Addresses

Energy in Transition: A View from 1960

*Hans H. Landsberg**

Twenty-one years ago, Resources for the Future (RFF), then about ten years old, released a heavy tome of a little over a thousand pages, half text and half statistical appendix, called *Resources in America's Future*. Together with my two coauthors, Leonard L. Fischman and Joseph L. Fisher, RFF's president at the time, I had put considerable effort into the project. So had fifteen staff members and consultants and eight research assistants. To the best of my knowledge, none of them ever revisited the scene after 1963, and if they did, they didn't tell the world. We hold no reunions, observe no anniversaries. Still I have never quite freed myself of a degree of curiosity, best phrased as "how did we come out?" My own copy of the book bears the scars of that curiosity. It is full of penciled-in figures, put there in different years, without much orderliness. Once in a while, a current event would cause me to do some quick figuring, some comparison shopping. But it has all been quite unsystematic.

Two things have kept me from tackling the job as a proper project. The first is that I cannot convince myself that there is a breathless audience waiting out there, consumed with curiosity about the results of "projected vs. actual." Thus, one would have to find a rationale other than personal curiosity, such as "What can we learn from the exercise?" Second, a systematic review would be a costly enterprise. Since the original venture predated the emergence of the computer age by a few years, one would have to do a great deal of dreary data gathering and manipulating, especially as much of the original structure rested on data fabricated, in the good sense, for the purpose of providing detail and facilitating the intro-

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duction of technological and other information and conjecture. The cost of that approach, of course, is a large area of noncomparability that has developed over time.

When I was given IAEE's award and informed that the cost of accepting it was delivery of a learned paper, I toyed briefly with the idea of putting a little time into looking at the energy projections for 1980 and lining them up against the 1980 facts; but it was only when it turned out that the occasion was to be a luncheon speech that I made up my mind to select this topic. In the midst of presenting and/or listening to serious research papers, after a pleasant meal, I figured I could use the occasion to satisfy my own curiosity, to pay the price of admission, and to give you a chance to relax.

With this preface, permit me to give you some of the results of my labors and suggest a few conclusions. I shall state the first conclusion even before mentioning a single number, and that is the enormous extent to which one is a captive of the time of writing or calculating, typically without realizing it. Take population: year-to-year growth had ranged between 1.7 and 1.8 percent in the 15 years that preceded our study. By one of those flukes of history, that nice continuity broke in 1962 (while we were reading page proofs, so to speak), and by 1968 this statistic had slipped to 1.0. Our group did not make its own population projection; it selected the "most likely" of the then available Census projections, which essentially had population grow at a compound 1.5 percent rate. Consequently, our population of 245 million by 1980 overshot the actual number by nearly 20 million (see Table 1).[1]

I suspect we did not stop to question the numbers both because of the eminence of the source and because we were impressed by the fact that the most authoritative projections made in the decade following the end of World War II had all greatly *under*estimated growth. In the text we cite a 1950 Census population projection for 1958 that undershot the mark by a full 10 million in only one decade. By 1990, *our* error, of course, will get greater, probably overstating the U.S. population by some 40 million, and I won't even talk about the year 2000. But even as I say that, I recognize that I am probably no less influenced by recent trends and recent thoughts about future trends than we were 25 years ago.

1. In this and all other tables, the projected (RFF) figures are taken from Landsberg, Fischman, and Fisher (1963). Note also that in this, as in the other tables, the reader will find divergences between RFF and "actual" numbers in the base year. Why should this be so? There are several reasons. For one, not all 1960 data were "final" when the manuscript was completed. Second, there have been changes in concept and/or definition since 1960; and, third, many of the data have undergone substantial revision since 1960. The apparent base-year inconsistency could have been avoided by showing only the percentage changes, in which case the base year number would have been immaterial, but it seemed more informative to report also the actual numbers and face the inconvenience.

Table 1. Demographic Parameters

		1960	*1980*	*Change (%)*
Population (millions)	RFF	179.9	245	36.2
	Actual	180.7	227.7	26.0
Labor force (millions)	RFF	72.8	102	40.1
	Actual	71.5	108.5	51.7
Participation rate (%)				
Total	RFF	57.6	57.8	0.3
	Actual	59.4	63.8	7.4
Male	RFF	79.8	78.4	−1.8
	Actual	83.3	77.4	−7.1
Female	RFF	36.3	38.3	5.5
	Actual	37.7	51.5	36.6
Households (millions)	RFF	52.6	73.0	38.8
	Actual	52.8	80.8	53.0

Source: RFF figures are from Landsberg, Fischman, and Fisher, Table A1-2. Actual figures are from *Statistical Abstract of the United States* (1984).

By the nature of population dynamics, our error was concentrated in the young age groups, those aged 14 or below. That was, in a way, fortunate, because that segment of the population did not figure as a base for many other estimates (such as drivers of cars, members of the labor force, and so on). Incidentally, I was amused to read the following sentence in our book (pp. 71–72): "The past history of population projections, compared with the actual course of events, gives one limited grounds for confidence." Amen.

How about the other big parameter, gross national product? Together with its components, GNP served as an important workhorse for a large number of projections. (See Table 2.) Here we look exceedingly good—that is, when we focus on *total* GNP. Our projections had GNP rise by 110 percent from 1960 to 1980. In fact, it rose 115 percent. Not a large discrepancy over a 20-year period, and one that virtually vanishes when cast in terms of annual compound growth rates (3.8 versus 3.9 percent per year). This happy result is the more remarkable in that the error has the opposite sign from the population projection error, where we *over*shot actuality. The explanation here lies in our substantial underestimation of the growth in the labor force, basically because we completely failed to foresee the rise in the female participation rate. While we had anticipated an increase in that rate of 2 percentage points between 1960 and 1980, the actual increase was no less than 14 percentage points. As a consequence, the actual labor force rose to 108 million in 1980, or 6 million above our projection (Table 1).

We thus missed two important trends: the rise in women's labor market participation rate and the decline in the growth of productivity. Expressed

Table 2. Gross National Product (billions of 1972 dollars)

		1960	*1980*	*Change (%)*
GNP	RFF	710	1495	110
	Actual	685	1475	115
Personal consumption expenditures	RFF	444	893	101
	Actual	452	932	106
Private domestic investment	RFF	96	224	132
	Actual	105	209	100
Government purchases	RFF	172	416	142
	Actual	128	284	122
GNP per capita ($000)[a]	RFF	3.95	6.11	55
	Actual	3.79	6.49	71
GNP per member of labor force ($000)[a]	RFF	9.76	14.65	50
	Actual	9.58	13.59	42

Source: RFF figures are from Landsberg, Fischman, and Fisher (1963), Tables A1–12, adjusted to 1972 dollars. Actual figures are from *Statistical Abstract,* Table 735.

[a]Population and labor force taken from Table 1.

in terms of GNP per member of the labor force, our projections had that relationship rise by just over 50 percent in the 20-year span; in fact, it rose by only a little over 40 percent.

Still, to the quick reader, we look good; more importantly, this happenstance of nearly offsetting errors helped greatly,, quite beyond what our ormer only slightly, and grossly overestimated private domestic investment, which we calculated to grow by 132 percent, whereas in reality it only doubled. We had anticipated what I can only describe as a sustained construction boom. By 1980, the level of annual residential construction was to reach 2.7 million housing units—quite a difference from a market that has limped along at an average of less than 1.4 million units between 1960 and 1980. (This error is even more remarkable in that we substantially underestimated household formation, and should thus have *under*-projected construction. The number of households went from 52.6 million in 1960 to 80.8 million in 1980, but our projection for 1980 was only 73 million. The unforeseen event here was an enormous rise in single-person households.)

The error in household formation illustrates again, I believe, the "captive imagination" syndrome, the inability to break out of conventional thinking molds, in this instance, household formation patterns. On the other hand, our rampant construction projections—our GNP construction item also ran way ahead of reality—were rooted largely in our conviction that the nation simply needed a lot of housing, quite beyond what our

notion of population growth alone would have justified. I believe the error here was not to distinguish sufficiently between "needs," as judged by the researchers, and likely "demand." Our failure to be demand-minded rather than requirement-minded may have misled us in other instances but hurt us most, I believe, in the housing projections.

The net outcome was that our undervaluation of the personal consumption expenditure segment of GNP was almost wholly offset by our overestimation of investment and government purchases, to give us the "almost correct" GNP.

To complete my sketch of the major variables we needed, let me say a word about our projection of the Federal Reserve Board's production index (Table 3). The picture here is very much the same as with GNP. In the aggregate, an astonishing closeness of projection and reality; in the components, wide divergence. Our projected overall index rose by 131 percent, the real index by 123 percent. Not bad for a 20-year span. As for the components, they are all over the place. We projected durable manufacturing to rise at 154 percent; in reality it climbed only 117 percent. Nondurables made up by rising 133 percent, against our low target of 101 percent. It gets worse the more one disaggregates. We thought transportation equipment would rise by 232 percent; it rose by a measly 80 percent. We thought rubber and plastics manufacture would rise by 200 percent; it rose by about 400 percent. As a matter of curiosity I should tell you that the statistics portraying the projection of the production index and its components take up 24 pages in the book, including 63 footnotes. We may have been wrong, but we were not lazy.

So much for major general parameters. What about our energy projec-

Table 3. Federal Reserve Board Index of Production, Selected Components

	Rate of Change 1960–1980 (%)	
FRB Index	*RFF*	*Actual*
Total	131	123
Manufacturing	135	126
Durables	164	117
Nondurables	101	133
Mining	72	66
Utilities	155	167
Transportation equipment	232	80
Rubber and plastics	200	392
Lumber	97	59
Food	69	90
Primary metals	87	42

Source: RFF figures are from Landsberg, Fischman, and Fisher (1963), Tables A1–29. Actual figures are from *Statistical Abstract*, Table 1368.

Table 4. Energy Consumption by Source (quads)

	1960		1980		Change (%)	
	RFF	*Actual*	*RFF*	*Actual*	*RFF*	*Actual*
By Source						
Coal[a]	11.10	10.80	15.77	17.79	42	60
Oil	19.35	19.92	32.91	34.20	70	72
Gas	13.26	12.39	24.15	20.39	82	65
Hydro	1.65	1.66	2.64	3.12	61	88
Nuclear	—	0.01	3.72	2.74	—	—
Total	45.35	45.23[b]	79.19	79.63[b]	75	75

Source: RFF figures are from Landsberg, Fischman, and Fisher (1963), Table A15–19. Actual figures are from *Annual Energy Review, 1983*, Table 1.

[a]Including exports.

[b]Adjusted for noncoal exports and "other."

tions? Off the bat, I have to tell you that from our 1960 base, we projected total energy consumption, including exports, to rise to 79.2 quads in 1980. We were wrong. It rose not to 79.2 but to 79.6 quads (Table 4). I have been in possession of this piece of information for some time, and I still don't know what to make of it, though I have slowly come to convince myself that we must have done something very wrong—otherwise how could we get the right answer when we have gone through a decade of great changes in the energy field, none of which entered our heads or calculations? To put it differently, had we done things right, we should have properly derived a number that turned out to be wrong.

I am only half joking, and, as you will see, things are not that simple. Indeed, once again, we smell like a rose because of offsetting errors. This holds true for consumption by *sector* of use as well as for consumption by *source* of energy. To illustrate, we were less sanguine on coal, having it grow by 42 percent instead of 60 percent; more sanguine on gas, having it grow by 82 percent instead of 65 percent; and oddly, we were nearly right on, of all things, oil—a highly counterintuitive outcome, largely explained by our transportation projections.

Let me look first at the user rather than the source. Here, it turns out, we underestimated the residential and commercial segment, largely because commercial use took off just about in 1960 (Table 5). We had relied heavily on an historically very stable ratio between commercial and residential use and saw no reason not to project that relationship into the future. It was our bad luck that the continuity broke after 1960. We substantially overestimated industrial energy use, in line with our overestimate of the investment component of GNP and of durables in the Federal Reserve Board index. As I have already mentioned, all the errors washed out and gave us the correct number of quads in 1980.

Table 5. Energy Consumption by Consuming Sector (quads)

	1960		1980		Change (%)	
	RFF	*Actual*	*RFF*	*Actual*	*RFF*	*Actual*
Residential and commercial	12.85	13.05	21.11	25.65	64	97
Industry	15.95	20.10	29.10	30.56	66	52
Transportation	9.19	10.60	18.53	19.69	102	86
Other	7.85	—	10.44	—	—	—
Exports and adjustments	—	1.81	—	3.72	—	—
Total	45.35	45.56	79.19	79.62	75	75

Source: RFF figures are from Landsberg, Fischman, and Fisher (1963), Table A15–18. Actual figures are from *Annual Energy Review, 1983*, Tables 1 and 4.

We modestly underestimated the growth of transportation, including automobiles (Table 6). Our method of deriving the future stock of cars was simple. We looked at past changes in the relationship between the number of vehicles and the size of the population segment aged 20 years or more, noted a steadily declining trend, projected that declining trend into the future, and multiplied by our population projection. Between 1930 and 1960, the number of persons aged 20 and over per automobile had dropped from 3.3 to 1.86. Our projection put it at 1.26 in 1980 and gave us a stock of cars in that year of 120.2 million. The actual stock in that year was 121.7 million, so we came out just about right. Considering that there were only about 60 million cars, or half as many, on the road in 1960, there was considerable leeway for error here.

I was intrigued enough to look a little further. The good news is that our 20+ population projection was very close to the 1980 position, obviously because those aged 20 and over in 1980 were born in 1960 and earlier, and the actual people/car ratio continued to decline as we had assumed, from 1.86 in 1960 to 1.26 in 1980, exactly matching our projection. The bad news is that we erred significantly in estimating both automobile purchases and production. We had pegged the former at 14 million in 1980, whereas the actual turned out to be 9 million. We projected domestic production at 12.6 million vs. an actual 6.4 million. We overshot production because we held imports steady at 10 percent throughout the 40 years. You know the actual situation. I have not been able to detect the flaw in our purchase projections, a flaw that seems more puzzling since we have hit the 1980 stock figure so well. It is quite possible, though, that we underestimated purchases in earlier years, overestimated them in later years, and came out all right in 1980, or that we overestimated replacement demand. I must add, parenthetically, that single-year figures often can be misleading. Car sales in 1977–79 averaged 11.0 million units

Table 6. Motor Vehicles, Selected Variables

		1960	*1980*	*Change (%)*
Automobiles				
Stock of cars (millions)	RFF	59.3	120.2	102
	Actual	61.7	121.7	97
Miles/vehicle (thousands)	RFF	9.9	9.8	−1
	Actual	9.45	9.14	−3
Vehicle miles (billions)	RFF	588	1178	101
	Actual	588	1130	92
Miles per gallon	RFF	14.3	14.3	0
	Actual	14.5	15.2	5
Gallons/vehicle/year	RFF	645	675	−3
	Actual	661	603	−9
Fuel consumption (million bbl)	RFF	981	1933	97
	Actual	981	1755	79
Car purchases (millions)	RFF	7.0	14.0	100
	Actual	6.6	9.0	36
Car production (millions)	RFF	6.7	12.6	66
	Actual	6.7	6.4	−4
Car imports (millions)	RFF	0.5	1.4	180
	Actual	0.5	2.4	380
Population 20+/car	RFF	1.86	1.26	−32
	Actual	1.79	1.26	−30
Stock of trucks (millions)	RFF	11.6	23.0	98
	Actual	11.9	33.6	183
Fuel (all vehicles) (billion bbl)	RFF	1.38	2.82	104
	Actual	1.38	2.74	99

Source: RFF figures are from Landsberg, Fischman, and Fisher (1963), Tables A5-2, A5-10, and A5-15. Actual figures are from *Statistical Abstracts, 1984*, Tables 1063, 1073, and 1074, and *Annual Energy Review, 1983*, Tables 48 and 49.

before they went into a tailspin in 1980, 1981, and 1982. Still, they were never near 14 million in any year. Nor are they likely to climb to 20 million, our heroic projection for 1990.

With regard to replacement demand, there is evidence that owners have been hanging on to their cars longer. In 1960, 43 percent of the stock in use was at least six years old. By 1980, that proportion had risen to 50 percent. As you would expect from the poor sales record, the figure was still higher in 1982, 52 percent. Still, the contrast between our simplistic approach to total registration and the good result, and the rather complicated way in which we estimated purchases, with poorer results, is somewhat unnerving. Finally, the straightforward assumption of a constant 10 percent import share was just plain wrong, but again, the idea of the United States becoming a large importer of automobiles was not anything we even fleetingly considered, and I doubt that, in 1960, anyone else did. Incidentally, when I look at our 1990 stock projection of

169 million vehicles, I am certain that we will have grossly overstated the number of cars for that year.

How well did our good guess at the number of automobiles serve us to project energy consumed in transportation? Did "conserving" since 1973 mess us up? It did, but only modestly. As you might expect, again in the spirit of the time, we held miles per vehicle and miles per gallon constant. We did declare that the pre-1960 deterioration of efficiency had come to an end (actually it did not do so until 1974) and that efficiency from now on was likely to be constant at the higher level of 14.5 miles per gallon (mpg). Instead, by 1980 it had climbed to 15.32 mpg and, as you know, continues to rise. Thus we overestimated 1980 fuel consumption for cars by about 10 percent, or one-half million barrels per day, not an inconsiderable amount. In the future, given our assumption of static fuel efficiency and steeply rising stock of automobiles, our projections will diverge increasingly from reality.

A quick review of other transport media reveals that we greatly underestimated the advance in air travel—passenger miles rose sevenfold against our projection of threefold—but the effect of that misjudgment is not significant in terms of energy use. More importantly, we correctly tagged the continuing decline in rail travel and the increase in rail freight, but greatly underprojected the expansion of trucking. We thought the number of trucks on the road would double, but it almost tripled.

Our projections for 1980 of total fuel consumed by all motor vehicles come astonishingly close to the facts; increasing from the 1960 base of 1.38 billion barrels to 2.82 billion, versus 2.74 billion barrels actually consumed. We projected a 104 percent rise, and the actual was a 99 percent rise. In the face of rather profound changes in the fuel market, this is again surprisingly close; as before, the aggregate outperforms the components. Still, I would not take any bets, even for the aggregate, from here on in.

Let me next turn to our ideas about electricity (Table 7). This particular source of energy—unlike total energy—has grown much faster than GNP. To begin with a summary, we underprojected electricity; utility sales were estimated to rise by 181 percent, but actually rose by 204 percent. Within the aggregate, demand sector projections differed widely. We undershot residential consumption by some 20 percent, while commercial consumption rose 60 percent above our projection. Only industrial use behaved just about as we had thought.

It is easy to see why we so underestimated commercial energy consumption: we postulated a fixed relationship to residential electricity consumption, whereas commercial began a steep climb in 1960 relative to residential consumption. Offices, shopping centers, all manner of nonresidential, nonindustrial consumers expanded rapidly. Also, since the "commercial"

Table 7. Electricity Consumption by User (billion kWh)

		1960	*1980*	*Change (%)*
Residential	RFF	193	594	208
	Actual	201	717	255
Commercial	RFF	113	308	173
	Actual	131	488	272
Industry	RFF	415	1,037	150
	Actual	356	889	150
Other	RFF	42	149	255
	Actual	—	—	—
Total	RFF	753	2,014	167
	Actual	—	—	—
Utility sales	RFF	665	1,869	181
	Actual	688	2,094	204
Utility generation	RFF	757	2,084	175
	Actual	756	2,286	204
kWh/Household	RFF	3,669	8,137	
	Actual	3,807	8,873	

Source: RFF figures are from Landsberg, Fischman, and Fisher (1963), Table A15-1. Actual figures are from *Annual Energy Review 1983*, Table 87.

Note: RFF breakdown includes self-generated.

designation in electricity statistics is a rate classification and includes large apartment houses, the shift in housing patterns probably contributed.

It is harder to discover the reason for underprojecting residential use. The fact the actual number of households exceeded our projection by about 10 million probably helped, even though many of these additional households were single-person and therefore relatively low-use units, and perhaps were largely located in apartments and metered as commercial. All told, per-household use of electricity exceeded our estimate for 1980 by 10 percent. On the other hand, we were quite successful in divining the direction, if not the actual magnitudes, in future household penetration rates of gas and electricity. To illustrate (Table 8), we courageously projected electricity's share in heating to rise from a mere 2 percent in 1960 to 12 percent in 1980. It rose even more steeply, to over 17 percent. We projected oil's share to decline from 30 to 21 percent. It dropped even more, to 18 percent. We did best in projecting the share of natural gas. We had it rise from 41 to 54 percent; it rose just 1 percentage point more. Further down the line, we somewhat overestimated the spread of the heat pump and grossly underestimated that of central air conditioning.

On the whole, our technological hunches turned out not only to point in the right direction but also to be of reasonable magnitude: electricity moving up fast, oil sliding back, and natural gas moving upward steadily

Table 8. Selected Residential Energy Uses, by Source (% of total)

		1960	*1980*
Home heating			
Oil	RFF	30	21
	Actual	32.4	18.1
Gas	RFF	41	54
	Actual	43.1	55.4
Electricity	RFF	2	12
	Actual	1.8	17.7
Other	RFF	27	13
	Actual	22.7	8.8
Main cooking fuel			
Electric	RFF	32.3	51.0
	Actual	—	53.7
Natural gas	RFF	67.7	49.0
	Actual	—	40.1
Main water-heating fuel			
Electric	RFF	30	41
	Actual	—	56.1
Natural gas	RFF	70	59
	Actual	—	31.9

Source: RFF figures are from Landsberg, Fischman, and Fisher (1963), Tables A10-8, A10-12, and A10-13. Actual figures are from *Annual Energy Review, 1983*.

but less rapidly than electricity. What preserved us, I believe, from greater error was the habit of looking regionally and taking price relationships into account.

The main purpose of our effort was not to make demand projections but to test the adequacy of U.S. resources to meet anticipated demand. Our findings in that respect were reassuring. The study's key comment was that "required energy should be available in the pattern projected at substantially constant real costs through 1975 or thereabouts. In the last two decades of the century, energy supply problems may arise for oil and gas." We further suggested that any oil and gas stringencies would be alleviated by (1) the increasing contribution of nuclear energy, which would begin to gain momentum in the 1970s and would account for half of all electricity by 2000; (2) oil from shale and tar sands; (3) conversion of coal into high-Btu gas and liquid fuel; and (4) imports of both oil and gas, which were viewed—remember, we were in 1960—as price-moderating items. We discounted any significant contribution from solar, wind, and geothermal.

Imports apart, these judgments appear to have stood up quite well. A couple of footnotes: first, the terms conservation and efficiency in connection with energy appear only episodically and without special emphasis; second, pollution turns up only in the discussion of water resources. In

1960, efficiency was incidental, and energy did not pollute, at least not in the literature. End of footnotes.

You must have been wondering, as I paraded these comparisons before you, whether there are any general conclusions, findings, or lessons, or whether this is just a hobby, an excuse for keeping busy. My answer comes in several parts.

My first observation is that extrapolation is not quite the mindless, primitive approach it is often made out to be (provided it is not straight-line, but then it rarely is). Barring sudden breaks, the past is indeed prologue, and even over a 20-year span, study of past trends and relationships, combined with accounting for likely new developments, either visible or thought probable for definable reasons, can yield good results. Momentum is a very respectable phenomenon. So is capital stock. Examples include the relative rise of electricity, and within it the rapid move toward electric heating; the decline in oil-fired electricity as well as oil-fed home heating; the slowdown in the nation's growth of automobile stock, which gave us a number barely over 1 percent away from that actually recorded in 1980; and the shrinkage of passenger rail traffic.

Second, our most notable misses were in areas where changes in efficiency were involved. Power-plant heat rates provide an intriguing illustration. The number of plants doing better than 10,000 Btu/kWh had risen from 2 in 1950 to 83 in 1960, leading us to venture that "this is perhaps the least shaky of the many projection bridges we have to cross." Thus we argued that in time the bulk of the nation's power plants would come to emulate the most efficient ones we knew (Table 9). One was AEP's coal-fired Breed plant, which generated at 8800 Btu per net kWh. Consequently, we stipulated a continuous improvement in the average heat rate, then hovering at about 10,800, to an impressive 9100 Btu per kWh by 1980.

Nothing has happened to justify this guess (Figure 1): the 1980 heat rate was around 10,500, or only modestly better than the 1960 level. The error obviously led us to underestimate fossil fuel demand for 1980. It will be much worse for our 1990 and 2000 projections. In the latter year we

Table 9. Electricity: The Heat Rate (Btu per kWh)

		1960	*1980*	*Change (%)*
Coal	Actual	10,550	10,350	−2
Gas	Actual	11,330	10,520	−7
Oil	Actual	11,460	10,380	−9
Total	Actual	10,760	10,388	−3.5
	RFF	10,860	9,100	−15

Source: RFF figures are from Landsberg, Fischman, and Fisher (1963), Table A15-10. Actual figures are from *Historical Plant Cost, 1983*, p. 94.

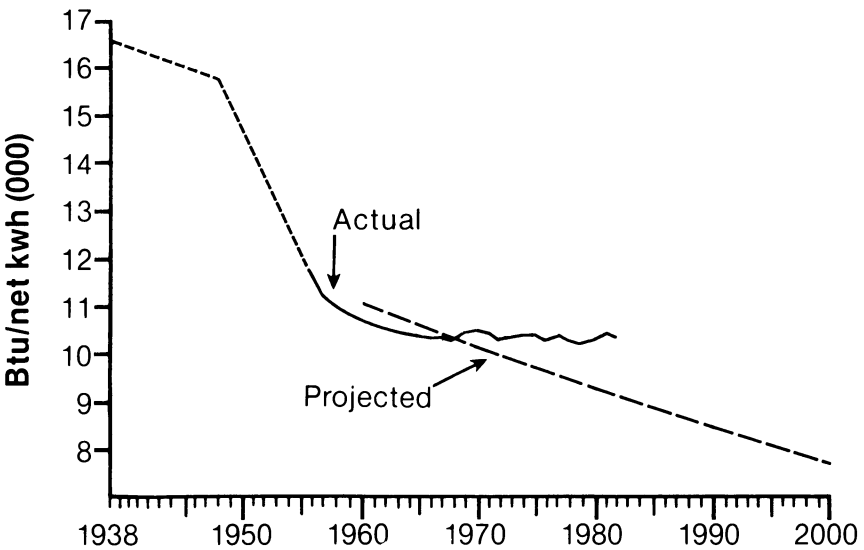

Figure 1. The heat rate (fossil-fuel steam electric utility plants).

stipulated a rate of 7500 (technically wholly feasible, I should add). Among the reasons for this divergence are the lower efficiency of nuclear plants; the diversion of power toward antipollution operations; disillusionment with high fuel-efficient plants; and the slower replacement of older, inefficient plants. I am certain there are others. Indeed, there must be others, for some I have mentioned would have operated only in the last 10 to 12 years.

As I have shown, the opposite effect held for automobiles, where we foresaw no movement toward higher efficiency. Indeed, efficiency had declined before 1960, so our only nod in the direction of efficiency was to assume that the decline had probably come to an end. Consequently, we stipulated a constant mpg number (14.5) for the balance of the century. The lesson is that thoughtful extrapolations do not protect from misreading the future. They do make it easier to track errors, as time passes.

In the overall source picture (Table 4), our projection of coal demand fell short by 12 percent, for oil by only 4 percent. We overprojected natural gas by 18 percent. We underestimated hydro, an error that was more than compensated for by overshooting nuclear power generation. The latter projection was something of a tour de force, since at the time of writing there was virtually no nuclear power production, thus no trend to extend or modify. We based our 40-year projection on likely regional cost differentials and arrived at generation of 400 billion kWh in 1980, a level about 80 percent higher than was achieved. Of course, we were in

excellent company. Leafing through the relevant pages of our book I noted that an authoritative Atomic Energy Commission estimate at that time gave nuclear power 38 percent of the electricity market in 1980. That would have worked out to nearly 900 billion kWh, close to a 300 percent overshoot!

The magnitude of our projected nuclear generation will move increasingly away from reality, rising to 770 billion kWh in 1985, to 1200 billion kWh by 1990, and twice that number by the end of the century. Having written a book rather than an annually revised report, we were less lucky than our fellow projectors in government agencies and commissions, who could adjust periodically and bury their tracks as time went on. Still, I have always thought that the 1980 estimate, projected from a zero base, was quite respectable.

Whether over a 20-year period these are minor or major failures I leave to others to judge. Compared with the magnitude of errors in short-term forecasts, they seem minor. John Lichtblau was recently quoted as saying, "Like all oil market forecasters during the 1970s, I've been traumatized by the experience of seeing 5- or 10-year projections rendered obsolete within the year they are made by seemingly irreversible unforeseen events." One positive aspect of these projections is that we projected both from the top down and from the bottom up. Thus we can pretty well trace the reason for the misjudgments, as I have tried to do for you here today. Transparency and documentation seem to me highly desirable elements of any projection. I don't know the lesson to be drawn here except, of course, to construct a wide band of scenarios, but that has always seemed a rather evasive practice to me, the more the worse.

My third observation: divining the future correctly in the aggregate can be quite an ego trip, but its usefulness depends largely on the question one seeks to answer. Nor can you bank on offsetting errors. Errors can also be compounding. As mentioned earlier, our 1980 total energy consumption projection, including exports, reads 79.2 quads versus an actual consumption of 79.6 quads. What bothers me, of course, is that given some radically new developments, including the oil price revolution and the emergence of environmental concerns that affect almost all forms of energy, we should not have come so close.

I begin to feel a little better about it when I look at the subaggregates and at the two past decades separately. While the total looks good, it does so only because the components often err in opposite directions and in roughly offsetting proportions. We underprojected coal and hydro, overprojected gas and nuclear, and got oil about right. We underestimated personal consumption expenditures but overestimated both investment and government purchases, with total GNP coming out just a little lower than reality.

Our petroleum projections, to select just one energy source, approximate reality closely: our projected rise over the 20-year period was 67 percent, the actual rise 74 percent. Once again, the explanation lies in offsetting over- and undervaluations of the constituent parts. We underestimated both the 1980 stock of automobiles (by 1.5 million, out of a total of 120 million) and miles per gallon, but overprojected miles per vehicle, with the result that we overshot fuel consumption for all road vehicles in 1980 by 5 percent. Even that modest error was in turn offset by our greatly underprojecting oil use in power generation (at least in 1980; by 1983 we were in line), as oil use by utilities continued its sharp drop from its all-time high reached in 1977, declined in industry, and, though this is hard to trace, in jet fuel.

A fourth observation is that any given year is only a stopping point on a continuum. As shown in Figure 2, in 1970 we were lagging behind reality. By 1980, slowdowns had pulled down trends sufficiently for us to be on target or above. I am certain that by 1990, and much more so by 2000, our projection will be unreasonably above trend. I need only mention that for 1990 our energy number is 102 quads. For 2000, it is 135. No way!

The course of the economy has something to do with this. Fortunately, 1960 and 1980 are reasonably comparable. The economy hit a peak in

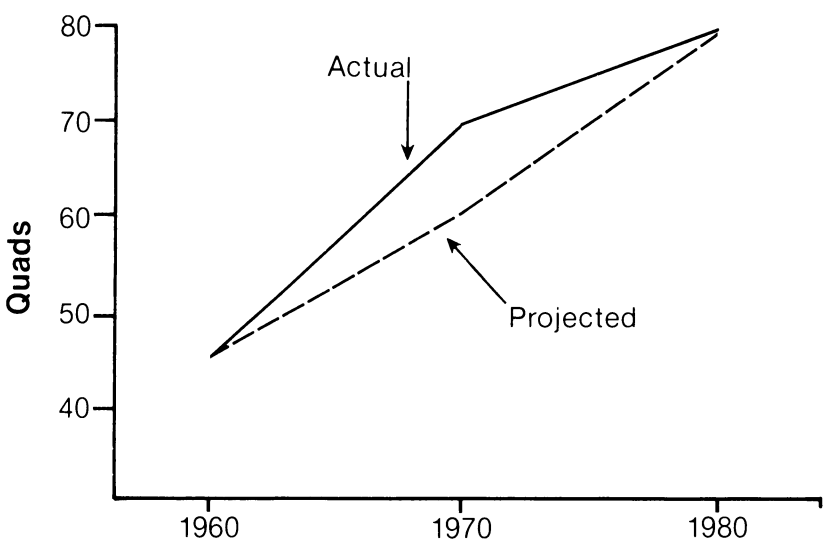

Figure 2. U.S. energy consumption, 1960, 1970, 1980.

April 1960, so it had four up and eight down months, and on the whole was not a prosperity year. In 1980, the economy hit a peak in January, then turned down. 1980 thus was worse than 1960, but both had a peak early on. One might cure this problem by moving to a three-year average, but for my purposes this was frosting on the cake. More important and less curable is the fact that the 1960s saw the longest expansion period in modern times: 106 months, a rise beginning in February 1961 and not ending till December 1969. The 1970s experienced 27 months of contraction and 94 of expansion. It was the poorer performance of the economy in the 1970s that helped keep our projections from lagging far behind reality.

Fifth, and this more pedestrian wisdom hit me especially hard as I labored preparing this talk, it is advisable to stick with major, easily accessible statistical series that have a fair chance of survival, so that you—and others—can track the estimates. We carried ingeniousness to excess by modifying old and inventing new series that now, after 20 odd years, have no counterpart in the published statistical record, making comparison often exceedingly difficult or wholly infeasible and, in any event, costly.

Sixth, and finally, over a time span as long as 20 years, there do occur events that are simply unforeseeable. I have mentioned the oil shock and environmental concern. These are not the only ones. Opposition to nuclear power was not visible in the late 1950s, nor were its technical complexities. An indirect technological factor has been the intrusion of automobile imports into the U.S. market. Thus we correctly estimated the stock of cars but grossly overstated domestic production.

So much for 20/20 hindsight or insights, if that is what they are. When they first were published, our projections were severely criticized for being too heavily oriented to technology and too feebly rooted in an economic context. Specifically, the role of price was said to be grossly neglected. Much of that criticism was to the point, but even if we could have managed this massive task if we had factored in prices, I have come to wonder what good it would have done us. Indeed, it might have caused us real trouble. In no way would we have guessed at the sextupling or better of real oil prices, with prices of other energy sources rising by hefty percentages. Neither recent inflation nor high interest rates would have surfaced in our projections, nor the profound ups and downs in the foreign exchange value of the dollar and their consequences for foreign trade. We did, of course, consider prices, mostly in allocating demand among the different energy sources and among their counterparts in terms of energy-using capital assets; but prices were never a major parameter. Moreover, because we were intent on testing for the adequacy of resources, we rationalized that making price adjustments would simply

remove the target of our exercise. On the whole, though, we were just fortunate.

I see no solution to these dilemmas, no matter whether one employs a plodding, inelegant approach, as we did, or a modern sophisticated one (computerized, etc.). No matter how disguised in equations, judgments on all of these future developments have to be injected, and it is the imponderables that ruin projections. Perhaps a major lesson is that 20—let alone 40—years is far too long a period for which to make assumptions that stand a fair chance of remaining valid.

Just consider the many questions in the energy field that are waiting for answers in the next 20 years:

Will nuclear energy resume its growth? Will there be breakthroughs on the breeder and on fusion?

Will solid-to-gas and solid-to-liquid conversion become commercially viable? For coal? For shale? If so, when?

Will solar make inroads or continue to serve only specialized markets?

Will the price of oil resume its upward movement? If so, how soon?

Will the developing countries put increasing pressure on energy supplies? If so, how soon?

When and at what cost will we have clean-burning coal?

Will the efficiency of the U.S. automobile climb above the government-mandated 27.5 mpg? How far and how soon?

I am sure you can add more questions to this illustrative catalog. Each introduces a major uncertainty into a projection of the future, quite apart from those that affect the economy as a whole and its component parts.

Perhaps what hit me the most as I thumbed my way through the book was how stable the world was 25 years ago when we constructed these projections, and how even a 20-year projection has benefited from the force of that stability. It is altogether possible, perhaps even likely, that once again I cannot escape from the spirit of the times when I judge that the balance of the century holds far greater uncertainties and is much more subject to destabilizing influences than was true in the past two decades, oil shock and pollution of the 1970s notwithstanding. Even if it were a likelihood, I would not want to stand here 20 years from now and review our year 2000 projections. Momentum, too, has its limits.

I close with a footnote. Following the completion and publication of the project in April 1963, we approached various government agencies, basically through what was then the Budget Bureau, to interest them in taking over the apparatus we had put together and maintaining it by updating. Our offer was rejected. I have always thought that this was regrettable. As a glimpse into the innards of this venture may have shown you, it has a good deal of merit. It could and would have been greatly

improved with modern approaches. What persuaded government to turn away was (1) the insistence of each agency affected that it be allowed to lay down its own framework and (2) the fear that maintaining any such comprehensive structure in a strategic location of government would give it undeserved and, more important, undesirable prominence and legitimacy, bordering on central planning. Perhaps it is preferable to have the Bureau of Mines, Department of Energy, Department of Agriculture, and all manner of agencies, commissions, and congressional committees, go off on their own. What they lack, however, is the discipline of a coherent framework. Recent attempts to move in that direction, especially in the wake of *Global 2000*, are interesting. The 98th Congress even had a bill before it, HR 3070, "The Critical Trends Assessment Act," whose purposes included identifying and analyzing "critical trends and alternat-
iing
ht Roundtable meets in Washington to keep the idea alive. But I doubt the times are propitious for such undertakings.

I don't know how useful these kinds of retrospective observations are to you. Perhaps, it occurs to me, those of you who teach and are looking for student term paper topics could do worse than to pick up one of those projections and call for a critical review. You might also consider all this just another kind of Trivial Pursuits—perhaps not even that, because losing carries no penalty, winning no reward, and there is even a question whether there are any "right" answers. Nonetheless, if more of us once in a while took time out to review our past output, it might produce a healthy sense of self-discipline in our profession.

REFERENCES

Annual Energy Review, 1983 (1984). Washington, D.C.: U.S. Department of Energy, Energy Information Administration, DO/EIA-0384(83).

Historical Plant Cost and Annual Production Expenses for Selected Plants, 1983 (1984). Washington, D.C.: U.S. Department of Energy, Energy Information Administration, D0E/EIA-0455(82).

Landsberg, Hans H., Leonard L. Fischman, and Joseph L. Fisher (1963). *Resources in America's Future.* Baltimore: Johns Hopkins Press.

Statistical Abstract of the United States (1984). Washington, D.C.: U.S. Department of Commerce, Bureau of the Census.