National
Hydroelectric Power
Resources Study

Volume XI
June 1981

Technology Assessment of National Hydroelectric Power Development

Prepared By:
Nero and Associates, Inc.
520 S.W. 6th Avenue, Suite 820
Portland, OR 97204

Under Contract to:
The U.S. Army Engineer
Institute for Water Resources
Casey Building
Fort Belvoir, Virginia 22060

Contract Number DACW72-81-C-0001

National
Hydroelectric Power
Resources Study

Technology Assessment of National Hydroelectric Power Development

Volume XI
June 1981

IWR-82-H-11

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NHS Volume XI

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
National Hydroelectric Power Resources Study Volume XI, Technology Assessment of National Hydropower Development

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER
IWR 82-H-11

7. AUTHOR(s)
Nero and Associates, Inc.

8. CONTRACT OR GRANT NUMBER(s)
DACW-72-81-C-0001

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Nero and Associates, Inc.
520 S.W. 6th Avenue, Suite 820
Portland, OR 97204

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
WRSC, Institute for Water Resources
Kingman Building
Ft. Belvoir, VA 22060

12. REPORT DATE
June 1981

13. NUMBER OF PAGES
355

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release: Distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Approved for public release: Distribution unlimited

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hydroelectric Power, Technology Assessment, Energy

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is an assessment of the potential impacts and public policy issues that may arise from future development of hydroelectric power resources.

Three alternate levels of potential hydroelectric power development are examined. Level I assumes in increase of 25,000 MW Capacity by the year 2000. Level II, an increase of 45,000 MW and level III, an increase of 75,000MW,The major issues and consequences of each level are defined and

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

discussed, and implementation strategies for each level of development are outlined. Achievement of Level I development appears feasible based on the availability of potential hydroelectric power sites and the current legal and institutional framework. Level II is achievable, but would require some changes in current laws and regulations and financial assistance to developers. Level III is unlikely to be realized by the year 2000.

TECHNOLOGY ASSESSMENT OF NATIONAL HYDROPOWER DEVELOPMENT

Final Report

This work is a result of research sponsored by the U.S. Army Engineer Institute for Water Resources under Contract #DACW-72-81-C-0001

Prepared by:

NERO AND ASSOCIATES, INC.
520 S.W. 6th Avenue, Suite 820
Portland, OR 97204
(503) 223-4150

Approved: Kish J. Sharma, Ph.D.
President

Date: June, 1981

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

Technology Assessment Participants

Project Manager:	Harold A. Linstone, Ph.D.
Core Team:	David C. Olson, Esq. Kish J. Sharma, Ph.D. Jack G. Johnson Arnold J. Meltsner, Ph.D. Paul D. Molnar Pieter A. Frick, Ph.D. Vary T. Coates, Ph.D.
Supporting Staff:	Heather Rode Ruth-Ellen Miller James Wilson Donna L. Wagner, Ph.D. Beverly Bookin Edward Wenk Jr., Ph.D. Robert L. Gay, Ph.D. Michael C. Blumm, Esq. Abdul Qayum, Ph.D. David R. Zoellner, Ph.D. Jane Sterrett
Project Coordinator:	Peggy Remsen
Project Secretary:	Kimm Olin

TECHNOLOGY ASSESSMENT OF NATIONAL HYDROPOWER DEVELOPMENT

Executive Summary

As mandated in the Water Resources Development Act of 1976, the Army Corps of Engineers has conducted an inventory of United States hydropower resources and prepared environmental, economic, legal, and marketing studies collectively designated "The National Hydropower Study" (NHS). The NHS was designed to produce recommendations to Congress concerning the future development of hydropower. This report, a component of the NHS, is an assessment of the potential impacts on our society of a concerted effort to increase development of hydropower resources, strategies to support the development, and an analysis of the public policy issues related to such an effort.

The magnitude of the potential impacts will depend on the level of development which occurs, its timing, the sites which are developed, and the mix of projects—small-scale to large-scale, private sector and public sector. This impact assessment and issue analysis is not site-specific. It addresses generic policy issues and characteristic impacts which may occur to differing degrees in different regions.

In order to reduce the task to manageable proportions, the assessment considers three possible levels of hydropower development. These alternatives, designated in the report as Levels I, II, and III, are merely points selected along the continuum of possible development. The assessment team developed a set of assumptions to accompany each level concerning the most feasible mix of project sizes, developers, location, and timing which would result in the postulated degree of development. The assessment asks: "What policy issues would have to be resolved, and what would the likely impacts be, if this level of hydropower development were achieved?"

This overview begins with the context for hydropower development, then describes the three alternative levels to the year 2000. Next the major issues are defined and their consequences for the development levels discussed. Finally implementation strategies and conclusions are outlined.

THE CONTEXT

Hydropower development must be considered in the context of assumptions about overall energy demand and supply, 1980 to 2000. Projections of energy demand for 2000 appear to be converging toward 100 to 110 quadrillion Btu, based on annual growth rates of 2 to 2.5 percent, considerably lower than historical growth rates of 4 to 5 percent. Electricity demand growth rates are projected at 2 to 4 percent, annually, rather than 7 to 9 percent as in the 1960's and 70's. Electricity's share of total energy, 31 percent in 1979, may increase however; the forecast for 2000 ranges from 25 to 45 percent. The use of oil and gas for electric generation is expected to decline while that of coal rises.

Hydropower plays a small but important supporting role in filling this demand. It currently supplies about 4 percent of total energy and 13 percent of electricity needs. Hydropower is based on the use of the river as an "energy concentrator". It is reliable, renewable, and storable; it can be efficiently converted into electrical energy, combined with other forms of energy, and integrated with other water uses in a river.

Hydropower generation is an old and well established technology. Although marginal improvement of design and manufacturing concepts will continue, no significant breakthroughs are anticipated. Standardization of turbines for the small-scale market is desirable and already under way. Expected advances in transmission and storage technology will probably not significantly affect the potential of hydropower except, in a negative way, by increasing the promise of the competing energy technologies such as solar and fusion power. However, in some situations, solar power and hydropower could be combined advantageously in integrated systems.

ALTERNATIVE LEVELS OF DEVELOPMENT

Level I envisions that hydropower capacity would increase from the present installed capacity of about 63,000 MW to about 88,000 MW by 2000 (excluding pumped storage). This is an increase of 25,000 MW or nearly 40 percent above existing capacity,

but probably would yield only an increment of 15 to 20 percent in energy produced—plant factors drop after the most favorable sites have been used. About 6,000 MW of the increase would come from small-scale projects (up to 30 MW). Some 10,000 MW would be on line by 1990; about 8,600 MW are already planned or being constructed. At least half of this would be gained by expansion of existing generating facilities. Between 1990 and 2000, an additional 12,000 MW would be added at existing facilities both with and without current hydropower capacity, plus 3,000 MW at sites not yet developed. Most of the development (88 percent) would be in three regions: the Pacific Northwest, Northeast and Southeast. Almost half would be developed by private and nonfederal public developers (e.g., municipal utilities, cooperatives) and the rest by federal agencies. Small-scale development totals 6,000 MW, large-scale 19,000 MW.

Level II projects an increase of 45,000 MW, raising present installed capacity from 63,000 MW to about 108,000 MW, or by about 71 percent, by 2000. Of the total, about 56 percent (25,000 MW) would be developed at existing water projects and the remainder (20,000 MW) at undeveloped sites. The first 10,000 MW would come on line by 1990; thereafter, the remaining 35,000 MW would be added. Small-scale development would contribute 7,000 MW, about 16 percent of the total, and is to be located primarily in the Northeast and Western regions. The 38,000 MW of large-scale development would be split equally between the federal and nonfederal sectors (48 percent/52 percent), primarily in the Pacific Northwest.

At Level III, 75,000 MW capacity would be added, an increase of about 119 percent over the 1979 level. Of this, 15,000 MW would come on line by 1990, with two-thirds located at existing water projects. Thereafter, another 15,000 MW would be developed at existing projects and 45,000 at undeveloped sites. Of the 75,000 MW total, about 86 percent would be large-scale and occur primarily in the Western region. A distinctive feature in this case is the dominant role projected for the federal government in expediting development.

Level I could be achieved given a relatively "surprise-free" continuation of present day conditions and trends: a highly pluralistic society with a large number of competing and conflicting interests and priorities, relatively rich and powerful but dissipating its potential in fractionalization. Both domestic energy production and environmental protection would continue to be accorded fairly high priority. Only minor public policy intervention would be required to accomplish Level I since current trends are already headed in this direction.

Level II probably is consistent with a strong cohesive drive for high economic growth, a strategy emphasizing increasing energy supplies rather than reducing demand, a "laissez-faire" policy toward industry, and federal support primarily directed towards large-scale and long-term risk-taking. Major goals of public policy would include military security, increased industrial productivity, and a stronger private sector as well as greater control at the state and local level. Nuclear power and coal would likely be viewed as the most promising energy resources with hydropower given strong support as a private sector, decentralized source of energy.

Level III could probably be achieved only under extreme circumstances, because it would require very strong federal action and immediate removal of many economic, regulatory, and institutional barriers. The assessment team concluded that such circumstances would occur in the event of severe, long-term energy shortages—for example, if a catastrophic nuclear accident resulted in a permanent ban of nuclear power, or Middle Eastern oil resources were destroyed by regional nuclear warfare, or there was inescapable evidence of an impending global catastrophe due to a build-up of carbon dioxide in the atmosphere.

These feasibility scenarios provide the societal context for considering the potential consequences of the three levels of hydropower development. Both analysis of public policy issues and evaluation of possible social impacts were undertaken in the light of future settings which appear to be most likely to allow or foster the given level of development. It must be borne in mind that, although these alternative levels

are merely points along a continuum, they were selected with some attention to opportunities and limitations revealed by the site inventory and screening conducted under the NHS.

PUBLIC POLICY ISSUES

There are general, institutional and legal, economic, and environmental issues which affect hydropower development. We briefly describe each issue and indicate its relation to the levels.

General Issues

- Hydropower as a Contribution to National Energy Needs

  Supplying about 4 percent of the total, hydropower currently plays a modest role in meeting national energy needs. Though some projections indicate no significant change in hydropower's contribution by 2000, under a low growth rate projection the addition of 25,000 to 75,000 MW envisioned in this analysis could supply some 20 to 60 percent of the nation's additional energy requirements as well as reduce United States' vulnerability to energy supply interruptions and optimize utility system performance. Hydropower's role in meeting peak demand and acting as an energy storage device can also be quite significant, and certainly will have an impact in reducing the vulnerability of some regions which are heavily dependent on imported fuels.

- Development Strategy

  Level I is the most readily attainable objective but it will not be realized without some attention to implementation. Level II requires an active strategy with a rather sophisticated balance between federal and

state, as well as public and private sector development. Level III is administratively easier to implement than Level II since a national energy emergency gives the federal government strong powers and public support.

Institutional and Legal Issues

- Changes in the Institutional Framework

While a moderate level of hydropower development (e.g., Level I) can be achieved within the existing institutional framework, more intensive development would necessitate structural changes. Currently, the nonfederal sector can more efficiently bring on line the nation's small-scale hydropower potential, but the institutional disparity between the nonfederal and federal sectors diminishes as a given hydropower project's size increases. The federal sector is historically more experienced in bringing on line large increments of power and has access to federal financing and allocation procedures which can better account for the variety of impacts stemming from larger projects. In any event, increased technical assistance and resolution of interagency conflicts are important in facilitating hydropower at any projected level of development. Beyond Level I, a strategy of partial decentralization can bring about institutional changes which would facilitate realizing the much larger level of development projected in Level II, and a strategy of centralization projected through a contingency plan should be readied for the strong development priority envisioned under Level III.

- Hydropower Development and Indian Reserved Rights

Hydropower development at Levels II and III could be inhibited by Indian treaties reserving tribal development, water and fishing rights, particularly in the Pacific Northwest where most of the potential capacity is located.

Non-Indian hydropower development on tribal reservations would also be an issue. Levels of resolution include negotiation, compensation, and condemnation. Severe measures would be politically feasible only in the context of a prolonged national energy crisis, such as that postulated under Level III.

- Federal Reserved and Preemptive Water Rights

Federal water rights reserved in connection with specific parcels of federal land neither hasten nor impede hydropower development, as Congress traditionally defers to state water law allocation systems in securing water rights for federal projects. The federal government, however, constitutionally has preemptive rights to water on all navigable waterways and can supercede state allocation systems although it must compensate for vested water rights preempted. Congress has almost never exercised these rights and is unlikely to do so without a significant supportive constituency or an energy crisis (Level III) of national proportions. A possible middle ground for Level II is the exercise of federal reserved rights at a limited number of sites specifically reserved for power development, where securing water rights under state systems would impede a particular development.

- Nonfederal Development at Federal Dams

Nonfederal development at federal dams is impeded by jurisdictional conflicts or overlapping agency programs. Both the Federal Energy Regulatory Commission (FERC) and Water and Power Resources Service (WPRS)* claim the right to levy dam use fees at federal dams and authority to approve final engineering designs; both FERC and the Bureau of Land Management (BLM) claim control to land access. Options are: negotiation of memoranda

* The Bureau of Reclamation (BuRec) was renamed the Water and Power Resources Service (WPRS) in December, 1979. The renaming has been rescinded as this report is going to press. (June, 1981). Therefore, please note that all references to WPRS herein refer to the Bureau of Reclamation, Department of the Interior.

of understanding between agencies or enactment of clarifying legislation. Both would hasten a final decision to either open such sites to nonfederal development or authorize immediate studies leading directly to federal development. Resolution of these institutional impediments would facilitate all three projected development levels, but prompt resolution is of particular importance for timely realization of Level I.

Economic Issues

- Small-scale Hydropower Development and the Federal Government's Role

"Small-scale" is variously defined, with the upper limit ranging from 1 MW to 30 MW and beyond. Using a maximum 30 MW figure, perhaps 6,000 to 11,000 MW is potentially developable, with much of it in the Pacific Northwest, New England, and the Southeast. Although a small-scale project is environmentally more benign and less intrusive than a large-scale one, maximum small-scale development will involve intervention at a great many sites. Utilities cannot always easily absorb small-scale facilities and many object strongly to existing legislation forcing them to buy the output, frequently at high rates on long contracts. Broad utilization of small-scale generation, however, could stimulate mass production of turbines, and help reduce the capital costs of small facilities. Small-scale hydropower development currently enjoys many institutional incentives. If desirable, additional incentives to achieve specified development levels could include: additional tax credits, loans, and other subsidies for developers and turbine manufacturers; dissemination of information; and encouragement of standardization of equipment. Small-scale development is viewed as an important component of Level I, but its potential significance diminishes in comparison with the large increments of hydropower envisioned under Levels II and III.

- Hydropower Development and the Framework Governing Water Rights and Uses

Hydropower affects competing uses of water and established water rights and allocations. In some regions, water demand is, or will be,

outstripping available supply. Options include: accelerating water rights filings for hydropower; encouraging or mandating interstate water compacts and planning; forming a national water resources authority to direct comprehensive planning; increasing the available supply by recycling, storage development, weather modification, desalination, management, and other techniques; reducing demand for water; and establishing more flexible allocation mechanisms. Acceleration of filings, reduction of demand, and water supply enhancement measures are appropriate for all three development levels; stronger measures only for Levels II and III.

- Hydropower and Competing Land Uses

Hydropower development can inundate wetlands, recreation, agricultural, and forest lands. Rough estimates for Level II indicate it might reduce presently cultivated acreage by as much as 2.8 percent. Options include: obtaining necessary flowage easements to permit inundation; using existing transmission corridors when possible; evaluating sites with regard to impacts on national agricultural productivity; increasing water conservation efforts; acquiring and preserving sites now; appropriating adequate funding to compensate preempted sites and displaced users. As the bulk of Level I development is envisioned at existing sites, these options apply primarily at Level II and III development where use of undeveloped sites would displace significant acreage.

- The Price of Electricity Produced by Federal Projects

The "preference clause" provided in federal legislation gives public entities first rights to purchase low cost federal hydroelectricity. It was designed to return to taxpayers the benefits derived from public investment, provide a yardstick for evaluating private utility rates, and increase the effectiveness of federal projects in stimulating economic development. Critics point out that the preference clause now permits different prices for different

customers, including individual taxpayers, in the same region and, by giving incorrect cost signals, hampers conservation efforts. Current structures for pricing are also based on averaging the costs of old and new plants and do not reflect the true replacement cost of electricity. Alternative pricing structures exist which could alleviate some of these inequities. These alternatives include marginal cost pricing and cost of alternative source pricing. Both approaches carry their own impacts, however, and neither might survive the intense conflicts engendered by a proposal to eliminate the preference clause. Neither approach is likely to be adopted in order to implement Level I, but both should be studied in conjunction with achieving Levels II and III.

- Capital Formation

The capital to be raised depends on the development level as well as the cost per kW: estimates range from $25 billion to $225 billion for implementation of Levels I, II, or III assuming a capital cost of $1,000 to $3,000/kW. The cost of capital and assembly of front-end financing are serious impediments because of hydropower's lengthy payback period. Possible actions include: loosening the lid on tax exempt bond issues; disseminating information about creative capitalization and innovative financing techniques; and reviving federal subsidies or increasing direct federal aid.

Environmental Issues

- Environmental Regulations and Hydropower Development

Developers claim that many environmental regulations are unnecessary and cumbersome and make many projects economically infeasible. Environmentalists insist that the regulations are necessary, and do not hinder development as reporting requirements add less than one percent to overall costs.

The physical collection of data is not a significant element of project cost, but regulatory and procedural requirements can be complex and time consuming. With a strong hydropower development priority, substantive environmental legislation could conceivably be selectively relaxed, modified, nullified, or waived. But options exist within the current environmental framework which could rationalize the development process without sacrificing environmental quality. Two options are a "one-stop"' central environmental review mechanism to coordinate both agency reviews and citizen involvement, and increased public assistance and incentives to meet high front-end environmental mitigation requirements at worthwhile projects. Such options are appropriate for all levels of development, but would be crucial for expedited implementation of Levels II and III. Moreover, significant modification or relaxation of existing environmental requirements may be a prerequisite to realization of Level III before 2000.

- Public Health and Safety

The likelihood of dam failure is very low. Hydropower development does not appear to entail new or significant risks. To the extent that it substitutes for coal-fired or nuclear plants it reduces public health risks associated with these sources; however, because of the low level of substitution possible this is not a driving factor. However, the unresolved question concerning the hazards associated with atmospheric carbon dioxide buildup from fossil fuel use may increase the appeal of hydropower development and the perceived value of other alternative energy sources as well.

- Hydropower Development and Anadromous Fisheries

Important anadromous fisheries exist in the Pacific Northwest, Northern California, and Alaska. Dams and industrial pollution long ago destroyed those along Northeast coasts, but, to encourage their return, fish ladders now are required for dam construction projects. While fish ladders may add 10 to 15 percent to the costs of a project, the value of an anadromous

fishery may be far greater. Providing adequate streamflows for downstream fish passage may also conflict with hydropower generation efficiency. Large-scale implementation of mitigation and enhancement techniques will be required under all levels of development, but resolution of fisheries conflicts will be most critical for timely implementation of Levels II and III, particularly in the Pacific Northwest where a significant proportion of development is envisioned. Options include: relaxing mitigation requirements; continuing or strengthening such requirements; providing better means of compensating developers for meeting such requirements; increasing fish hatchery production; trucking fish around dams; or providing adequate streamflows.

POTENTIAL IMPLICATIONS OF LEVELS I, II, AND III

It appears that Level I could be achieved with few institutional changes and minimal additional federal intervention. Capital formation could be a problem, however. Assuming $1,000 to $2,000/kW construction cost, it would require about a $25 billion to $50 billion investment for construction over 20 years—$1.2 billion annually until 1990, and from $1.5 billion to $3 billion through 2000. Availability of experienced technical personnel could pose a problem. The effect upon natural and recreational resources would be minimal and legal/institutional impacts generally minor. Similarly, few adverse environmental impacts are anticipated, but they must be assessed on a case-by-case basis. However, issues regarding competing water rights and fees for nonfederal development at federal dams must be resolved.

If Level I is achieved, the impact on the nation's energy situation would be small; however, the image of hydropower as a clean energy source would be sustained and hydropower development would be in a better position to respond if greater need arises. The additional water storage resulting from multipurpose development would also provide a buffer against localized water shortages.

The major uncertainties involved in reaching Level II development are: the viability of potential expansion or retrofitting at existing water projects; the possibility of reaching a consensus on the "best" use of land and water resources; the future trends in electricity demand growth; and the status of emerging competitive technologies such as solar and nuclear fusion. Achievement in Level II would offer some degree of replacement of fossil fuels and some substantial benefits in optimizing the performance of the overall utility system.

The most critical issues related to Level II development are the institutional barriers to large-scale nonfederal projects; the accommodation of Indian rights; and conflicts over water rights. The difficulties of raising investment capital would be considerably more severe than under Level I; it would require $45 billion to $90 billion. Within the Pacific Northwest, environmental stress (e.g., detrimental effects on water quality and flow) and perceived risks (dam failure) would be important issues.

The impacts of Level II are also considerably more important than those of Level I since much of the additional capacity would be developed at new sites. Raising $3.5 to $7 billion annually during the next decade for construction would have economic consequences. Additional hydropower engineers may be needed. Changes in electricity pricing structures are likely and electricity prices could rise. The fishing industry would be seriously affected in some regions while other local communities would be affected by immigration of construction labor. The regionally-concentrated reduction in agricultural, forest, recreational, and pristine lands could be significant.

On the other hand, substantial beneficial impacts would include the enhancement of generating systems' reliability and flexibility; provision of a hedge against inflation of energy prices; and substantially increased employment on a regional basis.

As already noted, Level III is likely to occur only with the recognition of an extended energy emergency. Its implementation would require strong, high priority

federal intervention and relaxation of many environmental regulations. Timely resolution of most issues identified earlier, particularly those associated with Indian rights, water rights, and agency jurisdiction conflicts, would be essential.

Meeting the capital requirements will require concerted actions. Domestic manufacturers would be required to produce the equivalent of 669 turbines of 66.7 MW size plus 350 units of 30 MW, assuming that all new plant capacity will be added as units of this size for large- and small-scale respectively. More likely, much of this equipment would have to be imported. Level III development, however, might provide enough impetus to bring about breakthroughs in small-scale generation and long-range transmission technologies. About $75 billion to $150 billion would be required for construction over 20 years—about $1 billion to $2 billion annually through 1990, but $6.5 to $13 billion annually thereafter, assuming construction cost is $1,000 to $2,000/kW. This would provide tremendous economic benefits to some communities, but the construction could also lead to severe levels of community change (e.g., boom towns).

Again there would be loss of productive lands in some regions. The impact on water supply and water rights would also be significant. Indian reserved rights and state water rights systems might have to be preempted. The courts would very likely be burdened to arbitrate suits brought by public interest groups. The level of conflict within society might rise significantly.

Concentration of generating capacity among a limited number of large-scale facilities under Level III might also increase vulnerability to enemy attack or terrorist actions. There would be increased release of toxic substances (from dredging), dewatering of some streams, increased erosion and degradation of water quality, as well as detrimental impacts on wildlife, fisheries, farmlands, wetlands, and recreational areas.

IMPLEMENTATION STRATEGIES

As noted above, Levels I, II, and III represent points on a continuum of hydropower development for purposes of this analysis. We have described the major issues relevant to these levels, set the issues in the context of the levels, and compared the probable impacts in each setting.

But the ultimate questions remain: How are these levels to be reached? Through what steps? By whom? In Chapter V, some answers are provided. Although speculative, these are based on the four preceding chapters of data, analysis, evaluation, and conclusions. As such, it is an exercise that we believe will focus the discussion, bound the scope of the task, conclude the analysis, and provide the reader with a clear barometer of the implications of translating these levels into political reality.

None of the levels considered will be realized before 2000 without designation as national goals and prompt attention to funding. Furthermore, realistically, none will be realized without successful intervention in four critical areas: political support, approval and legitimation, conflict management, and administration.

For Level I—the only level we regard as politically feasible under current conditions—this means prompt designation of 25,000 MW in incremental hydropower capacity as a national operational priority before 2000, and immediate attention to the funding, informational, and institutional liabilities faced by water resource agencies and developers. Political support must be calculated to take advantage of current interests in hydropower as a domestic renewable energy; administrative agencies must move aggressively into technical assistance and outreach; memoranda of understanding must be negotiated to resolve institutional disputes; governors and state agencies must be consulted and willing to provide support; and permit processing and review must be expedited by all relevant agencies. After roughly a year of experience in implementing and monitoring these measures, a combined legislative proposal should be readied to resolve lingering institutional conflicts; rationally allocate the respective roles for

federal and nonfederal developers; clarify water rights, fisheries, or other major issues as necessary; and streamline authorized federal planning and construction. Simultaneously, policy leadership should be exerted by the executive branch to encourage rapid administrative and judicial resolution of lingering conflicts.

With respect to Level II, attainment before 2000 is considered politically unlikely under current conditions. To achieve it, 45,000 MW in incremental hydropower capacity must be promptly designated as a national priority and immediate attention must be paid to funding and institutional concerns. In a Level II setting, we project implementation only as part of a broad program to expand economic growth within the private sector. Accordingly, an Office of Management and Budget (OMB) sponsored interagency task force should recommend a more decentralized federal role in hydropower development by means of a single, primary-mission federal agency. The task force report is prepared as a legislative package with strong presidential support as part of an omnibus economic growth package. State support for the legislation is mobilized because state involvement becomes more crucial. With congressional approval, the new agency delegates siting and approval powers to the regions and inaugurates broad programs to assist state licensing and clearance, and disburse loan funds and financial incentives for nonfederal developers. Federal water resource agencies move, under the new regime, into greatly expanded outreach and technical support services, and standards are revised and promulgated to maximize energy over other uses in water resources development.

With respect to Level III—whose likelihood of attainment before 2000 we premise upon the existence of a national energy emergency of low probability but grave impact—a contingency plan for such a crisis should be prepared by the Corps of Engineers.

Should the projected crisis occur during this decade, contingency can be implemented immediately with strong congresional and presidential support. Broad popular support also is assumed: consensus is a natural response to common perception of an emergency situation.

The major features of Level III implementation within a crisis scenario include: presidential proposal of emergency power legislation, interagency development of an integrated policy package proposing an Emergency Economic Board with wide authority to allocate resources and coordinate government actions, continuing consultation leading to expressions of support from both Congress and state governors, a televised presidential speech to Congress leading to passage of the proposed legislative package, and eventual establishment of the Emergency Economic Board at an OMB level in the White House to ensure top level monitoring and reporting. The Board itself is expected to consolidate all federal development under the Corps of Engineers and instruct the Water Resources Council to revise federal standards to maximize hydropower and prepare preemptive plans for securing water rights. The Board must also act to ensure expedited coordination and review within FERC and state government agencies.

It should be noted that all three levels will raise many questions about the impacts stemming from their implementation. Such questions properly will require considerable additional research for information and answers.

A concise summary of the assessment study is shown in Table 0.

CONCLUSIONS

The relatively benign environmental and resource impacts of hydropower, compared with fossil fuels, make it attractive for further development at or about the level envisioned in Level I—a 40 percent increase over present capacity, about two-thirds of which would be at existing dam sites. The contribution to the nation's energy supply will be modest but significant. Level II would be much more difficult to achieve. Level III might in some ways be easier than Level II in that it would only be undertaken in the event of a prolonged crisis, which forges societal cohesion and justifies extraordinary use of authority. However, the impacts of Level III could be much more disruptive and detrimental.

Achievement of any of the three levels will require:

- Reduction of lead times to bring capacity on line;
- Considerable infusion of public funds particularly for Levels II and III through both subsidies and incentives;

TABLE O

SUMMARY OF ASSESSMENT OF THREE LEVELS OF HYDROPOWER DEVELOPMENT TO 2000

LEVEL	I	II	III
BY 2000 ADD:	25,000 MW	45,000 MW	75,000 MW
ASSUMPTIONS	CURRENT TRENDS CONTINUE NO MAJOR INITIATIVES	STRONG, ECONOMIC GROWTH DRIVE TECHNOLOGICAL OPTIMISM PRIVATE-SECTOR EMPHASIS	NATIONAL CRISIS FEDERAL MOBILIZATION TO AVOID ECONOMIC COLLAPSE
KEY FEATURES OF HYDRO ADDITION (small scale ≤ 10,500 MW) (≥ 10,000 MW on line by 1990)	2/3 EXISTING DAMS 1/2 FEDERAL 1/2 NON-FEDERAL 1/4 SMALL SCALE	1/2 EXISTING, 1/2 NEW SITES 1/2 FEDERAL 1/2 NON-FEDERAL 1/6 SMALL SCALE	2/3 NEW CONSTRUCTION 3/4 FEDERAL 1/7 SMALL SCALE
RELEVANT ISSUES	ONLY MARGINALLY SIGNIFICANT ISSUES CAPITAL FORMATION	ECONOMIC ISSUES IMPORTANT CAPITAL FORMATION CRITICAL COMPETING LAND AND WATER NEEDS	CENTRALIZATION ENVIRONMENTAL ISSUES COMPETING LAND AND WATER NEEDS

LEVEL	I	II	III
MAJOR IMPACTS	NO MAJOR IMPACTS ENCOURAGE NON-FED DEVELOPMENT AT FEDERAL DAMS STREAMLINE INTER-AGENCY RELATIONS	MATERIAL, PERSONNEL SHORTAGES SUPPORT NON-FEDERAL & PRIVATE DEVELOPMENT NEW AGENCY TO STRENGTHEN FEDERAL/ NON-FEDERAL PARTNERSHIP	MATERIAL, PERSONNEL SHORTAGES PREPARE CONTINGENCY PLAN INCLUDING EQUIV-ALENT OF WAR PRODUC-TION BOARD
IMPLEMENTATION STRATEGIES	RECOGNIZE FINANCING PROBLEM GIVE TECHNICAL ASSISTANCE, OUTREACH NEGOTIATE INTERAGENCY MEMO OF UNDERSTANDING LATER, PROPOSE STREAM-LINING LEGISLATION JUDICIARY SETTLE DISPUTES RAPIDLY	CREATE INTERAGENCY TASK FORCE CHAIRED BY OMB WHICH RECOM-MENDS SINGLE AGENCY CONVERT TASK FORCE RE-PORT INTO LEGISLATIVE PACKAGE ESTABLISH LOAN FUND FOR PRIVATE DEVELOPERS	WHEN CRISIS OCCURS: PRESIDENT AND CON-GESSIONAL LEADERS CONSULT WHITE HOUSE AND OMB DESIGN POLICY PACKAGE INCLUDING EMERGENCY ECONOMIC BOARD AND MORATORIUM ON ENVIR-ONMENTAL STATUTES GET GOVERNORS' SUPPORT PRESIDENTIAL SPEECH PASS ENABLING LEGISLATION
FEASIBILITY	HIGH	MEDIUM	MEDIUM

- Protection of natural resources;

- Resolution or management of conflicts related to water rights, land use, and Indians' reserved rights;

- Development of improved pricing structures; and,

- Alleviation of possible shortages of capital, material, and equipment.

Level I appears feasible without other major changes. Level II requires rapid deployment of developmental capabilities, additional incentives and assistance to the private sector for large-scale projects. Level III requires implementation of a contingency plan for massive and rapid hydropower development, should the situation arise, with the federal government taking an active role in planning and construction as well as stimulating and coordinating nonfederal development in accordance with national goals and objectives.

Preface

This volume presents the results of the technology assessment of hydropower development in the United States. The Executive Summary provides an overview. The basic concept and context of hydropower are covered in Chapters I and II. Readers interested primarily in the issues should turn to Chapter III. Those concerned with action alternatives and implementation strategies will wish to focus on Chapters IV and V. A series of appendices follow Chapter V.

The project team would like to express its appreciation to the more than 100 citizens—federal, state, and local officials, American Indians, entrepreneurs, technologists, etc.—who, through interviews, contributed much to our understanding of the issues.

Finally, we would like to acknowledge the valuable support provided by Michael Walsh of the Institute for Water Resources, the Project Advisory Committee (Darryl Davis, Ed Barbour, Evan Vlachos, Helen Ramatowski and Tom White), the North Pacific Division of the Corps of Engineers in Portland, and the various federal and state agencies which furnished data to the team.

TABLE OF CONTENTS

Preface		i
Table of Contents		ii
List of Figures		iv
List of Tables		vi
CHAPTER I	Introduction	I-1
CHAPTER II	The Context	II-1
	2.1 The Water Setting	II-1
	2.2 Hydropower: The Concept	II-10
	2.3 Hydropower: Technologies	II-15
	2.4 The Energy Setting	II-20
CHAPTER III	The Issues	III-1
	3.1 General Issues	III-1
	3.2 Institutional and Legal Issues	III-9
	3.3 Economic Issues	III-21
	3.4 Environmental Issues	III-36
	3.5 Concluding Comment	III-53
CHAPTER IV	Alternative Levels of Development	
	4.1 Introduction	IV-1
	4.2 Assessment of Three Levels of Hydropower Development: The Process	IV-9
	4.3 Assessment of Level I Development	IV-9
	4.4 Assessment of Level II Development	IV-20
	4.5 Assessment of Level III Development	IV-31
	4.6 Comparison of Three Levels of Development	IV-41

CHAPTER V Implementation Strategies

5.1	Introduction	V-1
5.2	Level I Actions	V-1
5.3	Level II Actions	V-9
5.4	Level III Actions	V-14

LIST OF FIGURES

Figure 1-1	Conventional Hydroelectric System	I-2
Figure 1-2	Pumped Storage System	I-3
Figure 1-3	Report Outline	I-5
Figure 1-4	The Pattern of Shifts in Primary Energy Sources for the U.S.	1-7
Figure 2-1	Water Budget of the Coterminous United States	II-3
Figure 2-2	Average Annual Runoff	II-4
Figure 2-3	Inadequate Surface-Water Supply and Related Problems	II-8
Figure 2-4	Energy Demand and Supply Balance: 1979 (Quads)	II-21
Figure 2-5	Electricity Demand and Supply Balance: 1979 (Quads)	II-22
Figure 2-6	Retail Prices: Fuels and Electricity (1979 Dollars)	II-24
Figure 2-7	Estimates of Energy Requirements	II-25
Figure 3-1	The Issues Considered	III-2
Figure 3-2	The Cumulative Advantage of Non-Federal Over Federal Development Due to Federal Incentives	III-14
Figure 3-3	The Construction Funding Problem	III-37
Figure 3-4	Relative Ranges of Environmental Acceptability for Hydropower Configurations	III-41

Figure 4-1	Basic Considerations of Alternative Levels of Hydropower Development	IV-7
Figure 4-2	Relevant Issues for Level I Development	IV-15
Figure 4-3	Impacts of Level I Development	IV-17
Figure 4-4	Relevant Issues for Level II Development	IV-23
Figure 4-5	Impacts of Level II Development	IV-25
Figure 4-6	Relevant Issues for Level III Development	IV-35
Figure 4-7	Impacts of Level III Development	IV-37
Figure 4-8	Comparison of Issue Relevance and Levels	IV-43
Figure 5-1	Applicable Action Options for Level I Development	V-5
Figure 5-2	Applicable Action Options for Level II Development	V-10
Figure 5-3	Applicable Action Options for Level III Development	V-15

LIST OF TABLES

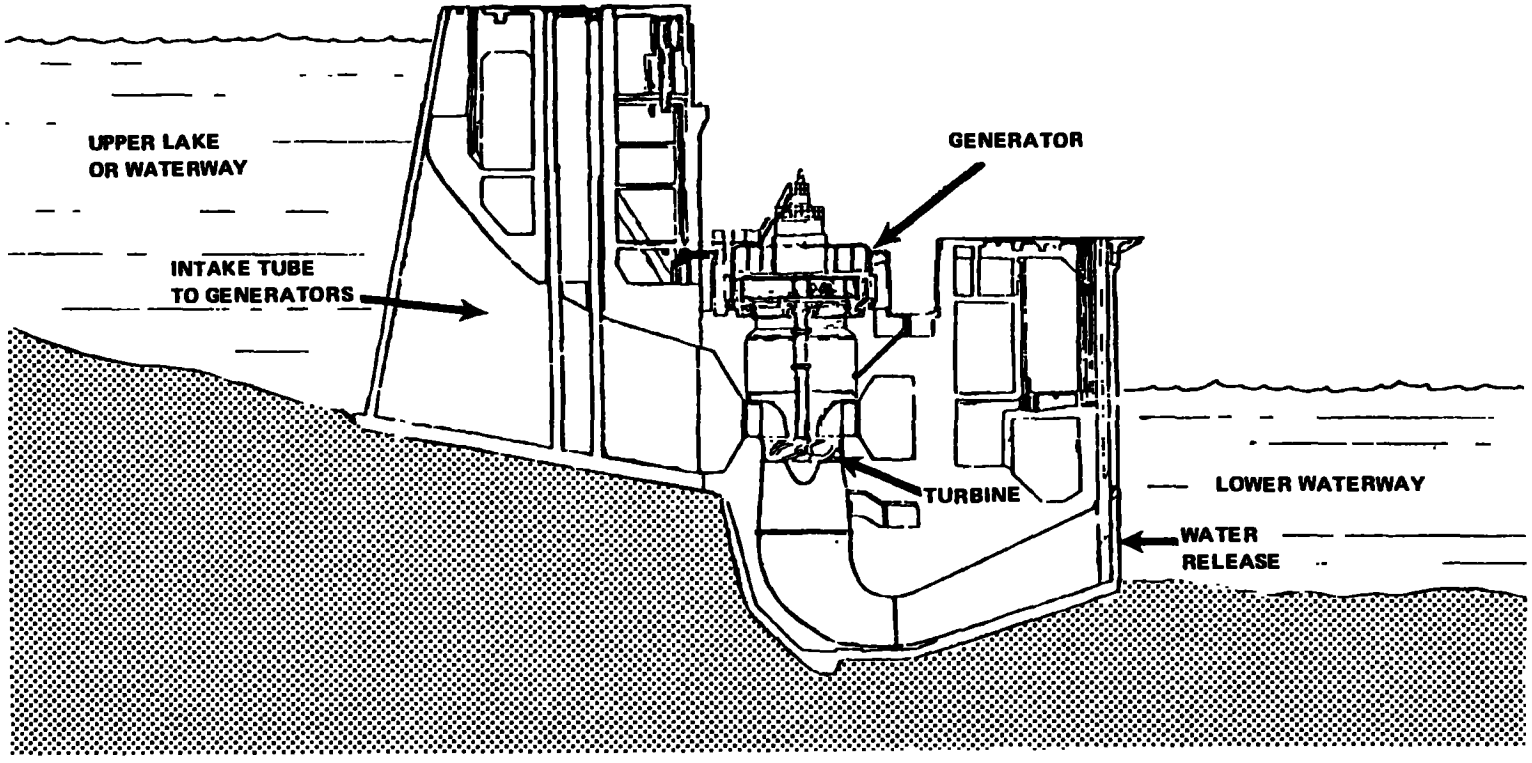
Table 2-1	Initial Availability of Power Generation Technology	II-29
Table 2-2	Technology Economics (Per CEC, 1980 Data)	II-30
Table 3-1	The Effect of Discounting	III-36
Table 3-2	Major Classes of Hydropower Impacts	III-38
Table 3-3	Safety of United States Hydropower Facilities, As of April 1981	III-45
Table 3-4	Estimated Total Fatalities for Worker and General Public From Electricity Generating Technologies, Per Effective Plant Year	III-46
Table 4-1	Alternative Development Plans	IV-6
Table 4-2	Categories of Impacts Considered in the Assessment	IV-10
Table 4-3	Characteristics of Alternative Levels of Hydropower Development	IV-13
Table 5-1	Possible Action Options: Master List	V-2

CHAPTER I
Introduction

Hydropower, in its simplest form, is the production of energy from water flowing through a turbine which spins a generator. Conventional hydroelectric systems use dams and waterways to harness the energy of falling water (See Figure 1-1). These include reservoirs or storage systems at dams and run-of-river type operations which cause minimal fluctuations of streamflows. Pumped storage systems (See Figure 1-2) use the same principle of falling water for the generating phase, but all or part of the water is made available for repeated use by pumping it from a lower to an upper reservoir.

This study is an overall assessment of potential hydropower development in the United States for the year 1980 to 2000. As such it deals with the impacts or consequences of alternative hydropower development levels. It asks: What are the pertinent major issues? What are policies to mitigate resulting problems? What are the uncertainties? The assessment is done at the national level, i.e., it is not site-specific;[1] it stipulates alternative national hydropower levels, not locations. It addresses conventional hydropower, primarily in terms of capacity; it deals only peripherally with pumped storage (See Section 2.2.2 of this text and Section A of the Appendices). Cost-benefit analysis is of very little relevance when sites are not defined. Thus, the emphasis in this study is on overall policy analysis, on qualitative rather than quantitative aspects.

This work represents one of several components of the National Hydropower Study (NHS) conducted by the U.S. Army Corps of Engineers under a congressional mandate in the Water Resources Development Act of 1976. An inventory of national hydropower resources and a set of environmental, economic, legal, and marketing analyses already have been prepared.

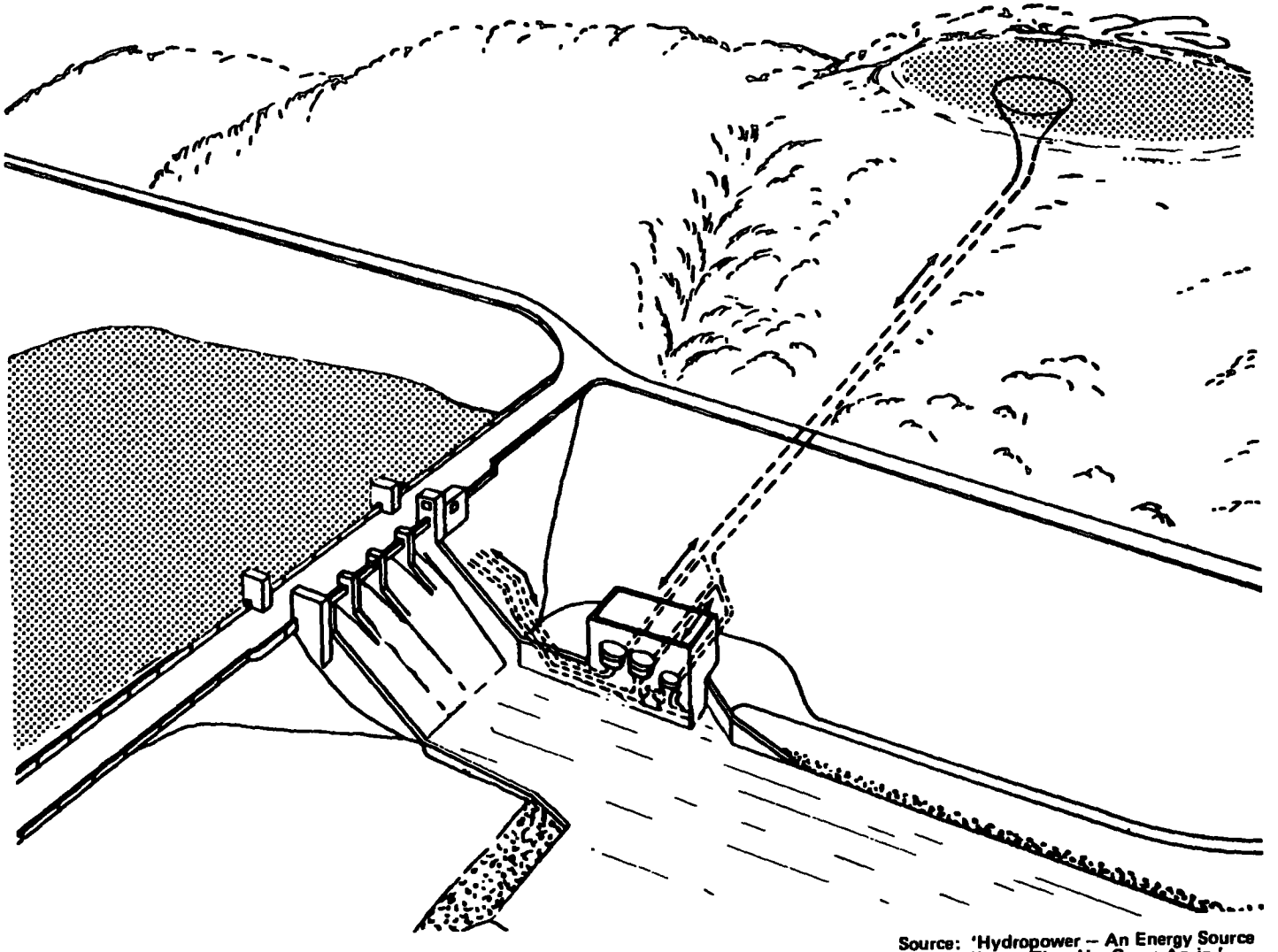


Source: Hydropower—An Energy Source Whose Time Has Come Again

General Accounting Office Report
EMD-80-30
January 11, 1980

Figure 1-1.

CONVENTIONAL HYDROELECTRIC SYSTEM



Source: 'Hydropower – An Energy Source Whose Time Has Come Again.' U.S. Government Accounting Office Report EMD-80-30 January 11, 1980

Figure 1-2.
PUMPED STORAGE SYSTEM

The scope of this assessment is shown in Figure 1-3. Chapter II provides the context for the assessment. Hydropower invokes several of the many functions of our water system and constitutes one of the various sources from which this country draws its energy. Although an ancient technology, hydropower may see improvements over the next two decades, and these, too, are surveyed. Finally, the institutional setting for hydropower, an important aspect for policy planning, is reviewed.

Chapter III focuses on the issues which are raised by further hydropower development. Besides overall or general issues there are three categories: institutional and legal, economic, and environmental. Each of a total of 14 issues is described and analyzed.

Using the environment and issues in Chapters II and III as a basis, we next consider three levels of hydropower development and associated societal settings in Chapter IV. They are defined in terms of hydropower capacity added during the period 1981-2000. The increments constitute a range of about 40 percent to 120 percent increase over current capacity. Each level is embedded in a scenario which helps to concretize the discussion of associated impacts and policy options. Chapter IV concludes with a comparison of the three alternative levels of development.

Chapter V carries each development level further, suggesting appropriate strategies and implementation steps. The assessment concludes with a comparison of relative feasibility of the three levels of development, and proposes an agenda of topics for further research in the area of future hydropower development.

The work of the study team included over 100 interviews ranging from state senators to hydropower equipment builders, lobbyists to American Indians, utilities to regulators. In spite of the many available reports and contacts, much uncertainty remains. Some of it is due to the lack of specification of sites, e.g., changes in water quality resulting from future hydropower development. More uncertainty results from the issues, which reflect differences in opinion or conflicts, e.g., the appropriate discount rate, the cost-effectiveness of the Corps of Engineers in developing small-scale hydropower. Still more uncertain is a lack of solid facts, e.g., future projections about electricity demand, supply and prices. And these uncertainties multiply as we approach the 21st century.

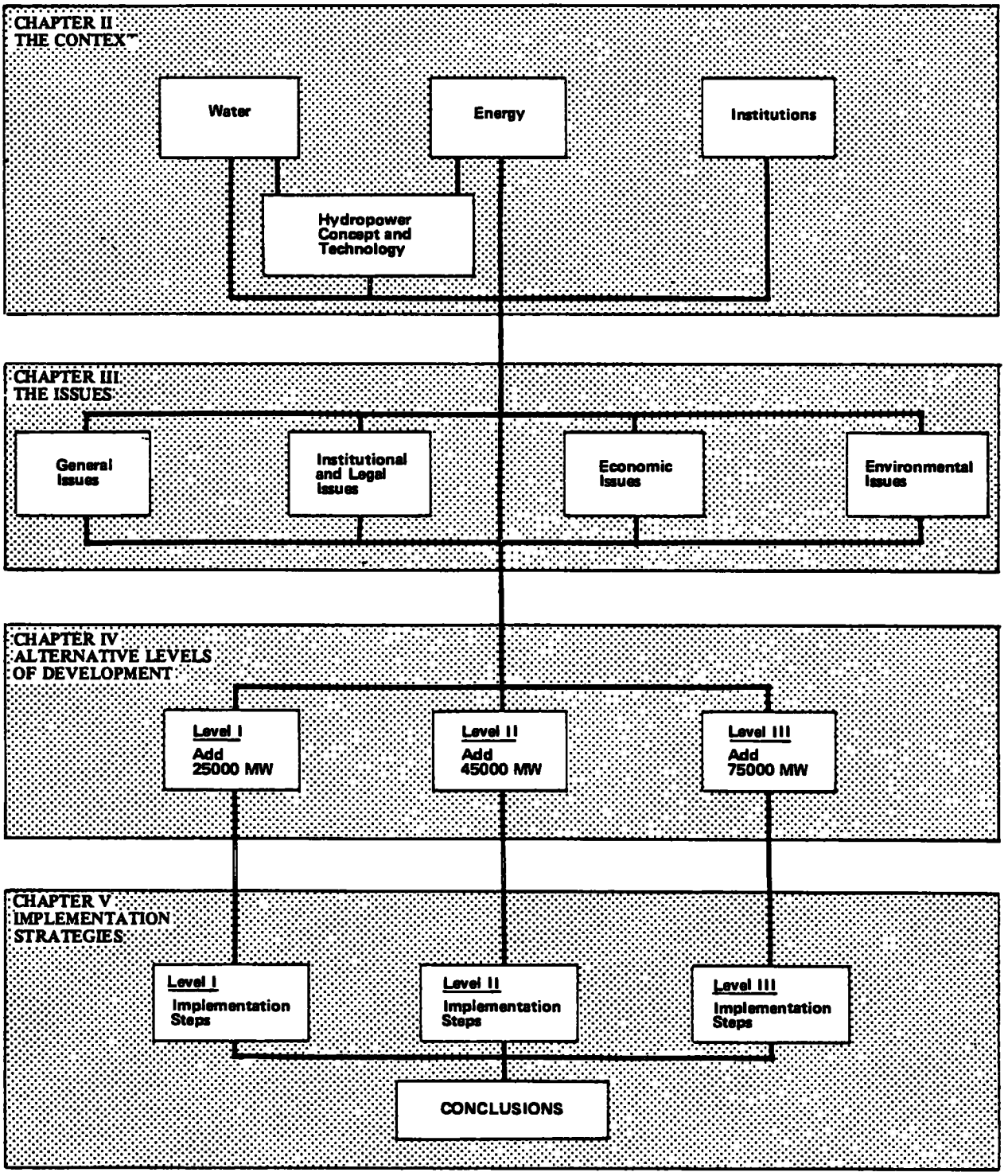
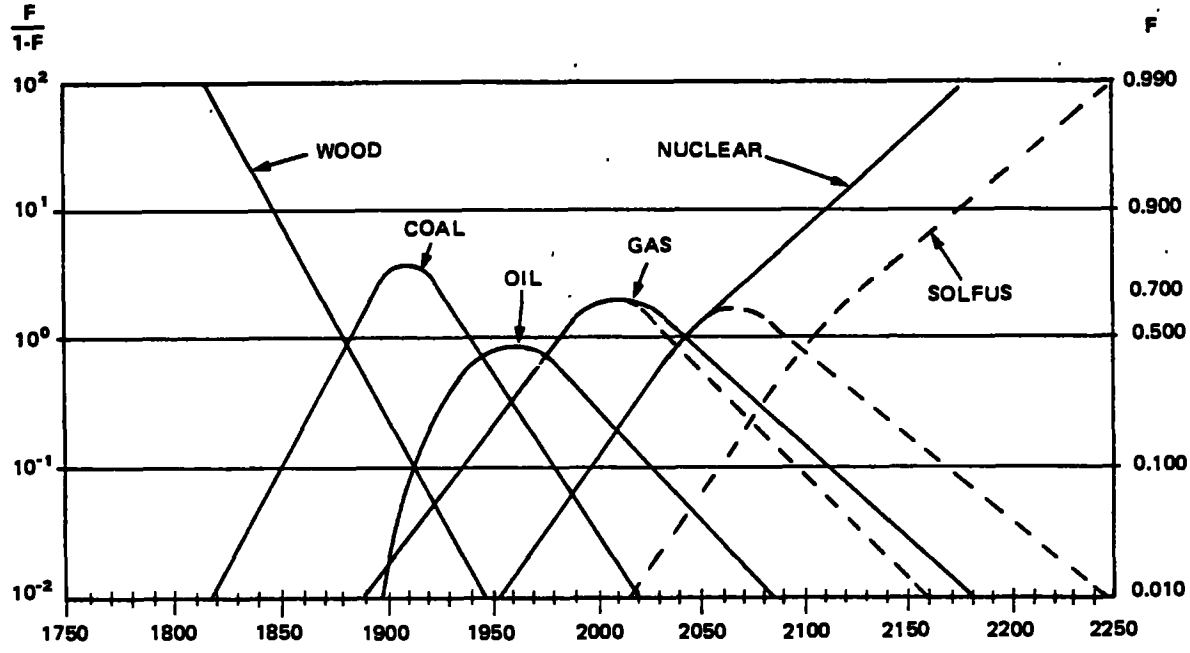


Figure 1-3.

REPORT OUTLINE

Our analysis of alternative levels of development over a limited time span provides a means to deal with these uncertainties. The emphasis is on "what-if" rather than on prediction, and on the next 20 years rather than on the 21st century.

It can be forecast with confidence that energy will not continue to be a critical issue for more than one generation. There are two possibilities: either we are well on the way to "solving" the problem or we are not. If we are it will no longer be viewed as critical; if we are not it will be accepted as a "condition" rather than continue to be treated as a critical "problem" to be solved. It is simply not reasonable to expect Americans to maintain their focus on the energy crisis for more than one generation. If history offers any clues regarding energy, we have reason for optimism in the long term. Since 1800 we have shifted prime reliance in a remarkably regular pattern from one energy source to another: wood to coal to oil and gas (Figure 1-4). In the 21st century, new prime energy sources will initially be either nuclear or solar or both (Refs. 1.1, 1.2). While hydropower has never been a prime source of energy for the United States (as it has for some other countries), it can ease the transition phase; this role justifies serious consideration of the implications of its further development.



F represents the fraction of energy consumption attained by a given type. There are two projections for the future: (a) nuclear fission only (solid line), (b) solar or fusion following nuclear fission (dashed line, "SOLFUS").

Figure 1-4.

THE PATTERN OF SHIFTS IN PRIMARY ENERGY SOURCES FOR THE U.S.

Source: Ref. 1.3

REFERENCES

1.1 C. Marchetti. "Primary Energy Substitution Models: On the Interaction Between Energy and Society". Technological Forecasting and Social Change, 10 (1977), pp. 345-356.

1.2 C. Marchetti. "Society as a Learning System: Discovery, Invention and Innovation Cycles Revisited." Technological Forecasting and Social Change, 18 (1981), No. 4.

1.3 M. Grenon. "Long Term Energy Strategies". Research Memorandum RM76-39, International Institute for Applied Systems Analysis, Laxenburg, Austria, April 1976, p. 4.

FOOTNOTES

1. For a good example of a (site-specific) assessment of a dam, see H. M. Fahim, "Dams, People and Development: The Aswan Dam Case", Pergamon Policy Studies, Pergamon Press, 1981.

CHAPTER II
The Context

In this chapter we set the stage for the subsequent analysis of alternative levels of hydropower development.

We begin with a discussion of water as a resource and hydropower as one of its present uses. Potential improvements in this technology are summarized. Next we view hydropower as an element in the total national energy picture so that its relative significance may be readily assessed.

2.1 The Water Setting

In the hydrologic cycle, water continually moves by evaporation from the sea into the atmosphere, by precipitation on land and sea, and by return flow in rivers to the sea. Some water falling on the land reevaporates from lakes, wet soil and vegetation, and some percolates underground, becoming ground water (Ref. 2.1).

The United States water supply derives both from precipitation and streamflow from Canada. Much water is stored temporarily as snow and ice on the ground, in ground water aquifers and in lakes and reservoirs. Ultimately, the water flows to the oceans, or it is evaporated or transpired to the atmosphere as part of the continuing hydrologic cycle.

The most comprehensive and authoritative overview of the nation's water situation is the United States Water Resources Council's Second National Water Assessment. The remainder of this section relies heavily on that report's Summary (Ref. 2.2).

2.1.1 Water Budget

On the average, about 40,000 billion gallons per day (bgd) of water passes over the conterminous United States in the form of water vapor. Of this, approximately 10 percent (about 4,200 bgd) is precipitated as rainfall, snow, sleet, or hail. The remainder continues in atmospheric suspension. Of the 4,200 bgd—equivalent to the average rainfall of 30 inches falling on the conterminous

United States—about two-thirds (2,750 bgd) is evaporated immediately from the wet surfaces or transpired by vegetation. The remaining 1,450 bgd accumulates in ground or surface storage; flows to the ocean, the Gulf of Mexico, or across the Nation's boundaries; is consumptively used; or is evaporated from reservoirs (Figure 2-1).

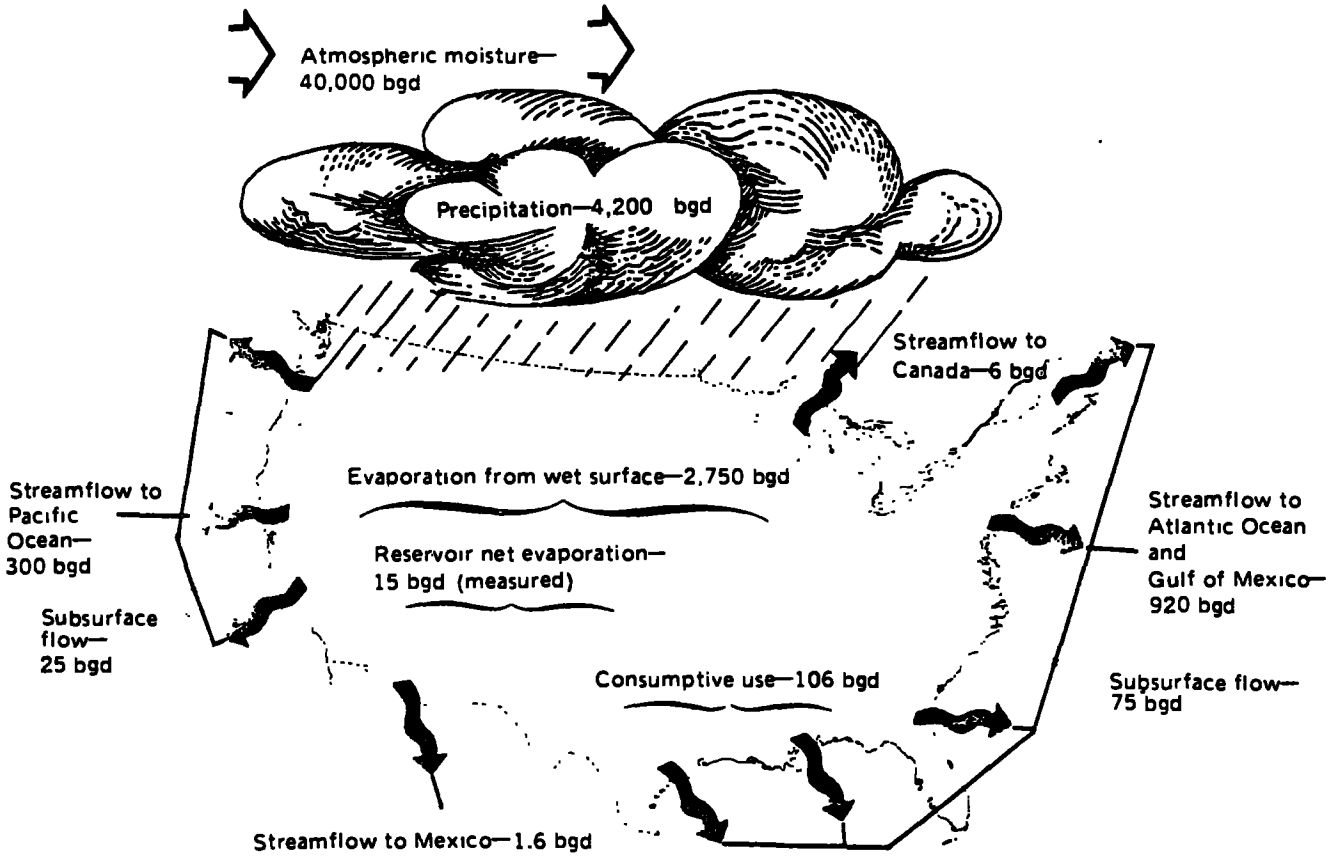
Only part of the potential 1,450 bgd can be developed for intensive beneficial uses. To date, with existing surface storage and because of the extremes of annual precipitation that cause floods and droughts, only 675 bgd is considered available in 95 out of 100 years.

Surface water can be available for use as fresh water in the United States from the time it strikes the land surface as precipitation until it is discharged into the ocean; mixes with saline water in estuaries, landlocked seas, or saline lakes; or passes across the borders of Canada or Mexico. It is usable only so long as it is not excessively polluted with natural or manmade pollutants.

Average annual runoff for the conterminous United States is highest in the Pacific Northwest and lowest in the Southwest and some of the intermountain valleys (Figure 2-2). The average annual runoff is sometimes assumed to be the theoretical upper limit of surface supplies. However, the increased storage required to make this quantity of water available for use would be so large that the resulting evaporation from the required reservoirs would substantially decrease the available water. Thus, a mix of increased storage and other alternatives seems to offer the most effective solution.

2.1.2 Fresh Water Streamflows

Surface water occurs in rivers, streams, lakes, swamps, marshes, and manmade reservoirs, whereas ground water occurs in the zone of saturation below the land surface. Streamflow varies from region to region, from season to season, and from year to year. For example, within a normal year and for a given region, the ratio of maximum streamflow to minimum streamflow can be more than 500 to 1. Annual variations in flow also are substantial. Even in areas of high precipitation and streamflow, a series of dry years sometimes



Source: Ref.2.2

Figure 2-1.

WATER BUDGET OF THE COTERMINOUS UNITED STATES

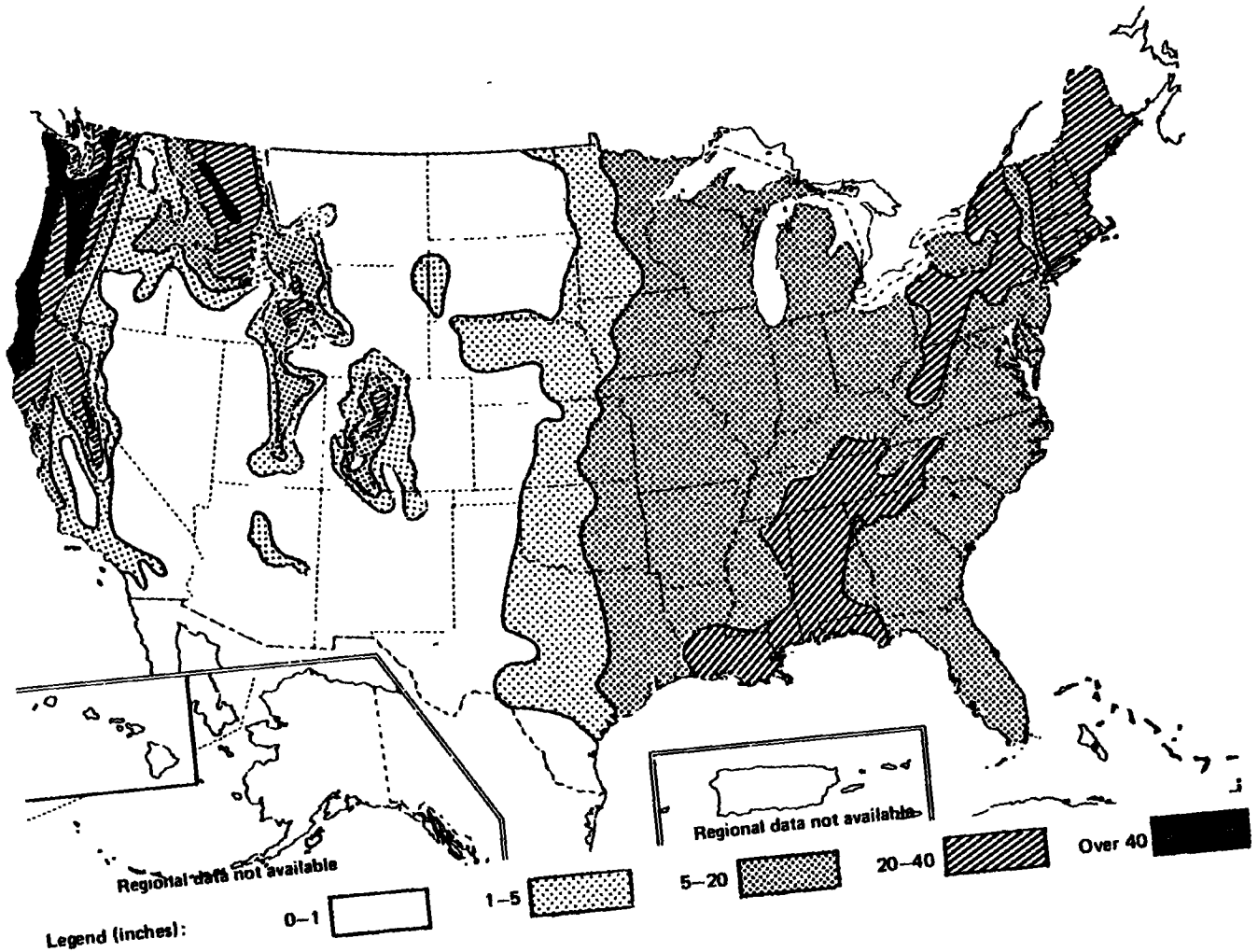


Figure 2-2.
AVERAGE ANNUAL RUNOFF

Source: Ref. 2.2

occurs, resulting in serious droughts such as those in the Northeast in 1961 and 1966, and in the West and other parts of the United States in 1976 and 1977.

Effects of droughts are particularly serious in areas that use a high proportion of the available average annual runoff or where storage and distribution facilities are inadequate to provide sufficient carryover during prolonged periods of low streamflow. In the humid East, streamflow tends to vary less from year to year and from month to month than in the other regions.

2.1.3 Ground Water

About 30 percent of the nation's streamflow, in an average year, is supplied by ground water that emerges as natural springs and other seepage. In turn, seepage from streams, rivers, canals, and reservoirs is a source of ground water recharge. Most of the flow in many smaller streams comes from ground water during the low-flow months. In years of below normal precipitation, all the streamflow during low stage may be ground water. Ground water, therefore, is important to the continuity of streamflow. However, to simplify this report's consideration of water supply/demand in the context of hydropower, subsequent text will focus on surface water (fresh water portion).

2.1.4 Water Use

"Water use" consists of two main categories: offstream use and instream use. Both are important to hydropower, which is classified as an instream use of water because usually water is not withdrawn from the source to some other location for use (pumped storage can be an exception). Other instream uses include fish and wildlife, recreation, esthetics, navigation and waste assimilation.

Offstream uses can be classified in several ways but the Water Resources Council's Assessment uses agriculture (irrigation and livestock), domestic and commercial uses, manufacturing, minerals production, steam electric generation, public land and others (including fish hatcheries). Of the water withdrawn, part is consumed, or not returned to the source after use, such as in the case of

vegetation transpiration. The portion not consumed returns to either a surface water or ground water source, perhaps at a location and/or time far removed from its location and time of withdrawal.

Traditionally, preference has been given to consumptive uses—primarily irrigation, municipal and industrial purposes. Water consumed, of course, is no longer available in the stream for hydropower generation downstream. Many storage reservoirs have been constructed for non-hydropower purposes such as urban water supply, irrigation, flood control and navigation, with no provision made for hydropower. In some projects, hydropower generation was incorporated to provide additional revenue to reduce the cost of water for the dominant project purpose. This limited-purpose approach often resulted in adverse environmental impacts and water not being available for some purposes that could have been incorporated.

Water uses often compete for the available water supply; some uses are compatible with hydropower, some are not. As mentioned previously, upstream withdrawals/consumption remove water which might otherwise be used for power generation. There also may be downstream uses such as water quality or navigation which require water releases during normal minimal discharge periods or are otherwise adverse to other uses. Recreational use of a reservoir may depend on minimal pool drawdown/fluctuation, thereby decreasing operational flexibility.

It is helpful to look at some of the uses which are particularly significant on a national basis to the future of hydropower. Such perspective may not always be valid in the case of a specific site or project, however.

Agriculture is the largest user of water, on the basis of both withdrawal and consumption, being responsible for about 83 percent of total water consumed in "1975",[1] and about 48 percent of total water withdrawn.

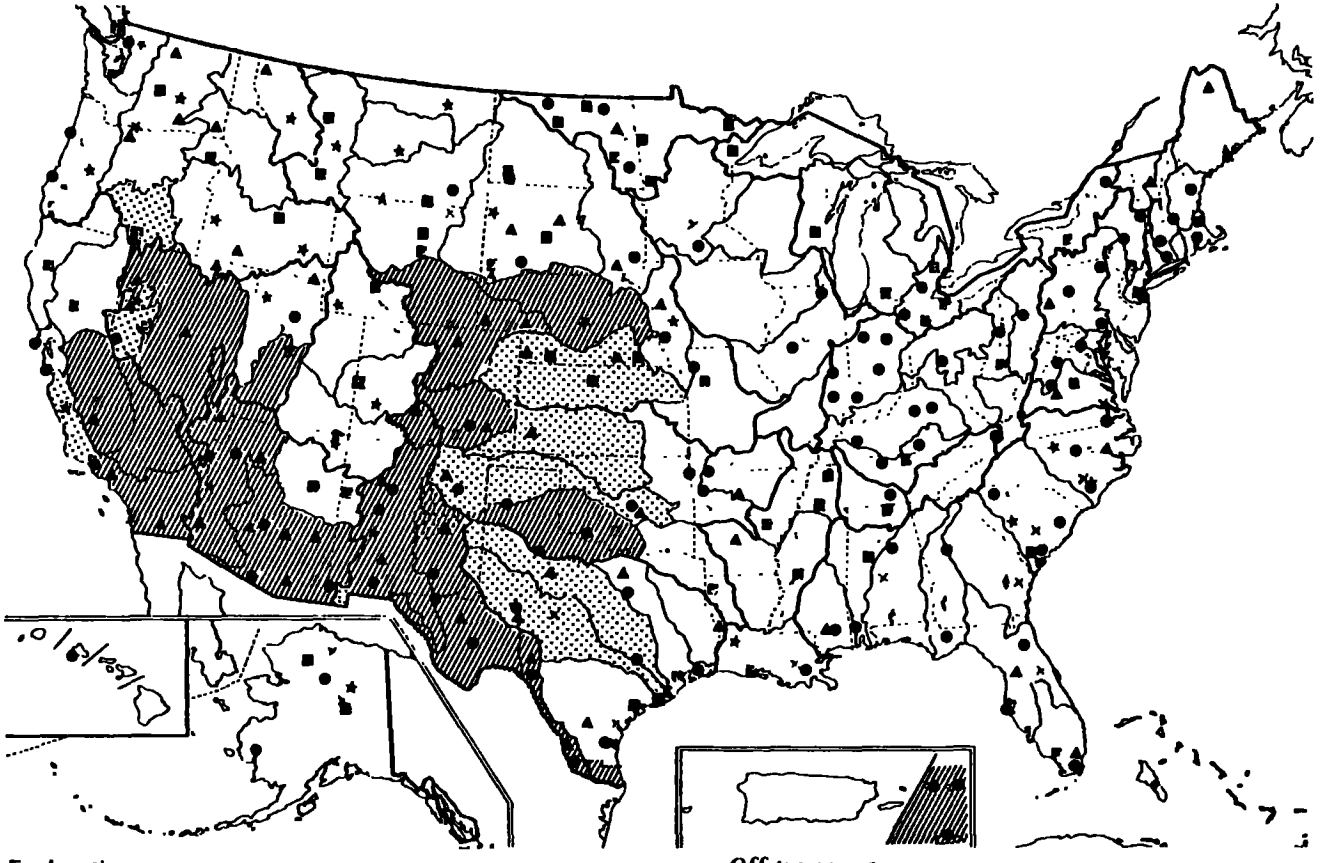
With respect to the United States surface water supply, the situation is best summarized by the following quotation and Figure 2-3 from the Water Resources Council's Assessment.

> Competing offstream uses of water for energy, agricultural, domestic, and industrial needs coupled with associated environmental and instream-flow uses have resulted in basinwide and local problems throughout the United States. The Second National Water Assessment projects that by the year 2000 the national increase in annual fresh-water consumption will further compound problems. The problem of inadequate surface-water supply is or will be severe by the year 2000 in 17 subregions located mainly in the Midwest and Southwest. However, an analysis of monthly water data shows that during low-flow months there will be an increase in the number of subregions, including some in the East, with inadequate supply (Ref. 2.2).

2.1.5 Other Water-Related Considerations

In the United States, water is public property and its disposition is regulated by the federal and state governments. Federal authority derives from the United States Constitution (commerce and navigation powers; supremacy clause, etc.), statutes, and myriad rules and regulations promulgated by federal entities.

Primarily as a result of the authority vested in them through the granting of statehood, the states administer rights to water use based essentially on two doctrines—riparian and prior appropriation. However, the states also have the right to transfer their ownership of water to other public and private interests under certain conditions. These state systems date back as far as the mid-1800's. Unfortunately their inability to keep track of the many actions which have occurred means that in much of the United States (particularly the West), records do not identify the legal owners of the waters, and efforts to adjudicate the many claims are woefully inadequate. Further clouding the situation are rights such as those held by the federal government associated with federal lands and by Indian tribes associated with their reservations.



Explanation

Subregion with inadequate streamflow ("1975"-2000)

- 70 percent depleted in average year
- 70 percent depleted in dry year
- Less than 70 percent depleted

Specific problems *(as identified by Federal and State/Regional study teams)*

- ★ Conflict between offstream and instream uses
- Inadequate supply of fresh surface water to support–

Offstream use

- ● Central (municipal) and noncentral (rural) domestic use
- × Industry or energy resource development
- ▲ Crop irrigation

Instream use

- ■ Fish and wildlife habitat or outdoor recreation
- ♦ Hydroelectric generation or navigation

Boundaries

- Water resources region
- Subregion

Source: Ref. 2.2

Figure 2-3.

INADEQUATE SURFACE-WATER SUPPLY AND RELATED PROBLEMS

Agreements such as compacts between states and treaties with Canada and Mexico provide both direction and constraints to water resource management. Approximately 50 interstate compacts and international treaties affecting water resources have been approved by Congress; still others are in negotiation. The purpose of most of these is to allocate the amounts of water among political subdivisions for existing or potential uses downstream. (Ref. 2.2) Not to be ignored are the frequent concerns about states' rights relative to the federal government, state versus state disagreements, and Indian water-related concerns such as fishing rights and fishery resources.

The great number of actors involved and the complexity of the issues related to control of water make this subject one of the most critical in terms of resource management in the public interest.

2.1.6 Water Supply/Use Implications for Hydropower

The foregoing information provides a basis for identifying some general implications for hydropower insofar as water supply/use are concerned, recognizing that, on a site-specific basis, the conclusions may be quite different.

In general, the competition for use of available surface water supplies will increase in extent and severity. In some areas, particularly the western half of the United States, increasing water shortage problems are expected. Uncertainties about hydrologic cycles pose serious questions about a high level of dependence upon hydropower. Even the relatively short history of western water data points out that poor water years are fairly common. Water management plans, therefore, must take that factor into account.

Some areas, such as the Columbia River Basin, could increase available water supply by development of major water storage projects, but the present environmental regulations and social climate make that a difficult course to follow. Changes in irrigation practice offer the only significant opportunity for water conservation, yet hydrologic and legal factors raise questions as to their usefulness for additional hydropower purposes.

If available water supplies cannot be increased appreciably, then it will be necessary to identify potential tradeoffs between competing uses and to effect compromises. Stated another way, it will be necessary to live within our means, waterwise. Water-related physical, legal, and institutional factors will combine to make the process a most difficult one.

2.2 Hydropower: The Concept

Having discussed water—the fuel for hydropower—it is appropriate now to elaborate upon hydropower itself. The following text presents the concept of hydropower as it currently exists; and, in doing so, touches upon physical concepts, means of generation, and some important distinctions regarding hydropower. This section is intended to give the reader a reasonable understanding of hydropower as a context for the discussion in subsequent chapters; it is not intended as a comprehensive report on the subject.

2.2.1 Physical Concepts of Hydropower

The following exerpt from an article entitled "Water and Energy" (Ref. 2.3) discusses the physical concepts of hydropower.

> A basic concept that is fundamental to hydropower is the fact that rivers are "energy concentrators." The fall of water on the surface of the earth is a generally widespread and diffuse action whose energy would, in itself, be difficult to harness. But where the rain or snow falls on rugged or mountainous topography with elevation significantly above sea level, the runoff excess forms rivers that concentrate the energy of falling water in a single path that, in a natural state, produces the erosion of land surfaces to form valleys and canyons. Harnessing this erosive power is the overall accomplishment of hydropower development. The early projects were designed simply to produce mechanical energy for lifting water for irrigation, grinding grain, or operating mills for industry. The advent of the knowledge of how to transform mechanical energy into electrical power in the latter part of the 19th century produced a great upsurge in river development for energy production.

The principal advantages of electric power derived from river developments are: (1) the energy of falling water can be easily and economically concentrated into usable form through hydraulic turbines; (2) the flow of water in rivers is generally continuous, and with the development of water storage in reservoirs, it can be easily and economically controlled as an assured and reliable source of energy; (3) water is a renewable and non-depletable resource; (4) the development of water power can be integrated with other water use programs which result in economical multi-purpose developments; (5) the mechanical equipment is highly reliable to produce uninterrupted and carefree service; (6) the conversion of potential energy to usable energy is a highly efficient process, whereby 80 to 85 percent of the theoretical energy is developed into usable electrical energy; (7) hydropower is easily controlled on a short term basis (i.e., seconds, minutes, or hours), so that its output can respond quickly to load fluctuations. It should be noted that other alternative electrical energy supplies presently being considered lack one or more of the above listed principal advantages, and, in some cases, the deficiencies inherent in these alternatives negate their feasibility for practical use.

Particularly in the case of direct conversion of solar or wind energy, the flux of energy is diffused and widespread, but generally of relatively low concentration. Rivers are "nature's way" of concentrating solar and wind energy into a convenient and usable form. Also, in the case of snow, solar energy is utilized in melting the snow pack in mountain regions to produce the liquid water energy inherent in the river systems.

2.2.2 Hydroelectric Generation

Hydroelectric plants convert into electric energy the kinetic energy of water as it flows from a higher to a lower elevation. The energy derived is a function of several factors. The amount of power generated depends on the head (the height of the water above the turbine), the rate at which water flows through the turbine and the efficiency of the turbine generator (Ref. 2.4).

Hydroelectric developments are generally classified as being either "conventional" or "pumped storage". Conventional hydroelectric developments use the available water only once and may be further classified either as "run-of-river" or "storage" projects. A run-of-river project must use streamflows essentially

as received at the project site and as modified by the effects of any upstream storage capacity. The project's storage capacity, or pondage, is not significant and generally allows only for daily or weekly regulation of flows.

A storage project provides sufficient storage capacity for monthly, seasonal or yearly regulation of streamflows by capturing water during periods of high flows and releasing it during low flow periods in accordance with the project's operating rule curve. Large storage projects have holdover storage adequate to provide flow regulation through dry periods lasting several years. Where storage projects are constructed high in the watersheds, such as in the Columbia River system, the effects of flow regulation can be utilized in successive down stream plants.

"Small-scale" and "low-head" generation stand out in sharp contrast to more traditional conceptions of hydropower development as large-size physical facilities producing large amounts of power. As a matter of fact, the origins of hydropower were in the realm of small-scale/low-head, and in the United States it was not until the early 1900's that large-scale developments came on line.

It is noteworthy that of the present United States hydroelectric power generation system of approximately 1,300 plants, about two-thirds were constructed prior to 1940 but provide only about 20 percent of the present 63,000 megawatts (MW) of installed capacity. Also, approximately 75 percent of the existing plants contain less than 25 MW of installed capacity but contribute only 7 percent of total installed capacity (Ref. 2.5).

Although there are varying definitions, generally small-scale hydropower includes generation up to 15 to 30 MW, and low-head includes facilities having a maximum head of 20 meters (66 feet). For purposes of this report, small-scale is defined as 30 MW or less. It should be noted that a facility can be low-head but need not necessarily be small-scale, nor does small-scale mean that a facility is low-head. Both forms of generation are enjoying renewed interest in the

United States as costs of thermal generation escalate, large-scale hydropower sites become less available to developers, and the need for additional generating capability becomes more acute in many areas.

2.2.3 Understanding Power Generation and Marketing

Two distinctions are important to an understanding of the generation and marketing of hydropower. The first is the difference between peakload, baseload and energy. The second is the difference between firm and secondary power. Although some of the following material refers specifically to the Pacific Northwest situation, it is useful here for its illustrative value (Ref. 2.4, 2.7).

At any given moment, a power system must be generating exactly as much power as is being demanded. The demand for power is often called the load on the system. The nature of the load, or demand, dictates the total capacity which must be installed as well as the type of equipment to be used.

"Baseload" is the minimum load in a power system over a given period of time; "peakload" is the maximum electrical demand in a stated period of time. Since generation and demand must be matched exactly, a power system must have the capability to generate at least enough power to meet the peakload, plus reserves for unexpected breakdowns or routine maintenance.

In contrast, "energy load" represents a demand on a system continued over a substantial period of time. Energy can also be specified as the total amount of electricity used over a period of time, or a level of power multiplied by the time the level is sustained—thus, "kilowatt-hours" (kWh)—which is the basis on which electricity is purchased. "Average energy" is a term commonly used to designate average output of a plant over an extended period of time. When generating units are added at a hydropower plant, its ability to supply peakloads is increased proportionately but its ability to generate energy will not increase unless more streamflow is available.

Thermal plants (fossil- or nuclear-fueled) require longer starting times but operate more efficiently once a steady output is reached. They are therefore particularly well-suited to supply baseloads. Peakloads, on the other hand, tend to be supplied by hydropower facilities where available (increasingly by pumped storage plants) as well as by gas turbines or external combustion engines, or diesels.

A second important distinction in electric power applies essentially to power marketing and the difference between firm and secondary power. In a hydropower system, the manner in which power becomes available depends on seasonal characteristics of the hydrologic cycle. These seasonal characteristics also determine the practices that power marketing entities follow in marketing hydropower generation as firm, secondary, or surplus power. "Firmpower" is that on which delivery can be assured even under critical or worst-case circumstances. Holding back the heavy streamflow of the summer and releasing it during the winter evens out the flow and raises the firm power level. In most years there is more runoff than in the critical year case. Accordingly, more electrical energy can be generated and this constitutes "secondary power".

Throughout the United States, except for the Northwest, most electricity is generated by thermal plants. As previously mentioned, a thermal system can be readily scheduled to meet a continual steady demand, because it operates more efficiently at a steady output. The problem in matching thermal generation to load is in handling peakloads.

On the other hand, the water that drives a hydrogenerator can be readily turned on or off by wicket gates to provide power for demand peaks, with no appreciable waste of energy between peaks. There can be a problem with hydropower, however, in meeting the baseload (that is, providing a continuous supply of power) because generation is directly related to streamflow which varies. For example, natural streamflow in the Northwest is heaviest during the spring and summer because of snowmelt in the high elevations in the western United States and Canada, but the peakload occurs in the winter due to electric heating needs.

2.3 Hydropower: Technologies

2.3.1 Turbine Technology

Even though the "paddle wheel" has been in use since Egyptian times, very few kinetic energy machines have since been developed. We refer to devices which convert the water's kinetic energy directly into rotational mechanical power. The maximum efficiency ever obtained for "undershot" water wheels is 60 percent, and, as a result, this ancient conversion process is only rarely used. While no startling breakthrough is expected in this field, current activity in the low-head (small-scale) hydropower field will undoubtedly lead to some new concepts. For example, a continuous "Venetian blind" realization of the "Banki" water wheel is employed in the Schneider Engine (Ref. 2.8).

As in late 19th century France, it is perhaps appropriate to award an annual prize for the best hydropower turbine invention, for no major new device has appeared since 1924, when Professor Kaplan introduced the variable pitch propeller turbine. Considerable effort has gone into the refinement of design methods, the development of special steel alloys for use in turbines, and perfecting model test techniques. As a result, mechanical efficiencies above 90 percent are possible for large installations where not only the turbine but also its draft-tube, penstock, and intake manifold are custom designed and built.

While the development of a new turbine capable of solving all our problems is unlikely, it is possible that:

- The refinement of existing design and manufacturing concepts will continue.

- Experimentation with alternative materials such as plastics and duralumin will reduce production and maintenance costs and permit operation under cavitating conditions.

- The development of propeller/impeller units for pumped storage plants using current technology will simplify the installation and maintenance of such plants.

- For the small-scale (low-head) market the standardization of turbines for off-the-shelf sales is already under way. Even though some loss in efficiency is unavoidable, mass production achieved through standardization is the key to micro hydropower development.

2.3.2 Other Technological Developments

Modularized techniques for the construction of impoundments and, in particular, for use in hydropower developments have been under study by the Water and Power Resources Service in Denver. While this concept is not likely to revolutionize the "dam building business", it could dramatically reduce construction costs for small installations. The future of modularization depends largely on the volume of business that hydropower development will capture.

A hydraulic control system is normally employed to regulate the wicket gate opening and/or propeller pitch angle in turbines and, therefore, the flow rate through the machine. To generate power at synchronous shaft speed requires that a "speed" governor be included in this control system. In recent years, electronic governors have been developed to replace the conventional mechanical equipment, and increased reliability can be expected. For small plants, however, the control equipment adds considerably to the cost of the plant, and induction generators are used in many cases. While eliminating the bulk of the control equipment, asynchronous generation invariably leads to a loss in overall efficiency and, for large installations, to power conditioning problems, in particular that of performing frequency conversion in the power output. As this problem is also present in the frequency conversion process for interfacing photovoltaic generation banks to the distribution network, it is likely to be resolved in the 1980's.

2.3.3 Transmission and Storage

Receiving little attention during the past three decades, high voltage technology reappeared as a dynamic and fruitful research area in the late 1970's. Some advances in transmission line technology were recently reported. Bonneville Power Administration, for example, is currently testing a multi-element conductor 9 gigawatt (GW), 1,200 kilovolt (KV) overhead line model. This ultra high voltage (UHV) line is expected to carry a price tag of $1 to $1.1 million per mile.

Work on direct current (DC) transmission lines is continuing at various centers in the United States and the USSR. While excellent for transmitting large blocks of bulk power without a direct consumer load, DC lines require expensive power conditioning equipment (rectifiers/frequency converters) at both ends for interfacing with conventional alternating current (AC) lines. It is for this reason that the use of DC transmission lines is expected to be applied only in special circumstances where, for example, transient stability problems occur in the lines.

A considerable amount of research is currently under way on storage in general and on storage of electrical energy in particular. The most popular storage methods under consideration are the following:

- Chemical. Through the use of batteries or a process of hydrolysis, electrical energy could be stored indefinitely. The conversion efficiency is very high, but the system capacity is still severely limited.

- Direct Storage. Experiments are currently being conducted to demonstrate the feasibility of storing low-frequency pulses in superconductive coils with virtually no loss. The superconductive storage process, however, is extremely expensive to maintain and is unlikely to become commercially viable before 2000.

- Thermal Storage. While the conversion of electrical power into heat is fairly efficient, the reverse process is much more difficult. Current research is centered around the development of heat engines for this purpose. Heat can, of course, be stored in various materials and, in particular, in water.

- Water Storage. Hydropower generating facilities have, by definition, water and therefore electricity storage capability. While this storage capability is limited, it can, in conjunction with the pumped storage concept, play a cardinal role in the development of other technologies such as photovoltaics and wind generation.

The rate of advancement in the theory and development of superconductivity and devices employing these concepts will greatly influence the development of new energy sources. Magnetic field densities of 6 to 8 Teslas, necessary to contain the plasma in fusion reactors of the Tokamak type, are possible only through the use of superconductive materials (Refs. 2.9, 2.10, and 2.11). While the construction of five Tokamak type reactors will be completed by 1985, it is doubtful if a commercially viable fusion reactor will be built in the 20th century. Extremely high field densities with virtually no transmission losses will render superconductive technology invaluable in producing new super generators and, in perhaps 30 years, the first commercial magnetohydrodynamic power project (Ref. 2.12).

2.3.5 Combinations Involving Hydropower

An intriguing possibility is the linking of solar and hydropower to effect a kind of synergism. Consider the eastern Washington area as a case in point. Electricity could be produced from solar photovoltaic arrays in the eastern desert areas during the day and transmitted over the existing Columbia River power lines. Hydropower is used to provide electricity at night over the same power lines. Thus, fluctuations are smoothed out, and a reliable renewable energy system is created.

2.3.6 Weaknesses

Few dams have been built in the last two decades, and an earlier generation of builders has retired or, due to lack of business, moved into other fields. There are few training opportunities, e.g., a short summer course at the University of Idaho in hydropower turbine technology. Although the Corps of Engineers still has a considerable number of dam builders, the most promising engineering students have not been entering hydropower engineering; as a result, the industry has aged.

Production capacity in the United States is constrained by the conditions of international trade. Most turbine-producing nations—Austria, France, the Scandinavian countries, and Japan—adopt a protective stance toward domestic production. Justification for such protectionism rests on the usual grounds of national dependence on sources of energy and the economic needs of young industries. Turbine production, (including that for such non-hydropower purposes as nuclear reactors) is one of the few non-military industries using precision boring mills of large magnitude. In the event of war, the existence of such machinery has historically proven critical to a shift in production to a war-time economy. Thus, for both military and economic reasons, major international turbine producers thus operate in a highly subsidized climate. Turbine manufacturers in the United States do not benefit from such governmental assistance although the Corps of Engineers does include a 50 percent differential in certain bids involving domestic versus foreign competitors.

This regulatory asymmetry strongly affects the competitive effectiveness of United States turbine manufacturers. United States manufacturers who attempt to find markets abroad find themselves handicapped occasionally by the refusal to consider American sources. Simultaneously, foreign governments exempt exported goods from various value-added taxes. This act promotes price competitiveness of exported turbines and contributes to the economic health of those regions engaging in turbine production.

2.4 The Energy Setting

We now consider the current and future demand supply situation for energy in general and electricity in particular.

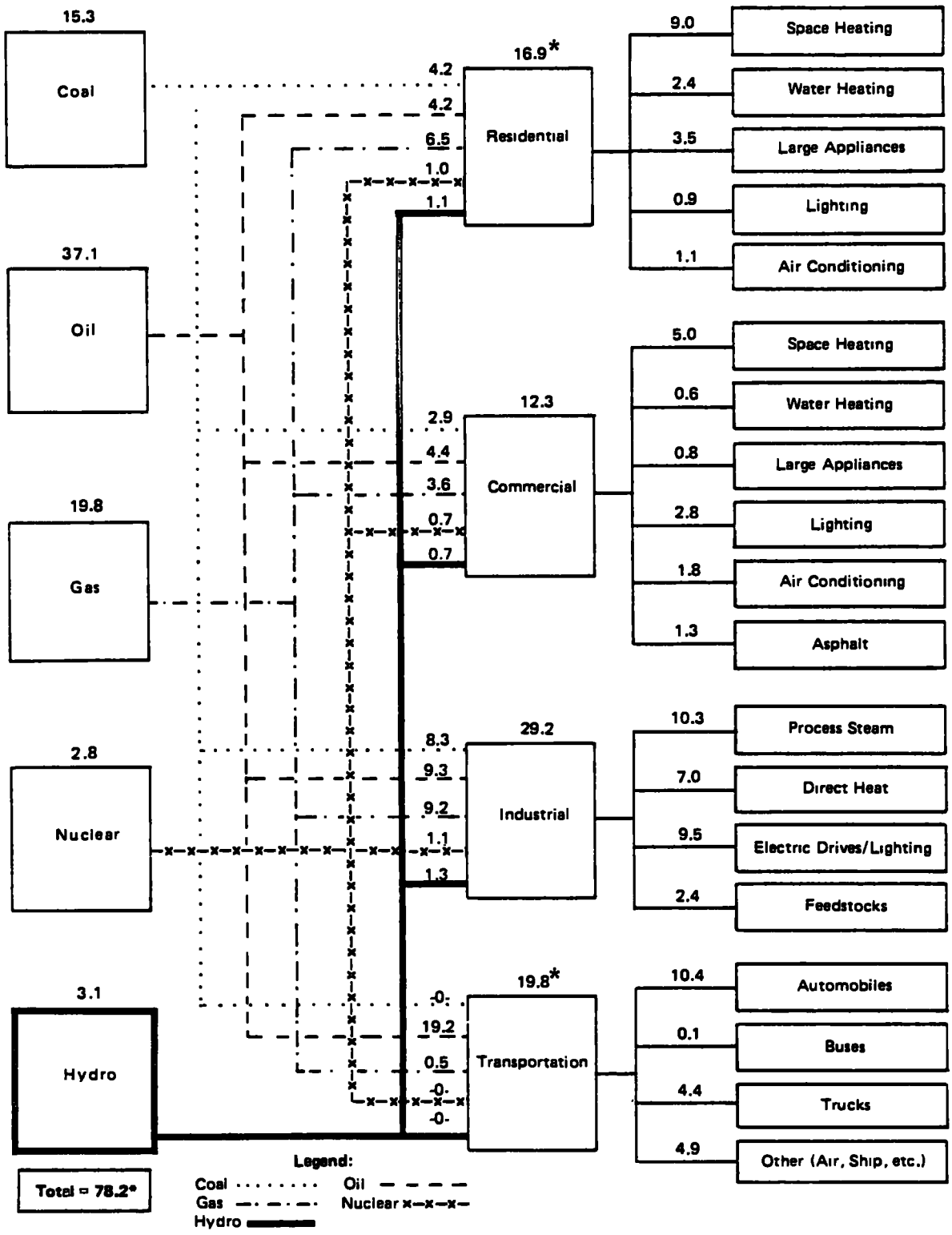
2.4.1 Energy and Electricity Demand and Supply: 1979

Figures 2-4 and 2-5 show energy and electricity demand and supply balances for the year 1979.[2] Following are basic facts which outline the current situation:

- In the residential and commercial sectors, energy is largely used for space heating and lighting, both of which can be supplied by electricity. Energy use in the industrial sector is more uniformly distributed for these end uses: process steam, direct heat, and electric drives. Energy use in the transportation sector is primarily by the automobile; electricity currently plays a minor role in this sector, e.g., in rail transit systems.

- There are five primary energy sources: coal, oil, natural gas, nuclear and hydropower. With the exception of natural gas, all supply sources must be transformed by appropriate fuel energy conversion processes (e.g., crude oil to gasoline, coal to electricity) so that they can match the characteristics of various end uses.

- Electricity plays a vital role in the United States energy picture, supplying about 31 percent of total energy needs. Figure 2-5 shows the utilization of electricity to supply the energy needs for the four major end-use sectors. The principal users are: industrial (40.3 percent), residential (35.0 percent), and commercial (24.3 percent). The transportation sector is a minor user of electricity (0.4 percent).



*Total may not be exact due to rounding.

Figure 2-4.

ENERGY DEMAND AND SUPPLY BALANCE: 1979 (QUADS)

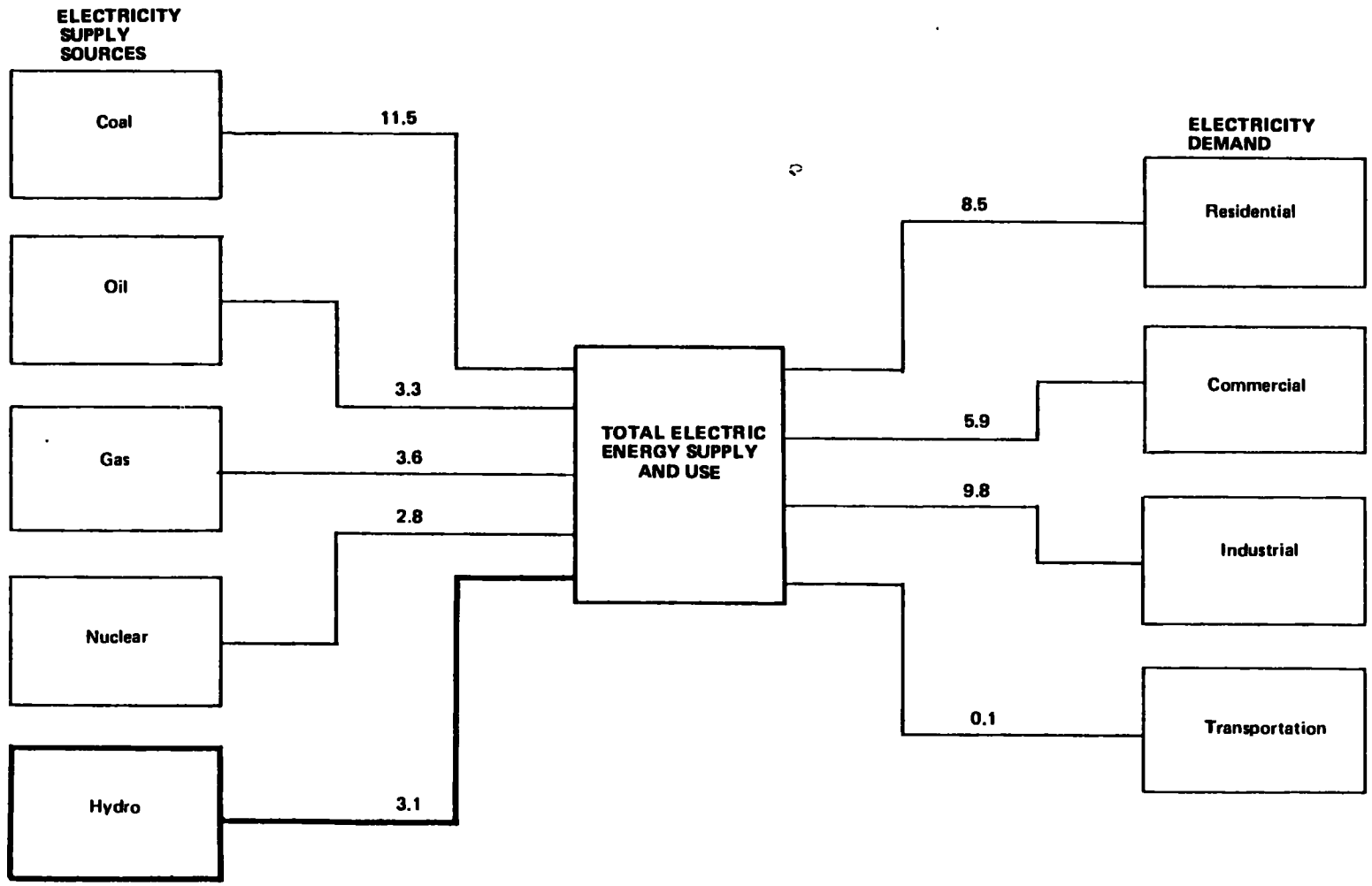


Figure 2-5.

ELECTRICITY DEMAND AND SUPPLY BALANCE : 1979 (Quads)

- The electricity generation mix consists of the following principal sources: coal, oil, gas, hydropower, and nuclear. Coal dominates the generation mix, with hydropower providing about 12.6 percent of the total capacity. In terms of energy, the coal's share becomes even larger because of its superior plant capacity factor. Hydropower supplies about 13 percent of total electric energy or about 4 percent of the nation's energy needs. (Energy derived from hydropower is estimated by using an equivalent heat rate of a fossil-fueled plant, about 13,389 Btu/kWh).

- The dependence of the United States on imported oil is significant, with almost 23 percent of energy needs supplied by it. Thus, imported oil and electricity together supply over one-half of national energy needs.

Perhaps the most striking feature of the recent energy picture has been the rapid rise in price, led by oil. Figure 2-6 vividly illustrates this aspect. In many regions of the United States, energy prices, including electricity, now account for a significant portion of a family's budget. The cost of energy implicitly included in products and services purchased by consumers has also significantly increased.

2.4.2 Energy Demand and Supply: 2000

Studies projecting future energy demand and supply have been emerging at a rapid pace. Figure 2-7 shows some representative estimates. These projections are based on differing perceptions and assumptions of forces driving energy demand and supply. However, certain trends seem to converge and are worth noting:

- Almost all of the projections are based on lower than historical growth of energy demand. The 4 to 5 percent annual rates of the 1960's and 1970's appear now as 2 to 2.5 percent (or even lower) annual growth

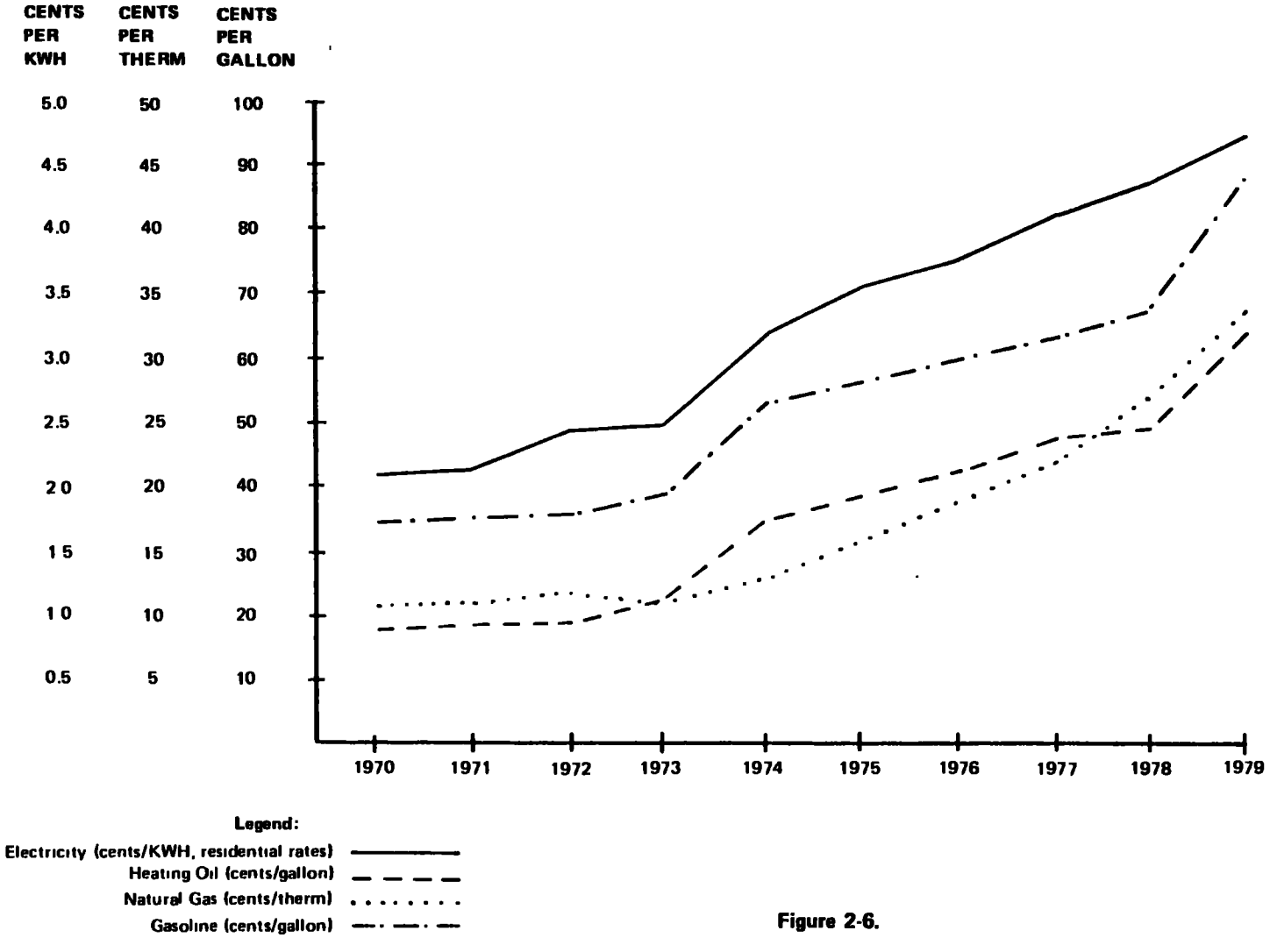
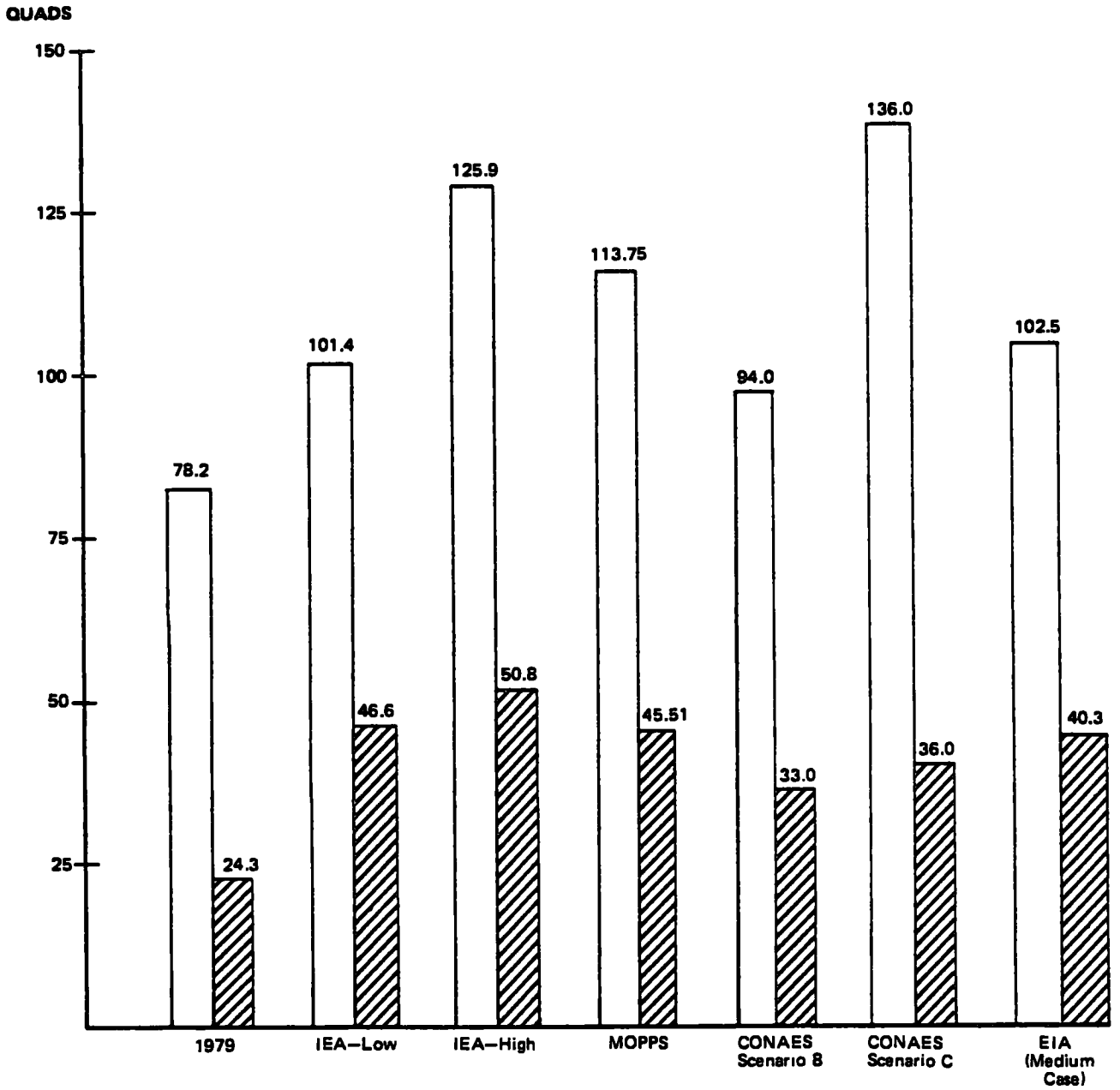


Figure 2-6.

RETAIL PRICES: FUELS AND ELECTRICITY (1979 DOLLARS)



Source: IEA: Institute for Energy Analysis, 1976.
MOPPS: Market Oriented Program Planning Standards. U.S. Department of Energy, 1977.
CONAES: Committee on Nuclear and Alternative Energy Systems, National Academy of Sciences, 1980.
EIA: Energy Information Administration, U.S. Department of Energy, 1980 Annual Report to the Congress, Volume III, 1981.

Figure 2-7.

ESTMATES OF ENERGY REQUIREMENTS
(Year 2000 Except as Noted)

in the coming years. Estimates of future energy requirements seem to be converging toward the 100 to 110 quadrillion Btu range; estimates higher than this are rare. The lower growth rates are predicted in response to energy price escalation and energy conservation efforts.

- Electricity demand growth rates, similarly, are being projected in the range of 2 to 4 percent per annum, rather than the annual 7 to 9 percent rates during the 1960's and 1970's. As the growth rate declines, the relative significance of the role of hydropower in the United States energy future becomes increasingly prominent, especially under the scenarios depicting high levels of hydropower development. However, it should also be noted that a rapid reduction in electricity demand growth rates can create pressures to slow down the rate of additions of all electric generating plants, including hydropower.

- Although total electricity demand growth rates are projected as declining, the share of electricity in the United States energy mix is expected to increase from about 31 percent of total in 1979 to about 35 to 45 percent by 2000.

- Some significant changes in the electrical generation mix, dictated by economic and regulatory considerations, seem likely by 2000. The contribution of oil and natural gas is expected to decline and that of coal to increase because of regulations such as PIFUA (Petroleum and Industrial Fuel Use Act).

- Almost all future estimates view the role of hydropower as essentially unchanged. Although total hydropower capacity is likely to increase by 2000, its share of total generating capacity and contribution to total United States electrical and energy needs is likely to decline.

- The major uncertainty affecting the likely generation mix stems from the expected contributions of solar and nuclear power. If the recent pessimism about the future of nuclear power turns out to be ill-placed and/or solar technologies such as photovoltaics succeed on a larger scale than currently expected, the resulting synergistic impact on the development of hydropower may be substantial.

- Estimates of the future price of energy are beset with uncertainties and regarded by many as highly speculative. Energy prices are likely to escalate, at least in response to rising inflation rates. Energy is expected to cost two to four times as much in 2000 as in 1979.

Together, these trends provide a rather uncertain outlook on energy futures, unless steps are taken now both to conserve energy use in all sectors and to increase supplies in some areas. In comparison with other alternatives, conservation has the advantage of high effectiveness and minimum lead time. But it suffers the "Tragedy of the Commons": what is conserved by responsible citizens is often consumed by irresponsible ones (Ref. 2.13).

2.4.3 Future Competing Technologies: Supply and Conservation

Several technologies will emerge in the next two decades and enter energy markets, although the extent of their penetration and timing cannot be stated with any precision. Self-fulfilling prophecies could very well govern the introduction of competing technologies.

The relevant technologies are:

- Supply technologies, e.g., coal liquefaction; and

- Conservation technologies, e.g., passive solar or improved building designs.

Both affect hydropower development by interacting with electricity supply and demand. Section E of the Appendices provide a detailed description of technologies in both classes. Some highlights of that discussion are presented here, primarily to provide a view of technology availability and economics.

The non-hydropower supply technologies considered here are grouped in terms of their dependence on the primary energy resource as coal, nuclear, solar, and geothermal.

Table 2-1, derived from various sources, delineates a likely timetable for the introduction of various competing technologies. They are grouped as available currently, in 1990, and 2000. The term "availability" means that economic and technical feasibility of a technology have been demonstrated and it is readily available for procurement.

Similarly, Table 2-2, derived from various sources, delineates the economics of various technologies. The cost data in the table must be interpreted cautiously. As noted in the table, cost estimates of many future technologies are highly uncertain. Meaningful cost estimates must await the construction and operation of the first commercial-scale facilities.

Several recent studies have pointed out the significant role of energy-E of the Appendices contain estimates of the potential for energy conservation in the residential, commercial, and industrial sectors. These estimates indicate that energy intensity (i.e., the energy used in future years as a percentage of that used now, for a given end use) in the residential and commercial sectors can decrease by a factor of about 0.1 to 0.5, depending upon the end use in question; similarly, energy intensity in the individual sector may decline by a factor of about 0.1 to 0.4. The cumulative impact of such reductions can be substantial, comprising at best 25 to 35 percent of the total United States energy needs.

Table 2-1

INITIAL AVAILABILITY OF POWER GENERATION TECHNOLOGY

Available Now (1980)	By 1990	By 2000	Beyond 2000
Conventional Boiler - Oil	Coal: - Low and Medium Btu - High Btu - Pressurized Fluidized Bed Combustion	Coal: - Liquefaction	Nuclear: - Fusion
Conventional Boiler - Gas		Geothermal: - Hot Dry Rock	Hydrogen
Conventional Boiler - Gas			Photovoltaic - Central Station
Atmospheric Fluidized Bed Combustion (Industrial)	Solar: - Distributed Photovoltaic - Thermal Electric - Wind		Ocean Thermal Energy Conversion
Nuclear: - Pressurized Water Reactor - Boiling Water Reactor	Fuel Cells: - First Generation		
Combustion Turbines	Geothermal: - Flash - Binary		
Geothermal: - Dry Steam	Nuclear: - Fash Breeder Reactor		
Conventional Hydropower			
Small-Scale Hydropower			
Wood-Fired Plants			
Combined Cycle			
Cogeneration			
Pumped Storage			
Conservation Technologies			
Solar: - Hot Water - Space Heating			

Table 2-2

TECHNOLOGY ECONOMICS (Per CEC, 1980 data)

	Energy Source	Cost in 1980 Dollars (C)
1.	Oil From Shale	$4.40-6.00 per MM Btu (A)
2.	Conventional Steam Boiler (Oil and Gas)	$0.053 per kWh (A)
3.	Combustion Turbines	$0.138 per kWh (A)
4.	Combined Cycle	$0.052 per kWh (A)
5.	Conventional Steam Boiler (Coal)	$0.044 per kWh (A)
6.	Pressurized Fluidized Bed Combustion (Coal)	$0.057 per kWh (B)
7.	Medium Btu Coal Gas	$4.40-6.60 per MM Btu (B)
8.	Coal-Derived Synthetic Natural Gas (High Btu)	$5.50-8.80 per MM Btu (B)
9.	Synthetic Oil from Coal	$5.50-7.70 per MM Btu (B)
10.	Pressurized Water Reactor	$0.047 per kWh (A)
11.	Geothermal:	
	a. Dry Steam	$0.023 per kWh (A)
	b. Flash	$0.057 per kWh (B)
	c. Binary	$0.064 per kWh (B)
12.	Conventional Hydropower	$0.052 per kWh (A)
13.	Small-Scale Hydropower	$0.018-0.079 per kWh (A)
14.	Wood-Fired Plants	$0.038 per kWh (B)
15.	Cogeneration	$0.036-0.042 per kWh (A)
16.	Wind (Utility)	$0.051 per kWh (B)
17.	Solar Thermal Electric	$0.077 per kWh (B)
18.	Photovoltaic - Distributed	$180.00-190.00 per kWh (B)
19.	Photovoltaic - Central Station	$0.129 per kWh (B)
20.	Ocean Thermal Energy Conversion	$0.030-0.160 per kWh
21.	Fuel Cells:	
	a. First Generation	$0.049 per kWh
	b. Second Generation	$0.043 per kWh
22.	Pumped Hydropower	$0.095-0.219 per kWh
23.	Advanced Battery	$0.127 per kWh

NOTE: (A) - Estimated with low degree of uncertainty.
(B) - Estimated with high degree of uncertainty.
(C) - Units are appropriate to the particular energy form. To convert $/MM Btu to $/kWh, divide by 293.

REFERENCES

2.1 R.L. Nace. "The International Hydrological Decade—Water and Man: A World View". UNESCO, 1969.

2.2 U.S. Water Resources Council. Second National Water Assessment, The Nation's Water Resources, 1975-2000; Volume 1: Summary. December 1978.

2.3 D.M. Rockwood. "Water and Energy". GeoJournal, 1979.

2.4 U.S. Department of Energy, Bonneville Power Administration. "Electrical Generation: Peak vs. Energy." 1977.

2.5 The Hydrologic Engineering Center. Potential for Increasing the Output of Existing Hydroelectric Plants, Draft Final Report, January 8, 1981.

2.6 U.S. Department of Energy. "Hydroelectric Power Evaluation." 1979.

2.7 U.S. Department of Energy, Bonneville Power Administration. "Firm, Secondary and Surplus Hydropower." 1979.

2.8 D.J. Schneider and E.K. Damstrom. "The Schneider Engine: Performance and Applications for Hydropower." Proceedings Waterpower '79, 1979.

2.9 G. Kaplan. "Superconducting Power Cables" (Special Report). IEEE Spectrum, Volume 17, No. 9, 1970.

2.10 T.H. Geballe and J.K. Kuhn. "Superconductors in Electronic-Power Technology." Scientific American, Volume 243, No. 5, 1980.

2.11 E.J. Lerner. "Magnetic Fusion Power." IEEE Spectrum, Volume 17, No. 12, 1980.

2.12 J. Fagenbaum. "Magnetohydrodynamic Power." IEEE Spectrum, Volume 17, No. 9, 1980.

2.13 G. Hardin. "The Tragedy of the Commons." Science, Volume 162, December 13, 1968, pp. 1243-1248.

FOOTNOTES

1. "1975" is the base year for the Second National Water Assessment; it represents assumed average conditions and quotation marks are used to indicate that the 1975 data are not actual data.

2. The energy quantity in Figures 2-4 and 2-5 (and elsewhere in this report) is shown in quads (Q). 1Q = 1 quadrillion Btu = 10^{15} Btu. 1 Q is equivalent to about 0.5 million barrels per day (MMBBL/D) of crude oil, assuming 5.6 million Btu per barrel; or, one trillion cubic foot of natural gas, assuming 1,000 Btu per cu. ft. of gas; or 0.3 trillion kWh of electricity at 3,413 Btu/kWh; or, 5 billion tons of coal with heating value of 20,000 million Btu/ton.

3. For example see: Roger Stobaugh and Daniel Yergin: Energy Futures, 1979; Sam Schurr, et al: Energy in America's Future, 1979; Hans Landsberg, et al: Energy: Next Twenty Years, 1979.

CHAPTER III

The Issues

In Chapter II we reviewed the concept and context of hydropower. We now turn to the issues raised by hydropower development. They may be generated by uncertainties or conflicts in value systems. For example, the health and safety issue arises largely from uncertainties such as the atmospheric carbon dioxide growth rate, and nuclear reactor related fatalities. On the other hand, competing land uses form an issue in view of conflicts between agricultural and energy/utility interests.

The report "Policy Issues in Hydropower Development" (Ref. 3.1), prepared for the Institute for Water Resources of the Corps of Engineers to serve as an input to this study, identifies a range of issues associated with the increased development of the nation's hydropower resources. Using this and other sources, the technology assessment team has focused on 14 issues which are of primary significance. They fall into four categories as shown in Figure 3-1:

- General Issues;
- Institutional and Legal Issues;
- Economic Issues;
- Environmental Issues.

For each issue we provide a brief description and analysis.

3.1 General Issues

3.1.1 Hydropower as a Contributor to National Energy Needs

Description

As discussed in Section 2.4, hydropower currently plays a relatively modest role in the United States energy picture, supplying about 4 percent of the energy

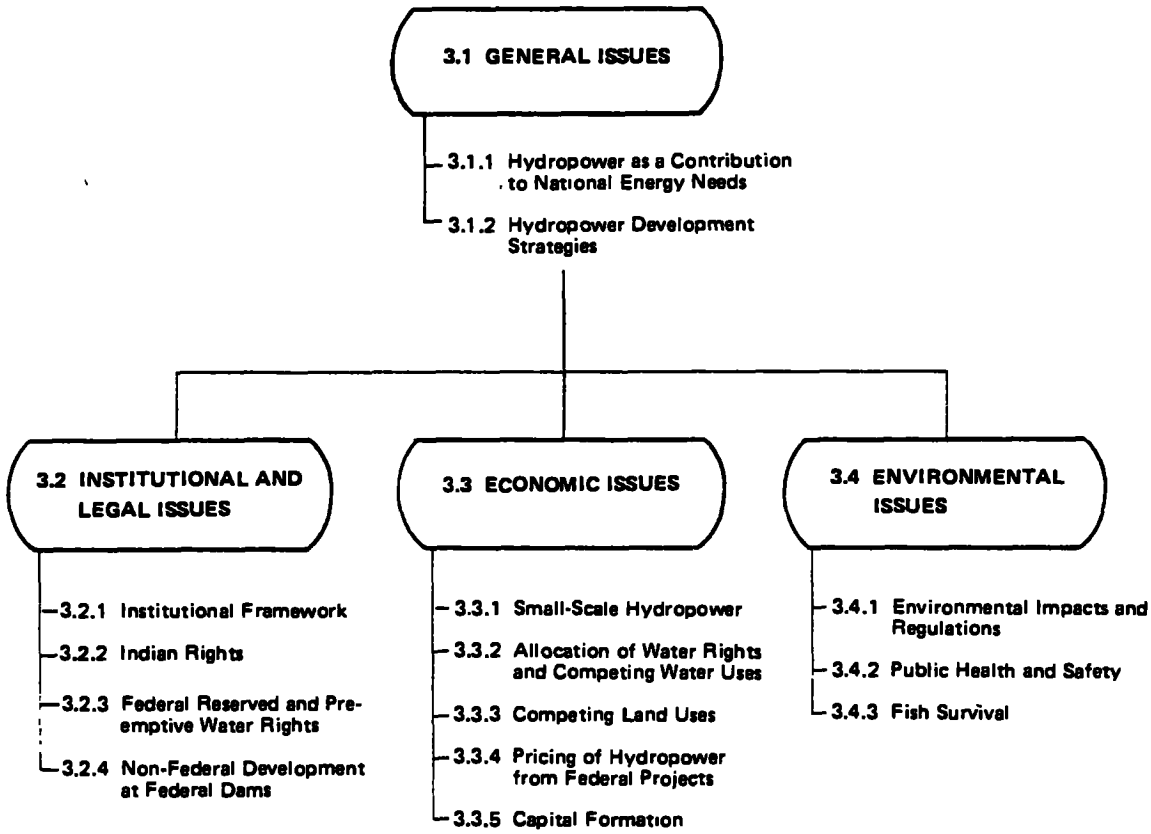


Figure 3-1.
THE ISSUES CONSIDERED

needs of the United States. At the national level, hydropower is also a modest contributor in terms of electricity generation mix, accounting for about 12 percent of the installed capacity and 13 percent of the electric energy generated by the total installed capacity in 1979. On the other hand, hydropower plays a significant role in supplying the energy needs of certain regions; in the WSCC (Western System Coordinating Council) region, for example, it supplies 40 percent of electric energy generated by this installed capacity.[1]

In addition to supplying a portion of the United States energy needs, hydropower often affects and improves the operation of a utility system. Because of its excellent load-following capability, it could assist in optimizing the performance of a thermal system. In regions such as the WSCC, where hydropower constitutes a significant portion of the baseload capacity, it improves the reliability of the utility system. Thus, the role of hydropower is important not only in terms of its energy contribution but also in terms of utility system performance.

One must also consider the role of hydropower in the context of future utility systems, which may derive a significant portion of generation from renewable resource-based energy systems, such as solar and wind. Hydropower may very well complement these alternative energy sources, and indeed, as people interviewed for this assessment pointed out, the role of hydropower as a "fine tuner" for optimizing utility system performance may become more visible.

Analysis

The significance of hydropower can be evaluated by considering two questions—to what extent it: (1) decreases the United States vulnerability to energy supply interruptions, particularly imported oil; and (2) increases the flexibility of United States response in meeting its energy needs as well as optimizing utility system peformance.

Considering first the issue of vulnerability, the United States currently imports almost 50 percent of its petroleum requirements, and import dependency has steadily increased over the past few years. Certain areas of the United States, notably New England and California, rely heavily on imported oil (in the form of distillate and residual fuel oil) for electricity generation. The Carter administration established a target of restricting oil imports to 8.5 million barrels per day. Assuming this import level and substitution of additional hydropower capacity on a one-to-one basis for imported oil (an optimistic assumption), the addition of 25,000 to 75,000 MW capacity could displace about 0.2 to 0.6 million barrels per day (MMbbl/D) of imported oil, assuming a plant factor of 0.5; if the plant factor is assumed as 0.1, the displaced amount of oil will be 0.04 to 0.15 MMbbl/D. This will correspond to 2.4 to 7.1 percent of the import level of 8.5 MMbbl/D, under the assumption of 0.5 plant factor, or about 0.5 to 1.4 percent for the assumption of 0.1 plant factor. At $32 per barrel, such displacement of imported oil will save about $2.3 to $6.9 billion per year for a plant factor of 0.5 and produce corresponding impacts on the balance of payments. Over the life of a fossil-fueled power plant, say 30 years, the savings amount to $69 to $207 billion for a plant factor of 0.5, assuming of course, no change in the price of imported oil (an optimistic assumption). On the other hand, if one assumes hydropower plant cost of $2,000/kW, averaged over the 1980 to 2000 time period, construction of additional capacity will require $50 to $150 billion; these, however, do not represent the total costs of bringing on line and operating the hydropower capacity, since other costs such as operating costs, financing and licensing costs must also be included. Thus, it is difficult to judge precisely the savings produced by hydropower development.

The issue of vulnerability can be also viewed from a perspective of supply interruptions. Recent events, particularly the cutoff in Iranian oil supply during 1978, have vividly illustrated that small fluctuations in the international oil supply system can cause significant disturbances in the economies of the Western world. A recent study (Ref. 3.2) noted that the probability of supply interruptions amounting to 1 MMbbl/D over the next decade as 0.95 (i.e., a near-certainty) and as 0.5 for 3 MMbbl/D.

When viewed primarily as a resource to: (1) meet peak demand; or (2) act as an energy storage device, hydropower assumes an even more significant role. Indeed, as people interviewed for the study noted, hydropower could make the most impact by displacing oil and gas used to fuel peaking units.

More important, perhaps, is the possibility that growth rates in United States energy and electricity demand could be very low. In such a case, installation of additional hydropower capacity, can substantially offset the role of coal or nuclear power plants. For example, if one assumes that the average growth rate of electricity demand is one percent per year during the 1980 to 2000 time period, then the electricity demand in 2000 increases by about 22 percent, and 25,000 to 75,000 MW capacity additions could supply about 20 to 60 percent of additional electric energy requirements, assuming a 0.5 power plant factor or 4 to 15 percent if the plant factor is 0.1. Although at first glance a low-growth scenario may seem implausible, let us recall that growth of electricity demand has dropped from about 7 percent per year during the 1960's and early 1970's to around 2 to 3 percent in recent years in many regions of the United States.

Finally, hydropower capacity additions at the 25,000 to 75,000 MW levels can reduce the vulnerability of those regions of the United States that are heavily dependent on imported fuels. For example, a significant portion of additional hydropower capacity is likely to be located in the WSCC region, consisting of California and many of the western states. Assuming the existence of adequate transmission line capacity to handle the additional hydropower capacity, the WSCC region could rely increasingly on hydropower and/or coal for most of its electricity needs, thus approaching self-sufficiency for electricity requirements.

The impact of hydropower in the next 20 years thus ranges from minor to significant, depending upon the level of hydropower development and the overall national and international context in which such development occurs.

> Hydropower poses a unique advantage. It is a compromise between the technological fix and the conservation ethos. First, it satisfies some of the technological fix kinds of requirements. Secondly, it has a relatively gentle impact on the environment.
>
> (A Sociologist)

3.1.2 Hydropower Development Strategies

Description

Policy-makers face a choice not only of whether to increase hydropower capacity but how to do so. The choice of trajectories—paths of development—is as important as the choice of capacity, which will be on line in 2000. Both choices are rooted in today's political and institutional context, because current decisions will act as commitments which constrain choice and action in the future. Much of the subsequent analysis of issues will address elements of various development levels, but the purpose of this discussion is to do so at a more general level.

Analysis

A development strategy can comprise the type, scale, and number of each unit of development; the timing, rapid or slow, of the development; the locus of control or coordination of the development; the goal or objective of the development; and the political context in which the development takes place.

A striking feature of hydropower development is the sheer number of potential sites and the variety of types, configurations, and sizes—all of which can differ by site. While for planning purposes we seek commonality in terms of measures of capacity or energy output, the fact is that there is no single common hydropower unit. Public and private policy-makers at various levels are confronted with a bewildering set of units—everything from a micro-hydropower plant which is being restored by a backyard engineer to a new dam

for a 200 MW plant. This diversity not only can cause confusion, e.g., low-head hydropower is not necessarily small in terms of megawatts, but can lead to the likelihood that present developmental organizations with specialized experts may not be suitable for the complete range of development. As one informed respondent put it: "The present systems for developing hydropower are in an organizational sense too unwieldy. You can't develop a creek with the same organization you develop the Columbia River."

The timing of development is not easily controlled on a societal level. Pushing the development of hydropower too fast could result in bottlenecks, e.g., in turbine production or the availability of transmission lines, unless anticipatory action is taken. On the other hand, going slow will not insure higher levels of hydropower in operation by the end of the planning period. The current situation, because of a variety of factors such as budgetary constraints and regulatory requirements, is proceeding at what seems a slow rate (Ref. 3.3). Generally, the larger the capacity of the project, particularly if it requires a new dam, the longer it takes to complete. According to one study, federal projects are taking from 12 to 16 years (Ref. 3.3). Nonfederal and private projects have been known to cut the lead time in half, and in some cases, for small sites, to a short three years. If one of our respondents is correct in his judgement that the "era of big dams is over now," then any development strategy will have to take into account these lead times coupled to a large number of projects.

The current locus of control and coordination at the federal level is best described as <u>fragmented centralization</u>. Authority and responsibility are shared by several agencies. This situation, while somewhat inefficient and costly in terms of delay and information requirements, is also a way of maintaining and resolving conflicting values. For example, it may be entirely appropriate that the Federal Energy Regulatory Commission (FERC) encompasses about 17 federal statutes and coordinates with numerous federal agencies in making licensing decisions. In the process, concern about a variety of issues, such as effects on

fish, wildlife, and water resources, can be voiced and taken into account. Thus the control element of a development strategy should be designed with both efficiency and conflict resolution in mind. Effective conflict resolution is efficient in the long run, as it can cut down the lead times for development.

Realistic goals are an essential element of any development strategy. Consider the widespread enthusiasm for small-scale hydropower as an appropriate technology. In California, for example, small hydropower is a "preferred energy source" and a state official "envisions the addition of 500 MW over the next 20 years." But how realistic is this estimate? The National Hydropower Study itself has been criticized for both underestimating and overestimating the hydropower potential, depending on the participant and region. As a case in point, one independent expert asserted that "the Corps has regularly overestimated the capacity of the sites they've inventoried. You'd have to fill reservoirs up like a bathtub, then pull the plug, to get that kind of power." Such criticism is unfair because it does not take into consideration the purposes of the site survey and the resource constraints under which it was taken. But there is still a lesson to be learned, i.e., to be very conservative in setting development goals.

One reason for conservatism is that there is bound to be some elimination of sites as the process of development proceeds from aggregate planning to actual construction. In general, intense opposition is more likely to occur when the bulldozers arrive—when the project is real to the local community. Even in pen and pencil studies there is likely to be some fall-off or elimination of sites. The Water and Power Resources Service (WPRS), for example, conducted an assessment of small hydropower in the West for its own projects. After numerous screenings to reflect engineering, economic, environmental, and social concerns, 150 potential developments were reduced to 37, an attrition of 77 percent (Ref. 3.4). In short, there is little point in inflating the expectations of policy-makers as to the potential of hydropower because, if these expectations are not met with actual performance, disillusionment sets in which can jeopardize the orderly development of hydropower.

The necessity for realistic goals leads us then to consider the political context. First, from a total energy point of view, hydropower does not seem to have a top political priority. In many documents, such as a recent federal government review of energy policy, hydropower has simply been lumped into the category of "solar and renewables" (Ref. 3.5). Second, both the recent administrations have acted to attenuate federal development of hydropower, partially because of severe budgetary constraints. Third, there is considerable interest in nonfederal development, and as one informant put it, the "political support for federal development of our natural resources is dead." Interests have shifted so that some states are ready to assume responsibility. "State development of natural resources," according to one expert, "is the wave of the future." Finally, the economic incentives are such that private developers can make money in hydropower.

A more decentralized strategy for hydropower development seems to be appropriate under most conditions. The very diversity in types, the avoidance of bottlenecks, the need to localize and resolve conflict, the need for specific site information, all argue for a decentralized approach. Moreover, the political context is more likely to support such an approach.

The decentralized approach has some disadvantages. It would not work well in a period of national emergency or under crisis conditions when resources must be controlled and allocated at a central level. In such a situation, a centralized strategy is preferred. Moreover, a centralized strategy favors standardization with its possible economies and is more likely to insure a timely reaching of hydropower goals. Systemic effects in water resource management are more likely to be addressed under a centralized approach but are not precluded by a decentralized development strategy.

3.2 Institutional and Legal Issues

3.2.1 Institutional Framework

Description

Traditionally the federal government plays a lead role in developing the nation's hydropower resources. However, as the nation enters a period of critical energy shortages, various federal agencies are involved in determining the

government's future development role. Clarification of federal/nonfederal, public/private sector responsibilities would facilitate efficient and timely development of hydropower resources. While a moderate level of development can be achieved within the existing institutional framework despite this impediment, more intensive development would be hampered significantly.

Analysis

The institutional framework governing hydropower development in the United States has undergone several changes (See Sec. B-1 of the Appendices). During the Depression, large dam building projects were part of a massive public works program implemented by the Roosevelt administration.[2] On the other hand, the 1950's were known as the "partnership" era in which the federal government encouraged state and private utility dam-building activities.[3] Since the Middle East oil embargo of the early 1970's, four policy directions affecting future hydropower development have been established by Congress:

- All projects must consider, account for, and internalize environmental costs unless important national security, social or economic goals are threatened.[4]

- The contribution of small-scale nonfederal hydropower at existing sites is to be promoted and encouraged. The Federal Energy Regulatory Commission (FERC) should facilitate as well as regulate the development activities of the nonfederal sector.[5]

- Federal incentives to nonfederal developers should be adopted and continued as long as they actually encourage development.[6]

- On the other hand, federal developers must pay greater heed than heretofore to conservation, "non-build" alternatives, and more rigorous cost-benefit analyses when undertaking water resource projects.[7]

As a result, few major new federal projects have been completed in the last several years. Efforts to streamline the lengthy federal development process have also proven unsuccessful. A report on the institutional and legal aspects of future hydropower development prepared for the National Hydropower Study (Ref. 3.3) concludes that "the current institutional framework favors small-scale, nonfederal development", and criticizes the federal development process for lack of clear direction, fragmentation of responsibilities, poor coordination, isolation from regional and local input, and organizational inflexibility. According to the environmental assessment report completed for the National Hydropower Study:

> ...without a shift in the current direction of federal hydropower policy, the development agencies will be unable to provide significant new hydropower capacity in the near future from large-scale development. The agencies heretofore have played no significant role in the development of small-scale hydropower... Despite the current interest in hydropower, federal actions so far have not sped the completion of many federal hydropower projects. One main reason is that no one agency has received overall authority to direct the federal government's role in hydropower development (Ref. 3.6, p. II-13).

Indeed, the authorizing legislation for the National Hydropower Study itself (Water Resources Development Act of 1976, PL 94-587, Section 167), wherein the Secretary of the Army is authorized "to conduct a study of the most efficient methods of utilizing the hydroelectric power resources at water resource development projects " has been described as "the <u>only</u> piece of policy legislation since 1974 that provides for a possible expansion of federal hydropower activity" (Ref. 3.6, p. II-10).

From the current institutional perspective, it is clear that the nonfederal hydropower development sector is in a better position to promptly and efficiently bring on line the small-scale potential identified in the Corps' hydropower site inventory, because there are fewer institutional barriers and greater institutional incentives for the nonfederal sector to do so.

> The federal government can't do small jobs. It can't work with small interest groups. It can't deal with mayors and city fathers. It is incapable of comprehending what it is they're doing. It is big, aloof, intimidating. Big federal agencies make bad vibes in a small town—they are not institutionally geared to that.
>
> (A Congressional Staffer)

But the institutional disparity between federal and nonfederal hydropower development sectors diminishes as the MW output of a particular project rises. Following are several key output figures to remember:

1.5 MW	Upper limit for streamlined FERC "short-form" license;
5 MW	Upper limit for availability of FERC licensure exemption for existing site hydropower project (Energy Security Act, 1980);
15 MW	Upper limit for availability of FERC licensure exemption for small conduit hydropower project; upper limit for direct federal assistance to nonfederal developer under Title IV (DOE administered Small Hydro Program) of Public Utility Regulatory Policies Act (PURPA) in the form of forgivable feasibility loans or low-interest construction loans at existing sites;
25 MW	Upper limit for availability of full 11 percent energy tax credit under Crude Oil Windfall Profits Tax Act (COWPTA, 1980) for hydropower development at existing sites; credit thereafter uses declining percentage up to 125 MW;
30 MW	Upper limit for PURPA Title II exemption from certain federal and state laws as prescribed by FERC rulemaking where FERC finds "such exemption is necessary to encourage small power production"; also, figure used for convenience herein, and by the Corps' Environmental Assessment contractor (Ref. 3.6) to differentiate small from large-scale projects;
80 MW	Upper limit to PURPA definition of "small power production facility" from whom utilities are required to buy output; i.e., the upper limit of PURPA nonfederal hydropower incentives (PURPA Title II);
125 MW	End of availability of COWPTA Energy Tax Credit for hydropower development at existing sites (on sliding scale, see 25 MW above).

The crucial figure is the 80 MW figure which cuts off PURPA's hydropower development incentive, i.e, a guaranteed market for a private developer's output. This is the incentive which has caused nonfederal development to boom since PURPA was enacted in 1978 (See Figure 3-2).

Above 80 MW, the institutional disadvantages of the federal sector diminish as some of its advantages begin to appear. These include all the advantages of a large organization experienced in planning for and bringing on line large increments of power, with access to federal financing mechanisms, years of experience in dealing with and securing congressional approvals, immense reserves of physical and technical expertise, and a plethora of informational backup, liaison, and government support services. Obviously, the Corps, WPRS, and TVA (the principal federal hydropower development agencies) differ markedly in their relative assets and skills in these areas, but the generalization holds as a useful index to federal development advantages.

3.2.2 Indian Rights

Description

Indian rights constitute an issue primarily in the Pacific Northwest. However, it is an issue with national impact because the Pacific Northwest has the largest hydropower potential of any region in the United States.

> The Corps has really been largely cooperative. For instance, on 404, that's industrial usage permits, we've been working very closely with them. But to date we have not really been able to get the state to sit down with the tribe. There has been alot of cooperation for a lot of issues that are still raised because of the threat to industry and then other local entities get involved. We don't care if there's any kind of development as long as the environments don't lose in exchange. We want to make sure the resources don't lose. Human (industrial) needs come second. First we are interested in the fisheries and the water. Without the water, there just ain't going to be any more humans.
>
> (A Northwest Indian Chief)

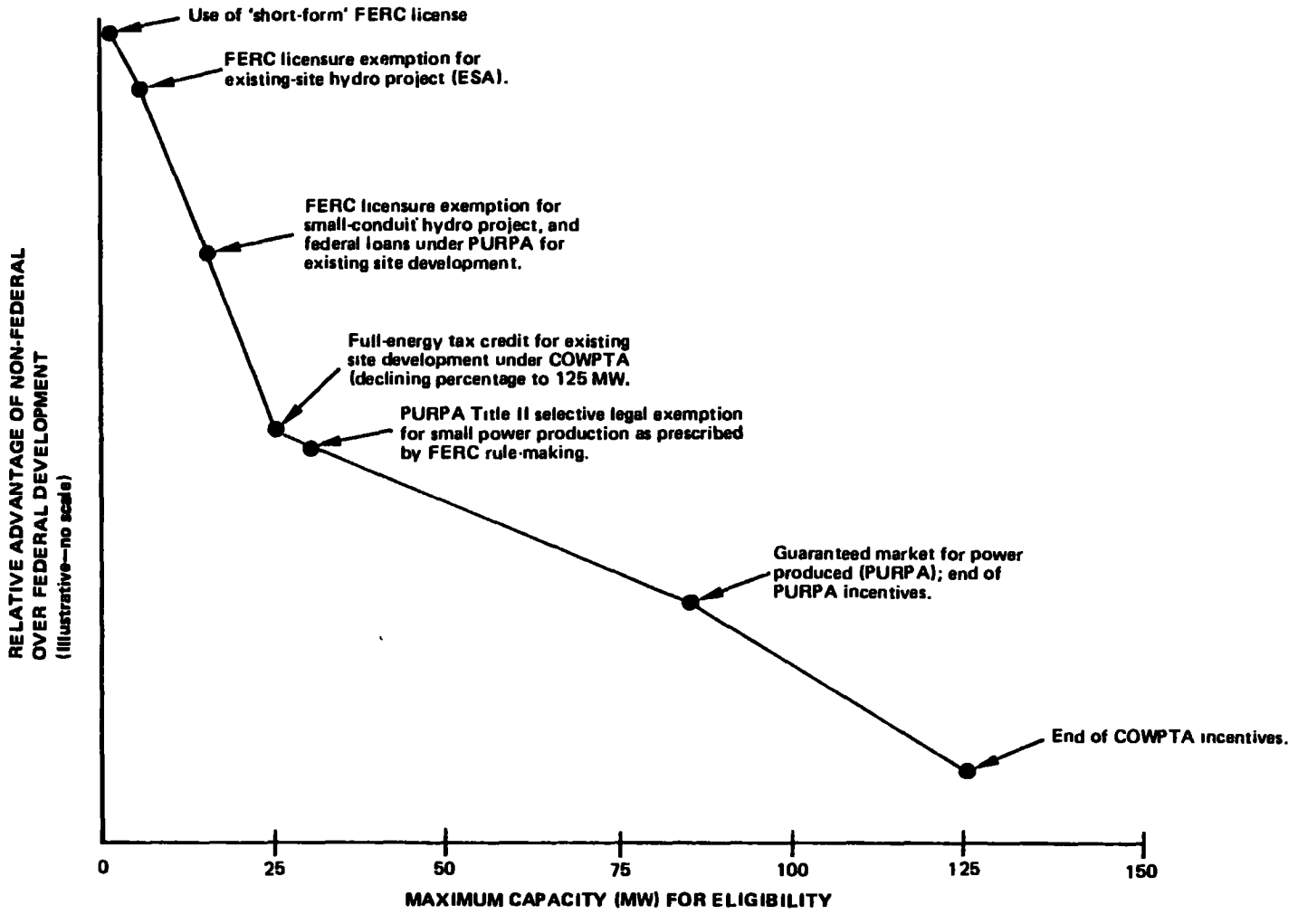


Figure 3-2

THE CUMULATIVE ADVANTAGE OF NON-FEDERAL OVER FEDERAL DEVELOPMENT DUE TO FEDERAL INCENTIVES

Analysis

The Pacific Northwest treaty tribes have strong legal/institutional/ support and judicial precedent for the validity of their rights over much of the region's waterways. There are three varieties of Indian reserved rights which cloud hydropower development in the area. They are reserved development rights, reserved fishing rights, and reserved water rights. In addition, there is the question of nonfederal development on Indian lands.

- Development rights. Indian reservation tribes have full rights to natural resources of the reservation sufficient to sustain their needs. Recent judicial authority supports the notion that "needs" includes the right to use reservation resources for economic development purposes. These rights derive from treaties with the federal government, and obligations on the government acting as trustee for the tribes.

- Fishing rights. Hydropower development and operations must proceed in conformity with Indian rights to hunt and to gather fish subject to a treaty. This embraces off-reservation rights to protect the environment upon which the resource depends. In the Pacific Northwest these rights are supported by court decisions and bolstered by the Regional Power Act.[8]

> The series of treaties signed between the tribe and the Federal government guaranteed that the Indian would be able to maintain his value system. The Indian people want to be able to drink clean water and to breathe fresh air, and they think that that is just as important as running hair dryers in the Northwest.
>
> (Lawyer for an Indian tribe)

- Water rights. In their effect on hydropower development, Indian reserved water rights are more important than federal reserved water rights because of their potential scope (See 3.2.3). They can be consumptive, exist regardless of whether they have been exercised, and can be used for most purposes without regard to state allocation systems.

An additional issue is the right of non-Indians to develop hydropower on Indian reservations. Such development is presently governed by FERC. Tribes cannot veto an unwanted FERC license affecting tribal lands, but the Department of the Interior (DOI), as trustee for the tribes, has "approval" power over a FERC license on such lands. The effect of DOI's disapproval is currently unclear. If FERC begins to license nonfederal development which affects reservation lands, this issue should be resolved by agreement between DOI and FERC, or by Congress. If unresolved, the courts will provide the forum, as litigation by the tribes based on violation of the government's trust obligation may be expected.

3.2.3 Federal Reserved and Preemptive Water Rights

Description

The federal government has very limited reserved water rights in connection with federal lands. Federal lands are lands reserved by the government for various purposes, governmental functions, or the public benefit. These lands are primarily in the Western United States. Although 46 percent of land in the Western states is federal, the water rights reserved by the federal government on these lands exist only for the original purposes of the reservation (i.e., parks, military, etc.). But federal rights to preempt water unconnected to federal lands exist on navigable waterways throughout the United States, and can validly supersede state allocation systems. The government can preempt state water law should compliance make a project impossible to accomplish. The government must, however, pay for any vested water rights it condemns.

Analysis

Federal water rights reserved in connection with specific parcels of federal land tend to have little impact in either hastening or impeding hydropower development. Congress traditionally defers to state water law allocation systems (See 3.3.2) in its framework for federal and nonfederal hydropower development. Where hydropower is not a primary purpose of a federal reservation, water rights

must be obtained from the states. Power is a primary purpose only at slightly over a thousand reserves managed by the Bureau of Land Management (BLM) under the 1910 Pickett Act (See Appendices, Sec. B-2). Congress has never exercised its reserved rights on these lands and seems unlikely to do so on behalf of a nonfederal developer in the absence of a national emergency situation.

The issue of exercising federal preemptive rights is ultimately a mixed question of policy, politics, and economics. It depends on the extent to which the federal government is willing to pay for vested water rights, and/or override state water law allocation systems in order to further hydropower development. That in turn may depend on whether Congress is willing to undertake the formidable task of building a national or regional constituency in support of such a move. Congressional and federal agency staffers have indicated that a water rights struggle between the federal government and the states is a struggle where ultimately the states cannot constitutionally expect to prevail. While this view is strictly correct from a legal standpoint, the politics of such a turnabout from traditional federal deference to the states over water rights is quite another matter. Although there are isolated cases where the federal government has intruded upon state water rights (e.g., Boulder Canyon Project Act of 1928 and the current California controversy surrounding the New Melones Dam), it is probably unrealistic to expect any concerted congressional intrusion into this area which has traditionally been left to the states. It would be extremely unlikely that Congress could adopt such a position without a significant supportive constituency or an energy crisis of national proportions.

> This has been a long-standing worry, water resources and federal control. There's a long body of law that affirms the rights of the federal government to preempt water, particularly in the west.
>
> What you've got to understand is that the original 13 colonies, those states made the federal government. They have different rights. Nevada didn't create the federal government. The federal government created Nevada. And when they did that, they assigned some rights, and withheld others. Real estate is territorial—and there's a lot of federal ownership. The worry is that 80 percent of Nevada is federally owned. Most water in the western states is apportioned by state water law. The worry is—will that law hold up against federal demand?
>
> (A Congressional Staffer)

> Resolving the issue is going to create worse uncertainty than living with it.
>
> (A Senior Congressional Aide)

3.2.4 Nonfederal Development at Federal Dams

Description

There are several important institutional constraints which currently impede or delay nonfederal development at federal dams. Resolution of these conflicts will serve the interest of nonfederal developers in bringing hydropower on line at existing federal dams—according to most sources faster and more economically than federal development agencies can do so.

These institutional constraints are important because of the extent of nonfederal developers' interest in federal dams. Existing federal dams are generally larger and have greater potential for profitable hydropower than their nonfederal counterparts. Some of the most serious institutional constraints are described below.

> Agencies end up at loggerheads. FERC will say, "This is our bailiwick. You make any commands and communications to us." But the Bureau of Land Management still insists on a permit. So you really have to go through two separate licensing procedures.
>
> (A Rural Electric Association Official)

Analysis

In late 1977, 54 applications for licenses and preliminary permits were pending before the Federal Energy Regulatory Commission (FERC). After passage of the Public Utility Regulatory Policies Act of 1978 (PURPA), the number more than doubled and, by August 1980, stood at more than 330 applications. In addition to the stress on FERC staffing and procedures, the volume of applications requiring review has other important implications as well. Many federal and

state agencies are required to review FERC applications and submit their comments, recommendations, or approvals before FERC may proceed. State water agencies must issue a Water Quality Certificate, state and federal Fish & Wildlife agencies must comment, and the Corps of Engineers must review applications and issue dredging permits where necessary. The skyrocketing volume of FERC applications thus has important consequences on other agencies who in turn face similar budget and staffing constraints. At federal dams, federal agencies must also review a nonfederal developer's engineering, design, and operation proposals. The Corps and WPRS have adopted, or are considering adoption of, procedures to enable them to bill these review costs to nonfederal developers. In the meantime, however, nonfederal developers at federal dams may face considerable delays from FERC and other state and federal agencies with comment and review authority as the volume of applications increase.

FERC levies annual charges on most of the nonfederal developers it licenses. The charge varies depending upon the licensee and the project, but can include administrative charges, use of government lands, water storage, headwater benefits, and dam use fees. FERC is self-supporting through the use of these fees, but much of the charges it collects are paid over to the agency or licensee whose facility is causing a benefit to the fee-payer.

Although some controversy surrounds the method by which FERC calculates these fees, there is currently an institutional conflict over whether FERC is the sole federal agency authorized to levy some of these charges. WPRS is currently seeking to set and impose its own dam use fees at their projects—apart from, and in addition to, the amount included in the annual fee set by FERC. Both the FERC and the WPRS positions are legally defensible, but the conflicts and the prospect of double fees are disincentives to nonfederal development at WPRS dams.

FERC states that it has exclusive jurisdiction in nonfederal hydropower licensure, and that a FERC licensee may enter and occupy federal lands for purposes of its license. DOI insists that the Federal Land Policies Management Act (1976) requires a FERC licensee to secure a right-of-way permit from the Bureau of Land Management (BLM), in addition to complying with all FERC procedures. The conflict is unresolved, and is a constraint on nonfederal development of hydropower on lands under BLM jurisdiction.

FERC and DOI differ on the nature of each other's authority to approve final engineering design on power production facilities at WPRS dams. DOI asserts that it has final authority; FERC declares that it recognizes and incorporates DOI's authority, but that FERC may reserve the right to resolve any disagreement between the licensee and WPRS. The conflict is unresolved.

Where hydropower is an original authorized federal dam project purpose, FERC will not permit or license nonfederal study or development. This has eliminated the possibility of nonfederal development at a number of projects where the federal government has not installed hydropower capacity otherwise authorized.

Ref. 3.6 indicates that about 22 percent of the nation's hydropower potential (after the Corps' screening) is at existing federal dams. Some of these dams have hydropower as one of their original project purposes, and some do not.

3.3 Economic Issues

3.3.1 Small-Scale Hydropower

Description

The variations in the definition of "small-scale" were discussed in Section 2.2.2. Using a definition of 30 MW as the upper limit of small-scale, it is estimated that 6,000 to 11,000 MW of such hydropower generation capacity may be available in the United States. Most of this potential is located in New England (Ref. 3.6, p. I-6) and includes many retrofit sites, i.e., sites where turbine equipment can be added at existing dams and reservoirs. Elsewhere (Southeast, Northwest) new sites will usually be necessary. Small-scale hydropower presents advantages and disadvantages which cannot be viewed merely as scaled-down versions of those discussed under large-scale hydropower development.

Analysis

On the beneficial side, small-scale facilities fit well into "appropriate technology" and conservation ethics. They provide an opportunity for local participation and old-fashioned American entrepreneurial talents. In many cases retrofitting an existing site or constructing a new one helps to create a sense of community. The federal government has taken a supportive stance through enactment of PURPA, the Public Utility Regulatory Policies Act of 1978. This law guarantees access to the electric power market for small producers, significantly changes the "monopsony" market characteristics of the electric power industry, and creates a strong incentive, for small-scale hydropower developers.[9]

This incentive has been instrumental in creating the small hydropower "boom" which has led to skyrocketing numbers of permit and licensure applications before the Federal Energy Regulatory Commission (FERC), and increased stress upon staffing and budget resources of a variety of federal and state agencies with review responsibilities (See 3.2.4).

Hydropower Boom Raises Thorny Issues at FERC...(Headline)

In a scramble reminiscent of the gold rushes of the last century, private entrepreneurs and public officials are racing to lay claim to likely sites on creeks and rivers. The lure today is not gold but hydroelectric power...

In 1977 FERC received 10 applications (to study hydro sites). Last year the number was 130; so far this year it's about 1400.

Washington Star, May 25, 1981, p. C-7

In allowing access by non-utility entrepreneurs to the electric power market, PURPA requires utilities to purchase small hydropower output (80 MW or less) at rates that are "just and reasonable." and which shall not "exceed the incremental cost to the electric utility of alternative electric energy."

Implementing regulations promulgated by FERC have focused on full avoided costs, i.e., the purchasing utility must buy the output of the small hydropower developer at the full cost of the energy it would otherwise use. In regions such as New England, with its large proportion of oil-based electric generation, these avoided costs are very high. FERC regulations also encourage long-term contracts between the producer and the purchaser. Such atmosphere generates enthusiasm for hydropower ventures even if the amount of energy produced is negligible in terms of national needs.

You have no lab. You have no inventory. No receivables. No payables. You don't have to have salesmen running around. The utility is your one and only customer. You have a watt-hour meter that tells them what you have generated, and there is no question about their paying their bills. The raw materials are for free. As the price of oil inflates, the utility will be paying us more, but the creek will still be free. Moreover, there should be quite a bit of satisfaction in producing electricity and producing it clean.

(Ref. 3.7)

Potential profitability attracts larger, non-local entrepreneurs to small-scale hydropower as well. This may hurt the small operators as, for example, food chains have swamped mom-and-pop grocery stores. FERC also reports

receiving about 100 "hybrid" applications in which private entrepreneurs join a public entity in filing for a site. These seem to range from legitimate joint ventures to questionable cases where a municipality is selling its name and the advantage it carries of knocking out purely private competitors (Ref. 3.8).

Established utilities, in general, are concerned about small-scale inefficiencies, voltage fluctuations, lack of reliability, and safety issues. There is also little advantage to a utility in expending considerable time and money in order to build a small-scale facility—interminable public hearings, adverse publicity—when a comparable effort devoted to a larger facility could have a much more profitable result.

It must also be recognized that the collective environmental impact of a hundred hydropower installations of 100 kW each may well exceed that of a single 10 MW plant. New construction usually has adverse effects not only on the aquatic life but also on the flora and fauna in the vicinity of the site. This problem is of concern in ecologically fragile areas such as Alaska, the coastal mountain range of Oregon, and the Olympic mountains of Washington.

3.3.2 Allocation of Water Rights and Competing Water Uses

Description

According to the United States Water Resources Council (WRC), 17 of the nation's 106 water resource subregions evaluated in the Council's Second National Water Assessment already have, or by 2000 will have, a seriously deficient supply of surface water (Ref. 3.9). In almost every case, hydroelectric power competes to some degree with other water uses, some of which are instream uses and others which are offstream uses. Numerous and varied mechanisms exist to allocate the supply of water, especially at the state level; the legal constraints to adequate water for additional hydropower development are very real and significant. The competition and the constraints to hydropower development are exacerbated during those periods when the precipitation and

runoff are well below average and the supply of water stored in reservoirs is low. This issue is very closely related to those concerned with water rights, federal reserved rights and Indian claims/rights (See 3.2.2 and 3.2.3).

> Competing uses and water rights are the two leading obstacles to hydropower development.
>
> (A River Basin Commission Staff Member)

Analysis

We first consider the problem of water rights affected by hydropower. Although hydropower is not a consumer of water, the use of water for hydropower purposes necessarily impacts other uses of a waterway (e.g., recreational and navigation). This is particularly important where many water claimants and users compete for available resources, and is quite significant under "prior appropriation" water rights systems of the Western states. Congress traditionally defers to state water allocation systems in its framework for federal and nonfederal hydropower development. WPRS must obtain its water rights from the states, and FERC requires nonfederal developers to do the same.

Such rights are more readily obtained under riparian (reasonable use) systems characteristic of Eastern states than under the prior appropriation systems of the West. In the East, nonconsumptive use of water for hydropower is generally a "reasonable use", but in the West "storage and release" projects may conflict with streamflow and usage rights already perfected by prior claimants of the water. The magnitude of the problem is apparent when it is realized that the bulk of the nation's undeveloped capacity lies in the prior appropriation states of the West.

Next we consider the problem of water supplies and uses. Historically, United States' growth, both in location and rate, has been related to an inexpensive and abundant supply of water. The country as a whole still has abundant supplies of water; however, projected population increases and expanded economic develop-

ment will generate water needs that will outstrip available supplies, if water policy and management practices do not respond to these increased pressures (Ref. 3.9).

In addition to the short supply, water users are becoming more and more aware that water left in a stream is not necessarily "unused." Instream requirements for esthetics, recreation, waste assimilation, and fish and wildlife habitat maintenance are getting increased attention. The regulation of streamflow required for hydropower generation causes rapid fluctuations of stream levels which in turn create problems for recreation and navigation.

> Federal water policy? There isn't any. None. There's a lot of clashing rights, a lot of programs without cohesion, and no effective mechanism for coordination.
>
> (A Water Consultant)

In addition to manmade, fluctuating demands on surface water, natural phenomena also change surface water supplies. Droughts are normal climatological phenomena which cannot be readily forecast.

> We can't plan electric power without planning water—whether we like it or not we'll have to pick up on competing water uses.
>
> (A Federal Power Marketing Agency Staff Member).

Offstream water use involves two variable components: withdrawal from a watercourse or aquifer and consumption of all or part of the amount withdrawn. The United State's consumption of water generally is more critical than withdrawals. Consumption is not proportionate to withdrawals among the functional use categories. Agriculture (irrigation and livestock watering) is the highest consumptive user, accounting for 83 percent of the total water consumed in 1975.

In many areas of the United States, available water is fully appropriated, limiting the expansion of agriculture in these areas. Under "dry-year" assumptions, agriculture's water supply will be completely used by 2000 in much of the West (Ref. 3.9).

> Power development is very competitive with other water uses. The problem is that water is underpriced and is thus inefficiently used. If it were adequately priced, we could reduce uses without suffering lowered output.
>
> (An Economist)

> One interesting thing is that irrigation and hydro go together quite well in some regions. We've found that in California and other areas, irrigation flows and peaking needs are often roughly the same (i.e., in summer season).
>
> (A Consulting Firm Member)

Finally, we turn to instream functional uses. Recreational use of water appears to be on a collision course with energy, municipal, industrial, transportation, and agricultural uses. Two competitors in particular deserve attention—energy and agriculture. Water is essential to all phases of energy development from mining to revegetation of mined lands. Management of reservoirs to maintain minimum reservoir pools during the recreation season and for coordinated water releases to enhance or protect downstream river recreation could be seriously affected by anticipated water requirements for energy development. Demands for water to support coal and other energy development will undoubtedly lead to consideration of new reservoirs. Various energy development proposals could also affect important recreation streams and eliminate recreation for many miles below the scene of energy developments.

Navigation is a nonconsumptive water user. A body of water of defined depth sufficient to maintain acceptable vessel operations (loads, tows, and speeds) constitutes a navigation system. In open rivers, navigation needs are adjusted to the natural regime of the water flow. Improvements in navigation conditions by dredging and other means, though essential for water transportation, are limited by river hydraulics, cost-benefit expectations, and adverse environmental effects.

Streamflows required to support navigation are generally less than those needed to maintain the quality of water, aquatic habitats, or other instream purposes.

> One of the biggest present day constraints on hydro is the question of the amount of water you can release for instream uses. Single-purpose state and federal agencies demand certain amounts of that water, and it is a major constraint.
>
> (A Water Consultant)

In summary, hydropower development will be constrained in many areas of the nation as demands for water approach or exceed the available water supply. The WRC states that "the technical resolution of inadequate surface-water supply is straightforward: (1) increase the available supply, and (2) reduce the present or projected demand" (Ref. 3.9).

> The main problem is one of competing uses of the affected resources, particularly when there is more than one state involved. And that's a situation only Congress can deal with.
>
> (A Water Consultant)

3.3.3 Competing Land Uses

Description

Construction of hydropower facilities, particularly at undeveloped sites, requires a significant commitment of land to accommodate the dam, reservoir, powerhouse, switchyard and transmission line right-of-way, and necessitates the relocation of roads, rail lines, and agricultural/residential/industrial development. Changes in uses of surrounding property are a secondary impact. Significant opposition can be expected at the local level. National involvement will be focused on the cumulative loss of lands for food and fiber production, and on adverse impacts upon aquatic and terrestrial wildlife habitats (particularly in ecologically-sensitive wetlands) and upon valuable scenic and recreation resources. The way in which these concerns are addressed will be dependent primarily on the location of the project; i.e., on public (federal, state, or local) or private land.

Analysis

From a national perspective, the potential loss of agricultural and forest lands is of critical concern. To determine the magnitude of land potentially affected, the development of an arbitrary 45,000 MW of capacity at new sites is assumed. Further assuming an average 100 acres of land for each megawatt of capacity and large-scale projects (e.g., 200 MW), a "worst-case" total of 4.5 million acres would be required; this represents about 0.2 percent of the nation's 2.3 billion acres. Not all of this acreage would be in active agricultural production, and much of what is cropland is likely to be of marginal quality. Nevertheless, if three-fourths were under cultivation, the total is 3.4 million acres; assuming a two-fold decrease in agricultural use of nearby land due to its increased value for recreation, industrial, and residential development, the total "worst case" loss of agricultural land would equal 10.2 million acres. This is about 2.8 percent of total land under cultivation (1974).

This potential loss is significant especially when combined with the annual conversion of about 3 million acres of farmland to urban uses, this at a time when it is estimated that an additional 80 to 140 million acres of productive cropland will be required to meet United States domestic and export food requirements by 2000. There is a surprising amount of dispute about such estimates. Some sources view them as excessively pessimistic and argue that the impact of hydropower on land use is often exaggerated (Ref. 3.10).

Major new sites are more remote from load centers, requiring the acquisition of additional transmission corridor rights-of-way in order to reach existing power grids. The latter may have to be enlarged in order to accommodate increased production. The development of new and the enlargement of existing transmission lines is likely to engender widespread public opposition, especially in view of the potential health hazards of 1,200 kW superconductive transmission lines (See Sec. 2.3.3).

Low levels of hydropower development primarily involving the expansion or retrofitting of existing facilities and construction of small-scale projects would create few land use conflicts.

On the other hand, higher levels of development would engender significant conflicts with competing land uses.

> The biggest conflict with hydro siting takes place where there are undeveloped river courses.
>
> (A Staff Member of Western State Land Regulatory Agency)

> A lot of archaeological sites have been flooded out by dam development. Sprague, Utah; Rarmes Rock Shelter at the Mouth of the Palouse—they were doing a study of that site in 1968 and had identified stuff that was at least 11,500 years old, but it could have been anywhere from 27 to 50,000 years old when it was flooded. They laid down sand and plastic over the site to protect it if the reservoir is ever drained. Leakey came to see it. Just between Hells Canyon and the Lower Grantie there are over 100 archeological sites. Every stream mouth with level ground is such a site. We found that people and bison lived here simultaneously—we'd always assumed that untrue. The Saliloh at the Dalles: that's been called the Chicago of the Northwest. It was the urban metropolis for our Indians. The site is now irrecoverable.
>
> (University Historian)

3.3.4 Pricing of Hydropower from Federal Projects

Description

The pricing issue directly affects hydropower development because it has major implications for financing projects, affects the nature of competition between hydropower and alternative sources of electric power, and determines benefits/costs resulting from hydropower development.

Historically, electricity produced by federal projects has been priced at or close to cost, with the intent to encourage economic development and rural electricifcation. The "preference clause", whose legislative history is traced in the Appendices, Section B-2, mandates that electricity from federal projects be first offered to state and local government organizations, such as public utilities, and to non-profit entities, such as rural cooperatives, before being offered to private utilities and industries.

The rationale for the preference clause is based on the following considerations:

- Electricity generated from federal projects belongs to the public;
- Benefits of public projects should go directly to the people through government or non-profit entities;
- Monopolies are discouraged by allowing a diversity of ownership of utilities;
- Local governmental and rural utilities should not be asked to rely heavily on electricity produced by the private utilities; such reliance can be reduced by giving them a preferred access to power produced from federal projects; and,
- Local control over power distribution should be encouraged.

Proponents of the preference clause argue that the above rationale is as valid today as it was when the clause was first enacted.

Strong arguments are put forth by the proponents of the preference clause when its elimination is proposed on the ground that it is not meaningful in the current setting. For example:

> The changing circumstances of the past ten years demonstrate that the preference clause is just as valuable a tool of public policy as it was when electrical power was cheap and widely available. Once it is acknowledged that hydroelectric potential is a national resource, it naturally follows that the resource should be distributed directly to the general public whenever it is possible to do so. The fact that not all persons share equally in those resources has never been an adequate reason to invalidate the principle of public benefit from publicly owned resources. The increasing price and scarcity of electric power makes it all the more important that the priority of governmental and non-profit entities be preserved.

> To decide otherwise would be to admit that an important national policy—public ownership of public resources—is to be honored only when it is worth little and that the desires of private industry should have precedence when the policy would otherwise convey a significant benefit on the public...In short, the changed conditions of 1970's make it more important than ever that the preference clause be retained (Ref. 3.11).

Critics of the preference clause argue that:

- Continuation of the current preference clause produces inequity, seems inconsistent with national energy objectives, provides incorrect signals for energy policy making, and more importantly does not allow recovery of actual costs. For example, Ref. 3.12 notes that the Bonneville Power Administration "has not been recovering true total and average costs". The article further points out the need to consider long-run incremental costs when basing the pricing structure.

- Federal electricity should be sold at "true market value". This would provide a strong incentive for energy conservation particularly where hydropower is used to meet peak demand.

- Private citizens should have access to electricity produced from federal projects.

- The preference customer concept permits significantly different electricity prices for different customers in the same region. Despite the original good intentions to provide benefits to the public at large, "it has created situations where electricity purchased by preference customers can be sold to industrial users at a price set by investor-owned utilities." In an effort to secure equitable access to federal power for most classes of domestic customer, at least one state (Oregon) has acted to create a state power authority to act as broker between the federal hydropower authority and domestic ratepayers.

Analysis

The current structure for pricing electricity is based on the "average cost" concept in which costs of newer, more expensive power plants are averaged with the lower costs of older hydropower plants. Consequently, the price does not reflect the true replacement cost of electricity and other energy forms.

Further, a significant factor is how future events affect prices, particularly the availability and cost of conventional (e.g., oil and gas) and non-conventional (e.g., solar) resources. For example, considerable uncertainty exists about the future availability and cost of imported oil, and the actual cost of new technologies expected to come on line over the next 20 years.

The continuation of preference clause policies will produce benefits and costs which are amply documented. But it would be instructive to consider the proposed alternatives to the preference clause and to examine their impacts.

Two approaches to replacing the preference clause are often mentioned:

- The marginal cost pricing (MCP) approach, in which each customer pays the incremental cost of the electricity used, allowing the electricity to be priced at its true market value.

  This concept can be applied in two ways: a pricing structure similar to "lifeline rates", or a pricing structure based on "fuel cycle" cost or cost of energy as experienced by the end user. The MCP approach in its strictest sense may be difficult to implement under the current political context for a number of reasons: rates charged will need to rely on information which can only be obtained by metering to determine "time of the day" use; revenues collected by relevant federal agencies will increase substantially; utilization and redistribution of the revenues could create substantial problems; and all fuels, including oil and gas, will also need to be priced at their marginal cost to prevent shifts to these fuels, if the MCP approach is only applied to electricity.

- The cost of alternative source (CAS) approach, in which the price is determined by the cost of the alternative source which can be substituted for hydropower. The cost can be in terms of the "least cost" or "maximum of the minimum cost" alternative(s).

  For the CAS approach, an alternative may be to index the price of electricity to the price of oil (average price, as reflected by the proportions of imported and domestic oil used) used for electricity generation in a given region, such as California or the New England states. In the Western coal states, the price can be indexed to the cost to the consumer of electricity generated by a coal-fired power plant.

In general, both approaches will produce impacts similar in character but different in magnitude, depending upon the development plan. These are summarized below:

- Price. The electricity price will likely increase, with the magnitude of price increase depending upon the particular approach used and a number of other factors. Under the "lifeline rates" approach, certain users will be asked to bear more of the incremental cost, for example, industrial users such as the aluminum industry.

- Hydropower Development. It is likely that the alternative approaches may shift electric power resource development away from hydropower since they shrink the advantages of hydropower. On the other hand, should the price of alternative sources of electric power also increase, the renewable nature of hydropower could prove to be a long-term advantage.

- Publicly-owned utilities. The elimination of the preference clause may impose a financial hardship on public-owned utilities since they would then need to compete with investor-owned utilities. The resulting financial strain could force some public-owned utilities to curtail services or to leave the electricity business.

- Energy demand. The increase in price of electricity will motivate users to improve the energy efficiency of specific end uses. For example, process improvements to reduce the energy intensity in the aluminum and steel industries may accelerate as a result, thus lowering electricity demand.

- Energy supply. As the price of electricity rises for certain users, there may be incentives for the users to shift to alternate energy resources, particularly the renewable ones.

- Revenues. Federal power marketing agencies, such as the Bonneville Power Administration (BPA), will collect increased revenue, creating redistribution problems. However, the increase can be used to accelerate the deployment of conservation measures.

- Rate payers. The changes in price structures will affect rate payers adversely, especially in the regions currently supplied by public-owned utilities. The changes in rate could be important and could result in an increase both in electricity bills and in the cost of products with substantial energy intensity. This in turn will likely raise dramatically the number of participants intervening in the rate making process.

- Income redistribution. As stated earlier, income redistribution is inevitable under the MCP and CAS approaches. It is possible that the net result of income redistribution may be insignificant, since a loss of income in a given area could be balanced by the gain in other area(s). The need for policies to compensate low-income groups may become important in areas dominated by the availability of hydropower from federal projects, such as the Pacific Northwest.

Thus, the nature and extent of changes resulting from replacement of the preference clause will depend both upon the level of development and the particular implementation procedures. On the other hand, movement away from the preference clause concept is likely to produce intense conflicts, public debate, and lengthy litigation.

3.3.5 Capital Formation

Description

The estimates of construction cost of new hydropower capacity over the next two decades cover a wide spectrum. With the figures varying from $1,000 to $3,000 per kW, the totals in 1980 dollars range from $25 billion for an additional 25,000 MW at the low end to $225 billion for an additional 75,000 MW at the high end. Considering the general concern about the shortage of capital, the serious problems faced by the utilities, the competition of nuclear and solar development programs for available capital, and the general public's desire to limit federal expenditures, the ability of either public or private agencies to raise sufficient capital for hydropower development is one of the major challenges for any significant hydropower expansion program.

Analysis

The cost of capital and the difficulty of assembling front-end financing are serious impediments for nonfederal developers. Hydropower has special financing needs because of its high front-end costs and lengthy payback periods. The existing federal tax structure (shelters, credits, exemptions, deferrals, abatements, etc.) is crucial in shaping nonfederal financial packages. Direct federal aid (grants, loans, guarantees, planning funds) is at present becoming less available under federal budget priorities. Federal developers face the vagaries of congressional budget cycles and policy priorities. Both sectors face the difficulty of assembling large amounts of front-end capital in an overheated economy where the cost of money is rising. One possible—and rather easy—solution is the introduction of foreign capital to finance United States dam construction. But this approach hardly strengthens United States energy independence.

The discounting of future costs plays a significant role in understanding capital requirements. For example, consider a simplified version of alternative construction programs. Assume that $5 billion has already been allocated and $2 billion per year will be provided during this decade. Thus by 1990 $25 billion

will have been spent, giving 12,500 MW new capacity (at $2,000 per kW). If $2.5 billion per year is made available during the 1990's we would develop another 12,500 MW, leaving us in 2000 with a total of 25,000 MW more hydropower than we have today. If we aim higher, and wish to add 32,500 MW during the 1990's, for a total gain of 45,000 MW, we would have to draw forth $6.5 billion annually during that decade (See Fig. 3-3). The strategy of delaying large incremental funding to the 1990's facilitates any decision for a significantly larger hydropower development program. This can also be seen in Table 3-1 where the net present values corresponding to the development programs in Figure 3-3 are shown.

Table 3-1

The Effect of Discounting

Additional Hydropower	Net Present Value* Zero Discount Rate	10% Discount Per Annum
25,000 MW	$45 billion	$20 billion
45,000 MW	$85 billion	$30 billion

*Assumptions: $5 billion already allocated annual funding distribution as in Figure 3-3.

If all of the 45,000 MW were rushed through construction during the 1980's, the net present value would be $57 billion instead of $30 billion, i.e., the same construction program would appear to be nearly twice as expensive.

3.4 Environmental Issues

3.4.1 Environmental Impacts and Regulation

Description

With regard to hydropower development, environmental factors are significant when they render specific projects environmentally unacceptable, increase costs to an unacceptable degree, or cause significant time delays. A summary of major classes of impacts is shown in Table 3-2 which is repproduced from

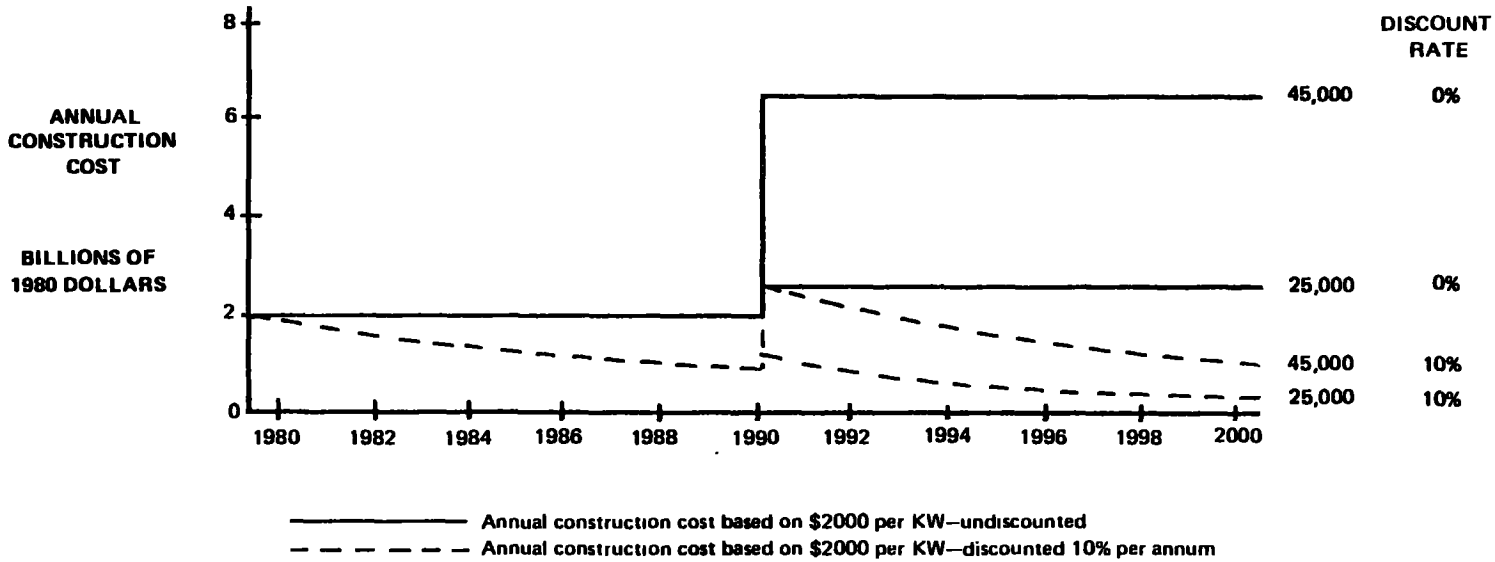


Figure 3-3.

THE CONSTRUCTION FUNDING PROBLEM

TABLE 3-2

MAJOR CLASSES OF HYDROPOWER IMPACTS

LARGE-SCALE

ACTIONS

- Switchyard Construction
- Relocation of Roads, Rail Lines, and Structures

IMPACTS

- Dam Safety Hazard
- Reservoir Stratification and Water Quality Problems
- Gas Supersaturation
- Delay in Fish Migration
- Potential for Flatwater Recreation, Flood Control, and Water Supply
- High Reservoir Evaporation Rates

PEAKING

ACTIONS

- Reservoir Storage and Release to Increase Value of Energy

IMPACTS

- Daily, Seasonal Downstream Flow Alteration
  - Dewatering and Stranding Fish
  - Change in Riparian Vegetation
  - Flooding Waterfowl Habitat and Eliminating Nesting Islands
- Daily, Seasonal Reservoir Level Fluctuation
  - Visual and Recreational Nuisance of Exposed Drawdown Zone
  - Loss of Warmwater Spawning Grounds
  - Transport of Nutrients in Shallow Water to Deeper Water
  - Bank Erosion

CONDUIT

ACTIONS

- Stream Diversion

IMPACTS

- Dewatered Stream
- Disruption of Deer and Elk Migration

UNDEVELOPED

ACTIONS

- Dam Construction
- Reservoir Clearing

IMPACTS

- Change from River to Lake Environment
  - Loss of Riparian Edge
  - Change in Aquatic Plant and Fish Species
- Blocked Migratory Fish Runs and Loss of Spawning Grounds
- Trapped Nutrients and Sediment
- Altered Downstream Flow Regime
- Alteration of Water Temperatures
- Conversion of Land Uses
  - Loss of Wilderness and Whitewater Recreation
  - Loss of Wetlands
  - Loss of Agricultural Lands
  - Loss of Archaeological and Historic Sites

ALL HYDROPOWER

ACTIONS

- Excavation and Powerhouse Construction
- Transmission Line Right-of-Way Clearing and Line Construction
- Power Generation
- Maintenance, Including Dredging

IMPACTS

- Visual Intrusion Caused by Powerhouse and Transmission Lines
- Fish Mortality from Turbine Passage
- Potential Loss of Critical and Other Wildlife Habitat from Right-of-Way Clearing
- Increased Demand for Local Services from Construction and Maintenance Workforce
- Potential Release of Sediment and Toxic Substances
- Recreational Hazard

Source: Ref. 3.6

Reference 3.6. A discussion of these factors includes both the environmental impacts and the regulatory structure designed to minimize them.

Analysis

Physical Impacts:

The most environmentally benign projects are those which add power to an existing facility without altering streamflow or water level, destroying wildlife habitat through construction of auxiliary transmission facilities, disturbing existing migrating fish patterns any more than has already occurred, and without damaging historically or archeologically significant sites.

Environmentally disruptive projects include new hydropower projects at previously undeveloped sites which alter physical configuration or streamflows. These may engender any or all of the above impacts as well as inundate farmlands and wetlands, dislodge sediments and toxic substances, dessicate streams, alter or destroy riparian plant and fish species, cause significant erosion in immediate and adjacent habitats, adversely affect water quality, result in losses of wilderness and whitewater recreation opportunities, and/or force relocation of transportation networks, structures, and population.

> I served on CONAES, the National Academy of Science's Committee on Nuclear and Alternative Energy Systems, for two years, between 1976 and 1978...The consensus of the panel was that, in terms of ecological impact..., hydropower was the worst of all energy systems, worse than coal, nuclear, geothermal, solar, etc. It's an abysmal technology, even if it is renewable. Being renewable doesn't automatically make it good. Hydro endangers more species, more fisheries, more wilderness, more everything than anything else. Remember, endangered species don't become so through the poisons or accidents of different technologists habitat changes. And nothing destroys habitat like hydro.
>
> (Freshwater Ecologist)

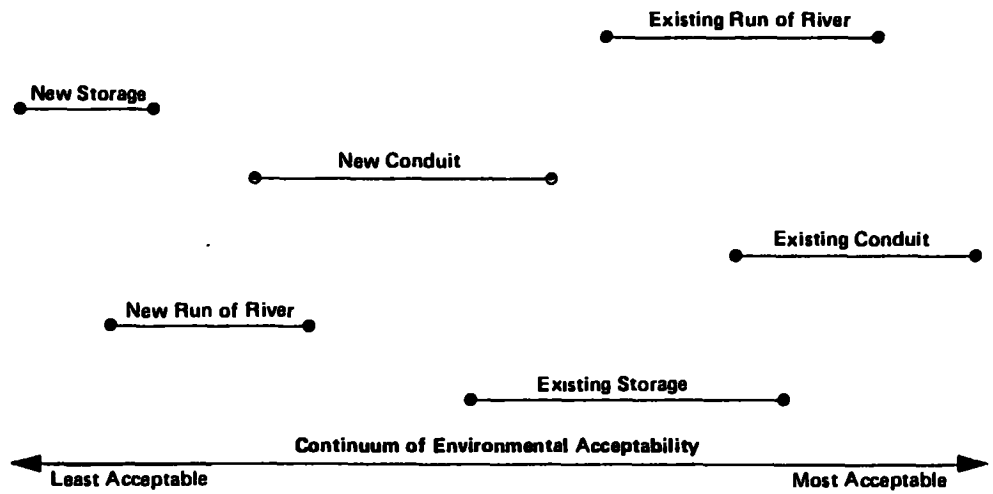
> The U.S. Fish and Wildlife Service raises a lot of good issues, a lot of serious problems: the deterioration of unique resources, wild and scenic rivers, archeological sites, Indian religious grounds...The underlying problem is not one of agency review. It's a resource allocation problem. Hydropower is clean, it's renewable, it's wonderful. But it's also the most destructive energy source for natural resources. It targets fish and wildlife. They depend for their habitat on the surface flow that we want to harness.
>
> (A National Wildlife Federation Staffer)

> We hear so much about the negative effects of hydropower development because those are the ones we want to mitigate; but there are several positive ecological effects:
>
> - Ability to control streamflow, especially in the eastern Pacific Northwest;
> - Ability to make the waterflows fish need at the right time;
> - Maintenance of a minimum flow, improving water quality, (Stratification—the main negative impacts of storage—can be dealt with by building multiple inputs and deciding which layer to draw from.)
> - Inundation can also benefit. It creates a waterbased ecosystem—like beaver dams. (A USGS pamphlet on natural selection at oil shale sites points out changing ecosystems are natural and useful.)
>
> Where you have a waterfall, flow diverted through a generator can make the site last longer. The biggest effect hydro development has is to slow down the tearing up of the river bed, by using that energy elsewhere.
>
> (A Water and Power Resources Administrator)

In Figure 3-4, the environmental acceptibility of the range of hydropower development is detailed.

Regulatory Impacts:

There are numerous federal statutes, regulations and policies, and a number of agencies with jurisdiction over the various environmental impacts associated with hydropower development. Ironically, the CO_2 induced climate changes associated with increasing fossil fuel use, which have been estimated to cause some of the potentially most catastrophic environmental impacts, are probably



Source: Ref. 3.6

Figure 3-4.

RELATIVE RANGES OF ENVIROMENTAL ACCEPTABILITY FOR HYDROPOWER CONFIGURATIONS

the least subject to clean regulatory authority and jurisdiction. The CO_2 problem is discussed in Section 3.4.2. In all fairness, many existing environmental statutes overlap, and many agencies function under competing mandates (See Section B-2 of the Appendices). The nature and extent of federal jurisdiction depends ultimately however, upon the location of the site, and status of the developer, and the size and physical configuration of the facility.

To facilitate timely development, FERC has undertaken a vigorous role in seeking coordination and conflict resolution among the many state and federal agencies with comment and review authority, and has endeavored as well to expedite the federal licensing process despite a geometric increase in application volume. Fortunately, complex regulatory and licensing processes tend to become more predictable over time; for example, drafting of environmental impact statements (EIS's) has become relatively routine after more than a decade of litigation and use.

On the other hand, environmental legislation has foreclosed development entirely at many sites with significant hydropower potential. For example, the Wild and Scenic Rivers Act of 1968 initially designated eight rivers for preservation in a free-flowing condition and recommended 27 others for further study. Currently, an additional 20 have been so designated and over 50 more are under study. Furthermore, many states have established their own state wild and scenic rivers acts; by early 1978, 19 states had designated almost 5,000 miles of river. FERC estimates that federally designated rivers alone preclude the development of 12,750 MW of hydroelectric capacity.

In its legal/institutional report, the Energy Law Institute concluded that "environmental regulation is the most important regulatory obstacle to hydropower, partly because of existing social priorities and partly because the environmental regulatory process is complex and unwieldy" (Ref. 3.3).

The economic burden of environmental regulation is largely procedural. Delays are in many cases a result of pluralism, i.e., the policy that all affected parties should be given an opportunity to participate in the project approval process. By comparison, the collection of substantive environmental data comprises less than 1 percent and implementation of mitigation measures normally less than 10 percent of total project costs, according to one estimate (Ref. 3.6).

3.4.2 Public Health and Safety

Description

Two major questions underlie this issue:

- What are the risks to public health and safety associated with the construction and operation of hydropower plants?

- What risks associated with the production of electricity from alternative sources, particularly coal-fired and nuclear power plants, are offset or enhanced by the development of hydropower?

Low-probability events such as dam failures from natural causes (e.g., earthquake) or sabotage, represent hydropower's greatest risk to public safety. Larger facilities located above population centers obviously pose a more significant threat to life and property in this regard. In addition, changes in water quality and dredging operations which disturb toxic substances can have an adverse impact upon public health. On the other hand, however, coal-fired power plants can produce air polluants which create serious health hazards, and the risks of an accident associated with nuclear plants are well publicized, mainly those related to reactor accidents and nuclear radiation exposure.

Analysis

As Table 3-3 indicates, 53 out of approximately 1,700 primary and secondary purpose United States hydropower dams are deemed unsafe by the Corps' National Dam Safety Inventory as of April 1981. One primary purpose hydropower dam (Lanesboro, Minnesota) is judged to require emergency measures to prevent failure. Emergency or remedial measures range from lowering the level of the reservoir to controlled breaching or destruction of the dam itself. The cost of taking remedial measures and making improvements to all unsafe dams has been estimated to run into the billions of dollars. The issue of who will make or pay for these improvements—federal or state governments or individual dam owners—is a key issue which has been addressed to date only on a case-by-case basis where failure is imminent.

Another important question is the role of hydropower development as a response to the risks associated with coal or nuclear power plants. The problem of evaluating comparable risks is difficult, however. In addition to the lack of accurate data, the definition of a system boundary delineating the components of each fuel cycle can vary.

The immediacy of impacts of risks from hydropower and other technologies must also be distinguished. Dam failure creates often massive but immediate impacts as does an uncontained nuclear accident. The impacts of coal-fired plants and radiation effects of nuclear plants have relatively long-term effects. Furthermore, whereas the impacts of hydropower are predictable and confirmed, those resulting from the operation of coal-fired and nuclear power facilities are both potentially more catastrophic and less easily assessed.

Nuclear power plants pose risks to both workers and nearby populations. Occupational risks are associated with radiation leaks from plant equipment or nuclear waste; catastrophic impacts can result from large-scale nuclear accidents or sabotage. Estimates of health impacts, based on the probability of reactor accidents, have received much publicity since the Three Mile Island accident.

Table 3-3

SAFETY OF UNITED STATES HYDROPOWER FACILITIES, AS OF APRIL 1981

Total Number of United States Dams	67,000
Total Number of United States Dams with Hydropower as Primary Purpose	1,355
Number of Hydropower Dams Deemed "Unsafe" Under Corps of Engineers Standards	32
Number of Hydropower Dams Deemed "Unsafe" and Requiring Emergency Measures	1*
Total Number of United States Dams With Hydropower As a Secondary Purpose	334
Number of Secondary Hydropower Dams Deemed "Unsafe" Under Corps of Engineers Standards	21
Number of Secondary Hydropower Dams Deemed "Unsafe" and Requiring Emergency Measures	0

*Lanesboro, Minnesota—seepage; instability.

Source: National Dam Safety Inventory, U.S. Army Corps of Engineers

Comparisons of nuclear power with other technologies appear routinely in the literature but consensus is lacking regarding their significance. The following table from the study by Schurr et al. (Ref. 3.13) provides one comparison:

Table 3-4

Estimated Total Fatalities for Worker and General Public From Electricity-Generating Technologies, Per Effective Plant-Year

Coal-Fired Plants		Nuclear	
Air Pollution	0.8	Routine radiation	0.001-0.005
General Safety	0.5-1.0	Gaseous wastes	0.07-0.3
Occupational Safety	0.3-5	Reactor accidents	0.0002-0.3
		Occupational	0.1-0.4
Total	0.8-14	Total	0.2-3.0

Analysis of air pollution impacts associated with coal-fired power plants (See Sec. D, Appendices) indicates that conformance with the National Ambient Air Quality Standards (NAAQS) for sulfur dioxide (SO_2), particulate matter (PM), and oxides of nitrogen (NO_x), and with national emission standards for coal-fired plants (New Source Performance Standards, or NSPS), considerably mitigates the air pollution impacts from these three pollutants. NSPS effectively require new coal-fired plants to eliminate at least the following percentages of their uncontrolled emissions at their source: SO_2 ($\geq$ 90 percent); PM ($\geq$ 99 percent); NO_x ($\geq$ 75 percent). Further reductions may be required on a site specific basis to comply with NAAQS, or with regulations to prevent significant deterioration of air quality.

Control technologies to meet the NSPS and NAAQS are generally available, although their cost effectiveness is often disputed, especially for removing SO_2 and fine particulates. The use of low sulfur coal and/or SO_2 scrubbers will generally mitigate SO_2 impacts, which have been the major concern due to their contribution to acid rain and visibility reduction. Even in Wyoming, which

adopted SO_2 emission standards tougher than NSPS (0.2 vs 1.2 lbs $SO_2/10^6$ Btu), combination of low sulfur coal and scrubbers reduces coal-fired power plant emissions well below NSPS. Only if other states adopt similar standards and low sulfur coal is unavailable, could such regulatory standards restrict plant construction, forcing consideration of alternative energy sources.

Impacts from fine particulates resulting from the operation of coal-fired power plants include both direct emissions and "secondary particulates" formed by conversion of gaseous SO_2 and NO_x emissions into sulfate (SO_4) and nitrate (NO_3) particles.

These emissions are widely dispersed due to their high plume rise and slow conversion to secondary particulates. Regional impacts include reduced visibility and "acid rains" usually at a great downwind distance from the power plants. Substitution of new hydropower facilities for proposed new coal-fired power plants would not effectively mitigate these impacts unless it occurred on a scale not likely in most regions of the United States. Such substitution would not significantly affect existing power plant emissions which contribute heavily to present regional impacts.

Accordingly, the substitution of hydropower for coal-fired power plants to mitigate SO_2, PM or NO_x impacts cannot be considered as a compelling decision factor in considering expansion of hydropower capacity unless site-specific conditions limit the use of coal-fired power plants (e.g., to protect pristine areas). However, emissions of another air pollutant—carbon dioxide—from fossil fueled power plants presents potential environmental impacts which warrant further consideration of hydropower substitution.

The CO_2 Issue

Carbon dioxide (CO_2) levels are steadily increasing in the global atmosphere, apparently in close correlation with increasing rates of fossil fuel combustion. Since pre-industrial times atmospheric CO_2 has increased 15 to 25 percent; the current annual increase is 0.7 percent. This threatens to warm

the earth's atmosphere, with potentially catastrophic environmental and socio-economic impacts, including: (1) disruption of agriculture over large regions of the globe due to altered rainfall patterns and other climate factors, and insect pest outbreaks; and (2) coastal flooding, due to melting of polar ice which raises mean sea levels.

There is great uncertainty about whether these impacts will actually occur, and about their timing and magnitude. This is due to inadequate knowledge of the earth's basic adaptive mechanisms—e.g., the earth's capacity to absorb excess CO_2 into its oceans, or through increased plant photosynthesis.

In order to help promote the unprecedented degree of international cooperation necessary to address this global problem, the Council on Environmental Quality (CEQ) recommends that the United States government:

- Give high priority to addressing the CO_2 problem in all national energy policy planning efforts; and

- Make every reasonable effort to increase reliance on energy conservation and renewable sources of energy (like hydropower) in this country, and abroad, through expanded international efforts to address CO_2 issues (Ref. 3.14).

The CEQ report examined three scanrios, which limited ultimate atmospheric CO_2 levels to no more than 1.5, 2.0, 3.0 times the pre-industrial CO_2 concentrations. This range would require the present 2.5 percent annual growth in fossil fuel use to be reduced to zero growth within 35 to 95 years, followed by continuing decline in fossil fuel use. Allowing global CO_2 levels to double or triple could result in potentially disatrous levels of climate modification, according to best available climate models.

The CO_2 problem is global in nature and cannot be considered for the United States in isolation. The extent of hydropower development considered in this study (75,000 MW maximum) is small compared to the total United States and world generating capacity from fossil fuels. Accordingly, substitution of hydropower for fossil fueled power plants at the level of development considered here is unlikely to alter the CO_2 level on a global scale.

3.4.3 Fish Survival

Description

The construction of new and retrofitting of existing dams can have considerable impact on anadromous fisheries. Anadromous fish spawn in fresh water but live their adult years in the ocean. Dams inhibit fish passage both to and from spawning grounds and can destroy the spawning grounds themselves through impoundment. Currently, the only important anadromous fisheries are located where much of the nation's potential hydropower exists: the Pacific Northwest, Northern California and Alaska. Once flourishing fish populations in New England have been destroyed by dam construction and industrial pollution.

It is the policy of the U.S. Fish and Wildlife Service to restore the Northeast's anadromous fishing industry. Preservation and enhancement of Pacific fisheries is a continuing policy of both federal and state agencies. Restoration of lost runs and preservation or enhancement of existing anadromous fish populations require different measures. The effects of further elimination of these species must also be considered.

Analysis

The impacts of various hydropower development configurations can differ considerably. While at one site a dam may endanger anadromous species, another may enhance fish survival by controlling natural fluctuations in water level. Turbines are associated with high fish kills, although shutdowns of this equipment do not necessarily increase fish levels (Ref. 3.15). The decline in fish populations

on dammed rivers may be a result of dams as well as other factors, such as decrease in food supply. Certainly, the relative merits of hydropower development versus fisheries protection must be carefully assessed. The construction of fish ladders increases the cost of a project by about 10 to 15 percent. The total range of costs associated with the destruction of an entire anadromous fishery is difficult to calculate. It has been estimated, for example, that the total catch in the Columbia River System in 1979 totaled about $130 million. But this total figure does not begin to reflect fully the economic hardship which would result in small Northwest communities heavily dependent upon the fishing industry.

Quantifying the value of sport fishing is also difficult. While total estimates of anadromous fish runs exist, estimates of total ocean and sport catches are somewhat speculative. Some estimates indicate that the dollar value of sport fishing is at least equal to, if not greater than, commercial activity. In any case, sport fishermen have organized a powerful lobby whose interests must be addressed in any program to extend hydropower development. An example of this clout was described in a recent issue of the Portland, Oregon, Willamette Week regarding a private hydropower development on the Willamette River:

> Led by the fishing delegation, the committee (a citizen's advisory board) nearly voted to end the project. The decision to build was never considered. The end result was a Final Report recommending that fish protection measures be even more strongly worded. In the end, the developer cancelled the project.
>
> Willamette Week, 2/16-23/81

According to the North Pacific Division of the Corps, the estimated cost of a new fish ladder at Oregon's Bonneville Dam is $70 million in 1980 dollars. The annual salmon catch on the Columbia River alone, valued at $7 to $10 million, would pay for the ladder in ten years.

However, the costs of installing fish ladders or trucking fish around dams generally increases as dam sites are located further up tributaries. In addition, maintenance of streamflows to facilitate the movement of juvenile fish downstream also may add to costs as sequential release of water negates a major advantage of hydropower in peak periods. Mitigation is a particular problem at small-scale sites where its costs are high while revenues for the power generated is modest.

According to one respondent:

> The issue is not so clear when you have private companies especially in retrofitting. There, if no fish ladder was originally installed on a dam, the federal government will rectify that to take any necessary steps to improve the environment. How can a private company justify those costs? How can the public demand that it incur them?
>
> (A Staffer from National Conference of State Legislatures)

The cost of mitigation is an especially important issue in the Northeast. As previously indicated, while the federal government has a policy to restore anadromous fish populations, it has not specified who is to pay for the installation of fish ladders. Since private developers (by far the majority of potential developers in the Northeast are private) are not compensated, the requirement to install fish ladders at restored sites as a means of restoring the fishery inhibits hydropower development. New sites already are required to construct such ladders.

> Many projects won't get developed because of those constraints. (The) Fish and Wildlife Service demands fish ladders that cost more than the dam. Like where a dam has been in place for 50 years and someone wants to install a turbine-well, those fish have gotten through the dam for 50 years, why should it be the developer's problem? Or if it is a problem why shouldn't fishermen pay for the project?

(A Federal Regulatory Official)

We need a more careful weighting of these things. Like Fish and Wildlife with its insistance that existing dams be fitted with fish ladders. That just can't be feasibly done. They don't offer to negotiate, or look at anyone else's point of view...We need a better perspective on the worth of energy and the consequences of various kinds of development.

(A Consultant)

Other development constraints may arise from Indian treaty rights as discussed in Section 3.2.2. Mitigation is expensive whether it is the high capital costs of constructing fish ladders, or operational costs associated with trucking or streamflow maintenance. This indicates the need to assess carefully the benefits provided by the fishery versus the costs and benefits associated with the dam. These costs will increase substantially as more and more small-scale units are added to the system. The cost of mitigation and the damage to the fishery must inevitably grow in proportion to the number of projects on a given waterway.

Further, even if a reliable cost-benefit analysis indicates the desirability of constructing a dam, opposition by environmentalists and sport and commercial fishing interests could result in protracted litigation. Finally, the elimination of anadromous fisheries would result in severe impacts upon commercial and sport fishermen, canners, tourism, and Indian tribes dependent upon the fishery for their livelihood. It is possible that some of these effects can be ameliorated by transplanting non-anadromous fish species; however, such an effort would be costly and require the development of new markets, the adaption of equipment and techniques and the achievement of unprecedented attitudinal changes by the affected parties.

With regard to these adverse impacts, one respondent reports:

> Tourism ranks second only in agriculture as a source of revenue in Idaho. It's bigger than lumber. And that tourism is largely dependent on anadromous fish. That's just Idaho—we're particulary subject to the damage of dam passage because we're so far inland. But fish come here all the way from the mouth of the Columbia—if they haven't been destroyed by dam and river hazards, overfishing, mechanical injury, or delayed migration.
>
> (A State Fish and Wildlife Staffer)

In any case, unless adequate mitigation is calculated as a front-end cost of new projects at undeveloped sites before the decision is made to proceed, the burden of new dam construction will fall disproportionately on the fishing industry.

3.5 Concluding Comment

In this chapter we have raised a series of issues of concern in further hydropower development. The importance of most issues depends on the level of development, at least in non-emergency situations. Thus a high level will require consideration of nearly all issues mentioned, whereas a modest level will only involve some of them.

In the next chapter we shall posit three levels of development and embed them in scenarios. We are then in a position to draw in the relevant issues from this chapter and develop strategies to deal with them (See Figure 1-3).

REFERENCES

3.1 Institute for Water Resources, U.S. Army Corps of Engineers. Policy Issues in Hydropower Development. Ft. Belvoir, VA, February 1981.

3.2 D.A. Deese and J.S. Nye. Energy and Security. Cambridge, MA, Ballinger Books, 1981.

3.3 Energy Law Institute. Legal and Institutional Aspects of a National Hydropower Expansion Program, (Draft Report). Concord, NH, October 1980.

3.4 United States Department of Interior, Water and Power Resources Service. Report on Assessment of Small Hydroelectric Development at Existing Facilities. July 1980.

3.5 United States Department of Energy, Assistant Secretary for Policy and Evaluation. Reducing U.S. Oil Vulnerability: Energy Policy for the 1980's. November 1980.

3.6 INTASA Inc., in association with EDAW, Inc. and Sverdrup & Parcel and Associates Inc. National Hydropower Study Environmental Assessment, Draft Final Report. January 27, 1981.

3.7 J. McPhee. "Minihydro." New Yorker, February 23, 1981.

3.8 Washington Star. May 25, 1981, p. C-7.

3.9 U.S. Water Resources Council. The Nation's Water Resources: 1975-2000, Second National Water Assessment, Volume 2. December 1978.

3.10 J.L. Simon. "Resources, Population, Environment: An Oversupply of False Bad News." Science, June 27, 1980, Volume 208, p. 1431.

3.11 L.C. White. The Right to Federally Generated Power, An Analysis of the Preference Clause. American Public Power Association, June 11, 1979.

3.12 Y. Levy. Federal Reserve Bank of San Francisco Economic Review. January 1980.

3.13 S. Schurr. Energy in America's Future. The Johns Hopkins Press, 1979, p. 367.

3.14 J.H. Krieger. "Scientists Grapple with CO_2 Problem." C & EN, January 26, 1981.

3.15 M. Bell. Fisheries Handbook of Engineering Requirements and Biological Criteria. Army Corps of Engineers, North Pacific Division, February 1973.

FOOTNOTES

1. For the purposes of analysis in this technology assessment, the nine Regional Electric Reliability Councils (plus Alaska and Hawai) which comprise the National Electric Reliability Council (NERC) have been used. See Figure A-1 in Section A of the Appendices for a map depicting the Regional Electric Reliability Council areas.

2. The first large-scale, multipurpose project was actually the Bureau of Reclamation's Hoover Dam, authorized by the Boulder Canyon Act in 1928. But the majority of the era's major projects were implemented by the Roosevelt administration (Tennessee Valley Authority Act of 1933, Bonneville Project Act of 1937, Fort Peck Project Act, etc.) For further discussion, see Section B-2 of the Appendices.

3. For example, considerable development responsibility in the Columbia River basin was returned to nonfederal entities under Eisenhower policies in the 1950's, resulting in main stem nonfederal projects such as Priest Rapids (Grant County PUD), Rocky Reach (Chelan County PUD), and Wanapum (Grant County PUD), all in Washington State. These smaller "primary purpose" hydropower projects did not necessarily maximize available hydropower potential at their respective locations.

4. The reader is referred to the Environmental Legislation part of Sec. B-2 of the Appendices of this report. Only the President has power to waive certain environmental limitations, i.e., project authorizations in wilderness areas. Legislation encouraging nonfederal development (PURPA, et al.) specifically declares that no provisions of environmental legislation may be exempted or waived. See, e.g. PURPA Title IV, Section 405 (b). The Tellico Dam controversy, which resulted in an exemption for the project from the requirements of the Endangered Species Act, was a narrowly prescribed instance which could not have occurred had the dam not already been substantially complete.

5. Public Utility Regulatory Policies Act of 1978 (PURPA); Crude Oil Windfall Profits Tax Act of 1980; Energy Security Act of 1980. See Section B-2 of the Appendices.

6. Ibid. Current federal policy favors indirect incentives more than direct subsidies. Funds authorized by Congress in Title IV of PURPA for project construction loans were held up by the Office of Management and Budget on the grounds that development would proceed without the funds. Title IV's loan program for studies and license applications has proceeded, though it was suspended for 45 days earlier this year (February, 1981) at OMB's request for similar reasons. Federal tax and investment incentives have remained crucial to nonfederal development and financing arrangements, however.

7. The Principles, Standards, and Procedures of the Water Resources Council govern all federal water projects. Recent amendments (1979) require federal projects to be evaluated in terms of their contribution to national economic development and environmental quality. All projects must be compared with alternative ways of achieving the same objective, including at least one "non-structural" alternative (i.e. achieving the same goal through conservation, management, pricing, or other non-engineering means). With respect to nonfederal developers, FERC is charged with ensuring they meet the same environmental standards as their federal counterparts. Nonfederal economic data is, however, accepted by FERC as valid. See Section B-2 of the Appendices to this report.

8. The Pacific Northwest Electric Power Planning and Conservation Act of 1980 (PL 96-501) elevates fish and wildlife protection to coequal satus with power generation in the Columbia River system of the Pacific Northwest. Representative Dingell, in his section-by-section analysis of the bill on the floor of the House stated, "...It is clearly intended that no longer will fish and wildlife be given a secondary status by the Bonneville Power Administration (BPA) or other federal agencies." 126 Cong. Rec. H 10681 (November 17, 1980)

9. "Monopsony" in economic theory is a 'natural' regulated monopoly characterized by the domination of the market by a single large purchaser.

CHAPTER IV

Alternative Levels of Hydropower Development

4.1 Introduction

This chapter describes three levels of hydropower development (denoted I, II, and III). They encompass a range of alternatives deemed reasonable for the technology assessment. We begin with a discussion of the overall future context, and general considerations and constraints affecting hydropower development. Next we provide an outline of the three alternative levels of hydropower development, followed by a discussion of the process to conduct the assessment of alternative levels. For each development level and its setting, the relevant issues, impacts, and action options are presented. Finally, we provide a comparison of three levels.

4.1.1 Considerations Affecting Overall Future Contexts

The United States continues to grow. Population is expected to expand from 228 million in 1980 to 260 million in 2000 to 290 to 325 million in 2025. The expectations of most of this population also continue to rise, thus compounding material and energy growth demands. On the other hand, most of our present basic resources as well as land area, are available in limited quantity in this country. Foreign resources must face the tremendous pressure of a world population growth from 4.4 billion in 1980 to 6 billion in 2000 and 10 billion in 2020. Most of this growth is occurring in the Third World, raising the proportion of poor from 70 percent to 80 percent of the world's population in just 20 years.

Before looking ahead, let us note that the United States in 1980 is significantly different from the United States in 1960. Accelerating economic growth has given way to slowing growth, the assumption of unlimited resources to an acute awareness of constraints, a widespread mood of undue optimism to one of excessive pessimism. Inflation, unemployment, disillusionment with the federal government's competence and with social institutions (e.g., criminal

justice system, schools) have become far more pronounced. Dissatisfaction is reflected in the fractionalization of the society with single issue groupings and an ever-increasing resort to litigation—the "lawyerization" of American society. Entitlements and rights have become of far greater concern to the individual than his or her responsibilities, and there appears to be little willingness to sacrifice for the long-term benefit of the society (e.g., in contrast to the Japanese). Such an attitude in turn makes the solution of resource problems for the United States far more difficult than it needs to be. It translates into long delays in implementation of any development levels and more power to divisive vested interests.

This country remains the richest in the history of the world, with impressive physical and unmatched intellectual resources. Further, if the past 200 years offer any guide, we may expect another surge of technological innovation before 2000 (Ref. 4.1). Thus the United States is in a better position to deal with problems—including energy—than any other country if—and it is a big if—it has the will and drive, as a society, to "grasp the nettle".

Since this assessment looks to the future, we must recognize at the outset that forecasts are hampered by at least three basic considerations:

- Unexpected or low probability events with major impacts will occur as they have throughout history.

- Some high probability events forecast to have small impacts will, when they occur, have unexpectedly serious impacts.

- When a complex system moves from one stable state through an unstable transition to a new stable state, it is inherently unpredictable.

Even with a far more profound understanding of our social system, these considerations would apply. We mention this not as an argument against long-range planning, but rather as a recognition of the limitations of "most likely" predictions. Indeed, it would be surprising to face no surprises. Hence this study includes one case involving a major unexpected event.

A few certainties for the coming 20 years under any scenario:

- The continuing aging of the United States population;

- The continuing rapid evolution of information technology (processing and transmission);

- The instability created by the widening gap between the United States and resource-barren poor nations;

- The growing competition for resources among the wealthier and industrializing nations; and

- Lack of consensus about the "best" use of this nation's natural resources.

4.1.2 General Considerations Underlying the Formulation of Alternative Levels of Hydropower Development

Some basic considerations and constraints applicable to hydropower will be helpful in understanding the three development levels.

- The Western region of the United States and Alaska have the largest hydropower potential. However, most of Alaska's potential is comprised of undeveloped sites remote from that state's load centers and far beyond current and foreseeable Alaska loads.[1] We have not included Alaska potential in our estimates for Levels I, II, and III because distance makes transmission to the "lower 48" infeasible without major technological advances.

- The large physical hydropower potential of the contiguous United States is significantly reduced by economic, environmental and social constraints. According to the Corps' report for the WSCC region (Ref. 4.2):

Through analysis of these (15,560 sites) initially inventoried projects, it was found that for the region as a whole 2,212 projects have an estimated power potential of 1 MW or more, while only 897 are potentially economically feasible, based on estimated total project costs. Analyses to date of potential non-economic constraints to the development of potentially economically feasible projects indicate that 619 projects are suitable for further study by reason of not having severe environmental, social, or other limitations.

The total estimated capacity of the 2,212 sites is 108,743 MW; the estimated energy is 221,211 GWh. For the 619 sites, the comparable totals are 31,574 MW and 74,234 GWh.

- The nation's existing hydropower system (about 1,300 plants) seems to operate efficiently, so that only a modestly increased energy output (11 percent, or about 30,000 GWh) can be achieved at existing hydropower plants.

- The Western Systems Coordinating Council (WSCC), Northeast Power Coordinating Council (NPCC), and Southeastern Electric Reliability Council (SERC) regions contain 88 percent of the estimated achievable annual energy increase.

- Historically, the annual rate at which hydropower is brought on line has been quite modest, about 1,900 MW (including pumped storage) per year during the 1970's.

- Only about 8,600 MW of conventional hydropower are expected to come on line through 1989, about 4,000 MW of which will be new construction (undeveloped sites), per reports from regional electric reliability councils.

- Water availability, from both physical and legal points of view, is a key to future hydropower development. Competition for available water supplies is expected to increase greatly. Further complicating this is the uncertainty associated with hydrologic cycles.

- In the large number of interviews conducted during this assessment, widespread opposition toward major dam and reservoir construction was revealed. That attitude may continue. High levels of new development are likely to run directly into that opposition centered around water rights, land use, environmental impacts (particularly on fish), economic and social arguments.

- High levels of hydropower development depend, to a large extent, on relationships between federal and nonfederal sectors. It is crucial that they work well together and create compatible, effective arrangements for joint participation in planning, design, construction, operation and funding.

- Cost factors are of great importance to hydropower development, particularly the cost of hydropower compared with the cost of other energy sources. Hydropower projects are capital-intensive with low operating costs, while thermal projects generally have moderate capital costs and high operating costs, due primarily to the cost of fuel. While there is greater uncertainty about the future operating costs of thermal plants, the increasingly significant economic and social opportunity costs of water for hydropower cannot be ignored. Doubts about future capital costs affect hydropower and thermal plants equally.

- Pumped-storage could play a much larger role in the future. Although that potential is recognized, it is not addressed fully in this technology assessment, but is briefly discussed in Section A of the Appendices.

4.1.3 Outline of Three Levels of Hydropower Development

There is no special significance about the three capacity levels we are postulating as alternatives: 25,000, 45,000, and 75,000 MW. They represent a range of hydropower development that was reasonable and useful for this analysis. The three levels are summarized in Table 4-1 and Figure 4-1.

TABLE 4-1

ALTERNATIVE DEVELOPMENT PLANS

	On Line by 1990					On Line Between 1990 to 2000				
		< 30 MW		≥ 30 MW			< 30 MW		≥ 30 MW	
	TOTAL	Fed.	Non-Fed.	Fed.	Non-Fed.	TOTAL	Fed.	Non Fed.	Fed.	Non-Fed.
LEVEL I - 25,000 MW										
Existing Projects w & w/o hydropower	5,000	500	1,000	2,000	1,500	12,000	1,000	1,000	5,000	5,000
Undeveloped sites	5,000	500	500	2,500	1,500	3,000	500	1,000	1,000	500
TOTAL	10,000					15,000				
LEVEL II - 45,000 MW										
Existing Projects w & w/o hydropower	5,000	500	1,000	2,000	1,500	20,000	1,000	1,000	8,500	9,500
Undeveloped sites	5,000	500	500	2,500	1,500	15,000	500	2,000	6,000	6,500
TOTAL	10,000					35,000				
LEVEL III - 75,000 MW										
Existing Projects w & w/o hydropower	10,000	1,000	1,000	4,500	3,500	15,000	2,000	1,000	9,000	3,000
Undeveloped sites	5,000	500	500	2,500	1,500	45,000	3,500	1,000	32,500	8,000
TOTAL	15,000					60,000				

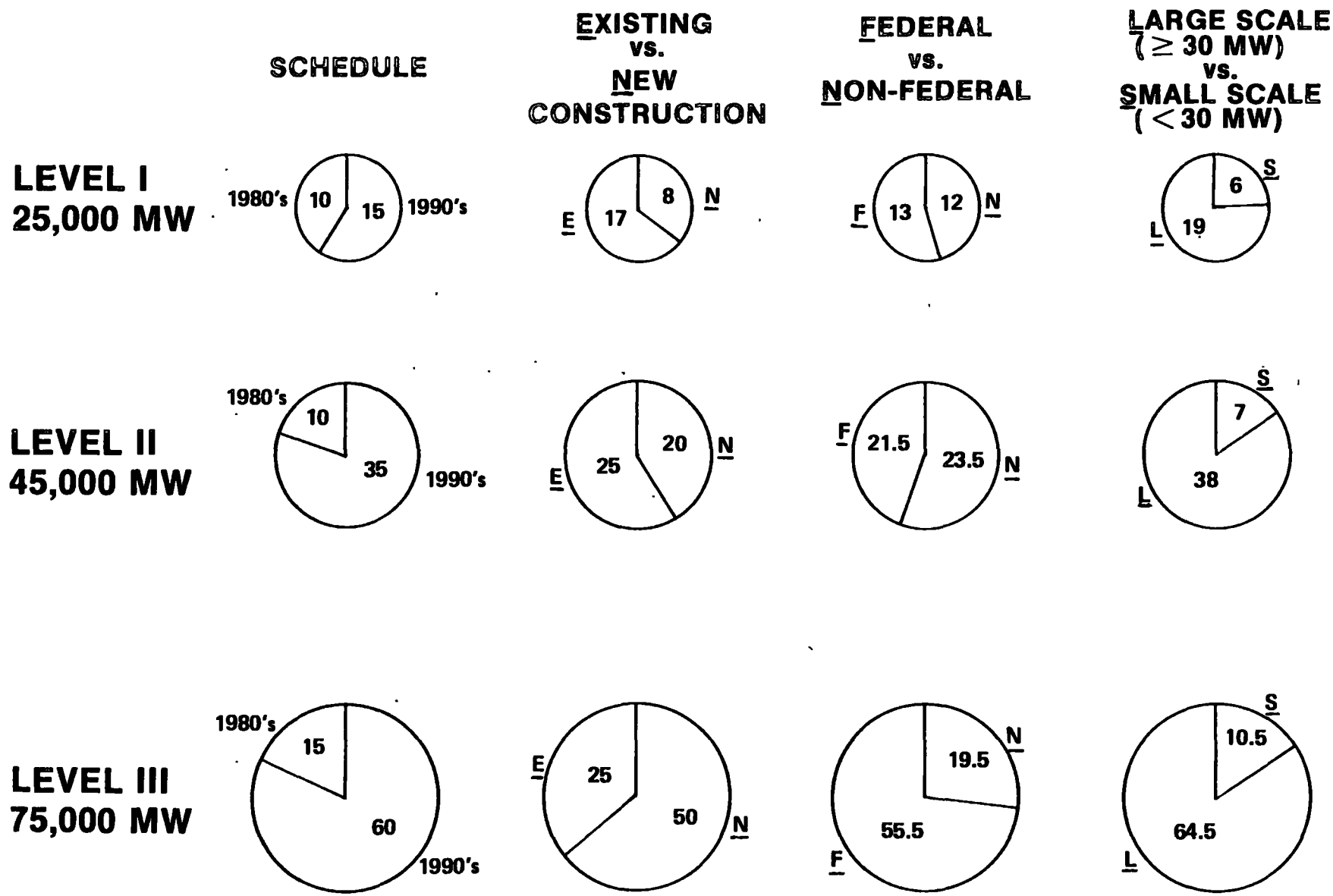


Figure 4-1.

BASIC CHARACTERISTICS OF ALTERNATIVE LEVELS OF HYDROPOWER DEVELOPMENT

(Numbers in circles = Gigawatts)

The three alternatives range from a relatively modest level of development (I) to a relatively high level (III), inevitably involving distinct departures from historic trends. The future is not simply an extrapolation of the past; it is essential to ask "what-if" questions rather than seek a "best" forecast or "desirable" goal. The three alternatives are thus mutually exclusive and not pieces of a single plan. They illustrate diverse situations which today's decision-maker must consider in preparing for the next 20 years.

Questions may arise regarding the validity of some of the numbers in Table 4-1 and Figure 4-1. The numbers used for the current decade are well-founded expectations based on projects in various stages of development. The minimum of 10,000 MW for additions in the 1980's is higher than that generally anticipated to come on line in that period, thereby allowing some flexibility in apportioning the total among the categories.

Throughout the formulation of the alternative levels, considerable use was made of several key sources of data and information,[2] not so much for the absolute numbers as for the relationships or ratios which could be derived and used to detail the following categories: large-scale/small-scale, 1980's/1990's, existing/undeveloped and federal/nonfederal (Figure 4-1).

With respect to the Corps' selection process of potential sites to be recommended for further study, the assessment team recognized the incomplete and dynamic nature of the data. For example, in response to public comments the earlier estimate of viable capacity total has dropped from the 70,000+ MW level to the mid-50,000 MW level. Although such a change is important, it was not crucial for this assessment since the three levels were selected to explore "what if..." kinds of analyses. Thus, it is sufficient to know that there are at least 75,000 MW of physical, and reasonably viable, potential existing within the United States.

Further, allocations of the total capacity for each level to the various categories (such as federal/nonfederal development) do not constitute a prediction but rather a reasonable estimate. Some of the key assumptions considered when determining the potential capacity development for each alternative level were:

- 10,000 MW on line by 1990, with a maximum of 5,000 MW at undeveloped sites, is possible.

- The viable potential capacity at existing water resource projects will be limited to 25,000 MW.

- The potential small-scale development (equal to or less than 30 MW) could be at most 11,000 MW by 2000.

- In keeping with the societal underpinnings for Level III, the ratio of federal to nonfederal development in Level III is assumed to be 75/25.

4.2 Assessment of Three Levels of Hydropower Development: The Process

Issues bearing on the development of hydropower were analyzed in Chapter III. As we move here to the discussion of specific levels of development, some of these issues take on increased significance, others become marginally relevant, and yet others cannot be examined adequately without site-specific details.

Hydropower development produces impacts on several key areas such as economics, technology, the environment, and institutions. The impacts often occur independent of particular issues but govern their resolution. Thus, we examine the impacts of the three levels of development in terms of these key areas. The identification and specification of impacts has by necessity been qualitative, since the focus of this assessment is at the national level. The impacts of each level of hydropower development were examined by asking and answering questions in various categories as shown in Table 4-2.

4.3 Assessment of Level I Development

We now describe Level I hydropower development and associated setting, and discuss its implications.

Table 4-2

Categories of Impacts Considered in the Assessment

Technological	• How will the postulated level of hydropower additions affect the development of: (a) hydropower technology; and (b) competing/alternative technologies?
Institutional/Legal	• What will be the implications of each level of hydropower development on: (a) Indian tribes, (b) public and privately-owned utilities; (c) regional power marketing agencies; (d) federal agencies, particularly the Corps of Engineers, FERC, and other agencies located in the Departments of Interior and Energy; (e) state agencies such as energy facility siting councils; (f) the judiciary process, for example litigations arising from issues such as water rights; and, (g) Congress, particularly the need for enactment of any new legislation for hydropower development. In addition, certain impacts interact to produce cumulative impacts. • What changes in the institutional/legal framework governing hydropower development are necessary in order to reduce long lead times which delay bringing power on line? Long lead times can result from certain impacts including economic (e.g., labor/skills requirements), environmental (e.g., compliance with laws, possibility of litigation), and institutional (e.g., impacts on Indian tribes).
Economic	• What will be the requirements for: (a) capital, (b) labor/skills, (c) equipment/materials, and (d) land? • Will the price of electricity be impacted and if so, how? • What will be the impact on regional and local development, particularly in regard to the changes in local economy, community structures and services, and fisheries as an economic unit? • What will be the implications for recreational resources (e.g., water-based recreational opportunities)?

Table 4-2 (Con't)

Energy	• Will the contribution of each level of hydropower development be significant in terms of both energy and capacity needs at the national level?
Environmental	• At which development levels can the regulatory delays imposed by environmental laws be reduced through methods short of altering the laws themselves? • How can the costs and benefits of environmental protection be better allocated so both developer and public equitably share the benefits and the burdens at each projected level of development?

4.3.1 Description of Level I

Level I development is characterized by a marked interest in hydropower, but without any major initiatives; things proceed by and large as they have during the past several decades. Hydropower related efforts consist of relatively minor adjustments in the existing framework of legislation, regulations, institutional arrangements and techno-economic structures.

The result is about 25,000 MW of additional installed capacity (conventional hydropower only) on line by the year 2000 (See Table 4-3), as compared with 63,000 MW in 1979. As mentioned earlier, pumped storage is not addressed in this assessment.

Level I development results from hydropower projects already under way as well as the hydropower potential which can be most readily and economically developed. About two-thirds of capacity additions are at existing developments where expansion and retrofitting are deemed feasible. Most of the development occurs in the WSCC, NPCC, ECAR and SERC regions. Other less significant measures utilized for capturing the available energy include rehabilitating or replacing existing units, modifying water handling facilities, and altering existing operating policies (e.g., reallocation of existing storage and/or change of annual and seasonal operation rule curves) (Ref. 4.3). The remaining one-third of additional capacity is added at undeveloped sites, about 60 percent of which is expected to occur by 1990. Most new development occurs in the WSCC region (primarily the Pacific Northwest portion) with the remainder largely in the SWPP, NPCC and SERC regions.

Small-scale development (up to 30 MW) totals 6,000 MW, or one-quarter of the total, and is predominantly nonfederal. With a 10,000 MW addition on line by 1990 and a slight increase in the 20/80 small-scale/large-scale ratio, we assume 2,500 MW of small-scale hydropower added by 1990 (Ref. 4.4). The remaining 3,500 MW are added subsequently. Large-scale development totals 19,000 MW and is more federally oriented. New site construction declines in the 1990's as a result of constraints on federal policy decisions in the 1980's. Overall, federal and nonfederal development are essentially balanced.

Table 4-3

Characteristics of Alternative Levels of Hydropower Development

(Additional Capacity in Megawatts)

Time	1980-1990			1990-2000			Total in 2000		
Level of Development	I	II	III	I	II	III	I	II	III
SCHEDULE									
Total	10,000	10,000	15,000	15,000	35,000	60,000	25,000	45,000	75,000
EXISTING VS. NEW FACILITIES									
Existing	5,000	5,000	10,000	12,000	20,000	15,000	17,000	25,000	25,000
New	5,000	5,000	5,000	3,000	15,000	45,000	8,000	20,000	50,000
FEDERAL VS. NON-FEDERAL									
Federal	5,500	5,500	8,500	7,500	16,000	47,000	13,000	21,500	55,500
Non-Federal	4,500	4,500	6,500	7,500	19,000	13,000	12,000	23,500	19,500
LARGE-SCALE VS. SMALL-SCALE									
Large-Scale	7,500	7,500	12,000	11,500	30,500	52,500	19,000	38,000	64,500
Small-Scale	2,500	2,500	3,000	3,500	4,500	7,500	6,000	7,000	10,500

4.3.2 Societal Setting

Hydropower development is affected by the societal setting in which it occurs. Thus, it is necessary to describe some of the major societal assumptions on which Level I development is implicitly based.

We assume that the socio-political mechanisms which serve to balance the interests of the competing groups comprising United States society are maintained. Despite changes in administration, basic trends continue: selective prosperity (i.e., booming and depressed sectors), peace, absence of strong societal cohesion, lack of enthusiasm for making significant sacrifices in quality of life for future gains (Ref. 4.5), deficit spending, inflation, some energy conservation motivated by market mechanisms (i.e., price increases), continued big government but no national energy program ("fragmented centralization"). There is general disillusionment with government's ability to solve problems.

The "lawyerization" of society continues and tends to inhibit experimentation and bold leadership. Nevertheless, the country "muddles through" without severe depressions and, with the world's most powerful military and economic engines (but not the highest GNP per capita), it remains very rich. The refrain "continuation of the trend" runs through the scenario, and it could be alternatively labeled "surprise-free".

4.3.3 Relevant Issues

As mentioned, the development of 25,000 MW additional capacity can be achieved with only minor adjustments in the existing framework of legislation, regulations, institutional arrangements and techno-economic structures. To further determine and focus these adjustments, we first examine the issues of particular relevance to Level I.

Figure 4-2 suggests the relevance of the issues discussed in Chapter III for Level I. We find that most issues seem marginally relevant for Level I.

Issue	Total: 25,000MW Federal: 13,000MW Non-Federal: 12,000MW Small-Scale: 6,000MW Large-Scale: 9,000MW
GENERAL	
3.1.1 Hydropower as a Contribution to National Energy Needs	○
3.1.2 Development Strategies	○
ORGANIZATIONAL AND INSTITUTIONAL	
3.2.1 Institutional Framework	○
3.2.2 Indian Rights	○
3.2.3 Water Rights	●
3.2.4 Non-Federal Development at Federal Dams	●
ECONOMIC	
3.3.1 Small-Scale Hydropower	●
3.3.2 Competing Water Uses	✖
3.3.3 Competing Land Uses	○
3.3.4 Pricing of Hydropower from Federal Projects	✖
3.3.5 Capital Formation	●
ENVIRONMENTAL	
3.4.1 Environmental Impacts	✖
3.4.2 Health and Safety	✖
3.4.3 Fish Survival	✖

Legend:

● - Highly relevant; ○ - Marginally relevant; ✖ - Relevant but resolution dependent upon site specifics

Figure 4-2
Relevant Issues for Level I Development

In terms of general issues, because Level I's contribution to the nation's energy supply is small even under optimistic assumptions, the entire additional capacity operates at a plant factor of 0.5. However, in spite of a rather modest contribution, the capacity additions will be helpful because they could displace fossil fuels used for peaking capacity in certain regions (e.g., New England and California). The choice of development strategies also seem marginally relevant, as development occurs under the inertia of current conditions, and no overwhelming changes in technology mixes (i.e., small- vs. large-scale) are postulated.

Two organizational and institutional issues seem quite significant: water rights and nonfederal development at federal dams. Substantial hydropower development by the nonfederal sector underscores the issue of competing uses of water.

Economic issues of significance involve capital formation. Even relatively modest small-scale hydropower development has the problem of marketing the generated energy. The land related issues seem only marginally significant, as the capacity additions in Level I involve largely an expansion and/or modification of existing facilities.

Consideration of the environmental issues requires site-specific information. However, it appears that the issues related to public health and safety and most environmental impacts, such as changes in water quality, should be marginal for the reason cited above—a significant portion of the development postulated in Level I involves existing facilities, with modest development of small-scale plants.

4.3.4 Impacts

The nature of the impacts in hydropower development depends upon the scale of technology (i.e., small vs. large), who develops it (i.e., federal vs. nonfederal), and how capacity additions are brought on line (i.e., expansion of existing facilities, retrofits, new development). Further, site-specific characteristics affect the nature of many of the impacts, particularly the environmental ones. The impact analysis of Level I development is summarized in Figure 4-3; the categories and interpretation of impacts are from Table 4-2.

Impacts	Total: 25,000MW	
	Federal: 13,000MW Large-Scale: 10,500MW Small-Scale: 2,500MW	Non-Federal: 12,000MW Large-Scale: 8,500MW Small-Scale: 3,500MW
A. Technology		
1. Hydropower	L	L
2. Competing/Alternative	L	L
B. Contribution to U.S. Energy Requirements		
1. Energy Needs	L	L
2. Fuel/Capacity Displacement	L	L
C. Economic		
1. Resources		
a. Capital	L-M	L-M
b. Labor/Skills	L	L
c. Equipment/Materials	L	L
d. Land	L	L
2. Electricity Prices	L	L
3. Regional/Local Development	L	L
a. Local Economy	L	L
b. Community Structures and Services	L	L
c. Fisheries	L	L
4. Recreational Resources	L	L
D. Environment		
1. Water		
a. Quality	?	?
b. Use/Supply	?	?
2. Air	L	L
3. Fish	?	?
E. Institutional/Legal		
1. Indian Tribes	?	?
2. Utilities		
a. Public	L-M	L-M
b. Investor-Owned	L-M	L-M
3. Power Marketing Agencies	L	L
4. Federal Agencies		
a. Corps of Engineers	M	L
b. FERC	L	L
c. Other (e.g., DOI, DOE)	L	L
5. State Agencies	L	L
6. Judiciary	L	L

Legend: L - Low level of impact; M - Medium level of impact; H - High level of impact; ? - Uncertain level of impact.

Figure 4-3

Impacts of Level I Development

The overall impacts of Level I, at the national level, are small because most capacity additions result from an expansion of existing facilities. Local and regional impacts could, however, be more significant than those indicated in Figure 4-3.

A summary of the impacts for Level I follows:

- Technology impacts, in terms of development of large-scale conventional hydropower technology and alternative/competing technology, will be low because Level I development requires relatively modest amounts of new development. However, small-scale development in Level I is significant and could provide an important impetus to this technology.

- Contribution to United States Energy Requirements at the national level will be low, considering the rather modest increase in energy expected from the additional capacity in Level I. Impacts at the regional level could be significant, and hydropower capacity could displace peaking capacity saving fossil fuels.

- Economic impacts include the capital required for implementing Level I, and the need for experienced, trained personnel. If one assumes that $1,000 to 2,000/kW will be the construction cost for new plants, capital requirements for adding 25,000 MW capacity amount to $25 to $50 billion over a period of 20 years; most of this investment, however, will be required during the 19902000 period. Such investment requirements are quite modest in comparison to those incurred during the recent past; for example, in 1978, the capital expenditures by electric utilities were estimated at about $36 billion. The expenditures by electric utilities were estimated at about $36 billion. The expectation of a tight fiscal climate, however, may make such investment decisions difficult, especially in the federal sector. Other economic impacts are expected to be low, considering the concentration of Level I

development around existing facilities. However, impacts such as those on local economy (fishing, community services) could turn out to be significant, depending upon the location of new development.

- Institutional and legal imapcts are, on the whole, marginal with some shifts in the roles of the Corps of Engineers, public utilities and investorowned utilities. Construction of 13,000 MW of capacity by the federal sector could increase the work load on the Corps. The role of private utilities could become more important, depending upon what share they have of the additional capacity located in the non-federal sector.

4.3.5 Potential Long-term Impacts

The implementation of Level I as suggested here will produce several potential long-term impacts:

- Total conventional hydropower capacity of about 88,000 MW will be in place by the year 2000.

- The nation will be better positioned for a comprehensive hydropower development program should a major crisis occur in the future.

- Additional water storage facilities could result from Level I development, which will be beneficial in countering future water shortages.

- The image of hydropower as a relatively benign source of energy will be sustained.

4.4 Assessment of Level II Hydropower Development

4.4.1 Description

In Level II, it is postulated that about 45,000 MW of additional installed capacity (conventional) is brought on line by the year 2000 (Table 4-3). The emphasis is on developing the reasonably feasible potential at existing water projects (some are producing hydropower, some are not); that potential (estimated at 25,000 MW) is fully developed in Level II. The remaining postulated capacity (about 20,000 MW) must come from undeveloped sites.

During the 1980's, Level II hydropower development reflects somewhat of a continuation of recent trends with federal development predominating slightly. For the 1990's however, it is assumed that development of the nonfederal sector takes effect more rapidly, tilting the overall balance slightly toward the nonfederal, increasing the share of large-scale development. Using the split of 16/84 for small-scale/large-scale (Ref. 4.4), we obtain 7,000 MW small-scale, located largely in the Northeast and West, and 38,000 large-scale additions, primarily in the Pacific Northwest.

Retrofit and expansion of existing facilities for an additional 25,000 MW and the "gearing up" for this type of effort results in a greatly accelerated program in the early 1990's (20,000 MW for the decade). Similarly, development at new sites shows the effect of increased planning and design efforts in the first decade, with a threefold increase in the 1990's as 15,000 MW come on line. Cooperative federal/nonfederal joint ventures and partnership arrangements become more common and facilitate the addition of 35,000 MW in the 1990's (Table 4-3).

4.4.2 Societal Setting

The societal setting supportive of the hydropower development postulated in Level II is characterized by a return to the drive for high economic growth based on mutual support of industry and government. The lesson of "Japan Inc."

is not lost; work attitudes shift from entitlements to responsibilities, from self-interest to team productivity. There is enough indication of success in the policies of the present conservative administration to encourage a "laissez faire" policy for industry, with federal support of large-scale or long-term risks. The philosophy is one of increasing supplies rather than reducing demands. There is a basis for technological optimism in the 1990's. Just as the post-Depression period (1933 to 1945) saw a cluster of basic technological innovations—radar, television, computers, atomic energy, rockets—so the 1985 to 2000 period experiences a set of vital innovations (Refs. 4.1 and 4.6). Candidates are solar energy systems, bioengineering of marketable products, aquaculture, undersea mining, electric automobiles, and control systems for everyday personal use (e.g., household, office). We note that at least three of these ease energy problems.

Besides favoring strong economic growth, high technology, and capital-intensive development, hard-line military policies succeed in maintaining ample supplies of important resources. The United States is seen as tough; willing to use force to protect its interests—both externally and internally. Energy has high priority for national security. Nuclear energy is pushed most strongly for the immediate future, with research and development on solar and fusion processes also heavily favored. Hydropower is given strong support but not at the same level. Regulations governing hydropower are eased to encourage the private sector. Decentralization is considered a desirable policy wherever it strengthens the private sector and does not impede economic development. Another factor favoring decentralization is security of the nation's energy network against attack. A recent study prepared for the Federal Emergency Management Administration (FEMA) on "Energy Vulnerability and War" strongly urges decentralization of the nation's energy systems. Drawing from the experience of World War II, the report notes that:

> Germany was crippled when its main synthetic fuel and electricity plants were decimated at the end of the war, whereas it would have been impossible to destroy Japan's network of small decentralized hydropower facilities. (Ref. 4.7)

4.4.3 Relevant Issues

The development of 45,000 MW additional capacity assigns special significance to some of the issues discussed in Chapter III. Figure 4-4 delineates the significance of each issue discussed in Chapter III and contrasts distinctly with that of Figure 4-2 for Level I; almost all of the issues appear "significant" now.

A general issue of significance is the set of strategies needed to develop the additional 45,000 MW capacity. Level II will not make a major contribution to United States energy needs, in spite of the fact that hydropower capacity will increase by almost 70 percent over that in 1979 (even under an optimistic assumption that the entire capacity will be developed as baseload units), unless electric energy demand growth is much smaller than currently forecast. The principal advantage of Level II is the likely displacement of relatively more expensive fossil-fueled peaking capacity by hydropower.

Development strategies become meaningful as the share of additional capacity in nonfederal development approaches and somewhat exceeds that in the federal sector. Further, since more than 50 percent of the capacity additions result from the modification and expansion of existing facilities, the issue of development in the nonfederal sctor will become more significant. The proper balance between centralization and decentralization becomes a focal point of the strategy for Level II development.

The institutional framework becomes a significant issue because large-scale development has traditionally been located in the federal sector. However, the nonfederal sector appears to have a more responsive institutional structure in place, as amplified in Chapter III. If the 45,000 MW of additional capacity is developed as centralized, large-scale plants, the issue of Indian rights is likely to become significant, depending upon the siting of such plants. Water rights problems could also constrain the deployment of Level II, especially in light of the fact that a substantial portion (about 77 percent) of the additional capacity is to be constructed during the 1990 to 2000 period.

Issue	Total: 45,000MW Federal: 21,500MW Non-Federal: 23,500MW Small-Scale: 7,000MW Large-Scale: 38,000MW
GENERAL	
3.1.1 Hydropower as a Contribution to National Energy Needs	○
3.1.2 Development Strategies	●
ORGANIZATIONAL AND INSTITUTIONAL	
3.2.1 Institutional Framework	●
3.2.2 Indian Rights	●
3.2.3 Water Rights	●
3.2.4 Non-Federal Development at Federal Dams	●
ECONOMIC	
3.3.1 Small-Scale Hydropower	●
3.3.2 Competing Water Uses	●
3.3.3 Competing Land Uses	●
3.3.4 Pricing of Hydropower from Federal Projects	●
3.3.5 Capital Formation	●
ENVIRONMENTAL	
3.4.1 Environmental Impacts	✖
3.4.2 Health and Safety	✖
3.4.3 Fish Survival	✖

Legend:

● - Highly relevant; ○ - Marginally relevant; ✖ - Relevant but resolution dependent upon site specifics

Figure 4-4
Relevant Issues for Level II Development

Economic issues related to land and water requirements, as well as pricing and capital formation, are of special significance for Level II. The competition surrounding surface water might very well intensify. Similarly, the land requirements to accommodate the new development portion of Level II (about 44 percent of total, or 20,000 MW), especially in the form of large or medium-scale plants, could become substantial. Pressures to reform pricing structures to obtain an appropriate return on public investments could accelerate as the portion proposed to be developed in the federal sector increases substantially. Effective and efficient capital formation will be essential in both federal and nonfederal sectors.

The significance of environmental issues, on the other hand, is difficult to assess without siting the 45,000 MW capacity. However, since about 44 percent of capacity additions result from the expansion and/or modification of existing facilities, environmental impacts will be lower than if the additions resulted entirely from new development. The construction of new capacity could create risks, depending upon their location. Further, the regional implications of new development are important; if, as expected, a substantial portion of the new additions will be located in the WSCC region, changes in water quality and flow conditions resulting from water storage could occur, affecting local ecosystems.

4.4.4 Impacts

Impacts resulting from the capacity and energy produced from Level II development are summarized in Figure 4-5 and discussed below:

- Technology impacts of Level II development will be noticeable for developing small-scale hydropower potential postulated in Level II. Since over one-half of the additional capacity is derived from modification and expansion of existing facilities, there will be little impetus to improve currently used conventional technologies. Similarly, although 45,000 MW is a significant amount of electricity generation capacity, it is not likely to produce pronounced shifts in the competing technologies.

Impacts	Total: 45,000MW	
	Federal: 21,500MW Large-Scale: 19,000MW Small-Scale: 2,500MW	Non-Federal: 23,500MW Large-Scale: 19,000MW Small-Scale: 4,500MW
A. Technology		
1. Hydropower	L	L
2. Competing/Alternative	L	L
B. Contribution to U.S. Energy Requirements		
1. Energy Needs	L	L
2. Fuel/Capacity Displacement	L-M	L-M
C. Economics		
1. Resources		
a. Capital	M-H	M-H
b. Labor/SKills	M	M
c. Equipment/Materials	M-H	M-H
d. Land	M	M
2. Electricity Prices	M	M
3. Regional/Local Development		
a. Local Economy	M	M
b. Community Structures and Services	M	M
c. Fisheries	?	?
4. Recreational Resources	M	M
D. Environment		
1. Water		
a. Quality	?	?
b. Use/Supply	M-H	M-H
2. Air	L	L
3. Fish	?	?
E. Institutional/Legal		
1. Indian Tribes	M	M
2. Utilities		
a. Public	M	M-H
b. Investor-Owned	M	M-H
3. Power Marketing Agcencies	M	M
4. Federal Agencies		
a. Corps of Engineers	M-H	L-M
b. FERC	M-H	M-H
c. Other (e.g., DOI, DOE)	L	L
5. State Agencies	L-M	L-M
6. Judiciary	L	L

Legend: L - Low level of impact; M - Medium level of impact; H - High level of impact; ? - Uncertain level of impact.

Figure 4-5

Impacts of Level II Development

- Economic impacts will result from greatly increased needs for materials and equipment, much of which may have to be imported.[3] On the positive side, as the size of potential markets for such equipment increases, United States manufacturing capacity could expand production and develop concepts such as standardization.

Other economic impacts of significance also include capital, labor, and land requirements as well as changes in electricity prices, fisheries, and local economy brought about by the deployment of 45,000 MW capacity. Capital requirements could amount to $45 to $90 billion over 20 year time period, assuming $1,000 to $2,000/kW capital cost.

It is estimated that construction of a 200 MW hydropower plant requires about 250 people each year over the construction period of about 4 to 5 years. This estimate includes skilled as well as unskilled labor. The construction of 45,000 MW capacity will require about 1,250 people during the 1980 to 1990 period, increasing to about 4,400 workers per year thereafter. Although these requirements appear insignificant in terms of the total United States labor force, it must be recognized that there currently exists a serious shortage of skilled manpower, especially those with experience in hydropower engineering. Further, in the worst case, 4.5 million acres of land will be needed, affecting perhaps 2.8 percent of the land cultivated in the United States. However, it should also be noted that secondary impacts such as gain in recreational areas could also result from Level II development.

Electricity prices could change for at least two reasons. First, the commitment to allocate a substantial capacity to the federal sector could very well be accompanied by pressures to obtain an appropriate rate of return on public investment. If such pressures could bring about a change in application of the preference clause, electricity prices will increase and other impacts will result as discussed in Section 3.3.4. Second, substantial development of large-scale hydropower by the non-

federal sector could force all hydroelectric pricing to a replacement cost basis or the cost of suitable alternative(s), which will also increase electricity prices.

The magnitude of fisheries impacts cannot be estimated without siting the additional capacity, since in some cases the effects could be beneficial and in others detrimental. But the addition of hydropower capacity increases the possibility of significantly impacting the fisheries of the Western United States.

Local economies in the vicinity of the hydropower plants will likely be impacted with the influx of labor population. Such impacts can be beneficial as the tax base of local communities expands. However, such impacts have also been known to be detrimental, because the local economy is burdened with providing essential services for construction on short notice and then faces a drastic cutback when construction ends. Such a phenomenon, labeled as "boom and bust", has been evident in parts of the Western United States, especially the coal regions in Montana, Wyoming and Colorado. Further, the in-migration of a transient labor force also causes community tensions, as evidenced in the communities affected by geothermal development in Northern California, and the communities affected by rapid coal development in some Western States.

- Environmental impacts, particularly on water and fish, could be significant for Level II development; their magnitude depending upon individual site characteristics. If the additional capacity development is supported by the construction of reservoirs, changes in water quality are likely to occur, prevailing standards may be violated, and the fish population diminished.

- Institutional and legal impacts focus on those involving Indian tribes, and a host of institutions. No matter how the additional capacity is developed, it will seriously increase the possibility of interactions and conflicts with Indian tribal rights.

Conflict between public and privately owned utilities could increase, focusing on questions about the appropriate rate for electricity produced by federal projects on the one hand, and the fees to be charged for the nonfederal projects benefiting from the federal dams on the other. The rate-making process of public utility commissions will face increased scrutiny by public interest groups as well as by the utilities themselves. The fuel displacement role performed by hydropower in Level II would not necessarily mean cheaper electricity; on the contrary, if replacement cost is used as a criterion, the price of electricity produced from additional hydropower plants may very well increase.

Although the impacts on each institution will be noticeable, it is the systemic nature of the impacts which will affect the implementation of Level II. The horizontal and vertical interagency conflicts which currently exist could be heightened and could create significant delays in the licensing and permit processes. Regional differences and overlapping jurisdictions could provoke vertical conflicts between federal, regional, state, and local agencies. Public interest groups who often favor the development of renewable resources do not always favor hydropower and would become more vocal. Further, bureaucracy would grow to keep up with the task of processing permits for the nonfederal sector.

A number of impacts could produce events and circumstances which could constrain the deployment of Level II. Of these, the following may require the attention of decision-makers and appropriate actions to mitigate them:

- Timely availability of critical materials and equipment;

- Difficulties in meeting capital requirements;

- Timely availability of skilled manpower, particularly the technical personnel experienced in hydropower engineering, small- as well as large-scale.

- Likelihood of an increase in electricity prices;

- Likelihood of declining revenues for fisheries;

- Disruptions in community structures and services;

- Increased competition for available water;

- Loss of agricultural and other productive land;

- Loss of scenic areas;

- Conflicts over water rights;

- Possible conflicts resulting from infringement upon Indian rights;

- Questions concerning the economic performance and viability of public utilities;

- Increased burden on public agencies—public utility commissions, power marketing agencies, FERC, Corps of Engineers, etc.

The synergistic impact of many of the above is manifested in an increased lead time for bringing on line the capacity postulated in Level II.

Several impacts however seem positive. Among these are:

- Improvement in system reliability brought about by the addition of hydropower capacity;

- Displacement of peaking capacity, in some regions, currently dependent upon oil and/or natural gas;

- Incentives to advance hydropower as well as other competing energy technologies, particularly those complementary to hydropower technologies;

- Increase in operating flexibility of utility systems, as Level II capacity additions penetrate the existing system;

- Provision of an inflation hedge, as hydropower is insensitive to escalation in fuel prices;

- Increased job opportunities and enlargement of the tax base at the local level.

4.4.5 Potential Long-term Impacts

If Level II were deployed as suggested here, a number of long-term impacts would occur. Among these are:

- Conventional hydropower capacity of about 110,000 MW.

- Standardization of critical equipment and power plant design.

- Manufacturing capability in place to produce critical equipment.

- Precedences concerning the relaxation of environmental regulations (e.g., National Environmental Policy Act requirements) and legislative mandates to accelerate energy resource development.

- Coordinating agency to resolve inter-agency conflicts.

- Enhanced local control.

- Means for localizing conflicts.

- Possible deployment of systemic water management and use.

- Possible changes in current pricing structures, and elimination of preference clause.

- Severe reduction in the domain of public utilities.

- Stronger role of power marketing agencies and Corps of Engineers.

- Regulatory agencies, such as FERC, more firmly rooted and established.

4.5 Assessment of Level III Hydropower Development

The high level of hydropower development delineated in Level III requires a justifiable context in which it is likely to occur. Thus, we describe the societal setting first, followed by a discussion of the associated hydropower setting.

4.5.1 Societal Setting

Here we must assume the occurrence of a shock such as the following:

- The loss of overseas oil sources due to a military reversal or destruction by nuclear weapons, making energy independence an inescapable goal rather than merely a political slogan; or

- A major nuclear plant accident in the United States, resulting in the stoppage of all nuclear power plants; or

- A sudden recognition that the carbon dioxide level in the air is inexorably leading to a global catastrophe, forcing curtailment of the use of fossil fuels.

In such an event strong federal action is required to avoid an economic collapse. Energy conservation becomes the foremost national priority because its potential for reducing demand has been estimated at 25 percent and because it is effective much more quickly. Next, both solar energy and hydropower receive major attention. Large-scale federal programs are initiated in both areas: research and development of solar energy, development and construction of hydropower facilities. State and local interference with energy projects is not tolerated, and regulations are modified to facilitate retrofit and new construction. It is fashionable and patriotic to develop small-scale hydropower, and small entrepreneurs are given incentives. Price controls are imposed.

The situation brings about a sense of cohesion which is instrumental in defusing the crisis.

4.5.2 Description of Level III

For Level III, the spotlight swings to hydropower and other energy sources which might provide relief. For purposes of analyzing this alternative, we assume that the crisis occurs by 1985, whereupon it triggers a national will toward "super-achievement" in bringing additional power sources on line at the earliest possible time. It is decided that only a strong federal presence, with centralized authority can ensure achievement of the goal of 75,000 MW by 2000, with 15,000 MW by 1990. The federal effort marshalls both national and international capabilities to carry out a quickly conceived "national energy development plan" in which hydropower plays a relatively minor role (in terms of capacity), but a critical role nevertheless (See Table 4-3).

Planning, design, and construction stages are greatly accelerated in a coordinated joint federal/nonfederal effort. Only at existing water resource projects, however, can meaningful additional capacity be brought on line by 1990. The result is a healthy 15,000 MW for the decade's efforts; occurring primarily in the WSCC region and to lesser extents in the NPCC, SERC and ECAR regions.

Concurrently with the work on existing sites, impressive progress is made in preparation for much new capacity at undeveloped sites on line in the 1990's. Those portions of the developmental process which traditionally have been quite time-consuming, prone to bureaucratic delays and subject to blockage by minor segments/interests of the general public, are shortened.

Given the crisis nature of the efforts, emphasis is on large-scale (greater than 30 MW) development where the unit benefits of effort are greatest. Consequently, although small-scale development is largest in absolute terms (10,500 MW) for this level, it is the lowest (14 percent) in terms of percentage of the level's total development. For comparison, Ref. 4.4 uses 11,400 MW for small-scale development. The emphasis on the federal role shows in the 1980's, as efforts to increase power production (primarily large-scale) at federal water resource projects are expedited.

Undeveloped sites are viewed as the principal source of capacity for meeting the planned goal: a necessity, in fact, inasmuch as the viable potential at existing projects is fully developed during the period. 50,000 MW comes on line during the two decades, of which 45,000 MW falls in the 1990's, reflecting the intensive and expedited preparatory work undertaken in the late 1980's. In order to achieve the 50,000 MW total, it is necessary to relax and in some cases negate some of the legal/institutional constraints, particularly with respect to environmental and preservation aspects. Conflicts are quickly arbitrated by the federal system. Development occurs primarily in the WSCC region and to lesser extents in the SWPP, SERC and NPCC regions and Alaska. Relatively minor amounts are in the remaining regions.

Of the total 75,000 MW, about three-fourths is federal, about 65 percent is at undeveloped sites and about 85 percent is large-scale. The distinctive feature is the federal government's actions to coordinate, direct and otherwise expedite development of energy resources, including hydropower (Table 4-3).

4.5.3 Relevant Issues

The development proposed in Level III is so substantial that almost all of the issues become relevant in its assessment. Figure 4-6 summarizes the relevance of the issues discussed in Chapter III to Level III.

The general issue concerning the significance of hydropower in the United States' energy supply picture now appears more important than in Levels I and II. The 75,000 MW capacity, depending upon how it is operated by a utility system (i.e., as baseload or peaking units) will be a noticeable contributor to United States energy needs. Development strategy for bringing on line the additional 75,000 MW capacity, however, is not as important, since a considerable portion of the 75,000 MW capacity is developed by the increasingly powerful federal sector.

The organizational and institutional issues also become extremely important. Although the societal scenarios underlying Level III development postulate centralization "to get things done", it will still be required to reconcile the roles of various institutions. Conflicts will intensify over Indian rights and water rights; public debate and litigation will increase dramatically.

All of the economic issues, including competing water and land uses, as well as those related to electricity pricing structures, and capital requirements and formation, become increasingly significant. Regional economies and existing water users will be seriously affected. Capital requirements of Level III are substantial and will require special attention to determine how they will be met, especially in a tight budget environment. The development of small-scale hydropower, now amounting to 10,500 MW, also requires attention at the federal level.

The environmental issues, again, cannot be adequately discussed without site-specific information. However, in general, Level III could produce significant changes in fisheries and the rapid, and increased construction of dams could accentuate changes in water quality as well as increase the risks resulting from dam failures.

Issue	Total: 75,000MW Federal: 55,500MW Non-Federal: 19,500MW Small-Scale: 10,500MW Large-Scale: 64,500MW
GENERAL	
3.1.1 Hydropower as a Contribution to National Energy Needs	●
3.1.2 Development Strategies	✖
ORGANIZATIONAL AND INSTITUTIONAL	
3.2.1 Institutional Framework	●
3.2.2 Indian Rights	●
3.2.3 Water Rights	●
3.2.4 Non-Federal Development at Federal Dams	○
ECONOMIC	
3.3.1 Small-Scale Hydropower	●
3.3.2 Competing Water Uses	●
3.3.3 Competing Land Uses	●
3.3.4 Pricing of Hydropower from Federal Projects	○/●
3.3.5 Capital Formation	●
ENVIRONMENTAL	
3.4.1 Environmental Impacts	✖
3.4.2 Health and Safety	✖
3.4.3 Fish Survival	●

Legend:

● - Highly relevant; ○ - Marginally relevant; ✖ - Relevant but resolution dependent upon site specifics

Figure 4-6

Relevant Issues for Level III Development

Most of these issues arise and become significant because the centralization postulated in Level III (a) could make the reconciliation of conflicting values and roles difficult; and (b) requires rapid escalation of construction of new plants generates problems related to technology, economics and environment.

4.5.4 Impacts

The impacts of Level III are similar to those of Level II, but on a much larger scale. The impacts of Level III development are summarized in Figure 4-7 and discussed below:

- Technology impacts will be significant in the hydropower sector as well as in the development of the competing/alternative technologies. Standardization of equipment, materials, and design specifications will be necessary for both large and small-scale development. Level III requires bringing on line about 60,000 MW capacity in 10 years. This is considerably higher from the historical rate of growth of hydropower in the United States during the past decade. Substantial capacity additions brought on line quickly are likely to produce long-term shifts in the generation mix of certain regions. New capacity can also improve system reliability and performance.

- The energy contribution of 75,000 MW capacity will be noticeable, regardless of how it is utilized (i.e., base vs. peakload), and will become especially important in case of supply interruptions which affect the availability of fuels for electric power generation. It could also provide considerable capacity displacement to meet the peakload requirements. In regions such as the NPCC it could help displace relatively expensive fossil fuels.

Impacts	Total: 75,000MW	
	Federal: 55,500MW Large-Scale: 48,500MW Small-Scale: 7,000MW	Non-Federal: 19,500MW Large-Scale: 16,000MW Small-Scale: 3,500MW
A. Technology		
1. Hydropower	M-H	M-H
2. Competing/Alternative	M-H	M-H
B. Contribution to U.S. Energy Requirements		
1. Energy Needs	M-H	M-H
2. Fuel/Capacity Displacement	H	H
C. Economics		
1. Resources		
a. Capital	H	M-H
b. Labor/Skills	H	M
c. Equipment/Materials	H	M-H
d. Land	H	M
2. Electricity Prices	H	M
3. Regional/Local Development		
a. Local Economy	H	M
b. Community Structures and Services	M-H	M
c. Fisheries	?	?
4. Recreational Resources	M	M
D. Environment		
1. Water		
a. Quality	?	?
b. Use/Supply	H	M-H
2. Air	L	L
3. Fish	M-H	?
E. Institutional/Legal		
1. Indian Tribes	H	M
2. Utilities		
a. Public	H	M-H
b. Investor-Owned	H	M-H
3. Power Marketing Agencies	H	M
4. Federal Agencies		
a. Corps of Engineers	H	M-H
b. FERC	M-H	M-H
c. Other (e.g., DOI, DOE)	M-H	L
5. State Agencies	M-H	L-M
6. Judiciary	M-H	L
7. Congress	M-H	L

Legend: L - Low level of impact; M - Medium level of impact; H - High level of impact; ? - Uncertain level of impact.

Figure 4-7

Impacts of Level III Development

- The economic impacts of Level III involve, first, the requirements for materials and equipment, which will be larger than those in Level II for federal development and the same as Level II for nonfederal development. These requirements will put substantial strains on current manufacturing capabilities. Production would have to be even more substantial to meet small-scale development needs.

  An economic impact of major significance is the need for large amounts of capital: requirement for $75 to $150 billion assuming capital cost of $1,000 to $2,000 per kW. Such an investment rate is considerably higher than in the past for hydropower development. These requirements will undoubtedly stress energy capital markets, even though a major portion of development occurs in the federal sector. The impacts of Level III, as a result, will be noticed in the national economy, probably as changes in electricity prices and adjustments in the economics of fisheries and the food-fibre sector. The impacts on local economies could prove to be beneficial, as the communities affected by development will experience increases in the prevailing tax base, enlargement of employment opportunities and government support to install and improve required services. The probability of seriously straining community structures and services, however, will increase.

  Without site-specific information, it is difficult to state the extent of impacts on land use. But, using assumptions similar to those delineated in Level II, the loss of agricultural land could amount to about 4.7 percent of the area currently under cultivation.

  Finally, although the impacts on recreational resources will depend upon the scale and type of development, the possibility of relaxation of environmental regulations and more moderate enforcement of enacted legislation is likely to diminish the importance generally assigned to the nation's recreational resources.

- Environmental impacts of Level III development will occur in both water quality and requirements. Similarly, fish population will decrease as water flow changes with the modification and expansion of existing large-scale facilities and storage and reservoir construction resulting from new development.

- In terms of institutional and legal impacts, Level III development could create serious conflicts over the hunting, fishing, land and water rights of Indian tribes, regardless of the scale and type of development. Similarly, implementation of Level III is unlikely without reconciling the conflicts over the current holders of water rights.

  Finally, almost all of the current institutional structures involved in the development of hydropower will be seriously affected. These include the agencies shown in the matrix of Figure 4-7. Institutions impacted significantly are: the Corps of Engineers (increased work load and pressures to rapidly construct the needed facilities); FERC (additional work load, could encounter the task of processing many additional applications per year and reconciling federal-nonfederal interactions); regional power marketing agencies such as BPA and TVA (distribution of much higher levels of generated energy, reliability assurance, price setting); public utilities (increased pressure to compete with big, investor-owned utilities); Congress (increase in legislation to approve federal projects, enacting legislation to bring about Level III without severe disruptions); and judiciary (possibility of an increase in litigation by various parties of interest, increasing role as arbitrator and "defender of public good").

In summary, the impacts of Level III in most categories will require anticipatory, early attention during the planning stages and then the sustained attention of relevant decision-makers and legislators.

4.5.5 Potential Long-term Impacts

Implementation of Level III development will produce potential long-term impacts. The principal ones are:

- Conventional Hydropower generating capacity of 138,000 MW.

- The creation of a top level federal entity to supervise the full-scale development of hydropower resources would provide the nation with the capability of implementing other types of alternative energy development.

- The concentration of resources and manpower will result in a level of centralization of power in the federal government that would seriously jeopardize traditional state and individual expectations of autonomy and reasonable freedom of action.

- The concentration of significant electrical generating capacity among a limited number of large-scale hydropower facilities could increase the nation's vulnerability to foreign attack and terrorist acts.

- The possibility of environmental trade-offs in order to achieve Level III. These include:

  - Alteration of wildlife habitat;

  - Disruption of migrating fish and wildlife patterns;

  - Inundation of farmlands and wetlands;

  - Increased release of toxic substances;

  - Dewatering of some streams;

- Changes in or destruction of riparian plant and fish species;

- Significant erosion in riverine habitats immediate or adjacent to hydropower projects at undeveloped sites;

- Alterations in water quality;

- Loss of scenic areas and recreational opportunities.

4.6 Comparison of Three Levels of Development

We now compare some of the salient features of the three levels of hydropower development..

4.6.1 Features of Development

The noteworthy aspects of the development of the three alternative levels were shown in Table 4-3. In terms of the schedule, capacity additions during the 1980's are identical for Levels I and II, while 50 percent more capacity is required for Level III. During the 1990's, Level I development proceeds closely at an historical rate of growth, while Levels II and III development occurs at almost twice and four times the historical rate of growth. In terms of new/existing capacity dimension, Level I development stems largely from existing facilities, while Level II and Level III split 50/50 and 25/75 existing and new facility development. Level I consists of almost 52 percent federal development, while Level II has almost the same percentage of nonfederal development. Level III, on the other hand involves predominantly federal development, 75 percent of total. In terms of scale of technology, Levels I and II contain 6,000 MW and 7,000 MW (about 24 percent and 13 percent of the total for Levels I and II) in the form of small-scale hydropower, increasing to 10,500 MW (14 percent of total in case of Level III). In terms of schedule, generally more new development takes place during the 1990's, whether it is federal or nonfederal. Similar considerations apply to small-scale development.

The major societal assumptions necessary for the three levels of development are as follows: For Level I, current trends continue and no major technological, economic, or institutional initiatives are required. For Level II, emphasis is on private sector development, based on the need to sustain noticeable economic growth and the faith in technological solutions that can bring this about. For Level III, the emphasis is on a crisis situation with federal mobilization to avoid economic collapse.

The issues of relevance for each level of development were discussed in previous sections. In general, the various issues described in Chapter III appear marginally relevant for Level I, but most institutional and economic issues, become quite significant for Levels II and III. The issues of highest relevance are compared for the three levels in Figure 4-8. We expand upon the comparison of key aspects in terms of issues and implications in the following section.

4.6.2 Technological

All three plans assume a considerable technical base of expertise. Curtailment of federal research and development implies that the private sector will take over this task in most fields. As pointed out elsewhere, the rather modest development of hydropower in the United States over the past two decades has inevitably affected the availability of skills (e.g., in hydropower engineering) and the availability of equipment and critical materials. Thus, Levels II and III must address revitalization of dam construction capability. Even Level I may have some implementation problems which could delay full realization beyond 2000. As some interviewees for this assessment pointed out, reliance on foreign hydropower technology to make up for domestic deficiencies could mean that the lack of self-sufficiency in energy supply is then extended from oil to hydropower.

Issue	Highly Relevant To:		
	Level I	Level II	Level III
GENERAL			
3.1.1 Hydropower as a Contribution to National Energy Needs			●
3.1.2 Development Strategies		●	
ORGANIZATIONAL AND INSTITUTIONAL			
3.2.1 Institutional Framework		●	●
3.2.2 Indian Rights		●	●
3.2.3 Water Rights	●	●	●
3.2.4 Non-Federal Development at Federal Dams	●	●	
ECONOMIC			
3.3.1 Small-Scale Hydropower	●	●	●
3.3.2 Competing Water Uses		●	●
3.3.3 Competing Land Uses		●	●
3.3.4 Pricing of Hydropower from Federal Projects		●	O/●
3.3.5 Capital Formation	●	●	●
ENVIRONMENTAL			
3.4.1 Environmental Impacts			
3.4.2 Health and Safety			
3.4.3 Fish Survival			●

Legend: ● - Highly Relevant; O - Marginally Relevant.

Figure 4-8

Comparison of Issue Relevance and Levels*

* Issues identified as highly relevant on a national basis (excluding those which may be highly relevant at a specific site but not in general).

4.6.3 Economic

The major economic problem is financing the construction of additional capacity. To a lesser extent current federal economic evaluation procedures and related uncertainties also affect hydropower development.

Level III, operating under crisis conditions, faces few funding problems: the federal government simply appropriates more money. The Department of Defense would be in a most favored funding position in a national security crisis—it is currently the only federal department with an increasing budget—and the Corps of Engineers is still a component of the Department of Defense although it has separate funding arrangements. Obtaining the needed funds should thus be nearly "business as usual" in the setting of Level III.

Level II does have serious financing problems, however. Controlling or programming the growth of the nonfederal sector's development of hydropower, at the scale postulated in Level II, could be problematic depending on capital supply and federal incentives. Leaving the task to the market, on the other hand, means considerable uncertainty about capital availability.

If we take discounting into consideration, high capital outlays are attractive only if they can be delayed to the more distant future. Thus, Level II development appears financially reasonable today only if the major expenditures are postponed to the 1990's.

Recently a Senate committee report accompanying S1641, a bill designed to encourage the development of small hydroelectric power, contained the following description:

> The present water resources program—covering the Army Corps of Engineers, the Water and Power Resources Service (formerly the Bureau of Reclamation), and the USDA Soil Conservation Service—is in disarray. It is plagued with delays and ad hoc decisions, factors that have inhibited national water resources development in recent years.

> The construction budget of the Corps of Engineers has declined by 50 percent, in real dollars, since the mid-1960's. Projects now take, on the average, a generation to initiate, with much of that time taken by congressional delays in authorizing and appropriating funds. The backlog of authorized projects is approximately $30 billion. There is no system for establishing priorities among backlogged projects or future projects (Ref. 4.9).

It would seem to us that this description is still applicable to the current situation and certainly to Level I. Delays, long lead times, and difficulty in obtaining financing are still with us. The current administration has not yet changed these conditions. Indeed, with its emphasis on cutting budgets and controlling off-budget expenditures as a stabilization device, it is going to be even more difficult for federal water resources agencies to obtain funding.

4.6.4 Legal/Institutional

Level I starts from some minor modifications of federal dominance to encourage market forces, a shift which reaches its logical conclusion in Level II. In Level III, the operative words are no longer federal incentives, but rather federal intervention, reallocation, and abrogation. Level III encompasses not just a centralized approach to development, but assumes that the federal government, in response to a crisis, is willing and able to step in and make minor changes. We refer to changes not only in legislation but in the way public business is conducted. First, we should be clear that very few crises can provide underpinnings needed for justifying Level III development. Generally we respond to a perceived crisis by trying to handle it almost routinely as we did in response to the 1973 oil embargo. Implementation of Level III would require support that may not be possible from a democratic point of view. The public would stand for such a centralization of power only under extreme threat (economic or military). Moreover, one should seriously think about whether the federal government has the capacity to deal with the crisis situation depicted as essential for Level III development. If we can judge that capacity by existing coordinating mechanisms, then it seems that the federal government would have to develop them relatively quickly, raising the possibility that much development would not occur until the latter years of the planning period and beyond.

Likely sources of strong support for the three levels could be:

Level I:	Federal agencies (least change from present)
	Some public interest groups (others opposed)
Level II:	Utilities
	Construction industry
	Raw materials and metal-based industries
	Hydropower equipment manufacturers
Level III:	Department of Defense
	Most industrial users
	Most citizens

From an institutional viewpoint both Levels I and II seem more feasible than Level III. More energy is produced, relatively speaking, from Level II development, and more participants receive the energy and pay for it. Comparatively, less energy is produced from Level I development, but its realization does not require many participants. However, it does require attention to institutional issues, such as the need to sort out the federal and nonfederal roles.

In a society characterized by sociocultural fragmentation, few issues focus so many value-laden and fiercely protected concerns as does water resources development including hydropower. Shifting and unlikely alliances coalesce and refracture around conflicting interests ranging from inundation of archeological sites to the sanctity of Indian fishing as an expression of religious freedom. Suggestions to clarify agency jurisdiction and authority in the interests of expediting hydropower development on a federal level might be seen as tantamount to riding roughshod over rights guaranteed by tradition, the Constitution, and the integrity of government-sanctioned agreements. The judiciary is mandated to protect at least some of these rights. The implications of "efficient" development are often potentially catastrophic on a social and a Constitutional level.

The rapid development of hydropower postulated in Levels II and III also implies standardization of institutional procedures surrounding authorization and funding of such projects. Because of the very site-specific nature of developmental problems, such standardization could result in inefficiencies in the trade-offs. For example, residential land, agricultural land, natural habitat and potential industrial development all span a wide range of values that depend not only on some intrinsic worth seen from some national perspective, but also on local priorities that emanate from a wide variety of traditions, perceived needs and local customs.

It should be noted that lending institutions have little recent experience in financing hydropower development, e.g., no standard procedures for assessing risk or disposing of equipment and sites where loans have been defaulted. This situation would tend to favor larger developers over small entrepreneurs even for small-scale hydropower.

Finally, there is concern about current economic evaluation procedures (Ref. 4.10, 4.11). It is felt among some observers that current Water Resources Council's Principles, Standards and Procedures, for example, might disadvantage federal development of hydropower or distort the allocation process between the public and private sectors. Without getting into the technicalities of cost-benefit procedures, this concern seems to be unwarranted with respect to Levels I and III. In the case of Level III, the crisis nature of the situation would encourage the construction of projects which under normal circumstances might be eliminated because of marginal cost-benefit ratios. In the case of Level I, most of the development is on existing sites for which the evaluation would be fairly straightforward.

It is for Level II that the concern may be warranted. Level II relies relatively more on private sector initiatives and the use of new sites. Since many of these sites might require multipurpose development in order to justify the construction of dams and related facilities, federal water resource agencies would face the difficulties associated with multipurpose economic evaluation,

and nonfederal developers would seek some type of cost-sharing to make projects feasible from their point of view. Moreover, pricing policies would have to be developed to reflect the multipurpose nature of the facility and the particular cost-sharing arrangement. Such problems, of course, are not insurmountable, but they can contribute to delay and to failure to achieve the requisite development level within the specified time period. Particularly with new, undeveloped sites it may not be practical to assume that the market will take care of the development, unless price levels change so dramatically that single-purpose hydropower development on new sites becomes a reality.

REFERENCES

4.1 A.K. Graham and P.M. Senge. "A Long Wave Hypothesis of Innovation". Technological Forecasting and Social Change, 17 (1980), pp. 283-312.

4.2 U.S. Army Corps of Engineers, North Pacific Division. "Review Draft, National Hydroelectric Power Study Inventory of Potential Hydropower Projects, Western Systems Coordinating Council Region, Main Report." January 1981.

4.3 The Hydrologic Engineering Center. Potential for Increasing the Output of Existing Hydroelectric Plants. January 8, 1981.

4.4 INTASA Inc., in association with EDAW Inc. and Sverdrup & Parcel and Associates Inc. National Hydropower Study Environmental Assessment, Draft Final Report. January 27, 1981.

4.5 G. Hardin. "The Tragedy of the Commons." Science, Volume 162, December 13, 1968, pp. 1243-1248.

4.6 G. Mensch. Stalemate in Technology. Ballinger Books, 1980.

4.7 "Energy, Security, and War." Science, Volume 211, February 13, 1981, p. 683.

4.8 President's Council on Environmental Quality. "Global Energy Futures and the CO_2 Problem." January 1981.

4.9 U.S. Congress, Senate Committee on the Environment and Public Works. National Small Hydroelectric Power Development, Report 96-774. 96th Congress, 2nd Session, May 1980.

4.10 U.S. General Accounting Office. Hydropower—an Energy Source Whose Time Has Come Again. January 11, 1980.

4.11 D.C. Major. A Review of Economic Evaluation Criteria for Hydroelectric Power Projects (Draft 1). February 1981.

FOOTNOTES

1. At this time, the two-project Susitna development (1,200 MW ultimate capacity) is the only major well-advanced development for Alaska; a total Alaska capacity of about 3,500 MW may be likely by 2000. However, cost and security problems combine to preclude transmission of power to the "lower 48", although a major breakthrough in transmission technology may change that situation.

2. Key sources of data used to project the three alternative development levels included: (1) The Corps' screening of potential sites in the NHS Inventory data base as of January 1981; (2) The NHS regional draft reports; (3) The NHS Environmental Study contractor's data base; (4) The NHS draft report on energy potentials at existing sites prepared by the Hydrologic Engineering Center; (5) various documents from the National Electric Reliability Council and U.S. Department of Energy (DOE); and (6) information provided by key officials of DOE and the Corps.

3. It is estimated that a conventional 200 MW hydropower plant requires approximately 150,000 tons of concrete; 14,000 tons of total steel and castings; and numerous other materials such as copper, brass, bronze, manganese, nickel and chromium. Some of these materials are currently considered as "critical" or "strategic" in that the United States is almost totally dependent on overseas supply sources for these materials (e.g., chromium and manganeze). On one extreme, if it is assumed that the entire 45,000 MW capacity is developed as 200 MW plants, material requirements become quite substantial (e.g., 3.4 million tons of concrete), although these requirements are distributed over a 20 year time period. 675 turbine-generator sets of 66.7 MW size also will be required, with almost 78 percent of these requirements occurring over a 10 year period, 1990 to 2000. Further, if the 7,000 MW small-scale capacity postulated in Level II is developed as 30 MW units, 233 units will be required over the next 20 years. It is more likely that unit size will be less than 30 MW, thus increasing the requirements for small-scale turbine generator sets.

CHAPTER V

Implementation Strategies

5.1 Introduction

Having discussed the issues (Chapter III) and three alternative levels of hydropower development (Chapter IV) we now draw out implications for the formulation of implementation strategies. These are not precise plans, but they do represent guidelines and indicate the relative ease of actualizing the three levels. A master list of action options is shown in Table 5-1. This is used as a guide to develop specific actions consistent with the characteristics and implications of each level of hydropower development.

5.2 Level I Actions

If Level I development is to be implemented successfully, actions to mitigate at least three impacts will be required. These impacts are delineated in Figure 5-1.

Economic actions will be needed to mitigate two impacts; lack of availability of experienced, skilled personnel for substantial small-scale development and capital requirements of as much as $50 billion over the next 20 years. Appropriate actions are:

- Standardize equipment and plant design to achieve economies of scale. Similarly, provide guaranteed markets to manufacturers so as to interest investors in the production of equipment required for small-scale plants.

- Provide tax incentives for capital formation by the private sector.

- Encourage rapid deployment of small-scale plants, thus significantly renewing interest in the technology and attracting engineering professionals. In addition, develop an engineering school curriculum oriented to small-scale plant design, construction, operation and maintenance.

Table 5-1

Possible Action Options: Master List

Technological	• Standardize the design and specifications for various scales of hydropower development; • Develop and deploy capability to rapidly manufacture the critical items such as turbine generator sets for small-scale development.
Institutional and Legal	
General	• Insist on clear and consistent policy on nonfederal development at federal dams; • Encourage federal development agencies to increase their role in technical assistance and coordination with nonfederal sector; • Decentralize federal development activities; • Centralize all hydropower development in the event of a national crisis;
Indian Rights	• Honor Indian rights; allow Indian veto power over reservation development; • Negotiate; • Compensate; or condemnation; • Abrogate.
Federal Reserved and Preemptive Water Rights	• Preempt state water allocation systems as necessary to further hydropower development; • Exercise reserved water rights at Pickett Act sites.
Nonfederal Development at Federal Dams	• Negotiate memoranda of understanding between affected agencies and FERC; • Allow agency determination of federal sites appropriate for nonfederal development; • Enact clarifying legislation.

Table 5-1 (Con't)

Economic

Small-Scale Hydropower	• Provide incentives for turbine manufacturers and plant developers through tax credits, low interest loans, and other subsidies; • Disseminate information for small-scale development.
Allocation of Water Rights and Competing Water Uses	• Accelerate water rights filings; • Encourage or mandate interstate water compacts and planning; • Form a strong, centralized national water resources authority to mandate comprehensive national/regional water planning; • Relax environmental standards; • Prepare contingency plans; • Increase available water supply; • Reduce demand for water; • Establish more flexible allocation mechanisms.
Competing Land Uses	• Obtain necessary flowage easements required to permit inundation of additional acreage; • Use existing transmission corridors when possible; • Evaluate sites with regard to adverse impacts upon agricultural productivity; • Acquire and preserve potential hydropower sites; • Appropriate adequate funding to compensate preempted or displaced uses.
Pricing of Hydropower from Federal Projects	• Continue the preference clause; • Replace current preference clause by marginal cost pricing (MCP); • Replace current preference clause by the cost of alternative source concept (CAS).
Capital Formation	• Loosen IRS lid on tax exempt bond issuance; • Disseminate creative capitalization information and provide assistance in forming innovative finance packages;

Table 5-1 (Con't)

	• Revive federal subsidies and loan programs; • Increase direct federal aid for front-end costs.
Environmental	• Encourage "one-stop" environmental review through a central review mechanism; • Shift selected environmental costs to the benefitting public through additional economic incentives.
Public Health and Safety	• Enforce continued safety oriented design of dams; • Increase reliance on conservation and renewable energy (including hydropower).
Fish Survival	• Assess carefully the benefits of an anadromous fishery vs. the benefits and costs of a dam; • Include adequate fisheries mitigation as a front-end cost of new projects at undeveloped sites; • Implement better means of compensating nonfederal developers at existing site retrofits whenever fish mitigation is a significant element of project cost.

Impacts Requiring Attention	TECHNO-LOGICAL			ECONOMIC							LEGAL/INSTITUTIONAL AND LEGISLATIVE							
	Standardization	Deploy Manufacturing Capability		Loan Guarantees	Market Guarantees	Tax Incentives	Direct Subsidy	Pricing Mechanisms	Compensation Mechanisms	Community Planning	Relax Applicable Environmental Regulations	Protected Area Designation	Siting Policy	Protection of Public Utilities	Relax Licensing Procedures	Set Up Coordinating Agency	Memorandum of Understanding	Enact Clarifying Legislation
Capital Requirements	●	●			●	●												
Skilled Labor	●																	
Federal/Non-Federal Role													●	●			●	●

Legend: ● - Applicable Action Option.

Figure 5-1
Applicable Action Options for Level I Development

Legal and institutional actions may be necessary at Level I to alleviate interagency conflicts and speed hydropower development at federal projects and sites. Mitigation actions include any or all of the following:

- Negotiate memoranda of understanding between affected agencies and FERC.
- Enact clarifying legislation.
- Authorize immediate federal study of authorized federal sites; the result of such a study should be a clear siting policy.
- Open federal sites for nonfederal development through legislation.

Small-scale hydropower is at present being given very serious institutional encouragement (See 3.2.1). If continuation of such encouragement is deemed desirable, it should include study of the following steps:

- Incentives for turbine manufacturers and hydropower plant developers. (e.g., tax credits, low interest loans, and other subsidies). Great care should be taken to invest federal funds only in organizations that actually develop sites rather than those living on feasibility studies. Seed money is needed since six to eight years of negative cash flow may be unavoidable before a project starts paying its own way.
- Dissemination of information. Small hydropower developers could well use advisory services patterned after the Agricultural Extension Service. Without such support a few companies could dominate the small hydropower business by governing hundreds of sites, computerizing the application process and developing turn-key operations.
- Encouragement of equipment standardization. Standard turbines and other components would help to insure volume production and reduce costs to buyers.

If, on the other hand, Congress decides as a matter of policy that institutional incentives favoring small-scale development have created as many public costs (to the federal Treasury, to purchasing utilities, to the environment, etc. as outlined above) as public benefits, then consideration should be given to allowing incentives already in place to run their course without further promotion.

Following are some steps to alleviate the financing bottleneck:

- Liberalization of limits on tax-exempt bond issuance. Current IRS rules limit tax exempt borrowing devices to nonfederal public developers who cannot sell more than a quarter of their output to private entities. By raising the lid to 50 percent or eliminating it entirely, capital formation in the nonfederal sector would be greatly encouraged. However, this would place significant stress on the federal treasury, raise interest rates, pressure the municipal bond market, raise the cost of money, and worsen inflation. The nonfederal sector would be able to bring power on line at an earlier date, but the federal sector would not benefit correspondingly.

- Dissemination of creative capitalization information and assistance in forming finance packages. Government can sponsor outreach and education programs for both developers and the financial community regarding innovative ways to finance projects in an inflationary, tight-money economy. Such methods include joint-action financing, leveraged leasing, restructuring of bond denominations and issuance, removal of municipal debt ceilings, property tax deferrals, state industrial revenue bond programs, etc.

  Trained manpower will be required to staff outreach programs through federal developers or FERC. High visibility and clear policy priorities will be needed. An energy bank is another possibility to be explored.

- Revival of federal subsidies and loan programs; increase of direct federal aid for front-end costs. Current PURPA feasibility loans are being held in abeyance (February 1981), and the PURPA construction loan program in DOE has been blocked by OMB since PURPA's enactment in 1978. Reviving and

increasing such direct federal aid to the nonfederal sector would put these programs back on track. The result, however, may amount to a burden on the federal budget, and a possible undesirable trade off in the form of a constraint on direct, multipurpose federal development.

- Encouragement of state utility commissions to provide an adequate rate of return on investment to the private utilities. Such action stimulates investment in hydropower plants which is being withheld under present conditions.

At least two measures could be taken to facilitate orderly development without necessitating major structural changes in the existing institutional framework:

1. Nonfederal development at federal dams. It is important to establish a clear and consistent policy regarding nonfederal development at federal dams, and to resolve conflicting mandates and statutory interpretations which set agencies at odds both with themselves and with nonfederal developers.

   a. Resolutions short of legislation: the Memorandum of Understanding (MOU). The MOU is a standard operating procedure for the resolution of interagency conflicts within government. Both FERC and the affected agencies should endeavor to arrive at a solution which simultaneously satisfies the concerns of each and promotes economical and efficient hydropower development. Such resolution would at present encourage nonfederal development. A possible disadvantage is that agency resolution may be convenient for interagency relations, but still not promote the interest of other developers or the public.

   b. Agency determination of federal sites appropriate for nonfederal development. Here, the MOU procedure would be utilized, but the parties would be the nonfederal developer and the federal agency in control of the dam, rather than the federal agencies themselves. This could serve as an appropriate, economical method of resolving the issue of "who develops" short of legislation.

c. Legislative solutions. Congress can resolve any of the issues outlined herein with clarifying legislation. This would be appropriate if affected agencies and developers are unable to resolve differences over the appropriate developer at individual sites, or over conflicting fees, systemic constraints, access or design approval. Congress could spell out with particularity the authority of FERC and the policies governing federal and nonfederal developers in these instances. In any event, it would behoove Congress to resolve conflicting mandates set up by its own legislation.

2. Technical assistance and coordination between federal and nonfederal developers. The role of federal development agencies in providing technical assistance and coordination with the nonfederal sector can clearly be enhanced both by the agencies and by Congress. Draft legislation, if necessary, would require clear policy language, planning/assistance monies, and coordination of technical and planning needs in support of feasible nonfederal development endeavors. The logical lead agency for such coordination and support functions is FERC. If necessary, Congress could amend the Federal Power Act to expand FERC's authority to call on relevant federal agencies for their substantive technical and informational expertise, rather than merely the review and comment functions such agencies exercise at present.

In summary, Level I can be implemented without substantial additional involvement on the part of the federal government. In a sense then, Level I is almost like a "do nothing" option. Some impacts, such as those related to land requirements and fisheries, seem inevitable. (But the design and implementation of actions, such as those outlined above, can facilitate the timely and successful implementation of Level I.)

5.3 Level II Actions

Figure 5-2 relates the applicability of various action options to impacts of particular concern. Specifically, the following actions are suggested:

Impacts Requiring Attention	TECHNO-LOGICAL		ECONOMIC								LEGAL/INSTITUTIONAL AND LEGISLATIVE					
	Standardization	Deploy Manufacturing Capability	Provide Adequate Rate Ret.	Loan Guarantees	Market Guarantees	Tax Incentives	Direct Subsidy	Pricing Mechanisms	Compensation Mechanisms	Community Planning	Relax Applicable Environmental Regulations	Protected Area Designation	Siting Policy	Protection of Public Utilities	Relax Licensing Procedures	Set Up Coordinating Agency
Materials and Equipment Availability	●	●														
Capital Requirements	●			●	●	●	●	●								
Skilled Labor																
Electricity Prices	●								●							
Fisheries									●			●	●			
Community Structures and Services									●		●		●			
Water Use/Requirements									●		●		●			
Loss of Productive Lands									●			●	●			
Loss of Scenic Areas									●			●	●			
Water Rights/Availability									●				●			
Indian Tribes									●			●	●			
Investor-Owned Utilities		●	●	●		●		●					●			
Public Utilities					●			●						●		
Lead Times to Construct Facilities											●				●	●

Legend: ● - Applicable Action Option.

Figure 5-2

Applicable Action Options for Level II Development

Technological actions will be needed to mitigate material and equipment shortages and to reduce lead times. These are:

- Standardize equipment and plant design.

- Develop manufacturing capability through the involvement of the federal government.

Economic actions response to a number of impacts, as shown in Figure 5-2. These are:

- In addition to standardization of equipment and plant design, provide loan guarantees in appropriate areas to stimulate rapid expansion of certain technologies.

- Provide guaranteed markets to stimulate production of critical parts and components such as turbines for small-scale plants.

- Develop and implement tax incentives, direct subsidies, and pricing structures to aid and sustain capital formation processes.

- Provide compensation, monetary as well as non-monetary.

- Through state utility commissions provide utilities an adequate return on investment to stimulate construction.

- Implement community planning efforts to minimize community disruptions.

Institutional, legislative, and legal actions are directed to mitigate various impacts as shown in Figure 5-2. These are:

- Relax environmental regulations to reduce construction lead times.

- Designate selected areas as protected from both public and private sector development.

- Develop and implement a siting policy to guide the location of future hydropower plants.

- Enact legislation to protect public utilities to a certain extent.

- Relax licensing procedures to reduce the lead time for bringing a hydropower plant on line.

- Set up a coordinating agency to reduce horizontal and vertical conflicts among various agencies and organizations.

More intensive hydropower development levels would require development strategies entailing some significant institutional alterations, particularly if medium (Level II) or maximum (Level III) feasible development is to be brought on line in less than 20 years, i.e., before 2000. Two strategies are suggested here and elsewhere in this report (See Sec. 3.1.2 and Chapter V). The strategies are partial decentralization in any United States social setting short of crisis, and centralization in a period of national emergency or a setting wherein resources must be controlled or carefully allocated.

An overall strategy of decentralization under the Level II scenario would suggest the following institutional changes:

- FERC shifts proceedings and resources to the regions. FERC retains a presence in Washington for coordination and marketing, but licensure, permits, and development strategy move to the regions. At the regional level, FERC develops joint action strategies with state siting councils and public/private development entities.

- Federal development agencies emphasize technical assistance, outreach, and coordination. The Corps and WPRS move into an assistance and information-provider role within their respective jurisdictions as regional development proceeds.

- Federal financial incentives emphasize tax and marketing guarantees. Current tax incentives and encouragements are continued and liberalized; capacity limitations on the availability of certain programs are loosened or removed (i.e., PURPA's 80 MW lid or COWPTA's 125 MW upper limit).

- Direct federal assistance becomes available for the risk minimization and environmental mitigation. Federal monies are devoted less to actual construction and more to underwriting private industry risks by minimizing and mitigating environmental disruption and providing assistance and backup to assure the adequacy of safety and design.

A byproduct of decentralization is the possibility of the growth of large new corporate entities that construct and/or manage hydroelectric facilities. One private corporation has already filed hundreds of applications across the country. Thus, a concentration of power is actually a possibility with a decentralization policy.

Assuming a national water crisis does not take precedence over the energy needs, the following general actions merit consideration:

- Acceleration of hydropower water rights filings. A program should be established to ensure that rights acquisition is under way at all feasible hydropower development sites identified in the National Hydropower Site Inventory. FERC should compare its licensure/permit filings with the Inventory and with any data available from federal development agencies or their own activities in connection with undeveloped sites. The filing process should begin at any sites where it is not already under way.

  Early notice should be given to rights holders and prior appropriators (in the West) and other users (in the East). It is a sound preliminary step toward cogency in enabling a national hydropower priority to get under way. Notice and filing will enable environmental intervenors to participate earlier in the decision to proceed at individual sites.

- Encouragement or mandating of interstate water compacts and planning. This is an alternative, like accelerated filings, to federal preemption of state water rights. Here, the emphasis would be on state and regional cooperation rather than a central authority (like the Water Resources Council).

  States and regions would be making their own decisions about resource allocation, and would be enabled to undertake action on a systemwide basis (i.e., throughout a river basin or along the course of an aquifer that crosses many political lines). This could, however, encourage regional parochialism in place of the state parochialism it was designed to replace.

- Relaxation of environmental standards. If high levels of hydropower development are sought, it will be necessary to relax selectively some of the existing environmental and social constraints to new water resource development; to operate multi-project river systems at a high level of coordination and efficiency; and to establish a mechanism for resolving water-related conflicts in a reasonable period of time. Although the resultant social-political ramifications would be considerable and traumatic at state and regional levels, the bases for such federal authority are firmly rooted in Constitutional clauses (Commerce, Navigation, etc.) and dependent legal instruments.

5.4 Level III Actions

The applicable actions are shown in Figure 5-3. Generally, these are identical to those examined for Level II. The applicability matrix is denser than that for Level II, for two reasons. First, the substantial capacity addition creates more dislocations. Second, the institutional climate is based on the context of a national emergency, which requires more actions than in Levels I and II.

Technological actions needed to mitigate the impacts of principal significance for Level III are:

- Standardize equipment, materials, and design specifications.

- Establish and increase necessary manufacturing capability.

Impacts Requiring Attention	TECHNO-LOGICAL			ECONOMIC							LEGAL/INSTITUTIONAL AND LEGISLATIVE					
	Standardization	Deploy Manufacturing Capability	Trans. Brkth. Res. Suppt.	Loan Guarantees	Market Guarantees	Tax Incentives	Direct Subsidy	Pricing Mechanisms	Compensation Mechanisms	Community Planning	Relax Applicable Environmental Regulations	Protected Area Designation	Siting Policy	Protection of Public Utilities	Relax Licensing Procedures	Set Up Coordinating Agency
Materials and Equipment Availability	●	●	●	●	●	●	●									●
Capital Requirements				●	●	●	●	●								●
Skilled Labor																
Electricity Prices	●		●	●	●			●								
Fisheries									●			●	●		●	
Community Structures and Services										●			●			
Water Use/Requirements	●								●	●		●	●		●	●
Loss of Productive Lands			●						●				●			
Loss of Scenic Areas									●			●	●			
Water Rights/Availability									●			●	●	●	●	●
Indian Tribes			●						●			●	●		●	
Regional Power Marketing Agencies									●				●	●		●
Lead Times to Construct Facilities	●	●	●						●		●	●	●		●	●

Legend: ● - Applicable Action Option.

Figure 5-3

Applicable Action Options for Level III Development

- Accelerate research and development on transmission technologies.

Economic actions are necessary to mitigate the significantly increased impacts of Level III development. Appropriate actions include:

- Provide guaranteed markets to stimulate investments and realize economies of scale.

- Design and rapidly implement compensation mechanisms.

- Initiate and develop strong community planning and preparation efforts.

Legal, institutional, and legislative actions will be of great importance if hydropower development as envisioned in Level III is to be achieved. Crucial mitigating actions are:

- Develop and implement policy for the siting of future hydropower plants.

- Relax environmental regulations to reduce lead times and ease the burden on utilities and public agencies, such as FERC and EPA.

- Declare selected areas as protected from any future hydropower development.

- Streamline and relax licensing procedures to speed up construction of hydropower plants.

- Establish a coordinating agency, such as the Energy Mobilization Board, to insure the timely implementation of Level III.

Appropriate actions to mitigate several impacts which seem adverse will be needed. They are fewer than in the case of Level II since the national emergency would undoubtedly alter value systems as well as priorities. The mitigation needs include:

- Timely availability of critical materials and equipment;
- Difficulties in meeting the capital requirements;
- Timely availability of skilled manpower;
- Possible difficulties in meeting water requirements of the various users;
- Possible conflicts over water rights, especially the current holders of such rights;
- Possible conflicts resulting from the infringement of Indian rights;
- Possible difficulty of enforcing current rate structures;
- Increased burden on public agencies involved in, and affecting, the development of hydropower—Corps of Engineers, regional power marketing agencies, FERC, etc.

Like Level II, many of these impacts produce a synergistic impact: long lead time for bringing on line the required hydropower capacity.

Centralization strategies represent mutually exclusive alternatives in the context of a serious national crisis. There are three alternatives:

- Consolidate authority with FERC. FERC is given power to use the resources and expertise of federal development agencies in furthering hydropower development. FERC is enabled to make the threshold federal/nonfederal development decision, and lead times in the federal sector are reduced. FERC uses the federal agencies in a technical assistance role at sites without political or environmental problems, or uses them for direct development at sites associated with significant or costly political/environmental liabilities.

Major institutional adjustments are required, but policies in place favoring the nonfederal sector are continued and expanded. FERC is able to telescope the federal development process, coordinate with all relevant federal, state, and local agencies and put its expertise in furthering private sector development to immediate use.

- Consolidate authority within one federal development agency (i.e., the Corps of Engineers). Both FERC and WPRS are absorbed under the Corps umbrella, removing them from the Departments of Energy and Interior to the Department of Defense. Institutional efficiency is achieved quickly in an organization accustomed to large-scale planning and execution under national crisis conditions.

  Congress retains control over an experienced hydropower development agency, and at the same time effectively delegates the initial federal/nonfederal build decision to a nationwide developer acting on the government's behalf. Institutional efficiency is achieved—but perhaps ultimately at the expense both of the nonfederal sector and the environment.

> Somebody is going to have to stand up and say: "You are in the unfortunate position of owning a resource of national significance."
>
> (A Government Official)

- Consolidate authority within a newly created "super" agency. An independent, self-financing development and regulatory agency (modeled on TVA with nationwide jurisdiction) under a crisis scenario has broad authority to coordinate site-selection, design, construction, and operation of all hydropower facilities, and marketing of the power produced. The agency has authority to coordinate with or call upon the resources of either sector (federal or nonfederal) in order to achieve the fastest and most economical results.

Congress could thus ensure speedy development in a crisis, but such actions might result in permanent centralization of power within the federal government at the risk of seriously jeopardizing state and individual rights.

If water problems are dominant from a national perspective, the following steps can be considered:

- Formation of a strong centralized national water resources authority to mandate comprehensive national/regional water planning. Such an authority would be one step short of federal intervention in state water rights allocation systems. The Water Resources Council and the River Basin Commissions would be models, but the authority would have broader powers of compulsion and a higher profile in the governmental hierarchy.

  However, the entity might duplicate most of the difficulties which beset the current WRC. These include mandating water resources planning principles and standards which impede rather than hasten development, and/or substituting irrelevant or inappropriate national procedures in areas or at sites needing local input and solutions. The entity could conceivably eliminate or reduce state and local parochialism if given sufficient powers and a broad enough mandate. But with such powers comes the accompanying risk of a national outcry over interference with state and local autonomy.

- Increasing the available water supply. This means increasing the amount of surface water available for dependable generation of hydropower. Techniques to increase supply include development of new resources, increase of the recycling or reuse of existing supply, and enhancements of efficiency in its distribution and use. General options include use of ground water for non-hydropower uses, weather modification, improved forecasting of runoff, evaporation suppression, vegetation management, alpine snowfield management, desalination and development of large and small reservoirs.

  Of the above options, only the development of large storage projects (dams/reservoirs) has the potential to make a significant contribution toward increasing available water supply for hydropower. Collectively implemented, however, the other options also would make a significant contribution. Development of large storage projects, in most cases, tends to evoke vigorous public opposition, depending upon the scope of the project's adverse impacts

(which would vary from site to site). Extensive and extended legal delays generally become the rule. High capital costs would evoke much discussion of the relative benefits of investment in this or other electric power potentials. Lastly, large storage projects make vast and permanent changes in the landscape and the ecology. Their irreversible nature must be carefully considered before committing such sites to development.

- Reduction of the demand for water. Techniques to reduce demand include increase of price to consumers, institution of a conservation program to reduce use or eliminate waste, and changes in institutional structures to increase efficiency of use or to shift demand geographically (Ref. 3.9).

  A national effort to reduce demand would be difficult to implement given the site-specific nature of the problem. There is need for caution on the point that water conserved, or saved, does not necessarily become available for hydropower use; under the prior appropriation system of rights, for example, the savings by a user would become available to the holder of the next junior water right. Lastly, increases in irrigation efficiency represent the greatest potential for demand reduction, but such efforts tend to be capital-intensive and relatively slow to implement on a wide-scale. Increased efficiencies in other consumptive uses would be of minor significance for hydropower purposes.

- Establishment of more flexible allocation mechanisms. Mechanisms to allocate the supply include state water laws; federal laws, subsidies, and practices; treaties; interstate compacts, state utility commissions; and other public and private institutions. If a strong hydropower development program were established, the present cumbersome and inflexible institutional arrangements would only increase litigation and legislation. An important short-run step to reduce conflict is an increased efficiency of water use and expanded conservation measures. In the long run, however, it is obvious that more flexible allocation mechanisms are needed (Ref. 3.9).

More flexible allocation mechanisms would enable society to allocate available water based on contemporary situations and without legal/administrative constraints instituted when society's need and preferences were vastly different. As an example, water savings stemming from increased irrigation efficiencies could be allocated to uses/users in accordance with society's current and anticipated needs rather than accruing to the next junior water right holder. Admittedly, such measures would represent rather significant departures from present water rights philosophies/systems, and probably would evoke considerable protest from established water interests.

TECHNOLOGY ASSESSMENT OF NATIONAL HYDROPOWER DEVELOPMENT

Appendices

This work is a result of research sponsored by
the U.S. Army Engineer Institute for Water Resources
under Contract #DACW-72-81-C-0001

Prepared by:

NERO AND ASSOCIATES, INC.
520 S.W. 6th Avenue, Suite 820
Portland, OR 97204
(503) 223-4150

Approved: Kish J. Sharma, Ph.D.
President

Date: June 1981

CONTENTS

Section A

Selected Information and Data from NHS Sources

Section B-1

Institutional Relationships

Section B-2

Summary of Legislation Relevant to Hydropower Development

Section C

Some Notes on the Cost of Hydroelectric Installation

Section D-1

The Carbon Dioxide Issue

Section D-2

Air Pollution Issues

Section E

Energy and Technology Data and Projections Working Paper

Section F

Societal Scenarios

Section A

Selected Information and Data from NHS Sources

Prepared by:
Jack G. Johnson

TABLE OF CONTENTS

	Page
Introduction	1
Present Situation	1
Pumped Storage	11

LIST OF FIGURES

Figure A-1:	Regional Electric Reliability Council Areas	2
Figure A-2:	Generating Capability by Regional Electric Reliability Councils, Alaska, and Hawaii	4
Figure A-3:	Flow Chart of Screening Process Used by NHS	9

LIST OF TABLES

Table A-1:	U.S. Hydropower and Total Electric Generating Capability	5
Table A-1:	Notes	6
Table A-2:	Undeveloped Hydropower Potential	8
Table A-3:	Summary of NHS Regional Plans	10
Table A-4:	Pumped Storage Projects in the United States In Operation as of November 1, 1980	13
Table A-5:	Pumped Storage Projects in the United States Licensed and/or Under Construction, November 1, 1980	15

SELECTED INFORMATION AND DATA FROM NHS SOURCES

Introduction

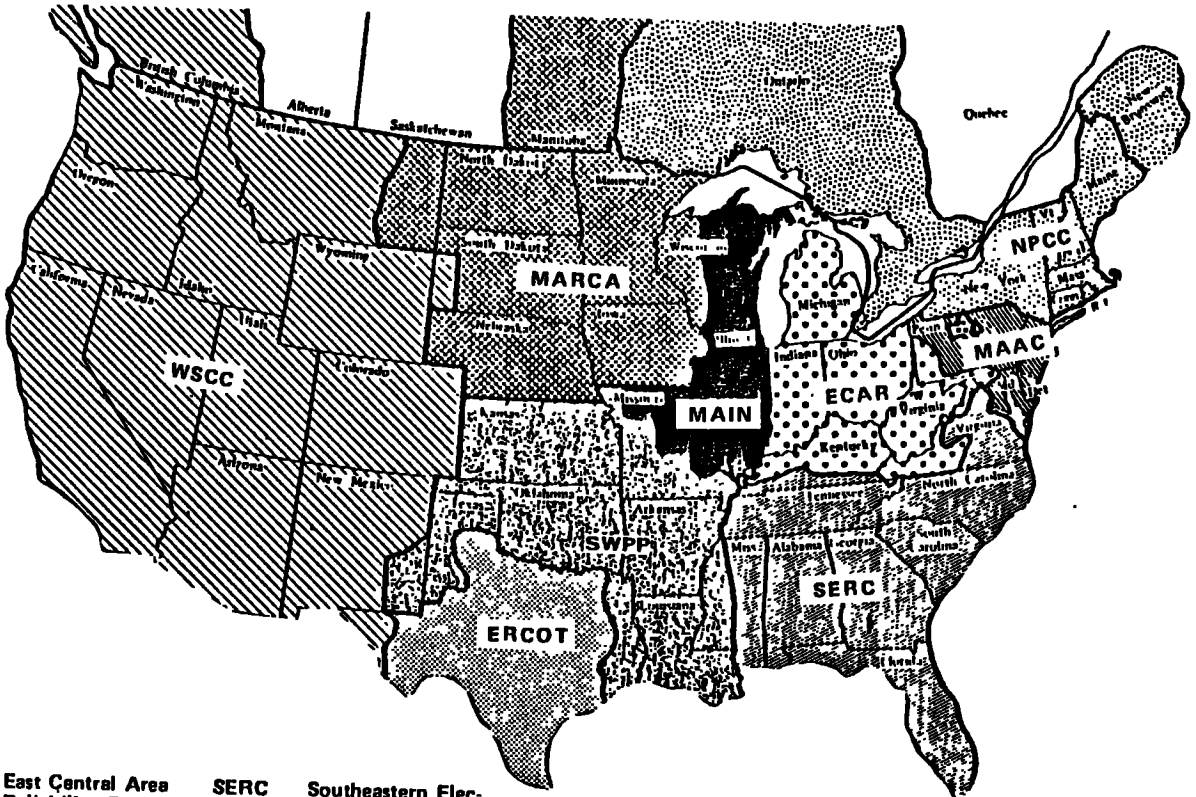
This section is intended as a consolidated source of basic information developed by the National Hydropower Study (NHS) and deemed useful for carrying out activities in the NHS Technology Assessment. Conversely, it is not intended as a comprehensive or all-inclusive source of information on hydropower—past and present—in the United States. It does not delve deeply into the details of environmental/economic/legal/institutional factors pertinent to hydropower (as these are addressed elsewhere), but rather focuses on such basic information as the total national generation capabilities, data on existing hydropower facilities and major identified potentials for hydropower development. While there are many sources of such information, this section and the Final Report draw primarily on information developed by the following NHS components:

- Harza Engineering Company, The Magnitude and Regional Distribution of Needs for Hydropower, Phase I-1978 Electric Power Demand and Supply, April 1979.
- Hydrologic Engineering Center, Potential for Increasing the Output of Existing Hydroelectric Plants, January 8, 1981.
- Dames and Moore, An Assessment of Hydroelectric Pumped Storage—Task 1, Investigation of the History of Pumped Storage, December 1980.
- INTASA Inc., in association with EDAW Inc. and Sverdrup & Parcel and Associates, Inc., National Hydropower Study Environmental Assessment, Draft Final Report, January 27, 1981.

A note of caution is in order regarding the nature and use of NHS information reflected in this discussion. Specifically, most of the other major NHS components were still in progress during much of the time this technology assessment itself was underway. Given the short schedule for the assessment, it was necessary to use information as it existed and to recognize that some of that information would be re-evaluated and reviewed, i.e., included in draft reports or documents not yet received and approved by NHS management and, therefore, subject to further revision as new information became available and as public and internal reviews progressed. Particularly difficult to accommodate was the fact that the NHS regional reports not only were evolving but their contents/formats were not completely or readily compatible for aggregation purposes. The short time frame also precluded significant efforts at accessing and manipulating the NHS data base (site inventory) to provide useful information for assessment purposes. Therefore, the reader is cautioned about using, some of the information contained herein on specific or detailed bases; where possible, the status of such information is identified.

Present Situation

This description of the present situation utilizes, for the most part, the nine Regional Electric Reliability Councils shown in Figure A-1 which cover the continental United States and comprise the National Electric Reliability Council (NERC). The



ECAR	East Central Area Reliability Coordination Agreement	SERC	Southeastern Electric Reliability Council
MAIN	Mid-America Interpool Network	SWPP	Southwest Power Pool
MAAC	Mid-Atlantic Area Council	ERCOT	Electric Reliability Council of Texas
NPCC	Northeast Power Coordinating Council	WSCC	Western Systems Coordinating Council

Source: U.S. Department of Energy, Electric Power Supply and Demand for the Contiguous United States, 1980–1989, June, 1980

Figure A-1.

REGIONAL ELECTRIC RELIABILITY COUNCIL AREAS

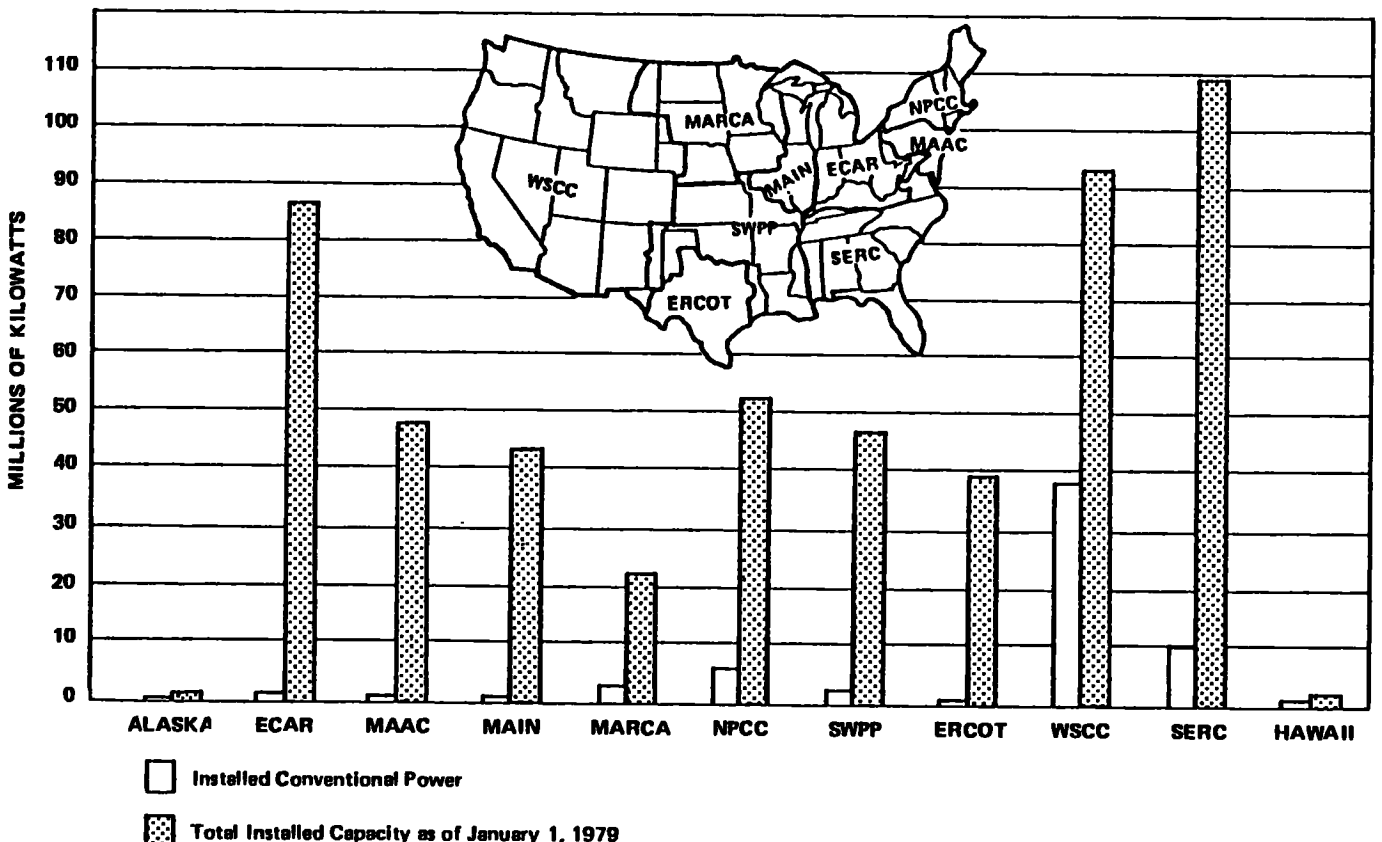
nine regions, plus Alaska and Hawaii, are the subdivisions used by one of the NHS contractors (Harza) and much of the information used herein was drawn from that study (Ref. 1). The present situation is described essentially for the study's base year which is 1978.

Developed hydropower capability totals about 73,000 MW (including about 10,000MW of pumped storage) and constitutes about 13 percent of the nation's total generating capacity. This amount of capacity produces an annual average energy generation of about 273 billion kilowatt hours per year (Ref. 2). According to Harza's Phase 1 report, as of January 1, 1978, hydropower was the third largest producer of electric power after coal and oil-fired steam plants; and in terms of total net electrical energy generated during 1977, however, hydropower accounted for only about 10 percent of the nation's total electric energy production being in fifth place after coal, oil, natural gas and nuclear. With respect to the role of hydropower in the present electrical system, the Harza report states:

> The function of hydroelectric power varies in different parts of the country and changes as its percentage of the national total continues to decline. In the Pacific Northwest hydropower provides variously baseload, intermediate load, and peakload generation. In other parts of the country, hydropower is primarily used for peakloads rather than for base. With adequate storage for flow regulation over daily or longer periods, most of the nation's hydroelectric powerplants provide rapid response to changes in system loads. In some power systems hydropower is the principal source of spinning reserve. Except for MARCA, ERCOT, Alaska, and Hawaii, pumped storage is currently being used throughout the country to meet peak system demands and improve the efficiency of baseload thermal plants by increasing their offpeak loading (Ref. 1).

The current role of hydropower in the United States, however, is complex and is best discussed on a regional basis as is done in the following text. Figure A-2 shows electric utility generating capability by regional electric reliability councils; and Table A-1 shows the distribution of total hydropower capability by reliability councils, type of generation and components of total generating capability.

The bulk of the nation's hydropower capability (58 percent) is in the Western Systems Coordinating Council (WSCC); following far behind is the Southeastern Electric Reliability Council (SERC) and the Northeast Power Coordinating Council (NPCC) with 14 and 11 percent, respectively (Ref. 1). For the WSCC, hydropower represents about 44 percent of its total generating capability; the next highest is about 15 percent each in the NPCC and Alaska. The WSCC's role as United States leader in development and utilization of hydropower is largely attributable to the Pacific Northwest, which contains over 70 percent of the WSCC's hydropower generating capacity.



Source: Ref. 1

Figure A-2.

GENERATING CAPABILITY BY REGIONAL ELECTRIC RELIABILITY COUNCILS, ALASKA, AND HAWAII

Table A-1

U.S. Hydropower and Total Electric Generating Capability[1]

Area/System/Region	HYDROPOWER CAPABILITY		TYPE OF HYDROPOWER (MW/Percent)		TOTAL (Hydro + Non-Hydro GENERATING CAPABILITY FOR THE AREA/SYSTEM/REGION		
	MW	Percent of U.S.Hydro	Conventional	Pumped Storage	Percent of Area: Hydro	Percent of Area: Convent. Pumped Storage	Total Capability[2] (MW)
Western Systems Coordinating Council (WSCC)	40,709	57.5	38,816 / 95.3	1,893 / 4.7	43.8	(41.8 / 2.0)	92,929
Southeastern Electric Reliability Council (SERC)	10,164	14.4	9,276 / 91.3	888 / 8.7	9.5	(8.7 / 0.8)	106,901
Northeast Power Coordinating Council (NPCC)	7,956	11.2	5,324 / 66.9	2,632 / 33.1	15.2	(10.1 / 5.1)	52,009
East Central Area Reliability Coordination Agreement (ECAR)	3,275	4.6	898 / 27.4	2,377 / 72.6	4.1	(3.0 / 1.1)	83,886
Mid-Continent Area Reliability Coordination Agreement (MARCA)	2,781	3.9	2,781 / 100.0	-- / --	12.7	(12.7 / --)	21,847
Southwest Power Pool (SWPP)	2,506	3.5	2,218 / 88.5	288 / 11.5	5.7	(5.0 / 0.7)	43,692
Mid-Atlantic Area Council (MAAC)	2,233	3.4	947 / 42.4	1,286 / 57.6	4.7	(2.0 / 2.7)	46,783
Mid-America Interpool Network (MAIN)	875	1.2	575 / 65.7	300 / 34.3	2.1	(1.4 / 0.7)	41,285
Electric Reliability Council of Texas (ERCOT)	230		230[3] / 100.0	-- / --	0.6	(0.6 / --)	37,029
Alaska	132	0.3	132 / 100.0	-- / --	14.5	(14.5 / --)	908
Hawaii	3		3 / 100.0	-- / --	0.2	(0.2 / --)	1,462
TOTALS	70,864		61,200 / 86.4	9,664 / 13.6			

See next page for notes.

Table A-1

NOTES

1. These data represent plants reported to DOE by Reliability Councils. In addition, there are small unreported plants (primarily industrial and municipal), the capabilities of which are approximately as follows (in MW):

   ECAR - 206
   ERCOT - 109
   MAAC -
   MAIN - 104
   MARCA - 173
   NPCC - 461
   SERC - 106
   SWPP - 94
   WSCC - 251
   Industrial plants in Hawaii - about 16

   U.S. Total - 1,476

2. Subscripts "s" and "w" denote that the figure given is for the summer or winter period, respectively.

3. Includes only ERCOT members; there is, in Texas, an additional 313MW capacity reported by utilities and approximately 109MW for unreported plants.

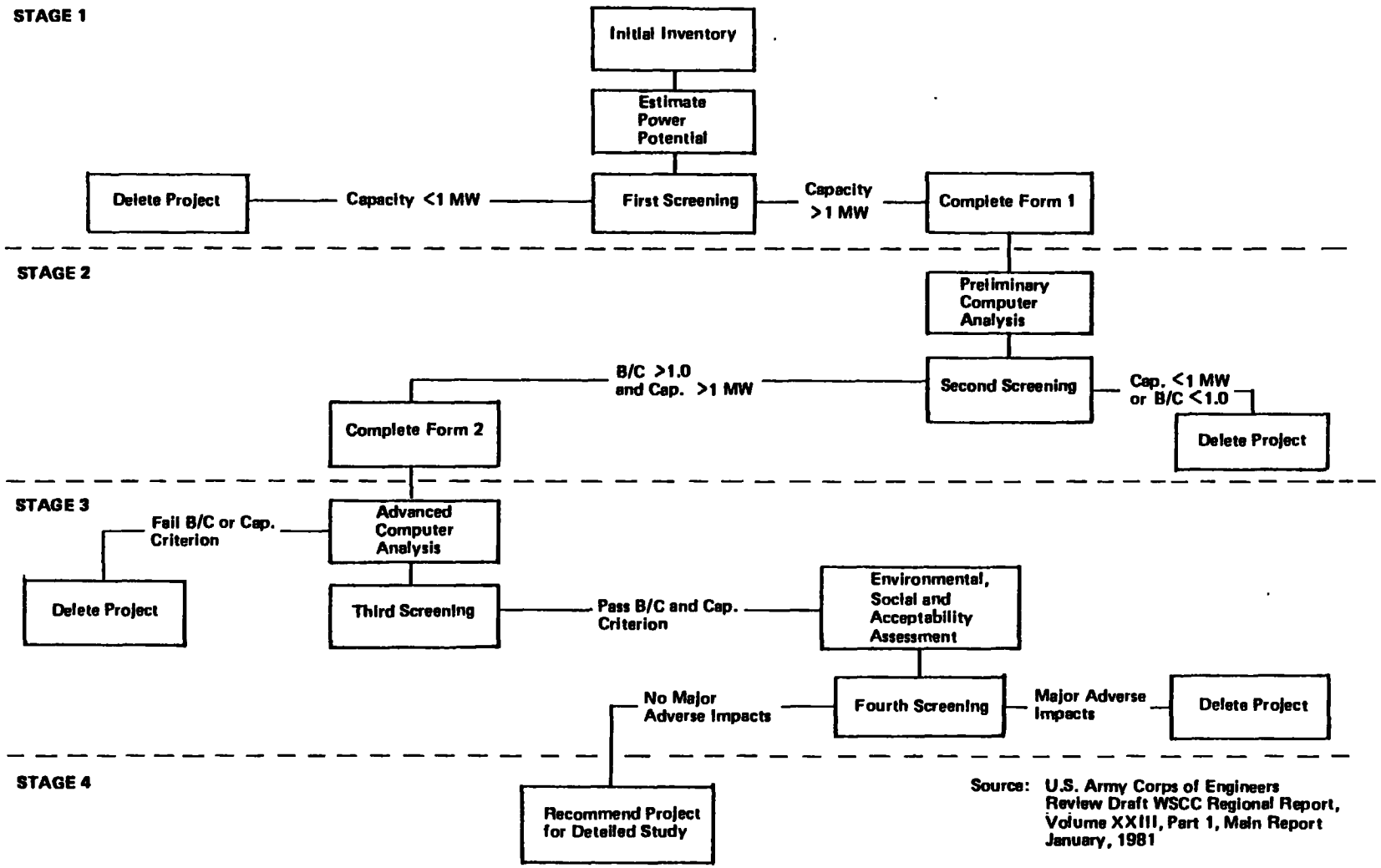
4. Source: Harza Engineering Co., NHS Phase I report, April 1979.

Table A-2

Undeveloped Hydropower Potential[1]

Area/ System/ Region	Undeveloped[2] Sites (> 5 MW)		Undeveloped at[3] Existing Dams		Total Potential	
	Potential Installed Capacity (MW)	Average Annual Energy (000 MWh)	Potential Installed Capacity (MW)	Average Annual Energy (000 MWh)	Potential Installed Capacity (MW/Pct.)	Average Annual Energy (000 MWh)
ECAR	4,844	14,968	4,143	10,135	8,987 (5.8%)	25,103
MAAC	2,634	6,522	1,441	3,550	4,075 (2.6%)	10,072
MAIN	641	2,346	1,295	4,298	1,936 (1.2%)	6,644
MARCA	2,700	8,140	5,090	13,300	7,790 (5.0%)	21,440
NPCC	3,987	9,795	8,545	29,800	12,532	39,595
SERC	6,700	12,054	9,412	35,595	16,112 (10.4%)	47,649
SWPP	1,670	3,880	5,910	16,990	7,580 (4.9%)	20,780
WSCC	42,720	141,970	18,090	45,550	60,810 (39.2%)	187,520
ERCOT	1,070	1,570	750	1,880	1,820 (1.2%)	3,450
Alaska	33,250	175,665	119	535	33,369 (21.5%)	176,200
Hawaii	35	229	33.5	57.4	68.5 (0.04%)	286.4
TOTAL	100,251	377,139	54,828.5	161,600.4	155,079.5	538,739.4

1. Compiled from data in NHS report by Harza Engineering Co. "The Magnitude and Regional Distribution of Needs for Hydropower," Phase II. July 1980.
2. Based on data reported as of January 1, 1976, by FERC in report "Hydroelectric Power Resource of the United States"
3. Based on data in 1977 Corps of Engineers report "Estimate of National Hydroelectric Power Potential at Existing Dams".



Source: U.S. Army Corps of Engineers Review Draft WSCC Regional Report, Volume XXIII, Part 1, Main Report January, 1981

Figure A-3.

FLOW CHART OF SCREENING PROCESS

Table A-3

Summary of NHS Regional Plans (Potentials recommended for further study)*

REGION	Near-Term			Long-Term			Total		
	No. of Sites	Incr Cap. (MW)	Incr. Ener. (GWh)	No. of Sites	Incr. Cap. (MW)	Incr. Ener (GWh)	No. of Sites	Incr. Cap. (MW)	Incr. Ener (GWh)
NPCC	539	2,329	8,330	116	2,497	8,372	655	4,826	16,702
MAAC	26	493	1,155	21	467	670	47	960	1,825
ECAR	100	1,920	7,460	94	2,520	5,700	194	4,440	13,160
SERC	83	1,333	2,033	100	5,415	11,486	183	6,748	13,519
MAIN	77	741	2,555	9	165	733	86	906	3,288
MARCA	46	1,022	1,573	2	24	81	48	1,046	1,654
SWPP	52	997	3,531	50	1,247	3,816	102	2,244	7,347
ERCOT	16	135	290	36	469	952	52	604	1,242
WSCC	323	9,969	16,665	296	21,605	57,569	619	31,574	74,234
Alaska	10	44	291	49	3,518	15,141	59	3,562	15,432
Hawaii	6	12	37	10	31	119	16	43	156
Subtotal	1,278	18,995	43,920	783	37,958	104,639	2,061	56,953	148,560
Puerto Rico	13	35	109	4	24	71	17	59	180
TOTAL	1,291	19,030	44,029	787	37,982	104,710	2,078	57,012	148,740

* Per draft regional reports of January 1981 and as compiled by NHS management staff

Nor has WSCC's hydropower potential been fully developed. As shown in Table A-2, based on pre-NHS site-inventory data and revised significantly downward by the NHS in late 1980, the WSCC has over 39 percent of the nation's remaining undeveloped hydropower potential with much of the region's potential located in the Pacific Northwest portion. The national potential identified at this early time totaled about 155,000 MW of installed capacity, divided about two-thirds at presently undeveloped dam sites exceeding 5 MW potential and about one-third at existing dams where additional generating units and/or improved facilities and equipment could be installed. In terms of potential, the runner-up is Alaska with about 22 percent. However, Alaska's considerable potential is comprised primarily of undeveloped sites, most of which are not needed to meet the state's relatively small loads and are remote from load centers both in Alaska and the contiguous states.

It should be noted, also, that Table A-2 excludes potentials equal to or less than 5 MW, but the excluded amount of potential dependable capacity is not considered significant on a national basis. DOE officials are quoted as estimating that small-scale sites (up to 15 MW) presently provide only 3,000 MW (Ref. 3). There is wide variance with respect to estimates of the potential of small-scale hydropower, ranging from 3,000 MW to the Corps' preliminary inventory figure of about 13,000 MW. Because many of these sites are on intermittent streams, dependable capacity will probably not be high. However, in terms of energy credit, the sites may have significant value.

Later in the NHS study, analyses of the hydropower potential resulted in a significantly lower estimate than those shown in Table A-2. As a result of the Corps' three-stage screening process, illustrated in Figure A-3, a preliminary list was issued recommending potentials meriting further study. A summary of the recommendations, essentially as of January 1981, is provided by Table A-3, its data being compiled from the Corps' NHS "review-draft" regional reports. The reader is cautioned that the dynamic status of the information dictates that the table be used only for general illustrative purposes. In fact, it appears that the figures for the WSCC region will undergo even further reduction as a result of public review and comment.

Illustrative of the substantial impact of the screening processes are the following data from the WSCC review draft report of January 1981 (Ref. 4). The initial regional inventory of sites listed 15,560 sites (including mutually-exclusive alternative projects) to be subjected to the screening process. According to the Corps' report:

> Through analysis of these initially inventoried projects, it was found that, for the region as a whole 2,212 projects have an etimated power potential of 1 MW or more, while only 897 are potentially economically feasible, based on estimated total project costs. Analyses to date of potential non-economic constraints to the development of potentially economically feasible projects indicate that 619 projects are suitable for further study by reason of not having severe environmental, social, or other limitations.

The total estimated capacity of the 2,212 sites is 108,743 MW; the estimated energy is 221,211 GWh. For the 619 sites, the comparable totals are 31,574 MW and 74,234 GWh.

In the United States, hydropower has been most beneficial in the role of providing power to meet peakloads due to its capability to respond quickly to changing loads. On an annual basis peakloads occur in either the winter or the summer, depending upon the geographical area served. In most areas of the United States the annual peak occurs in the summer due to air-conditioning demands, while in the Pacific Northwest heating demands cause the peak to occur in winter. Additional flexibility, reliability and capability in meeting loads are provided by the interconnections between power systems and regions which allow interchanges of power to occur. Seven of the NERC regions are strongly inter-connected and essentially constitute a single network (ECAR, MAAC, MAIN, MARCA, NPCC, SERC, SWPP) wherein the interconnections are adequate for the exchange of significant amounts of power in emergencies. In addition, there are major interties between subregions of the large WSCC region (such as PNW/PSW intertie).

Pumped Storage[1]

Pumped storage is a means of utilizing hydropower potential to better serve an area's unique load characteristics. In the typical configuration, a higher elevation surface reservoir is filled with water by pumping from a lower elevation surface reservoir during offpeak periods when demand is low and excess capacity is available (when low-cost thermal or other baseload energy is available or when water is being spilled at other hydropower plants). During times of peakload, the stored water can then be released to meet peak demand. Another configuration is to utilize an underground reservoir to receive the water from the higher reservoir when the project is generating power. In all cases, the capability of a project to generate intermediate or even baseload power is dependent upon the water storage capacity.

Although the objectives of pumped storage facilities have changed dramatically over the last 50 years, the common purpose of almost all such plants is to store energy for use during peak demand periods when generally larger baseload electric generating plants are inadequate or inefficient.

Pumped storage plants are best utilized to meet the peak demands which occur daily since their quick response and easily regulated output capability cannot be matched by larger fossil fueled or nuclear plants. The pumping energy for the pumped storage plant is obtained during offpeak hours which also allows the baseload fossil fueled and nuclear plants to operate at a more level output and therefore more efficiently. As a result, even though pumped storage plants roughly use 3 kilowatts of pumping energy for every 2 kilowatts of generation output, they are economical to construct and operate due to the increased efficiency of the entire, integrated electric generating system of a utility. In addition, they may at the same time allow postponing of construction of new, costly baseload plants.

In summary, although pumped storage plants provide reliability, flexibility, spinning reserve and voltage regulation, actual justification of the plants has been based primarily on net savings in total annual production costs for an entire system when compared to alternatives to pumped storage. Over the last 30 years, pumped storage has done very well in the comparison. Furthermore, pumped storage plants are fulfilling an increased role in a modern utilities system, often supplying the intermediate load as well as peak demand for long periods each day. Utilization factors up to 25 percent are common for plants which were originally justified at factors as low as three to five percent.

Nationally, pumped storage represents about 14 percent of the total hydropower generating capability, and is located predominantly in the eastern third of the United States. In the ECAR area, pumped storage totals 2,377 MW and represents about 73 percent of the area's relatively small capability. The pumped storage projects are of great importance to the ECAR system because they increase minimum loads during offpeak hours, thereby improving the efficiency of baseload thermal units. By contrast, 1,893 MW exist in the WSCC area, but that amount represents only 4.7 percent of that area's hydropower capability.

Table A-4 lists the pumped storage projects now in operation in the United States.

Table A-5 lists the pumped storage projects now under construction and/or licensed by FERC. The total capacity to be added to the nation's generating capability when and if these projects are complete is 9,346 MW.

TABLE A-4

PUMPED STORAGE PROJECTS IN THE UNITED STATES
In Operation as of November 1, 1980

Project or Plant name	State	Owner or developer	Year of initial operation	Installed Capacity in megawatts: Reversible	Installed Capacity in megawatts: Conventional	Installed Capacity in megawatts: Total
Rocky River	Connecticut	Connecticut Light and Power Co.	1929	7*	24	31
Buchanan	Texas	Lower Colo. River Authority	1950	11*	23	34
Flatiron	Colorado	Water and Power Resource Service	1954	9	63	72
Hiwassee	North Carolina	Tennessee Valley Authority	1956	60	57	117
Lewiston	New York	Power Authority of the State of New York	1961	240		240
Taum Sauk	Missouri	Union Electric Co.	1963	408		408
Yards Creek	New Jersey	Jersey Cntl. P. & L. Co., Public Service E. & G. Co.	1965	387		387
Smith Mountain	Virginia	Appalachian Power Co.	1965	236	300	536
Cabin Creek	Colorado	Public Service Co. of Colorado	1966	300		300
Senator Wash	California	Water and Power Resources Service	1966	7		7
Muddy Run	Pennsylvania	Philadelphia Electric Co.	1967	800		800
O'Neill	California	Water and Power Resources Service	1967	25		25
Thermalito	California	California Department of Water Resources	1968	82	33	115
Edward G. Hyatt	California	California Department of Water Resources	1968	293	351	644
Salina	Oklahoma	Grand River Dam Authority	1968	260		260
San Luis	California	Water and Power Resources Service	1968	424		424
Kinzua	Pennsylvania	Cleveland Elec. Illum. Co. & Pennsylvania Elec. Co.	1970	396	26	422
Degray	Arkansas	Corps of Engineers	1971	28	40	68
Mormon Flat	Arizona	Salt River Project Power District	1971	47	9	56
Horse Mesa	Arizona	Salt River Project Power District	1972	97	34	131
Northfield Mtn	Massachusetts	Connecticut Light and Power Co.	1972	1,000		1,000

*Turbines are not reversible. Separate pumps are used.

Source: Dames and Moore, An Assessment of Hydroelectric Pumped Storage: (Draft) December, 1980.

TABLE A-4 (cont'd)

PUMPED STORAGE PROJECTS IN THE UNITED STATES
In Operation as of November 1, 1980

Project or Plant name	State	Owner or developer	Year of initial operation	Installed Capacity in megawatts		
				Reversible	Conventional	Total
Ludington	Michigan	Consumers Power Company & Detroit Edison Co.	1973	1,978		1,978
Blenheim-Gilboa	New York	Power Authority of the State of New York	1973	1,000		1,000
Castaic	California	Los Angeles City & State of California	1973	637	56	693
Grand Coulee	Washington	Water and Power Resources Service	1973	314		314
Jocassee	South Carolina	Duke Power Company	1974	612		612
Bear Swamp	Massachusetts	New England Power Co.	1974	600		600
Carters	Georgia	Corps of Engineers	1975	250	250	500
Raccoon Mtn.	Tennessee	Tennessee Valley Authority	1979	1,530		1,530
Fairfield	South Carolina	South Carolina Elec. & Gas Co.	1979	518		518
Wallace	Georgia	Georgia Power Company	1980	216	108	324
			Total	12,772	1,374	14,126

TABLE A-5

PUMPED STORAGE PROJECTS IN THE UNITED STATES
LICENSED AND/OR UNDER CONSTRUCTION, November 1, 1980

Project or Plant name	State	Owner or developer	Capacity in Megawatts Reversible	Conventional	Total
Harry S. Truman	Missouri	Corps of Engineers	160		160
Clarence Cannon	Missouri	Corps of Engineers	31	27	58
Helms	California	Pacific Gas and Electric Co.	1,050		1,050
Bath County	Virginia	Virginia Electric and Power Co	2,100		2,100
Rocky Mtn.	Georgia	Georgia Power Co.	675		675
Bad Creek	South Carolina	Duke Power Co.	1,000		1,000
Montezuma	Arizona	Arizona Power Authority	505		505
Davis	West Virginia	Allegheny Power System	1,025		1,025
Seboyeta	New Mexico	Public Service Co. of New Mexico	600		600
Mt. Elbert	Colorado	Water and Power Resources Service	200		200
Cornwall	New York	Consolidated Edison Co. of N.Y.	2,000		2,000
		Total	9,346	27	9,373

Source: Dames and Moore, An Assessment of Hydroelectric Pumped Storage: (Draft) December, 1980.

REFERENCES

1. Harza Engineering Company. The Magnitude and Regional Distribution of Needs for Hydropower, Phase I-1978 Electric Power Demand and Supply. April 1979.

2. Hydrologic Engineering Center. Potential for Increasing the Output of Existing Hydroelectric Plants. January 8, 1981.

3. Bureau of National Affairs, August 28, 1980.

4. U.S. Army Corps of Engineers, North Pacific Division. "Review Draft, National Hydroelectric Power Study Inventory of Potential Hydropower Projects, Western Systems Coordinating Council Region, Main Report." January 1981.

FOOTNOTES

1. Principal source of pumped storage information is the Dames and Moore NHS draft report, An Assessment of Hydroelectric Pumped Storage—Task 1, Investigation of the History of Pumped Storage. December 1980.

Section B-1

Institutional Relationships

Prepared by:
Edward Wenk, Jr.

This is an abbreviated version of a paper entitled "Political and Institutional Effects of National Hydropower Development—Proposals for Mitigating Measures." Copies are available from Nero and Associates, Inc.

TABLE OF CONTENTS

	Page
Public/Private Relationships	1
Historical Note	1
Analysis	2
Institutions and Individuals	3
Criteria	3
Federal, State, and Regional Government Relationships	4
Historical Note	4
Analysis	5

INSTITUTIONAL RELATIONSHIPS

Public/Private Relationships

Historical Note

From both the Declaration of Independence and the Constitution, it is clear that the nation was founded on premises of a balanced public/private partnership. The national government was expected to provide for the common defense, a system of law and justice, a common currency, and for stewardship (yet undefined) of public lands. Most economic functions were left to the private sector. Federal authority was severely delimited in favor of the states. This was consistent with cultural norms of self-reliance, commitment to material progress and a tradition of individualism. Indeed, private development of public resources went unchecked for a century.

From the outset, however, the federal government acted to stimulate the private sector's growth and health—with navigation aids to the merchant marine (1807 creation of the Coast Survey), assistance in private construction of barge canals (1824), land grants and surveys for the westward extrusions of railroads (1850's), weather forecasting, research and educationl activities to heighten productivity of farming (1862), geological surveying to help mining (1879), research in aeronautics (1915). Later, government was obliged to initiate a different role as watchdog over entrepreneurial enterprise, to assure public safety (on steamboats and railroads, 1838; mines, 1910), public health (around 1902), protection of the public from excesses of private exploitation (child labor) competition, and monopoly: and, in a limited way, to assure conservation of natural resources (1905). During the great Depression, the federal government with popular support extended its traditional boundaries in order to deal with the breakdown of the private enterprise system in providing employment. Unprecedented impetus was given to the concept of social welfare. And as part of that concept, the government entered certain technological areas as promoter and developer, especially of water resources and hydropower (TVA and BPA). Arrangements such as the "preference clause" triggered battles over public-private roles that still influence the current scene. The New Deal also triggered a stream of new regulatory functions.

With World War II, the federal government dramatically increased support for scientific research and development. Its share rose from perhaps 20 percent of the national total to over 70 percent. At present, it still contributes over 50 percent. The government helped build and sustain a defense industry by contract. That involvement continues. After the war, federal promotion of technology grew in new directions. The government promoted a national highway network, a massive space program, nuclear materials production, health research and care, a passenger railroad system, and lately alternative forms of energy. All are instances where planning, funding and management by federal authority were coupled to private sector participation. Recent history demonstrates a surge of regulation over public health and safety, environmental and consumer protection, nature conservancy, and over the marketing practices of privately produced goods and services (fossil fuels, airlines).

A number of federal agencies created after 1945 were technologically based. All were expected to interact closely with the private sector: the Atomic Energy Commission, NASA, the National Institute of Health, and the National Science Foundation are good examples.

A new round of public/private linkages has recently occurred. Issues center on energy production (solar, synfuels, oil decontrols), tariff protection against foreign competition, assistance to slumping industries (e.g., Chrysler), proposals to accelerate tax benefits through rapid depreciation, and attempts to drastically reduce government regulation. While the direction of this trend toward conservative economic policy is clear, long-term effects are not.

Over the nation's 200-year history, states and municipalities have also become involved in public/private sector relationships. For example, toll roads, fire protection, and water supplies initially developed by private entrepreneurs were taken over in the 19th century by state and municipal authorities. States and municipalities often became primary agents for public works, built by contractors but operated by public authority. Public authorities also took over much responsibility for power/electric supply and urban transit. And at the same time, many public bodies introduced lures to industry to relocate and contribute to their regional economy. Lately, states have indicated a desire to reinforce their own authority over industrial regulation, public health and safety, and environmental protection, independent of the federal government.

Analysis

This brief history reveals that the question of "appropriate" division of roles between public and private sector has not been subject to doctrinaire delineation. Role divisions fluctuate. Roles change over time, depending much on the need for a collective response to exogenous factors, i.e., military or economic threats, perceived threats to the quality of life; or unprecedented technological opportunities, sometimes advanced by a powerful lobby. These roles also change in response to shifts in public attitudes. To be sure, certain basic traditions fix role boundaries. National security, for example, is almost exclusively a federal responsibility; production of consumer products and services is a private responsibility. Public works directly serving citizens (water, sewer and highways) are largely a state or local responsibility; public health and safety are a shared federal/state/local responsibility; public welfare, similarly, is no longer only a private sector responsibility.

As an example of role division fluctuation, hydropower is a case in point. It is characterized by a widespread mix of federal, public nonfederal and private investor-owned entities. Few identifiable generic principles of political theory act to stake out fixed and permanent roles. Development practices have tended to depend on circumstances at a particular time. Many regions, such as the Pacific Northwest and the Tennessee Valley, have their own historical traditions of government.

The federal government moved first into massive hydropower promotion and development only when a public works consensus was forged during the Depression. This consensus was also precipitated by public outrage over investor-owned monopolistic practices of previous years. Similarly the federal government entered the realm of environmental regulation in the 1970's with increasing vigor after a wave of popular concern over the environment.

Federal involvement as a direct hydropower developer (not regulator) has followed patterns that emphasize a number of fundamental considerations, including: national security, mitigation of economic dislocation; need for economies of scale; inadequate or nonexistent service by private sector of public needs; and national/regional economic development. The system has nevertheless shown a preference for private sector responsibility where all other factors are equal, or where many of these fundamental factors are not present.

Institutions and Individuals

While the appropriate public/private role depends on a constantly shifting social context, there is a second source of influence—those institutions and their individual leaders who have a stake in the outcome.

The question of balance in roles can be blurred by the fact that key choices as to role balance are made by government, one of the contenders for position. Obviously, however, the President and Congress are obliged to be far more responsive to a broad constituency and sensitive to the public good than any given entrepreneur. Entrepreneurs tend to desire freedom from governmental regulation, but often seek privileges, subsidies, and other incentives. So the special interests do not always reveal a fully predictable, doctrinaire approach to "appropriate" balance.

There are others with concern over who wins and loses, however, who have had a major voice in public decisions in the last decade—public interest groups. Rather than expressing a doctrinaire preference for either a strong public or private role, such groups have focused attention on the many first and second order impacts of various public and private actions. For hydropower development, the Army Corps of Engineers, for example, has by no means been subject to less scrutiny than private utilities or developers.

Criteria

This leaves an opportunity to consider what is appropriate in order to produce desireable overall social performance.

Here, four different classes of criteria may be used to judge social performance. Hydropower output, at minimum, should be delivered with:

- Least cost and highest reliability;
- Conservation of present and future resources;
- Equitable assessment of costs and delivery of benefits;
- Minimum disruption to the environment and the affected public.

Current policy initiatives and past history tell us that nonfederal hydropower development initiatives will be encouraged at most projected levels of hydropower delivery, unless a national emergency is perceived which warrants governmental intervention. We already regard this as a necessary condition for hydropower development at Level III. Incentives to pool federal and nonfederal planning should be continued and encouraged. This leaves next the question of federal, state and regional relationships.

Federal, State, and Regional Government Relationships

Historical Note

In the first years of the nation, states possessed both the political power reserved them by the Constitution and as much as could be extracted in practice. Except for military security and foreign policy, the federal government only infrequently entered new technological fields. States tried to block creation of a new Department of the Interior around 1849, although management of federal lands was eventually recognized as an essential function beyond geographic fragmentation. Nevertheless, the state's role remained predominant even after the federal Department of Agriculture was created and programs established state experiment stations and land grant colleges. The states rights issue exploded in the Civil War, but thereafter seemed dormant until federal initiatives during the Great Depression. Federal rights to preempt water in the West remain, in accord with historic federal incentives seeking to accelerate settlement in the wilderness. But the states rights issue is still with us, as the Sagebrush Rebellion indicates.

The surge in federal activity during the Great Depression was marked by new programs and funding, but except for hydropower, long-term implementation was generally left to the states. In the case of highways, federal funding assistance first became available in the 1920's, but on condition that each state establish a central highway commission for technical planning and supervision. This pattern was reinforced with the 1956 Highway Trust Fund. Then, the federal government established construction standards as a condition of grant awards. This domination was universally accepted largely because of preparatory work by professional guilds—state and federal highway engineers collaborating through a highway research board of the National Research Council.

As federal government size and influence grew, states repeatedly called for exercise of their "rights," but such calls were ironic. As more and more federal money became available to upgrade roads, water supplies and sewage plants, competent state pass-through bodies were created to receive the federal funds. And federal grants

carry federal mandates. Since 1958, the total expenditures by state and local government have drawn increasingly on federal sources, rising from 12 to well over 30 percent of the total. The structure of partnership has now become crystallized, with extensive functional networks coupling state agencies and their federal counterparts. The primary controversies arose over whether programs linked the federal government to states or directly to municipalities. In the latter case, some state involvement was generally maintained. There were also complaints by states that federal projects or actions imposed an undue burden of side effects on states that deserved compensation, as with military base construction, dam construction, offshore leasing for oil/gas development.

Various devices have been invoked in recent years to facilitate partnerships and to improve federal sensitivity to problems and opportunities at state levels that are otherwise ignored—especially of need for flexibility to meet diverse situations. Creation in 1976 of an intergovernmental consultative body attached to the office of the President's science advisor never fully attained that function, and its future seems uncertain, at the present time. But the requirement for reciprocal communications and symmetry in relationships is crucial for harmony and effective governance.

On the regulatory side, including public health, safety and consumer protection, individual states have established a variety of statutory mechanisms often parallel to and connected with federal activities. In a few cases they are relatively independent, for example in energy facility siting. In a few states, new energy policy offices have established high levels of expertise in demand forecasting. The overlap between federal and state activities has led to occasional conflict in areas such as environmental protection, nuclear power safety, marine safety on Puget Sound, and Indian fishing rights. Resolution is frequently afforded only by the courts.

For functional areas that cross state boundaries, regional entities have been created, but have not widely proliferated. River basin commissions constitute the primary example for management of water resources. Similar regional "commissions" have recently been established (1976) to manage salt water fishery stocks within the 200-mile limit. In the Pacific Northwest, at least five different regional networks link energy facilities, and the Bonneville Power Administration has been given responsibility under an advisory council with state representation for electrical power planning and conservation (1980). In all, location of many natural, including energy, resources themselves clearly crosses political boundaries. Though states are often explicitly represented in regional management, their exercise of power tends to be reflected more through daily administration rather than through broad state policy input. Nevertheless, states have been reluctant to relinquish authority to regional bodies, and have tended to do so only when it suited their interests.

Analysis

As with federal/private relationships, federal/state relationships have evolved through patterns that are regionally diverse. Changes have occurred primarily in the context of economic and technological developments, national crises, or shifts in public preferences. Until recently, the trend was toward a greater federal role, often prompted by greater availability of funds through federal sources.

Like the federal government, states reflect a built-in conflict between development and conservation. Most states have agencies devoted to both constituencies, and the ebb and flow of influence varies. Except for the decade of the '70s, developmental interests have tended to predominate, and states often took overt initiaties to lure industry relocation. On occasion, only a federal incentive such as coastal management grants have driven states to emphasize the encouragement of conservation and environmental protection.

One further consideration should be highlighted. Even where the federal government takes the initiative and provides most of the funds, as with highways, implementation can vary enormously from state to state. Such diversity can be expected in other situations where the state is a partner—especially if states assume greater power in a federal/state partnership.

Recently, a trend is gaining impetus which could reduce the size, budget, and influence of the federal government. This is certainly the hallmark of the current administration. If this trend continues, federal functions can conceivably be taken over by the private sector in areas with a certain economic return: hydropower development is one example. Nevertheless, among those functions abandoned by the federal government, but deemed important though uneconomic for the private sector, individual states may be obliged to exercise a stronger role. This decentralization may be advantageous in putting decisions closer to the citizen and thus ensuring greater participation in important, public processes. It will certainly impose new demands for state funding which may collide with strong sentiment for tax relief. It will also place new demands on states for technical expertise. Such capability is often lower than federal technical capability, so that new demands will arise for adequate staffing. Decentralization may also be expected to impose pressures to improve state administration over licensing procedures.

FOOTNOTES

1. The Interstate Commerce Commission, the Federal Trade Commission, and the Civil Aeronautics Board are a few examples.

Section B-2

Summary of Legislation Relevant to Hydropower Development

Prepared by:
David C. Olson

Table of Contents

		Page
I.	Fundamental Sources of Authority	1
	A. Over Nonfederal Development	1
	a. Federal Energy Regulatory Commission (FERC)	1
	1. Federal Power Act	1
	B. Over Federal Development	2
	a. Water Resources Council (WRC)	2
	1. Water Resources Planning Act of 1965	2
	2. Principles & Standards	2
	3. Procedures	2
	C. Over Federal Developers	3
	a. Army Corps of Engineers (Department of Defense)	3
	1. U.S. Const.	3
	2. 33 U.S.C.	3
	3. Rivers & Harbors Act of 1912	3
	4. Flood Control Act of 1917	3
	5. Water Resources Development Act of 1976	3
	b. Water & Power Resources Service (Department of Interior)	4
	1. Reclamation Act of 1902	4
	2. 43 U.S.C.	4
	3. Small Reclamation Projects Act of 1956	4
	c. Tennessee Valley Authority	4
	1. Tennessee Valley Authority Act of 1933	4
II.	Legislative History and Framework for the "Preference Clause"	5
	1. Desert Land Act of 1988	5
	2. Town Sites & Power Development Act of 1906	5
	3. Raker Act of 1913	5
	4. Federal Water Power Act of 1920	5
	5. Boulder Canyon Project Act of 1928	6
	6. Tennessee Valley Authority Act of 1933	6
	7. Rural Electrification Administration Act of 1936	6
	8. Bonneville Project Act of 1937	6
	9. Fort Peck Project Act, Reclamation Act of 1939, Water Conservation Act	6
	10. Flood Control Act of 1944	6
	11. Pacific Northwest Electric Power Planning & Conservation Act of 1980	6

		Page
III.	Environmental Legislation Relevant to Hydropower Development	7
1.	Fish & Wildlife Coordination Act (1934)	7
2.	Federal Power Act (1920; 1935)	7
3.	Heritage Conservation Act of 1963	7
4.	Wilderness Act (1963)	8
5.	Federal Water Projects Recreation Act of 1965	8
6.	National Historic Preservation Act of 1966	8
7.	Archeological & Historic Preservation Act of 1974	8
8.	Wild & Scenic Rivers Act of 1968	8
9.	National Trails System Act (1968)	9
10.	National Environmental Policy Act of 1969	9
11.	Clean Air Act (1969; 1979)	9
12.	Clean Water Act (1972; 1977)	9
13.	Coastal Zone Management Act of 1972	10
14.	Endangered Species Act of 1973	10
15.	Resource Conservation & Recovery Act of 1976	11
16.	Toxic Substance Control Act of 1976	11
17.	Federal Lands Policy & Management Act of 1976	11
IV.	Hydropower Development and Finance Incentives	11
1.	"Pickett" Act of 1910	11
2.	Public Utility Regulatory Policies Act of 1978 (PURPA)	12
3.	Crude Oil Windfall Profits Tax Act of 1980 (COWPTA)	13
4.	Energy Security Act of 1980 (ESA)	14

SUMMARY OF LEGISLATION RELEVANT TO HYDROPOWER DEVELOPMENT

I. FUNDAMENTAL SOURCES OF AUTHORITY

A. OVER NONFEDERAL DEVELOPMENT

a. Federal Energy Regulatory Commission (FERC)

1. Federal Power Act, 16 U.S.C. §§ 791 et seq. (FPA)

The FPA defines the institutional parameters of the Federal Energy Regulatory Commission (FERC; formerly the Federal Power Commission). FERC is the principal federal agency responsible for the regulation and oversight of nonfederally constructed hydroelectric dams in the United States. FERC regulates construction and operation of hydroelectric dams under Part I of the FPA (1920), and sale and transmission of electricity in interstate commerce under Part II of the FPA (1935). FERC is charged with enforcement of and coordination with a large number of federal and state laws which regulate or affect various aspects of hydropower development. Many of these laws are cited elsewhere in this Section.

FERC licenses four types of hydroelectric power projects:

- Projects located on navigable waterways;
- Projects affecting interstate commerce;
- Projects utilizing federal lands; and
- Projects which utilize surplus water or water power from federal dams.

FERC has authority to issue preliminary permits, licenses, and exemptions in certain instances. FERC also has the power to dedicate public lands for use as hydroelectric sites, give its licensees the power of eminent domain, and assess annual charges based on administration, use of government lands, dam use, headwater benefits, and water storage. FERC programs are self-supporting through the use of these fees.

FERC processes must be coordinated with other federal and state agencies. FERC cannot issue a license affecting the navigable capacity of a waterway without the approval of the Corps of Engineers. FERC will not license a site designated by Congress for study by a federal development agency, nor will it license nonfederal production of power at a federal dam authorized to produce power. FERC can, on its own motion, refrain from issuing a permit or license at any site, and recommend that Congress study the site through federal hydropower development agencies. FERC may also comment on federal development proposals.

FERC conducts a comprehensive environmental review. The review must be coordinated with a number of other federal and state agencies, to assure compliance with many of the statutes and procedures discussed elsewhere herein. An Environmental Impact Statement (EIS) (see:National Environmental Protection Act, NEPA, this index) may be required of a project unless FERC makes a specific Finding Of No Significant Impact (FONSI) at the site. In addition, FERC licensees must provide for recreational

uses, mitigate environmental impacts, assure dam safety, provide fish passageways and other fish protection, maximize capacity and output within the site's environmental and physical limitations, and coordinate with, inform, and consult affected and relevant state, local and federal agencies.

As a public agency, FERC and its processes are open to scrutiny, participation, and reveiw by any interested citizen or group. Participation may occur at any point in the project authorization process either directly with FERC itself, or indirectly through the processes of the agencies and entities with whom FERC must consult. Decisions and orders of FERC may be appealed to a U.S. Circuit Court of Appeals.

FERC has a system of preferences it uses to resolve conflicts at sites which more than one applicant desires to develop. In general, licenses are preferred to permits, comprehensive development is preferred to single-purpose development, and the first-in-time applicant will prevail unless the competing applicant is a state or municipal entity. There is a licensure (though not an exemption) preference for state/municipal entities whose hydropower developments plans are 'equally adapted to the comprehensive use of the waterway.' FERC has ruled that this preference also extends to a public applicant competing for a privately-held license that is up for renewal (license terms normally are 50 years). The latter ruling is recent, and litigation is expected.

B. OVER FEDERAL DEVELOPMENT

a. Water Resources Council (WRC)

1. Water Resources Planning Act of 1965 (PL 89-90), 42 U.S.C. §§ 1962 et seq.
2. Water Resources Council, Principles and Standards for Planning Water and Related Land Resources, 38 Fed. Reg. 24778 (1973); revised, 44 Fed. Reg. 72978 (1979).
3. Water Resources Council, Procedures for Evaluation of National Economic Development (NED) Benefits and Cost in Water Resources Planning, 44 Fed. Reg. 72892 (1979).

The Act (1.) established the Water Resources Council of the United States (WRC). The WRC has promulgated the Principles and Standards (2.) and Procedures (3.) under which all direct federal hydropower development must proceed. The 'Principles' lay out the policy framework for all federal water resource plans and projects, and the 'Standards' and 'Procedures' provide for consistency and uniform measures in costs and benefits of alternative plans. The 'Procedures' were promulgated after a period of considerable controversy over the 'Standards' as they had been applied by federal water resource program administrators. The 'Procedures' require federal developers to pay greater heed to conservation, nonbuild alternatives, and more rigorous cost/benefit analysis when undertaking federal water resource projects. The Act (1.) also established River Basin Commissions as bodies for interstate and regional water management and planning within the major river basins of the United States.

C. OVER FEDERAL DEVELOPERS

Three major development agencies exist with the federal government: the Army Corps of Engineers (Department of Defense) with nationwide jurisdiction; the Water and Power Resources Service (WPRS) (Department of Interior) with jurisdiction in 17 Western states, and the Tennessee Valley Authority (TVA) with jurisdiction in a large area of the Tennessee and Mississippi River basins. The first two agencies (Corps and WPRS) must undergo a lengthy Congressional review, approval, and funding process to bring hydropower on line. Estimated time frames for large, multipurpose projects at undeveloped sites range from 12 to 30 years. The last agency (TVA) is a federal corporation with independent authority and funds. TVA is capable of bringing hydropower on line within its jurisdiction faster than WPRS or the Corps because it is not obliged to seek three separate approvals from Congress (study authorization, advanced design, and construction).

All three agencies are, however, obliged to proceed with their water development projects under the Principles & Standards, and Procedures promulgated by the Water Resources Council. Hydropower produced at federal dams is transmitted and marketed through five federal Power Marketing Administrations (PMA's) under the administration of the Department of Energy (DOE). Public utilities and electrical cooperatives are granted preferred access to federally-generated hydropower at traditionally low rates under the provisions of several major pieces of legislation. DOE sets these rates, which are subject to review by FERC.

a. The Army Corps of Engineers (Department of Defense)

1. U.S. Const. Art I, § 8, cl. 3
2. 33 U.S.C.A. § 1 et seq., Rivers & Harbors Act of 1899
3. Rivers and Harbors Act of 1912, 33 U.S.C.A. § 609
4. Flood Control Act of 1917, 33 U.S.C.A. § 701
5. Water Resources Development Act of 1976, § 167, 42 USC 1962 d-5q, 90 Stat. 293

The Constitutional authority of the Corps of Engineers over the navigable waters of the United States is found in the Commerce Clause (1.). The primary mission of the Corps has traditionally been navigation and flood control. The Corps is the major federal entity responsible for regulation of the navigable waters of the United States, and is the federal government's only direct hydropower developer with nationwide jurisdiction (2.). Construction, modification, or alteration of the navigable waterways of the United States is prohibited without the permission of the Corps (2.). This review power is incorporated by the Federal Power Act, which authorizes the Corps to review any FERC license before it is issues.

The Corps may not generally study or construct a project without specific authorization from Congress. The Corps has very limited continuing authority for hydropower development. The Corps is, however, authorized to provide for future hydropower development at any of its authorized projects (3.), and is required to include data on

hydropower potential in its survey of flood control projects. (4.) Most recently, the Corps is authorized to study the nation's physical potential for expanded hydropower development, the measures necessary to bring it on line, and its role in contributing to the nation's electric energy supply (5.).

b. The Water & Power Resources Service (WPRS) (Department of Interior)

1. Reclamation Act of June 17, 1902, 43 U.S.C. 383
2. 43 U.S.C. § 391, 491
3. Small Reclamation Projects Act of 1956, 43 U.S.C. § 422 a-k.

The Water and Power Resources Service (WPRS)[1] has jurisdiction only in 17 Western states and Hawaii (1.). Its original function was the reclamation of arid lands through irrigation, but WPRS has since evolved into a major multipurpose water project development agency (1., 2.). WPRS tends to have more budgetary flexibility than the Corps, as it exists within a department (Interior) with a number of water and energy programs, and a Secretary with a measure of discretionary authority over the department's budget. Many of the projects constructed by WPRS are turned over to nonfederal entities to own and operate. WPRS is required by Section 8 of the Reclamation Act (1.) to comply with state law in acquiring water rights for its projects. WPRS has its own program of grants and loans to public nonfederal organizations within its jurisdiction (3.). Project participants must generally repay all or a part of the project's costs over the life of the project. WPRS marketed power from its own dams until the mid-1970's organization of the Department of Energy. In recent years, WPRS has been engaged in various jurisdictional disputes with FERC over nonfederal development of power at WPRS dams.

c. The Tennessee Valley Authority (TVA)

1. Tennessee Valley Authority Act of 1933, 16 U.S.C.A. § 831 et seq.

The Tennessee Valley Authority (TVA) is a federal corporation with independent authority and funds (1.). TVA is capable of bringing hydropower on line within its jurisdiction faster than WPRS or the Corps because it has broad authority to "produce, distribute and sell" electric power within its jurisdiction, can set its own rates, and can finance its projects through revenues, electric power bonds, or Congressional appropriation. WPRS and the Corps are limited to the latter. Hydropower was a major focus of TVA energy and economic development endeavors from 1933 to the late 1940's. TVA also has extensive preference rules in the sale of TVA power (see Preference Clause Legislation, infra). The TVA region is centered in the Tennessee and Mississippi River Basins; TVA and its activities are subject to environmental legislation and regulation. A major exception, however, is that TVA is exempted from the provisions of the Fish and Wildlife Coordination Act (see Environmental Legislation, infra).

II. LEGISLATIVE HISTORY OF THE "PREFERENCE CLAUSE"

Note: The "preference clause" is a provision of numerous federal laws which provides that excess electric power generated at federal facilities should first be offered to public entities, including states, municipalities, and other nonprofit organizations organized for the public benefit. Only after these preferred customers' needs have been met does the preference provision allow the distribution of excess federal power to investor-owned utilities and for-profit entities.

The following eleven statutes are not exhaustive, but trace the evolution of federal preference policy through its most significant legislative manifestations to the present day.

1. Desert Land Act of March 3, 1877, 19 Stat. 377.

   The first statute which granted an actual preference in the distribution and use of public resources. The Act provided that surplus reclamation water and other non-navigable water on public lands should be held for public use.

2. Town Sites and Power Development Act of April 15, 1906, 34 Stat. 116117.

   First federal legislation granting a preferene for municipal purposes in the use of surplus hydroelectric power generated by federal irrigation projects. Passed at the urging of President Roosevelt, after Roosevelt (and later Taft) vetoed a number of bills authorizing private water development, and urged comprehensive federal development.

3. Raker Act of 1913, 38 Stat. 242, 245.

   Provided municipalities and water districts with a right-of-way over public lands for the construction of aqueducts, tunnels and canals for a waterway, provided that grantees of the right to develop water and electric power could not sell or lease those rights to any corporation or individual other than another municipality, municipal water district or irrigation district. Transfer of these rights to any private person, corporation, or association was prohibited; the rights reverted to the United States in the event of such a transfer.

4. Federal Water Power Act of 1920, Stat. 1063, 16 U.S.C. 800
   see: Federal Power Act discussion and materials

   In addition to setting up the framework for the Federal Power Commission (now the Federal Energy Regulatory Commission), the Federal Power Act represented the first statute to grant a preference to a particular class of uses by entities organized for the public benefit. Under the Act, the FPC must give preference in the award of hydroelectric plant licenses to states and municipalities, so long as they would serve the public interest as well as would non-preference licensees.

5. Boulder Canyon Project Act of 1928, 45 Stat. 1060, 43 U.S.C. 617d(c)

Authorized Hoover Dam, constructed by DOI's Bureau of Reclamation (now WPRS). Provided the first user preference in the actual sale of electric power. Also eventually led to litigation establishing the scope of federal reserved water rights (Arizona v. California, 373 US 546) (1963).

6. Tennessee Valley Authority Act of 1933, 49 Stat. 1076, 16 U.S.C. 831

Provided preference in the sale of TVA power to states and municipalities, and extended the preference to include non-profit cooperatives. Required that contracts with non-preference customers for the sale of electricity contain provisions authorizing the cancellation of the contract on five years' notice in the event that the power was needed for preference customers. The Act was amended in 1935 to give TVA the authority to purchase existing private electric utilities.

7. Rural Electrification Administration Act of 1936, 49 Stat. 1365, 7 U.S.C. 904

Authorized loans for rural electrification; granted preferences to municipalities, utility districts, and cooperative non-profit or limited-dividend associations.

8. Bonneville Project Act (1937) 50 Stat. 733, 16 U.S.C. 832

Contains preference clauses for states and municipalities. Guarantees a minimum of 50 percent of the Project's power to preference customers through the end of 1941. Directed that people within transmission distance of the Project be given a reasonable time to create public bodies and cooperatives which would be eligible for preference power.

9. Fort Peck Project Act, 50 Stat. 403, 16 U.S.C. 833
Reclamation Act of 1939, 53 Stat. 1193
Water Conservation and Utilization Act, 54 Stat. 1125, 16 U.S.C. 590z7

Three preference power statutes passed by Congress in the late 1930's.

10. Flood Control Act of 1944, 58 Stat. 890, 16 U.S.C. 825s

Authorized the Secretary of the Interior both to transmit and sell surplus electric power, giving preference in the sale of the power to public bodies and cooperatives. A major Act extending preference policies to most federal generation and transmission activities.

11. Pacific Northwest Electric Power Planning and Conservation Act (PL96501) (December 5, 1980)

Though the Act substantially alters the distribution and power supply arrangements of the Bonneville Project Act in the Pacific Northwest region, the Bonneville preference structure is retained. The Act states that BPA preference customers

are never to pay more for their power under the Act than they would if the Act had not been passed. If charges reach a higher level than they would have without the legislation, a rate ceiling comes into effect and the difference must be made up by non-preference customers. Preferential eligibility is retained as granted by the Act of 1937 (above). Public utilities will receive requirements contracts (to meet projected load growth). Preference customers will receive no less power under the Act than they would otherwise have received; BPA must terminate power sales contracts with investor-owned utilities (with five years notice) if necessary to honor the preference.

III. ENVIRONMENTAL LEGISLATION RELEVANT TO HYDROPOWER DEVELOPMENT

1. Fish & Wildlife Coordination Act (1934), 16 U.S.C. § 661 et seq. (PL 85624) amended 1958, 1965.

Purpose: to provide that wildlife conservation shall receive equal consideration and be coordinated with other features of water-resources development programs. The Act mandates that all federal agencies consider the fish and wildlife impacts of their actions. Implementing agencies (U.S. Fish and Wildlife Service, National Marine Fisheries Service and state agencies) can recommend fish passage facilities, fish hatcheries, or wildlife habitat mitigation at hydropower projects. Mitigation techniques, especially where a project affects anadromous fish, can add significantly to project costs and make some projects infeasible. Note that TVA is exempt from the Act. (See TVA infra.)

2. Federal Power Act, 16 U.S.C. § 791 et seq. (1920 and as amended)

The FPA (see FPA entry infra) includes two provisions which require important environmental considerations of hydropower developers. Section 811 mandates that FERC require fishways prescribed by federal fisheries agencies (see Fish and Wildlife Coordination Act, above). Section 4(e) requires FERC to secure the approval of the Corps of Engineers before issuing a license which affects the nevigability of a waterway. The source of the latter requirement is the Rivers and Harbors Act of 1899.

3. Heritage Conservation Act of 1963 (PL 88-29)

Purpose: to assure adequate outdoor recreation resources and conserve, develop, and use such resources for benefit and enjoyment of the American people. Implementation: National Heritage Conservation and Recreation Service; FERC. The Act is meant to ensure that project developers take recreational uses into account when developing hydropower.

4. Wilderness Act (PL 88-577 as amended), 16 U.S.C. § 1131-1136

Purpose: to protect and manage undeveloped federal land to preserve its wilderness character, the Act establishes the National Wilderness Preservation System. The Departments of Interior and Agriculture are authorized under the Act to establish wilderness areas. FERC cannot license a project in a wilderness area. Only the President has power to authorize development in a wilderness area, and then only if the President specifically finds that such development "will better serve the interests of the United States and the people thereof than will its denial."

5. Federal Water Projects Recreation Act of 1965, 16 U.S.C. § 460, 1-12

Purpose: to require federal development agencies to consider enhancement of outdoor recreation and fish and wildlife opportunities in planning water resource projects. The word "enhancement" is echoed as well by other statutes applying to nonfederal development, notably the Fish and Wildlife Coordination Act and NEPA. "Enhancing" such opportunities has been cited as a serious impediment by some hydropower developers, who allege that fish and recreation agencies, both state and federal, have used the word to require unrealistic and extremely expensive additions and improvements to hydropower projects which significantly alter project feasibility. In New England, for example, "enhancement" has led to endeavors to require projects to restore fish runs and stocks which had otherwise vanished over a century ago.

6. National Historic Preservation Act of 1966 (PL 89-665), 16 U.S.C. § 470
   and
7. Archeological and Historic Preservation Act of 1974 (PL 93-291)

A National Register of historic sites is maintained under the 1966 Act. Developers must take into account the effect of any project on any historic site included in or eligible for inclusion in the Register. The 1974 Act is intended to preserve historic/archaeological data which might be lost or destroyed as a result of federal projects, activities, or programs. Construction agencies, FERC, or State Historic Preservation Officers can request a survey before licensure or construction.

8. Wild and Scenic Rivers Act of 1968 (PL 90-542), 16 U.S.C. §§ 1271-1281

Purpose: to protect and preserve selected rivers in a free-flowing condition for the benefit of this and future generations. FERC cannot license any facilities sited upon or that dirctly affect such rivers. The National Hydropower Study's Site Inventory has excluded hydropower sites on such rivers. The 1968 program designated 8 rivers and recommended studying 27 others. Fifty-nine rivers are currently under study, and 28 have been designated (1980). Many states have established their own state wild and scenic river acts. Nineteen states had designated approximately 4,845 miles of river by early 1978. FERC policy is to withhold licensure from any project on a river under study.

9. National Trails System Act of 1968 (PL 90-543), 16 U.S.C. § 1241-1249

Purpose: to establish a national system of recreation and scenic trails of historic significance. Two trails exist and are being managed at present (by the Heritage Conservation and Recreation Service and the U.S. Forest Service). They are the Appalachian Trail in the east and the Pacific Crest Trail in the west. FERC and federal development agencies must confer with Interior and Agriculture over any project that may affect these trails. Hydropower projects may not "substantially interfere with the nature and the purposes of the Trail." No hydropower development has been hindered or denied as yet by this Act.

10. National Environmental Policy Act of 1969 (PL 91-190), 52 U.S.C. § 4321 et seq.

National Environmental Policy Act (NEPA) ensures that environmental impacts of federal actions will be considered by federal agencies in their decision-making processes. NEPA requires all federal agencies to include a detailed Environmental Impact Statement (EIS) whenever they undertake "major actions significantly affecting the quality of the human environment." An EIS is legally insufficient if the action-taking agency has failed to consult with and obtain comments from other agencies with jurisdiction over, or expertise relevant to the environmental aspects of the agency's proposed action. NEPA also created the Council on Environmental Quality to assist federal agencies in planning, and to advise the President on national policies designed to improve the environment. The CEQ has authority to issue regulations governing the preparation of the EIS by federal agencies, and the power to oversee an agency's EIS proceedings. CEQ regulations bind federal hydropower development agencies (Corps, WPRS, TVA et al), though there is an interagency conflict over whether FERC is also bound by them. FERC's position is that CEQ recommendations on hydroelectric licensing are advisory only—but FERC has in any event adopted NEPA regulations closely paralleling CEQ guidelines. FERC generally will require an EIS on all projects larger than 1.5 MW. A FONSI (Finding Of No Significant Impact) will usually be filed on smaller projects.

11. Clean Air Act (1969, amended 1979) (PL 91-604; PL 95-95), 42 U.S.C.A. §§ 1857-1858a

Requires point-source polluters obtain permits from designated state air quality agencies or from EPA. No significant deterioration of clean air is allowed in designated areas, such as wilderness or national parks. Hydropower construction activities and dust control are generally under the purview of the Clean Water Act, Section 404 permit from the Corps.

12. Clean Water Act (1972, amended 1977) (PL 92-500; PL 95-217) 33 U.S.C. §§ 1251 et seq.

Purpose: to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Three sections affect hydropower development.

Section 401: authorizes state water quality agencies (or the EPA where no state agency exists) to issue Water Quality Certificates. Such certificates are concerned largely with effluents and minimum streamflows. FERC requires each license applicant to obtain such a certificate. Federal development agencies must also obtain a water quality certificate from state agencies if a project is located in a state where they exist. Certificate standards vary from state to state, and developers need to be aware of variable limitations.

Section 402: requires discharge permits from EPA for point sources of water pollution. Some judicial authority supports the notion that hydroelectric dams are point sources of pollution, however EPA disagrees and regulations have not as yet been issued.

Section 404: gives jurisdiction to the Corps of Engineers to issue permits regulating the dredging and discharge of fill materials into waters of the United States. Such materials must be disposed of at sites selected under EPA guidelines. The Corps will not issue a permit until a proper site is found. FERC requires every license applicant to obtain a Section 404 permit; federal development agencies are not so bound, but have agreed to abide by Corps guidelines regulating the disposition of dredge and fill material.

13. Coastal Zone Management Act of 1972 (PL 92-583)

Purpose: to preserve, protect, develop, and where possible restore or enhance the resources of the Nation's coastal zones for this and succeeding generations. States are encouraged to protect and manage their coastal lands and federal funds are provided to enable them to do so. If a hydropower project, federal or FERC-licensed, is located in an area subject to the jurisdiction of a Coastal Zone Commission sanctioned under the Act, then the project is subject to the provisions of the commission's coastal zone plan. Such plans allow for only limited development in coastal zones in many coastal states. Such limits may hinder or obviate hydropower development in a coastal zone.

14. Endangered Species Act of 1973 (PL 93-205), 16 U.S.C. §§ 1531 et seq

Purpose: to conserve the ecosystems upon which endangered and threatened species depend. Procedure: the Secretary of the Interior lists species in danger or likely to be in danger of extinction. Development is barred if it will affect a significant portion of the critical habitat of an endangered species. The burden is on the developer to demonstrate to fish and wildlife protection agencies that no critical habitat is threatened. Permits and licenses can be denied if the project threatens such habitat. The Act is the only major piece of federal legislation with the authority to stop development on a project after it has already begun. Though the Act has terminated few projects, litigation and delay over the Tellico Dam controversy resulted in Congressional amendment of the Act in 1978. The amendment authorized an exemption process through the establishment of review boards in certain narrowly prescribed circumstances.

15. Resource Conservation and Recovery Act of 1976 (PL 94-580)
and
16. Toxic Substance Control Act of 1976 (PL 94-469) 15 U.S.C. § 2601

Purpose: to control and regulate hazardous wastes and toxic substances from point of generation to point of final disposal. The Acts together made control of such substances a major legislative concern of the 1970's. Both laws have tremendously expanded the involvement of the federal government in the regulation and control of hazardous wastes and toxic substances. Report and permit requirements are applicable to any individual generating, transporting, or storing such substances. A "cradle to grave" reporting procedure is mandated, and EPA requires disposal only at certain sites maintained by public or private entities under strict standards. If a hydropower developer or project generates or dredges toxic substances or hazardous wastes, the procedures of the Act(s) are triggered. The potential release of sediments and toxic substances has been identified as an environmental impact of all hydropower development by the Corps' environmental assessment contractor.

17. Federal Lands Policy and Management Act of 1976 (PL 94-579), 43 U.S.C. §1701 et seq (FLPMA)

Purpose: to establish public and land policy; to establish guidelines for its administration; to provide for management, protection, development, and enhancement of public lands and for other purposes. The Act is important because it is the source of a current interagency conflict between the Bureau of Land Management (BLM) and the Federal Energy Regulatory Commission (FERC). Section 501(a) of FLPMA authorizes BLM through Interior to grant a right-of-way on public lands for "systems for generation, transmission, and distribution of electric energy." The section also provides that applicants must comply with all applicable requirements of the Federal Power Act. The Federal Power Act, however, in Section 4(e) authorizes FERC to issue licenses for projects "upon any part of the public lands." FERC maintains it has exclusive jurisdiction in licensing right-of-ways for power projects on public lands. The Department of the Interior maintains that FERC licensees must obtain a BLM right-of-way permit in addition to their license. Obviously, both positions are supported by legislative authority, and the conflict is as yet unresolved. The National Forest Service also supports the BLM view.

IV. HYDROPOWER DEVELOPMENT AND FINANCE INCENTIVES

1. "Pickett" Act of 1910, 43 U.S.C. § 141

Authorizes President to withdraw any of the public lands of the United States, in his discretion, and reserve them for water power sites, irrigation or other public purposes. The withdrawal or reservation remains in effect until revoked by the President or an Act of Congress. At present, the Act has resulted in 1,011 powersite reserves, classifications, and water power designations. These

lands total 13,883,806 acres. An additional 115,000 acres have been withdrawn under the Act for reservoir purposes. According to law that has developed governing federal reserved water rights, the federal government should be entitled to sufficient water at reserved water power sites for power purposes without obtaining the rights under state law. However, Congress has traditionally deferred to state water law allocation systems in authorizing project development, and seems unlikely to exercise its reserved rights at Pickett Act sites.

2. Public Utility Regulatory Policies Act of 1978 (PURPA) (PL 95-617) 16 U.S.C. §§ 2601 et seq

Purpose(s): to encourage conservation of electric energy, improvement of wholesale distribution of electric energy, conservation of natural gas, and to create a program for expeditious development of hydroelectric potential. PURPA signals a broad commitment by Congress to encourage nonfederal development of small-scale hydropower. The sections relevant to hydropower are:

TITLE II: requires utilities to purchase power at rates that are "just and reasonable" (not to exceed the purchasing utility's avoided costs) the output of hydropower facilities with less than 80 MW capacity (Section 210). Development of electric generation capacity by persons not otherwise engaged in the electric utility business is encouraged, and developers are guaranteed access to the market at fair rates. FERC regulations allow generation at existing and new sites to qualify for PURPA protections and guarantees. State public utility commissions are also required to develop implementation procedures.

FERC is given authority to order the interconnection or wheeling of the output of small power producers to existing transmission systems. FERC cannot issue such an order if it determines that such interconnection or wheeling would result in an uncompensated economic loss to a utility or producer, would place an undue burden on same, or would impair the reliability of any affected electric utility in terms of its system or other customers (Sections 202-204).

FERC is authorized to encourage utility pooling (Section 205). FERC is obliged to require public utilities to report anticipated electric shortages and develop contingency plans (Section 206), and is obliged to review public utility automatic adjustment clauses (Section 208). A study of electric reliability standards is commissioned, and the Secretary of the Department of Energy is encouraged to recommend such standards in consultation with FERC. (Section 209)

In addition to requiring utilities to sell power to, and buy power from qualified small power production facilities (Section 210), FERC is required to prescribe rules exempting small hydro (less than 30 MW) facilities from the Federal Power Act, and from State laws and regulations "if the Commission determines such exemption is necessary to encourage cogeneration and small power production."

Public utility officers and directors must disclose possible conflicts of interest under Section 211, and an Office of Public Participation is established in FERC under Section 212. A licensure exemption is authorized for small conduit hydro facilities (less than 15 MW) under Section 213.

TITLE IV: establishes the Small Hydroelectric Power program (up to 15 MW/existing dam) within the Department of Energy to "encourage the development of small hydroelectric power projects in connection with existing dams which are not being used to generate electric power." (Section 401)

Section 402 authorizes a DOE loan program for up to 90 percent of the costs of feasibility studies or approvals necessary to bring small hydro on line at existing dams. The loan is forgivable if the project is ultimately determined to be infeasible. Section 403 authorizes a loan program for up to 75 percent of the actual construction and acquisition costs of a small hydro project. DOE is to give preference to applicants "who do not have available alternative financing" and the project itself must not have "significant adverse environmental effects," including adverse impacts on fish and wildlife, recreation, streamflow, or other water uses. Section 402 (feasibility) loans are for terms up to 10 years, and Section 403 (construction) loans are for terms up to 30 years.

It should be noted that the Office of Management and Budget (OMB) has halted disbursement of PURPA construction loan monies under this Title since passage of the Act. OMB has taken the position that the monies are unnecessary because development would take place without the loan program. The feasibility study loan program of Section 402 has proceeded, but has been criticized for lack of impact (GAO, January 11, 1980, EMD8030). It was recently suspended for 45 days in February, 1981 at OMB's request; the current Administration is scrutinizing federal involvement in a number of loan programs and eyeing them for possible cuts.

Section 405 of Title IV requires FERC to establish a program for simple and expeditious licensing procedures for small hydro (up to 15 MW projects at existing dams). The Section specifically affirms, however, the requirements of all relevant federal environmental legislation in connection with expeditious licensing, and requires FERC to consult with the Council on Environmental Quality and the Environmental Protection Agency regarding environmental effects. FERC has responded to Title IV by reducing application requirements for conduits and for existing site projects, particularly for projects of 1.5 MW or less, for whom a "short-form" application has been developed.

3. Crude Oil Windfall Profits Tax Act of 1980 (COWPTA) (PL 96-223)

The Act contains among its provisions important incentives for hydropower development. Tax credits are available under COWPTA through 1988.

Tax credit: An energy tax credit is made available to developers of hydro projects at existing sites of 125 MW or less. A maximum 11 percent tax credit is available on a sliding scale: the full 11 percent for projects 25 MW or less, and a declining percentage of the 11 percent for projects between 25 MW and 125 MW.

Fish passage: fish passageways and ladders at hydro facilities are eligible for the 11 percent energy tax credit under the Act, and for a basic investment tax credit of 10 percent.

Tax exempt bonds et al.: tax exempt status is provided under COWPTA for publicly issued debt instruments which support small-scale hydropower development at sites owned by public entities and municipalities.

4. Energy Security Act of 1980 (PL 96-294), 42 U.S.C. §§ 8701 et seq

Section 408 of the Act authorizes FERC to exempt individual hydropower projects and classes of projects located at existing sites of 5 MW or less from the FERC licensing process. FERC's implementing regulations require a developer seeking such an exemption to have the "requisite property interest" in the site. Once qualified, an applicant can secure an exemption even if permit or license applications are pending from other developers at the same site. FERC is currently preparing an EIS on proposed regulations exempting classes of existing sites of 5 MW or less from the licensing process.

FOOTNOTES

1. The Bureau of Reclamation (BuRec) was renamed the Water and Power Resources Service (WPRS) in December, 1979. The renaming has been rescinded as this report is going to press. (June, 1981). Therefore, please note that all references to WPRS herein refer to the Bureau of Reclamation, Department of the Interior.

Section C

Some Notes on the Cost of Hydroelectric Installations

Prepared by:
Pieter A. Frick

LIST OF FIGURES

		Page
Figure C-1:	Project Costs	2
Figure C-2:	Flowchart for Construction of a Small Hydroelectric Plant	3
Figure C-3:	Power Plant Cost	4
Figure C-4:	Comparison of Turbine Costs vs. Head	5

Some Notes on the Cost of Hydroelectric Installations

Total project costs for constructing hydroelectric plants vary considerably and depend largely on the plant size, its exact location and proximity to an electrical power distribution network. A cost breakdown for two similarly sized installations is given in Figure C-1, illustrating the variability in cost for the civil works required in these projects.

Three main cost components are identified in Figure C-1, namely the civil works, the power plant and indirect costs. The civil works account would typically include:

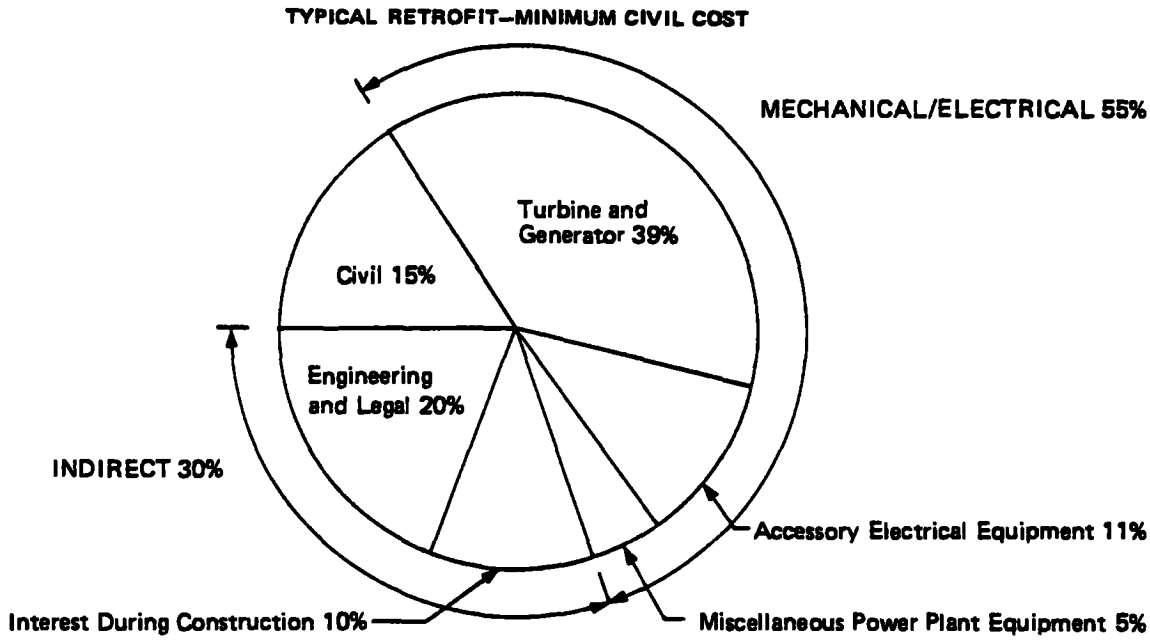
- Land, land rights cost;
- Reservoir, dam, waterway and spillway construction;
- Costs incurred for building access roads, railroad bridges, etc.. to the site; and
- Construction costs for penstocks, draft tubes, surge chambers, etc.

The power plant category would typically include the following cost items:

- Turbine and generators;
- Generation control, transformers and protection equipment;
- Switchyard, transmission lines and miscellaneous power plant equipment.

Considerable variability can be expected in the indirect cost account for hydroelectric plants. This is largely due to present interest rate variations in financing such plants and the cash flow problems associated with difficult to predict construction period operations. A typical flow chart for the construction of a small hydroelectric plant is given in Figure C-2 showing a considerable range in expenditure levels over the 40 month period. To avoid confusion and the promotion of misinformation we discuss only the quantifiable power plant costs below.

Power plant costs for a number of federally developed hydroelectric plants are graphically represented in Figure C-3. This shows that the power plant cost is not only a function of the plant's installed capacity, but depends initially on the size of the head. The actual turbine costs account for most of the cost variation with head as illustrated in Figure C-4 where turbine (plus generator) cost vs. head is plotted for a number of standard turbine types in sizes of 0.5, 1.0, 5, 10 and 15 MW units. It is interesting to note that Figure C-4 indicates that the per unit cost for bulb turbines is considerably higher than that for its twin sister the tube turbine. This is due to the fact that there are no local (United States) manufacturers for bulb units and the cost figures are distorted by abnormally high shipping costs.



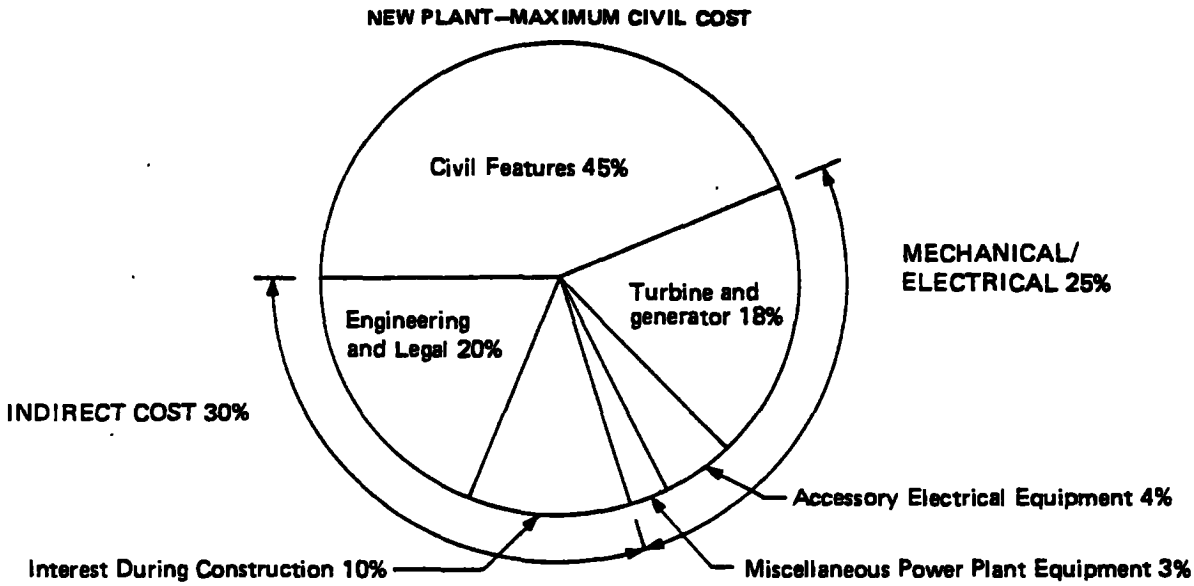


Figure C-1.
PROJECT COSTS

Source: Ref. 1

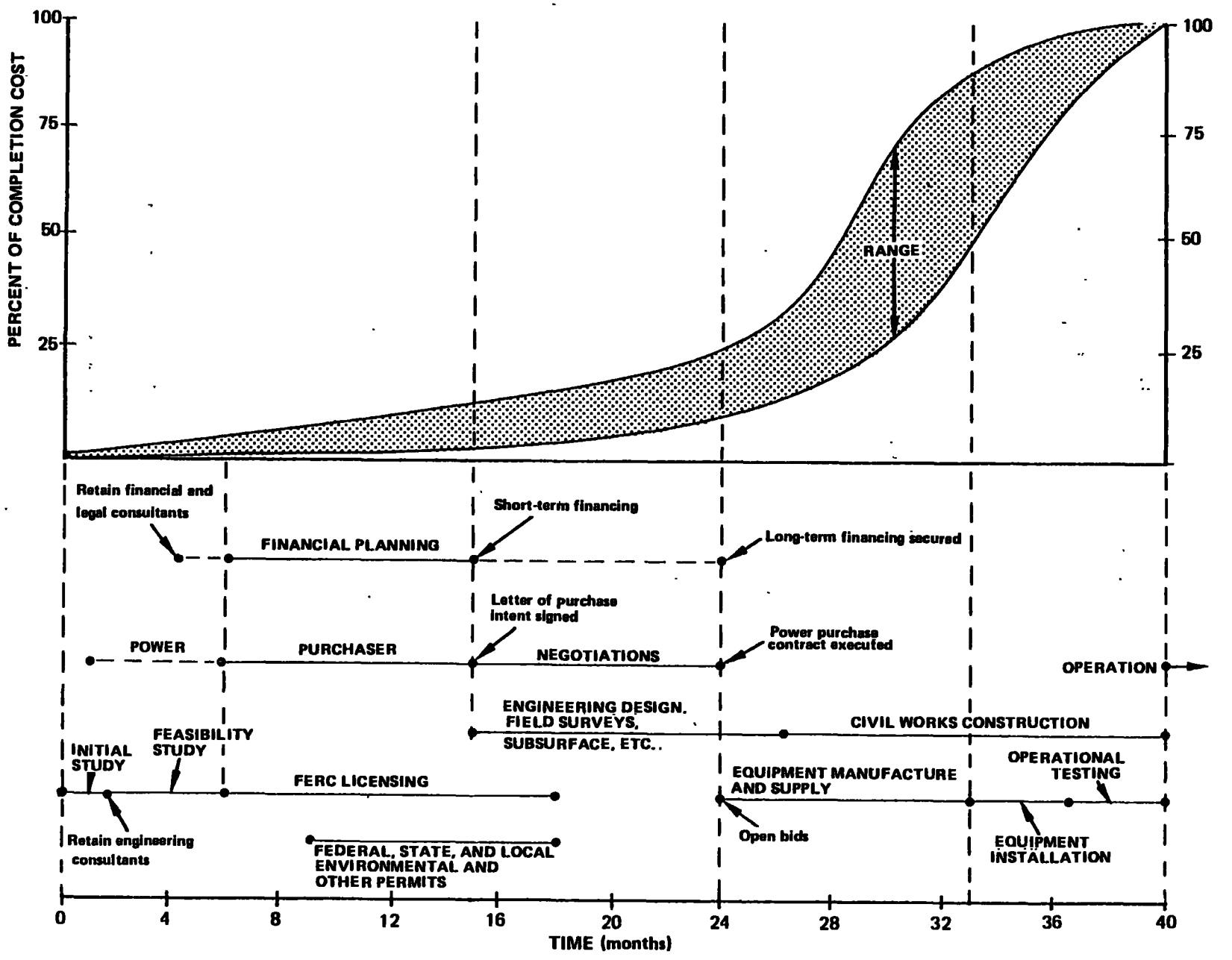
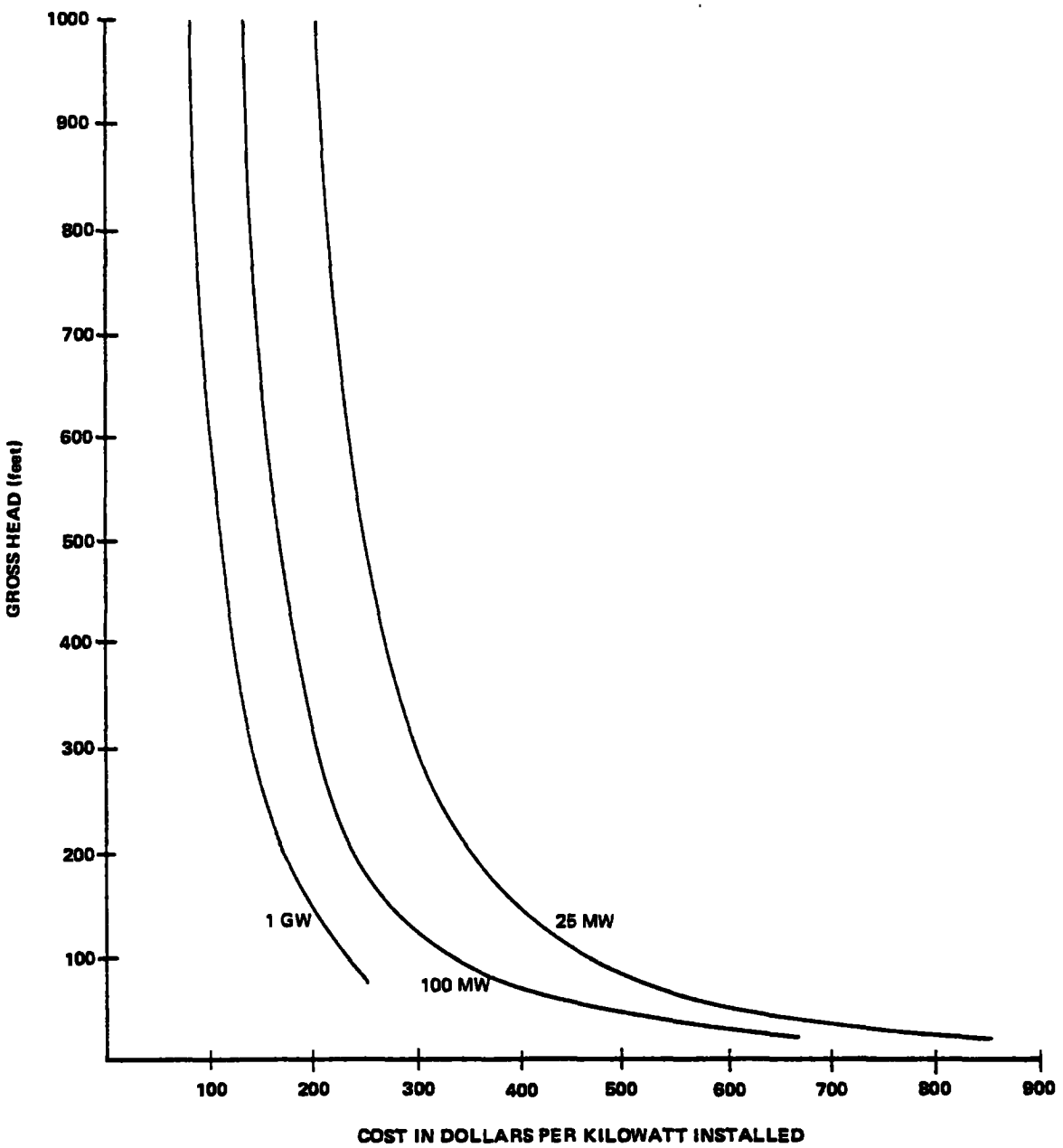


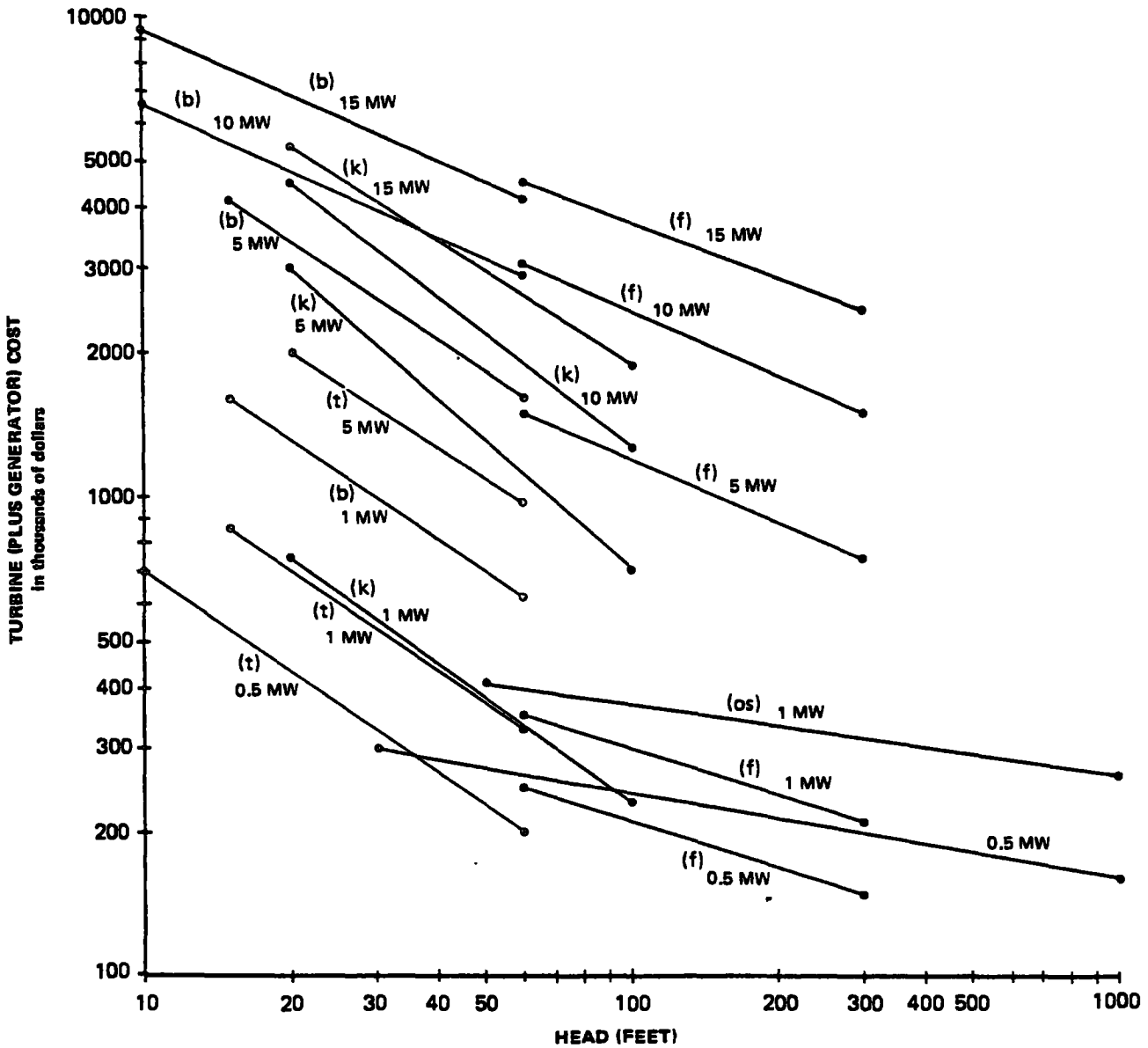
Figure C-2.

FLOWCHART FOR CONSTRUCTION OF A SMALL HYDROELECTRIC PLANT



Source: Ref. 2

Figure C-3.
POWER PLANT COST



(b)—Bulb Turbines
(t)—Tube Turbines
(f)—Francis Turbines
(k)—Kaplan Turbines
(os)—Ossberger Turbines

Source: Ref. 1

Figure C-4.

COMPARISON OF TURBINE COSTS VS. HEAD

The selection of control equipment for propellor type turbine installations becomes an important cost factor, particularly for small plants. While the highest turbine efficiencies can only be obtained in installations equipped with both variable wicket gate and variable blade pitch angle controls, they add 15 percent and 10 percent to the cost of a turbine respectively. Similarly, the cost of a "speed governor" (+/-$64,000 (Ref. 1)) necessary for synchronous generation can be saved when an induction generator is employed. Asynchronous generation will, however, result in an overall loss of efficiency in the range of 7 to 10 percent.

The cost associated with accessory electrical equipment such as transformers, circuit breakers and other switchyard protection equipment vary directly with the plant size. In fact the only variability in cost for this category appears in the expenditure for transmission lines linking a plant to the nearest distribution network.

Accurate cost figures on low head installations (20 ft. or less) are unfortunately not available at this time. This fact and the uncertainty in civil works cost estimating processes pose constraints on involvement of the private sector in a national hydro-electric development program.

REFERENCES

1. U.S. Army Corps of Engineers. Feasibility Studies for Small-Scale Hydropower Additions—A Guide Manual. July 1979.

2. U.S. Department of Energy, Federal Energy Regulatory Commission. Hydroelectric Power Evaluation, Report Number DOE/FERC-0031. August 1979.

Section D-1

The Carbon Dioxide Issue

Prepared by:
Robert L. Gay

TABLE OF CONTENTS

	Page
Introduction	1
The "Greenhouse Effect"	1
The Potential Problem	1
Potential Impacts	3
Uncertainty About CO_2-Induced Impacts	5
Timing	6

LIST OF FIGURES

Figure D-1-1:	Mauna Loa Monthly Averages of Atmospheric CO_2 Concentrations, With Seasonal Effect Removed	2
Figure D-1-2:	Range of Global-Scale Mean Temperature With and Without CO_2 Effect and Projected CO_2 Temperature Disturbance in the Context of Ice Age Chronology of the Past 150,000 Years	4
Figure D-1-3:	Atmospheric CO_2 Concentrations and Energy Production Curves	8
Figure D-1-4:	Production Curves for Global Fossil Fuel Use	8
Figure D-1-5:	Alternative Production Curves Leading to 50% and 100% Increases in Atmospheric CO_2 Levels	10

LIST OF TABLES

Table D-1-1:	Illustrative CO_2 Containment Scenarios Based on Different CO_2 Ceiling Levels and Fossil Fuel Use Growth Rates	9

THE CARBON DIOXIDE ISSUE

Introduction

Section D-1 addresses the issue of potential climatic changes related to warming of the global atmosphere caused by carbon dioxide (CO_2) emissions from fossil fuel combustion. This potentially enormous but presently uncertain environmental impact is made more likely by the continuing trend of increasing fossil fuel combustion to produce electric power. Reliance upon hydropower facilities to replace some portion of the projected growth in fossil fuel-fired power plants could be of interest in mitigating possible adverse environmental impacts associated with CO_2 buildup in the atmosphere.

This discussion briefly describes the nature of the CO_2 problem, potential induced impacts produced by changes in CO_2 levels, the uncertainties involved, and implications for the Hydropower Technology Assessment Project. It also suggests a crude method for estimating whether the hydropower expansion associated with Levels I-III in this assessment could reduce proposed fossil fuel use growth in the United States to levels which are consistent with any of several CO_2 containment scenarios proposed by the Council on Environmental Quality (CEQ) (Ref. 1).

The "Greenhouse Effect"

Carbon dioxide comprises only 0.03 percent of the earth's atmosphere, but it is a crucial regulator of global temperature, through its role in the earth's radiation balance. Because the earth receives so much heat from the sun, it must radiate an equal amount of heat back into space, or grow warmer over time. CO_2 is almost transparent to the sun's incoming radiation, but strongly absorbs a portion of the earth's outgoing radiation. This causes the CO_2 to warm up, with a net warming of the global atmosphere—by about 10° C above what it would be if CO_2 was absent. Thus CO_2 acts like a greenhouse, admitting solar radiation, but impeding outgoing heat radiation.

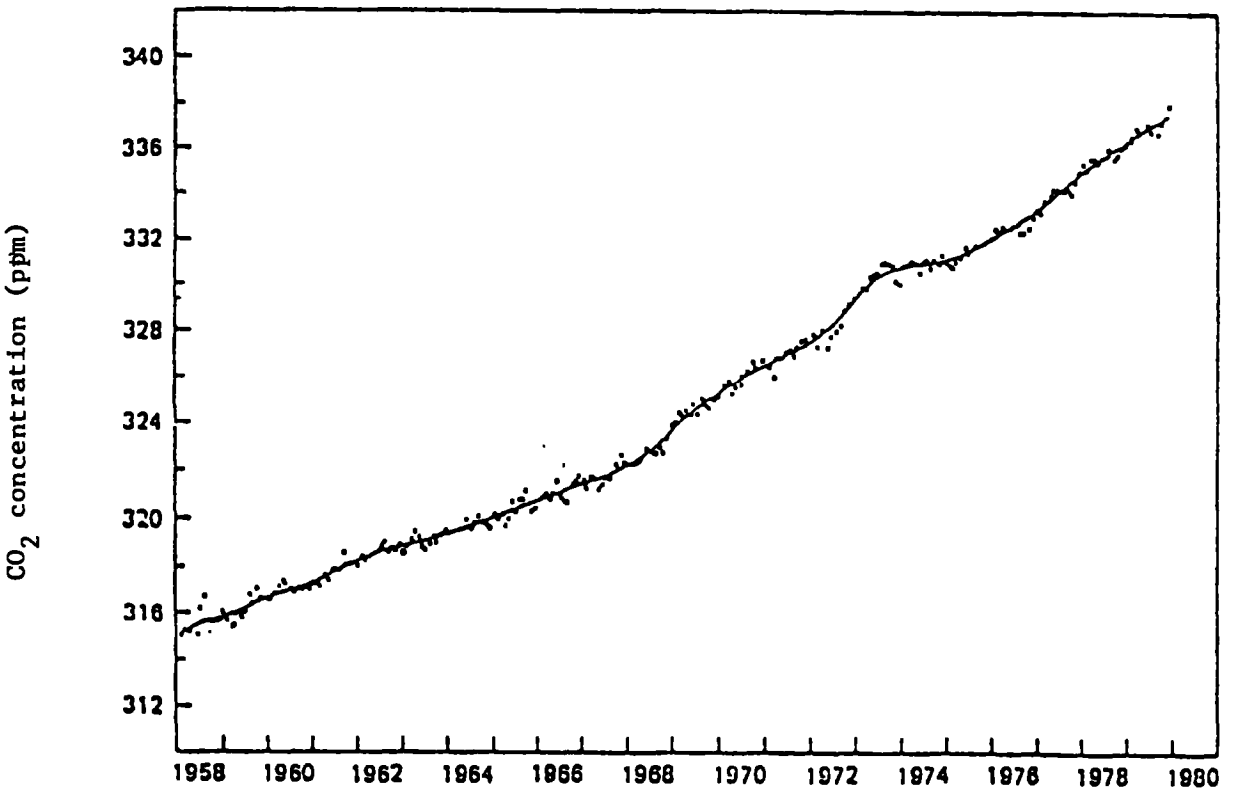
The Potential Problem

CO_2 levels in the global atmosphere have steadily increased since industrialization began in the 19th Century. Many scientists are now concerned that the rate of increase in atmospheric CO_2 concentrations—currently about 0.7 percent per year; about 7 percent since reliable measurements began in 1958 (Figure D-1-1); and an estimated 15 to 25 percent since preindustrial times—is so rapid on a geologic type scale, that unprecedented warming of the earth's atmosphere could occur, with potentially catastrophic environmental and socio-economic impacts.

Concern is heightened by the estimate that man is manipulating the two major sources of atmospheric CO_2 in ways that will further increase CO_2 levels relatively rapidly—by burning fossil fuels, and by clearing land of its vegetation, which absorbs

Figure D-1-1

Mauna Loa monthly average of atmospheric CO_2 concentrations with seasonal effect removed.



Source: C.D. Keeling and Co-workers, Scripps Institution of Oceanography (cited in Ref. 1).

CO_2 through photosynthesis. Increasing atmospheric concentrations of CO_2 in the past few decades correspond closely with increasing global use of fossil fuels. Best estimates indicate about half of the CO_2 released from fossil fuel combustion is retained in the atmosphere, causing the CO_2 buildup there, with the rest presumably absorbed by the world ocean or the land biosphere (by plants and soil humus).

Potential Impacts

The most widely accepted analyses estimate that CO_2 in the atmosphere will double its preindustrial concentration sometime between the year 2020 and 2040, depending primarily on the rate of fossil fuel use. It is estimated that this could increase the global average temperature at the earth's surface, by about 3° C. (+/-1.5°C). Smaller increases are projected in the equatorial region, with higher increases in polar regions, including as much as 7 to 10° C increases in the north polar regions during winter. This 3° C average temperature rise could make the earth warmer than at any time in the last few thousand years at least. (Figure D-1-2)

The potential impacts from such global warming stem from potential climatic changes, and include:

1. Disruption of agricultural activity over large regions due to changes in rainfall patterns, shifting of regional climate factors critical to agricultural productivity toward the earth's poles, and increased outbreaks of insect pests.

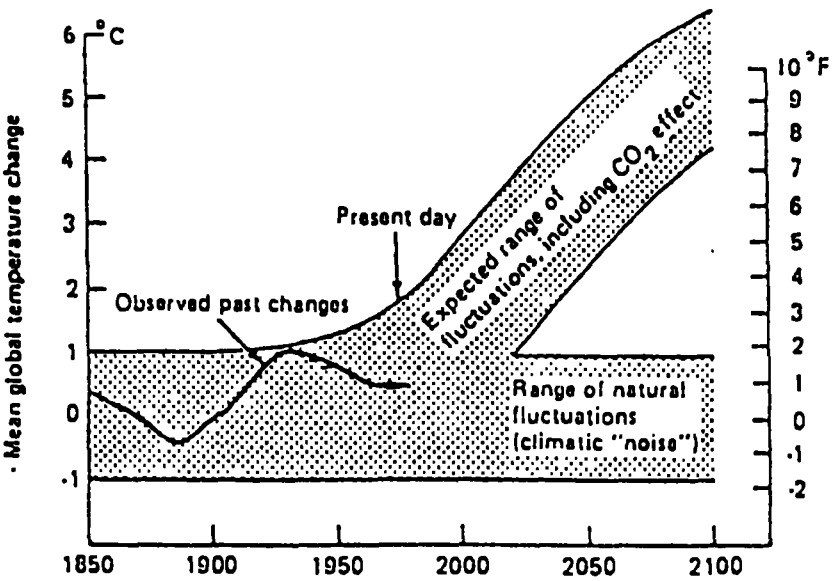
   Significant rainfall shifts have occurred in the past associated with temperature increases of as little as 0.6° C (Ref. 1); 4,000 to 8,000 years ago (Altithermal Period) the earth was apparently 1 to 3° C warmer than today, and rainfall patterns were quite different. For example, the Sahara Desert was more like a prairie; and, some subcontinental regions were wetter while others were drier than we know them now. Subsequent cooling has resulted in the world climate patterns of today.

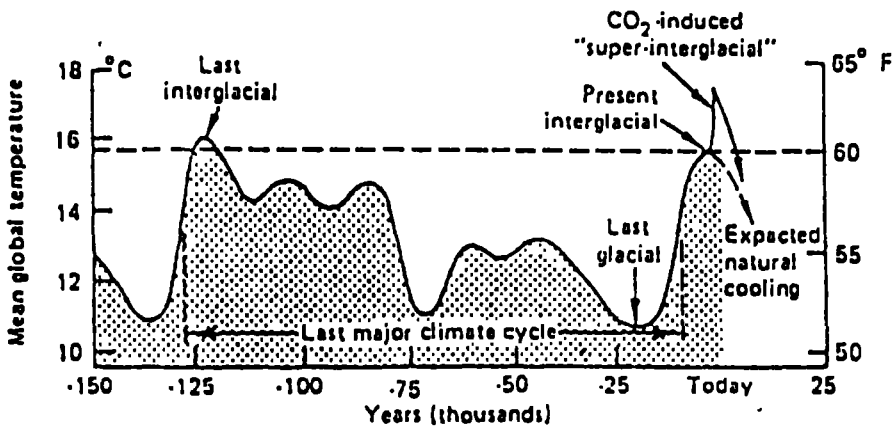
   Yields of major food crops, (e.g., corn, wheat, rice) and even their suitability to their present regions of dominate production, could be undermined by climate shifts. The ability to feed a growing world population would suffer, especially during climate transition. Outbreaks of insect pests often accompany periods of hotter, drier weather.

   Climatic shifts would not be uniform, or honor political boundaries. Some nations and economies would benefit, while others would suffer. Inflation would accompany any scarcity of food crops. Flooding caused by rainfall changes (e.g., any shift in monsoon patterns), or crop failures, could produce refugee problems.

Figure D-1-2

Above: Range of global-scale mean temperature, with and without the projected CO_2 effect. Below: Projected CO_2 temperature disturbance in the context of Ice Age chronology of the past 150,000 years.





Source. Based on J. Murray Mitchell, Jr., "Some Considerations of Climatic Variability in the Context of Future CO_2 Effects on Global-Scale Climate," in William P. Elliott and Lester Machta, *Carbon Dioxide Effects Research and Assessment Program: Workshop on the Global Effects of Carbon Dioxide from Fossil Fuels*, Miami Beach, March 7-11, 1977, U.S. Department of Energy CONF-770385 UC-11) Washington, D.C.. U.S. Government Printing Office, 1977), Figure 6, p. 98. (cited in Ref. 1)

2. Coastal Flooding due to increased sea level, resulting from melting of polar ice.

   Doubling of CO_2 concentrations is estimated to increase ocean levels by 5 meters or more. Such an increase could flood coastal areas of the United States presently containing 11 million people, or 5 percent of the United States population.

3. Fisheries Impacts:

   Reduced temperature differentials between the equator and the poles could reduce winds over the oceans, altering the ocean currents and circulation patterns, affecting nutrient upwelling, and hence the location and productivity of ocean fisheries.

Many scientists agree that the risks of climate change due to CO_2 warming effects are real and potentially large, but that the timing and magnitude of such effects is still very uncertain. These two aspects of the CO_2 issue are discussed in the following sections.

Uncertainty About CO_2-Induced Impacts

Many scientists agree that measurable man-induced climate changes are probably on the way, if the present buildup of CO_2 continues as predicted. However, there is great uncertainty about the nature, timing, and magnitude of CO_2 induced warming and climate changes, and about the environmental, social, and economic disruption they might cause.

One reason is that there is little in man's experience with which to compare the CO_2 situation. Global temperature changes on a similar scale have apparently occurred before, but over much longer time periods (thousands of years) for which there is little or no historical records (Figure D-1-2).

The major sources of uncertainty include:

1. The rate at which CO_2 will actually be added to the atmosphere—especially from fossil fuel combustion—and the rates at which other elements will be added which exert similar warming effects, such as particulate matter in the lower atmosphere, waste heat from surface industry, and other gases like methane (Ref. 3). The rate of forest clearing, or other alteration of the earth's vegetative cover, which acts as a CO_2 "sink" is also uncertain.

2. The degree to which the earth's natural adaptive mechanisms—including the ocean's thermal characteristics and ability to absorb excess CO_2, natural heating/cooling cycles, and even reforestation—could counteract CO_2 warming effects, thereby warding off climatic impacts.

3. The degree to which increases in CO_2 concentrations will increase the average global temperature...and which regions of the globe will be most affected.

4. The reliability of theoretical models to predict climate change resulting from global warming.

   Such models have serious limitations. They never simulate the true complexity of global atmospheric processes, especially over the long time periods called for in this situation. They cannot incorporate the earth's natural adaptive processes very well, because too little is known about them. There is in adequate empirical data for model calibration. Models have trouble simulating the effects of recent historical temperature changes that have been documented.

   Nevertheless, such models are essential to quantitative prediction of climate change. And they are reasonably credible in their present state of development, according to a National Academy of Sciences review of such models which concluded: "We have found no reason to doubt that climate changes will result, and no reason to believe that they will be negligible" (Ref. 1).

5. Ability of scientists to measure true increases in atmospheric CO_2 levels before these become large enough to do substantial harm.

Underlying these uncertainties are the present inadequacies of man's knowledge about the natural adaptive mechanisms of his planet to cope with CO_2 buildup. For example, the world's ocean has the capacity to easily absorb all of the excess CO_2 from burning the world's entire stock of fossil fuels. However, it is currently believed that the ocean cannot respond to the projected CO_2 increases fast enough—i.e., that elevated CO_2 levels would persist for thousands of years before the "excess" CO_2 could be absorbed by the world ocean. Active research on the ocean's thermal characteristics is ongoing, and will hopefully reduce uncertainty about the CO_2 absorption capability of the oceans.

Similarly, a 1 percent increase in the world's stock of plant material would be enough to take care of the CO_2 produced by the current rate of fossil fuel consumption (2.5 percent annual growth rate). This would not be effective, however, unless the new plant material could be protected from decay or being eaten, and thus discharging its CO_2 back to the atmosphere. Reforestation could serve well, because trees can store CO_2 for a long time, but potential increases in the world's forest volume are limited and uncertain.

Timing

If the CO_2 induced problems occur, it will be because mankind consumed the earth's stock of fossil fuels in such a relatively short span of time (decades) that the earth's natural adaptive mechanisms (e.g., ocean CO_2 absorption), which operate on a much longer time frame (hundreds to thousands of years), could not respond in time to prevent global warming which lasted for a period of many human lifetimes.

Fossil fuel use rates grew at about 4 percent per year during 1940-1973, and at about 2.5 percent per year since then. Steep price increases for oil and competitive energy sources probably account for the reduced rate in recent years. Figure D-1-3 compares a 4 percent growth rate for fossil fuel use with a 1 percent growth rate, and shows the resulting growth in atmospheric CO_2 concentrations for both cases, using a model of global climate. Even at the lower (1 percent) growth rate for fossil fuel use, CO_2 would double its preindustrial level by about the year 2070 and triple it by about 2130. At the 4 percent growth rate, CO_2 levels would reach 8-10 times preindustrial levels by early in the 22nd century. Thus, even at a modest (1 percent) rate of increase in fossil fuel use, which is less than the present rate, CO_2 concentrations could reach levels associated with potentially disastrous climate modification.

One response to this situation could be to solicit international cooperation in limiting CO_2 levels - e.g., in limiting fossil fuel use worldwide. The President's Council on Environmental Quality (CEQ) has examined three fossil fuel use scenarios based upon limiting atmospheric concentrations of CO_2 to 1.5, 2.0, and 3.0 times preindustrial levels (Figure D-1-4). All three scenarios require a slower growth rate for fossil fuel use than presently exists, declining eventually to zero growth within the next 35-95 years, followed by a decreasing use rate for fossil fuels. To achieve any of these scenarios, while maintaining our present (2.5 percent) fossil fuel growth for the next decade, would require an even steeper decline in fossil fuel use later on in order to stay within the original constraint related to ultimate CO_2 concentration in the atmosphere.

Table D-1-1 illustrates this for three different CO_2 containment scenarios which allow atmospheric CO_2 levels to increase by 50 percent, 100 percent, and 200 percent over preindustrial levels, respectively. For each of these three scenarios, three cases (A, B, and C) are shown, which vary fossil fuel use growth rates as shown in Figure D-5. In all cases, the growth in fossil fuel use slows to zero, followed by a period of decreasing fossil fuel use, in order to keep CO_2 within the levels specified in that containment scenario.

The more rapid the initial (1980-1990) fossil fuel-use rates, the earlier peak fossil fuel use is reached, and the more rapid must be the decrease in fossil fuel use, in order to keep atmospheric CO_2 levels within the ceilings dictated by the containment scenario (Figure D-1-5). Figure D-1-3 shows that CO_2 buildup lags the buildup in fuel use, so that maximum CO_2 concentrations occur well after peak fuel use rates. Thus, long-term CO_2 concentrations of 1.5, 2.0, and 3.0 times the preindustrial level (of 292 ppm CO_2, as estimated by CEQ) are higher than the CO_2 levels estimated at peak fuel use.

If the growth rate for fossil fuel use continues at its present level, the world will increase its reliance on fossil fuel use over the next few decades so much that reversing this reliance could be difficult, even if CO_2 induced climatic effects begin to occur as predicted. Planning for alternative energy futures must begin now, if it is to be orderly. It will require a high degree of international cooperation. Such efforts cannot afford to wait for research and monitoring to "prove" what the ultimate consequences of CO_2 increases would be. This could take years, and might be impossible.

Figure D-1-3

Atmospheric CO_2 concentrations and energy production curves (growth in 1980 of 4% and 1% per year).

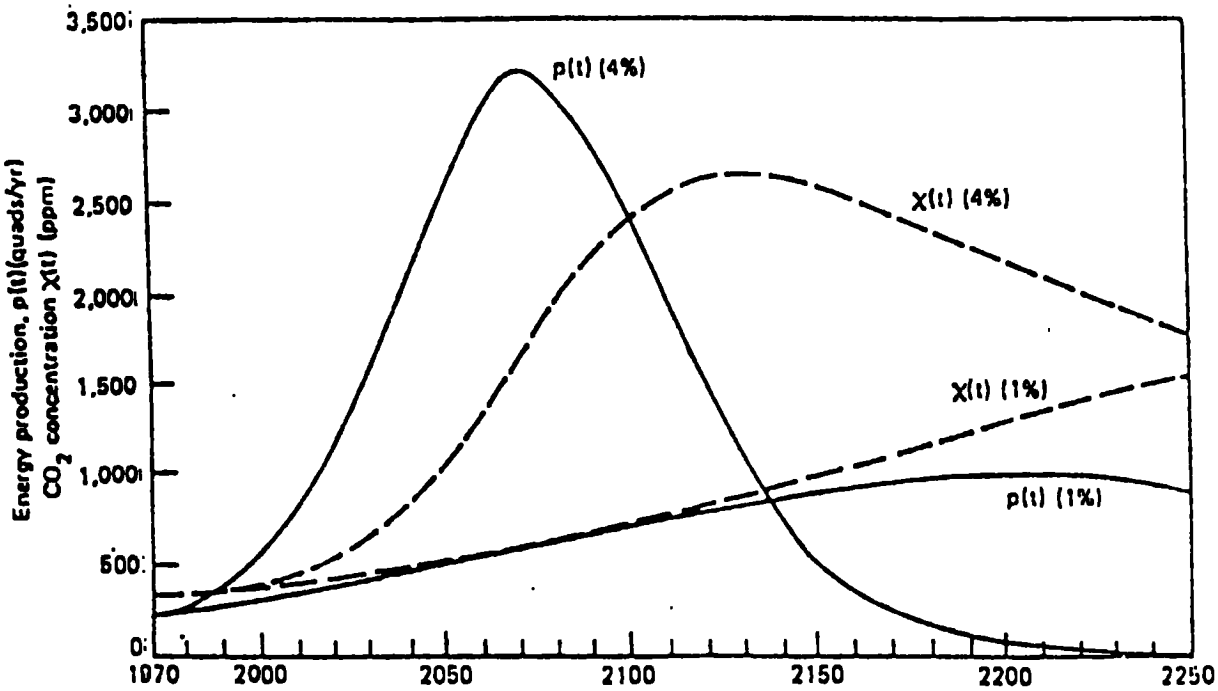
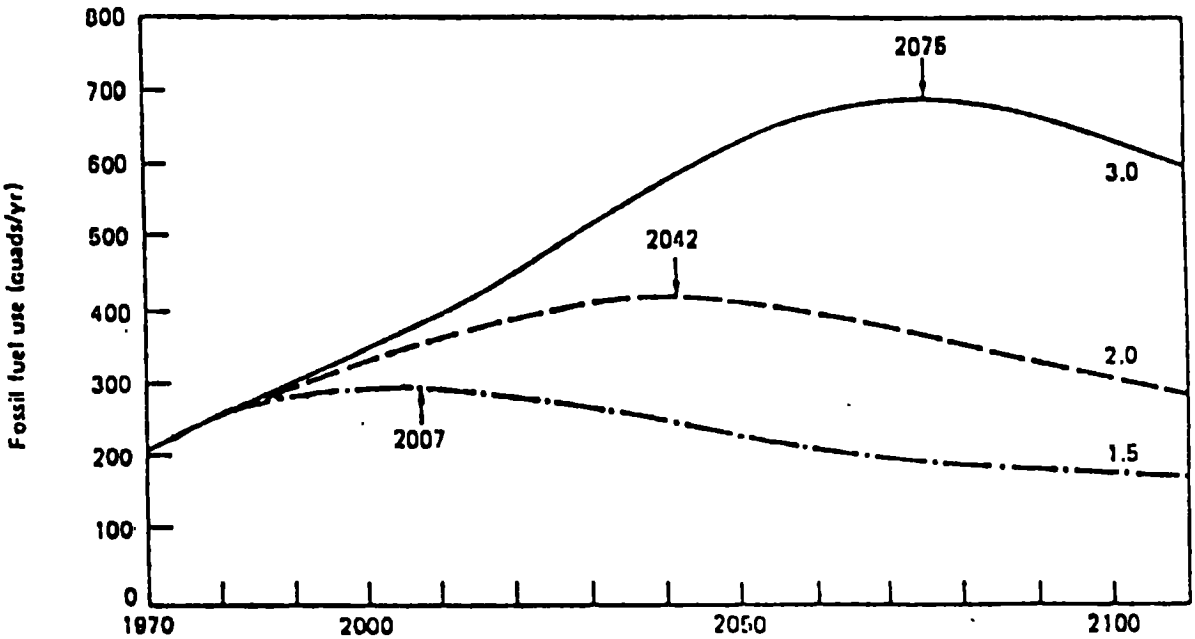


Figure D-1-4

Production curves for global fossil fuel use to yield a buildup of atmospheric CO_2 equal to 1.5, 2.0, and 3.0 times the pre-industrial level (years for peaks of curves shown in parentheses).



Source: Ref. 1

TABLE D-1-1

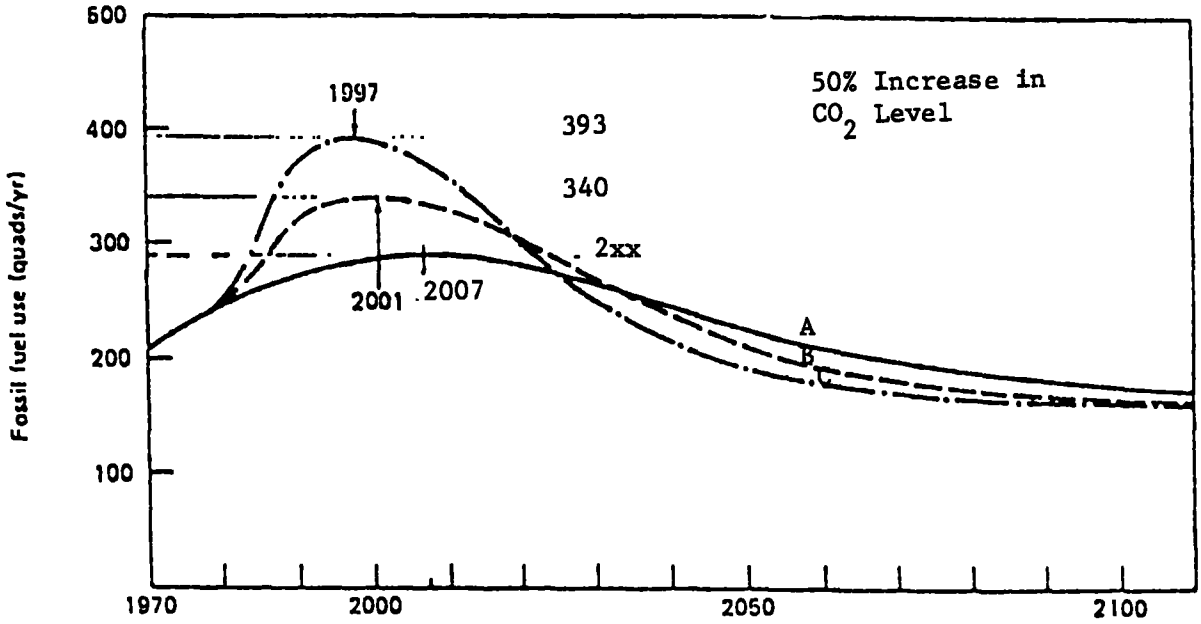
ILLUSTRATIVE CO_2 CONTAINMENT SCENARIOS
BASED ON DIFFERENT CO_2 CEILING LEVELS
AND FOSSIL FUEL USE GROWTH RATES

Entry										
1.	Increase in CO_2 Above Preindustrial Levels		50%			100%			200%	
2.	Scenario No.	1A	1B	1C	2A	2B	2C	3A	3B	3C
3.	Fossil Fuel-Use Growth Rate (%/Year)									
	1980	1.0	2.5	4.0	1.3	2.5	4.0	1.4	2.5	4.0
	1990	0.7	2.5	4.0	---	2.5	4.0	---	2.5	4.0
	2000	---	---	---	1.1	---	---	---	---	---
	2040	---	---	---	---	---	---	1.0	---	---
4.	Year of Peak Fossil Fuel Use	2007	2001	1997	2042	2031	2021	2075	---	---
5.	Fossil Fuel Use (Quads/Yr)									
	a. Peak	288	340	393	415	472	528	682	---	---
	b. Equilibrium	163	163	163	220	220	220	330	330	330
6.	Atmospheric CO_2 Levels									
	a. Peak Fuel Use	391	---	---	453	---	---	619	---	---
	b. Equilibrium Fuel Use	438	438	438	584	584	584	876	876	876

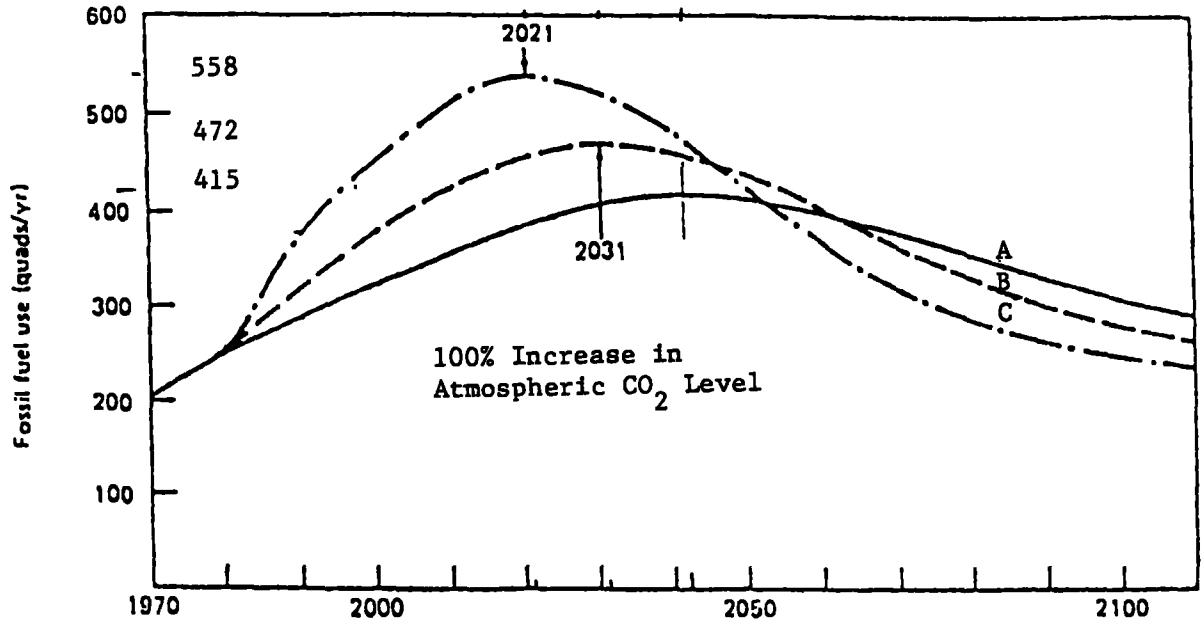
Source: Data from Ref. 1 text and graphs.

Figure D-1-5

Alternative production curves leading to a 50% increase in atmospheric CO_2 levels. The solid line represents an immediate but gradual response. The middle curve (— —) represents a 2.5% growth in fossil fuel use from 1980 to 1990. The high curve (—·—) represents a 4% growth from 1980 to 1990.



Alternative production curves leading to a 100% increase (doubling) in atmospheric CO_2 levels. The solid line represents an immediate but gradual response. The middle curve (— —) represents a 2.5% growth in fossil fuel use from 1980 to 1990. The high curve (—·—) represents a 4% growth from 1980 to 1990.



Source: Ref. 1

Accordingly, to buy precious time, and to preserve maximum flexibility in choosing our energy futures, CEQ recommends that the United States deal with the CO_2 problem as follows:

1. Give high priority to incorporating the CO_2 issue into United States energy policy planning.

2. Increase reliance on energy conservation and renewable sources of energy.

3. Undertake new and expanded cooperative international efforts to address CO_2 issues.

REFERENCES

1. Council on Environmental Quality. "Global Energy Futures and the Carbon Dioxide Problem". January 1981.

2. C.F. Cooper. "What Might Man Induced Climate Change Mean?" Foreign Affairs, April 1978, pp. 500-520.

3. "Methane Gas in Atmosphere Increasing". The Oregonian, January 25, 1981, Portland, Oregon.

4. "Greenhouse Prophecy Bears Chilling Consequences". The Oregonian, December 21, 1980, Portland, Oregon.

Section D-2

Air Pollution Issues

Prepared by:
Robert L. Gay

TABLE OF CONTENTS

	Page
Issues Addressed	1
Summary of Findings and Conclusions	1
Introduction	2
Air Pollutants from Coal Burning	2
National Air Pollution Standards Considerably Mitigate Coal-Burning Impacts	3
Controlled Emission Rates from Coal-Fired Plants	6
Effect of Stringent Air Pollution Standards	6
Fine Particulates	9

LIST OF FIGURES

Figure D-2-1: Comparison of Percent Removal of Uncontrolled SO_2 Emissions from Coal-Fired Plants as Required by the Federal New Source Performance Standards and the Wyoming Standard	11

LIST OF TABLES

		Page
Table D-2-1:	Coal Characteristics Which Affect Air Pollution Emissions	2
Table D-2-2:	National Ambient Air Quality Standards for SO_2, PM, and NO_x ($\mu g/m^3$)	4
Table D-2-3:	Air Pollutant Emission Standards for New Coal-Fired Electric Utility Plants	5
Table D-2-4:	Maximum SO_2, PM and NO_x Emissions from a Hypothetical Coal-Fired Plant Operated Exactly at the Federal New Source Performance Standard Emission Rates	7
Table D-2-5:	Actual Emissions from Three 500 MW Coal-Fired Plants	8
Table D-2-5:	Comparison of Percent Removal of Uncontrolled SO_2 Emissions from Coal-Fired Plants as Required by the Federal New Source Performance Standards and the Wyoming Standard	10

AIR POLLUTION ISSUES

Issues Addressed

This paper discusses several air pollution issues of interest to the Hydropower Technology Assessment Project, including:

1. Attractiveness of hydropower development as a substitute for coal-fired power plant development, in order to avoid the air pollution impacts from coal burning;

2. Whether Wyoming's stricter air pollution standards could inhibit development of new coal-fired plants sufficiently to make a hydropower alternative significantly more attractive;

3. Whether fine particulates from coal-fired power plants are of sufficient impact to increase the attractiveness of a hydropower alternative.

Summary of Findings and Conclusions

National Ambient Air Quality Standards (NAAQS) for sulfur dioxide (SO_2), particulate matter (PM), and oxides of nitrogen (NO_x), and federal New Source Performance (emissions) Standards (NSPS) for these three pollutants for coal-fired power plants, considerably mitigate coal-burning air pollution impacts. Accordingly, substitution of hydropower for coal-fired power sources, to avoid the remaining impacts from coal, will not normally be a compelling decision factor in considering expansion of hydropower, unless site-specific conditions make coal burning especially unwanted—e.g., to protect pristine (Class I) areas from significant air quality deterioration. Such cases would probably be rare.

Wyoming's stricter SO_2 emission rate ceiling for coal-fired power plants (0.2 lbs $SO_2/10^6$ Btu) will not make coal-fired plants more difficult to develop in that state, unless coal with sulfur content greater than 1 percent is used. This seems unlikely, given the abundance of the cleaner coal (less than 1 percent sulfur) throughout the western United States, and the predominant use of such low-sulfur coal in Wyoming and other western states. When coal sulfur content is < 1 percent, federal SO_2 emissions standards require a greater percentage removal of uncontrolled SO_2 emissions than the Wyoming standard does. If other states adopted the Wyoming standard, and could not readily obtain coal with < 1 percent sulfur, coal-fired power plant development could be retarded there.

Fine particulate impacts from coal-fired power plants include both direct emissions of fine particles and "secondary particulates," formed by conversion of gaseous SO_2 and NO_x emissions into sulfate (SO_4) and nitrate (NO_3) particles in the atmosphere. These emissions are widely dispersed, however, due to their relatively high plume rise and gradual conversion to secondary particulate. Their main impacts are contributions to regional problems, like acid rainfall and visibility reduction, usually over wide areas and often at great downwind distances from the power plants themselves. Substitution of hydropower for new coal-fired plants would not effectively mitigate these impacts, because it could not occur on a sufficient scale, and would not affect existing power plant emissions, which have contributed heavily to existing regional impacts.

Introduction

Expansion of reliance upon hydropower avoids environmental impacts of alternative energy sources—actually trading them off for other environmental impacts which accompany hydropower development. Among the most notable impacts which could be avoided by expanded reliance on hydropower are air pollution impacts associated with fossil fuel (oil, coal) fired electric utility generating facilities. Substitution of new hydropower facilities for new coal-fired power plants is especially interesting, since uncontrolled emissions from coal burning are high, and there is considerable promotion of expanded use of this country's coal reserves. Such substitution of hydropower for coal would be most relevant in regions of the country which have significant potential for both kinds of development.

Air Pollutants From Coal Burning

Regulated air pollutant emissions from coal-fired power plants include sulfur dioxide (SO_2), particulate matter (PM), and oxides of nitrogen (NO_x). Table D-2-1 lists several characteristics of coal which help determine its potential pollutant emissions.

Table D-2-1

Coal Characteritsics Which Affect Air Pollutant Emissions

Coal Characteristics	Range for Coal Used in USA
Sulfur Content	0.3 - 4.5% by weight
Ash Content	7 - 13% by weight
Heating Value	7,000 to 13,000 Btu/pound
Moisture Content	3 - 35% by weight

(Source: Ref. 2)

Most coal produced or used in the United States would have characteristics within the ranges shown in Table D-2-1 (Ref. 2). Sulfur content and ash content directly affect SO_2 and PM emissions. NO_x emissions depend more on conditions in the combustion chamber (temperature, excess air, etc.) than on coal characteristics. The heating value of coal governs how much coal must be burned in a given facility to produce a given amount of power. Higher moisture content is associated with coal of lower heating value.

National Air Pollution Standards Considerably Mitigate Coal-burning Impacts

Table D-2-2 summarizes the three types of National Ambient Air Quality Standards which have been established for SO_2, PM and NO_x. These are primary standards to protect public health, secondary standards to protect public welfare, and (tertiary) standards to prevent significant deterioration of air quality in areas where the baseline air quality levels are cleaner than the applicable (primary or secondary) standard.

Table D-2-3 summarizes the allowable emissions of SO_2, PM, and NO_x, from new or expanded electric utility coal-fired plants. These are federal standards, commonly referred to as New Source Performance Standards (NSPS) for coal-fired plants. Less strict standards apply to existing plants built before these standards were adopted (June, 1979), but they are not considered here, because new hydropower facilities could substitute only for new coal-fired facilities. For simplicity, Table D-2-3 also refers only to use of bituminous coal, which accounts for the great majority of coal produced in the United States, and a lesser majority of the United States coal reserves (Ref. 2).

Together these national ambient and emissions standards provide considerable mitigation of impacts resulting from coal-burning. For example, under the NSPS (Table D-2-3), a new coal-fired plant would typically have to remove at least 90 percent of its uncontrolled SO_2 emissions on a continuous basis, even if its average SO_2 emissions were well below the 1.20 lbs SO_2 10^6 Btu standard. To be eligible to only remove 70 percent of its SO_2 emissions would probably require precleaning of coal. Likewise, coal-fired plants would typically be required to remove at least 99 percent of their uncontrolled PM emissions, and about 75 percent of their NO_x emissions, based on EPA definitions of uncontrolled emission levels (Ref. 1).

In addition to the stringent controls on the emissions at their source, the national ambient air quality standards (Table D-2-2) establish ceiling concentrations which cannot be exceeded for SO_2, PM, and NO_x. Before new coal-fired plants can be built,

TABLE D-2-2

NATIONAL AMBIENT AIR QUALITY STANDARDS FOR SO_2, PM, AND NO_x ($\mu g/m^3$)

Pollutant	Primary Standard ($\mu g/m^3$ not to be exceeded)	Secondary Standard ($\mu g/m^3$ not to be exceeded)	Prevention of Significant Deterioration Increments ($\mu g/m^3$ increase above Class II Area)	(Baseline not to be exceeded) Class I Area
Particulate Matter				
- Annual Geometric Mean	75	60	19	5
- 24-Hour Maximum	260	150	37	10
Sulfur Dioxide				
- Annual Arthritmetic Mean	80	None	20	2
- 24-hour Maximum	365	None	91	5
- 3-hour	None	1300	512	25
Nitrogen Dioxide				
- Annual Arithmetic Mean	100	100	- None Established Yet -	

Table D-2-3

AIR POLLUTANT EMISSION STANDARDS FOR NEW COAL-FIRED ELECTRIC UTILITY PLANTS

Pollutant	Federal New Source Performance Standards
Sulfur Dioxide	(a) Emission rate shall not exceed 1.20 lbs. SO_2 per 10^6 Btu of heat input, and;
	(b) -90 percent reduction of uncontrolled SO_2 emissions shall be achieved if uncontrolled SO_2 emissions exceed 0.60 lbs $SO_2/10^6$ Btu of heat input, or; -70 percent reduction of uncontrolled SO_2 emissions, if these are less than 0.6 lbs SO_2 / 10^6 Btu.
Particulate Matter	Emissions rate shall not exceed 0.03 lbs PM/10^6 Btu of heat input.
Oxides of Nitrogen	Emissions rate shall not exceed 0.60 lbs $NO_x/10^6$ Btu of heat input.

Source: Federal Register 44 (113), 33580-81 (June 11, 1979).

dispersion modeling analyses must be carried out to show that residual (controlled) plant emissions would not cause violations of any of these ambient standards. Failure to meet this test could require further restriction of plant emissions or a plant's location—e.g., if the proposed location were too near to pristine areas protected by Class I status, under prevention of significant deterioration requirements. These ambient standards would also apply to the combined impacts when several plants are co-located.

Controlled Emission Rates from Coal-fired Plants

Table D-2-4 summarizes the maximum hypothetical emissions of SO_2, PM, and NO_x which could be legally emitted from a new 500 megawatt (MW) coal-fired plant, operated in compliance with the national standards in Table D-2-3. For example, this estimate assumes that after 90 percent removal of uncontrolled SO_2 emissions, residual SO_2 is emitted at 1.2 lbs / 10^6 Btu of heat input. These calculations also assume that typical facilities would operate about 55 percent of the time (load factor) and that their efficiency in converting the heating value in coal into electric power would be about 33 percent.

These hypothetical maximum annual emissions are small enough that they would not normally be expected to result in ambient SO_2 levels which could violate the ambient standards in Table D-2-2. Site-specific problems would be expected only if such a facility were located in an area with especially poor ventilation and frequent temperature inversions, or too close to Class I Possible Significant Deterioration (PSD) areas (Table D-2-2).

Table D-2-5 shows actual SO_2 emission rates from three 500 MW coal-fired plants recently built in Oregon and Wyoming. They are substantially lower than the maximum allowable rates shown in Table D-2-4. The Boardman #1 plant emits only 0.6 lbs SO_2 / 10^6 Btu, without any SO_2 controls, by using low sulfur coal. Boardman is not subject to the 90 percent SO_2 removal requirement, because it was already under construction in June, 1979. The two Wyoming plants emit SO_2 at very low rates, by using both low sulfur coal and pollution control equipment (scrubbers) which removes 90 to 95 percent of the uncontrolled SO_2 emissions.

Thus, actual emissions of SO_2, PM, NO_x are mitigated by federal pollution control standards to such an extent that substitution of hydropower to avoid coal-fired air pollution emissions is not likely to be a major decision factor, unless site-specific conditions make coal burning impacts especially objectionable.

Effect of Stringent Air Pollution Standards

At least one state (Wyoming) has adopted standards to control coal-fired plant air pollutant emissions which are even more stringent than the federal standards in Table D-2-3 in some respects. This could encourage hydropower expansion if the stricter state standard makes coal-fired plants significantly more difficult and costly to develop—especially if other states also adopted similarly tough standards.

Table D-2-4

MAXIMUM SO_2, PM, AND NO_x EMISSIONS FROM A HYPOTHETICAL COAL-FIRED PLANT OPERATED EXACTLY AT THE FEDERAL NEW SOURCE PERFORMANCE STANDARD EMISSION RATES

Pollutant	New Source Performance Standard Emission Rates (lbs / 10^6 Btu)	Maximum Annual Emissions From a Hypothetical 500 MW Coal-fired Plant* (tons/year)
Sulfur Dioxide	1.20	15,000
Particulate Matter	0.03	375
Oxides of Nitrogen	0.60	7,500

* Assumes coal-fired plant load fator = 55%, powerplant efficiency of coal plant = 33%, and 1 Kwh = 3,415 Btu

Table D-2-5

ACTUAL EMISSIONS FROM THREE 500 MW COAL-FIRED PLANTS

Emissions Parameter	Boardman #1 (Boardman,OR)[1]	Jim Bridger #1 (Wyoming)[2]	Basin Electrical #1 (Wheatland, WY)[2]
Measured Emission Rate ($lbs/10^6$ Btu)			
SO_2	0.69	0.08	0.036
PM	0.016	—	—
NO_x	0.57	—	—
Coal Used			
% Sulfur	0.38	0.64	0.33
% Ash	7.8	—	—
Btu/lb	10,744	9,578	8,515
Emission Controls			
SO_2	None	Scrubber (soda ash liquor)	Scrubber (limestone)
PM	ESP[3]	ESP[3]	ESP[3]

1. September 1980 source test results, obtained from Reference 6.

2. From Wyoming Department of Environmental Quality.

3. Electrostatic precipitator.

Wyoming requires that SO_2 emission rates from coal-fired plants not exceed 0.2 lbs SO_2 / 10^6 Btu, compared to the federal standard of 1.2 lbs SO_2 / 10^6 Btu. However, the Wyoming standard does not also require, as the federal standard now does (Table D-2-3), that 70 to 90 percent of the uncontrolled SO_2 emissions be removed, regardless of the average SO_2 emission rate. This makes the Wyoming standard more stringent than the federal standard, only for coal with > 1 percent sulfur content, as shown in Table D-2-6 and Figure D-2-1.

For coal with < 1 percent sulfur content, the federal standard requires a greater percentage reduction of uncontrolled SO_2 emissions than the Wyoming standard. This is illustrated in Table D-2-6 and Figure D-2-1, using hypothetical coal with 10,000 Btu/lb heating value and variable (S) sulfur content.

Coal with < 1 percent sulfur is relatively abundant in the West (Ref. 2). Coal-fired plants in Wyoming currently use and have excellent long-term access to coal with < 1 percent sulfur. Thus the Wyoming standard does not restrict development of new coal-fired plants in that state. It would inhibit use of higher sulfur content coal in Wyoming, as it would in any other state which adopted similar standards.

Fine Particulates

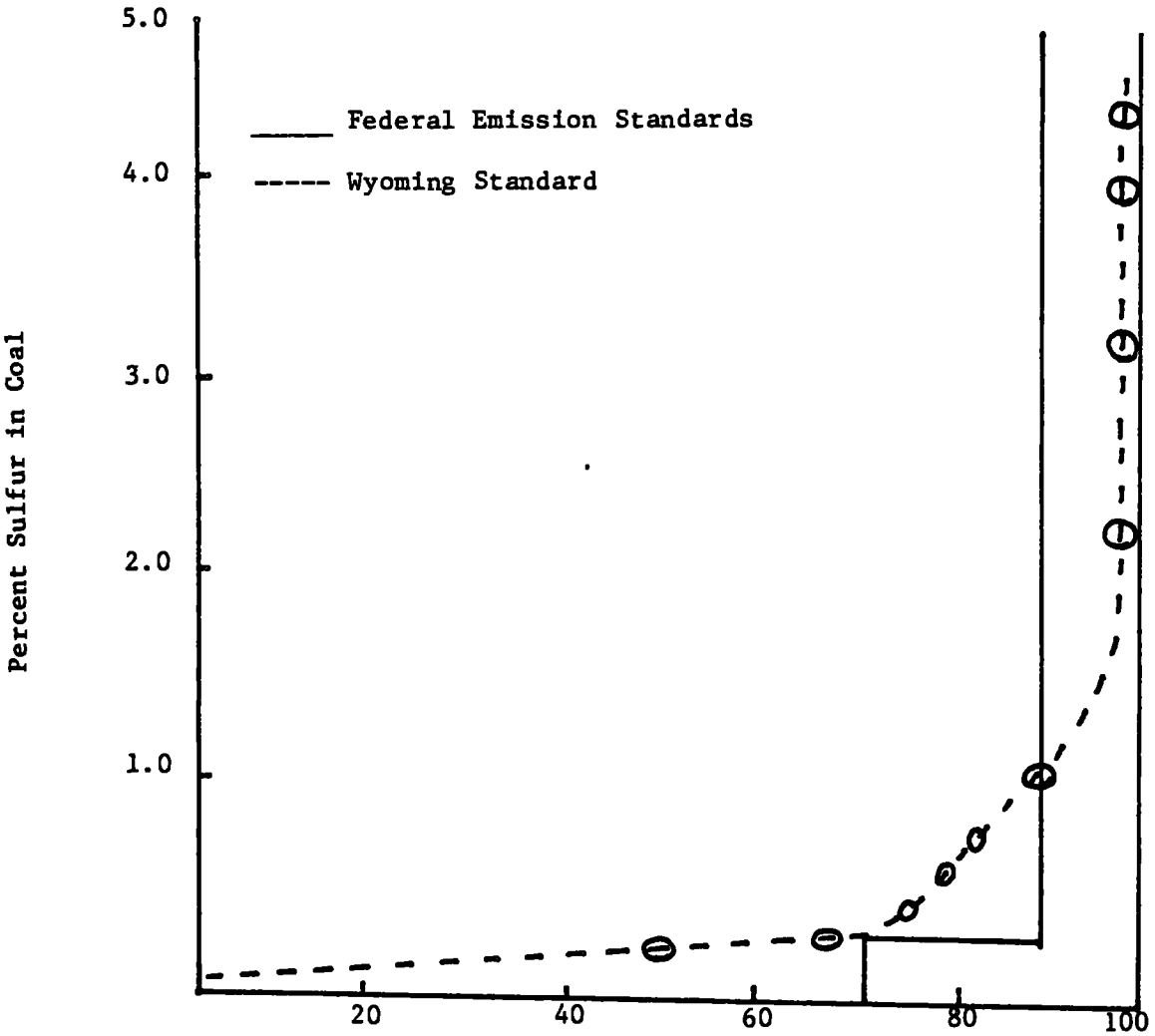
Fine particulates are especially troublesome, because they can: (1) threaten public health—e.g., by penetrating into lungs, causing physical damage and exposing tissue to toxic chemicals absorbed on particle surfaces; (2) contribute to acid rain problems: (3) scatter light and reduce visibility; and (4) travel long distances affecting populations far from the emissions source. Particle sizes below 15 microns in diameter are inhalable, but are mostly trapped in nasal and throat passages. Particle sizes below 2 microns are respirable into the lungs. Particle sizes of 0.5 - 1.0 microns are especially effective at scattering light and reducing visibility. Existing national PM standards (Table D-2-2) are based on total mass of particulate in the air, without regard to particle size. However, EPA is developing fine particulate standards which will finally recognize and limit the special health and welfare impacts of fine particulates (Ref. 5).

TABLE D-2-6

COMPARISON OF PERCENT REMOVAL OF UNCONTROLLED SO_2 EMISSIONS FROM COAL-FIRED PLANTS AS REQUIRED BY THE FEDERAL NEW SOURCE PERFORMANCE STANDARDS AND THE WYOMING STANDARD

Sulfur Content of Coal-fired 10,000 Btu/lb	Uncontrolled SO_2 Emissions (lbs $SO_2/10^6$Btu)	Percent Removal of Uncontrolled SO_2 Emissions Required to Comply with Standard: Wyoming Standard (0.2 Lbs $SO_2/10^6$Btu)	Federal Standard (Table III) Emissions	Maximum Allowable SO_2 Emissions Under Federal Standard (NSPS) Emissions Rate (T/yr SO_2)	(lb-$SO_2/10^6$Btu)
0.0	0·0	0	0	0	0.0
0.1	0.2	0	70	1,350	.06
0.2	0.4	50	70	2,700	.12
0.3	0.6	67	70	4,050	.18
0.38	0.76[2]	74	90	1,710	.076
0.5	1.0	80	90	2,250	.10
1.0	2.0	90	90	4,500	.20
2.0	4.0	95	90	9,000 (4,500)[2]	.40 (.20)[2]
3.0	6.0	96.7	90	13,500 (4,500)[2]	.60 (.20)[2]
4.0	8.0	97.5	90	18,000 (4,500)[2]	.80 (.20)[2]
4.5	9.0	97.8	90	20,250 (4,500)[2]	.90 (.20)[2]

1. For coal with 10,000 Btu/lb and 0.38% sulfur:
   a. 10^4 Btu/lb coal = 10^4 Btu/0.0038 lbs Sulfur = 10^4Btu/0.0076 lb SO_2 = 10^6 Btu/.76 lb SO_2 = 0.76 lbs $SO_2/10^6$ Btu of heat input
   b. .76 lbs SO_2 - 0.20 lbs SO_2 (100) = 73.7% removal of uncontrolled SO_2 required to meet Wyoming Standard. .0.76 lb SO2
2. Corresponds to Wyoming Standard



Percent Removal of Uncontrolled SO_2 Emissions Required

Figure D-2-1

Comparison of Percent Removal of Uncontrolled SO_2 Emissions from Coal-Fired Power Plants, as required by the Federal New Source Performance Standards and the Wyoming Standard.

Most PM pollution control equipment is least efficient at trapping the smallest particulates. Coal-fired power plant PM emissions (Tables D-2-4, D-2-5) are essentially all fine particulate in the 1.0 micron or less size range. Only particulate this fine escapes the electrostatic precipitators used to control PM on most such plants.

"Secondary Particulate" refers to fine particulate aerosols, formed by conversion of gaseous pollutants like SO_2 and NO_x into small particles of sulfate (SO_4) and nitrate (NO_3), which usually form in the 1.0 micron or less particle size range. Virtually all of the SO_2 emissions from coal-fired plants eventually convert to SO_4 particles, but on a time scale of hours to days, allowing wide downwind dispersal of the resulting particles. Secondary sulfate and nitrate from power plants and from "urban plumes," in the Northeastern United States are considered the chief contributors to the acid rainfall problems in Northern New England states and Canada, including problem areas hundreds of miles away from the emission sources.

Coal-fired power plant emissions produce both primary (PM) and secondary (SO_4 NO_3) fine particulate. It is distributed widely and over large areas due to its relatively high plume rise at the plant site, and to the gradual conversion to secondary particulate in the atmosphere. Under these conditions, ground level concentrations of fine particulate from coal-fired power plants have little opportunity to build up. Secondary sulfate concentrations are often so low as to be hard to detect at all in the air, even when rain in the area has become acidified through their action. Also, sulfate in the 1.0 micron particle size range has been shown to be especially effective in scattering light and reducing visibility.

Recent PM aerosol characterization studies in Portland and Medford, Oregon, (Refs. 3, 4) indicate that most fine particulate inside these two urban nonattainment areas comes from local sources—e.g., residential wood combustion, and vehicle exhaust—rather than from long-range transport of pollutants from remote sources. These studies did not specifically look for coal-fired plant emissions, and the results probably are not representative of midwestern and eastern cities located in regions with heavy commitments to coal combustion as a power source.

Fine particulate from coal-fired power plants is not likely to affect PM standards attainment in urbanized areas. Its primary impacts wil be its contributions to acid rainfall and general visibility reduction over large areas including some at great distance from the plants themselves. Health effects of such widely dispersed emissions are impossible to evaluate but are probably small.

Future advances in coal-fired PM emission control technology will not affect fine particulate impacts very much because most of the fine particulate associated with coal-fired plant emissions is secondary particulate from gaseous precursors. Elimination of all SO_2 emissions from coal-fired power plants would significantly reduce secondary particulate formation, but this is not anticipated.

Substitution of hydropower for new coal-fired power plants could not significantly mitigate regional problems like acid rainfall, because such substitution would not occur on sufficient regional scale, and because it would not address existing power plant emissions which are the source of existing problems.

REFERENCES

1. "New Stationary Sources Performance Standards; Electric Utility Steam Generating Units". Federal Register, 44 (113) 33580 - 33624 (June 11, 1979). Final rules promulgated by the U.S. Environmental Protection Agency.

2. "Coal Research, Development and Demonstration Program," Draft Environmental Impact Statement. Energy Research and Development Administration, ERDA - 1157 - D. September 1977.

3. A. Cooper, G. Watson, and J. Huntziker. "Portland Aerosol Characterization Study". Oregon Graduate Center, Beaverton, Oregon, April 1979.

4. R.T. DeCesar and J.A. Cooper. "Medford Aerosol Characterization Study". Oregon Graduate Center, Beaverton, Oregon, February 3, 1981.

5. U.S. Environmental Protection Agency. "Air Quality Criteria for Particulate Matter and Sulfur Oxides," External Review Draft No. 1. Research Triangle Park, North Carolina, April 1, 1980.

6. Memorandum by P.B. Bosserman, 14817 Southeast Raintree Court, Milwaukie, Oregon. "Impact of Possible Hydroelectric Expansion on Conversion of Industrial and Electric Utility Boilers to Coalfired Power." January 19, 1981.

Section E

Energy and Technology Data and Projections Working Paper

Prepared by:
Kish J. Sharma

Table of Contents

		Page
I.	The Facts	1
	A. 1979 Energy Use	1
	B. Distribution of Energy Use (1979)	1
	C. United States Petroleum Supply, 1970-1979	4
	D. Electricity Generation	4
	E. Fuel Prices (1979)	4
	F. Capital Expenditures (1975-1978)	4
	G. Energy and Economic Growth	4
II.	The Futures	12
	A. Energy Use	12
	B. Sources of Electric Power	12
	C. Future Competing Technologies	15
	D. Supply Technologies	15
	1. Coal	17
	a. Environmental Control Technologies	21
	b. New Advanced Coal Technologies	22
	(1) Technologies for Coal Combustion	22
	(2) Technologies for Coal Conversion	23
	2. Nuclear	24
	3. Solar	25
	4. Geothermal	31
	E. Energy Conserving Technologies	31

List of Figures

Figure E-1: Future Power Technology 16

List of Tables

		Page
Table E-1:	1979 Energy Use	2
Table E-2:	Distribution of Energy Use (1979) (End Use Consumption)	3
Table E-3:	U.S. Petroleum Supply (Quads/Year)	5
Table E-4:	U.S. Generation Installed Capacity (1978)	6
Table E-5:	U.S. Total Electric Energy Generation (1978)	7
Table E-6:	Electricity Generation Cost (cents/kWh)	8
Table E-7:	Average 1979 U.S. Fuel Prices	9
Table E-8:	Energy Sector Capital Expenditures ($ Billions, Current)	10
Table E-9:	Energy and Economic Growth	11
Table E-10:	Percentage Distribution of Energy Requirements (2000 Except as Noted)	13
Table E-11:	Changes in Sources of Electrical Energy (GW-Year) in 2000	14
Table E-12:	Initial Availability of Power Generation Technology	18
Table E-13:	Department of Energy Estimates for New Energy Technologies (Estimates Developed in 1979)	19
Table E-14:	Technology Economics	20
Table E-15:	Solar Contributions by 2000 (Projected)	26
Table E-16:	Solar Water Heating Cost ($ per MM Btu, Estimated in 1979) Mean Daily Solar Radiation (Btu/Ft^2/Day)	27
Table E-17:	Photovoltaic Technology Development	29
Table E-18:	Solar Photovoltaics (Cents/kWh)	30
Table E-19:	Potential for Energy Savings in Residential & Commercial Sectors (CONAES data)	32
Table E-20:	Potential for Energy Savings in the Industrial Sector (CONAES data)	33

ENERGY AND TECHNOLOGY DATA AND PROJECTIONS WORKING PAPER

This document is divided into two parts. Part I, "The Facts", describes the historical data on energy, including electricity, use and supply. Part II, "The Futures", describes projected energy, including electricity, use and supply. A substantial portion of Part II is devoted to the discussion of future technologies of particular relevance to this study, and the ones which will compete with hydropower as alternative generation technologies.

I. The Facts

A. 1979 Energy Use

Table E-1 delineates energy used in the United States for the year 1979 in four major sectors: residential, commercial, industrial and transportation.[1] The energy requirements are derived from five primary energy sources: coal, oil, gas, hydropower and nuclear. With the exception of gas, the other energy resources are converted into various energy forms, such as refined products and electricity. The largest energy consuming sectors are industrial and transportation. Oil is by far the principal energy resource, followed by gas and coal. The contribution of hydropower is relatively small.

B. Distribution of Energy Use (1979)

It is perhaps more important to know the specific end uses which depend upon the availability of energy. Table E-2 shows the distribution of energy use for various end uses, for the year 1979. In the residential and commercial sectors, energy is used largely for space heating and lighting purposes. The energy use in the industrial sector is more uniformly distributed for three purposes: process steam, direct heat, and electric drives. Energy use in the transportation sector is dominated by automobiles.

The information in Table E-2 leads to two interesting implications for our study. First, if one assumes that electricity can be substituted for every possible end use, its maximum contribution could be 60 percent of the total, not counting the possible electricity use in the transportation sector. This, of course, is far too optimistic but not impossible, and can be labeled as an "almost-all-electric-economy".

On the other hand, if we assume that electricity is needed only for the cases where there is no likely substitute (e.g., for lighting, electric drives), its contribution could be about 16 percent of the total. This again is far too conservative but not impossible, and can be labeled as an "almost-no-electric-economy". From the demand side, these could provide the basis for two extreme scenarios for electricity use.

Table E-1

1979 ENERGY USE

	Residential		Commercial		Industrial		Transportation		Total	
	10^{15}BTU	% of Total	10^{15}BTU	% of Total	10^{15}BTU	% of Total	10^{15}BTU	% of Total	10^{15}BTU	% of Total
Coal	4.2	5.3	2.9	3.7	8.3	10.6	—	—	25.3	19.6
Oil	4.2	5.4	4.4	5.6	9.3	11.9	19.2	24.6	37.1	47.5
Gas	6.5	8.4	3.6	4.6	9.2	11.7	0.5	0.7	17.8	25.4
Hydropower	1.1	1.4	0.7	1.0	1.3	1.6	—	—	3.1	4.0
Nuclear	1.0	1.2	0.7	0.9	1.1	1.4	—	—	2.8	3.5
GROSS ENERGY	16.9	21.7	12.3	15.8	29.2	37.2	19.8	25.3	78.2	100.0

Table E-2

DISTRIBUTION OF ENERGY USE (1979)
(END USE CONSUMPTION)

	Quads	% of Total U.S.
Residential		
Space Heating	9.0	11.4
Water Heating	2.4	3.0
Large Appliances	3.5	4.5
Lighting	0.9	1.2
Air Conditioning	1.1	1.4
TOTAL RESIDENTIAL	16.9	21.6
Commercial		
Space Heating	5.0	6.4
Water Heating	0.6	0.8
Large Appliances	0.8	1.1
Lighting	2.8	3.6
Air Conditioning	1.8	2.3
Asphalt	1.3	1.6
TOTAL COMMERCIAL	12.3	15.9
Industrial		
Process Steam	10.3	13.0
Direct Heat	7.0	9.0
Electric Drives/Lighting	9.5	12.1
Feedstocks	2.4	3.1
TOTAL INDUSTRIAL	29.2	37.2
Transportation		
Automobiles	10.4	13.2
Buses	0.1	0.1
Trucks	4.4	5.7
Other (Air, Ship, Pipelines, other Miscellaneous)	4.9	6.3
TOTAL TRANSPORTATION	19.8	25.3
TOTAL U.S.	78.2	100.0

C. United States Petroleum Supply, 1970-1979

Because of the unique role of oil in the United States energy picture, it is instructive to examine the trends in the nation's petroleum supply. Table E-3 shows increasing dependence on imported oil. The dependency has almost doubled during the period 1970-1979.

D. Electricity Generation

Turning to electricity, Table E-4 shows the installed capacity in gigawatts for the various types of power plants. Coal dominates the generation mix. Hydropower amounts to about 12.6 percent of the installed capacity. The share of coal as a producer of electric energy, expressed in quadrillion Btu, becomes even larger because of the superior value of average capacity factor (Table E-5); and hydropower supplies about 13 percent of the total electric energy. (The distinction between capacity and energy supplied is important.)

Electricity generation costs are expressed in Table E-6 as a function of power plant cost and fuel cost, expressed as $/million Btu for comparison purposes. Since both of these cost are highly variable and uncertain, Table E-6 can be used to estimate generation cost for a range of values assigned to power plant and fuel costs. For example, if one assumes that the plant cost for a coal-fired power plant is $800/kW, and with the cost of coal to the utilities in 1979 at $1.25 per million Btu, the generation cost will be about 3.5 cents/kWh.

E. Fuel Prices (1979)

Table E-7 shows the prices for various fuels for two groups: utilities and other consumers. The relative advantages of various fuels, from a price perspective, can be gauged from the information in Table E-7. The shift from oil to gas in certain regions of the United States for space heating can be explained partially in terms of the relative price advantage of gas over oil. Similarly, the price advantage of coal for electricity generation is also obvious from Table E-7. Hydropower, of course, utilizes fuel which is "free" as far as the price is concerned.

F. Capital Expenditures (1975-1978)

Some of the energy technologies are quite capital extensive. Table E-8 shows capital expenditures in the energy sector, by fuel type. The data shows that electric utilities have been increasing their capital expenditures over the years, with the period 1975-1978 showing an increase of about 52 percent. These data should be useful in assessing the financial implications of increased hydropower capacity.

G. Energy and Economic Growth

In the recent past, there has been considerable debate about the coupling between energy and economic growth. Comparisons have been made, particularly with West Germany, Japan and Sweden, to illustrate the more productive use of energy in these countries compared with the United States. Table E-9 shows the improvement in the energy productivity of the United States economy for the time period 1970 to 1978. It also shows that the two sectors are coupled

Table E-3

U.S. PETROLEUM SUPPLY (QUADS/YEAR)

Year	Domestic Production	Imports	Other (To Balance S & D)	TOTAL	Percentage of Supply Imported
1970	23.9	7.2	0.6	31.7	22.8
1971	23.6	8.3	0.8	32.7	25.4
1972	23.7	10.0	1.5	35.2	28.6
1973	23.2	13.2	0.8	37.2	35.6
1974	22.2	12.9	0.7	35.8	36.2
1975	21.2	12.8	1.0	35.0	36.6
1976	20.6	15.5	1.4	37.5	41.3
1977	20.8	18.4	0.3	39.5	46.6
1978	20.6	17.5	0.4	38.5	45.4
1979	20.4	17.4	1.1	38.9	44.7

(Firm, official 1980 data are not yet available).

Table E-4

U.S. GENERATION INSTALLED CAPACITY (1978)

	GW	% of Total
Coal	228.9	39.6
Oil	147.4	25.5
Natural Gas	74.9	13.0
Hydropower	72.9	12.6
Nuclear	53.6	9.3

Table E-5

U.S. TOTAL ELECTRIC ENERGY GENERATION (1978)

	Quads	% of Total
Coal	10.5	44.3
Oil	3.93	16.6
Natural Gas	3.27	13.8
Hydropower	3.00	12.7
Nuclear	3.00	12.5

Table E-6

ELECTRICITY GENERATION COST (cents/kWh)

	Fuel Cost ($ Per MM Btu)			
Plant Cost ($/kW)	$ 0.50	$ 1.00	$ 2.00	$ 5.00
$ 1,000	3.3	3.8	4.8	7.9
800	2.8	3.3	4.3	7.4
600	2.3	2.8	3.8	6.9
500	2.0	2.6	3.6	6.7
400	1.8	2.3	3.4	6.5

Table E-7

AVERAGE 1979 U.S. FUEL PRICES

	$/Physical Units	$/MM Btu
Electric Utilities		
Residual Fuel Oil	$17.56/bbl.	$ 3.38
Natural Gas	$1.90/1000CF	1.84
Coal	$27.50/ton	1.25
Uranium	$40.00/lb.	0.76
Petroleum	$18.40/bbl.	3.40
Consumers		
Gasoline	$1.00/gal.	$ 8.00
Diesel Fuel	$.72/gal.	5.21
Heating Oil	$.81/gal.	5.87
Natural Gas	$.33/therm	3.49
Wood	$100.00/cord	3.57

Table E-8

ENERGY SECTOR CAPITAL EXPENDITURES ($ BILLIONS, CURRENT)

Year	Coal	Oil & Gas	Nuclear Fuels	Electrical Utilities	Total
1975	1.32	16.18	0.84	23.40	41.74
1976	1.64	20.05	1.52	25.70	48.91
1977	1.90	22.07	1.84	32.52	58.33
1978	2.44	22.51	n/a	35.76	—

Table E-9

ENERGY AND ECONOMIC GROWTH

Year	Energy Growth	Economic Growth	Ratio of Energy Growth/Economic Growth
1970	+ 3.3	- 0.3	—
1971	+ 1.8	+ 3.0	0.6
1972	+ 4.8	+ 5.7	0.84
1973	+ 4.1	+ 5.4	0.76
1974	- 2.6	- 1.4	—
1975	- 2.8	- 1.3	—
1976	+ 5.3	+ 5.7	0.93
1977	+ 2.0	+ 4.9	0.41
1978	+ 2.4	+ 3.8	0.63

Source: Statistical Abstract of the U.S. and DOE Annual (1979) Report to the Congress.

through mechanisms which cannot always be clearly defined. Based on this data the relation between energy and economic growth seems far too complex to be presented by a single coupling.

II. The Futures

A. Energy Use

Several studies have projected future energy use. Table E-10 contains estimates derived from some representative sources: EIAF ("Energy in America's Future", a study by Schurr et al.); IEA (Institute for Energy Analysis, Oak Ridge); CONAES (Committee on Nuclear And Alternative Systems, The National Research Council); RFF-NIH (Resources for the Futures, National Institute of Health study); MOPPS (Market Oriented Program Planning Standards, a Department of Energy (DOE) study); EIA (Energy Information Administration, DOE).

Certain trends emerge from the data in Table E-10:

- The use of electricity as an energy form will increase substantially (5 to 10 percent) by the year 2000.
- Energy used in liquid form will continue as a major source for the rest of this century.
- The use of coal is likely to increase substantially.
- Technologies such as solar are likely to make a minor impact on the energy supply situation by the year 2000.
- Estimates of total energy consumption in the year 2000 seem to range about 100 to 110 quadrillion Btu. This reflects a much lower growth rate than in the 1970's.

B. Sources of Electric Power

Table E-11 shows estimates about likely changes in electricity generation mix by the year 2000. Two rather conventional forecasts are shown in Table E-11; these, however, bracket many other forecasts of future generation mix. The data in Table E-11 is shown in gigawatt-years which can be converted to gigawatt-hours by multiplying the estimates by 8,760; to convert them into quadrillion Btu, multiply by 0.094.

The estimates indicate additional capacity to supply electrical energy as equivalent to 250 to 541 GW-year in 2000; an estimate of 500 GW-year seems likely according to many estimates. This would represent little over 3.0 percent annual increase from 1979. The negative quantities in the case of oil and gas

Table E-10

PERCENTAGE DISTRIBUTION OF ENERGY REQUIREMENTS
(2000 EXCEPT AS NOTED)

	1979	(Schurr) EIAF (1979)*	IEA (1976)*	(2010) CONAES (1979)*	RFF-NIH (1977)*	MOPPS (1977)*	EIA (1980)*
Coal		10	10	10	6	14	
Gas		17	12	15	13	15	
Liquids		33	28	39	42	27	
Electricity	31.1	40	50	36	38	40	
Total		100	100	100	100	100	

	1979	IEA Low	IEA High	MOPPS (DOE-'73)	Schurr (EIAF)	CONAES Scenario B	CONAES Scenario C
Total Energy (Quads)	78.2	101.4	125.9	113.75	115.0	94.0	136.0
Electricity (Quads)	24.3	46.6	50.8	45.51	40.0	33.0	36.0
Electricity at Percent of Total Energy	31.1	45.9	40.3	40.0	34.8	35.1	26.0

* Year when forecast was made

Table E-11

CHANGES IN SOURCES OF ELECTRICAL ENERGY (GW-YEAR) IN 2000

	IEA		EPRI	
	Low	High	Low	High
Coal	52 (4.9)	210 (19.7)	163 (15.3)	268 (25.2)
Nuclear	169 (15.9)	188 (17.7)	208 (19.6)	277 (26.0)
Oil & Gas	-26 (-2.4)	-26 (-2.4)	-49 (-4.6)	-34 (-3.2)
Hydro & Geothermal	44 (4.1)	44 (4.1)	18 (1.7)	30 (2.8)
Wind & Solar	11 (1.0)	11 (1.0)	1 (0.1)	1 (0.1)
TOTAL ADDITIONAL	250 (23.5)	427 (40.1)	341 (32.1)	541 (50.9)

Data in parentheses ( ) indicates quadrillion Btus.

reflect a situation in which these plants are being replaced and/or decommissioned in response to the Petroleum and Industrial Fuel Use Act of 1978. Although hydropower and geothermal sources are expressed as a single estimate, the contribution of geothermal is likely to be small, about 1 to 2 GW-year, the rest being hydropower.

C. Future Competing Technologies

The next several decades will undoubtedly witness transition to a newer set of energy technologies. Several new technologies will enter the energy markets, although the answers to the questions "which ones?" and "how much contribution?" are not always clear and certain.

The future technologies relevant to this study are those which can: (a) help supply the electricity demand, whatever that may be, and (b) reduce the demand, or rather the rate of growth in demand for electricity. Technologies in group (a) will be labeled "supply technologies", while those in group (b) will be referred to as "energy conserving technologies".

D. Supply Technologies

Supply technologies considered here are grouped in terms of their dependence on primary energy resource. Thus, we consider technologies which are coal-based, nuclear, solar and geothermal. This group represents a likely mix of technologies which are relevant to this study, and are likely to compete with hydropower as alternatives.

An overview of the evolution of the technology group is shown in Figure E-1, derived from an article by Rudman and Whipple in EPRI Journal, April 1980. The various stages of technology evolution are defined as follows:

- Scientific feasibility—concept demonstrated in a laboratory environment.
- Engineering feasibility—translation of scientific concept into practical applications.
- Commercial feasibility—private investors begin to order equipment.
- Utility integration—new technology is shown to be more "economically attractive" than alternatives available to utilities.
- Significant use—technology finds a widespread use.

Rudman and Whipple further comment: "Recent experience shows that the time required for a new technology to achieve a significant use in the electric power industry is now roughly 30 to 40 years, significantly longer than a decade or so...."

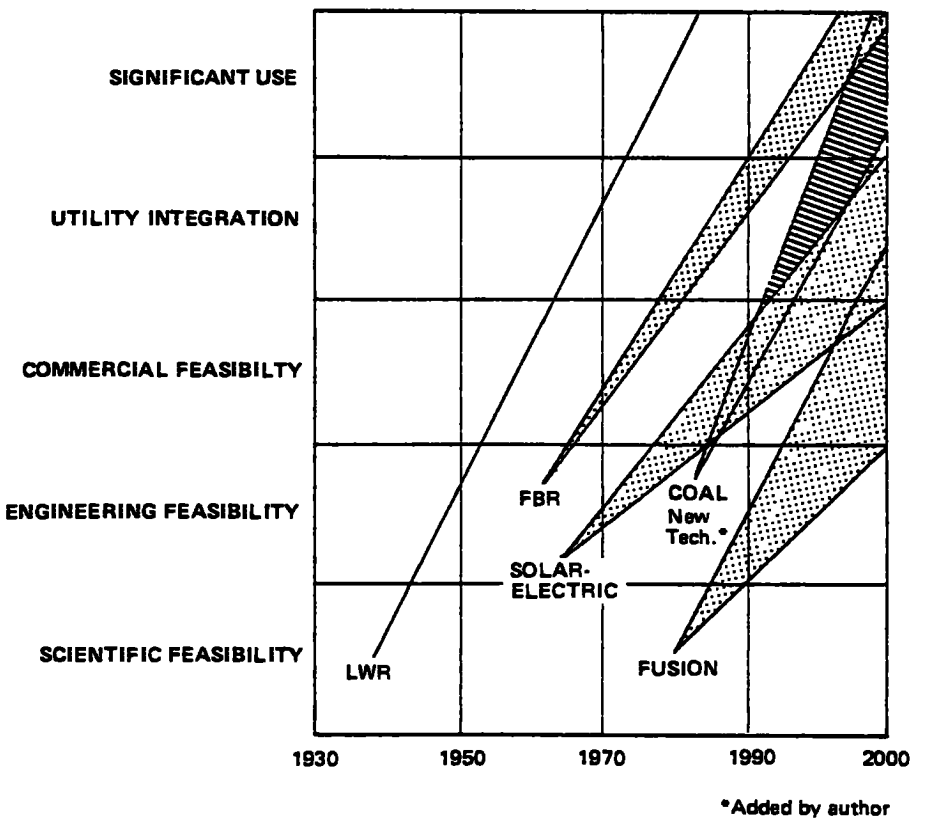


Figure E-1.
FUTURE POWER TECHNOLOGY

Source: EPRI Review, April 1980

While Figure E-1 provides a view of a general translation of new technologies into the market place, we need specific information about when a technology will become available, how much it will help in meeting the energy requirements, and what it might cost.

Table E-12, developed using various sources (DOE, EPRI, etc.), delineates one likely time table for technology introduction. Technologies are grouped as currently available (i.e., 1980), available by 1990, and by 2000. The term "availability" means that the economic and technological feasibility have been demonstrated and supplier(s) are available to procure the technology in question.

Similarly Tables E-13 and E-14, (developed by using various sources), delineate other technical and economic data for the technologies of interest. The cost data in both tables must be interpreted cautiously. As noted in Table E-14, the cost estimates of many future technologies are beset with a high degree of uncertainty. The firm cost estimates must await, in most cases, the construction and operation of the first few commercial scale facilities. Further, the DOE estimates in Table E-13 will be revised shortly with the issuance of its 1980 annual report to the United States Congress.

With this review as a perspective, the remainder of this section describes the various energy technologies. Coal-based technologies are discussed first, followed by nuclear, solar and geothermal.

1. Coal

The present use of coal is primarily as an industrial and utility fuel. The role of coal for electric power generation will be affected by the environmental ramifications of the increased use of coal. The coal technologies of interest to this study are therefore: (a) those which will allow the increased use of coal by the currently used technologies, without running into problems of environmental degradation; (b) new technologies which will combust coal differently for power generation, such as fluidized bed combustion; and (c) new technologies which convert coal into gaseous and liquid forms.

The environmental problems affecting coal can be grouped into two categories: (a) emissions resulting from coal combustion which fall into the category of criteria pollutants; these include sulfur dioxide, oxides of nitrogen, and particulates; (b) carbon dioxide resulting from the combustion of any carbon-containing material. There are also the water quality, solid waste disposal, health and safety problems related to the use of coal for electric power generation. Only the technologies applicable to criteria pollutants will be considered here. The carbon dioxide problem indeed affects all combustible products. Carbon dioxide was addressed in Section D-1.

Table E-12

INITIAL AVAILABILITY OF POWER GENERATION TECHNOLOGY

Available Now (1980)	By 1990	By 2000	Beyond 2000
Conventional Boiler - Oil	Coal: - Low and Medium Btu - High Btu - Pressurized Fluidized Bed Combustion	Coal: - Liquefaction	Nuclear: - Fusion
Conventional Boiler - Gas		Geothermal: - Hot Dry Rock	Hydrogen
Conventional Boiler - Gas			Photovoltaic - Central Station
Atmospheric Fluidized Bed Combustion (Industrial)	Solar: - Distributed Photovoltaic - Thermal Electric - Wind		Ocean Thermal Energy Conversion
Nuclear: - Pressurized Water Reactor - Boiling Water Reactor	Fuel Cells: - First Generation		
Combustion Turbines	Geothermal: - Flash - Binary		
Geothermal: - Dry Steam	Nuclear: - Fash Breeder Reactor		
Conventional Hydropower			
Small-Scale Hydropower			
Wood-Fired Plants			
Combined Cycle			
Cogeneration			
Pumped Storage			
Conservation Technologies			
Solar: - Hot Water - Space Heating			

Table E-13

DEPARTMENT OF ENERGY ESTIMATES FOR NEW ENERGY TECHNOLOGIES
(Estimates Developed in 1979)

	1990 Production (10^3 bbl Oil Equivalent/Day)	1990 Prices (1978 Dollars)		1990 Number of Plants	1990 Cost of Plants (Billion 1978 Dollars)
		Per Physical Units	Per bbl Oil Equivalent		
Liquids					
Enhanced Oil	300-3,000	$10-35/bbl.	$10-35	—	13.4-133
Oil Shale	30-300	15-30/bbl.	15-30	1-6	0.9-5.4
Coal Liquids	30-200	25-35/bbl.	25-35	1-4	1.8-7.2
Gas					
High Btu (from Coal)	450	$3.75-4.50/MM Btu	$20-25	0-10	014
Low/Medium Btu	5-350	2.50-4.00/MM Btu	15-25	0-15	0-10.5
Electricity					
LWR	4,000-5,000	25-35 mills/kWh	$40-60	130-167	93-114
Coal with SO_2 Control	3,000-6,000	25-40 mills/kWh	40-70	100-200	60-120
FBC (Fluidized Bed)	5-50	20-60 mills/kWh	35-100	25-250	0.2-2.5
Low Head Hydro	150	55-80 mills/kWh	95-135	500-3,000	0.8-6.0
Photovoltaics	130	100-400 mills/kWh	170-240	—	—
Biomass	75-100	45-60 mills/kWh	75-100	6-8	2.2-2.9
Geothermal	121	60-100 mills/kWh	100-170	—	—

Table E-14

TECHNOLOGY ECONOMICS

	Energy Source	Cost in 1980 Dollars (C)
1.	Oil From Shale	$4.40-6.00 per MM Btu (A)
2.	Conventional Steam Boiler (Oil and Gas)	$0.053 per kWh (A)
3.	Combustion Turbines	$0.138 per kWh (A)
4.	Combined Cycle	$0.052 per kWh (A)
5.	Conventional Steam Boiler (Coal)	$0.044 per kWh (A)
6.	Pressurized Fluidized Bed Combustion (Coal)	$0.057 per kWh (B)
7.	Medium Btu Coal Gas	$4.40-6.60 per MM Btu (B)
8.	Coal-Derived Synthetic Natural Gas (High Btu)	$5.50-8.80 per MM Btu (B)
9.	Synthetic Oil from Coal	$5.50-7.70 per MM Btu (B)
10.	Pressurized Water Reactor	$0.047 per kWh (A)
11.	Geothermal:	
	a. Dry Steam	$0.023 per kWh (A)
	b. Flash	$0.057 per kWh (B)
	c. Binary	$0.064 per kWh (B)
12.	Conventional Hydropower	$0.052 per kWh (A)
13.	Small-Scale Hydropower	$0.018-0.079 per kWh (A)
14.	Wood-Fired Plants	$0.038 per kWh (B)
15.	Cogeneration	$0.036-0.042 per kWh (A)
16.	Wind (Utility)	$0.051 per kWh (B)
17.	Solar Thermal Electric	$0.077 per kWh (B)
18.	Photovoltaic - Distributed	$180.00-190.00 per kWh (B)
19.	Photovoltaic - Central Station	$0.129 per kWh (B)
20.	Ocean Thermal Energy Conversion	$0.030-0.160 per kWh
21.	Fuel Cells:	
	a. First Generation	$0.049 per kWh
	b. Second Generation	$0.043 per kWh
22.	Pumped Hydropower	$0.095-0.219 per kWh
23.	Advanced Battery	$0.127 per kWh

NOTE: (A) - Estimated with low degree of uncertainty.
(B) - Estimated with high degree of uncertainty.
(C) - Units are appropriate to the particular energy form. To convert $/MM Btu to $/kWh, divide by 293.

a. Environmental Control Technologies

New technologies applicable to current coal-fired power plants are those necessary for environmental control to remove sulfur dioxide so that emission standards can be met. At present, there are two commercial means for removing the sulfur from coal. First, a reasonable amount of inorganic sulfur is removed by mechanical cleaning and washing. The second method involves the use of so-called flue-gas-desulfurization (FGD) systems which "scrub" the combustion gases. Basically, an FGD system brings sulfur dioxide so that it can be removed from exhaust gases. FGD systems are usually divided into those in which the scrubbing agent is wet or dry, and whether the used scrubbing agent is thrown away or regenerated. It is expected that by 1985 about 55 to 60 GW capacity (out of total of 300 GW) will involve FGD systems.

The currently used FGD system is wet scrubbing with lime or limestone. These systems have been beset by design and operating problems. These problems are gradually being solved, but the FGD systems are not easy to operate and involve substantial operating costs. The costs vary but they range from $80 to $120 (1975 dollars) per kW of generation capacity. Better processes may be available soon, such as the regenerable double-alkali process and the Wellman-Lord process. On the whole, it seems likely that sulfur dioxide removal can be effectively done, albeit at additional costs.

Nitrogen oxide is formed during coal combustion by drawing nitrogen from both coal and air. The only available techniques to control nitrogen oxides are appropriate design and operation of combustion equipment. Two-stage combustion is the most successful design approach for boilers. No new techniques are expected in this area; however, the current techniques may provide control of nitrogen oxides to meet the air quality standards.

As for the particulates, there are four types of control systems: mechanical collectors, electrostatic precipitators, wet scrubbers and fabric filter baghouses. The real problem faced here is the size of particles. Although the large sized particles can be handled effectively by most methods, especially the electrostatic precipitators, the smaller, respirable particles are of utmost importance because they pose dangers to health. The electrostatic precipitators can remove about 99.9 percent (by weight) of particulates, but they are effective for only the larger particles, as noted earlier. Fabric filter baghouses provide the most effective control for smaller particles, but their use for utilities has been limited because of the high temperature and corrosive chemicals in exhaust gases. Because of the necessity to control small particles, it is likely that the baghouse systems will see increased use, but substantial improvement in filter devices will be necessary before this occurs.

b. New Advanced Coal Technologies

(1) Technologies for Coal Combustion

Advanced technologies for coal combustion include primarily the Fluidized Bed Combustion (FBC). The FBC is a promising technique to overcome both the sulfur dioxide and nitrogen oxides problems associated with conventional coal-fired power plants. This happens in two ways. First, the coal is burnt in a mixture with limestone to absorb sulfur, which is turbulently suspended in a stream of combustion air rising from beneath the bed. Second, the coal is combusted at a much lower temperature than the conventional coal-fired boiler (about 1500°F, as opposed to about 3000°F), thus substantially reducing the oxides of nitrogen.

Two types of FBC are being explored, atmospheric (AFBC) and pressurized (PFBC). In the first one, the combustion takes place at atmospheric pressure; AFBC is thus simple in design. PFBC (about 6 to 16atm) is much more complicated and relatively less developed. Its promises are higher efficiency and lower emissions. AFBC systems in small sizes are already available and will find use in the industrial sector first. Large scale operations for the utility sector will come later. The PFBC, on the other hand, seems to be several years away from commercial use. The FBC will make a small contribution to the electricity supply picture and is unlikely to displace large capacity before the year 2000.

Fuel cells convert the energy contained in fuel electrochemically to electricity. Fuel cells are essentially non-polluting, noiseless and efficient. Their modular construction allows installation ranging from a small to large capacity. A 4.5 MW demonstration is being attempted in New York City. Current fuel cells employ phosphoric acid as an electrolyte. Second generation fuel cells will use molten carbonate electrolyte, which can overcome carbon monoxide problems associated with the phosphoric acid fuel cells. The economics and the need for cheap fuel (e.g., low to medium Btu gas converted from coal) limit the applicability of the fuel cells. By the year 2000, total capacity attributed to fuel cells is unlikely to be significant.

Magnetohydrodynamic (MHD) generation technology can produce electricity without the use of turbines, by expanding hot, electricity-conductive gas through a magnetic field. The resulting induced electric field can be used to produce electric power by placing electrodes to collect the current. The MHD technology is pollution-free and could be highly efficient (about 50 percent as opposed to about 32 percent for conventional coal-fired plants). Most estimates suggest MHD technology will be available on a commercial scale in the early part of 21st century.

(2) Technologies for Coal Conversion

The technologies here can be separated into those converting coal to gaseous or to liquid forms.

Coal gasification actually is an old technology. It was used in many United States cities up to World War II, when cheap pipeline-quality natural gas became available. In Europe, the technology was used until the mid-1950's when Middle-East oil began to displace this energy form.

The coal gasification technologies can be labeled as "low and medium Btu" (150 to 300 Btu/cu-ft) or "high-Btu" (1000 Btu/cu-ft) with most currently available technologies falling into the first category. To displace natural gas, high-Btu gas technologies will be required.

Low-Btu gas can be useful as industrial and utility fuel. When oxygen is substituted for air in the gasifier, the heating value of the product can increase by 30 to 50 percent, resulting in a high quality medium-Btu gas. Because the added oxygen increases the cost, and because the gas cannot be transported economically beyond a distance of 150 miles, the low-medium-Btu gas will be used for local applications. The commercially available processes for low-medium-Btu gas production are the Lurgi, the Winkler, and the Koppers-Totzek processes. As the economics of alternate fuels changes, these technologies will find increased use. For the utilities, its use may be primarily in combined-cycle plants.

High-Btu gas, equivalent in quality to natural gas, can be used for electricity production. However, its use as a clean fuel, directly displacing natural gas, seems more likely. The choice, however, will depend upon the cost to the consumer per Btu delivered.

Most technologies that produce high-Btu gas involve methanation of medium-Btu gas. The Lurgi process has been tested as a source of input to the methanation process. However, Lurgi does not appear to be an efficient and economic process for high-Btu gas production. Consequently, a number of second and third generation technologies are under development. Among these, HYGAS and Bi-Gas processes are being developed with federal support.

The availability of gasification technologies, like most synthetic fuel technologies, for commercial use is at best uncertain. Uncertainties about federal support, the OPEC price of oil, and capital availability make it difficult to estimate the full impact of gasification technologies on United States energy supply. In addition, firm estimates of production costs must await the actual construction and operation of a number of plants. It seems likely, however, that gasification technologies will become available during the 1990's. Their impact on total electric power generation is likely to be small, since there are more beneficial uses of this product than for electricity generation.

Coal Liquification technologies convert coal into various forms of liquid fuels: synthetic crude, synthetic gasoline, methanol, and other products, such as distillate fuel oil. Among these, the SASOL process (coal to synthetic gasoline) is the only commercially used coal liquification process (in South Africa) to date.

Among the many liquification processes being evaluated are two solvent extraction processes: Gulf's SRC-II and Exxon's Donor Solvent (EDS) process, and one catalytic liquifaction process, the H-Coal process. Each of these processes yields about three barrels of liquid per ton of coal. The production of methanol from coal is also well advanced.

The SRC-II process is closest to commercial scale, with a DOE facility consuming about 30 tons of coal per day and producing about 100 barrels of oil. A 6000 ton/day plant is proposed for operation in the mid-1980's. A 250 ton/day plant utilizing EDS process is under construction in Texas, while two plants for H-Coal process are being constructed and proposed. A 6000 ton/day plant is under construction in Kentucky, and a 20,000 ton/day plant is proposed for construction by the mid-1980's. The size of these plants can be put in perspective by noting that a commercial scale plant will probably produce 100,000 barrels per day, requiring over 30,000 tons of coal per day.

The same types of uncertainties as those mentioned for gasification technologies affect the large-scale production of liquid fuels from coal. Firm estimates of production costs will need to await actual construction and operation of the first few plants. Most estimates suggest that these technologies will make some contribution to United States energy supply, but they are unlikely to supply more than 1 million barrels of liquid fuel per day by the year 2000.

2. Nuclear

Virtually all the nuclear power plants operating, in the United States are light water reactors (LWR). The new advanced nuclear technologies of interest are: HTGR (High Temperature Gas Cooled Reactor), breeders, and fusion power.

The HTGR overcomes the disadvantage of the LWR, namely its limits on operating temperature, by using helium to transfer the heat, and graphite as the agent to slow down the neutrons for fission reaction. Its widespread use would require new types of reprocessing plants and fuel fabrication facilities. The impact of HTGR on the electricity supply situation is largely uncertain. Currently, no reliable estimates exist, and it seems unlikely that HTGR will supply any substantial portion of electricity demand before the year 2000. Currently, only one commercial HTGR is operating, in Fort Saint Vrain, Colorado.

The breeder reactor "breeds" fissionable U238, which is more abundant in natural uranium than U235. The Liquid Metal Fast Breeder Reactor (LMFBR) is being investigated as a promising technology. The French (leaders in this technology) have estimated the capital cost of LMFBR to be about 40 percent higher than that of LWR. Liquid metal, sodium, is used as a heat transfer agent. The LMFBR technology is expected to take several more years to mature and could run into social and environmental problems, because its deployment would involve considerable amount of fissionable plutonium. The LMFBR is not expected to be a major competing technology, at least before the year 2000.

Similarly, most estimates suggest fusion as an unlikely source of electricity before 2000 and perhaps not even in the early past of the 21st century. None of the fusion schemes has yet achieved the necessary requirements of confinement time, temperature and plasma density for delivering more energy than it consumes. There are significant problems to overcome in designing systems large enough for any possible commercial use of fusion power. Naturally, because fusion does not have the safety problems of fission and is virtually an unlimited source of supply, it is envisaged as the ultimate nuclear technology. However, it is unlikely to affect the electricity generation mix before the year 2000.

3. Solar

Estimates of the potential contribution of solar technologies to the U.S. energy supply situation are very diverse. Table E-15 contains some representative estimates. These place solar contribution in the range of 5-10 MMbbl/Day of oil equivalent, or about 10-20 quadrillion Btu by the year 2000. Estimates higher than 10 MMbbl/Day or 21 quadrillion Btu exist but seem far too optimistic and perhaps speculative.

Solar technologies involve two different sets of technologies. First, there are the spatially distributed systems, solar units for space heating and water heating, as well as the distributed applications of wind and photovoltaic systems. The other types of systems are often labeled central station concepts and are generally for utility applications. Photovoltaics, wind farms and solar thermal electric ("power tower" concept) are the principal technologies in this group.

Solar units for hot water and space heat are commercially available now, although they face a number of constraints which will need to be overcome before their widespread use occurs. Estimates of solar heating cost depend upon a number of assumptions about solar insolation, installed system cost and generally available financing. Estimates for the range of assumptions about system cost and solar insolation are delineated in Table E-16.

Table E-15

SOLAR CONTRIBUTIONS BY 2000 (PROJECTED)

	Solar Energy in Oil Equivalents (MM bbls/Day)	Total Energy Consumption (MM bbls/Day)	Solar Energy as Percentage of Total
CEQ	12 (25.4)	50 (106.0)	23%
SRI-1 (BAU)	5 (10.6)	73 (155.0)	7
SRI-2 (Low Solar Cost)	10 (21.2)	70 (148.4)	13
SRI-3 (High Fuel Cost)	6 (12.7)	45 (95.4)	12
HBS			
- Solar & Water Heating	3 (6.4)		
- Other On-Site Technology	2 (4.2)		
- Wood & Forest Products	3 (6.4)		
- Hydro (Large)	2 (4.2)		
	10 (21.2)		

Notes
1. Figures in parentheses ( ) indicate quadrillion Btus.
2. CEQ: Council for Environmental Quality
3. SRI: Stanford Research Institute, now SRI International
4. HBS: Harvard Business School Study (Energy Futures, Stobaugh & Yergin editors)

Table E-16

SOLAR WATER HEATING COST ($ per MM Btu, Estimated in 1979)

MEAN DAILY SOLAR RADIATION (Btu/Ft^2/DAY)

System Cost	1,200 (Boston)*	1,400 (Seattle)	1,800 (Chicago)	2,200 (Phoenix)
60	$64.50	$58.70	$45.66	$37.36
50	57.80	48.92	38.05	31.13
40	45.66	39.14	30.44	24.90
30	34.25	29.35	22.83	18.68
20	22.83	19.57	15.22	12.45

* - Winter

Wind energy, although plentiful, is dilute. The current DOE plan is to operate wind systems of 2 MW size in North Carolina. This system consists of a 200-foot blade, operating at a speed of 30 miles per hour to deliver the rated output. On an average, half the rated output production seems more likely. Thus, to produce 1 GW, 1000 such systems will be required. If one assumes a separation between windmills of one half mile, the 1000-unit system would require land area of about 250 square miles. Perhaps the separation can be reduced to about one third mile; in this case, the requirements would be about 140 square miles. In any case, land use and aesthetic issues will need to be overcome before such a large-scale program can be taken seriously. At the present time, it seems that windmills can be most promising in specialized, distributed locations.

Perhaps the most promising solar technology is photovoltaics, which involves the conversion of solar energy directly into electricity. The American Physical Society (APS) recently completed an extensive study of photovoltaic systems. The general conclusion of the study seems to suggest that photovoltaics could become a dominant technology, but that would take at least 30 years. It is quite likely that technology breakthroughs could occur sooner, perhaps in the 1990's. The APS study is pessimistic, however, about the near-term potential of photovoltaics, suggesting that it could supply about 1 percent of the United States energy requirements by 2000. There are other estimates which are far more optimistic, suggesting that as much as 5 to 10 percent of United States energy requirements by 2000 will be met by the use of photovoltaics.

The principal problems associated with photovoltaics involve improving system efficiency and reducing unit costs. Results from a study on solar energy completed by the U.S. Congress Office of Technology Assessment (OTA) provide estimates of the state-of-the-art of photovoltaic technology expressed in terms of system efficiency, and the market size for various assumptions about the unit cost (Table E-17). As shown, advanced photovolatic concepts (thin films and focused system) appear to be most promising.

The economics of photovoltaics is shown in Table E-18 for the range of assumptions about system cost and solar insolation. It appears that the system cost will have to go below $1 per peak Watt before photovoltaics can become competitive with the existing systems, unless, of course, the costs of fuels used in the existing systems become prohibitive.

Biomass is often cited as another source of solar power. Again, biomass could be useful as a supplemental energy source on a local scale, but its widespread use for electricity production seems quite unlikely. For example, it has been estimated that a land area of about 250 square miles would be required to sustain and provide fuel for a 1 GW power plant. With the persisting concern over food production and supply, it seems unlikely that biomass will be employed on a large scale for sustained electricity production.

Table E-17

PHOTOVOLTAIC TECHNOLOGY DEVELOPMENT

	State-of-Art System Efficiency		Market Size (Annual Sales in MW)		Cost
Photovoltaics	Maximum Measured	Possible	Range of Estimate	(DOE Goal)	(Dollars per Peak Watt)
Silicon	(5-6)	10-15	1-10	(1)	10
Thin Films	(8-14)	2-3	3-75	(8)	3
Optimal System	10-18	12.5	70-200	(75)	1

Table E-18

SOLAR PHOTOVOLTAICS (CENTS/kWh)

System Cost ($/Peak Watt)	Mean Daily Solar Insolation (Btu/Ft^2/Day) 1,200 (Boston)*	1,400 (Seattle)	1,800 (Chicago)	2,200 (Phoenix)
15	162.9	139.5	108.6	88.5
10	108.6	93.0	72.4	59.0
5	54.3	46.5	36.2	29.6
2	21.7	18.6	14.5	11.8
1	10.9	9.3	7.2	5.9

NOTE: Insolation figures typical for cities indicated in parentheses.

* - Winter

4. Geothermal

The estimates of the future geothermal power potential in the United States are indeed diverse, in the range of 2 GW to 440 GW. However, the 440 GW estimate is far too optimistic and seems quite speculative. Geothermal potential can be estimated only on a site specific basis. The CONAES report estimates geothermal capacity as 7 GW under a "business as usual" case and 60 GW under a "crash program". The present 0.5 GW capacity, utilizing dry steam, is located in the geyser region in Northern California. It is expected that this capacity could increase by another 1.5 GW by mid-1980. The ultimate practical capacity of geyser regions is estimated at about 5 GW. Future developments in hydrothermal (hot water) resources could increase geothermal capacity over the next 20 years by another 20 GW, according to the estimates by EPRI. On the whole, then, geothermal resources are not likely to make a significant contribution at the national level, although their impacts at the regional level are bound to be felt.

E. Energy Conserving Technologies

Energy savings achieved through improved energy efficiency of various end uses (e.g., appliance and building performance standards) can obviously have a major impact on electricity requirements and hence on the electricity supply mix. In this section, we describe general conservation measures.

Energy efficiency improvements in the residential and commercial sectors will be primarily due to improved building and residential design (e.g., orientation of the structures, use of energy conserving features such as insulation and insulated windows), which will decrease the energy requirements for space conditioning and lighting. The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) has developed guidelines for energy efficient buildings. The Energy Conservation and Policy Act of 1975 requires that the states adopt ASHRAE 90-75 or similar standards.

The energy efficiency of United States industry is also likely to improve. Indeed, the energy required per unit output in industry decreased by nearly 20 percent between 1973 and 1979. The industry can, and has, reduced energy consumption by better housekeeping, waste-heat recovery and insulation, introduction of new processes, including substitution of materials, and recycling.

The use of cogeneration can reduce industry requirements for purchased-electricity. Cogeneration consists of utilizing high temperatures in fuel combustion to produce electricity and using low-temperature exhaust steam from turbine-generator units for industrial process heat. Cogenerating electricity and steam will produce substantial savings in energy use by industry, since about 35 to 40 percent of energy used in the industrial sector is for producing low temperature, low pressure process heat.

CONAES and other studies have estimated energy conservation potential in the residential, commercial and industrial sectors, depending upon assumptions about increase in energy prices. The data indicate that energy intensity of residential and commercial buildings could go down as shown in Table E-19; similar information for the industrial sector is shown in Table E-20.

Table E-19

POTENTIAL FOR ENERGY SAVINGS IN RESIDENTIAL & COMMERCIAL SECTORS (CONAES data)

Application	Intensity*
Thermal Integrity	
Residential	0.63 - 0.76
Commercial	0.42 - 0.7
Gov't and Education	0.35 - 0.5
Space Conditioning	0.66 - 0.94
Air Conditioning	0.66 - 0.94
Electric Heating	0.52 - 0.90
Gas and Oil Heating	0.58 - 0.8
Refrigeration and Freezing	0.58 - 0.92
Lighting	0.60 - 0.70

* expressed as the ratio: $\frac{\text{2010 Intensity}}{\text{1975 Intensity}}$

Table E-20

POTENTIAL FOR ENERGY SAVINGS IN THE INDUSTRIAL SECTOR
(CONAES DATA)

Industry	Intensity*
Agriculture	0.85 - 0.95
Aluminum	0.55 - 0.79
Cement	0.60 - 0.75
Chemicals	0.74 - 0.84
Construction	0.58 - 0.73
Food	0.66 - 0.86
Glass	0.69 - 0.82
Iron and Steel	0.72 - 0.83
Paper	0.64 - 0.76

* expressed as the ratio: $\frac{\text{2010 Intensity}}{\text{1975 Intensity}}$

Section F

Societal Scenarios

Prepared by:

Harold A. Linstone
James Wilson
Paul D. Molnar

This is an abbreviated version of a detailed paper on the subject. Copies of the paper can be obtained from Nero and Associates, Inc.

Table of Contents

	Page
A. The Development of Scenarios	1
B. The Setting for Future Hydropower Development	3
Scenario 1	4
a. Summary	4
b. Impacts on Hydropower	4
Scenario 2	5
a. Summary	5
b. Impacts on Hydropower	5
Scenario 3	5
a. Summary	5
b. Impacts on Hydropower	6
Scenario 4	6
a. Summary	6
b. Implications for Hydropower	6
Scenario 5	7
a. Summary	7
b. Impacts on Hydropower	7

List of Figures

Figure F-1: Plans vs. Scenarios 2

List of Tables

Table F-1: Impact of Hydropower Development on Five Scenarios 8

SOCIETAL SCENARIOS

A. The Development of Scenarios

Three societal settings were developed for this project to facilitate the discussion of Levels I, II, and III. The themes for these scenarios were as follows:

A. Continuation of current trends, or "Fragmented Centralization";

B. Revitalized economic growth with multiple technological innovations; and

C. A national crisis.

In the initial stages of the study, five scenarios were developed with the following themes:[1]

1. Surprise-free continuation of current trends
2. Liberal revitalization
3. Corporate state
4. Technical optimism
5. Conservation ethic

It was felt, in response to comments from the Project Advisory Group, that five scenarios were: (a) too many, and (b) overlapping in terms of their context and structure. Consequently, it was decided to develop three scenarios by combining the principal and common features of each of the five scenarios. Thus, Scenario A was developed by using the theme and features of Scenario 1, and Scenario B from Scenarios 3 and 4. The theme of Scenario 5 was present in all three scenarios to a different degree. A scenario based on the theme of national crisis was added because it was felt that the underpinnings for Level III hydropower development needed a much stronger justification, namely a setting mandating rapid development of a high level of hydropower development. This is described in the Final Report, p. IV-42.

Obviously, there is no single "best" scenario for a given hydropower development level. A level of 25,000 MW increase by 2000 may be possible with any of the three scenarios (A, B or C). A more ambitious level, 45,000 MW, is conceivable with either B or C, and the extreme level of 75,000 MW appears possible only in the case of C. The correspondence is shown in Figure F-1. Furthermore, an infinite set of scenarios can be generated. It is fruitless to look for a highest probability scenario. This can be illustrated by the following hypothetical example: Consider a scenario comprising 20 events, each having a very high likelihood of occurrence (e.g., 90 percent). Then the likelihood of the joint occurrence of all 20, i.e., of the postulated scenario, is only 12 percent. Any realistic scenario for a 20 year period must involve many events, hence has inherently a low probability of occurrence.

The shaded cases in Figure F-1 are used in the Final Report and summarized on pp. IV-18, 28 and 42. There is no extensive detail presented here since the scenarios merely serve as societal settings to concretize the policy analysis for hydropower

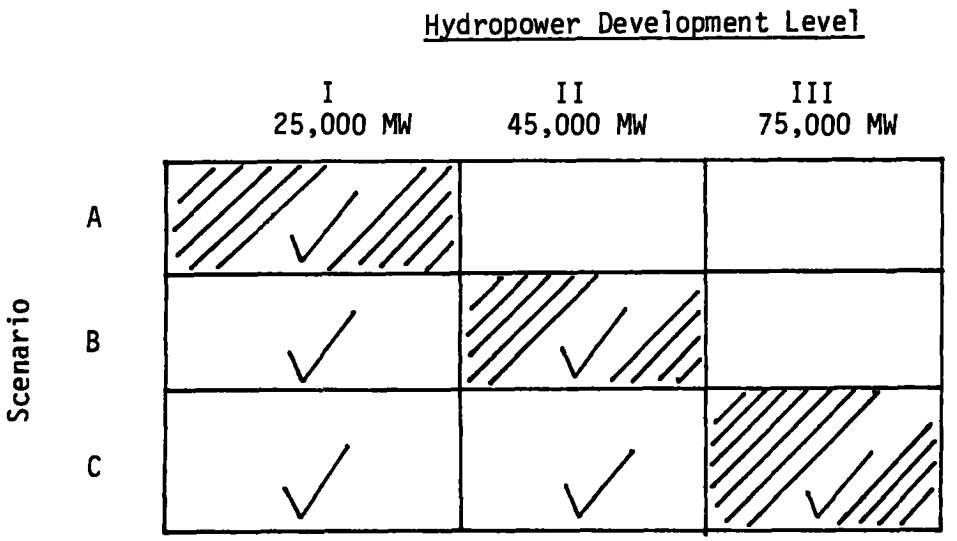


Figure F-1: Plans vs. Scenarios

Note: Shading indicates pairs used in the Final Report.

development Levels I, II and III. However, as stated earlier, a paper delineating the details of the five scenarios is available upon request from Nero and Associates, Inc.

Two of the three settings are self evident: (A) continuation of current trends and (C) national crisis. Setting B involves a combination of a mutually supporting government-industry relationship, a cluster of new technological innovations leading to new industries and a strong national defense posture. The high economic growth resulting from this concatenation reverses the slowing growth pattern of the past decade, and thus the trend assumed in (A).

In the following section, we provide a discussion of the original five scenarios, beginning with a description of the future setting in which hydropower development could occur.

B. The Setting for Future Hydropower Development

The United States continues to grow. Population is expected to expand from 228 million in 1980 to 260 million in 2000 to 290 to 325 million in 2025. The expectations of most of this population also continue to rise, thus compounding the total material growth demands. On the other hand, land area and water supplies, as well as most basic resources, are available in limited quantity in this country. Use of non-United States resources must face the tremendous pressure of a world population growth from 4.4 billion in 1980 to 6 billion in 2000 and 10 million in 2020. Most of this growth is occurring in the Third World, raising the proportion of poor from 70 percent to 80 percent of the world's population in just 20 years. The international pressures on the United States are exacerbated by two technologies: telecommunications and CBR (Chemical-Biological-Radiological) weaponry. The former makes the gross inequities vividly apparent to the poor world, and the latter provides tremendous leverage in terms of blackmail and terrorism.

Before looking ahead, let us note that the United States in 1980 is significantly different from the United States in 1960. Accelerating economic growth has given way to slowing growth, the assumption of unlimited resources to an acute awareness of constraints, a widespread mood of optimism to one of pessimism. Inflation, unemployment, disillusionment with the federal government's competence and with social institutions (e.g., criminal justice system, schools) have taken hold in the last 20 years. Even technology itself has lost prestige as its environmental impacts have become a major issue. Dissatisfaction is reflected in the fractionalization of the society, with single issue groupings and an ever-increasing resort to litigation. The individual's entitlements and rights have become of far greater concern than his or her responsibilities.

We must recognize at the outset that forecasts are hampered by at least three basic considerations:

- Unexpected or low probability events with major impacts will occur as they have throughout history;
- Some high probability events forecast to have small impacts will, when they occur, have unexpectedly serious impacts;
- When a complex system moves from one stable state through an unstable transition to a new stable state, it is inherently unpredictable.

Even with a far more profound understanding of our social system, these considerations would apply. We mention this not as an argument against long-range planning, but rather as a recognition of the limitations of prediction. We are somewhat in the situation of a scouting party in a Western expedition. We probe in several possible directions to gain insight about the terrain ahead and facilitate immediate decision-making, appreciating that much remains uncertain. Thus, we consider five scenarios to 2000 and their impacts on future hydropower development policies. Many mixes of these scenarios are, of course, possible.

First a few certainties for the coming 20 years under any scenario: the continuing aging of the U.S. population (e.g., over 35 percent of whites aged 45 and older in 2000), the continuing rapid evolution of information technology (processing and transmission), the instability created by the widening gap between the United States and resource-barren poor nations, and the growing competition for scarce resources (e.g., oil) among the wealthier and industrializing nations.

Scenario 1:

a. Summary

The socio-political mechanisms that serve to balance the interests and ambitions of the various competing groups which comprise American society become so constricted and overloaded that it becomes increasingly difficult for these mechanisms to operate effectively. Single issue groups dominate the political arena and the result is socioeconomic and political paralysis.

The move to the Sun Belt continues, over-straining the carrying capacity of that region. More frequent shortages lead to higher levels of frustration as the government tries to respond to both economic and environmental pressures with measures which satisfy no one. The nation is increasingly trapped in a web of conflicting objectives, regulations and legislation. Small projects and cosmetic "solutions" are undertaken, but the situation worsens. The drain on capital and resources slowly erodes the standard of living.

b. Impacts on Hydropower

No large-scale cohesive energy program exists. Private development of hydropower proceeds on a highly selective basis. No major changes in regulations occur: for each rule eased or scrapped another is added. The constant threat of litigation discourages entrepreneurs, both large and small. No large construction projects are even considered. The Corps is the only organization with

a clear intent in building hydropower facilities. Currently approved construction of new facilities and retrofits at federal sites proceeds. Private operation of facilities at federal sites becomes more frequent.

Scenario 2:

a. Summary

The currently perceived "swing to the political right" is short-lived, as the policies of a conservative administration prove more disastrous than those of the preceding one. A major depression, the worst since the 1930's, occurs and is blamed on the current government. A new administration is swept into office with a strong mandate to reestablish federal leadership. Social cohesion is finally achieved and leads to a workable balance between economic and environmental concerns. Major innovations are seen in the federal bureaucracy; a kind of managerial revolution takes place. In consequence, the resource problem is attacked from two directions, conservation and substitution to minimize dependence and dislocations.

b. Impacts on Hydropower

Hydropower, particularly small-scale, is strongly encouraged. A national energy plan moves on a wide front to develop solar and fusion energy for the long term, gas and coal for the near term. Pollution control is strict, but private hydropower is supported by incentives with a minimum of delay and required paperwork. A national water policy is established which gives priority to energy-related water use. Formation of Public Utility Districts (PUD's) accelerates.

Scenario 3:

a. Summary

The currently perceived "swing to the political right" proves emminently successful and sets the stage for a long conservative era. Economic growth, high technology and capital-intensive development are strongly favored. Hard-line military policies succeed in maintaining ample supplies of imported resources. United States military interventions occur and provide a national security rationale for social cohesion. Special interest groups, such as fishermen and environmentalists, are muted, and litigation as a tool to delay and impede industrial development becomes unpopular. Work attitudes shift from entitlements to responsibilities, from self-interest to team productivity: the United States has learned from Japan. The federal government furnishes strong support to private industry for research and development, large-scale projects and plant modernization. In addition to a strong military establishment, a large-scale space program is planned. The United States is seen as strong, willing to use force to protect its interests—both externally and internally. Economic growth is high, but military activities drain away a considerable portion of the gains.

b. Impacts on Hydropower

Energy has high priority for national security. Nuclear energy is pushed most strongly for the immediate future, with research and development on solar and fusion processes also heavily favored. Hydropower is given secondary support. Regulations governing hydropower are eased to permit private utilities to build and retrofit dams where profitable. State and local interference with energy projects is not tolerated, as "national security" is invoked. There is no interference with small "patriotic" entrepreneurs who wish to push low-head hydropower, and the requirement imposed on utilities to buy such power from small operators at reasonable prices is maintained. A semi-public funding agency is created to facilitate financial arrangements for private and municipal energy projects. Leasing of federal facilities to private operators is encouraged. The preference clause is dropped.

Scenario 4:

a. Summary

Following the economic doldrums of the early 1980's, a cycle of basic technological innovation begins about 1985 and lasts until 2000. Just as the 1933 to 1950 period saw a cluster of vital innovations—radar, television, computers, atomic energy, rockets—so the 1985 to 2000 period experiences a remarkable set of practical technological successes. Candidates are solar and fusion energy, bio-engineering of marketable products, aquaculture, undersea mining, electric automobiles and control systems for everyday personal use (e.g., households, offices). The Third World, no longer seen as a vital resource base for the United States, is treated with benign neglect. The gap between rich and poor becomes wider than ever while the United States, Western Europe and the Far East draw closer together. A joint multi-national space industrialization program is begun.

b. Implications for Hydropower

Hydropower is initially of high interest, but in 1990 is no longer of any priority, i.e., it is overtaken by new energy concepts. Federal support shifts to the more exotic concepts, but private exploitation of hydropower is encouraged. The allocation of water is tightened, and systems control of long term river flow becomes more sophisticated. There is a concerted effort to reduce both industrial and agricultural use of water through technological improvements. Pollution controls and mitigation of health and environmental problems are rapidly developed. Organizational flexibility is a key to survival in this setting. Non-responsive agencies are replaced by new creations, and obsolete utilities go bankrupt.

Scenario 5:

a. Summary

The failures of one administration after another, together with the hair's-breadth avoidance of a nuclear or biochemical catastrophe (military or industrial), have drastically altered popular attitudes. Survival and decentralization, conservation and environmental protection become the primary national concerns. Carrying capacity is a primary criterion for federal planners. Preservation of wilderness and scenic areas, environmental safety and purity, shift to renewable resources and de-urbanization become national objectives. Legislation forces industry to absorb clean-up and replenishment costs, raising prices and lowering the material standard of living (but not the quality of life). Technological emphasis is on solar and fusion energy, carbon dioxide reduction, recycling and materials substitution. The scare of the near-catastrophe has fashioned a new social cohesiveness; polluters and waste-makers are derided as immoral and socially undesirable. A steady-state economy is no longer a dirty word. Decentralization is reflected in regionalization of many activities. Tax incentives favor small entrepreneurs and community enterprises.

b. Impacts on Hydropower

Hydropower is favored as a clean, non-depleting energy source. Private and municipal enterprises are encouraged, and low-head hydropower is "chic." The strict controls inhibit large-scale projects. There is a national energy policy, but no formal plan or program. State and local governments have more opportunities for initiative, and public participation in the decision-making process is favored. Local PUD's play an increasingly central role in power distribution as utilities have difficulty assuring profits in this regulatory context. The preference clause is maintained. Tax exemptions are extended to bonds sold to finance modest hydropower projects. The slower pace of economic development eases the strains on water and energy allocation.

Table F-1 summarizes the impacts of future hydropower development on the five scenarios.

Table F-1

Impact of Hydropower Development on Five Scenarios

Scenario

ISSUE	1	2	3	4	5
Contribution to National Needs	lethargy	national energy plan (solar, fusion)	national security, new energy policy	low emphasis on hydro	small-scale hydro favored
Institutional Roles	paralysis, little risk-taking	strong fed. involvement	federal primacy, private sector encouraged	balanced fed, private	state, local govts. more influential, citizen participa
Water Rights	no significant impact	disturbance of existing rights	subservient to national security needs	based on cost-benefit	litigation determined, rights disturbed
Large/Small-Scale	mostly private new companies	small-scale strongly pushed	private large-scale has priority	little interest	low head hydro chic strict controls on large hydro
Competing Water Uses	no significant impact water shortage becoming severe Fed/St. conflict	national water policy water use reduction technology	water rationing if needed	more efficient water use	slowed economic growth eases competition local/state dominance
Pricing	no major change	preference clause kept	preference clause dropped	preference clause dropped. True value (MC) used	rate structure inverted, preferente clause dropped
Financing	no major change	semi-public corporations	private investments	public and private investments tax exemptions energy bank	tax exemptions, energy bank, individual financing
Marketing	no major change	extension of BPA and TVA like organizations national scope	grid systems dominated by large utilities	BPA and TVA like organizations nation wide	conservation campaigns
Risk	no major change	federal insurance	federal insurance	minor concern	risk minimization
Public Health	no major change	high priority	attention minimized	sophisticated monitoring	strong concern
Competing Land Uses	no major change	land use planning	environmentalists lose influence	no concern	small-scale creates no problems

FOOTNOTES

1. The five scenarios were developed and specified by means of seven sectors (e.g., population, social attitudes, national economy) and 35 factors distributed among the sectors (e.g., size, age distribution, regional distribution and urbanization in the case of population). This approach, known as the Field Anomaly Relaxation Method, was developed to aid internally consistent scenario generation (see R. Rhyne, "Technological Forecasting Within Alternative Whole Futures Projections", Technological Forecasting and Social Change, 6 (1974), pp. 133-162.)

☆U.S. GOVERNMENT PRINTING OFFICE: 1982-391-889