Approved 2/7/84
Date

MINUTES OF THE House COMMITTEE ON Energy and Natural Resources.

The meeting was called to order by David J. Heinemann at
Chairperson

3:30 ~~a.m.~~/p.m. on January 30, 1984 in room 313-S of the Capitol.

All members were present ~~except~~

Committee staff present:

Ramon Powers, Legislative Research

Theresa Kiernan, Revisor of Statutes,

Pam Somerville, Committee Secretary

Conferees appearing before the committee:

Amory Lovins, Rocky Mountain Institute

The meeting was called to order by the Chairman who in turn introduced Mr. Amory Lovins, Rocky Mountain Institute, to address the committee on the economic status and policy options of the Wolf Creek Nuclear Power Generating Facility.

Mr. Lovins began by stating that utilities are in the business of selling electricity, and at present, Kansas rates are, in equivalence to oil, approximately $100 per barrel. He then turned attention to the Wolf Creek Nuclear Generating Station and addressed their present economic feasibility.

Presently, Wolf Creek is at 67 to 70% completion with construction costs amounting to approximately $50 million per month or $1.3 million per day. In terms of consumers, the average cost is $4.00 per day. He stated that "utilities are literally bleeding to death very quickly" and if the plant were not completed, rate payers could save about .9 billion dollars, minimum estimate, which is worth approximately 3¢ per killowatt hour over the life of the plant.

Mr. Lovins stated that when one looks at the financial condition of the utilities (KG&E, and KCPL) their recorded net income was 89 million but nearly all of the income was that of an entry that is called "allowance for funds used during construction". It is not cash income, but rather "funny money". He stated that when one looked at what cash was actually earned, KG&E had a negative figure and KCPL had approximately $5 million. In addition, KG&E has been borrowing money to pay dividends to their stockholders.

In closing, Mr. Lovins stated that "If he had any of their stock, I'd sell it immediately," and that Wolf Creek should be "scrapped" before it produces the first kilowatt of electricity. (See Attachment 1).

A question and answer period followed Mr. Lovins presentation.

There being no further business before the committee, the meeting was adjourned at 5:00 p.m.

The next meeting of the House Energy and Natural Resources Committee will be held January 31, 1984 at 3:30 p.m. in Room 519-S.

David J. Heinemann, Chairman

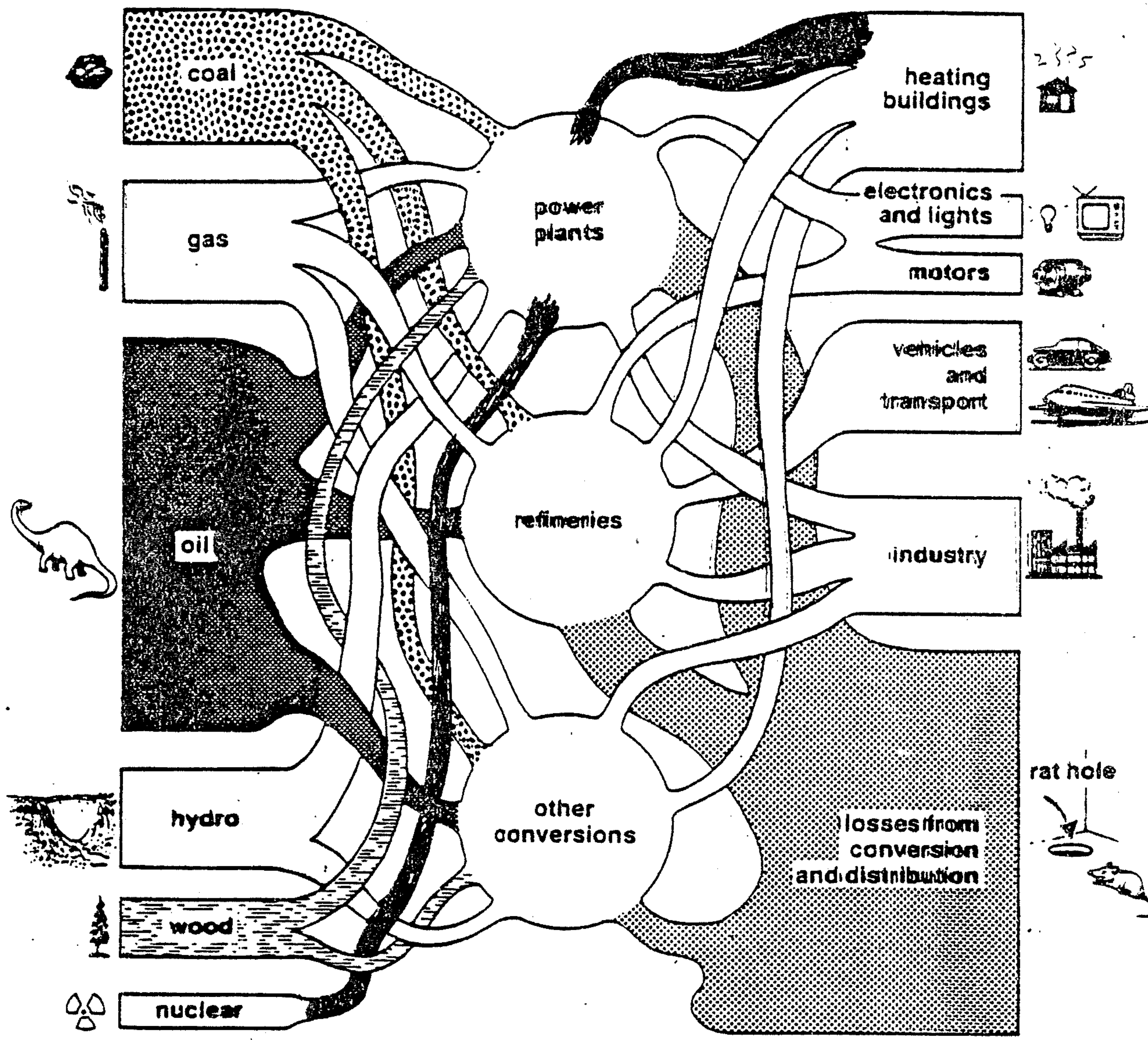
Date Jan. 30, 1984

GUESTS

HOUSE ENERGY AND NATURAL RESOURCES COMMITTEE

NAME	ADDRESS	ORGANIZATION
Dick Compton	Hays, Kansas 67601	Midwest Energy, Inc.
[illegible]	Topeka	Budget
[illegible]	"	"
Jan. Johnson	"	"
Jim Hayes	"	"
Pat Schafer	"	"
Linda [illegible] Woody	[illegible]	National Organization for Women
Darlene [illegible]	Topeka	[illegible] of Churches
Ed Reinert	Topeka	Ks League Women Voters
Roger Dandnia	Baldwin, Ks. 66006	Barbara Hubbard Campaign Staff
[illegible]	[illegible] K.	NAW.
Dana Jackson	Salina Ks	KNRC
[illegible]	Salina Ks.	[illegible]
[illegible]	Salina Ks	Smoky Hills Audubon
[illegible]	Topeka	[illegible]
Winifred [illegible]	Salina	League of Women Voters
Ronald Jones	Salina	Sierra Club
Don Dooske	Topeka	self
[illegible]	Lawrence	KNRC
[illegible]	Topeka	Ks [illegible] Corp
Burt DeBaun	Osage City	House of Reps
Ed Rogers	Wichita KS	House of Rep

A SCHEMATIC, STYLIZED "SPAGHETTI CHART"



Attachment 1
1-30-84

% OF TOTAL DELIVERED ENERGY (Heat Supplied Basis) REQUIRED IN VARIOUS FORMS IN SELECTED INDUSTRIAL COUNTRIES ~1975

Form required	USA	Canada	Japan	Sweden	UK	France	FRG	Av. W. Europe
Heat — total	**58**	**69**	**68**	**71**	**66**	**61**	**75**	**71**
< 100° C.	35	39	22	48	55	36	50	45
100 - 600° C.	15	21	31	14	6	14	12	13
> 600° C.	8	9	15	9	5	11	13	13
Portable liquids	**34**	**24**	**20**	**19**	**26**	**29**	**18**	**22**
Electricity - specific	**8**	**7**	**12**	**10**	**8**	**10**	**7**	**7**
Industrial motors	5	4	7	6	4	6	4	4
Other electrical*	3	3	5	4	4	4	3	3
Supplied as electricity	**13**	**17**	**16**	**18**	**14**	**12**	**13**	**11**

*Lights, electronics & telecommunications, electrochemistry, electrometallurgy, household non-thermal appliances, electric railways, arc-welding, etc.

REFRIGERATORS

~14 - 16 ft^3 (~ 400 - 460 l), auto- or semi-autodefrost with top freezer

Approximate kW-h electrical use per year:

1950	U.S. average (manual-defrost freezer)	750
1975	U.S. average	1800
1976	California minimum efficiency standard	1400
1980	U.S. market: worst	1580
	best	900 - 1100
1977	A.D. Little, Inc. est. technical potential	650
1981	Japanese market: typical	700
	best (Toshiba 411A)	550
1980	A.D. Little, Inc. est. improved prototype	420
1980	Nørgård est. cost-effective	260
1979	Schlussler prototype (measured)	288
1983	Schlussler commercial (measured)	175
1982	Schlussler prototype (measured)	64
1983	Schlussler prototype (est., under construction)	15
1982	Seasonal-storage icebox	0.5

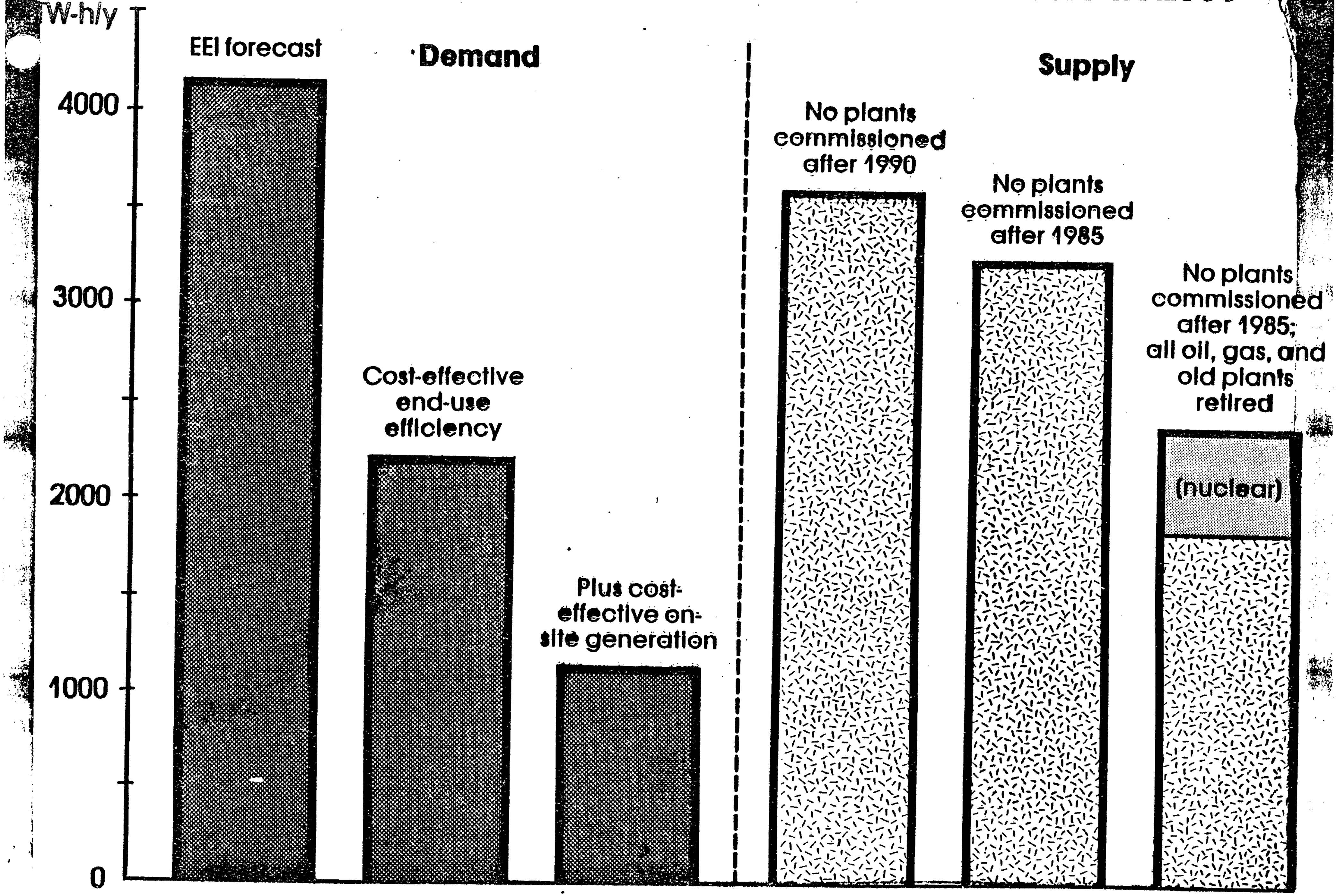
A typical frost-free refrigerator uses over $100 worth of electricity per year. U.S. refrigerators now use 17 GW(e) — about half the output of all nuclear power plants.

SOURCES: H. R. HOLT, U. S. DEPARTMENT OF ENERGY, Jan. '82
D. GOLDSTEIN, **TECHNOLOGY REVIEW**, pp 36 - 46, Feb./March 1983
L. SCHLUSSLER, P.E. (726 Bayside #6, Arcata, CA 95521),
PERS. COMMS., 1980-83

SOME MAJOR OPPORTUNITIES FOR SAVING ELECTRICITY

Application	%saving in that use	~ years payback against 8¢/kW-h (1980 $) nominal marginal delivered price
Industrial motors (U.S., U.K., FRG):....... sizing, coupling, controls, clutches	≳50	3-4
Household appliances: redesign...... (Danish analysis)	>70	4 (for costliest increment of efficiency)
Lights: comfortable levels, task • and daylighting, efficient bulbs & fixtures (U.S.)	75-90	1-5
Alumina smelters: switch to best....... process (U.S., Europe)	25-40 (100 with Mitsui blast furnace)	5-10
Electricity now used for low-........... temperature heating & cooling (1/3 - 1/2 of all electrical demand in many OECD countries): replace with efficiency improvements & passive solar	≈100	1-10

CENTRAL-STATION DEMAND AND SUPPLY FOR ELECTRICITY IN 2000



SOURCE: SERI, A NEW PROPSPERITY: BUILDING A SUSTAINABLE ENERGY FUTURE
(USHR Commerce Committee and Brick House Publishing [Andover, MA], 1984)

Implementing the SERI "Sawhill Report" could, by the year 2000,

— at least double U.S. energy productivity,

— reduce primary energy demand by a quarter, and demand for nonrenewable fuels by nearly half, even with a two-thirds increase in real GNP;

— make energy supply at least one-third renewable (now 7+%);

— require gross investment of ~\$0.8 trillion (1980 \$).

But that ~\$0.8 trillion investment would

— avoid the need for ≳\$1.0 trillion (1980 \$) in new central-electric facilities;

— eliminate oil imports and, if desired, nuclear power;

— leave ≳\$2 trillion worth of coal, oil, and gas in the ground;

— avoid the social costs of mining, transporting, and burning those fuels; and

— go far towards making the energy system inherently resilient.

Upwards of 90% of the ~\$0.8 trillion investment stream could be financed just by

— savings on electric bills and

— loans from a revolving fund capitalized only by electric utilities' retained earnings (at the 1980 rate).

Thus less than \$100 billion net would be needed, over 18 years, from the capital marketplace — not much more than is now invested in energy supply each YEAR. Net result: an EXPORT of the order of \$2 trillion (1980 \$) from the energy sector back into the capital marketplace.

FIGURE 20.

Installed electricity generating capacity, 2025 (GW)

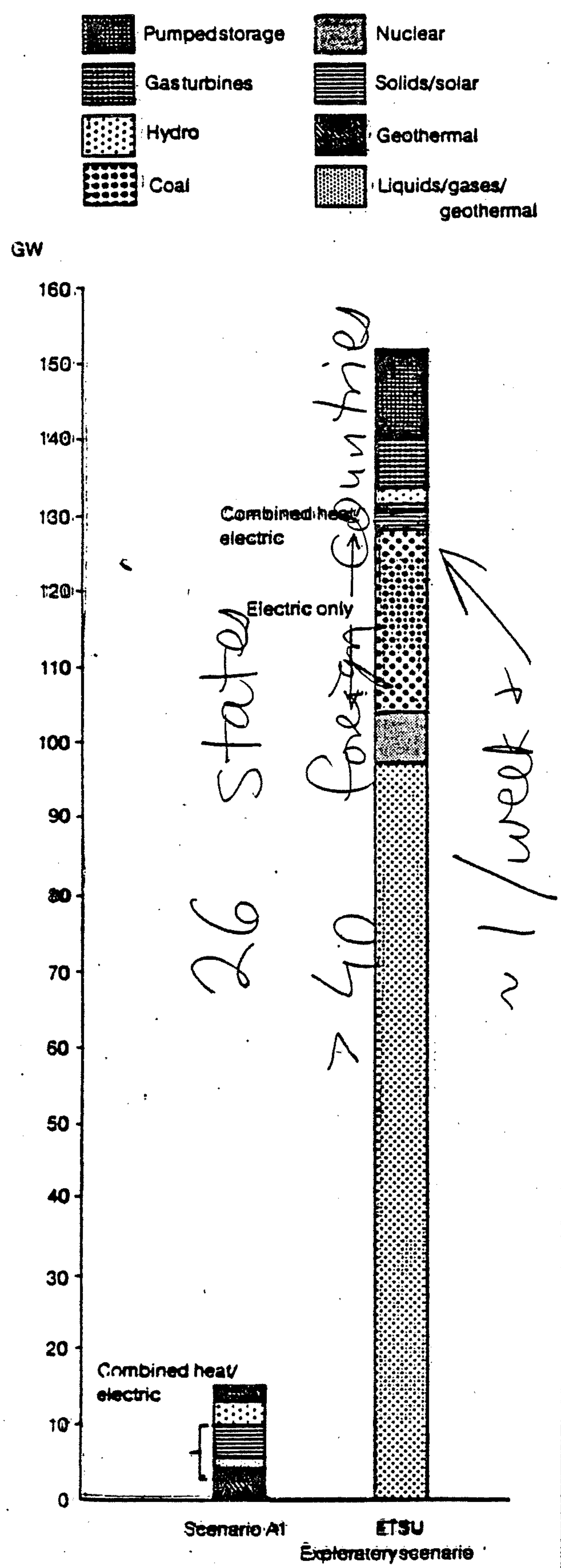
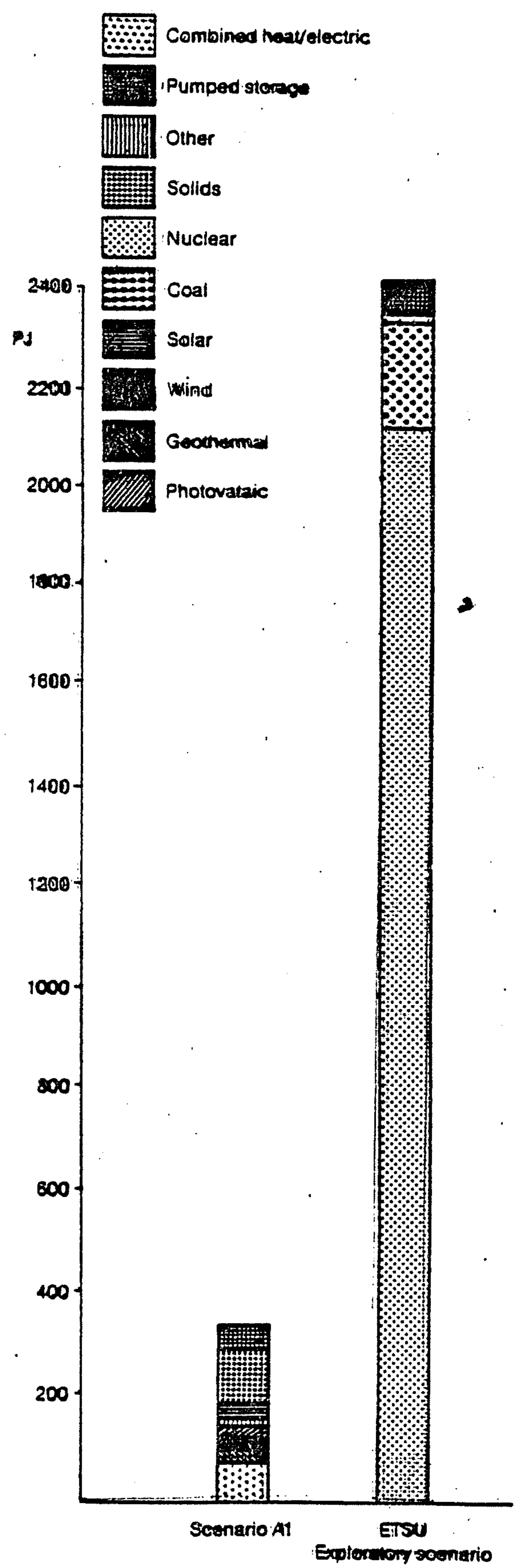
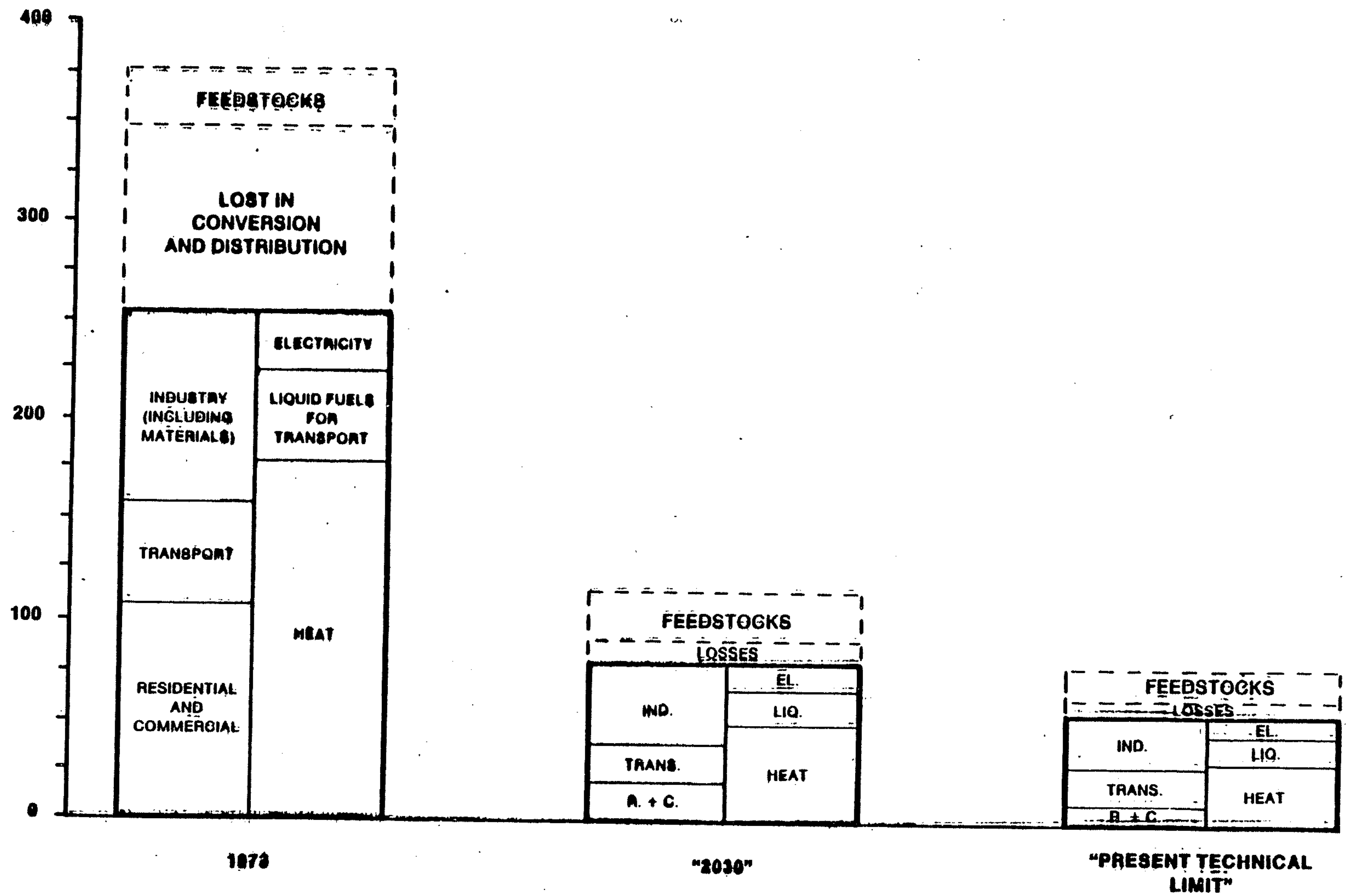


FIGURE 21.

Annual electricity supplied to national grid, 2025 (PJ)



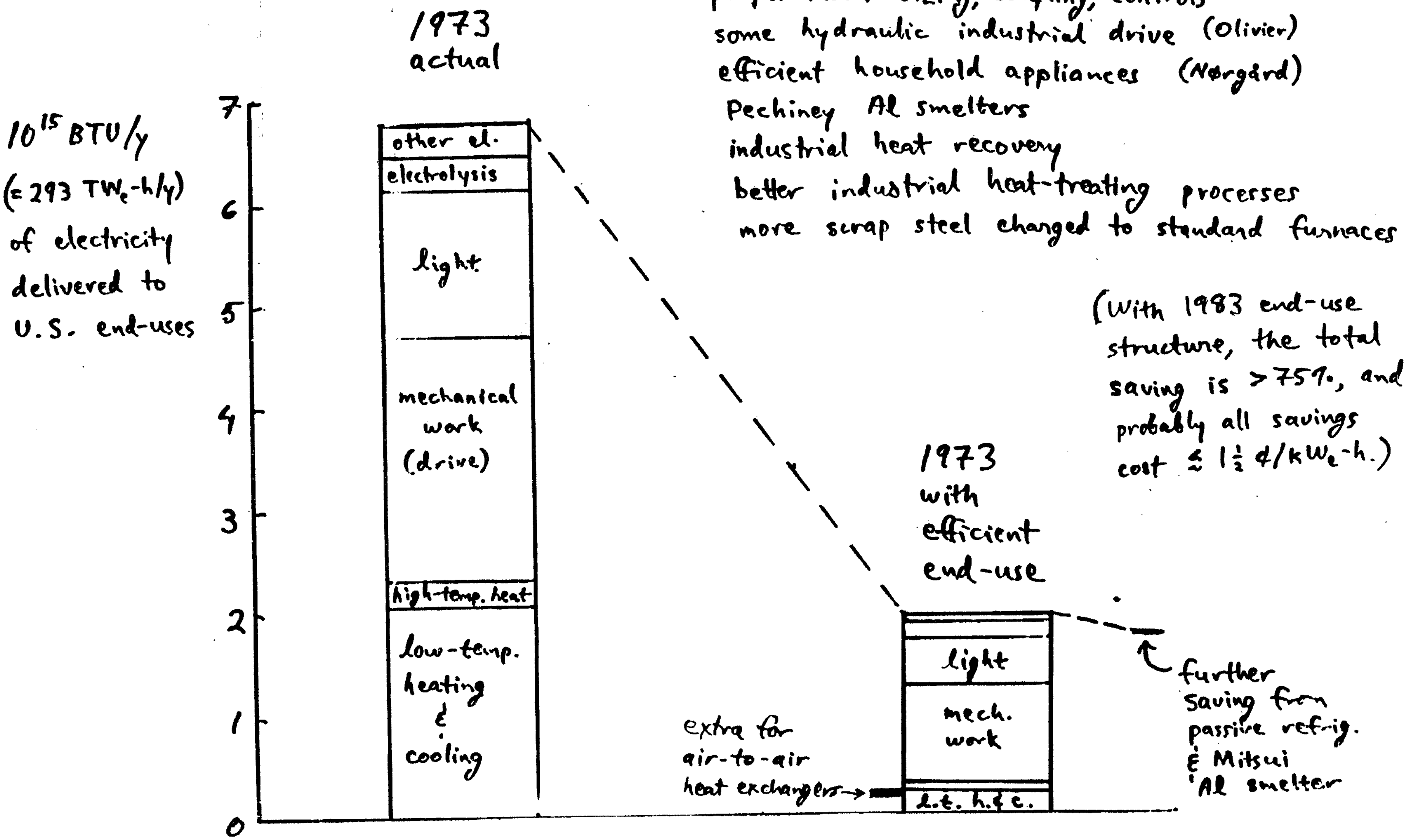


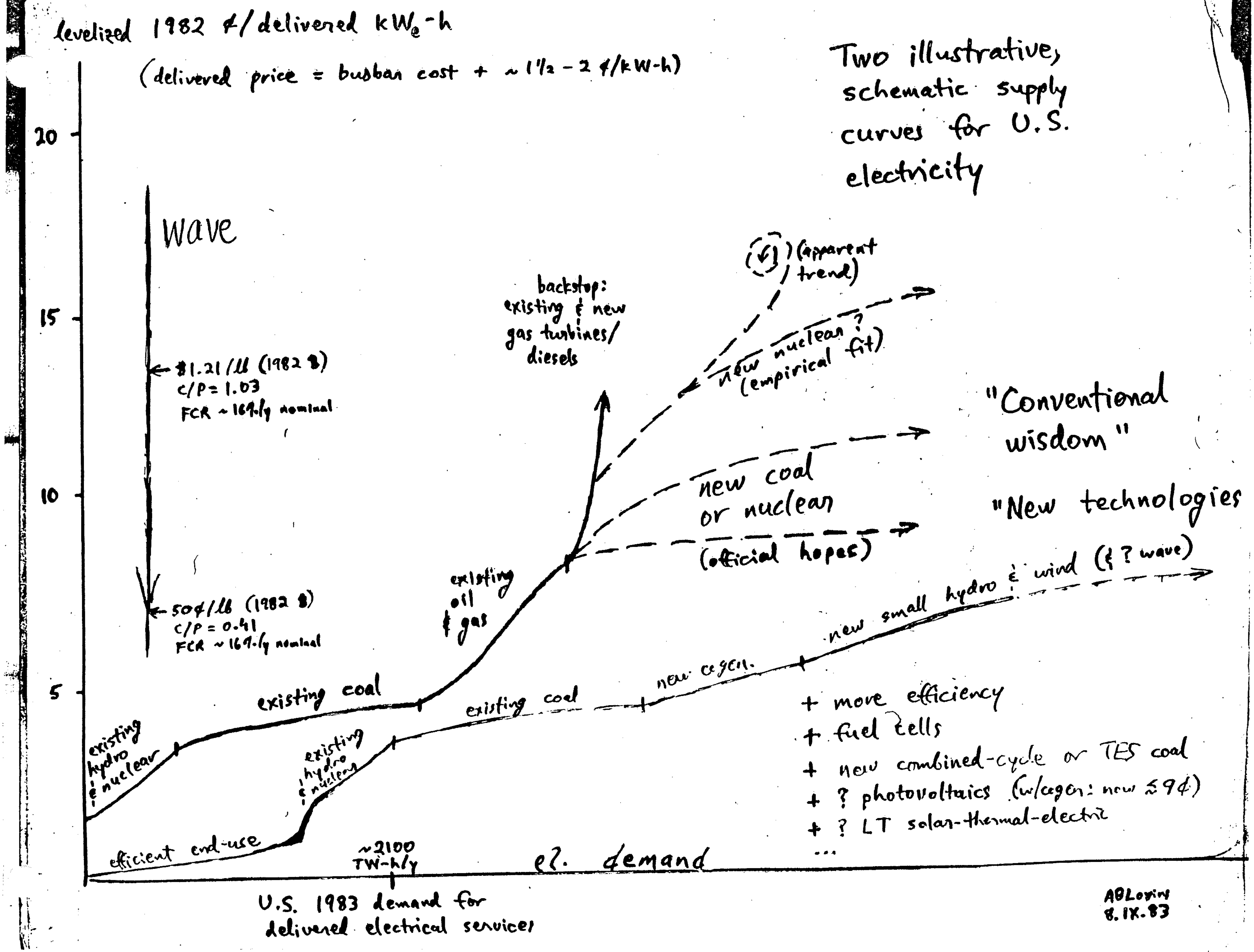
400
300
200
100
0
FEEDSTOCKS
LOST IN CONVERSION AND DISTRIBUTION
INDUSTRY (INCLUDING MATERIALS)
TRANSPORT
RESIDENTIAL AND COMMERCIAL
ELECTRICITY
LIQUID FUELS FOR TRANSPORT
HEAT
FEEDSTOCKS
LOSSES
IND.
TRANS.
R. + C.
EL.
LIQ.
HEAT
FEEDSTOCKS
LOSSES
IND.
TRANS.
R. + C.
EL.
LIQ.
HEAT
1973
"2030"
"PRESENT TECHNICAL LIMIT"

Saving 71–73% of 1973 U.S. electricity use with best 1983 technologies costing < 2¢/kWe-h:

1981 $ throughout

- superinsulation/passive building retrofits
- best commercial refrigerator (17 ft^3, 175 kWe-h/y)
- 60–100 lm/W lights, task- & daylighting
- proper motor sizing, coupling, controls
- some hydraulic industrial drive (Olivier)
- efficient household appliances (Nørgård)
- Pechiney Al smelters
- industrial heat recovery
- better industrial heat-treating processes
- more scrap steel charged to standard furnaces




levelized 1982 ¢/delivered kW$_e$-h
(delivered price = busbar cost + ~1½ - 2 ¢/kW-h)
Two illustrative, schematic supply curves for U.S. electricity
20
15
10
5
wave
← $1.21/lb (1982 $)
c/p = 1.03
FCR ~ 16%/y nominal
← 50¢/lb (1982 $)
c/p = 0.41
FCR ~ 16%/y nominal
backstop: existing & new gas turbines/diesels
(apparent trend)
new nuclear ? (empirical fit)
"Conventional wisdom"
new coal or nuclear
(official hopes)
"New technologies"
existing oil & gas
existing coal
existing hydro & nuclear
efficient end-use
existing hydro & nuclear
existing coal
new cogen.
new small hydro & wind (& ? wave)
+ more efficiency
+ fuel cells
+ new combined-cycle or TES coal
+ ? photovoltaics (w/cogen: now ≲ 9¢)
+ ? LT solar-thermal-electric
...
~2100 TW-h/y
el. demand
U.S. 1983 demand for delivered electrical services
ABLovins
8.IX.83

Some 1982 financial data

	KG&E (BB+)	KCP&L (BBB)
net income: reported	$84.7M	$80.9M
cash	-0.3M	5.1M
current retained earnings: reported	$18.3M	$17.3M
cash	-67 M	-58 M
AFUDC:	$85.0M	$75.8 M
× net income	1.004×	0.94×
× net for common	1.21×	1.21×
× current retained earnings	4.65×	4.38×
× cash earnings	N/A *	14.9×
CWIP:	$812M	$697M
% which is Wolf Creek	87%	97%
× net plant in service	1.33×	0.42× (Kansas: 1.63×)
× net income	9.6×	8.6×
× current retained earnings	44.5×	40.3×
× cash earnings	N/A *	136×
1982 construction:	$162 M	$207 M
× operating income	2.5×	2.7×
× net income	1.9×	2.6×
× current retained earnings	8.9×	12.0×
× cash earnings	N/A *	40.6×
cash interest coverage	0.995×	1.08×
cash fixed-charge coverage	0.82×	0.85×
current ratio	0.57	1.23
source of preferred dividends	all borrowed	mostly borrowed
" " common "	" "	all borrowed
" " interest payments	a little "	cash earnings
" " 1982-5 construct'n. funds	all external	nearly all external
av. residential el. price	6.05 ¢/kW-h	6.74 ¢/kW-h
" " " " (heat equiv.)	$97/bbl	$109/bbl
" 1979-82 demand growth	-1.51 %/y	-0.067%/y
" " " res. price increase (uncorrected for inflation)	14 %/y	8 %/y
peak reserve margin: 1983 (pool requires 18%)	33%	26%
1985 proj'd.	58%	44%

*not applicable — negative cash earnings

Wolf Creek, by 9/30/83, had cost $1.78 billion.

If finished on time with no surprises, it would cost at least $0.9 billion more — so it's about 2/3 done.

Counting operating as well as construction cost, it's less than half done.

Continuation is costing a further $52½ million per month, or $1¾ million per day, or $4 per day for each Kansas customer.

KCC estimates that, with no delays, surprises, or decommissioning cost, Wolf Creek power will cost about 9–11½ ¢/kW-h at the plant, or about 10½–13¢/kW-h delivered. The average 1982 residential price was 6.05¢ (KG&E) to 6.74¢/kW-h (KCP&L). So rates would rise a minimum of 50–80% with Wolf Creek.

<u>Without</u> Wolf Creek, ratepayers would save (in round numbers)...

actual savings would probably be larger	3¢/kW-h	to pay for completing construction @ $0.9 billion
	+ 0.6¢/kW-h	to fuel the plant
	+ 0.8¢/kW-h	to operate and maintain the plant
	+ 0.6¢/kW-h	to decommission it and manage its radioactive wastes
	+ 0.4¢/kW-h	to repair and replace major components
	+ 0.2¢/kW-h	for electricity lost on the way from the plant to consumers
	5.6¢/kW-h	
actual cost prob. less →	− 1.5¢/kW-h	to replace the plant by using electricity more efficiently (by buying smarter motors, lights, appliances, etc.)
minimum →	4.1¢/kW-h	net saving

One common way to treat abandoned plants is to give the investors their money back, without a return on it, by charging its construction cost to the ratepayers over some period like ten years. If this were done, the net saving to ratepayers would increase to about <u>6.5¢/kW-h</u> (about what Kansans <u>paid</u> for electricity in 1982) because they'd still be paying for the already-built part of the plant, as they'd do anyway, but not for about $0.6 billion (in present lump-sum value) of return.

If KCC found that part or all of Wolf Creek was not a prudent investment, the imprudently incurred costs would be paid by shareholders, not ratepayers, so their net savings would be even greater.

In general, investors will be pretty glad to get their money back without a return, since if construction continues, there is a much higher risk that they will lose the principal too — debt-holders by default, equity-holders by dilution and reduced market value.

About half of any losses to investors will be made good by taxpayers via tax writeoffs. But cancellation will save the Treasury a large sum — perhaps about $0.4 billion in tax subsidies not yet paid to the utilities.

PREPARED TESTIMONY ON LONG-TERM DEMAND FOR ELECTRICITY

Given at Washington DC before the Subcommittee on Energy Conservation and Power, Committee on Energy and Commerce, U.S. House of Representatives, 7 February 1984

Amory B. Lovins and L. Hunter Lovins
Rocky Mountain Institute
Drawer 248, Old Snowmass, Colorado 81654

Summary

Long-term demand for electricity is very uncertain. Building enough power plants to hedge against the risk of high demand is prohibitively costly: one percentage point of uncertainty in the growth rate is equivalent by 2000 to about a quarter of today's total generating capacity, costing over 300 billion 1983 dollars. An affordable utility strategy must therefore seek to reduce future demand, its uncertainty, and the cost of insuring against that uncertainty. Plants costing billions of dollars and taking ten years to build are too risky to invest in.

The Chiles Report claims that the U.S., which has ordered no large power plants since late 1981, must now order one per week--a trillion dollars' worth (1982 $) by 2000. We find that claim without foundation. The Report's econometric methodology could not forecast the future even if done right: only a disaggregated, end-use-based, engineering/economic analysis can reveal what savings are possible and worthwhile. In fact, the Chiles Report's structure and assumptions are fatally flawed. It supposes that energy demand is quite insensitive to price, that electricity will be relatively cheap, and that this relative cheapness will cause electricity to double its 1972 market share (a key assumption embodied in a single undocumented number). The Report's assumptions that power-plant costs and interest rates will be low and stable regardless of world oil prices, and that demand is guaranteed to provide enough revenue to amortize all power plants built, are wishful thinking. The conclusion that electricity use must grow at least in step with GNP has proved false in five of the past ten years. The further conclusion that the electricity/GNP ratio will drop in the next twenty years only five percent as much as it rose in the past twenty years can only be sustained by ignoring changes in economic structure, actual post-1973 trends in energy savings and alternative supply, and the enormous scope for using electricity more efficiently. New technologies have made possible a 75% potential saving throughout the economy, at a cost below that of just running existing coal or nuclear power plants. Far from being short of capacity, utilities are thus likely to experience declining demand and a need to write off $100-200 billion of uncompetitive thermal power plants. But the Chiles Report dismisses without analysis the prospect of saving much electricity and does not even mention a massive Federal study which reached the opposite conclusions.

The Congressional Research Service report paralleling the Chiles Report begins with a similarly flawed methodology (albeit using somewhat more sensible assumptions), then supplements it with a cursory review of some efficiency options. That review reveals the fragility of Chiles's findings. But its assumptions too ignore most of the best new ways to save electricity. Those savings opportunities have already made every thermal power plant in the country uncompetitive. Building more, even costlier plants will only make that problem worse and everyone poorer. Utilities need instead to follow those industry leaders who are now saving themselves and their customers money by reallocating capital to least-cost investments.

PREPARED TESTIMONY ON LONG-TERM DEMAND FOR ELECTRICITY*

Given at Washington DC before the Subcommittee on Energy Conservation and Power, Committee on Energy and Commerce, U.S. House of Representatives, 7 February 1984

Amory B. Lovins and L. Hunter Lovins

Rocky Mountain Institute

Drawer 248, Old Snowmass, Colorado 81654

Introduction

We appreciate this Subcommittee's invitation to comment on how and why the divergent views of long-term electrical demand reflected in the Chiles Report [DOE/PE-0045, June 1983] and in the Congressional Research Service (CRS) study [98-M, August 1983] differ from the findings of our own analyses. Attachment One summarizes our professional qualifications.

The Department of Energy's Report of the Electricity Policy Project (the "Chiles Report") is of remarkably low analytic quality, even coming from a group whose title--Policy, Planning and Analysis--accurately describes its apparent priorities: policy first, analysis afterwards.

Assessing the Chiles Report is like peeling an onion: its errors are wrapped in successive layers, each going more to the heart of the matter and being a cause for greater regret. We will, however, summarize the Report's main structural problems in reverse order, from the heart outwards to the more transparent and superficial layers. Our critique deals almost entirely with the demand projections which underpin the entire Report; we note problems with other sections only in passing, not from exhaustive review. But we console ourselves with the reflection that being based on assumptions which cannot withstand elementary scrutiny, those parts probably neither require nor deserve much review.

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*The authors are greatful to Seth Zuckerman for editorial assistance.

The Chiles Report gives the wrong answer to the wrong question. It fundamentally mistakes the strategic context in which utility managers find themselves. The Report's first error is in its basic approach. It extrapolates how much electricity Americans might use in 2000, how many power plants it would take to generate that much electricity, and how those "needed" plants can be paid for. This is the wrong question in two respects: first, because it provides a type of answer that is useless for planning under pervasive uncertainty; second, because it deals with the single type of energy which utilities sell rather than with the type of energy market which exists: a market in which people choose from among many ways of providing each energy service they want.

After discussing these two respects in which the Chiles Report is irrelevant, this testimony will explain why it is also analytically invalid; comment briefly on the CRS report; and summarize our own views of what sorts of futures utilities need to prepare for.

Deciding Under Uncertainty

The strategic concept of reducing both the degree of uncertainty and one's vulnerability to it are central to modern utilities' planning and survival. The Chiles Report's failure to appreciate these critical concepts casts the most serious doubt on its validity and usefulness.

The Report suggests that the lights will go out sometime in the 1990s--perhaps sooner in some regions--if this nation does not immediately begin ordering $1 trillion (1982 $) worth of additional power plants, or more than three times the utilities' existing net asset base. The CRS study casts doubt on whether those new power plants would be necessary or economic. Our own work implies that most utilities' problem over the next few decades is likely to be not a shortage but a surplus of generating capacity--a surplus so large and so uncompetitive that approximately $100-200 billion worth* of thermal power plants will somehow have to be written off. Such is the range--by no means pressed fully to its limits--of the uncertainty which utility planners face.

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*In net historic mixed current dollars.

What matters here is not which analyst is right--which nobody can know until it happens--nor even which analyst is believed to be right. (Our own record of foresight about declines in energy demand is probably better than that of any analyst in the energy industries, but we too overestimated demand; we were just less wrong than they were.)

No, what matters is not which of the many current forecasts one trusts; it is rather the consequences of the very wide margin by which they (and many others) disagree. Even a far narrower range of uncertainty would be economically devastating. The Chiles Report, for example, predicts that electrical demand will grow by 3% per year, plus or minus one percentage point--a relatively narrow margin of claimed uncertainty. But that one percentage point amounts, by 2000, to the equivalent of a fourth of today's total generating capacity, with a current capital cost of about a third of a trillion 1983 dollars.

Nobody can afford to hedge a risk of that size, in either direction. It is therefore necessary to reduce the size of the uncertainty (especially on the side where insurance requires investment), or the cost of hedging a given amount of uncertainty, or both. Consistent with this view, the best utility managers now believe that long-term demand for electricity is inherently unknowable within very wide limits, and that the cost of being far wrong <u>either</u> way is unacceptable. They conclude that the only sensible strategy is to behave so that demand uncertainty hardly matters--and that this is best done not by building more big power plants, but rather by acquiring resources and capabilities which can respond very quickly and relatively cheaply to volatile future demand. (This is, for example, the new Bonneville Power Administration policy.)

In this view, <u>any</u> capital-intensive, long-lead-time investment is a strategic blunder, while any cost-effective measure which has relatively low capital intensity, short lead time, small scale, modularity, and high velocity of cashflow is a vital means of preserving flexibility in the face of inherent uncertainty. This view, which we have long put forward, was endorsed by some of

America's leading utility heads three months ago at the Sundance Symposium (a "summit meeting" organized by Stewart Udall for the Institute for Resource Management). The Chiles team, marching stolidly into the 1950s, apparently never considered it.

How Efficiency Can Reduce Uncertainty

Reducing the range of uncertainty against which one must otherwise buy costly hedges requires policy instruments which will improve end-use efficiency to an extent and at a rate that are fairly predictable. Federal or state appliance standards offer a simple example. Consider refrigerators--the biggest single component of the electric bill in homes whose space and water heating are not electric. Electric demand for refrigeration is simply the number of refrigerators times the average demand of each unit. The rates at which the refrigerator stock expands and turns over are known from demographic and market-saturation studies, subject only to a narrow range of uncertainty from income elasticity. (That uncertainty is less than that of income itself, since ownership of refrigerators is already highly saturated.) If an appliance standard puts an upper bound on the electric consumption of each new refrigator sold, then the trumpet-shaped spread of forecasts of future electric demand for refrigerators is dramatically narrowed. If a more sophisticated system of rebates, PURPA efficiency buybacks, or similar measures provides an incentive for buying units better than the minimum standard, the uncertainty is narrowed further--and in a way that can operate quickly, at a rate known from a considerable body of utility rebate experience. Such measures thus offer a short-term backstop which insures against unexpectedly rapid growth in demand from each end-use category, and therefore from all end-uses combined. By ignoring means of influencing the degree and cost of uncertainty in future electrical demand, the Chiles Report neglects the most effective tool available for making residual, unavoidable uncertainties affordable.

Is There Demand for Electricity?

The Chiles Report's forecasting methodology presupposes that there is a demand for electricity--for kilowatt-hours--whose future pattern can be inferred from how many kilowatt-hours people bought in the past. The Chiles group did not use the alternative methodology of analyzing the demand for energy services (comfort, light, shaftpower, electrolysis, etc.) which electricity, among many other options, has been used to provide. That is, the Report's approach is based not on end use and least cost--on how much of what kind of energy can do each task cheapest--but rather on extrapolating historic patterns of gross energy consumption, and of electricity's share of that derived demand. This approach ignores the single most important conclusion of the past decade's experience of energy modelling: that the only way to understand future patterns of demand for any form of energy is a highly disaggregated, end-use-based, engineering/economic assessment which provides supply curves for each desired task, listing the marginal contributions and marginal costs of each way of doing that task, and thus enables one to choose the best buys first--just as the marketplace will eventually do. This state-of-the-art method permits, for example, California utilities and regulators to agree quite closely in their demand forecasts, to feel confident about them, and to achieve far greater accuracy than previously.

Only 8% of delivered energy uses in the U.S. (and a similarly small fraction abroad) require electricity and can use this special, exceptionally costly form of energy to economic advantage. Yet 13% of U.S. energy is now delivered in the form of electricity, with the balance being used (in our view, uneconomically) for low-temperature heating and cooling. Many utilities do not perceive the difference between how much electricity is sold and how much is the right form of energy to do each task at least cost: they just see people who, at least for the time being, are buying kilowatt-hours. But there is no demand for raw kilowatt-hours, for electricity per se, any more than there is a demand for barrels of sticky black goo. If people want comfort, kilowatt-hours are only one of many means to that end, and if comfort can be more cheaply obtained from roof insulation than from electricity, it is only a matter of time before people will find that out and buy less electricity. In short, electricity planners will continue to come unstuck as they have done for years--during 1974-79, private utilities' forecasts of peak demand <u>one year ahead</u> overstated actual growth by 160%--until they appreciate that what they are competing with is not mainly oil and gas, but weatherstripping. To assess such competition requires an assessment of the cost and performance of a myriad options available in the energy service marketplace. This is hard work, but there is simply no substitute. And if a team of four private British analysts, with no institutional support, can do this (as they recently did*) in the greatest detail so far achieved in the world--a 5000-sector model done just with sharp pencils and hand calculators--the American taxpayer deserves no less from DOE with its far greater resources.

Central to such analysis is an acknowledgment of the primacy of microeconomic logic. No prediction of what even a very imperfect market economy will do can long avoid coming to grips with the minutest details of what people may find it sensible to buy. As one of us (ABL) wrote to Secretary Hodel in response to his request for our comments on the Chiles Report:

> I suspect the policy directions implied by the Report, and the present policies of this Administration--essentially higher prices and subsidies for electricity--will complete the economic destruction of this vital industry by making its product even more uncompetitive and its investments even less able to be amortized from revenues. Before your Department proceeds, therefore, with measures to encourage orders for big power plants at a rate averaging one plant per week from now on--in a country that has ordered no such plants since 1981--you need an electrical market review that takes economics seriously.

What would competent analysts in DOE have found if they had taken economics seriously--and had sought to peer into the future by a method that does not just parrot the past?

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*In the Olivier report, discussed below on pp. 33 and 39.

Econometrics Cannot Forecast

Central to the Chiles Report is the notion that the future is like the past --only more so. This approach is hallowed by eighty years of utility planning that achieved fair accuracy, until about 1970, by simply applying a straightedge to semilog graph-paper. Nowadays the graph-paper and the straightedge live more discreetly in the bowels of a computer program, but the program's basic premise is unchanged: that future behavior can be deduced from historic behavior without reflecting their different circumstances in more detail than can be captured by a few simple summary numbers, such as GNP and price.

The method by which the Chiles Report extrapolates past into future behavior is essentially econometric. Econometric analysis seeks to explain historic data by equations whose independent variables are usually real prices and aggregate income or economic activity. The fit yields coefficients (elasticities) which are simply a shorthand way of summarizing the aggregate effect of millions of decisions made in the past, by complex individual people, under conditions which no longer exist. Unfortunately, econometrics cannot, even in principle, foresee the development of new energy-saving or -using technologies, new attitudes, or new institutional conditions which help or hinder particular technological choices. It assumes a static society with eternally fixed values, lifestyles, economic structures, and development patterns. Where real life is rich in slow variables, econometrics sees only constants, and is thus blind to even the most profound changes in how people think and act. Thus, for example, data from a period in which people did not much care about energy, real prices were falling, numerous barriers hindered efficient investment, and most of the best energy-saving measures now known did not yet exist*, can hardly anticipate people's responses to psychological energy shocks, perceived insecurity of supply, rising real prices, the emergence of a freer market in energy services, and a dizzying array of cost-effective ways to wring more work from our energy than we ever thought possible.

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*More than half the best energy-saving measures known now did not exist two years ago.

Econometrics, though it has little predictive value over decades, has a methodology which most analysts apply in a clear and rigorous fashion. The Chiles Report, however, has reshaped econometrics in a most peculiar way. Ordinarily, econometrics assesses a commodity's "own-price" elasticity of demand (how closely demand for it depends on its own price) and "cross-price" elasticities (which quantify substitution among different commodities according to their relative prices). The Chiles Report nowhere expresses, nor does it provide enough data to calculate accurately from the results, an own-price elasticity of demand for electricity. The implicit elasticity that we estimate, though, is very low. The Report implies on p. ES-6 that its own-price elasticity is comparable to those of other, lower-demand projections. We do not believe it. A utility survey of the econometric literature through 1976, for example, found historic long-run own-price elasticities of sectoral demand for electricity ranging up to -2.11*, with a mean of -1.2 [Philadelphia Electric Co., Exh. WCH-1, pp. 28-33, Limerick Investigation, Pa. PUC Docket I-80100341, 1982]. The Bonneville Power Administration thinks some Northwest end-uses have own-price elasticities as strong as -2.4 (residential electric space heat) or -3.6 (aluminum smelting) [BPA, "Analysis of Alternatives Related to WNP-3," 26 May 1983, p. 18]. The Chiles Report evidently assumes a price-demand coupling 5-10 times weaker.

The only own-price elasticity the Report considers is that of "aggregate energy"--a variable which includes and hence is not independent of electricity. This elasticity is claimed to be -0.5 to -0.7 (meaning that a 1% increase in the real price of "aggregate energy"--a commodity which nobody can actually buy--will reduce its long-run demand by 0.5 to 0.7%)†. Even this very small price response is assumed to take a very long time, expressing two-thirds of its effect in twelve years and the remainder in the ensuing twenty-four years--so the elasticity during the Report's time horizon (1981 to 2000) is probably in the vicinity of -0.35 to -0.50. Both this and the full long-term response assumed

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*This means that, other things being equal, a 1% increase in the real price of electricity will reduce long-rund demand for it by 2.11%.

†The elasticity is actually given, e.g. on pp. 3-6, 3-7, and 3-43, as <u>positive</u> --meaning that the more energy costs, the <u>more</u> people buy. Such an assumption would help to explain the model's results; but we presume the Chiles team actually assumed a conventional, negative elasticity and just wrote it sloppily.

span a far narrower elasticity range than is reported in responsible studies throughout the econometric literature. And of course any assumed own-price elasticity suffers from all the defects noted above, such as omission of most of the worthwhile energy-saving measures now on the market. We will quantify this omission later: suffice it to say that some very new technologies can reduce demand far below what was possible before they became available.

The Report estimates how much of the "aggregate energy" bought at a particular price will be electrical energy, not by assessing what share makes economic sense, but by assuming a cross-elasticity of 0.25 (p. 3-42) or 0.23 (p. 3-64)*, with an unstated time-lag and no stated range. Although this assumption is not considered significant enough to list among "Major Input Assumptions" (p. 3-43), and although no sensitivity test is provided, this single, undocumented, but extremely sensitive† assumption appears to drive all the model's results. The model calls for an additional 438 GWe by 2000 chiefly because it assumes that electricity will be cheap relative to aggregate energy (44% below its 1972 ratio and 15% below today's) and that people will have a great propensity to substitute electricity for direct fuels. These assumptions result in a doubling of electricity's 1972 market share by the year 2000 (p. 3-63). Other analyses find less electric demand because they assume lower cross-elasticity, or a higher ratio of long-run electric to aggregate energy price, or--commonly--both.

Efficiency: If In Doubt, Leave It Out

How does the Report model people's tendency to use energy more productively when it costs more--a trend which has, in the past decade, reduced by about one-fourth the aggregate energy used to make a dollar of GNP? Apparently by shuf-

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*The definition used in the Report is unstated, obscure, and ambiguous. We suspect it means that a 1% increase in aggregate energy price will increase demand for electricity by 0.25% or 0.23%, other things being equal. Since, however, the aggregate and electric price variables are not independent--the former includes an ever-increasing share of the latter--the definition is meaningless. Worse, it risks implicitly and invisibly including a significant element of positive own-price elasticity of electric demand, wrapped up in the cross-elasticity that is supposed to show only the degree of electric substitution for fuels.

†The dotted line in Fig. 3-31 (p. 3-63) implies that raising the 0.23 cross-elasticity to 0.43 could increase electricity's market share by about a third. Choosing a lower cross-elasticity, as the other cited studies do, would probably reduce the share by considerably more. These inferences, however, are indirect.

fling it between categories until it falls through the crack. The Report says on the one hand that higher aggregate energy prices yield curtailment of uses or substitution "between energy forms" (pp. 3-5, 3-8)--apparently defined to ex-clude higher end-use efficiency. Efficiency gains are implied on p. 3-13 to be somehow included in own-price elasticity, but are lumped in with privation. The authors do not seem sure quite where they have stuck it. Apparently they con-sider efficiency improvement a "competing energy form" for purposes of saying it is small, but ignore it when considering the array of options against which electricity must compete (p. 3-40)--even though they predict that electricity price will by 1995 be 40% (in real terms) above its 1981 average level, or equi-valent in terms of 1983 average prices to about 11¢/kW-h, approaching Manhattan rates. This should elicit plenty of efficiency, since most efficiency improve-ments cost (we shall suggest) only about a tenth that much.

How does income affect demand for electricity? This time the Report does not use electricity's share of the "aggregate energy" market (sensitively deter-mined by the mysterious cross-elasticity) and that aggregate demand's assumed income elasticity, whatever that might be. Rather, the Report assumes an in-come elasticity for <u>electricity alone</u>--but nowhere states what it is. (The near-est to an explanation, on p. 3-43, says only that whatever the income elasticity is, it is assumed to rise suddenly by 50% over its 1980 level when GNP reaches twice its 1980 level. That doubling happens, at the assumed GNP growth rates, early in the next century, so it probably does not affect the model's behavior.) Since the model apparently does not include explicit saturations (p. 3-10), it is free to generate arbitrarily large numbers of refrigerators per house, houses per person, etc. That is, since the model does not consider end-use, the model-lers never have to say what all that electricity is being used for, and thus can never discover whether, for example, they are unwittingly assuming that each person is watching two televisions, driving three electric cars, operating a home computer, and using seven lights and an Orgasmatron, all simultaneously.

What about technological change? Apparently the model assumes that this can only <u>increase</u> electrical demand (pp. 3-12ff). The text states at p. 3-14:

In PPA's demand modeling, a technology-related cross-elasticity in favor of electricity was postulated and given alternative values in different runs. However, the model combines the technology-related elasticity and the income-related elasticity so...they cannot be varied independently.

That is, the addition of new electricity-using processes and gadgets is implicitly assumed*--in a way that is opaque to readers, since technical change is inseparably lumped into rising income. In contrast, a new device which uses less electricity than the device it replaces is left to carve out its own niche within the already shriveled own-price and cross-elasticities. The assumptions made about technological change and income are further obscured by being nowhere stated in the Report.

Electricity and GNP

In essence, the Report concludes that electrical demand will grow at about the same rate as real GNP. It assumes that GNP growth, in turn, must and will be rapid, since more modest rates of economic swelling would, it claims--like energy conservation--imply "major changes in the way in which Americans live" [p. 1-3]. In contrast, wasteful energy use, or economic scenarios implying five cars, a boat, and a helicopter in every garage, would presumably imply no life-style changes--aside, perhaps, from those implicit in Los Angelizing the planet.

Does the assumed correlation of electricity and GNP make sense? Consider first the actual patterns of electrical demand shown in the Report for each sector. During 1973-80, the electricity used by the average American home rose only 0.80% per year (p. 3-24): three-quarters of the sectoral demand growth was due, not to more intensive use, but to more households (p. 3-74), and the demographic trends which brought this about are slowing. The extra electrical demand of additional air-conditioners and electric space-heaters, touted as a reason for high demand forecasts, has (as the Report states on pp. 3-25 and 3-71) been offset since 1973 by more efficient buildings and appliances. (Not

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*In a 17 November 1983 NARUC speech, the Chiles group's Staff Director praised "the miriad [sic] of cost effective measures which will serve to expand the use of electricity rather than contract it." He gave no examples of the latter and only one of the former--electric heat, which he assumed is cost-effective.

knowing what to assume about the continuation of these trends, the Report apparently assumes more electric space-conditioning without more efficiency. In particular, new homes are assumed [p. 3-79] to be a major source of new electric heating and cooling loads, not a source of new efficiency improvements. The awkward fact that the number of new housing starts using electric heat fell by a third during 1970-81, or that the average thermal efficiency both of those new houses and of older ones has dramatically improved, is ignored.)

The commercial sector shows a similar trend during the recent period of increasing real electricity price: electric demand per commercial customer grew only 1.25%/y during 1973-80, and 62% of sectoral demand growth came from more floorspace, not greater intensity per square foot (p. 3-27). Again, since 1975 the electric usage per customer has flattened out and actually begun to drop.

In industry, the same pattern is even stronger. During 1975-80, electric demand per unit of industrial output <u>fell</u> by 1.05%/y (p. 3-31). With U.S. population growth rates declining, and with specific demand in each sector--demand per house, per commercial customer, and per unit of industrial output--essentially flat during the economic growth of the past six to ten years, where is the projected 3% annual electric demand growth supposed to come from?

The mindset which produces that result is the same one which led to proclamations, in the early 1970s, that <u>energy</u> and GNP are inextricably linked. That myth was punctured by the mid-1970s and utterly deflated by 1980. Nonetheless, the ratio of <u>electricity</u> to GNP, having risen at gradually decreasing rates during periods of declining real electricity price, held fairly steady for longer, with electricity sales growing some 3% more than GNP during 1973-83. The electricity/GNP ratio leveled out in 1973 (p. 5-49), fluctuated in a narrow range during the mid-1970s, and has since generally been declining to its present level, which is well below that of 1975-77 and (with due allowance for 1983's 100-year-record summer heat wave) is still falling. It is true, then, that the electricity/GNP ratio <u>has</u> been more durable than the energy/GNP ratio was. Why might this be?

A little reflection suggests eight reasons why the electricity/GNP ratio should have been slower to change than the energy/GNP ratio:

1. Power plants take so long to build that, with rolled-in pricing, it takes many years for marginal costs to work fully through into average prices--far longer than for most increases in costs of fuel supply.
2. Higher fuel prices hit fuel consumers with full force, whereas their impact on electricity prices is diluted by high fixed (capital) charges.
3. Electricity is probably the most heavily subsidized form of energy.
4. Many utilities still have, or have only recently abandoned, declining-block rates and other promotional tariffs.
5. Many utilities still promote electric sales. (We understand the Edison Electric Institute is planning a major new sales drive.)
6. More electrical than fuel-using equipment is bought by people who will not use it and do not care about its running costs. Most people, for example, buy their own cars and can shop for fuel-efficient ones, but more than half of household electrical appliances are bought by a builder or housing authority (or a landlord: about 35% of all households are renters). Similarly, most commercial air-conditioning and other mechanical equipment is installed by lessors, not chosen by lessees.
7. In particular, about half the new houses being built are electrically heated--a major source of projected demand growth--because, even though few utilities still give kickbacks to builders to install electric heat, many builders think it reduces their up-front cost, thus apparently providing a cheaper house for which more buyers can qualify for mortgages*.
8. Although the important fuel-saving measures--insulation, weatherstripping, better cars, etc.--are nothing new, most of the important technologies for saving electricity have only come on the market in 1982-83.

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*But default looms when utility bills exceed mortgage payments: the bank risks being stuck with a house nobody can afford to live in. In fact, not only would the house cost less to build if superinsulated so it could be heated by a few light bulbs, but the competitor for the builders' next loan is the utility's offsite investment. This is so enormous that, on the data given in Attachment Two, it probably costs a nuclear utility more to build the capacity to serve a baseboard heater than it costs the contractor to build the entire house!

By ignoring these warning signs, the Chiles Report is able to assume (on p. 3-90) that the electricity-GNP ratio will decline only about 5% as much in the next twenty years as it increased during the past twenty: that is, that a very electricity-intensive economy, having been once achieved, is somehow "locked in." Indeed, the Report states (p. 3-16) that electric demand growth "consistently outpaced GNP growth during the 1960-80 period." But a glance at the actual EIA data reveals that this ceased to be true in 1973. The absolute value of electricity/GNP elasticities fell below 1.0 in 1973-4, '76-9, and '82-83. Electrical demand grew more slowly than real GNP in five of the past ten years--hardly reason to suppose a stable, let alone increasing, ratio in the future.

Obsessed with what its Staff Director has fancifully called* "the current forecasting consensus" that electricity use is forever locked to GNP, the Report seems at every turn to misconstrue what is actually happening. On p. 3-75, for example, the Report recognizes the "long-term trend toward a more service-oriented economy," especially "in the white-collar portion of the commercial sector." The Report concludes that this means both continued growth in commercial floor-space and "a gradual increase in the more electric-intensive types of floor space." Yet the Report fails to note that, according to Eric Zausner [Booz, Allen, & Hamilton], service industries use, on average, only about a quarter as much electricity per worker as do manufacturing industries. Such key shifts are not considered under "Composition of GNP" (pp. 3-3ff), and some appear not to be considered at all.

Shifts in composition of industrial output were apparently not analyzed. A decline in the most energy- and electricity-intensive industries as (for example) aluminum smelters go offshore and the steel industry rationalizes was not modeled (p. 3-15), but only included implicitly, and probably very incompletely, via the DRI macro-modeling of GNP growth and aggregate price elasticity (pp. 3-79/80). No data are presented to show that, as claimed, such shifts in composition do not significantly affect the results. They were the largest source of reductions in French industrial energy intensity during 1960-78, and are officially projected nearly to equal all German industrial efficiency gains to 2030.

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*J. Steven Herod, 17 November 1983 address to NARUC, Detroit.

Fishy Data

Many of the Report's dubious conclusions would have looked less plausible even to its authors had they troubled to include data after 1980. The Report, dated June 1983, is right up-to-date with, for example, a contractor study on industrial energy demand dated May 1983 (p. 3-93 n. 6). Yet all the data series used to justify the Report's results end in 1980--too soon to show the effects of the dramatic rises in real price which hit most sectors, some for the first time, in late 1979. Reference to national reserve margins of 30-35% "in the 1980s" (p. ES-8) gives today's readers a similar feeling of déjà vu, given that weather-corrected average margins are over 40% and climbing fast.

Peculiar ways of presenting data--Fig. 2-1 on p. 2-3, for example--mislead the authors into stating such absurdities as that "Today, more than 37 percent in the industrial sector and more than 50 percent of the energy consumed in the commercial sector are used in the form of electricity." These are of course shares of primary energy, some two-thirds of which is thrown away at the power station as warm water and cooling-tower plumes; the 1982 electric share of end-use energy (that which is actually used as stated) in the industrial sector was actually only 12%, and the primary share was not 37% but 33%, its highest level so far. (The distortion in the commercial-sector data is similar, but EIA no longer supplies commercial data separated from residential.) Such confusion encourages DOE analysts to project, as successive National Energy Policy Plans have done, futures in which about two-thirds--in some cases as much as five-sixths--of projected primary energy growth goes to conversion and distribution losses, mainly from electrification, and hence never reaches consumers at all.

Some crucial data are not presented at all. A glaring omission, for example, is any mention of the assumed cost of capital--on which the conclusions about adequate sources for a trillion-dollar program are doubtless based. It seems unlikely that the Report actually assumes real interest rates consistent--say around 8%/y--with the high rates of return it calls for.

The Report seems to have similar trouble with definitions. It seems on pp. 2-11 and 3-1, for example, to misunderstand the nature of baseloading. Under the normal utility procedure of "economic dispatch," a baseload plant is not one of any particular size or fueling type, but one which has a low running cost and is thus dispatched whenever available. (Renewable sources, regardless of size or availability, are generally best in the merit order and are therefore treated as baseload, even though they--like central stations--are not available all the time. Big thermal plants are "baseload" only in contrast to high-running-cost combustion turbines.) It is equally wrong to use a fixed value for desirable reserve margin (the Report assumes 20%) without specifying the size, dispersion, and outage statistics of generating units, the desired standard (or spectrum of standards) of dispatch reliability, and assumptions and algorithms for economic optimization of reserve margin. This one decision would govern an investment program that could easily exceed $100 billion. And it is wrong to conclude (p. 5-5) that utilities are becoming less capital-intensive without factoring out the effects of post-Eisenhower tax subsidies which now, for example, socialize approximately 107% of the lifetime cost of money, or about 42% of the lifetime capital charges, of a marginal nuclear plant built by a private utility*.

Conclusion By Assumption

The Chiles Report is riddled with assumptions which are critical to its findings but are unsupported, and often unsupportable, by rigorous analysis. We offer three examples.

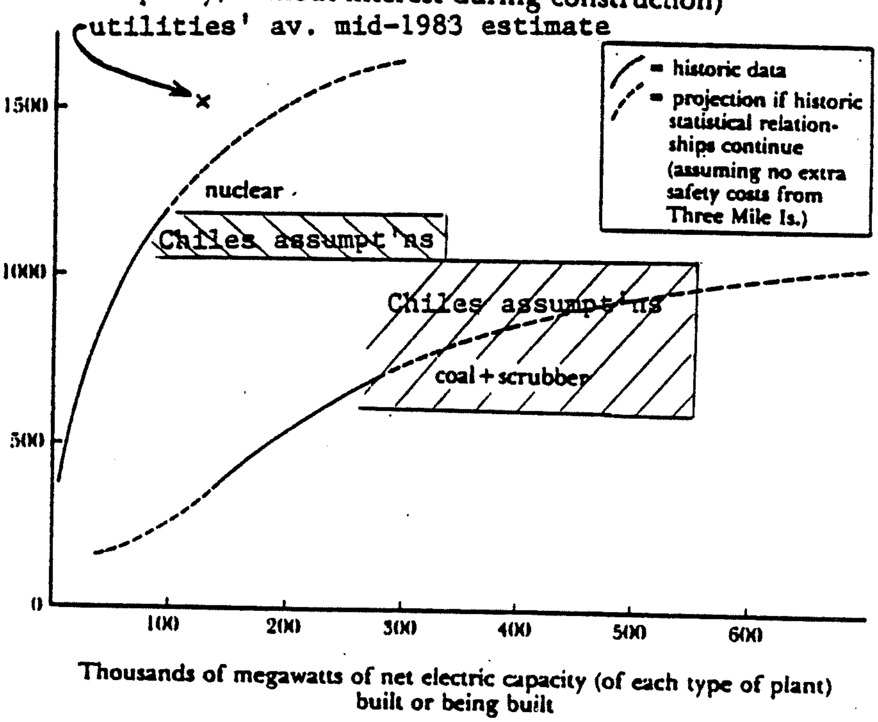
First, the Report states on p. ES-4, and purports to show in Chapter 5F and elsewhere, that "Future electricity prices are expected to continue to be relatively stable in most regions" (the stated exceptions being the Northwest, with its old cheap hydropower, and the Southwest, with its gas dependence). This conclusion flows from the assumption on p. 3-65 that the long-run cost of electricity is determined chiefly by the price of coal and the cost of capital. But

*This counts only investment tax credit and accelerated depreciation (EPRI Technical Assessment Guide 1982, P-2410-SR, Tables VI), interest deductions, and dividend reinvestment exclusions. It does not count Federal budget line-item subsidies to the nuclear industry, cheap financing of Federal projects, Price-Anderson liability limits, etc. See A.B. Lovins, "Note on Subsidies to US Nuclear Power Systems," Rocky Mountain Institute, 19 October 1983.

three tacit assumptions, all arguably false, also underlie the finding: essentially zero real escalation in plant capital cost, positive price elasticity of revenue, and constant (and low) long-term interest rates. The first of these assumptions--that after factoring out inflation in factor input prices (person-hours, tons of concrete and steel, etc.), the real cost of installing an additional kilowatt of central-station generating capacity is constant--has been empirically false for a long time, even in such centrally planned economies as France and the Soviet Union. In the U.S., for example, between the year-ends of 1971 and 1978, the real cost of an installed kilowatt increased by 142% (13.5%/y) for nuclear plants and by 68% (7.7%/y) for coal plants [C. Komanoff, Power Plant Cost Escalation, Komanoff Energy Associates, New York, 1981]. Komanoff has indeed explained 93% of the observed scatter in the costs of all commercial nuclear plants commissioned through 1978, and 68% of that for 116 comparable coal plants, by a multiple regression which provides that the more plants are built, the more each kW costs. The reasons for this correlation are fundamental.

Its results can be summarized by the following supply curves. The solid portions show empirical data; the dashed portions show a moderated continuation of pre-1979 trends. For comparison, the shaded areas show the Chiles Report's approximate assumptions; the "x" shows utilities' mid-1983 estimates of the average completion cost of all U.S. nuclear plants now under construction (note that this average is well above the costs projected from past data).

Figure A.3 Plant construction cost (1979 steam-plant dollars per net electric kilowatt of installed capacity, without interest during construction)



SOURCE: Brittle Power, op. cit. (Komanoff regressions)

Clearly, only by a dramatic break with past trends can the Report's assumption of constant long-term real capital costs be satisfied. On the contrary, what appears to be happening is a further speeding of real cost escalation (at least for nuclear plants), to a level well above that predicted from historic behavior. The empirical direct construction cost (1983$) of the nuclear plants now under construction already averages $2000/kW--at least a fourth greater than the Chiles team assumed for the next two decades.

The second assumption vital to constant long-term real electricity prices is long-term demand sufficient to generate enough revenue to amortize all the plants built. If more plants are built, but people choose not to buy that much electricity, then the increased fixed charges of the plants must be spread over fewer kilowatt-hours sold, raising the price of each. The Report assumes, with no analytic basis, that demand will be as robust as forecast, despite the supposed 40% increase in real electricity price (or whatever increase actually occurs if plants and money turn out to cost more than assumed).

The third key assumption is constant long-term interest rates. If real interest rates rise from the rate (unstated but apparently low) assumed in the Report, so will the cost of electricity from newly financed plants. This phenomenon has been such a burden on utilities, especially in the past few years, that it is extraordinary that the Report should assume it away--the more so in out-years in which military spending and hence Federal budget deficits are projected to swallow up essentially all private savings.

Another type of fallacy, with a similar root, is that the long-term real price of electricity is very insensitive to world oil prices (p. 3-37). This assumption drives the finding that electricity will become much cheaper relative to aggregate energy (p. 3-65), which in turn drives the conclusion that electricity will double its 1972 market share, as described above. One problem with the basic assumption, though, is that expensive oil--especially if the price rises as quickly as it did in 1973-74 or in 1979--tends to drive interest rates steeply upwards, making new power plants prohibitively expensive (as suggested in the previous paragraph). At the same time, oil price shocks, and costly energy generally, tend to elicit more energy efficiency, cutting markets for all kinds of energy including electricity. This is just what happened after both the oil shocks of the 1970s. The nuclear industry was certain that the oil price rise of 1973 would greatly expand the its market because nuclear power, whose price was considered independent of that of oil, would become more competitive. In fact, annual nuclear orders plummeted from 38 (1972 and 1973) and 34 (1974) to 4 in 1975, dwindling to zero after 1978 (even before Three Mile Island). An industry aware of macroeconomics would not have been surprised. The Chiles team, apparently, has learned nothing and forgotten nothing.

A third unsupported assumption, developed at length in Chapter 5, is that over their lifetimes, new coal or nuclear power stations (treated in the Report as economically equivalent and interchangeable) will cut rates; that not building those new plants will raise rates; and that investing in the plants offers ratepayers a 16-40% internal rate of return (presumably in real terms). These suppositions rest on a false comparison--coal or nuclear versus inefficient oil-fired power stations, rather than all three of those versus least-cost alternatives. That is, if it is cheaper to shut down oil-fired power plants by using electricity more efficiently than to replace them by coal or nuclear power plants, then those plants are a bad buy regardless of whether they make cheaper electricity than the oil-fired plants. In terms of opportunity cost, the coal or nuclear plants indeed offer a <u>negative</u> rate of return: every dollar spent on them <u>slows down</u> oil replacement because the same dollar cannot be spent on other measures (more efficient buildings, lights, motors, appliances, etc.), which will save more electricity, and more oil, faster and cheaper. For example, weatherization and accelerated scrappage of inefficient light vehicles could <u>each</u>, over the next decade, save about five million barrels per day--about ten times as much as all the oil now burned in U.S. power plants. Each of these two opportunities would be like finding in the U.S. an oilfield equal to Saudi Arabia's largest, with a lifting cost of only a few dollars per barrel.

Further, the economic assumptions which lead the Report's authors to suppose that new coal and nuclear plants are worth buying are disingenuous. The upper end of the range of capital cost assumed for a marginal coal plant ($1000-1600/kWe, 1982 $) is not too unreasonable at the margin, and the coal cost ($2.10/$10^6$ BTU or about 21 m$/kW-h) and O&M costs (0.6 m$/kW-h) [pp. 5-25, 5-27], though at the low end of most prudent forecasts for the 1990s, are not utterly insupportable. If the capacity factor (unstated) is at a reasonable level--say 65% or thereabouts--the fixed charge rate used must be around 10% real, also a good round number if one supposes long-term real interest rates as low as about 4%/y. But then the 4.4-5.5¢ busbar price stated must also be real, without adding back the assumed inflation rate to express the resulting generation cost in nominal dollars of 1982 or any other year--as if to say that investors were repaid in real rather than nominal dollars. (At the sort of nominal fixed charge rate normal in utility accounting--say about 18% levelized--the 4.4-5.5¢ would become 5.9-7.9¢, with the upper bound a much more reasonable estimate than the lower one--but also reversing the coal-vs.-oil conclusion, especially for combined-cycle oil plants.)

Where Chapter 5 becomes really meretricious, however, is in treating coal and nuclear plants as equivalent. The data do not support the theology: as Komanoff has shown from utilities' reports of actual costs, the real marginal capital cost of nuclear plants is at least 2.5 and possibly nearer 3.0 times that of coal plants, and the empirical average capacity factor for large nuclear plants is only 0.55. Aside from capital cost--which is arbitrarily assumed to be well below the $2000 (1983 $, interest excluded) average for all reactors now under construction--the Report states none of its nuclear-economics assumptions, so it is hard to analyze them. (The contractor study cited, which we do not have, apparently deals with only three plants.) But we can say definitively that no set of assumptions consistent with actual experience could possibly yield the result stated. New nuclear plants, on average, have sent out costlier electricity than contemporaneous coal plants in each year since about 1975, and the gap is widening rapidly*. Attachment 2 summarizes our own conclusion that with empirical data and EPRI accounting (including the assumption that the real cost of capital is only 3.7%/y, far below today's market), the marginal capital cost of a complete nuclear power system is about $9,020 (1983 $) per delivered kilowatt. The delivered price of its electric output would then be about 11.1¢/kW-h using a 9.1% real fixed charge rate; and with a nominal fixed charge rate of 17.6%, that price becomes about 19.8¢/kW-h (nominal 1983 $), equivalent in heat content to oil at about $320 per barrel. In fact, utilities report that delivered prices of electricity from the nuclear plants being completed during 1982-84 are ranging from about 7¢ to more than 20¢/kW-h (nominal 1983 $), not counting many costs in our analysis (such as present-valued net capital additions).

Refutation by Emphatic Dismissal

The Chiles Report disposes of results inconsistent with its theology by saying they are wrong. It states, for example, that the "spiral of impossibility" or "death spiral" hypothesis is "unsupportable" (p. ES-12). (The hypothesis --described in 1976 by E. Kahn et al. of Lawrence Berkeley Laboratory [LBL-4474] and ourselves--states that if costly power plants take much longer to build than it takes consumers to respond to the higher price charged during their construction to pay for them, consumers will use less electricity by the time the plant is built than they were expected to do, leading to a shortfall in revenue. That shortfall then requires higher prices, which further depress the growth or even the level of demand, requiring still higher prices, etc.) To read the Report, one might suppose that this hypothesis is still hypothetical. The managers of the Bonneville Power Administration, Britain's Central Electricity Generating Board, and many other utilities wish it were: they struggle daily with its ef-

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*As economist Charles Komanoff has shown in detail. Contrary data issued by the Atomic Industrial Forum, and blessed by such organizations as ERDA/DOE, used a biased sample which omitted the best coal plants (more than half those in operation) and the worst nuclear plants, and used a bizarre accounting convention whereby worse nuclear plant performance would reduce the imputed price of coal power and vice versa. The AIF has not published such annual comparisons since Komanoff was unkind enough to point out their chicanery, though some DOE officials noticed neither their recent absence nor the reasons for it.

fects. On page 1 of The Times of London, 1 March 1980, for example, the Chairman of the CEGB lamented: "We face a disturbing prospect: a vicious circle of rising electricity prices causing further reductions in demand, which in turn would push up prices still more." Moreover, the Department of Energy sponsored an excellent study at Los Alamos National Laboratory which confirmed that, in the circumstances we stated, the "spiral of impossibility" is real [A. Ford & A. Polyzou, "Simulating the Spiral of Impossibility in the Electric Utility Industry," LA-UR-81-3383, 1981]--even though the model omitted such important effects as a higher cost of money for utilities in trouble. Such work is nowhere cited; the Report only cites as counterexamples some anecdotal spot data from a biased sample of five of the nation's five thousand-odd utilities.

Proof by Vigorous Assertion

Pages 4-46ff repeat the five-year-old canard that it is safer to overbuild than to underbuild: overbuilding means some trivial extra carrying charges, while underbuilding means enormous blackout costs. We had thought that this thesis, advanced in 1978 by E.G. Cazalet et al. [EA-927, EPRI, and EPRI Journal, May], was deservedly dead and buried long ago. It is an artifact of poorly constructed computer models which assume that all forms of generating capacity are expanded at the same rate, so that baseload shortages automatically incur outage costs rather than building or running more the array of peaking or intermediate-load-factor plants. The models' use of planning reserve margin as the key dependent variable obscures the choice between plants of different lead times. The Los Alamos researchers, for example, like most smart utility planners today, prefer to underbuild long-lead-time plants, then make up any shortfall with short-lead-time plants at lower cost. The models which underlie the Report's findings assume low capital costs and charges for big plants, so that even very large overcapacity does not greatly increased fixed costs. Outage costs are treated as homogeneous, as if it were as serious to cut off an electric water heater as a hospital operating theater. (It would make more sense to install local backup in critical applications, as hospitals do, or to market interruptible power to users with low outage costs.) Uncertainties are assumed to be symmetrical with respect to over- or under-production, although policy instruments are available (like appliance standards and efficiency buybacks) to reverse this assumption. Any serious analysis of the over- vs. under-building issue must at least consider the contrary views put forward in a substantial body of literature: for example, the work of A. Ford and I.W. Yabroff [LA-UR-78-3228 and Energy Systems and Policy 4(1-2):57-98 (1980)], E. Kahn ["Project Lead Times and Demand Uncertainty: Implications to Financial Risk of Electric Utilities," E.F. Hutton Fixed Income Research Conference on Public and Investor Owned Utilities, New York, 8 March 1979], and R. Boyd and R. Thompson ["The Effect of Demand Uncertainty on the Relative Economics of Electrical Generation Technologies with Differing Lead Times," UCDavis and Ca. GSA]. The Chiles group seems simply ignorant of the whole dispute.

Equally devoid of analytic support is the notion that the electric utility industry can spend an average of about $65 billion per year (1982 $)(p. 6-19)--two-thirds more than its average 1977-82 rate of construction expenditures--without crowding out other borrowers. The $42 billion (1982 $) per year spent in the 1970s* is no precedent: utilities were then increasing construction eight times as fast as cash earnings, confiscating equityholders' assets by selling common stock below book value, and borrowing to pay dividends which the Report states (p. ES-21) were two-fifths larger than cash earnings. During 1977-82, investor-owned utilities spent $30.4 billion per year on plant and grid construction. Of that, only $17.2 billion, or 57%, was raised in the market: the rest came from liquidating themselves to build power plants they don't need, can't afford, and won't be able to pay for. To sustain construction expenditures two-thirds larger than that unsustainable level would require far more external capital, or make the companies devour themselves faster, or both.

Most glaring among the Report's omissions is any discussion of least-cost analyses on their technical merits. With the partial exception of some work by

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*We assume this Chiles figure to be correct, but note that the the EEI 1982 Statistical Yearbook gives the total expenditures by investor-owned utilities (about 78% of the entire utility industry) for building generation, transmission, and distribution to be only $27.1 billion per year in the 1970s, implying about $35 billion per year for the entire industry (1982 $).

the Sant group, no such alternative study is even identified as having been considered (pp. 5-72ff). Chapter 3 blandly dismisses low-demand futures in general (p. 3-66) because they "underestimate users' propensities for substituting electricity for other energy forms" (a propensity no doubt known to the Chiles team by divine revelation) and because they do not project "a continuation of the [electrification] trend which has been seen through much of the twentieth century to date and now appears likely to continue through 2000." Who can deny that trend is destiny? And who will dare to suggest that electricity might enjoy a stable or increasing share, but of a dwindling market for total energy--as has lately been the case?

Chapter 5 goes further by admitting that the authors have read "several" least-cost studies, but says they were studied and found to be wrong. "Some" of these unnamed but doubtless sinister studies did not mix their options in the way the Chiles team would have liked (that is, they gave too little emphasis to the need for building power plants despite conservation programs). The Report presents results which purport to show that it is worth mixing cheap power plants with costly conservation in the case of one anonymous oil-fired utility, based on numerous unstated assumptions and no sensitivity tests. "Some" least-cost studies, too, "were analytically flawed." Only one example of one flaw, in an unnamed study, is given: that comparisons were made only through the early 1990s, and were thus biased against a new coal plant by not reflecting its long-term oil and gas displacement. If costs were not levelized, the complaint might be legitimate; but then it would be equally true to say that the oil and gas displacement by the efficiency alternative was not reflected in adequate proportion to <u>its</u> front-end cost.

Nowhere, however, does the Report state which least-cost studies it examined, what they found, how they differ from its own findings, who is right, and why. The most elementary requirements of scholarship remain unfulfilled. The main findings on pp. 5-75 and 5-85--that no efficiency improvement is worthwhile in all utility service territories, that not building more big power plants will raise long-term costs--rest on the thinnest of hot air.

Alternative Generation

Analyses by such groups as OTA have found a large technical potential (usually in the vicinity of 100-200 GWe by 2000) and, given avoided-cost buyback, an economic potential of tens to hundreds of GWe, for industrial cogeneration. The Report baldly states, with no analysis or citation, that "given the energy prices assumed..., cogeneration...is unlikely to increase very much" (p. 3-81). This apparently means (p. 4-34) no more than about 7 GWe over the next seven years; post-1990 cogeneration is simply ignored. Other generating alternatives get even shorter shrift. "Current utility plans, which extend through 1991," are said on p. 4-34 to include 0.4 GWe solar, 0.4 GWe wind, 0.9 GWe biomass/ municipal solid waste, 2.4 GWe geothermal, and 1.4 GWe net hydroelectric. These plans, based on a 1982 NERC report, amount to a total of 5.5 GWe.

For comparison, as of 28 October 1983 a single utility, Southern California Edison Company, was ahead of schedule on its plan to acquire 2.15 GWe of firm renewable and alternative generation by 1992. According to its President*, this one utility had already built, is building, or has obtained contractual commitments for about 1.54 GW of alternative generation (not counting its 0.1-GWe coal-gas project)--116 projects, including 0.70 GWe biomass and cogeneration (0.24 GWe now operational), 0.06 MWe solar (0.011 GWe operational), 0.56 GWe wind, 0.12 GWe geothermal, and 0.10 GWe small hydro. Pacific Gas & Electric Company had achieved broadly similar commitments. (Both of these utilities, incidentally, have underreported their own hydroelectric programs to NERC by about a factor of ten.) It appears likely that utilities in California alone, with a tenth of the country's loads, will achieve the 1992 alternative-generation goals which the Chiles Report envisages for the entire country, even though some of those California utilities, notably Edison, pride themselves on paying less than full avoided cost.

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*Howard P. Allen, 28 October 1983 text of 5 November talk at Sundance Symposium.

Further analytic errors are evident in the renewable-source cost assumptions reported in notes 48-49 on pp. 4-62 and 4-63. Dispersed photovoltaic power, for example, is reported to cost (in 1983 $) 52¢/kW-h in 1980, 21¢/kW-h in 1990, and 14¢/kW-h in 2000. In fact, Intersol Power Corporation, a Martin-Marietta spinoff in Lakewood, Colorado, is prepared today to install 100 MWe of tracking 70-sun Fresnel photovoltaic modules, each producing 5.4 net kWp, at a turnkey price of $2300/kWe (1983 $) including some power conditioning and storage. In Colorado this price is equivalent to busbar power at 12¢/kW-h at a 17.8 %/y nominal fixed charge rate--well below the likely marginal nuclear cost. Similarly, the Report states that centralized wind generation cost (in 1983 $) 43¢/kW-h in 1980 and is projected to fall to 9¢/kW-h by 2000, with decentralized wind generation following a similar pattern. Most of the wind machines now competing on the grid in at least six states have already beaten the 9¢ price; some on the market can do 4-6¢ in good sites. Such studies as our Brittle Power: Energy Strategy for National Security [Brick House, Andover MA, 1982, Appendix 3] document many competitive renewable sources, both electric and nonelectric, now on the market--and caution against point estimates of cost, since differences of marketing structure, technical complexity, and integration with end-use efficiency improvements can change costs by up to a thousandfold or more.

Failures Too Numerous to Mention

It is almost superfluous to mention further flaws in the Chiles Report, but a few more examples may illustrate the diversity of its problems:

- The Report mentions (p. 5-3) "diminished economies of scale," and then proceeds to ignore them, whatever they are. Appendix One of Brittle Power documents approximately fifty effects of scale on the economics of energy (especially electrical) systems. Most of these effects penalize large scale. Their net effect, in all but a very few exceptional cases with large point loads, is a strong net diseconomy--meaning that if one found an instance where it was cost-effective to build a power station, it would be cheaper to build it small (tens of MWe or less) than big.

- The Report implies that outages are caused by insufficient generation. In fact, some 95% are due to grid failures. No major outage in U.S. history has been caused by lack of generating capacity. On the other hand, further central electrification would greatly reduce the resilience and increase the brittleness of the grid. This threat to national security, documented in a report for FEMA [Brittle Power, op. cit.] and the subject of GAO reports and three Congressional hearings, is ignored.
- On pp. 5-80ff, the Report converts a misuse of the concept of avoided cost into an argument against its correct use. (That said, if a utility can elicit enough alternative generation, at a fair return to the outside entrepreneurs, by paying less than avoided cost, it could well do so and rebate the saving to its ratepayers and shareholders. Ideally, utilities would run an auction to ask who would supply how much alternative saving or generation at each of an increasing series of prices, until demands are met--presumably at below full avoided costs.)
- The Report consistently omits many elements of the capital cost of a complete electricity-delivering system (see examples in Attachment Two).
- The Report suggests that good regulation means allowing all rate hikes promptly and encouraging construction of many new power stations. Serious consideration of long-term utility economics suggests that rate hikes and construction probably make virtually any utility worse off. Many utility managers who do not think more construction and higher rates are in their own financial interest feel, rightly, that present regulation tends to penalize their vision and to reward exactly the kind of poor, profligate management which the Chiles Report favors. The Report will doubtless be cited in support of encouraging outmoded management approaches.

- Table 5-10 fallaciously assumes that efficiency improvements which displace utility oil and gas at a cost less than the fuel cost will not reduce rates, or that such a low cost is impossible, or both. The argument is apparently (5-65) that it is a bad buy to save oil and gas by efficiency when one could do so instead by building a coal or nuclear plant. If the efficiency costs less than oil, gas, coal, <u>or</u> nuclear, that argument is clearly wrong.
- The discussion of no-losers tests (pp. 5-48, 5-58, 5-67ff) consistently confuses rates with bills. Conservation may increase <u>rates</u> but lower <u>bills</u>, which after all are what people pay. Moreover, nonparticipants in conservation programs <u>should</u> help pay for cost-effective demand-reducing investments for the same reason that nonparticipants in demand growth now help pay for new power plants: all consumers are marginal users (they have the option of reducing their use), and the system should acquire least-cost resources for everyone's benefit. To the extent that nonparticipants bear costs without receiving personal benefits, they have an incentive to go for the benefits too.

<u>How to Spend 429 Pages Evading the Issue</u>

The basic issue in forecasting long-term electric demand is how well electricity can compete in an energy-service marketplace, particularly against a rapidly expanding array of efficiency options. There must be few utility executives or regulators in the country who are not aware that electric demand is very uncertain, or that its uncertainty arises largely from not knowing how much electricity will be saved how fast. Great analytic effort has lately been devoted throughout the industry to trying to address these uncertainties. The Report had an opportunity to contribute to the state of the art of that effort. Instead, it copped out. Page 5-54 states:

> We shall not attempt to define the amounts of different potential efficiency measures which are economically feasible in particular parts of the country or in the country as a whole. Such a task is forbidding, if not impossible, and is meaningless unless it is realistic.

Fortunately, forbidding (if not impossible) though the task may be, it has already been done quite well, at public expense, in the monumental 1981 SERI study A New Prosperity, which this Subcommittee asked the then Deputy Secretary of Energy to commission and which this Subcommittee was instrumental in bringing to light after DOE tried to suppress it. The SERI analysis showed, in brief, that reasonable rates of introduction of 1980 technologies, cost-effective against the running cost of existing coal plants, could reduce U.S. electrical demand by a quarter by 2000 despite a two-thirds increase in real GNP. Thus national generating capacity would probably be adequate in 2000 if no new plants were commissioned after 1985, even if all old, oil- or gas-fired, and even nuclear plants had by then been retired.

The SERI study is arguably the most detailed and sophisticated engineering/economic analysis of energy and electricity demand done to date in this country. Yet it is not among the three [nongovernmental] studies which the Chiles Report included for comparison (p. 3-94, n. 11). Since the Chiles team does not cite the SERI analysis or discuss its contrary conclusions, one can only suppose that it has been consigned within DOE to a sort of Index Librorum Prohibitorum--not to be mentioned, let alone read, on pain of instant excommunication.

The CRS Study: A Trifle Less Unrealistic

This Subcommittee asked the Congressional Research Service to do a study largely parallel to the demand portion of the Chiles Report. The resulting Committee Print (98-M, August 1983) helps to correct some of the Chiles Report's more egregious absurdities, but still seriously underestimates the scope for cost-effective electricity savings. The CRS report's problems can be briefly summarized thus:

- The methodology used (econometric regressions on GNP and on the ratio of electric to aggregate energy price) remains crude and uninformative. (It also runs the risk, in principle, of double-counting historic efficiency improvements--though conservatisms in the technical assumptions, as noted below, would more than outweigh any such effect.)

- So is the assumption of point values for load factor and reserve margin to convert electrical energy demand to required generating capacity.
- Although CRS's ratio of electric to aggregate energy price spans a much wider range than the Chiles Report's, and in particular considers higher (more realistic) values, reliance on such ratios obscures the extent to which electricity <u>and</u> fuels are uncompetitive with efficiency gains. The use of higher ratios, however, does help to allow for the likelihood that some combination of high capital costs, high interest rates, negative price elasticity of revenue, and fuel escalation may push long-term electricity prices from new plants far above Chiles's low, stable levels.
- By assuming that efficiency improvements cost more than running existing thermal plants (taking account also of grid costs and losses), the CRS study concludes, incorrectly, that there is virtually no market for more efficient electrical use before 1990, thus understating its potential.
- Like the Chiles Report, the CRS report assumes (p. CRS-18) marginal electricity prices which appear in many cases to be unrealistically low. It is also unclear whether the <u>delivered</u> price, not the busbar cost, has been used for comparison with options installed at the point of end use--a possible difference of the order of 2¢/kW-h.
- It is conservative, but not methodologically justifiable, to assume (p. CRS-19) a discount rate two points higher for "least-cost methods" than for new power plants. If anything, the balance of risk, and perhaps of engineering lifetime, generally favors efficiency and small sources [see e.g. E. Kahn <u>et al.</u>, LBL-11398, 1980].
- The use of the term "least-cost methods" as a catchall for efficiency <u>and</u> alternative generation begs the question of what <u>are</u> the least-cost options, and obscures the choices between and among these two categories.
- The only specific example given in the section on efficiency gains (pp. 20ff) is outdated: much better light bulbs are now for sale (see p. 37 below).

- The assumption that new superinsulated housing cuts space-conditioning loads by only 80% is very conservative. The further assumption that "widespread adoption" of such construction practices is "unlikely before the turn of the century unless a strong educational effort is made"* ignores the availability and the proven effectiveness of such efforts, e.g. in western Canada, Sweden, and Denmark, where thousands of new buildings (and some retrofits) are already more efficient than the CRS assumptions. In Saskatoon, for example, more than three-fourths of new housing starts now use superinsulation methods that were invented only six years ago.
- The assumption that "the maximum potential for energy performance improvement [in commercial buildings is]...20 percent for existing buildings and [a total of 30] percent for new" is extraordinarily conservative. Any able consultant can count with high confidence on 40+% savings from retrofitting virtually any commercial building. Moreover, many new commercial buildings are not just 20% better than the existing stock as assumed but 60-90+% better.
- Some of the most cost-effective electricity-saving measures, such as service voltage equalizations, are apparently omitted. Integral-horsepower industrial motors, which use about 40% of all electricity used in the United States, receive no specific analysis, although they offer a cost-effective potential saving of the order of 70 GWe installed.
- The discussion on p. CRS-25 (load management by utility controls on air conditioners) could have profited from utility experience: some innovative utilities have readily approached the maximum theoretical saving.
- The discussion of passive solar retrofit (pp. CRS-26/27) assumes much higher cost and lower performance than many well-designed systems today.
- The use of a very restrictive "firm capacity" definition for windpower and other renewable resources is asymmetrical and incorrect. <u>All</u> power sources are intermittent and unreliable, in different degrees and for different reasons. In fact, aggregates of renewable generators, especi-

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*In his NARUC address (<u>loc. cit.</u>, p. 14n <u>supra</u>), the Chiles Report's Staff Director says superinsulation "raises difficult political questions as to how we can accomplish such sweeping changes in a democratic society." Apparently he anticipates no such problems from building about 600 new power plants. In fact, market forces alone are making superinsulation dominate on the Canadian prairie; a national building code (requiring cir. 1.5-2 btu/sq. ft -ddf) does so in Sweden.

ally dispersed ones, tend to be firmer power resources than large central stations, because their outages are shorter, milder, more predictable, and statistically more likely to be compensated by increased output from other renewable sources. Indeed, in some important markets, such as Southern California, the output of wind plus photovoltaics is virtually a perfect match to existing utility load curves (as CRS shows on p. 88).

- The estimates of renewable supply potential seem very low in the light of actual orders placed in the past few years. Indeed, it appears to us that orders for small hydro and windpower since 1979 have exceeded orders for all central power stations (19.6 GWe, or 14.5 GWe net of cancellations).
- We know of no analytic basis for the assumption that only a third of U.S. houses could cost-effectively use photovoltaics when arrays become cheap. Indeed, some flat-plate arrays which now sell in bulk for $4.95 per peak watt (1983 $) would probably be cost-effective in many areas today in a very well-designed cogeneration mode, and would compete even at three times their present price in community-scale cogeneration. The statement (p. CRS-33) that photovoltaic power now costs about $1/kW-h apparently assumes very costly storage and power conditioning (many flat-plate systems can actually produce at about 40¢/kW-h), and no waste-heat credits.
- The statement (pp. CRS-34/38) that solar space-conditioning becomes harder to justify in more efficient buildings is exactly backwards. Greater efficiency reduces both average and peak loads, increases thermal time constants, and permits space-heating to be done by slightly oversizing a solar water-heating system. In a superinsulated house, completely solar (active) heating can indeed be cheaper than partly solar heating or than any other non-passive kind of heating: see e.g. our <u>Least-Cost Energy: Solving the CO_2 Problem</u> [with F. Krause & W. Bach, Brick House, Andover MA, 1982, pp. 114-116].

- The statement (p. CRS-34) that third-party renewable generators feeding the grid look uneconomic without storage reflects two fallacies. First, renewables, being superior in merit order to thermal plants, are to be used first as a fuel-saver, and later (at higher penetrations) as a water-saver. Very efficient end-use makes the grid ultimately hydro-dominated, making the storage essentially free. Second, for reasons set out by such analysts as Sir Martin Ryle ("The Economics of Alternative Energy Sources," Nature 267:111-117 [1977]), the storage problem is much worse for central stations than for dispersed renewable sources--reversing CRS's economic conclusion at pp. CRS-34, 190ff, and passim.
- The air-pollution problem of cogeneration noted at p. CRS-72 would not normally arise under the EPA "bubble concept"; moreover, cogeneration, particularly with coal and other solid fuels, lends itself to very clean fluidized-bed combustion.
- The cogeneration estimates on p. CRS-78 are clearly low. Southern California Edison alone has already contracted for 0.7 GWe (of which 0.24 GWe is operational), including a 0.30-GWe Getty Oil project scheduled for 1986 completion. Edison's target for 1992, 1.0 GWe, is now likely to be exceeded; yet it is CRS's 1994 target for all of California. One company alone, Applied Energy Services, now has over a half-billion dollars' worth of cogeneration under contract or letters of intent.
- CRS fails to draw the obvious conclusion (from pp. CRS-80 to -82) that smaller wind machines may well be more cost-effective than multi-MW ones.
- The assumption on p. CRS-110 that new buildings can be far more efficient than retrofits is correct with regard to ease but not to ultimate result. Extensive work in Europe (see Least-Cost Energy, op. cit.) has shown that it is well worthwhile retrofitting most existing houses to zero heat load --a conclusion supported by Olivier et al.'s 5000-sector British analysis [Energy-Efficient Futures: Opening the Solar Option, Earth Resources Research Ltd. London, January 1983

- In view of the correct statement on p. CRS-112 and pp. 116-117 that experienced contractors are building superinsulated houses for no greater first cost than badly insulated houses, it is wrong to refer on p. CRS-21 to "the current level of added costs" as a deterrent. Indeed, some superinsulation recipes appear to reduce first cost by eliminating the need to install furnaces and other mechanicals.
- The real discount rates assumed (p. CRS-113) are probably much higher than those which the Chiles Report uses to justify new power plants--a likely source of the discrepancy in the two studies' demand estimates.
- The list of options on pp. CRS-117/118 assumes a shorter-than-realistic lifetime for energy-saving measures, and appears not to assume the most recent and cost-effective glazing technologies.
- The prototypical house (p. CRS-115), 1974 vintage, is probably no better than half as thermally efficient as the average house being built today. CRS has modified DOE's assumptions about existing insulation levels in a way that understates the potential for further savings.
- The potential gains from more efficient refrigerators, lights, etc. (pp. CRS-135ff) do not assume the best available technology. Thus the savings on p. CRS-159 are very far from the "maximum potential," and similarly in the industrial sector (p. CRS-166). We offer examples below.
- The ISTUM results (p. CRS-167) were very conservative when done and are more so now. They assume 1980 technologies--an important shortcoming because few of today's best electricity-saving measures existed in 1980. Exxon's estimated potential for 110 TW-h/y (ca. 25 GWe installed) savings just from variable-speed industrial motor drives is 73% of ISTUM's entire 1990 saving projected from all measures.
- While we dispute that the calculated savings (pp. CRS-168/169), 32% of projected electrical demand in 2000, are anywhere near the "maximum potential" at up to marginal cost--CRS has arbitrarily halved an underestimated potential--we consider even this very conservative estimate a useful refutation of the Chiles results, which in practical effect ignore even this modest potential. This would be clearer if the list of "unconservatisms" on p. CRS-172 were complemented by a similar list of ways in which the CRS analysis underestimates potential savings.

- The technological discussion on pp. CRS-192ff is quite out of date. For example, it omits passive cooling, mentions dependence on tax credits for renewable but not for nonrenewable technologies, assumes oversized water heaters, ignores simplified systems (such as the batch DHW heaters now in use on 11% of Japanese houses) and simplified marketing structures (see Brittle Power, op. cit., Appendix 3), overstates present photovoltaic prices by severalfold, ignores the synergism between renewables' cost-effectiveness and high end-use efficiency, and neglects photovoltaics with modest concentration (e.g. from Winston collectors) and waste-heat use. It fails to note the cost-effectiveness of simple dish collectors for cogeneration and even for direct steam generation (as Solar Steam of Tacoma, Washington has vividly demonstrated).
- CRS states on p. 189 that about 5% of U.S. "energy needs" are now met by renewable sources. Based on published data from EIA and from Resource & Technology Management, Inc. (Arlington VA), we think the correct fraction of primary energy is between 7% and 8%. (We note with regret that the EIA analysts who study wood use have not been allowed to include their results in national aggregate data--with the bizarre result that most EIA statistics omit a source, wood, now delivering about twice as much energy as nuclear power, a source prominently featured in the statistics.)
- CRS states on p. 213 that oil and gas now generate 25% of U.S. electricity. The actual 1982 figure was 20% (two-thirds of it gas) and falling --17%, for example, in the first four months of 1983, including winter peak months.
- It is not true--as Congress noted when establishing PURPA's full-avoided-cost concept--that renewables have no capacity-saving value (pp. CRS-214, 217). Photovoltaics can shave peaks (p. 214) when the sun shines on-peak --as it generally does on hot afternoons in summer-peaking areas.
- The contention (p. CRS-216) that solar units can raise capacity costs

forgets that sunk costs are forever sunk. A utility which is in surplus cannot blame its past overinvestment on future fuel-saving investments.

- The statement on p. CRS-217 that off-peak solar generation's displacement of baseload capacity is "usually an uneconomical situation for utilities since baseload generation is their lowest cost production" reveals a serious misunderstanding of economic dispatch (echoed in the characterization of "baseload" on p. CRS-221). Solar, not large thermal, plants give the lowest-cost production and would be dispatched whenever available, displacing all thermal plants up the load-duration curve.
- Transient (cloud-passage) photovoltaic outages are easily averaged over a modest geographic area (p. CRS-218); they are less of a load fluctuation than utilities routinely deal with now from space-conditioners. CRS's remarks on spinning reserve also apply more to thermal than solar plants.
- The discussion of load management by peak curtailment of air conditioning (p. CRS-226) forgets that thermally efficient buildings have long thermal time constants and thus automatically shift any residual space-conditioning load to later times, typically in the middle of the night.
- It is incorrect (p. CRS-247) to imply that nuclear and coal plants, particularly large ones, have essentially identical availabilities. The actual average capacity factor of large reactors to date, for example, is 0.55 (cf. p. CRS-249), whereas 200-400 MWe coal plants have typically displayed availabilities averaging around 0.70.

In summary, the CRS report contains many technical flaws; uses a methodology that cannot reveal most of the potential for saving electricity and money; slightly tempers that choice by supplementary analyses of some aggregated patterns of electrical use and savings; and makes such very conservative assumptions in those analyses that the potential for saving is still greatly understated. We now summarize some of our own analytic results in this area.

How Much Electricity Is Worth Saving?

An unnoticed revolution in technologies to raise electrical productivity has been accelerating over the past few years--the fruits of R&D begun in the mid-1970s. We have calculated that the full use of the best electricity-saving methods now on the world market (most of them available in this country) would reduce electric demand, to provide the present U.S. economic output, by approximately three-quarters, assuming a cost of savings not above about 1.5¢/kW-h (1981 $). This is less than the running cost alone for any type of new thermal plant, even a nuclear one; so if one had just finished building one of those 200-odd new nuclear plants the Chiles Report advocates, it would save the country money to write it off, never operate it, and buy efficiency instead.

The technologies we have assumed in reaching this conclusion include:

- Lights. Philips (Norelco) "SL" bulbs. We have used them in our own home for the past year. They screw into a standard socket, give better light than normal bulbs (excellent color, no hum or flicker), use a quarter as much electricity, last ten times as long, and pay back, at reasonably high duty factors, in about a year or two at the U.S. retail price (about $22; in Europe, about $10-14). For fluorescent tubes, Luminoptics high-frequency ballasts are "tunable" to mix natural and artificial light. We assume task- and daylighting, and lighting at below headache level. The U.S. commercial lighting standard is seven times that of Sweden (which is among the highest in Europe) and has no rationale: indeed, much of it seems to stem from an uncorrected typographical error decades ago.
- Motors. Proper sizing and controlling of industrial motors and the use of better windings and drive trains can typically double their practical efficiency at a cost of about 0.6-0.8¢/kW-h, as shown e.g. by Murgatroyd et al. at Imperial College (London) and by the German Fichtner-Studie. Olivier et al. (op. cit.) have shown that in many applications, direct hydraulic drive can treble original efficiency at similar or lower cost.

Just doubled industrial drive efficiency would save about 70 GWe of capacity, more than replacing every nuclear plant in the country.

- Appliances. A typical U.S. 16-18 cu. ft. refrigerator today uses about 1300-1500 kW-h/y. The best model in U.S. mass-production uses 900-odd. The best model (assuming unchanged size and performance throughout) in Japanese mass-production uses about 520, having improved 5.5-fold in ten years. The best model on the U.S. market--handmade for photovoltaic homes--uses 175. The best U.S. prototype uses 64. Its next version, for the first time using a well-designed compressor, is expected to use about 15. Passive models use zero. Highly efficient refrigerators whose cost is similar to that of present models would save about 25 GWe of capacity. Similar redesign of all major household appliances would reduce residential electric bills by upwards of three-fourths, costing about 1.2¢/kW-h.
- Smelters. The best aluminum-smelting processes use about 40% less electricity per pound than current U.S. practice. An experimental Japanese (Mitsui) process now being tested for commercial use uses no electricity.
- Space conditioning. With the possible exception of special cases such as computer centers, delicate instruments, hospital operating rooms, and the like, we have been unable to find significant instances in which electric space-conditioning, even with efficient heat-pumps, is economically justified at marginal costs. New technologies for heat recovery, new and retrofit superinsulation, and glazing (our new home, for example, uses R-5.3+ glazing that provides a net passive gain facing due north), and the rediscovery of classical methods of passive cooling, make this conclusion well worth realizing in practice.
- Miscellaneous. We assume more charging of scrap to blast furnaces, as is normal practice in Japan; more fluidized-bed heat treatment of metal parts; and cost-effective recovery of industrial process heat. We assume slightly better office equipment, such as that which enables our 4000 sq ft house/bioshelter/research center in the Colorado Rockies to draw a projected average total electric load of about 0.8 kWe for everything, or about 0.2 W/sq ft--a fifteenth of the load which the National Electric Code requires wiring to supply for lighting alone.

The cumulative effect of such technologies is stunning. Taken together, these opportunities could quadruple U.S. electrical productivity in the coming decades, starting now. Most if not all of them cost less than just running existing thermal plants (or even delivering very cheap power from old hydro plants). We must conclude, therefore, that:

- every thermal power plant in the U.S. is probably economically obsolete;
- over 75%--probably 80+% at average prices, or about 90% at marginal prices--of the electricity now sold is uncompetitive;
- higher rates will probably reduce utilities' long-run revenues;
- more construction will therefore require more revenue but produce less;
- the Chiles Report's prescription is therefore a royal road to insolvency.

What matters are the relative prices, present and future, of electricity and its real competitors--efficiency and some renewables--not those of electricity, oil, and gas, which are all almost equally uncompetitive with efficient end-use.

Our findings are not unique. Olivier's monumental least-cost study for Britain, cited on p. 33, assumes the best 1980 technologies competitive with running existing coal plants, and finds that by 2025, the least-cost generating capacity required is only one-ninth of the official British Chiles-like projection. A simpler German analysis [Least-Cost Energy, op. cit.] showed that the best 1980 technologies, nearly all cost-effective at 1980 prices, could treble electrical efficiency in the world's most heavily industrialized economy. Similar results are emerging in Scandinavia: in Sweden, the world's most energy-efficient industries can cost-effectively double present electric efficiencies.

The critical question is not whether the potential for such vast improvements in America's electrical productivity actually exist--that seems beyond dispute--but how fast that opportunity will be seized. The Chiles Report invites utilities to play You Bet Your Company that their customers are too dumb to discover most of the alternative investments in the next 50 years. History suggests otherwise. Since 1979, this nation has actually gotten more than a hundred times as much new energy from savings as from all expansions of energy supply combined--and more new supply from renewable sources than from any or all of the nonrenewables. Whether these trends continue, slow down, or speed up depends largely on policy--on actions not just by the Congress and by Federal agencies but especially by state and local governments, utilities, private groups, and communities. A trillion dollars for more power plants would stifle such initiatives, funnel scarce resources away from cheaper opportunities, reinforce utilities' present surpluses and disdain for savings, and bankrupt at least the utility industry if not the national economy.

The Damocletian sword of skidding demand now hanging over the electric utility industry demands great caution. Higher prices will make the industry's product--already priced well above a monopolist's profit-maximizing level--even more uncompetitive than it is already. Higher subsidies will only enable and encourage utilities to make more imprudent and unaffordable investments. There are no "black holes"--no infinite, inelastic markets--to which to sell surplus power. The only salvation in sight is the consistent enforcement, by utility managers and their regulators, of a rigorous least-cost investment strategy; insistence on prices that tell the truth; innovative programs of utility and third-party investment to channel energy capital to short-lead-time, fast-payback opportunities; and systematic identification and purging of institutional barriers to efficient investment at all levels.

As stated in our Mitchell Prize essay, "Electric Utilities: Key to Capitalizing the Energy Transition" [reprinted, with many typographic errors added, in Technological Forecasting & Social Change 22:153-166 (1982)], electric utilities today must choose between participation and obsolescence; between being obstacles to or vehicles of an historically unique transition to least-cost alternatives as a competitive market emerges in energy services. By failing to recognize this opportunity, by seeking instead to intensify all the trends and policy errors that have brought utilities to the brink of disaster, and by casting economically conservative critics of these errors as "anti-technologists bent on selling visions of radically different futures for electric power" [Herod, loc. cit., p. 15], this Administration has so far been the most hostile in history to the real economic interests of the utility and nuclear industries.

It is to Secretary Hodel's credit that he has shown no noticeable enthusiasm for formulating, let alone advancing, the Chiles group's recommendations. Let him now scuttle the Report for good; and let those responsible for such a waste of public money be called to account. Let him be remembered as the Secretary of Energy who had the vision to keep this nation's largest industry from going broke trying to build the unfinanceable to make the unmarketable to sell to the unfoolable--the canny American consumer.

In summary, then, our responses to the questions put to us by this Subcommittee are as follows:

1. Is the Chiles Report's forecast of 438 GWe of additional capacity needed by 2000 valid? No; it vies with the Inhaber Report for Professor John Holdren's description--"the most incompetent technical report I have ever known to have been distributed by grown-ups."
2. Is the Report's suggestion of building 438 GWe of thermal plants a reasonable strategy for meeting demand for electric energy services at least cost? No; it nowhere considers what all or even most of the options are for providing those services, nor which will be cheapest.
3. How did DOE treat efficiency improvements? In essence, they didn't. Is this a sound forecasting method? No; it's utterly fishbrained.
4. Is the CRS study right to say that the electrical demand implied by 3% annual real GNP growth can generally be met without new power plants? Yes, but to a much greater extent, and at lower cost, than CRS says.

This Subcommittee is to be warmly commended for appreciating the importance of these issues. The United States spent last year three times as much money on building nuclear power plants--many of which will not, and all of which economically should not, be finished--as it invested in its automobile industry. The utility industry spends each year on uneconomic power plants about half as much money as the Chiles Report suggests, but about twice as much as was invested in all energy efficiency and renewables in 1980. The money needed to bring the energy transition to maturity in a timely fashion is being poured down a rathole --building giant power plants that cannot pay for themselves, and each of which, directly and indirectly, loses the economy about 4,000 net jobs*. This foolishness has gone on at least one or two hundred billion dollars longer than our economy can afford. It is long past time that investors who bought WPPSS bonds at 14%/y tax-free (an obvious risk premium) learned that the risk comes with the premium; that utility managers stopped believing in Santa Claus; and that this nation got on with the task of making itself free to choose, so that the genius of free enterprise can help us to do the cheapest things first.

* * *

*According to input-output regressions by Prof. Bruce Hannon (U. of Illinois). Being based on decade-old coefficients and costs, the figure is probably low.

<u>Attachment One</u>

BIOGRAPHICAL SKETCH OF AMORY B. LOVINS AND L. HUNTER LOVINS

Amory and Hunter Lovins work together as analysts, lecturers, and consultants on energy and resource policy in over fifteen countries. Their prophetic analyses have placed them among (in <u>Newsweek</u>'s phrase) "the Western world's most influential energy thinkers." They received a 1982 Mitchell Prize for their essay on reallocating electric utilities' capital more efficiently, and shared a 1983 Right Livelihood Award (the "alternative Nobel Prize").

Mrs. Lovins, 33, earned BA degrees from Pitzer College in political studies and in sociology, and a JD from Loyola University [Los Angeles] School of Law, with the Alumni Award for Outstanding Service. She is a member of the California Bar. For six years she was Assistant Director of the California Conservation Project ("Tree People"), which she helped to establish. She has served on the City of Los Angeles Energy Management Advisory Board, lectured extensively, published many papers, and coauthored four books with Amory.

Amory Lovins, 36, is a consultant experimental physicist educated at Harvard and Oxford. A former Oxford don, he holds an MA (Oxon.) by Special Resolution and four honorary doctorates. He was Regents' Lecturer in the University of California both in resource policy (1978) and in economics (1981); Grauer Lecturer n the University of British Columbia; and 1982 Distinguished Visiting Professor in the University of Colorado. In 1980-81 he served on the Energy Research Advisory Board of the U.S. Department of Energy. He has briefed five heads of state, testified to legislative and regulatory hearings in eight countries, and published a dozen books and over a hundred technical and popular papers.

Mr. Lovins's clients have included several U.N. agencies, the OECD, the International Federation of Institutes for Advanced Study, the MIT Workshop on Alternative Energy Strategies, Resources for the Future, ERDA, OTA, Petro-Canada, the Science Council of Canada, the Government of Lower Saxony, the Governments of Alaska, Montana, and California, and others in the public and private sectors.

The Lovinses have long taken a special interest in the problems of electric utilities, and work with utility managers and regulators in about thirty states and several foreign countries. They have been invited reviewers of utility analyses for the Secretary of Energy and the U.S. General Accounting Office, and have addressed such groups as the Administrator and top management of Bonneville Power Administration, the Corporate Planning Committee of Edison Electric Institute, a strategic planning workshop of the American Public Power Association, and utility conferences sponsored by E.F. Hutton, the California PUC, and the Institute for Resource Management.

The Lovinses were 1982 Henry R. Luce Visiting Professors at Dartmouth College, and have performed research contracts for the German Federal Environmental Agency and the U.S. Defense Civil Preparedness Agency. Their 16mm film "Lovins on the Soft Path" has received blue ribbons at four film festivals. The Lovinses are Policy Advisors to Friends of the Earth, sit on a wide variety of boards and committees, and give about a hundred lectures each year. Mrs. Lovins is currently President and Executive Director, and Mr. Lovins is Director of Research, of Rocky Mountain Institute (Drawer 248, Old Snowmass CO 81654), a nonprofit foundation exploring the connections between energy, water, agriculture, security, and economic development.

Attachment 2

The Approximate Short-Run Marginal Capital Cost of a US Nuclear Power System

© Amory B. Lovins, 15 November 1983

Economic assumptions: Constant 1983 US$ throughout.
$1.04 (1983) = $1.00 (1982) (est. GNP deflator); $1.282 (1982) = $1.00 (1979); $1.508 (1982) = $1.00 (1977)[a]

Engineering assumptions: Average light-water reactor of ca. 1 GWe net output; 10-year construction time (shorter than current); 30-year operating lifetime (longer than likely); 0.55 levelized lifetime capacity factor[b]; 6.91% grid loss[c].

Financial assumptions[d]: standard 1982 US private-electric-utility accounting with capitalization 50% debt, 15% preferred, 35% common.
Real %/y costs of money: 2.3 debt, 2.8 preferred, 6.3 common; discount rate 3.7 (5-5.5 would be more realistic).
Total net Federal and state income taxes 50%; property tax and insurance 2%; no net salvage value; 8.5%/y inflation.
Resulting parameters: real fixed charge rate/y 11.6% (year 1), 9.1% (30-y levelized); 30-y present-valued multiplier to pay debt & equity returns, taxes, & insurance: x1.641 (with tax preferences, x1.231)[e].

Cost assumptions: Nuclear plant, including land, construction to startup:
Direct construction cost = $2,000/net installed kWe[f]
Interest-during-construction multiplier: x1.206[g]
Total plant cost: $2,000 x 1.206 = $2,412/kWe
Initial core: $75/kWe[h]
Net capital additions: $1,243/kWe[i]
Incremental grid investment: $574/kWe installed[j]
Incremental investment in front-end fuel-cycle facilities for reload fuel: $136/kWe installed[j]
Decommissioning: $68/kWe[k]
Waste transportation facilities: $10/kWe[m]
Waste storage/disposal facilities: $100/kWe[m]

Total capital cost for complete system: $4,618/kWe net installed
÷ 0.55 capacity factor = $8,396/kWe sent out
÷ 0.9309 for grid loss = $9,020/kWe delivered
x 0.091/y ÷ 8766 h/y = 9.4¢/kW-h capital charge (real)

Assuming fuel costs ca. 0.6¢/kW-h, nuclear plant operating and maintenance costs ca. 0.8¢/kW-h, and grid O&M costs ca. 0.3¢/kW-h (all consistent with empirical US values at the short-run margin), this whole-system capital cost implies a levelized delivered electricity price (at 9.1%/y real fixed charge rate) of ca. 11.1¢/kW-h real, equivalent in terms of heat content to oil at $179/barrel, or about six times the mid-1983 world oil price. Adding back the assumed inflation rate to get nominal 1983 dollars makes the electricity price 19.8¢/kW-h (heat-equivalent to over $320/bbl). In fact, the delivered electricity price from new US reactors being commissioned in 1982-84 ranges from about 7¢ to over 20¢/kW-h.

The assumptions, believed to be realistic or conservative, omit capital cost of reserve margin (often equivalent to about a third of nuclear capacity because the plants are both large and unreliable); costs of security, R&D, and regulation; and externalities such as occupational exposures, all risks of accidents or sabotage, and the proliferation of nuclear bombs.

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Notes

a. This is the Handy-Whitman Nuclear Production Plant Deflator for the typical North Central region of the United States. That index is a weighted average of specific inflation in factor costs for nuclear plant construction.

b. The cumulative average capacity factor to date for all U.S. commercial nuclear power plants >800 MWe is 0.545, based on original design ratings.

c. Average U.S. grid loss from plant busbar to all final purchasers (EIA data).

d. Electric Power Research Inst., Technical Assessment Guide 1982, P-2410-SR.

e. Since this analysis assesses social internal cost, it is computed without tax subsidies; ref. d, Appendix A, Table VI_{NO}. A 10% investment tax credit, and the 10-year tax life in the 1981 tax act, socialize/subsidize 64% of the cost-of-money multiplier, making delivered nuclear electricity look ca. 1/5 cheaper.

f. This is the average of U.S. utilities' mid-1983 estimates of actual completion cost for all reactors now under construction and due to be commissioned in or after 1982. The figure, based on detailed utility survey data, was supplied by economist Charles Komanoff, Komanoff Energy Associates, 451 Broome St, 11th floor, New York NY 10013, who also provided helpful comments on this paper.

g. This applies the Comtois formula for 10 years at a low 3.7%/y real interest.

h. Assuming a 1-GWe PWR with:

Initial design enrichment 2.63% ^{235}U; tails assay 0.3%; thermal efficiency 0.325; capacity factor 0.55; burnup 33 GWt-d/TU; 3-y refueling interval.

Carrying charge 3.7%/y real, with lead times of 3 y for yellowcake production and conversion, 1.5 y for enrichment, and 0.6 y for fabrication.

Prices as assumed for 1985 by USDOE (Energy Information Administration, Projected Costs of Electricity from Nuclear and Coal-Fired Power Plants, DOE/EIA-0356/2, p. 56), converted from 1980 to 1983 $ by 1.206 GNP deflator, yielding (in 1983 $) $41/lb U_3O_8, $6.9/kgU conversion, $150/SWU enrichment, and $183/kgU fabrication).

i. Present value of a stream of expenditures for refurbishment of a single salt-water-cooled reactor commissioned in 1985. The annual values for years 1-15 are derived from a multiple regression on 49 US nuclear plants during 1970-80; all explanatory variables have confidence levels >99.8%. (Energy Systems Research Group, Report 83-14/B, Ch. 4, July 1983 [120 Milk St., Boston, Mass. 02109]). Annual values are assumed constant in years 15-25, declining to zero in year 30. The first-year value assumed, $29/kW, compares with the $24.7/kW (1983 $) actually incurred by the average US nuclear plant in 1980 alone; and during 1970-80, net capital additions per kWe increased (id.) by 15.9%/y real.

j. From 1978 Bechtel Corporation data documented by A.B. Lovins in notes 20-21, "Bechtel Cost Data," Science 204:129 (1979) (q v. generally).

k. This assumes that decommissioning costs 10% of original direct construction cost, and is multiplied by 0.34, i.e. discounted for 30 years at 3.7%/y real. USDOE estimates are generally around 5% (see pp. 273 and 271m in C. Komanoff, Power Plant Cost Escalation (1981), ref. f), but USDOE in 1980 confirmed that a detailed industry estimate of $167/kWe (undiscounted 1983 $) is "representative of the most current...estimates" for dismantlement--the method favored by USNRC (see USEIA, Nuclear Power Regulation, DOE/EIA-0021/10 [1980], Tables 16 & 17). The California Energy Commission assumes that 10% of original cost is realistic. The latest industry study, by Pennsylvania Power & Light Co. for its Susquehanna 1 plant, shows 6.2%. Some expert estimates are much higher; the only empirical data, from such reactors as Elk River (which ran at 20 MWe for only four years), suggest that decommissioning costs about 24% of original capital cost.

m. Author's estimate of present value, consistent with a capital charge of about $0.0013/kW-h, well within the generally accepted range. The US General Accounting Office has estimated that waste transportation and permanent disposal, assuming no need for interim storage, will cost, in undiscounted 1983 $, about $373/kgU (Comptroller General of the US, Economic Impact of Closing Zion Nuclear Facility, 21 October 1981), equivalent to about 0.15-0.21¢/kW-h at nominal burnups; this cost includes both capital and operating components, but is probably at least 90% capital cost. The author believes these cost estimates will probably prove to be much too low.