging	Icing	Shading	Asbestiform Particles	Health Hazard	Dispersion of Pathogens	Noise	Aviation Hazard	Entrainment	Impingement	Thermal Death	Cold Shock	Increased Predation	Disease Susceptibility	Gas Bubble Embolism	Insect Pre-Emergence	Migration	Species Shift	Loss of Species Diversity	Spawning
Once-Thru	X	X	X				X	X	X	X	X	X		X	X	X	X	X	X	X	X		X			X	X			X	X			X	X	X	X	X	X	X	X	X	X	X	X
Wet, Natural Draft Cooling Tower	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X									
Wet, Mechanical Draft Cooling Tower	X	X	X		X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X									
Dry Cooling Tower	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X			X		X		X							X		X	X	X	X										
Cooling Pond	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X			X	X			X	X			X	X	X	X		X	X	X		X	X	X
Spray Canal	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X			X	X	X		X	X	X	X		X	X	X		X	X	X

Fig. 7. Revised Sample Impact Matrix

(2) water quality, (3) air quality, (4) land use, (5) social impacts, (6) economic impacts, and (7) health and safety. A near consensus was reached on the following ranking of preferences from highest to lowest: (1) health and safety, (2) aquatic life and water quality, (3) air quality, (4) social and economic impacts, (5) land use. This is the order in which the impacts have been arranged in the revised sample impact matrix given in Fig. 7.

That group concluded that it is at least theoretically possible with probability distributions on measurable impacts and preferences on impact attributes to obtain a numerical evaluation for ranking the alternatives for a specific site. In a practical sense, this objective can be at least approached. However, the ranking may be sensitive to the backgrounds and values of the persons making the evaluations.

All three groups recommended that the sample matrix, by its very organization, tried to equate inequatable items, such as "gas bubble embolisms" to "recreational opportunities." For this reason the groups felt that a hierarchial arrangement of alternative impacts would be more suitable for analysis purposes. Again, the panels advised against generating weighted impact matrices on a generic basis.

C. Technology Assessment and Methodology Development

Panelists felt that the technology assessment technique was nothing more than a reiteration of previous research. Moreover, the technique ignores many interactions that are taking place within a technology and focuses on one-way, cause-effect relationships. In contrast, the panel felt that the methodology development technique offered an alternative whereby interactions and feedback could be more accurately gauged. The panelists felt that social consequence evaluation is so complex a problem that no technique that might aid in this evaluation should be overlooked.

D. The Program Philosophy

The panelists were asked to discuss the philosophy that should prevail throughout the program. The original title of the program was the Social Costs of Waste Heat Discharge Alternatives. However, many of the panelists objected to this term because (1) it seemed to deny the existence of any social benefits resulting from the various cooling technologies and (2) it seemed to suggest to some that a monetary value could be assigned to every effect of a cooling device. For these reasons, the panelists suggested the substitution of "consequences" for "costs."

The consensus suggested that the philosophy of the program should be to present a statement of consequences of the individual cooling technologies to a decision-maker, given the framework of present regulations. This cannot be done on a nationwide or even a regional basis, some suggested, but must be site specific. It was felt that analytical methods should be developed to handle site-specific choices, but when testing methodologies with specific sites, some generalizations could probably be made on a regional and a national basis.

In conclusion, the participants felt that the major objectives of the program should be (1) to provide tools to be used in working toward a goal of quantifying impacts, (2) to provide information needed in the decision-making process, and (3) to determine the decision-maker for this program.

The social consequences program staff was impressed by the interest and the many ideas generated by the panel members. Following the workshop, the program staff met and discussed the recommendations of the panelists and formulated a program plan that defined the direction and scope of the program.

IV. THE FUTURE

Quantification of social consequences is a difficult chore and is in its embryonic stage. Methodologies to measure social impact in depth and with consistency are lacking. Quantification of environmental impacts in purely economic terms is, at best, misleading. Moreover, regional and national evaluations may obscure more information than they yield. Faced with such a jungle of potential pitfalls, how will the Social Consequences program proceed?

Given, as developed in the workshop, that the definition of social consequences is: "the sum total of the internal consequences (consequences produced by the utilities and compensated for by the utilities or all of its customers) and the external consequences (consequences produced by the utilities but not compensated for by the utilities or all of its customers)," the program will proceed along the following lines:

1. The decision-maker to whom this program is addressed is ERDA who will use the results to identify research needs as well as make the results available to regulatory agencies.

2. Sites will be selected in the Midwest for analysis in the first phase of the program. These sites will have representative cooling technologies and will enable the project team to employ existing and to develop, when needed, methodologies to analyze and quantify social consequences.

3. Matrix techniques will be used as checklists as well as investigated for use in a more quantitative role.

4. Techniques for social assessment will be developed and tested at each of the sites.

5. Tentative generalizations will be made from the results obtained at the selected sites.

6. Phase 2 will be more ambitious in that sites in various regions of the country will be selected, analyses performed, and the generalizations of step (5) will be validated and refined.

7. A practical methodology for evaluating the social consequences of alternative cooling technologies will result from steps (1) - (6).

It is not envisioned that a single number quantifying the impact of an action will result from the methodology developed in this program. The goal of the program will be to produce, for the decision-maker, a statement of consequences of the individual cooling technologies for various regions of the country, based on site-specific cases.

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