EIA and CHP: What Is Going On?

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ABSTRACT

In December, 2002, the Energy Information Administration (EIA) released its *Annual Energy Review, 2001* (hereafter AER01) with extensive revisions to both the electricity data and the categories under which the data are reported. The basics of these revisions are explained in Appendix H, "Estimating and Presenting Power Sector Fuel Use in EIA Publications and Analyses" (which can be downloaded from the "Appendices and Glossary" link). This revision was timely and eliminated the growing "adjustments" that reconciled the discrepancy between the sum of fuels consumed by the four end-use sectors and the electricity sector with the total energy consumed by the four end-use sectors (i.e., with electricity losses allocated back to the four end-use sectors). This adjustment jumped from almost nothing in 1988 to 128 trillion Btu (TBtu) in 1989 and grew to a half-quadrillion British thermal unit (quad) by 1998. In 1999 it was -3.2 quad and in 2000, as reported in the AER 2000, it was -4.3 quad. After revisions, the adjustment nearly disappears, with the largest adjustment over the period 1989-2001 at 10 trillion Btu (TBtu). Even with these revisions, however, there are still some very strange numbers. This paper explains these revisions and accounting techniques, and tries to reconcile some of the data via an appeal to the detailed Independent Power Producer survey, EIA Form 860b, for 1998 and 1999.

Introduction

Prior to the revision reported in the AER01, EIA reported electricity according to whether power was produced by a utility or a nonutility power producer (a class of producers, including cogenerators, small power producers, and independent power producers) that EIA began reporting separately in 1989.[2] In a footnote related to electricity system losses, the AER 2000 parenthetically reported that nonutility direct use of electricity and nonutility sales of electricity to end users were allocated totally to the industrial sector. That is to say, all cogeneration plants were assumed to belong to the industrial sector, and fuel use was considered consumed by that end-use sector.

While this seems a reasonable assumption, and for several years did not create any serious reporting problems, as the electricity industry continued to restructure, errors began to grow. The growth of these errors shows up dramatically in Table 2.1a in AER 2000, "Energy Consumption by Sector, 1949-2000." The table reports "primary" and "total" energy consumption for the four end-use sectors (primary is total fossil and renewable energy used; total adds in purchased electricity and electricity system losses). The primary energy consumption for the four end-use sectors plus the primary energy consumption for the

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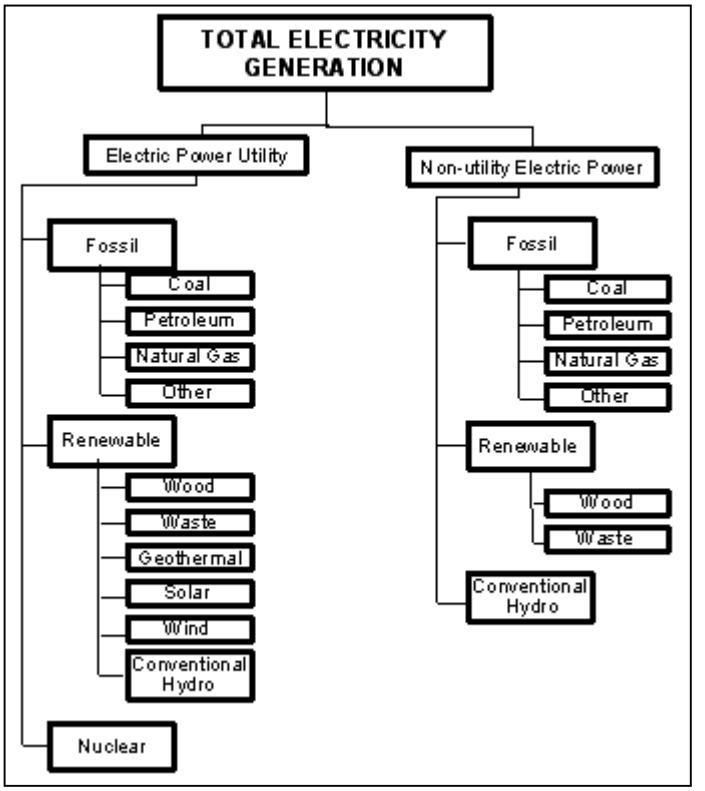
[2] In 1985, EIA stopped reporting institutions that generated power primarily for their own use (universities, military establishments, and cogenerators) as part of the electricity statistics. It is clear from Appendix H of AER01, that sometimes cogeneration was reported as part of the electric power sector.

electricity sector should add to the sum of the "total" energy for the four end-use sectors. But it does not. To reconcile total primary energy consumption with the total consumption for the four end-use sectors required an "adjustment" equal in 2000 to -4,291 TBtu – this is equivalent to 4.4% of total primary energy consumption for the economy. These adjustments were virtually nil prior to 1989. After the break out of nonutility generators, they grew from 128 TBtu in 1989 to 533 TBtu in 1998, then declined to -3,237 TBtu in 1999. The adjustment a year later was nearly a quadrillion Btu lower.

With the revisions reported in AER01, power generation and fuel consumption is now reported separately for electric-only generators and by combined heat and power (CHP) generators – those generators that also provide heat to a customer. This division is more consistent with the current structure of the electricity industry, although some of these CHP plants provide heat only to themselves and one of the CHP sectors is considered part of the electric power sector. This is in sharp contrast to separating the electricity sector into "utility generators" and "non-utility generators" as was the case before the revision. The prior structure is shown in Figure 1, below; the current structure of reporting is shown in Figure 2, below.

Figure 1. EIA Electricity Reporting Prior to Revisions

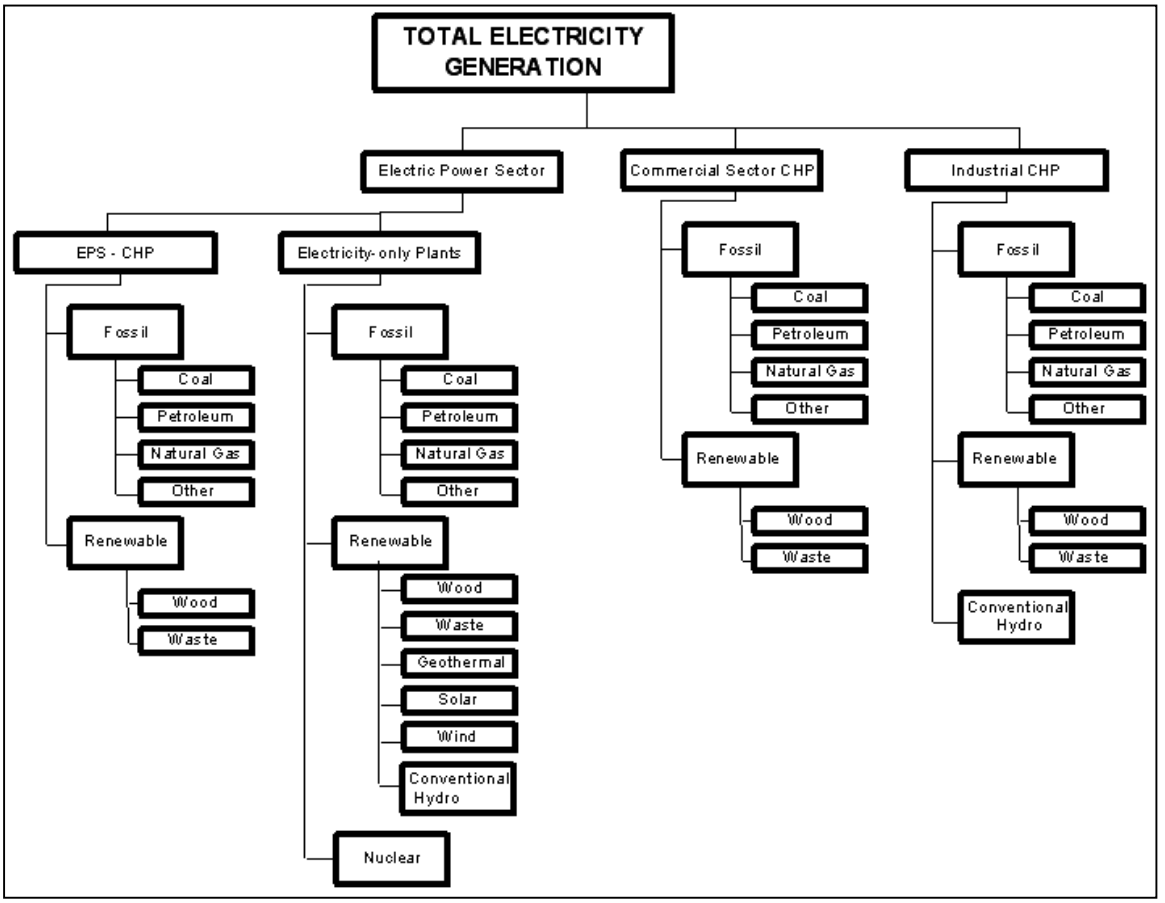


The advantage to this approach is that now there is scrupulous accounting for fossil and renewable fuels used by the commercial and industrial sectors for production of heat and power which was not the case before. It was this lack of appropriate accounting, most likely, that gave rise to the very large adjustments prior to the revision. While these revisions have eliminated the need for large "adjustments" in the data, some problems remain. The major

problem is determining efficiency when two products are jointly produced. CHP produces heat and power jointly, so there is an arbitrary element of how efficiencies are assigned to the production of heat (steam) and power. It is here that we believe a much better job could have been done. We return to this point later.

The paper is organized as follows. The next section describes the changes that underlie the revision in AER01 (as explained in Appendix H of that publication). This description is followed in the third section by a close examination of the combined heat and power (CHP) data reported in Chapter 8 of AER01, the electricity chapter. Electricity production and fuels for both electricity production and useful thermal energy are reported in tables 8.2a-d and 8.3a-e if the electricity chapter. The implied efficiencies for useful thermal output in these tables seem high, given the explanation in Appendix H. The heat rates for electricity production are a residual, and these seem consistent with the explanations. These efficiencies prompted a look at some of the underlying data. Section four examines data from the nonutility power generation survey for 1998 and 1999, focusing just on those power producers that provided electricity to the industrial sector. In section five we draw some tentative conclusions from this data and suggest ways these discrepancies can be resolved.

Figure 2. Current Structure of Electricity Generation as Reported by EIA



EIA Revisions as Reported in Appendix H

Appendix H makes it abundantly clear that EIA has gone to considerable effort to improve the estimates of power production, especially for CHP. The reporting is now more consistent with the restructured electricity sector, and places CHP plants in one of three end-use sectors. By carefully identifying which industries use the output from CHP plants, the classification of end-use sectors is also improved.

Section IV of Appendix H, "Electric Power Surveys and Publications," explains the methods used to revise the data. All CHP plants have been identified separately, and classified according to which industry receives the power and useful thermal energy produced. If, for example, the CHP plant is associated with a hospital, it is classified as a commercial CHP plant; if it sells its power and useful thermal energy to a paper mill, it is classified as an industrial facility.

For recent years (1998-2001), EIA reviewed data from facilities with heat rates for power production outside the range of 5,500 to 40,000 Btu/kWh, and all plants with efficiencies greater than 100%. Where discrepancies could not be resolved from the survey, calls were made to the establishment to why these discrepancies were reported. Where reports were outside this range in earlier years, the numbers were adjusted to be consistent with resolved data. To allocate fuel between power production and useful thermal output, they used a standard engineering device: they assumed an efficiency for one (thermal output) and calculated the other efficiency (power) as a residual.

It is difficult to allocate fuel use to power production and useful thermal energy, because these are joint products. The technique used by EIA to make this split is straightforward: EIA assumes that steam is produced in a boiler that operates at 80% efficiency, so all useful thermal output divided by 0.8 indicates the fuel used to produce that thermal energy, and all remaining fuel is used to produce electricity. While this is a reasonable approximation, it exaggerates the efficiency of some industrial processes; for example, a furnace burning black liquor or wood wastes would operate at considerably lower efficiency because the fuel has a much higher moisture content than does fossil fuel. Given this explanation, one would expect that all fuel used to produce thermal output divided into useful thermal output would be approximately 0.8.

It is reasonable to make these assumptions, and EIA is to commended for a thorough analytical effort to make sense of data that, by itself, does not appear to make sense. Nonetheless, these assumptions skew the efficiencies for the CHP sectors by not taking into account individual sector considerations; specifically, the efficiency of biomass boiler in the industrial sector. The next section examines the data reported in Chapter 8 of AER01.

CHP Data Reported in Chapter 8

Tables 1 through 3, below, summarize the data from Chapter 8. Table 1 shows production of power for the electricity sector and for all of the CHP sectors (in the electric power sector, in the industrial sector, and in the commercial sector) on a Btu basis. Column 2 of Table 1 shows net generation converted from kWh to trillion Btu for all sectors, column 3 shows the portion of this produced by the electric-only sector, with the difference being "Total CHP Electricity" shown in column 7. Columns 8-11 show the useful thermal output for the three CHP sectors separately and in total, and columns 12-15 show the sum of power

and useful thermal output for the three CHP sectors and the total. It is worth noting that in 2001, the useful thermal output was about of half of electricity output for the electricity sector but three times the power production for the commercial sector and nearly 4 times the electricity production for the industrial sector.

Table 2 reports the consumption of combustible fuels for the electricity only sector and each of the three CHP sectors that correspond to electricity production, useful thermal output, and total. These numbers, along with those of Table 1, are used to calculate the numbers shown in Table 3, the efficiencies for production of power, useful thermal output, and in total.

The numbers in Table 3 are of interest for several reasons. Given the explanation in Appendix H, Section IV, one would expect that the numbers in columns 8-11 to be 80%, but they are not, quite. With a large fraction of CHP in the industrial sector generating useful thermal output from waste wood and black liquor, one would expect these numbers to be smaller than for the other sectors, but this is not, generally, the case. They are larger than for the commercial sector in 7 of 13 years and larger than the electric power sector in 6 of 12 years (one year a tie). By the same token, given that the 80% rule is used in industry, one would expect that CHP electricity production would be at a lower efficiency than for the other sectors since the thermal output is too high. This is the case comparing industry and the electricity sector, but not comparing industry with the commercial sector – in 12 years of 13, industry efficiency of electricity production is higher than for the commercial sector, with the 13th year a tie.

And overall, one would expect that industry, with its large, and more direct, steam requirements and its more intensive energy management experience, would have the highest overall efficiency, and that is clearly the case, as shown in columns 12-15. Overall efficiency for the industrial sector is typically about 5% higher than for the commercial sector and about 16% higher than for the electricity sector.

In an effort to understand these differences, we examine the EIA 860b survey results, as we explain in the next section. To telegraph our findings, we can only say that the work that EIA did to clean up the numbers, which was beyond the scope of this project, may account for the differences that we found in the reported data. Without this cleaning up of the data, one needs to purge a large portion of the responses for them to make much sense.

Table 1. Net Generation - Electricity Sector

All Sectors, Electricity Only, CHP Electricity, and CHP Useful Thermal Output - Trillion Btu

Year	All Sectors	Elec-tricity Only	CHP Electricity				CHP Useful Thermal Output				CHP Combined			
			Electric Power Sector	Comm-ercial	Indust-rial	Total CHP Electricity	Electric Power Sector	Comm-ercial	Indust-rial	Total CHP Thermal	Electric Power Sector	Comm-ercial	Indust-rial	Total CHP Thermal
1989	10,122	9,572	145	15	391	550	114	38	1,437	1,589	259	52	1,828	2,139
1990	10,319	9,683	201	19	416	636	133	43	1,548	1,724	334	62	1,964	2,361
1991	10,483	9,767	246	19	452	717	140	50	1,674	1,863	385	69	2,126	2,580
1992	10,525	9,703	312	21	489	822	167	57	1,752	1,976	478	78	2,241	2,798
1993	10,912	10,020	369	24	499	892	173	59	1,771	2,003	541	83	2,270	2,895
1994	11,084	10,120	422	26	516	963	195	62	1,863	2,120	617	88	2,379	3,084
1995	11,445	10,419	483	28	515	1,026	203	63	1,886	2,152	686	91	2,402	3,179
1996	11,755	10,709	500	31	515	1,046	213	73	1,897	2,184	713	104	2,413	3,230
1997	11,919	10,858	506	30	526	1,061	221	86	1,920	2,227	727	116	2,446	3,288
1998	12,356	11,275	525	30	526	1,081	222	82	1,965	2,269	747	112	2,491	3,350
1999	12,610	11,517	530	29	533	1,093	238	78	1,978	2,294	768	107	2,511	3,387
2000	12,977	11,853	562	27	535	1,124	249	82	1,971	2,302	811	109	2,506	3,425
2001	12,695	11,574	583	25	512	1,121	278	78	1,949	2,305	861	103	2,461	3,426

Table 2. Consumption of Combustible Fuels During Production of Heat and Power – By Energy Sector

All Sectors, Electricity Only, CHP Electricity, and CHP Useful Thermal Output - Trillion Btu

Year	All Sectors	Elec-tricity Only	CHP Electricity				CHP Useful Thermal Output				CHP Combined			
			Electric Power Sector	Comm-ercial	Indust-rial	Total CHP Electricity	Electric Power Sector	Comm-ercial	Indust-rial	Total CHP Thermal	Electric Power Sector	Comm-ercial	Indust-rial	Total CHP Thermal
1989	22,278	20,742	375	47	1,131	1,553	141	47	1,767	1,955	515	95	2,898	3,508
1990	22,285	20,472	529	60	1,243	1,832	164	53	1,912	2,130	693	113	3,155	3,961
1991	22,437	20,387	658	59	1,357	2,073	173	61	2,070	2,305	831	120	3,427	4,378
1992	22,688	20,367	842	64	1,438	2,343	208	71	2,163	2,442	1,050	135	3,601	4,785
1993	23,581	21,110	991	70	1,429	2,490	214	74	2,185	2,473	1,205	144	3,614	4,964
1994	24,067	21,389	1,147	75	1,477	2,699	243	78	2,304	2,625	1,390	152	3,781	5,324
1995	24,306	21,486	1,260	83	1,500	2,843	251	78	2,329	2,658	1,511	161	3,829	5,501
1996	24,966	22,027	1,304	95	1,565	2,964	263	91	2,350	2,703	1,567	185	3,915	5,667
1997	25,746	22,856	1,318	93	1,506	2,917	276	104	2,386	2,766	1,593	197	3,892	5,683
1998	26,967	24,096	1,327	89	1,492	2,909	275	99	2,458	2,832	1,602	188	3,950	5,740
1999	27,178	24,258	1,342	91	1,516	2,948	293	96	2,453	2,841	1,635	187	3,968	5,790
2000	28,423	25,447	1,408	82	1,514	3,005	307	102	2,441	2,850	1,715	184	3,955	5,855
2001	28,036	25,056	1,456	78	1,472	3,006	343	97	2,413	2,854	1,799	176	3,885	5,860

Table 3. Net Energy Generated/Combustible Fuel Consumed During Production of Heat and Power in the Electricity Sector

All Sectors, Electricity Only, CHP Electricity, and CHP Useful Thermal Output

Year	All Sectors	Elec-tricity Only	CHP Electricity				CHP Useful Thermal Output				CHP Combined			
			Electric Power Sector	Commer-cial	Indust-rial	Total	Electric Power Sector	Commer-cial	Indust-rial	Total CHP	Electric Power Sector	Commer-cial	Indust-rial	Total CHP Thermal
1989	45.4%	46.1%	38.6%	30.7%	34.6%	35.4%	81.3%	79.9%	81.3%	81.3%	50.2%	55.3%	63.1%	61.0%
1990	46.3%	47.3%	37.9%	32.3%	33.5%	34.7%	81.2%	80.6%	81.0%	81.0%	48.1%	55.1%	62.3%	59.6%
1991	46.7%	47.9%	37.3%	32.9%	33.3%	34.6%	80.8%	81.0%	80.9%	80.9%	46.4%	57.5%	62.0%	58.9%
1992	46.4%	47.6%	37.0%	33.4%	34.0%	35.1%	80.2%	80.4%	81.0%	80.9%	45.6%	58.2%	62.2%	58.5%
1993	46.3%	47.5%	37.2%	34.0%	34.9%	35.8%	80.5%	80.3%	81.0%	81.0%	44.9%	57.8%	62.8%	58.3%
1994	46.1%	47.3%	36.7%	34.9%	34.9%	35.7%	80.3%	80.1%	80.9%	80.8%	44.3%	57.9%	62.9%	57.9%
1995	47.1%	48.5%	38.3%	33.8%	34.4%	36.1%	80.9%	81.1%	81.0%	81.0%	45.4%	56.7%	62.7%	57.8%
1996	47.1%	48.6%	38.3%	32.6%	32.9%	35.3%	81.0%	81.2%	80.8%	80.8%	45.5%	56.4%	61.6%	57.0%
1997	46.3%	47.5%	38.4%	31.9%	34.9%	36.4%	80.3%	82.4%	80.5%	80.5%	45.6%	58.6%	62.8%	57.9%
1998	45.8%	46.8%	39.5%	33.5%	35.3%	37.2%	81.0%	82.9%	79.9%	80.1%	46.6%	59.5%	63.1%	58.4%
1999	46.4%	47.5%	39.5%	32.2%	35.2%	37.1%	81.3%	81.1%	80.6%	80.7%	47.0%	57.3%	63.3%	58.5%
2000	45.7%	46.6%	39.9%	32.8%	35.3%	37.4%	81.0%	80.3%	80.8%	80.8%	47.3%	59.1%	63.4%	58.5%
2001	45.3%	46.2%	40.0%	32.1%	34.8%	37.3%	81.0%	80.3%	80.8%	80.8%	47.9%	58.8%	63.4%	58.5%

The 1998-1999 EIA 860B Survey

There are four surveys from EIA that are available for analysis, but only two of these provide the data to allow some understanding of what EIA did in the course of its revision of the electricity data. Those are the surveys for 1998 and 1999 before the survey changed. These data sets contain a number of different files, including information on the technologies used to produce electricity and both energy consumed as part of the production of electricity and useful thermal energy. But these data are erratic and one begins to understand how much effort EIA put into cleaning up this data set.

Table 4, below, shows the results of compiling the raw data into categories that correspond to the data reported above, in Tables 1-3. While the instructions indicate that the data are reported in kWh for electricity production and the consumption of fuel is reported in millions of Btu, if you accept that as gospel, the efficiencies are bazaar. None of the calculated efficiencies, for over 1089 industrial plants in both 1998 and 1999 is above 3%. But if the data are treated as both Btu of output, the results are more sensible. With this as an operating assumption, the efficiencies are reported below for different categories of efficiency.

Table 4. Fraction of Plants Reporting Different Efficiencies

Implied Efficiency	>1	<0.1	0.1<>0.15	0.15<>0.9	0.9<>1	Average
Power Only	0.225	0.113	0.076	0.498	0.086	0.606
Power + heat	0.233	0.112	0.073	0.491	0.090	0.6051

Nearly a quarter of all plants reported efficiencies of greater than 1; clearly the laws of physics have something to say about this, and it casts some doubt that this could occur. Over 11% of reporting plants showed efficiencies of under 10%, which certainly is possible, but probably not very economic. Nearly 8% of plants reported efficiencies of between 10% and 15%, which includes the 40,000 Btu/kWh region (8.5%) that EIA included in its analysis. But the bulk of plants, nearly 50%, fell within the 15% to 90% range, which when stated in heat rates, falls between 3792 Btu/kWh and 22,747 Btu/kWh. Clearly the lower limit is too low, the higher limit is probably too high. It is also interesting to note that nearly 9% of plants report efficiencies between 90% and 100%, which, when combined with the first category, suggest that nearly 30% of all plants are violating the laws of physics.

We singled out the plants that used either wood wastes or black liquor as reported technologies in their reporting to see if the supposition, stated above, of lower efficiencies for these plants was consistent with the reporting. What we found, by now to no surprise, was that the efficiencies of these plants was over 63%, even higher than the average for all plants.

Conclusions

Unraveling what is really going on in CHP is difficult, and maybe not completely possible. That EIA has queried plants to see what they really did to produce the power and useful heat says a lot for their tenacity and persistence. And while we think the entire

analytical community can thank EIA for this effort, there is one troubling aspect of the analysis. The efficiencies of steam production vary, depending on the technologies use to raise steam and the fuels used. By adopting a blanket assumption about the efficiency of steam production, the contribution of more efficient technologies is ignored and thus cannot be accounted for. Moreover, the fuel mix will most certainly also affect the efficiency of steam production, with the reliance on biomass in the industrial sector a particularly concern. By not accounting for differences in technologies and fuel types, EIA has reduced the value of efficiency calculations to the point where only the "CHP combined" efficiencies can be relied upon.

A Note about the Data

All the data for this analysis, both the electricity data from the *Annual Energy Review, 2001*, and the survey results for form 860B can be found at EIA's website, www.eia.doe.gov.

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