This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the laboratory.

UCID - 16685

LAWRENCE LIVERMORE LABORATORY

University of California/Livermore, California

A CRITIQUE OF THE DIXY LEE RAY REPORT,
THE NATION'S ENERGY FUTURE

C. J. Anderson
P. H. Moulthrop
W. J. Ramsey
B. Rubin
G. C. Werth

February 3, 1975

MASTER

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Prepared for U. S. Atomic Energy Commission under contract no. W-7405-Eng-48

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

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

A CRITIQUE OF THE DIXY LEE RAY REPORT,
THE NATION'S ENERGY FUTURE

ABSTRACT

We review the 1973 Dixy Lee Ray Report, The Nation's Energy Future, in light of events since its publication. We suggest some shifts in energy R & D criteria needed to bring the Report into congruence with today's world of energy politics and prices and examine the Report by transportation, thermal use, and electricity marketing sectors.

INTRODUCTION

The purpose of this report is to review the Dixy Lee Ray Report, The Nation's Energy Future,¹ which recommends an integrated energy research and development program. Her report was written between June 29 and December 1, 1973. This review is done in light of events since the Ray Report was written and examines changes in program emphasis that may be warranted. This analysis is grounded in a rationale we developed previously² and is based on our views of the energy needs of the United States.³

The Ray Report has strongly influenced energy R & D planning, even though it was essentially written before the oil embargo of October 1973. The plan includes consideration of all energy forms for both short and long term payoff. It takes account of conservation of energy and energy resources, along with the environmental effects of energy production and usage.

The Report recognizes an intensified role for coal in the economy along with an important contribution from industry's participation in energy R & D. It concludes with recognition of the need for basic research in support of the specific programs.

The strategy of the Ray Report R & D program is quite clear on examination of the funding proposed. The recommended national energy R & D program for FY 1975-1979, including the private contribution and supporting program, totals \$23.5 billion and is given in Table 1.

PUBLIC AWARENESS

Several aspects must be examined in analyzing the Ray budget in view of today's needs for energy R & D. Public awareness of the energy problem has changed. When the Ray Report was written, worldwide industrial expansion was outstripping energy supply thus causing spot shortages of natural gas, electrical generation capacity, gasoline, and fuel oil. Since the Report was written, the Arab oil embargo occurred, along with

Table 1. Ray Report recommended national energy research and development program, FY 1975-1979.

Self-sufficiency task	Costs in \$ million for payoff by:			
	1985	1985-2000	After 2000	Total (\$ million)
1. Conserve energy and energy resources				
Federal.....	1,160	280	—	1,440
Private.....	3,200	300	—	3,500
Subtotal.....	4,360	580	—	4,940
2. Increase domestic production of oil and gas				
Federal.....	430	30	—	460
Private.....	4,300	200	—	4,500
Subtotal.....	4,730	230	—	4,960
3. Substitute coal for oil and gas on a massive scale				
Federal.....	1,690	485	—	2,175
Private.....	2,500	500	—	3,000
Subtotal.....	4,190	985	—	5,175
4. Validate the nuclear option				
Federal.....	1,100	2,990	—	4,090
Private.....	1,000	250	—	1,250
Subtotal.....	2,100	3,240	—	5,340
5. Exploit renewable energy resources to the maximum extent feasible				
Federal.....	135	150	1,550	1,835
Private.....	220	30	—	250
Subtotal.....	355	180	1,550	2,085
Total				
Federal.....	4,515	3,935	1,550	10,000
Private.....	11,220	1,280	—	12,500
Grand Total.....	15,735	5,215	1,550	22,500
Supporting programs ^a	Costs (\$ million)			
Environmental effects	650			
Basic research	300			
Manpower development	50			
	1,000			
				Total 23,500

^aIncremental federal funding to present programs.

a sharp increase in the world price of oil. The Federal Energy Administration was formed to help alleviate the consequences of the embargo, and currently a global economic crisis due to flow of petro-dollars is occurring.

Prior to the writing of the Ray Report, the National Petroleum Council had projected⁴ a serious energy problem both in level of imports and in total cost of imports. Since the writing of the Report, energy growth rates are down somewhat, but changes in demand in response to price increases have not yet substantially reduced oil usage. In fact, oil imports are higher now than before the embargo. Also, higher energy prices contribute to inflation, and all other elements of domestic and world economic structures are upset trying to pay the oil bill.

When the Ray Report was written, environmentalists stood in full confrontation with energy suppliers, resulting in the curtailing of offshore drilling, delays in approvals for the Alaskan pipeline, and strict schedules for the introduction of tougher emission standards. Since the Report, offshore leasing and drilling have been resumed, the pipeline was approved, and some emission standards have been delayed. Today it is becoming apparent that economic pressures can temper environmental concerns.

CONTEXT OF R & D

The context in which energy R & D is viewed has changed since the Ray Report was written for several reasons. At that time, the economy of the United States was far healthier and adequate funding was available for expansion. Since then, both inflationary and recessionary trends have set in, with the result that investments in new plant construction have been delayed.

When the Ray Report was written, the Organization of Arab Petroleum Exporting Countries (OAPEC) was believed to be of limited effectiveness, and embargo threats were not considered credible. Since the writing of the report, the embargo shocked the entire world and it is now seen that OAPEC is an exceedingly effective device. Further, embargo threats must be considered real.

Oil prices at the time of the writing of the Ray Report were on the order of \$3.50 per barrel and rising slowly. Since then, the price of a barrel of oil has jumped to \$11, and other energy prices have been rising rapidly. This has resulted in vigorous activity in the domestic drilling industry.

The implied energy policy of the United States at the time of the writing of the Ray Report was achievement of energy independence for the United States. Since then, consuming nations have begun to recognize that coordinated action may be desirable, and today our country recognizes that international collaboration is an inescapable necessity for dealing with the oil exporting countries. This policy has been expressed using the word "interdependence."

The basic energy policy of the United States today⁵ is cooperation with other industrialized countries in five areas. In the first two areas, conservation, and the production of domestic oil and new sources of energy, the United States' contribution is by means of Project Independence. In the third and fourth areas, increasing world-

wide economic security and assisting the less developed nations, the United States proposes common loan and guarantee facilities and other similar programs. In the fifth area of cooperation, negotiation with oil producers for lower prices, consumer solidarity is considered a prerequisite and is grounded in the first four areas of cooperation.

ROLE OF ENERGY R & D

Finally, the role of energy R & D must be examined. The Ray Report foresaw a substantial contribution to energy independence resulting from the proposed R & D program. However, the recently issued Project Independence report shows that a far smaller R & D contribution will be realized. Project Independence does, however, recognize that additional R & D in both environmental control and effects is needed. We believe that with timely action, R & D can still make a significant contribution in 1985 and, furthermore, that R & D is needed to avert more serious crises later.

The Ray Report anticipates an industrial contribution to energy R & D of \$12.5 billion over FY 1975-1979. Since the report, new investment opportunities in current modes of fuel production have occurred as a result of higher energy prices. These opportunities have acted as a disincentive for industrial investment in energy R & D.

The current energy policy of the nation is based on increased domestic supply and conservation. Our view of the result of this policy is shown graphically in Fig. 1, which gives our estimate of the energy flow in 1985.

PROBLEMS

There are two problems with this view of the future (Fig. 1). The first involves estimates of domestic oil reserves. It is necessary to determine how much time remains to establish alternate sources of liquid fuels and/or a more conservative approach to oil use. Figure 2 indicates the year in which oil usage would exhaust United States Geological Survey estimated recoverable reserves as a function of two different growth rates in oil usage. Actually, the more likely situation is given by the smooth curves. These curves indicate that ways to reduce oil consumption and/or introduce alternate fuels must be implemented in the next 12 to 15 years regardless of the growth rate or the resource estimate.

A second problem with the strategy of increased domestic supply and conservation is with effective conservation. As an example, our economy has become increasingly dependent on the private automobile for absolutely necessary transportation. When faced with the immediate need for conservation of petroleum during the OAPEC embargo, Americans responded by making virtually no discernible changes in their choice of mode of transportation to work as shown in Fig. 3. In other areas, conservation effects were

Fig. 1. Results by 1985 of the nation's current energy policy of accelerated supply plus conservation.³ Units are 10¹⁵ Btu.

Fig. 2. Life of U.S. domestic oil reserves.

Fig. 3. Impact of embargo on choice of mode of transportation to work. (Source: FEA Project Independence Report, Nov. 1974).

seen but in transportation to work, which has the poorest load factor of any automobile use, no change was seen.

A problem also arises with respect to the expectations for industrial involvement in the energy R & D program outlined in the Ray Report. Currently, high-profit low-risk investment opportunities with rapid payoffs are available in the traditional energy industries such as oil production where current prices are approximately \$11 per barrel. The average oil and gas well internal discounted cash flow rate of return on investment is given in Fig. 4. This return is high enough to divert funding from shale oil projects, for example, which depend on continued high world oil prices for eventual profit.

A further unresolved problem with the participation of industry in energy R & D involves patent protection in joint government-industry programs.

CRITERIA SHIFTS

As a result of these observations and problems, we conclude that some shifts in energy R & D criteria are needed to bring the Ray Report into congruence with today's world of energy politics and prices. These changes are:

- Greater emphasis on demand reduction (conservation), particularly in the transportation sector.
- Greater emphasis on increased oil supply or oil substitutes, particularly for the transportation sector.
- Recognition that R & D is needed to solve societal needs in terms of markets rather than in terms of technical opportunity for increasing supply. These markets are transportation, thermal use, and electricity.
- R & D should be judged in time phases.
 - High priority for R & D needed for unsolved problems with today's systems.
 - For near term payoff, projects should be judged on estimates of environmental acceptability, time of availability, potential contribution to demand reduction or increased supply, and price.
 - Longer term projects should be judged on their technological merit. They should have the potential for contributing to society's long term energy needs.
- Realization that disincentives to research may limit industrial investment in R & D.
- The challenge of the high price of oil requires an emphasis on shorter range R & D with possibly a stretch-out of long range R & D.

Use of these new criteria focuses attention on oil and transportation, the major and only unsubstitutable market for oil. Accelerated domestic petroleum production and strenuous conservation efforts, particularly in transportation, will be required to achieve drastically reduced oil imports by 1985. These points are best examined by analyzing the R & D program in terms of end-use sectors or markets, rather than in terms of technical opportunity as in the Ray Report.

Fig. 4. Average gas and oil well return on investment.³

A recognition of the time of payoff is included in the Ray Report. However, we feel that insufficient attention was given to solving already existing problems with today's systems. Because of the time-lagged behavior of capital equipment replacement, continued viability of existing systems must have high priority. Traditionally, the short term has been the arena of industrial activity; however, since industrial activity seems not to be following the precepts of the Ray Report, government action may be indicated. Meeting the challenge implied by the very high price of oil requires an emphasis on shorter term R & D with a delay or extending of the longer term programs.

ANALYSIS

Following the above criteria, we analyzed the federal portion of the Ray 5-year R & D program by casting it into a transportation, thermal, and electricity format for three areas: unsolved problems with today's systems (1975-1985 payoff), new systems (1975-1985 payoff), and longer range planning (payoff beyond 1985). This analysis is given in Tables 2, 3, and 4. The entire Ray program is included in our analysis for

Table 2. Unsolved problems with today's systems (1975-1985 payoff). Based on the Ray Report 5-yr-program cost estimates.

Market sector	Costs (\$ million)
<u>Transportation</u>	
Mode shifting (social motivation research)	15
Emission controls	31
	<u>46.0</u>
<u>Thermal uses (residential, commercial, industrial)</u>	
Stack gas cleanup (gases, particulates, trace elements)	196.1
	<u>196.1</u>
<u>Electricity</u>	
Reactor safety	470
Facility siting	14
Radioactive waste disposal	182.1
Uranium enrichment	294.2
Uranium and thorium exploration methods (resource assessment)	40
HTGR	163.8
Waste heat disposal (dry cooling)	53.1
	<u>1217.2</u>
Total	<u><u>1459.3</u></u>

Table 3a. New systems (1975-1985 payoff). Transportation sector. Based on Ray Report 5-yr-program cost estimates.

Market sector	Costs (\$ million)
<u>Transportation</u>	
Demand Reduction (conservation)	
Reduced consumption	
Social and economic studies on effects of regulation, taxation, prices, and peak loads	30
Improved efficiencies	
Improved automobile	69.0
Rail, bus, ship, air	205.0
Increased supply	
Improved oil finding, drilling, recovery	155.9
Improved heavy oil recovery	—
Oil from shale (surface and <u>in situ</u>)	149.3
Liquids from coal (surface and <u>in situ</u>)	477.8
	<u>1087.0</u>

Table 3b. New systems (1975-1985 payoff). Thermal uses. Based on Ray Report 5-yr-program cost estimates.

Market sector	Costs (\$ million)
<u>Thermal uses (residential, commercial, industry)</u>	
Demand reduction	120.0
Reduced consumption	
Social and economic studies on living patterns, energy efficient buildings, retrofit of insulation, total energy systems, and motivation needed to effect such changes.	30
Improved efficiencies	
Furnaces, water heaters, heat pumps	—
Advanced industrial processes	—
Distribution systems	66.8
Increased supply	
Solar space heating and cooling, industrial process heat	85.5
Coal desulfurization (solvent refined coal, coal cleaning)	415.5
Improved coal recovery methods	102.8
Coal recovery methods by <u>in situ</u> processes	—
High Btu gasification (surface and <u>in situ</u>)	363.4
Gas stimulation (hydraulic and explosive fracturing)	96.3
	<u>1280.3</u>

completeness but this does not indicate our assent to the inclusion of particular program elements. However, we included several elements not specifically enumerated in the Report because we believe that they are important. These are listed without estimated costs.

Table 3c. New systems (payoff 1975-1985). Electricity sector. Based on Ray Report 5-yr-program cost estimates.

Market sector	Costs (\$ million)
<u>Electricity</u>	
Demand reduction	
Reduced consumption	11.3
Social and economic studies on usage, rate structures, system optimizing action (modeling), peak demand management, motivation to use less electricity. Urban waste utilization.	30
Improved efficiency	
Topping cycles	
Advanced high-temperature gas turbines	315.0
Potassium vapor and MHD	102.2
Ceramic turbines	11.8
Fuel cells	96.5
Transmission by extra high voltage and underground lines	82.3
Storage - batteries, flywheels, pumped air, steam	50.9
Cryogenic machinery	--
Increased supply	
Low Btu gasification, surface and <u>in situ</u> with combined cycle	200.0
Advanced combustion of coal	291.1
Geothermal - hot water and brine	93.7
Improved uranium recovery (<u>in situ</u>)	--
	<u>1284.8</u>
Total (transportation, thermal uses, electricity)	<u>3652.1</u>

SUMMARY AND CONCLUSIONS

Table 5 summarizes our funding analysis. The funding is rather evenly divided between programs with payoffs before 1985 and with payoffs after 1985. Using the marketing format to examine the Ray Report, we can see that the Report places heavy emphasis on R & D in the electricity sector for all time phases, disproportionately little emphasis on thermal usage, and even less on transportation. The funding regardless of time phase is distributed as follows:

Transportation	13.3%
Thermal uses.	16.2%
Electricity	70.5%
Total	<u>100.0%</u>

Table 4. Longer range planning (payoff after 1985). Based on Ray Report 5-yr-program cost estimates.

Market sector	Costs (\$ million)
<u>Transportation</u>	
Private vehicles	200.0
Improved liquid fuel engines	
Electric vehicles	
Hybrid and other systems	
Public transportation (passenger and freight)	
Urban	
Intercity	
Basic research relative to transportation	-
	<u>200.0</u>
<u>Thermal uses (residential, commercial, industrial)</u>	
New industrial processes (aluminum, steel, chemicals)	-
Hydrogen-production, other coal R & D	120.0
Bioconversion	20.4
Basic research relative to thermal uses	-
	<u>140.4</u>
<u>Electricity</u>	
Solar electricity (photovoltaic, wind, ocean)	94.1
Advanced fission reactor systems including fuel cycles	2912.8
Fusion systems (magnetic, laser, and hybrid)	1450.0 ^a
Advanced geothermal (hot dry rock, low-temp. systems)	91.3
Cryogenic and hydrogen systems for storage	
and transmission	-
Basic research relative to electricity	-
	<u>4548.20</u>
	<u><u>4548.20</u></u>
Total	4888.6

^aPlus 329 DOD.

In conclusion, in view of events since the Ray Report was written, we find that it has the following major shortcomings:

- Industrial investment in energy R & D was projected at far too high a level.
- R & D needs for the transportation market were vastly under-recognized, both in reducing demand (by reduced consumption and improved efficiency) and in increasing supply (by improved oil finding, drilling, and recovery, improved heavy oil recovery, oil from oil shale by both surface and in situ processing, and liquids from coal by both surface and in situ processing).
- The need for conservation in general was recognized, but federal energy R & D programs were difficult to define at that time. Now, more effort is warranted to do a better job.

Table 5. Ray Report funding summary.

	Costs		
	(\$ million)	(%)	(% of total)
<u>Unsolved problems with today's systems (payoff 1975-1985)</u>			
Transportation	46.0	3.2	
Thermal	196.1	13.4	
Electricity	1217.2	83.4	
	<u>1459.3</u>	<u>100.0</u>	14.6
<u>Near-term new systems (payoff 1975-1985)</u>			
Transportation	1087.0	29.7	
Thermal	1280.3	35.1	
Electricity	1284.8	35.2	
	<u>3652.1</u>	<u>100.0</u>	36.5
<u>Longer range planning (payoff after 1985)</u>			
Transportation	200	4.1	
Thermal	140.4	2.9	
Electricity	4548.2	93.0	
	<u>4888.6</u>	<u>100.0</u>	48.9
Total	10,000		100.0

REFERENCES

1. D. L. Ray, The Nation's Energy Future, Atomic Energy Commission, Washington, D.C., Rept. WASH-1281 (1973).
2. B. Rubin, S. Winter, W. Ramsey, G. Werth, A Rationale for Setting Priorities for New Energy Technology Research and Development, Lawrence Livermore Laboratory, Rept. UCRL-51511 (1974).
3. C. J. Anderson, E. Behrin, E. A. Green, G. H. Higgins, W. J. Ramsey, B. Rubin, and G. Werth, An Assessment of U.S. Energy Options for Project Independence, Lawrence Livermore Laboratory, Rept. UCRL-51638 (1974).
4. J. G. McLean and W. B. Davis, U.S. Energy Outlook: A Report of the National Petroleum Council's Committee on U.S. Energy Outlook, National Petroleum Council (1972).
5. Secretary of State Kissinger, Dept. of State Bulletin, Dec. 2, 1974.

NOTICE

"This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights."