LIAISON STAFF MEETING
Wednesday, July 21, 1976
7:30 a.m.

Energy

MEETING WITH GEORGE HUMPHREYS
& GLENN SCHLEEDE

Thursday, August 12
3:30 p.m.

re: CEQ Draft Report on Energy R&D

Hold for memo from Russ Peterson

THE WHITE HOUSE
WASHINGTON

Tues, Aug 10

Kris:

JMC would like to meet briefly with Humphreys & Schleede re: the attached on Wed. Can you set this up?

thanks

C

3:30 thurs.

THE WHITE HOUSE

WASHINGTON

August 10, 1976

Talk to Glenn & George

MEMORANDUM FOR: JIM CANNON

FROM: GLENN SCHLEEDE

SUBJECT: CEQ DRAFT REPORT ON ENERGY R&D

The Non-Nuclear Energy Research and Development Act of 1974 requires CEQ to evaluate the Federal Government's energy research, development, and demonstration (RD&D) program, including public hearings and submission of a report to the Congress.

CEQ has completed the draft report and has been reviewing it with OMB for the last two or three months. OMB staff, today, told me that they had reached an impasse with CEQ staff on some parts of the report, particularly those sections dealing with energy conservation.

OMB staff believe the treatment of energy conservation is inconsistent with Administration policy. I agree.

You may recall that we went through a similar situation with ERDA last March or April when ERDA was seeking to claim a very large role for the Federal Government in developing energy conservation technology. After considerable discussions, ERDA agreed to make clear in their report that the primary responsibility for energy conservation RD&D should rest with private industry.

The President has already been criticized for not requesting enough money for energy conservation and the Congress added $40 million to his request for ERDA.

I believe the CEQ report issued in its current form would provide the basis for still additional criticism.

The report could be revised to bring it in line with existing policy, but this would require some rewriting and probably would require acceptance by CEQ of a philosophy different from the one they are espousing in the draft.

I am bringing this to your attention now because:

-- CEQ staff are aware that I agree with OMB on the need for a substantial change in the report, and

-- The matter probably is being escalated within OMB.

A copy of the report is attached.

cc: George Humphreys

Part 2

BUILDING ENERGY CONSERVATION INTO ENERGY RD&D

The Council defines "adequacy of attention to energy conservation" in federal energy research, development and demonstration (RD&D) to mean the capability to identify the full range of possible energy conservation RD&D options, to create a factual basis for comparing them to other energy RD&D choices, and to develop appropriate programs to assure that the best options are made available to the nation. This part of our assessment measures program planning and implementation at the Energy Research and Development Administration against this definition of adequacy.

Since its first National Plan (ERDA-48) was published in June of 1975, ERDA's attention to energy conservation has been under critical review by the Council and by others. For example, testimony at the Council's public hearings, held last September, questioned whether ERDA had given adequate priority initially to energy conservation, considering conservation's possible future role, and the small amount of federal resources allocated to ERDA's conservation RD&D program compared with the resources allocated to other energy RD&D options.

In April of 1976, ERDA updated its first plan. ERDA 76-1 singles out conservation technologies for increased attention, ranking them with several supply technologies as being of the highest priority for national action. This represents a major change from the initial plan. It is based on further analysis of conservation opportunities, is responsive to public comments on the initial plan, and reflects ERDA's conclusion that only moderate progress is being made to date on the development of supply technologies. ERDA 76-1 establishes an immediate 5-year planning period during which energy conservation opportunities ready for commercialization will receive special attention. Further, the President's FY1977 Budget increases ERDA's energy conservation RD&D resources by 64 percent.

The Council's assessment focuses on the revised National Plan and its underlying analyses. We believe that ERDA's National Plan for Energy RD&D is a substantial accomplishment for such a new agency:

- o The plan is a major improvement over its predecessor in addressing energy conservation. It is a benchmark from which to begin a systematic effort toward a more complete approach to conservation RD&D.

- o The Plan itself -- and its agenda for the future -- illustrates ERDA's commitment to a rational and analytical approach to energy RD&D. It is moving toward the systematic and explicit identification of our energy problems and the development of technology to resolve them.

- o ERDA has undertaken a substantial effort -- some of which began before ERDA 76-1 but was not yet completed by the first quarter of 1976 -- to improve the Plan and to make the ERDA program more effective.

- o ERDA is actively seeking wide review and comment on its programs and appears responsive to comments and criticisms received.

These developments are encouraging. In responding to our mandate, however, the Council must measure "adequacy" against plans and programs as they are now in place and operating, not simply on progress since ERDA's establishment or on commitments to improvement. We recognize ERDA's progress and the many positive steps already underway, but based upon our independent assessment of ERDA's planning and program implementation at the end of the first quarter of 1976 we have identified the following problems:

- Many critical issues affecting the role of conservation in the overall energy RD&D program have not yet been resolved (these are discussed in Chapter III). In particular, the appropriate planning, development and commercialization time frame and levels of effort for conservation RD&D programs have not been thoroughly addressed.

- The current National Plan is not yet built on a strong analytical foundation.

- Granting that conservation is a new program in a new agency, there remain serious questions about the rate of progress in developing the analytical ability to compare conservation technologies with the more advanced energy supply technologies.

We recognize that the magnitude and technical direction of an adequate conservation program are not easy to determine. We also realize that simply "throwing" money at conservation would be wasteful. Nevertheless, the Council is seriously concerned about the pace of improvement on several counts:

- Many of the basic agency policies and capabilities necessary to give conservation the same level of planning and management attention as supply enhancement, particularly the more advanced technologies such as nuclear and coal, are still in a very rudiemntary stage of development. Action plans to reach these objectives are unspecific. It appears that ERDA may fall short of correcting these problems in the next two years.

- The Conservation programs are not generating the essential technical, economic and environmental information to permit analysis of conservation opportunities and planning based on conservation-supply comparisons; nor is work to produce it in the future in place within all of the programs.

- Conservation program resources are limited, not just for technical program development, but for the fact-finding and other basic analysis which will permit sound conservation planning. This is in comparison with the supply programs which get major technical and analytical support from ERDA's extensive field laboratory structure.

As we have noted, conservation RD&D is one of ERDA's high priority programs for the next 10 years. Thus, delay in building the capability to analyze, plan, and implement energy conservation RD&D options could jeopardize the near-term contributions of ERDA's programs. In short, much of the near-term could pass before ERDA fully integrates this capability into its overall planning and management structure.

Equally important, the Council believes that there are potentially significant conservation RD&D opportunities over the mid-term and long-term. We believe that these opportunities must receive full consideration in the critical early formative stages of ERDA's planning program. Momentum tends to build as commitments are made to specific sets of technologies and continues as multi-year claims are made on future funds. Already there is a great momentum behind a number of mid-term and long-term supply programs such as those to produce gas and liquid fuels from coal, and advanced nuclear systems, backed up by a comparatively sophisticated planning capability. If mid- and long-term energy conservation programs continue to receive inadequate attention in the early stages of this new agency, it will be difficult to redress the balance later.

ERDA should accelerate its ability to analyze and develop potential conservation RD&D options across all time frames. To assure adequate attention to energy conservation we believe that the following general improvements must be implemented within the next two years.

- o ERDA's analytical capability for planning, which is already quite advanced, should be expanded to incorporate fully conservation technology options, including information on economic, environmental and social impacts.

- o The planning process should compare specific conservation and supply RD&D opportunities across all planning periods and use these comparisons for establishing priorities and allocating available resources.

- o The conservation RD&D programs must identify conservation RD&D opportunities over all planning periods, generate sufficient information to analyze them, and organize research programs with sufficient focus to realize the benefits of the best of the opportunities.

- o ERDA should carefully evaluate the role of federal conservation RD&D vis-a-vis the likelihood that the private sector will undertake the RD&D necessary to recognize the potential national benefits of energy conservation.

The remainder of this part of the report expands on these findings.

Chapter III

MAJOR ENERGY CONSERVATION ISSUES

The Council reviewed ERDA 76-1 and also looked carefully at its underlying analyses. This chapter evaluates the National Plan from the perspective of adequacy of attention to energy conservation. It raises a series of issues which we believe were not adequately addressed in ERDA 76-1 but are essential to building conservation into ERDA's programs. In our view, these issues should be given high priority attention and should be addressed specifically in the next version of the National Plan in order to provide the basis for public review and debate which ERDA recognizes is important. The major "adequacy of attention" issues, which we have framed in question form, are as follows:

- o Is the near-term priority role established by ERDA for new energy conservation technologies -- primarily stressing demonstration and application of existing end-use products and processes -- the correct one?
- o Is the energy conservation program of adequate size when measured against the potential benefits of conservation-intensive energy choices and the RD&D resources allocated to supply enhancement?
- o Are all potential conservation RD&D options given full consideration and are the energy conservation technology programs designed with adequate technical focus?

Near-Term Role for Energy Conservation RD&D

Thus, there are two additional adequacy of attention issues with respect to the substance of ERDA's near-term strategy:

- o Is ERDA's energy conservation strategy sufficient to make technically and commercially adequate conservation technologies available in the near-term?
- o Is current energy conservation RD&D adequate to the high priority, near-term goal that ERDA set?

A major purpose of ERDA's revised Plan is to broaden the Nation's range of available energy options. Table II-1 lists the Plan's ranking of "highest priority" demand and supply technologies. The Council agrees that energy conservation can play a critical role in the near-term and supports the additional resource commitment.

Table II-1: Proposed Priorities for RD&D Technologies

Highest Priority Demand	
Near-Term Conservation (Efficiency) Technologies	. Conservation in Buildings and Consumer Products . Industrial Energy Efficiency . Transportation Efficiency . Waste Materials to Energy
Highest Priority Supply	
Near-Term Major Energy Systems	. Coal-Direct Utilization in Utility/Industry . Nuclear-Converter Reactors . Oil and Gas Enhanced Recovery
New Sources of Liquids and Gases for the Mid-Term	. Gaseous and Liquid Fuels from Coal . Oil Shale
"Inexhaustible" Sources for the Long Term	. Breeder Reactors . Fusion . Solar Electric

*Source: ERDA 76-1

But we are concerned with the lack of precision as to ERDA's role during this period. Since near-term energy conservation is given high priority, commercial or almost commercial technology will form the basis for the RD&D program for the next 5 years. The Plan describes the major near-term opportunities in the three energy end-use sectors as:

- Industry conservation: "[a] host of more efficient technologies ... is known."
- Buildings conservation: "[a] number of specific technologies exist ... that need to be integrated and may require innovative marketing by industry to motivate consumers to accept and install them."
- Transportation energy conservation: "[the] transportation sector ... can reduce its petroleum consumption by using well-proven technologies and by implementing well-studied operational changes."

ERDA 76-1 identifies the main RD&D obstacle with respect to this host of available technologies as overcoming "problems of economic uncertainties, and normal resistance to the acceptance of new 'products'." A five-part energy conservation strategy is based on this statement: A national policy conducive to the adoption of energy-efficient technologies; a five-year planning horizon; accelerated identification of promising technologies and dissemination of information about their application; integration of market and institutional barriers into the plans for developing the most attractive conservation technologies and for facilitating their implementation; and demonstration programs to work out the implementation details.

Early application of available conservation technologies may make sense as a good consumer investment and is in the public interest. But much of ERDA's strategy is a commitment to existing technologies, essentially "off the shelf." The agency does not devote any significant resources to upgrading the efficiency of these technologies. For example, heat pumps are being employed in several building demonstration projects but there is no RD&D program to improve heat pump performance or develop advanced types of heat pumps. In contrast, ERDA does plan to upgrade, prior to commercialization, economically and technically submarginal supply technologies such as coal liquefaction, coal gasification, and tertiary oil recovery. Conservation technologies do not receive the same attention

Two additional questions relate to ERDA's concept of energy conservation's future role:

- o Is the near-term the correct high priority timeframe for federal energy conservation RD&D?
- o Is there more, new and different mid-term and long-term conservation RD&D that should also have high priority considering potential national benefits?

One of the chief reasons for ERDA's assignment of high near-term priority to conservation is that few, if any, major new supply technologies can provide significant amounts of energy by 1985. However, while concentrating on energy conservation in the near-term, we believe that ERDA may be neglecting important and needed conservation opportunities in the mid- and long-term planning periods. Conservation in these periods could become an important source of energy if new supply technologies lag in development because of a combination of technical and institutional problems, (in the past, major transitions to new fuel supplies have taken 50 years or more = ERDA is hoping for significant results from its supply programs in 10-20 years) or because of potentially serious environmental problems (see Part III of this report). The longer new supply technologies lag, the greater contribution energy conservation can make to reduce the gross energy required to meet the same human needs.

In addition, should new supply technologies fail or fall short of current expectations, the cost of energy could rise even more than expected. Higher-priced energy automatically generates a market for improved energy conservation technology. However, failure to conduct basic RD&D now to provide energy conservation opportunities for the mid- and long-term could mean that neither conservation nor supply technologies will be available when and if they are needed.

Relative Size of the Conservation and Supply RD&D Programs

Four underlying issues should be addressed by ERDA:

- Are the short-term factors which translate conservation's high RD&D priority into ERDA's smallest energy RD&D program (its newness and relatively early state of planning) also applicable in the mid-term and long-term?
- Is ERDA, in developing its program, considering the conservation benefits and the likelihood that private RD&D will produce the technology needed to realize these benefits?
- Should a substantial federal conservation RD&D program exist as a hedge against the risk of losing the large benefits of conservation?

Earlier in this chapter we noted that ERDA's proposed energy conservation budget increased by 64 percent between FY1976 and FY1977. However, from a different perspective, energy conservation received only 6 percent of the agency's total increase between the two years (see Figure II-2).

Comparison of energy conservation's share of ERDA's total program (not just the annual increase) shows a small conservation effort relative to supply -- 4 percent of the total (see Figure II- for a comparison). Conservation ranks next to smallest among the major RD&D programs.

The primary reasons for this situation are obvious: conservation is a new program that has started small and is growing fast; conservation is still in the early and relatively inexpensive stages of planning and development whereas some of the supply technologies are well into the more expensive demonstration stage. However, we believe that these are short-term conditions. They should be assessed to assure that conservation is receiving a share of RD&D resources commensurate with the potential benefits and the appropriate federal role. In the future ERDA should make explicit comparisons of the allocation of resources versus the potential benefits of conservation relative to supply RD&D. ERDA-76-1 observes that a barrel of oil saved can reduce imports at less cost than producing one through development of new supply technology; that energy conservation generally has a more beneficial effect on the environment; and that capital requirements to increase energy use efficiency are generally lower than capital needs to produce an equivalent amount of energy from new sources (most new supply technologies are highly capital intensive). Further, these benefits continue over time because the use of conservation as a "source" of energy can relieve pressure for new supply technologies.

As a measure of benefits, ERDA 76-1 estimates energy impact goals for each energy technology in the year 2000. On the basis of this benefit measure, the proportions of RD&D effort directed at energy conservation and at the supply technologies with which it competes in the near- and mid-term vary widely. Supply enhancement technologies contribute about 66 percent of the total year-2000 goal and receive about 90 percent of the ERDA RD&D effort in FY1977. Conservation technologies contribute 22 percent and receive 4 percent.

These comparisons link energy savings with the one-year ERDA funds directed at conservation. These comparisons are not the kind that we would like to use in assessing the rationality of ERDA's allocation of funds among energy conservation strategies or between conservation RD&D and supply RD&D. Rather, the question is of the additional benefits (in terms of likely national savings) expected from allocating additional ERDA funds to a particular research area. The expected total energy savings from a conservation strategy may be high, but the impact of additional ERDA research on this savings may be small, either because the full potential is known or because the required research is being carried out by other public or private institutions. Another strategy may offer less potential for total energy savings, but the savings actually realized could be highly dependent on ERDA research.

ERDA has not yet established research planning and analysis which produce the kinds of information required to make these judgments. The CEQ review, therefore, though recognizing the weakness in the analysis, has had to depend upon comparisons between total savings and research allocations. They do illustrate, in a general way, the apparent cost-effectiveness of investments in energy conservation.

To further illustrate the benefits side of the equation, the Council estimated consumer savings from technical improvements in major portions of the transportation and buildings end-use sectors (see Table II-3). The proposed funding levels in FY1977 for these R&D programs amounted to $12.8 million, $1.2 million, and less than $2.7 million respectively.

Table II-3: Energy Conservation Benefits and RD&D Effort

	Incremental* Benefits ($millions)
• AUTO EFFICIENCY	
- Redesign of non-engine components	$59,000 mm
- Engine re-design	
. Stratified charge, <u>or</u>	21,000
. Diesel, <u>or</u>	23,000
. Stirling, <u>or</u>	28,000
. Brayton	29,000
• BUILDING EFFICIENCY	
- Improved insulation	19,000
- Advanced heat pumps	6,000

*After allowance for the time-value of money; constant 1975 dollars.

These rough estimates, as did ERDA's, indicate large potential benefits from improved end-use devices. Measured cumulatively over time, rather than just at the year 2000, the gap between potential of benefits and the level of federal RD&D planned to ensure these benefits grows even wider. Although this represents a very crude comparison, which does not consider the full social costs of implementation the ratio of potential benefits compared to current expenditures appears so cost-effective as to justify significant investment.

ERDA 76-1 observes that establishing national priorities for energy RD&D does not equate necessarily with priorities for the allocation of federal funds. Specifically, it states that primary responsibility for the development of conservation technologies rests with the private sector because in general, they can be implemented with less government involvement than can supply technologies. This may be the case, particularly for near-term conservation opportunities.

Major allocation of resources among RD&D options should not be made subjectively. When the benefit/cost ratio of a conservation technology appears to be high, care must be taken to compare that opportunity on an equal footing with all competing options. The risk that, for institutional or other reasons, the private sector will not develop energy conservation technologies, or will not develop them soon enough should be carefully considered in allocating resources. If the risk appears to be too great in terms of lost or diminished benefits to justify near exclusive reliance on private industry, the government should develop these technologies.

Identifying and Implementing Conservation RD&D Program Opportunities

In this area there are three issues which require attention:

- o What alternative approaches might be used to identify and compare conservation RD&D opportunities?
- o Are ERDA's present energy savings estimates backed up by research work focused with sufficient depth on high payoff options?
- o What factors explain the large variations in levels and concentration of effort among the energy conservation programs?

As noted, ERDA 76-1 states that conservation technologies provide a potential cost-effective alternative to development of other energy technologies. Realizing this benefit will require the identification of potential conservation, as well as supply, opportunities. In order to provide an objective basis for comparison, all potential opportunities should be ranked according to cost-effectiveness without attention to whether they are conservation or supply oriented. This combined ranking could then be used for allocation of available RD&D funds. Of course other factors, such as the likelihood of commercialization of a technology or whether the technology will be commercialized without government assistance, must be considered before final resources allocation decisions are made. At this early stage in its development, ERDA has not yet implemented such a ranking process.

ERDA measures its planned conservation RD&D accomplishments in relation to a "no conservation" forecast of future energy use. This kind of yardstick alone cannot identify what energy conservation RD&D should be carried out in relation to supply RD&D. One alternative approach would be to measure conservation objectives against the maximum feasible energy savings physically achievable, using principles of the Second Law of Thermodynamics. In contrast to a "no conservation" energy forecast, theoretical physical principles provide a steady reference for measuring present against potential technology efficiencies.

The Second Law of Thermodynamics states the maximum fraction of a given quantity of heat energy which can be converted into useful work (the fraction is always less than 1.0). Energy is not destroyed in producing work; instead it changes from a high-quality form (one with a large fraction of its heat content available to perform work) to a lower-quality form. This quality feature stems in part from the temperature of the energy source rather than simply the quantity of heat energy it contains. A change in quality or work-producing potential -- rather than a change in quantity of energy -- is what is used up irretrievably in converting energy into work. Under a Second Law approach, source of energy and the work it is used for should be matched, with high temperature energy sources reserved for tasks only high temperatures can do and successively lower temperatures devoted to low-temperature tasks. Second Law efficiency measures the extent of a perfect match achieved in practice.

Rough thermodynamic calculations indicate that the ERDA-48 energy conservation outlook -- a 25 percent improvement by today's energy efficiency standards -- captures by the year 2000 only about 20 percent of the theoretical maximum efficiency improvement (see Table II-4).

Table II-4: Idealized Maximum and Planned Energy Savings

ENERGY CONSERVATION TARGET	ERDA Year-2000 Goal (Quads)	2nd-Law Maximum	Percent
Industrial Process Heat	2.0	13.9	14
Automobile Transportation	3.7	11.6	32
Bus, Truck and Rail Transportation	1.8	8.0	22
Building Space Heating Systems	1.6	7.4	22
Air Transportation	1.3	7.3	18
Industrial Electric Drive	1.0	4.6	22
Building Air Conditioning Systems	0.7	4.6	15
Buildings Electric Devices	1.1	2.9	38
Buildings Thermal Improvement	0.4	2.8	14
Ship Transportation	-	1.5	0
Iron and Steel Production	0.2	0.8	25
Primary Aluminum Production	0.04	0.3	13
Electric Mass Transportation	-	0.2	0
Total	13.84	65.9	21%

Source: Based on ERDA-48 Vol. 2 and <u>Efficient Use of Energy: A Physical Perspective</u>, American Physical Society

We <u>emphasize</u> that Second Law principles only indicate a theoretical maximum energy efficiency and only serve to estimate the maximum size of the efficiency gap where real world energy conservation RD&D opportunities may exist. These calculations by themselves could not translate directly into an RD&D program. First, the full measure of idealized energy savings cannot be realized in practice. As thermodynamic efficiency is increased more and more, other physical factors begin to act as a limit. Most important, the Second Law of Thermodynamics does not consider economics. For both reasons, it can only suggest an upper limit on the extent of energy conservation possibilities that should be explicitly explored.

Among those conservation opportunities presently being pursued by ERDA's Office of Conservation Programs (OCP), there are issues of focus which warrant attention. Ideally, individual energy conservation RD&D programs should focus on opportunities with the greatest energy savings potential. RD&D in these high payoff areas should be concentrated to ensure technical and commercial success. Of course, it is true that a lack of correlation between the size of energy savings and the level of effort could have several causes: differing energy saving opportunities, the state of advancement of technology, or existence of non-federal research efforts, for example. In addition, as pointed out earlier, the benefits in terms of additional national savings from allocating RD&D funds to a particular research effort must be considered. However, large deviations between focus of effort and potential energy savings provide a signal that ERDA's system for assigning priorities with the energy conservation RD&D program may be inadequate.

The Council reviewed 145 project areas within 18 budget categories of the Office of Conservation FY1977 program and budget and compared them for consistency in focus of effort versus potential savings. Two criteria were used. The OCP budget categories expected to contribute the largest share of 1985 energy savings might be expected to receive the largest share of the total OCP budget. Within each high payoff budget category, the average level of funds available for each project area might be expected to match the high average energy savings expected from each (see Table __).

Table_____ FY1977 Budget, 1985 Savings, and Project Areas, by Budget Category

BUDGET CATEGORIES	APPLICABLE PORTION 1/		PERCENT 2/	
	FY77 Budget	1985 Savings	Budget	Savings
ELECTRIC ENERGY SYSTEMS & ENERGY STORAGE				
1. Electric Energy Systems				
Systems Management & Structuring	6,010	710	6.5	11.1
Electric Power Transmission	12,890	60	12.3	0.9
Electric Energy Systems Implementation	--	--	--	--
2. Energy Storage	20,840	450	19.8	7.0
END USE CONSERVATION & TECHNOLOGIES TO IMPROVE EFFICIENCY				
1. Industry Conservation				
Unit Operations & Equipment Efficiency Process Analysis & Modification Alternative Fuels, Materials & Processes Agriculture & Food Processes	8,650	2,250	8.2	35.0
Industry Information	--	--	--	--
2. Buildings Conservation				
Commercial Buildings	3,850	200	3.7	3.1
Residential Buildings	3,075	280	2.9	4.4
Community Systems	6,850	600	6.5	9.3
Urban Wastes Appliances Technology	5,950	360	5.7	5.6
Performance Standards	--	--	--	--
Dissemination & Transfer	--	--	--	--
3. Transportation Energy Conservation				
Heat Engine Highway Systems	14,790	510	14.1	7.9
Electric & Hybrid Systems	4,550	80	4.3	1.2
Implementation & Equipment Non-Highway Transport Systems	1,800	340	1.7	5.3
Technology Studies	--	--	--	--
4. Improved Conversion Efficiency	15,000	580	14.3	9.0
TOTAL	105,055	6,420		

1/ Thousands of barrels of oil per day -- equivalent. U.S. Energy Research and Development Administration, FY1977 Budget Estimates

2/ May not add to 100 percent due to rounding.

Note: To arrive at the 12 "direct" program areas shown in Table _____, the "support" subprograms and their associated funds ($7 million) were excluded. Also, to simplify, several of the remaining 18 program areas were combined (see the "Applicable Portion" column in the table). Then, the percentage of total "applicable" funds and energy savings accounted for by each "direct" program area was calculated. The "Percent" columns, at the right-hand side of the table, indicate that the distribution of the budget by program area does not coincide with the distribution of expected savings.

Our major observation is that the two areas of largest expected savings -- industry conservation and new technologies for buildings ("other buildings") -- are being funded below their expected contribution to energy savings. They account for about 50 percent of the 1985 savings and about 20 percent of the effort in FY1977. In contrast, energy storage and heat engine highway systems account for about 30 percent of the budget and only about 10 percent of the savings.

Resolving the Issues

Addressing and resolving these issues is critical to ERDA's energy RD&D mandate and to meeting the responsibilities that its mandate implies. All of them are inherently complex, and the answers will make an enduring imprint on our future energy choices. Their resolution will depend on the methodology ERDA employs to plan and implement energy RD&D.

In ERDA 76-1, the agency recognizes the distance remaining to be covered in achieving a fully adequate national energy RD&D plan and energy research program. To further ERDA plans and programs, a new framework for planning and implementing energy RD&D -- a Program Planning, Budgeting and Review System -- will be set up. The concepts it reflects are ambitious and theoretically advanced. Today, however, rudiments are there, but little else. Consequently, the remaining two chapters of this part of the report discuss the methods ERDA used to forumulate the energy RD&D program that ERDA 76-1 represents and the actions that are underway to enhance ERDA's capacity to address the issues set forth above.

Chapter IV

DECIDING WHAT ENERGY CONSERVATION RD&D SHOULD BE CARRIED OUT

The Council believes that adequate provision for building conservation in ERDA's overall planning for into /energy RD&D requires:

- o A task-oriented, energy systems definition of energy choices.
- o A process for deciding what RD&D should be carried out based upon ongoing comparisons of all potential RD&D options.
- o Comparisons based on comprehensive assessment of the energy, economic, environmental, and social impacts of the options.

We recognize that ultimately, the decision maker's judgment will determine the composition of RD&D programs. The three elements listed above will provide the basis for informed decisions and should be major factors in determining the appropriate composition of the conservation RD&D effort. The remainder of this chapter expands on these elements and compares the approach used in establishing priorities in ERDA 76-1 and in allocating resources among potential technology options. We then identify and evaluate improvement efforts which ERDA is undertaking. Finally, in the apprndix to this chapter we provide an illustrative example of an analytical approach which we believe includes the principal elements for adequate consideration of energy conservation.

Task-Oriented Approach

The task-oriented approach identifies energy RD&D opportunities by looking first at the basic nature of the tasks energy can perform and at alternative ways to do them using different amounts of energy. Starting with end-use, it then poses and compares alternative configurations of end-use devices and supporting distribution systems, transport modes, conversion processes, and energy resources to serve them.

In the past, our energy decisions, including those related to ERDA's National Plan, have not taken this approach. Typically, we looked first at energy resources and alternative conversion processes and methods. Often, this traditional systems approach ignored the final end-use step as well as the nature of the tasks which create our energy needs. As a result, new and different end-use methods and devices often were overlooked entirely in posing future energy choices and deciding what energy RD&D should be carried out.

We can clarify the difference by considering home heating as an example. The traditional analysis begins with mining of coal and then compares ways of converting, transporting and distributing it to homes in raw form or as a gaseous or liquid fuel or electricity. The task-oriented approach begins with the problem of maintaining a comfortable indoor residential environment in the most efficient manner.

The task-oriented approach is a better way of analyzing energy choices because, by broadening the view of energy end-use, it opens up new possibilities for energy conservation early on. As a first step in the search for energy RD&D opportunities it asks: "What is to be accomplished by spending energy on a given use?" Also the task-oriented approach encourages consideration of the maximum efficiency that should be achieved in getting the job done rather than simply improving the efficiency of methods and devices now in use.

Most important, unless the analysis begins with end-use, RD&D priorities and funds could be misdirected because possible end-use energy savings may not come to light. End-use technology improvements are an integral component of each alternative energy system. Not fully considering end-use may produce wrong answers about the relative attractiveness of different supply and end-use conservation technologies.

Without incorporation of a task-oriented, energy systems definition of energy choices, RD&D priorities and funds may be misdirected.

Ongoing Comparison Process

An adequate method for building in conservation identifies and evaluates energy RD&D work to be carried out concurrently at many levels in the organization and therefore at different levels of detail, all closely interacting and linked in the overall national planning process. A national plan for energy RD&D evolves and is implemented by planning at top levels and all the way down and up the line.

The most detailed comparisons of RD&D alternatives should be done within individual RD&D program offices and at the level of specific RD&D tasks or projects -- for example, competing designs for a heat pump or for a high-Btu coal gasification process unit. The detailed information for the top-level comparisons should be developed as a product of day-to-day research work.

At decreasing levels of detail, options should be identified and evaluated in both planning and implementing a national plan. At the top, the comparisons and decisions regard the larger system -- for example, alternative liquid fuel, gaseous fuel, or electricity-based transportation systems. To adequately build in energy conservation, information must be brought together at this level in a way which makes possible comparative evaluations of conservation and supply RD&D opportunities.

Comprehensive Assessment of Consequences

Comprehensive assessment of energy RD&D options is critical to ensure that a task-oriented approach and an ongoing comparison process ultimately produce adequate attention to energy conservation. Comprehensive assessment has two dimensions. One concerns estimating the energy, economic, environmental, and social benefits and costs of competing RD&D options. The other involves identifying, evaluating, and comparing energy end-use conservation options to their supply counterparts over each proposed supply RD&D planning period.

A method for comparing conservation with other RD&D should produce timely impact assessments addressing major public conerns. This can best be done by building the assessment into each energy RD&D program. Without timely assessments, drawn from research built into every energy RD&D effort, comparisons of all attractive RD&D opportunities cannot be carried out, and conservation opportunities may not be fully considered.

Without comprehensive measurement of impacts of alternative uses of RD&D resources, attention to energy conservation in federal RD&D will be of questionable adequacy.

Principal Findings

ERDA recognizes that an approach similar to that outlined above is necessary for RD&D planning and decisionmaking. Measures to improve its planning process, discussed later in this chapter, could establish the basis for adequate consideration of conservation. But a careful review of the analytical and planning processes as expressed in ERDA 76-1 indicates significant problem areas:

- ERDA has not performed task-oriented or systemwide evaluation to identify what energy RD&D is needed.
- Fundamental economic and environmental information basic to a functional building-in method is not available. More important, the research work ultimately needed to provide this information is not built into the energy RD&D efforts of its supply and conservation program offices.
- ERDA's planning and budgeting are not effectively linked at the top. Consequently, broad agencywide decisions about what RD&D should be carried out cannot be translated with confidence into specific research.
- A general lack of policies, planning guidelines, and decision criteria exists for insuring that all energy RD&D opportunities are compared objectively.

ERDA 76-1 makes commitments which could solve these problems; and work is underway in a number of areas to implement these commitments. As discussed in this chapter, these represent a major commitment which could provide the basis for adequately building-in energy conservation. To ensure adequate attention to energy conservation, these commitments should be implemented as rapidly as possible.

Without such an improvement, ERDA will not be able to make objective comparisons between energy conservation and energy supply technologies within the next 2 years.

ERDA's Building-In Method

This section examines the methods used to formulate ERDA 76-1 and the current research of ERDA's Office of Conservation Programs.

Description of Energy Choices

The Brookhaven Reference Energy System (RES) -- ERDA's primary planning tool -- can systematically compare the energy costs of alternative energy systems. It contains energy sources and technologies, and energy flows from resource extraction through to the end-use devices which convert delivered energy (e.g., liquids, gases, solids or electricity) into desirable work (e.g., BTU's of residential space heat).

Energy efficiency is an important, explicit factor in the RES calculations at each step from extraction through the end-use device. Also, alternative end-use devices (e.g., a heat pump as a substitute for electrical resistance heating) can be inserted into the energy flows from extraction to each major category of end-use. For this reason, ERDA's RES capability is a sound and sophisticated tool through which a task-oriented planning approach ultimately can be achieved.

However, the RES cannot fully accomplish task-oriented, energy systems definition of energy choices. First, the investment costs of the end-use devices in the RES are not factored into its calculations. Second, only the end-use device itself is contained explicitly within the system descriptions. For example, energy conserving opportunities applicable within more broadly defined energy using units (e.g., improved insulation of homes) but external to the end-use device (e.g., the furnace or air conditioner) are not accounted by the RES. This means that the costs of these kinds of improvements, which make up a large share of the energy conservation RD&D opportunities ERDA anticipates, cannot be included explicitly in energy systems comparisons.

Finally, the RES presently is not configured to automatically adjust levels of end-use efficiency (or use efficiency at critical intermediate steps such as electricity generation) in response to the expected costs of energy supply. However, the economics of supply technology have a profound effect on the basic economic attractiveness of energy conservation technologies and, as a result, on the level of energy demands. Also, end-use efficiencies achieved through economically competitive new end-use technologies have an equally profound effect on the relative attractiveness of alternative supply technologies.

Until all investment costs associated with the end-use of energy are incorporated in the RES along with capability to automatically adjust energy efficiency opportunities in light of changed supply costs, the RES cannot help to accomplish the matching of supply and conservation intrinsic to the task-oriented approach.

Evaluation of Energy Choices

Evaluation of energy choices beginning with end-use alternatives has three steps. First, the basic nature of the tasks that energy might perform should be described.* Second, tasks that energy can perform should be

* In a general sense, ERDA does this. In formulating inputs to the Reference Energy System they begin by estimating the amount of various services (e.g., miles of automobile travel) consumers may demand in the future.

examined by searching out a wide range of methods and devices that use different amounts of energy. Third, energy conservation opportunities should be assessed in relation to indicators of improvement potential, for example the principles of the Second Law of Thermodynamics referred to earlier, rather than against the energy efficiencies of today's end-use devices and methods. On these terms, there are three problems underlying ERDA 76-1:

- The kind of analysis by which ERDA set priorities did not use the best capabilities of its planning tool.
- The scenarios used to determine strategy emphasis are not developed from a task-oriented basis.
- The number of energy conservation opportunities does not reflect an assessment of energy RD&D potentials.

The Brookhaven system can calculate the least-cost combination of myriad energy supply options which our economy should tend to select in the future. ERDA, however, did not use this capability in formulating the National Plan. Instead, future energy choices were described in ERDA-48 and ERDA 76-1 with six-subjectively-determined energy futures. The energy choices which make up these six "scenarios" were evaluated by calculating by hand their impacts on our domestic resources and energy costs. Briefly, the six scenarios are: a baseline of no new initiatives; improved efficiencies in end-use, synthetics from coal and shale, intensive electrification, limited nuclear power, and a combination of all the technologies.

Because none of these scenarios reflects the combination of energy choices that the economy might in fact produce, their usefulness in determining an energy RD&D mix is limited. Moreover, of the four scenarios which contrasted alternative energy choices (excluding the baseline and the combination of all technologies) conservation improvements available from new technologies are generally reflected only in the improved end-use efficiency scenarios. The other scenarios varied supply and, although a few items from the conservation scenario were considered, the Plan did not carry out the kind of systemwide balancing of energy supply and energy conservation opportunities required by a task-oriented approach.

Finally, ERDA's national planners and its end-use conservation program offices "negotiated" the assumptions used in the improved end-use scenario. Negotiations appear to have been over what percentage of improvements in today's end-use devices to use in the Plan. They did not consider potential energy conservation possibilities.

RD&D Comparisons Throughout Planning

An ongoing comparison process links top-level planning with planning of detailed research programs and, in turn, with budget decisions and program implementation. In doing this, the need to make side-by-side comparisons of alternative RD&D opportunities should be kept in mind. Also, at the point where top-level comparisons are made, the planning process should ensure that the costs and benefits and other attributes of competing technologies are based on detailed research programs designed to deliver these results.

We found that ERDA has made general comparisons of this type in establishing broad agency priorities. However, specific energy conservation and supply enhancement RD&D technology opportunities are not lined up for comparison based on cost, benefit and impact information.

The planning and implementation approach outlined in ERDA 76-1 promises a side-by-side ranking of energy RD&D options. To produce this ERDA envisions various analyses of energy markets, both private and public investment attractiveness of new energy technology ventures, and energy-economic-environmental tradeoffs. A "Program Strategy" document is expected to synthesize these studies.

The kinds of analyses needed to produce strategy statements are currently in the first stage of development at ERDA.

Information and Planning Periods for Comparisons

ERDA's impact information reflects three inadequacies:

- The environmental research that is basic to environmental assessments is not built into conservation RD&D.
- ERDA's macroeconomic impact assessment capabilities, although its most advanced impact assessment area, are not adequate.
- The information and analytical capability necessary to compare the impacts of energy conservation and supply enhancement technologies do not yet exist for the mid- and long-term periods.

Adequate information on the economic, environmental, and social impacts of energy choices is basic to planning. Identifying and evaluating such impacts must be built into each RD&D program. Impact assessments addressing areas of major public concern should be available on a timely basis, and the assessments should influence what RD&D is carried out.

ERDA's environmental assessment process is discussed in the following chapter and in Part III of this report.

Although in general, ERDA's macroeconomic impact assessment capabilities appear more advanced than its environmental assessment capabilities, they need further development. Since formulation of the first National Plan, the economic impact capabilities of RES have been extended. ERDA 76-1 tested possible impacts of new energy technology on national economic growth and other conventional indicators of economic well-being. The tests compared new technologies against the alternative of simply allowing energy prices to rise enough to balance demand with supply.

The tests suggest that relying only on price increases to ration limited energy supplies has serious economic impacts. As an alternative, new supply technologies may become attractive. However, we do not believe this analysis alone is sufficient. The tests should also explicitly consider the economic and other impacts of new conservation technologies. Until this is done, ERDA's macroeconomic impact information will not be adequate for building energy conservation into energy RD&D.

Guidance to assure necessary impact information is generated and procedures to ensure that all impacts of public concern are fully considered should be formalized. These procedures should extend below headquarters level where the day-to-day research is done.

Comparison Planning Periods

ERDA's rationale for energy RD&D is providing choices for the future. To do so, energy conservation and supply enhancement technological opportunities should be assessed over comparable periods of time. This will focus attention on the comparative economic, environmental, and social impacts of the alternative technologies. The conservation program is not yet generating the information necessary for these comparisons.

Plans for Improvement

ERDA presently is improving its agency-wide and specific program planning capabilities in a major way.

Program Planning, Budgeting and Review (PPBR) System

This system is to provide "an integrated approach to analyzing future energy technology needs; formulating the federal role in addressing those needs; designing targeted programs to conduct ERDA's portion of the plan; allocating resources consistent with the Plan and program design; and ensuring that ERDA's programs are effectively managed."

The components of this approach include:

- "normative planning," which establishes broad energy technology goals
- "strategic planning," which defines how the goals can be achieved most effectively
- "program planning," which describes in detail how the ERDA program will be implemented
- "resource allocation," which directs ERDA resources at the most important activities
- "program implementation," which delineates the specific activities to be accomplished within approved budgets
- "program evaluation," which identifies differences between the operating plan and actual conditions.

A number of formal documents are envisioned by ERDA to accompany these components (see Table II-6).

ERDA's PPBR system, an advanced approach to management of a large, complex organizatioon, is still in its early stages. Future reports of the Council will address its use in considering and effecting conservation RD&D.

Table II-6: PPBR System Outputs

- National Plan for Energy RD&D: documents the comprehensive goals and priorities that help define what should be done if energy problems are to be resolved through technology development (e.g., ERDA-48 and ERDA 76-1).

- Program Strategy: for each technology program, presents major program goals and strategic implementation milestones derived from an analysis of the effectiveness of RD&D in resolving energy problems and the need for a federal role in RD&D.

- Program Plan: details the most cost-effective federal program for implementing each technology program's strategy and specifies how each program will be managed and related to other federal programs.

- ERDA Budget: presents comprehensive near-term priorities and the annual allocation of resources.

- Program Approval Document: a 1-year operating plan, carved out of each program plan, which provides a baseline for monitoring program operations during 1 fiscal year.

- Environmental Development Plan: the EDP outlines the environmental research program planned in parallel with each technology program plan, to resolve environmental issues at a pace consistent with the rate of technology RD&D.

- Environmental Impact Statement: required by the National Environmental Policy Act, conveys the results of the environmental research outlined in each program's EDP to major program decision points.

Source: ERDA 76-1

Better Analysis

More specific improvements are underway to enhance ERDA's capabilities for defining systemwide energy choices and for identifying and evaluating energy RD&D opportunities. ERDA plans to:

- o Add the investment cost of alternative end-use devices to its principal assessment tool, the Brookhaven Reference Energy System.
- o Investigate the macroeconomic impacts of nonprice-induced energy conservation.
- o Implement a newly developed technique (called "relevance trees" by ERDA) for structuring a task-oriented approach to identifying energy RD&D opportunities and for evaluating and ranking these opportunities in a systemwide context independent of whether they represent conservation or supply enhancement RD&D.
- o Revise the ERDA 76-1 scenarios.
- o Include Second Law of Thermodynamics calculations in its Reference Energy System estimates.

The further step of comparing energy conservation and supply enhancement RD&D in planning is progressing:

- o Having identified the kinds of analyses needed to support planning, ERDA's next goal is to analyze in more detail programs that are aimed at the same or similar markets.
- o A second goal is to apply tools such as venture analysis, economic impact analysis, tradeoff studies, net energy analysis, and constraint studies (in order to quantify) the costs and benefits of selected energy technologies.

The Council believes these improvements can result in adequate attention to energy conservation. However, we are concerned that although ERDA is initiating the required work, RD&D opportunities will not be comprehensively ranked during 1976. With budget leadtimes, with legal restrictions on moving funds between programs,and with multi-year commitments, work planned and budgeted during 1976 will not be begun until 1978. RD&D in 1978 still may not benefit from the necessary comparisons of conservation and supply. The Council believes that ERDA should establish an action agenda for implementing its improvement efforts. Until these improved analytical planning methods are being used to consider conservation on an equal basis with all other options in establishing RD&D priorities, ERDA's plans should make clear that priorities will be closely reevaluated on an annual basis.

Example of a Task-Oriented Approach

A national program of energy RD&D should, as a minimum, evaluate energy choices in terms of complete energy production and use pathways. The most essential feature of doing so is the identification and evaluation of competing energy choices beginning with end-use needs.

Our earlier discussion of a task-oriented building-in methods. described one system pathway: from mining coal, step-by-step, through its final use to heat a home. This discussion illustrates the need for

comparisons of competing energy systems which encompass extraction, conversion, transmission, distribution and end-use. It shows how environmental, economic, and social impacts change the attractiveness of individual configurations of conversion, transmission, and distribution technologies. But most important, the value of new and different end-use technologies becomes clear. Coal is the source of energy in all the examples throughout the energy conservation section.

Systems Definition of Energy Choices

Residential space heating needs may be satisfied with many different system configurations.* Geographical variables affect the availability and quality of coal, seasonal annual heating needs, and the technologies at each step from extraction on.

In our illustration a number of individual technical components were combined at each extraction, conversion, transmission, distribution, and end-use step to form alternative pathways from coal through residential space heat. These technical components were configured for New York, Chicago, and Los Angeles using coal from the east, midwest, and west.** For each coal source and city, economically second-rate

* To simplify the illustration, we do not consider residential space cooling, as well as other residential energy uses (e.g., water heating) which relate to space heating.

** In the interest of brevity, only Chicago is discussed here.

pathways were eliminated, until the best configuration reflecting four systemwide alternatives remained: direct burning of coal to generate electricity, coal liquefaction, high-Btu coal gasification, and a dual conversion system consisting of an intermediate low-Btu coal gasification conversion step and an electrification final conversion step.*

Initially, we limited comparisons of the four systemwide alternatives to the estimated full life-cycle costs per unit of space heat available in a residence. We made the comparisons in three steps. The first began with extraction (coal mining)but stopped with the cost of energy "as delivered" to the residence but before costs of installing and maintaining alternative residential space heating systems were factored in (Figure II-5 shows the example results fro Chicago).**

Horizontally, the figure shows six points where the estimated energy costs were compared. The first three points (left-to-right) make up the production and delivery portion of the pathway. The last three complete the energy production and use pathway by including costs of three end-use devices. Each represents a more efficient residential heating device: today's devices, an improved version of today's devices, and a heat pump, respectively.

The costs are shown by an index rather than estimated dollars per unit of energy. The index was derived by dividing the estimates available for each technical component by the cost of $13 imported crude oil at a comparable step in its conversion to residential_space heat.

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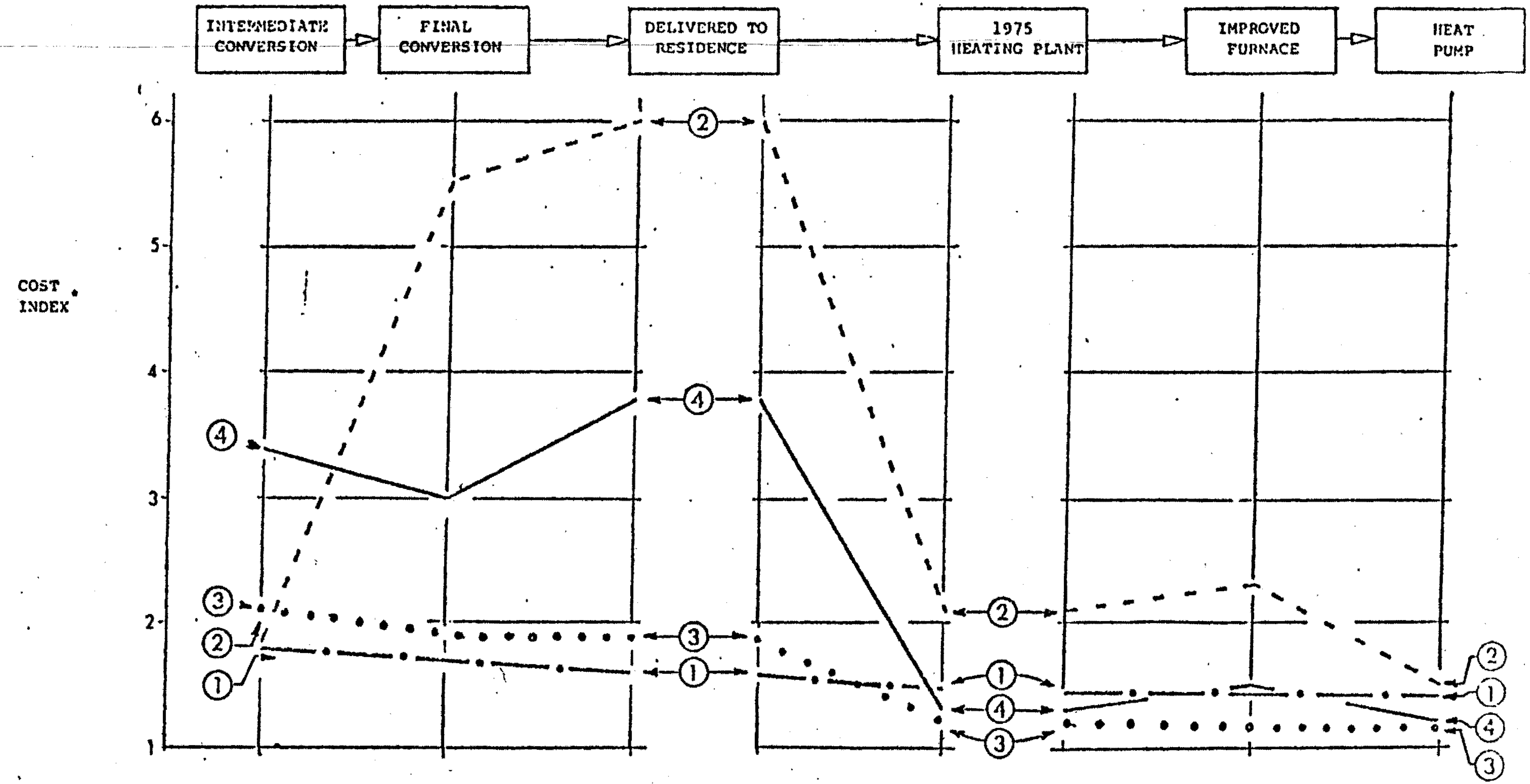
* Of these conversion technologies, coal liquifaction, high-Btu gasification, low-Btu gasification, and improved direct generation through

FIGURE II-5: Economics of Four Systems to Heat Chicago with Coal-Derived Energy



LEGEND:

(4) DIRECTLY BURN WESTERN COAL TO GENERATE ELECTRICITY.

(3) GASIFY WESTERN COAL TO PRODUCE HIGH-BTU PIPELINE QUALITY GAS.

(2) GASIFY WESTERN COAL TO PRODUCE LOW-BTU GAS TO, IN TURN, GENERATE ELECTRICITY.

(1) LIQUIFY WESTERN COAL AND REFINE TO PRODUCE FUEL OIL.

* Cost index = 1.0 represents heating Chicago residences with $13.00 imported oil.

It is immediately apparent that the relative economic attractiveness of the four systems changes dramatically as the comparison extends beyond the conversion step -- gasification, liquefaction, or electrification -- to the point of use. Compared only on an as-delivered basis(to the residence from the coal), the coal-synthetic oil and gas systems are about twice as attractive economically as burning coal directly to produce electricity. The dual-conversion system -- coal to low-Btu gas to electric -- looks uniquely unattractive for residential space heating here.

The second step in the example analysis extended the comparison of the four systemwide choices for residential space heat to include the efficiency and life-cycle investment and operating costs of today's space heating devices (see Figure II-5). Including both energy production and use in the economic comparisons brings the attractiveness of direct coals to electric system more into line with synthetic oil and gas. The reason is the 100 percent end-use efficiency of electrical resistance heating compared to the lower efficiency of gas-fired and oil-fired residential heating plants.* The dual-conversion system, however, still looks inferior despite its 100 percent end-use efficiency.

In the former case, a system with higher delivered energy costs before end-use becomes more economically competitive when its higher end-use efficiency is considered. In the latter, a 100 percent efficient end-use device does not make economic sense when supplied by a high-cost dual conversion energy pathway. The need for systemwide analysis of energy choices is clear.

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* This 100 percent level should be interpreted as a relative measure of efficiency for well-insulated electrically-heated homes, against which gas-and-oil-fired systems can be compared.

Task-oriented Viewpoint

A question remains about whether new energy conservation technology can improve the overall economic performance of these four systems or can change their relative economics. To illustrate, the analysis next considered more efficient oil and gas heating plants as well as an electric heat pump* (see Figure II-5). Without a heat pump, more energy efficient gas and oil heating plants lower total costs per unit of space heat for their systems. Better furnaces decrease the relative economic attractiveness of the electric configurations, again because electrical resistance heating is already 100 percent efficient.

Adding a heat pump, however, makes the direct coal-to-electric configuration economically comparable to coal synthetics for Chicago's space heat needs. It should also be noted that the dual-conversion low-Btu gasification-to-electric option may also approach the economically competitive range for purposes of deciding what RD&D candidate technologies to pursue.

Comprehensive Assessment of Consequences

Energy costs alone cannot adequately reflect impacts of energy RD&D options. For example, the four residential space heating systems have other economic, environmental, and social impacts which should be compared comprehensively. The environmental quality assesment illustrates the need for comprehensive impact measures.

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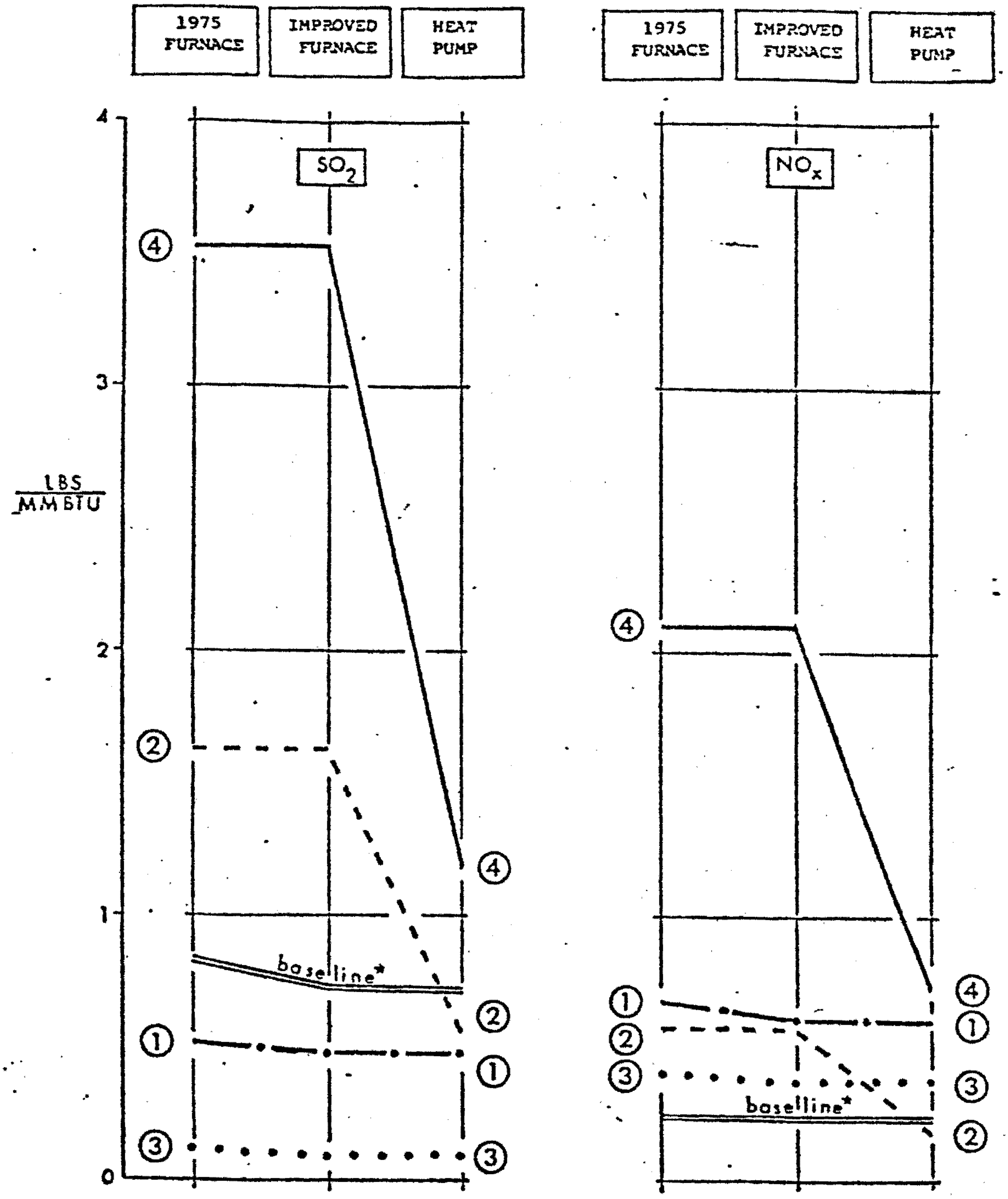
* A natural-gas actuated heat pump was excluded because initial costs lower gas heat economic feasibility. Again to simplify the illustration, new end-use technologies potentially capable of affecting gas heat like the way heat pumps affect electric heat are excluded, for example, solar-assisted gas heating systems.

Environmentally, the four systems that produce residential space heat from coal also produce different land, air, and water pollutants. They occur at different geographical locations, all with potentially unique vulnerabilities to each pollutant. For example, the environmental impacts will be measured in terms of only two air pollutants -- sulfur dioxide and nitrogen oxides, and to simplify, total pounds of SO_2 and NO_x emitted will be used as the measure. Like the economic comparisons, environmental comparisons are made before and after energy conservation technologies are added (see Figure II-6).

These two environmental impacts influence the relative attractiveness of the options for meeting Chicago residential space heating needs with coal. Considered before energy conservation improvements, two technologies -- liquefaction and high-Btu gasification -- stand out as especially advantageous economically and environmentally. They also produce less SO_2 than today's oil-based heating systems. In contrast, before-conservation comparisons add environmental disadvantages onto the economic disadvantages of the direct-coal-to-electric system.

FIGURE II-6: Environmental Consequences of Coal-Based Residential Heating



④ DIRECTLY BURN WESTERN COAL TO GENERATE ELECTRICITY.

③ GASIFY WESTERN COAL TO PRODUCE HIGH-BTU PIPELINE QUALITY GAS.

② GASIFY WESTERN COAL TO PRODUCE LOW-BTU GAS TO GENERATE ELECTRICITY

① LIQUIFY WESTERN COAL AND REFINE TO PRODUCE FUEL OIL.

* Represents heating Chicago residences with $13.00 imported oil.

More important, energy-use efficiency improvements can have a major effect on the relative environmental position of the four competing systems. On economics alone, improving today's heating plant moved all but the dual conversion system (low-Btu gasification to electric) into a comparable cost range. Coupling environmental measures with slightly improved oil and gas furnaces, however, further reduces the attractiveness of the direct coal-to-electric option relative to oil and gas synthetics.

Heat pumps were shown earlier to represent an economically worthwhile addition to the electric systems, but not dramatically so. Applied to the electric-based systems, however, a heat pump significantly decreases SO_2 and NO_x emissions. After heat pumps are included in the system, then, the electric systems appear equally-attractive economically and environmentally to synthetic oil and gas. To build energy conservation into RD&D adequately, more sophisticated end-use technologies -- exemplified by the heat pump -- may become especially attractive when environment is more fully considered. In addition, an entire class of supply enhancement technologies -- coal-to-electric systems -- may become a more attractive candidate for RD&D.

The intent of the coal-Chicago illustration is to demonstrate that systematically addressing additional impacts of competing RD&D options changes their relative value dramatically. The illustration is clearly incomplete for deciding what energy RD&D should be carried out. Addressing other environmental, macroeconomic, and social impacts would provide more insights into different kinds of opportunities for RD&D and could reorder the ranking of opportunities. The Council suspects that would