Appendix C-4

Electric Advanced Technology Description

One of the Electric Sector policies is a change in the level of technological progress through enhanced R&D. The changes are largely made in the ecpdat input file for CEF-NEMS. The model has two forms in which capital costs, operating cost, and heat rates can be entered: either has a single value that may have factors applied to it over time, or as an array of values based on the year of construction.

For fossil technologies, capital costs were entered as the overnight capital cost for the nth of a kind plant (in 1987$/kW). A technical optimism factor raises the cost of the first few plants, declining until the nth plant is reached. A contingency factor is also added to the cost. Following the nth plant, capital costs decline based on a learning curve factor and the amount of capacity constructed. Fixed and variable operating and maintenance (O&M) costs may be added as an array (as done for the sequestration options) or as a single value. The changes for the fossil technologies are shown in the three tables below: C-4-1, C-4-2, and C-4-3.

Table C-4-1 New Fossil Technology Parameters in CEF-NEMS

Technology	Scenario	Capital Cost, 1997 $/kW[a]	Technical Optimism[b]	Contin-gency Factor	Fixed O&M, 1997 $/kWyr	Variable O&M, 1997$/MWh
Integrated Coal Gasification Combined Cycle	BAU	1018	1.16	1.072	31.8	0.78
	Mod	880	1.16	1.072	30.9	0.68
	Adv[d]	880	1.16	1.072	30.9	0.68
IGCC with Sequestration	BAU					
	Mod					
	Adv	880	1.16	1.072	30.9	9.0-8.0[c]
Advanced Gas Combined Cycle	BAU	375	1.12	1.08	14.1	0.51
	Mod	322	1.12	1.08	14.1	0.51
	Adv[d]	322	1.12	1.08	14.1	0.51
Advanced Gas CC with Sequestration	BAU					
	Mod					
	Adv	322	1.12	1.08	14.1	5.0-4.0[c]
Advanced Gas Combustion Turbine	BAU	309	1.12	1.051	8.9	0.10
	Mod	266	1.12	1.051	8.9	0.10
	Adv	238	1.12	1.051	8.9	0.10
Fuel Cell	BAU	1389	1.16	1.05	14.6	2.0
	Mod	1194	1.16	1.05	14.6	2.0
	Adv	952	1.16	1.05	19.6	0.27

[a] Capital cost for 5th plant of this type. Earlier plants have technical optimism and learning factors that raise the capital cost. Later plants have lower cost due to learning factors. CEF-NEMS actually uses 1987$/kW; to convert divide this value by 1.343.
[b] The factor that the capital cost is raised for the first plant above the 5th plant. The costs for the 2nd through 4th have this value decreased and is set to 1.0 for the 5th plant.
[c] Sequestration technologies use costs of advanced technology plus $50/tonne C to cover cost of sequestration. Variable costs are raised based on heat rate and fuel type of plant.

Table C-4-2 Fossil Technology Heat Rate Schedules for each Scenario

	IGCC			Adv. Gas Combine Cycle		
	BAU	Mod	Adv	BAU	Mod	Adv
2000	8333	8325	8285	6927	6919	6868
2001	8197	8179	8101	6870	6852	6735
2002	8060	8034	7916	6812	6786	6602
2003	7924	7888	7732	6754	6720	6470
2004	7787	7743	7547	6696	6653	6337
2005	7651	7597	7363	6639	6587	6204
2006	7514	7452	7178	6581	6520	6071
2007	7378	7306	6994	6523	6454	5938
2008	7241	7161	6809	6465	6388	5805
2009	7105	7015	6625	6408	6321	5672
2010	6968	6870	6440	6350	6255	5539
2011	6968	6870	6365	6350	6255	5406
2012	6968	6870	6290	6350	6255	5273
2013	6968	6870	6215	6350	6255	5140
2014	6968	6870	6140	6350	6255	5007
2015	6968	6870	6065	6350	6255	4874
2016	6968	6870	5990	6350	6255	4874
2017	6968	6870	5915	6350	6255	4874
2018	6968	6870	5840	6350	6255	4874
2019	6968	6870	5765	6350	6255	4874
2020	6968	6870	5690	6350	6255	4874

Table C-4-3 Fossil Technology Heat Rate Schedules for each Scenario

	Adv. Gas Combust Turbine			Fuel Cell		
	BAU	Mod	Adv	BAU	Mod	Adv
2000	9133	9093	9013	5787	5760	5760
2001	9020	8972	8810	5744	5712	5712
2002	8907	8851	8608	5702	5664	5664
2003	8793	8729	8405	5659	5617	5617
2004	8680	8608	8202	5617	5569	5569
2005	8567	8487	8000	5574	5521	5521
2006	8453	8365	7916	5531	5473	5473
2007	8340	8244	7833	5489	5425	5425
2008	8227	8123	7749	5446	5377	5377
2009	8113	8001	7666	5404	5329	5329
2010	8000	7880	7582	5361	5281	5281
2011	8000	7880	7582	5361	5281	5281
2012	8000	7880	7582	5361	5281	5281
2013	8000	7880	7582	5361	5281	5281
2014	8000	7880	7582	5361	5281	5281
2015	8000	7880	7582	5361	5281	5281
2016	8000	7880	7582	5361	5281	5281
2017	8000	7880	7582	5361	5281	5281
2018	8000	7880	7582	5361	5281	5281
2019	8000	7880	7582	5361	5281	5281
2020	8000	7880	7582	5361	5281	5281

The CEF-NEMS model uses either a method of specifying the values for two different years and then extrapolating between them for other years, or entering an array of annual values. Both methods were used in the analysis; the tables C-4-2 and C-4-3 show the values as arrays to assist in comparisons.

Fossil fuel parameters for the BAU scenario are the same as used by EIA in the AEO99. For the Moderate scenario, the values used by EIA in their High Technology sensitivity were used. For the Advanced scenario, personnel of the Office of Fossil Energy were queried as to the appropriate values given an enhanced push towards higher efficiencies of new technology. The values used (Table C-4-4) are consistent with, if not slightly lower than, the Vision 21 program plan (DOE/FE 1999).

Table C-4-4 Fossil Technology Efficiencies in 2020 for Advanced Scenario

Technology	Heat Rate	Efficiency
Int. Coal Gas Combined Cycle	5690	60%
Adv. Gas Combined Cycle	4874	70%
Adv. Gas Combustion Turbine	7582	45%
Fuel Cell	5281	65%

Figures C-4-1 to C-4-4 show the capital costs as output by CEF-NEMS for each advanced fossil technology. It includes the effects of learning, technical optimism, and regional cost variations. These figures are based on the average of capital costs for each region of the country for each year weighted by the amount of capacity added in that year. Consequently, regional variations in cost get incorporated into the weighted average and the cost can go up or down between years depending on the region that the capacity was added. The graphs for technologies that had essentially no capacity added (e.g., IGCC and fuel cells), simply show the values for one region.

Fig. C-4-1 Capital Costs for Advanced Gas Combined Cycle Capacity Including Regional Variations

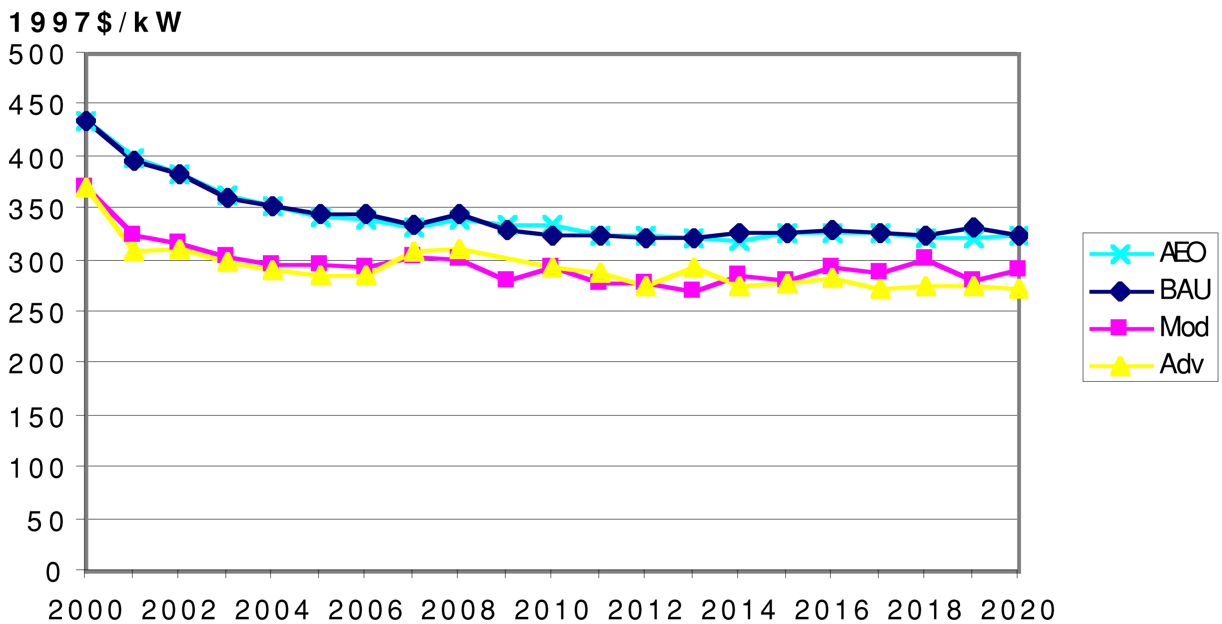


Fig. C-4-2 Capital Costs for Advanced Gas Combustion Turbine Capacity Including Regional Variations

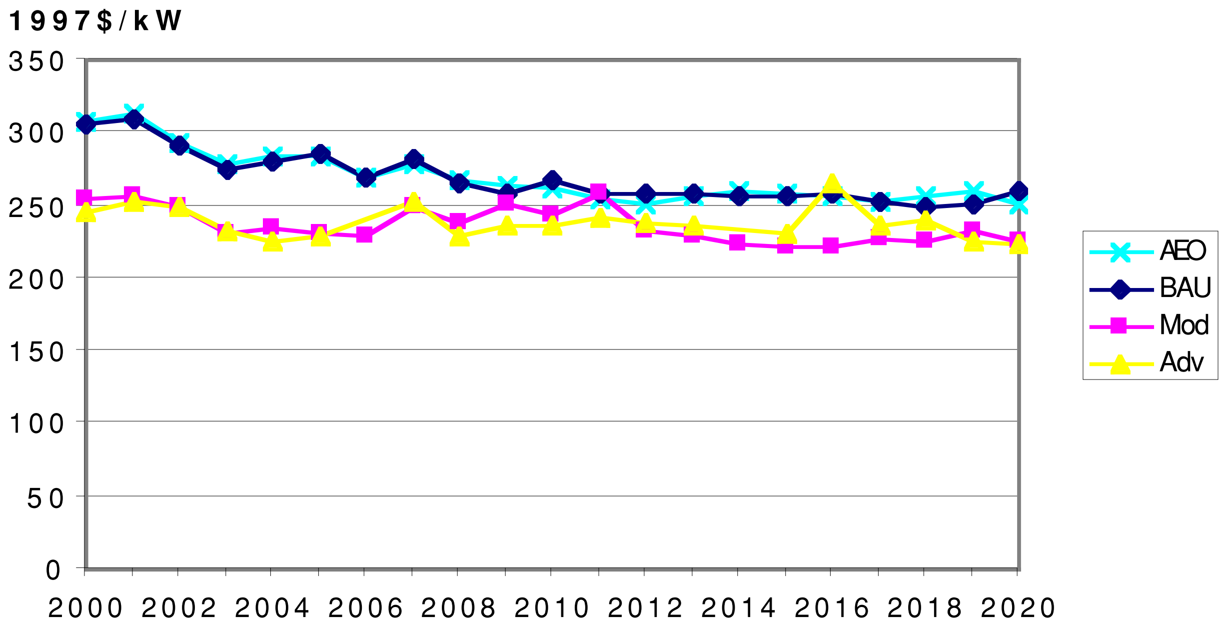


Fig. C-4-3 Capital Costs for Integrated Gasification Combined Cycle Capacity Including Regional Variations

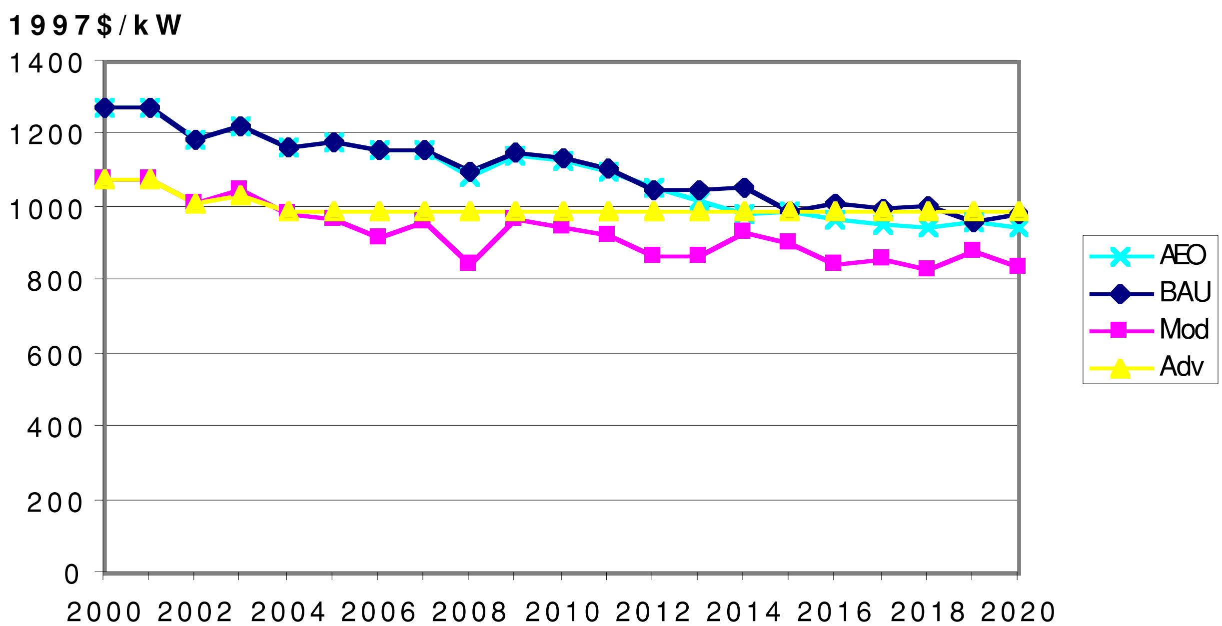
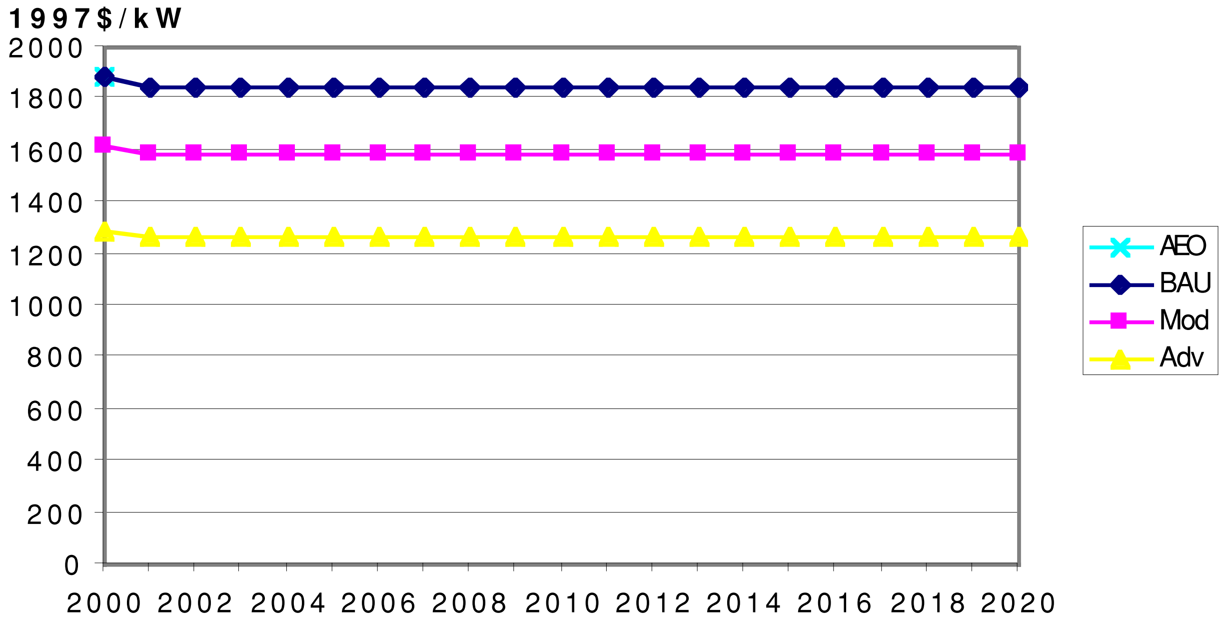


Fig. C-4-4 Capital Costs for Fuel Cell Capacity Including Regional Variations



More conservative values for heat rates and capital costs of IGCC and gas combined cycle have been provided by experts on the Review Team. These have been run as a sensitivity, with results presented in Chapter 7. The values used (and comparable values in the base scenarios) are:

Table C-4-5 Fossil Technology Capital Cost and Heat Rate Sensitivities

	Capital Cost (1997 $/kW)[a]		Heat Rate (Btu/kWh)		
	Sensitivity	**Base**	**Sensitivity**	**Base**	**Year for Heat Rate**
IGCC Moderate	1000	942	8400-7500	8333-6968	2000-2010
IGCC Advanced	900	942	7449-6800	6440-5690	2010-2020
Gas CC BAU	475	405	7200-6800	6927-6350	2000-2015
Gas CC Moderate	450	348	6749-6200	6919-6255	2000-2015
Gas CC Advanced	425	348	6199-5700	5539-4874	2010-2020

[a] Cost is raised from 1987$ to 1997$ by a factor of 1.343. Values include contingency factor.

Sequestration was allowed to enter the market starting in 2010. Rather than model completely different sequestration plants, the IGCC and Gas CC plants had their variable costs raised. Because sequestration was assumed to cost an additional $50/tC, with a 90% sequestration, the variable O&M cost for the IGCC and Gas CC plants were increased each year based on the fuel used, the plant s heat rate, and the cost of sequestration:

O&M cost ($/MWh) = O&M $\text{cost}_{\text{Base}}$ + Heat Rate * Carbon intensity * Cost of sequestration/1.0e6

Where: Heat Rate varied by year from 6440 to 4874 Btu/kWh, depending on technology and year.
Carbon intensity for coal = 25.72kg/MBtu, for gas = 14.47 kg/MBtu

One difficulty in modeling sequestration in CEF-NEMS is that it is a separate plant type from the IGCC and Gas CC it is based on. Consequently, the first few plants, which cannot come on before 2010, are treated as first-of-a-kind, with consequent technical optimism and learning curve factors raising their cost. This, in combination with the $50/tC cost of sequestration, means they are more expensive than regular IGCC and Gas CC plants, even with the allowance cost of $50/tC.

The advanced nuclear technology was modified for the Moderate and Advanced scenarios (Table C-4-6). In the Moderate scenario, the cost of advanced nuclear technology was kept the same as in the BAU (and AEO99 reference) case, but the Technical Optimism factor was reduced from 1.19 to 1.00. This is to represent that the advanced nuclear plants would be based on technologies constructed in other countries so would not need the technical optimism factor that otherwise would be needed. In the Advanced scenario, the capital cost of the advanced nuclear was reduced by roughly 10% to represent improvements in the construction cost through advanced designs and R&D.

Table C-4-6: Advanced Nuclear Technology Parameters

Technology	Scenario	Capital Cost, 1997 $/kW[a]	Technical Optimism[b]	Contin-gency Factor	Fixed O&M, 1997 $/kWyr	Variable O&M, 1997$/MWh
Advanced Nuclear	BAU	1430	1.19	1.100	55.7	0.41
	Mod	1430	1.00	1.100	55.7	0.41
	Adv	1270	1.00	1.100	55.7	0.41

[a] Capital cost for 5th plant of this type without contingency. Earlier plants have technical optimism and learning factors that raise the capital cost. Later plants have lower cost due to learning factors. CEF-NEMS actually uses 1987$/kW; to convert divide this value by 1.343.
[b] The factor that the capital cost is raised for the first plant above the 5th plant. The costs for the 2nd through 4th have this value decreased and is set to 1.0 for the 5th plant.

The Renewable technologies were also changed in the Moderate and Advanced scenarios. The main parameters that were changed were the capital cost, the fixed operating and maintenance (O&M), and the capacity factors (for wind). Similar to the fossil technologies, the values used for the BAU and Moderate scenarios were based on the AEO99 reference and High Renewables cases. For the Advanced scenario, the most optimistic parameters were used from either the AEO99 High Renewables case or the EPRI/DOE technology characterizations. The availability of biomass cofiring was added, as described in Chapter 7.

Whereas the fossil technologies capital costs were set by using the nth-of-a-kind capital cost that declined with capacity additions, in the Moderate and Advanced scenarios the renewable technologies used an input annual schedule. In addition, O&M costs changed over time for some of these technologies. Table C-4-8 through Table C-4-12 expands on the values in Table C-4-7. They show the capital and O&M costs for various renewable technologies over time for those scenarios that used annual schedules. Below each table is a figure showing the resulting capital costs for each technology that includes the effects of learning, technical optimism, regional cost variations, and any growth constraints. These are based on the weighted average of capital costs for each region of the country for each year, weighted by the amount of capacity added in that year.

Since the graphs include the regional variations in cost, the points may be higher or lower than the values in the tables if capacity was added in a high or low cost regions. For example, Table C-4-10 shows that the capital cost for photovoltaics in 2000 in the Moderate and Advanced scenarios is 3864$/kW.

However, the capacity added that year was in the Rocky Mountain and California regions, which have higher regional cost factors where the costs were 4017 and 4133 $/kW, respectively. This means the resulting average cost from CEF-NEMS shown in Figure C-4-7 was 4075$/kW.

For the two technologies that had essentially zero capacity added, solar photovoltaic and solar thermal, the differences in capital costs between scenarios are essentially moot. Geothermal capital costs in CEF-NEMS are determined on a site-by-site basis rather than through a national technology cost with regional multipliers. Consequently, the true capital costs from the model as shown in Figure C- 4-9 do not reflect the cost differences that were entered into the model as shown in Table C-4-12.

Table C-4-7: New Renewable Technology Parameters in CEF-NEMS

Technology	Scenario	Capital Cost, 1997 $/kW[a]	Years for Capital Cost	Fixed O&M, 1997 $/kWyr[b]	Years for O&M Costs[c]	Capacity Factor
Biomass (Gasification Wood)[d]	BAU	1451	2005-2015	43.55	2005	
	Mod	1394-1168	2001-2015	37.58	2005	
	Adv	1394-1168	2001-2015	37.58	2005	80
Geothermal (flashed-steam)	BAU	2159	2001	96.93	2001	
	Mod	1424-1246	2001-2015	71.53-49.18	2001-2020	
	Adv	1372-1100	2000-2020	87-58	2000-2020	96
Wind	BAU	778	2000	25.93	2000	
	Mod	680-611	2000-2016	21.4-16.2	2000-2020	(class 4) 30-38 (class 6) 40-49
	Adv	680-611	2000-2016	21.1 — 16.4	2000-2020	(class 4) 30-38 (class 6) 40-49
Solar Thermal (Power tower)	BAU	2120	2000	46.59	2000	
	Mod	3555-2338	2000-2016	58.02-21.65	2000-2020	
	Adv	3555-2338	2000-2016	58.02-21.65	2000-2020	43 - 77
Photovoltaic (central utility)	BAU	3226	2000	9.82	2000	Varies by region
	Mod	3864-1010	2000-2018	10.82-2.05	2000-2020	Varies by region
	Adv	3864-1010	2000-2018	10.82-2.05	2000-2020	Varies by region

[a] In BAU scenario capital cost for 5th plant of this type, with contingency. Earlier plants have technical optimism and learning factors that raise the capital cost. Later plants have lower cost due to learning factors. In Moderate and Advanced scenario, costs shown are for specified years; cost schedule is entered into NEMS for each year. CEF-NEMS actually uses 1987$/kW; to convert divide this value by 1.343.
[b] Fixed O&M cost schedule for reference case has single value for all times. Moderate scenario values may vary by year, generally declining over time.
[c] Initial value shows year when technology is available. Range shows when values may vary over time.
[d] Variable O&M for Biomass is 0.52¢/kWh. All other technologies have no variable O&M cost.

Table C-4-8: Biomass Data for Each Scenario

	Capital Cost (1997$/kW)			Fixed O&M Cost (1997$/kW)		
	BAU[a]	Mod	Adv	BAU[a]	Mod	Adv
2000	1451	1576	1576	43.55	37.58	37.58
2001		1532	1532		37.58	37.58
2002		1497	1497		37.58	37.58
2003		1463	1463		37.58	37.58
2004		1428	1428		37.58	37.58
2005		1394	1394		37.58	37.58
2006		1359	1359		37.58	37.58
2007		1339	1339		37.58	37.58
2008		1320	1320		37.58	37.58
2009		1301	1301		37.58	37.58
2010		1283	1283		37.58	37.58
2011		1263	1263		37.58	37.58
2012		1244	1244		37.58	37.58
2013		1225	1225		37.58	37.58
2014		1206	1206		37.58	37.58
2015		1188	1188		37.58	37.58
2016		1168	1168		37.58	37.58
2017		1168	1168		37.58	37.58
2018		1168	1168		37.58	37.58
2019		1168	1168		37.58	37.58
2020		1168	1168		37.58	37.58

[a] BAU capital costs used a single value for the 5th of a kind plant, with technical optimism (1.19), contingency factor (1.072), and learning adjusting the value as a function of the capacity installed. BAU Fixed O&M cost was entered as a single value.

Fig. C-4-5: Capital Costs for Biomass Capacity Including Regional Variations

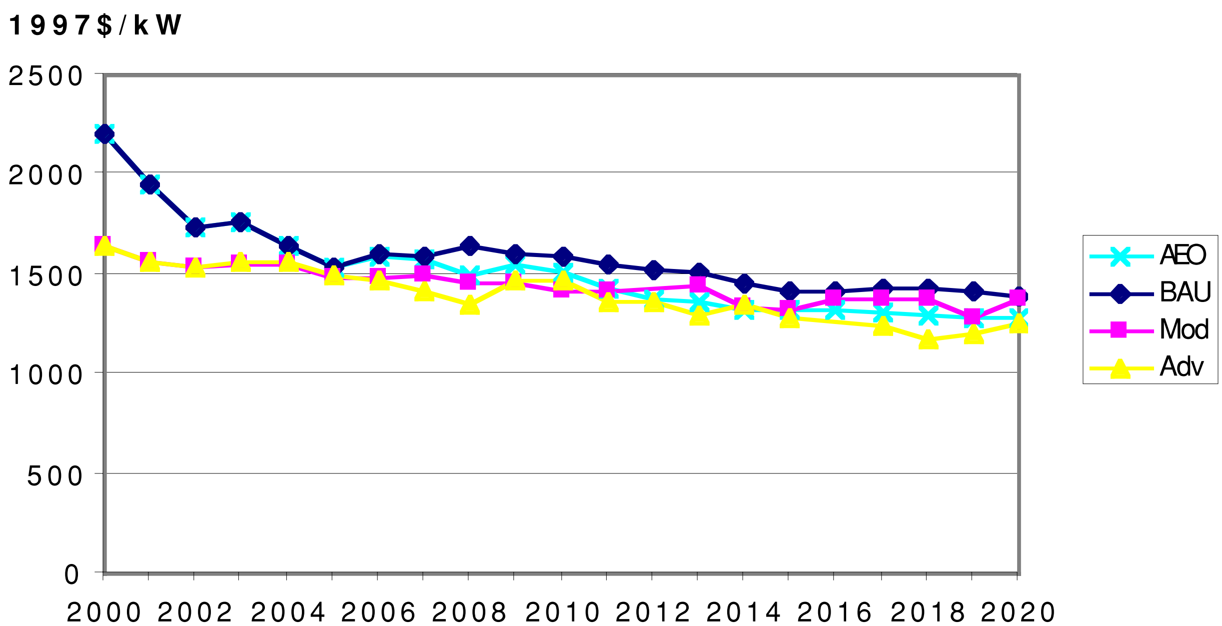


Table C-4-9: Wind Data for Each Scenario

	Capital Cost (1997$/kW)			Fixed O&M Cost (1997$/kW)		
	BAU[a]	Mod	Adv	BAU[a]	Mod	Adv
2000	778	680	680	25.9	21.4	21.4
2001		674	674		20.2	20.2
2002		669	669		19.0	19.0
2003		660	660		17.8	17.8
2004		653	653		16.5	16.5
2005		644	644		15.3	15.3
2006		635	635		15.3	15.3
2007		627	627		15.4	15.4
2008		625	625		15.5	15.5
2009		624	624		15.6	15.6
2010		621	621		15.7	15.7
2011		620	620		15.7	15.7
2012		618	618		15.8	15.8
2013		615	615		15.8	15.8
2014		614	614		15.9	15.9
2015		612	612		16.0	16.0
2016		611	611		16.0	16.0
2017		608	608		16.1	16.1
2018		608	608		16.1	16.1
2019		608	608		16.2	16.2
2020		608	608		16.2	16.2

[a] BAU capital costs used a single value for the 5th of a kind plant, with contingency factor (1.073) and learning adjusting the value as a function of the capacity installed. BAU Fixed O&M cost was entered as a single value.

Fig. C-4-6: Capital Costs for Wind Capacity Including Regional Variations

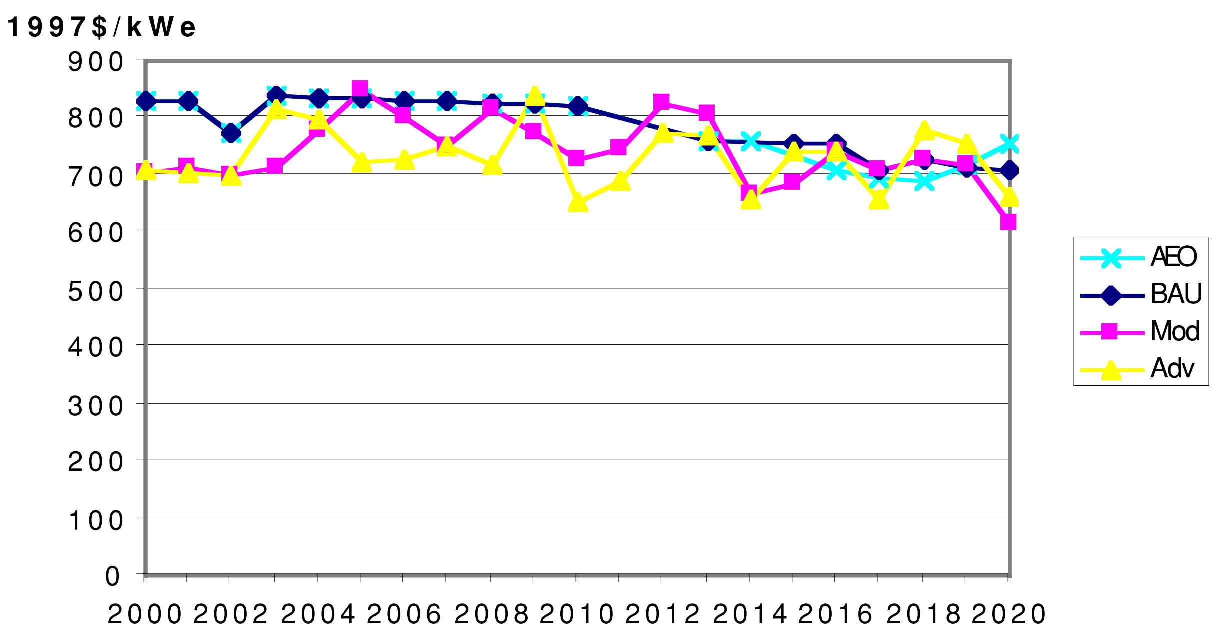


Table C-4-10: Photovoltaic Data for Each Scenario

	Capital Cost (1997$/kW)			Fixed O&M Cost (1997$/kW)		
	BAU[a]	Mod	Adv	BAU[a]	Mod	Adv
2000	3226	3864	3864	9.82	10.82	10.82
2001		3455	3455		9.66	9.66
2002		3046	3046		8.49	8.49
2003		2637	2637		7.32	7.32
2004		2382	2382		6.15	6.15
2005		2128	2128		4.98	4.98
2006		1873	1873		4.59	4.59
2007		1619	1619		4.22	4.22
2008		1364	1364		3.84	3.84
2009		1328	1328		3.45	3.45
2010		1293	1293		3.09	3.09
2011		1258	1258		2.98	2.98
2012		1223	1223		2.87	2.87
2013		1186	1186		2.77	2.77
2014		1151	1151		2.67	2.67
2015		1115	1115		2.57	2.57
2016		1080	1080		2.46	2.46
2017		1045	1045		2.35	2.35
2018		1010	1010		2.26	2.26
2019		1010	1010		2.15	2.15
2020		1010	1010		2.05	2.05

[a] BAU capital costs used a single value for the 5th of a kind plant, with technical optimism (1.12), contingency factor (1.05), and learning adjusting the value as a function of the capacity installed. BAU Fixed O&M cost was entered as a single value.

Fig. C-4-7: Capital Costs for Photovoltaic Capacity Including Regional Variations

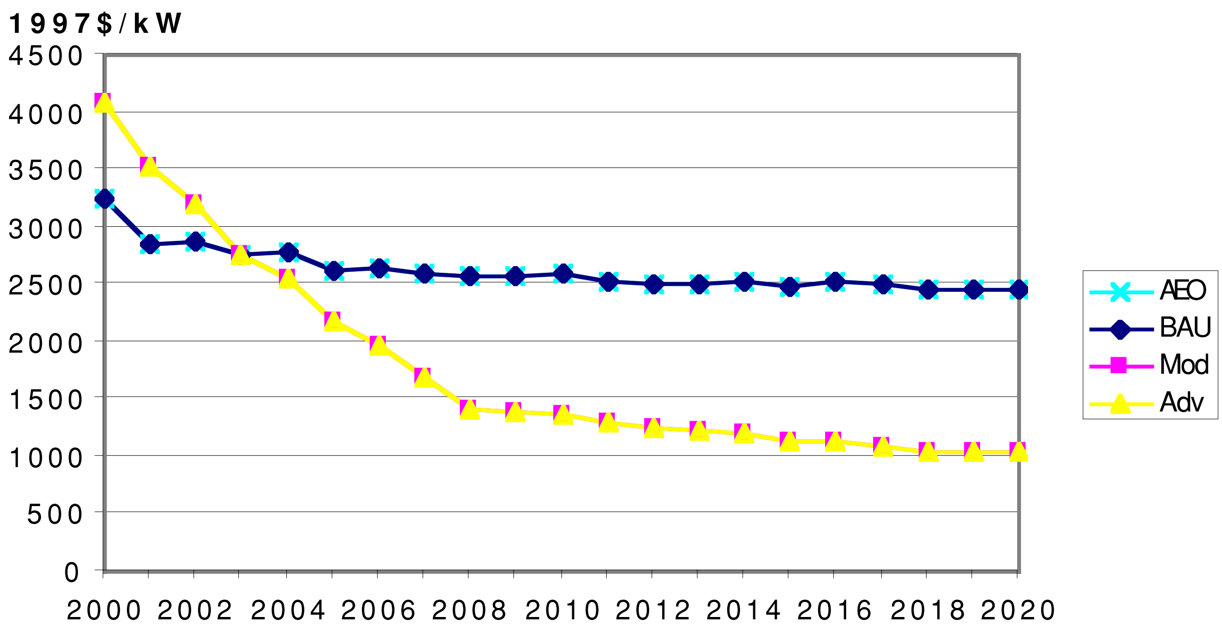


Table C-4-11: Solar Thermal Power Data for Each Scenario

	Capital Cost (1997$/kW)			Fixed O&M Cost (1997$/kW)		
	BAU[a]	Mod	Adv	BAU[a]	Mod	Adv
2000	2120	3555	3555	46.6	58.0	58.0
2001		3391	3391		50.2	50.2
2002		3229	3229		42.4	42.4
2003		3065	3065		34.6	34.6
2004		2903	2903		26.8	26.8
2005		2740	2740		19.9	19.9
2006		2576	2576		21.1	21.1
2007		2414	2414		22.3	22.3
2008		2405	2405		23.6	23.6
2009		2398	2398		24.8	24.8
2010		2391	2391		26.0	26.0
2011		2384	2384		25.5	25.5
2012		2377	2377		25.1	25.1
2013		2370	2370		24.7	24.7
2014		2361	2361		24.2	24.2
2015		2354	2354		23.8	23.8
2016		2347	2347		23.4	23.4
2017		2338	2338		23.0	23.0
2018		2338	2338		22.5	22.5
2019		2338	2338		22.1	22.1
2020		2338	2338		21.6	21.6

[a] BAU capital costs used a single value for the 5th of a kind plant, with technical optimism (1.19), contingency factor (1.07), and learning adjusting the value as a function of the capacity installed. BAU Fixed O&M cost was entered as a single value.

Fig. C-4-8: Capital Costs for Solar Thermal Capacity Including Regional Variations

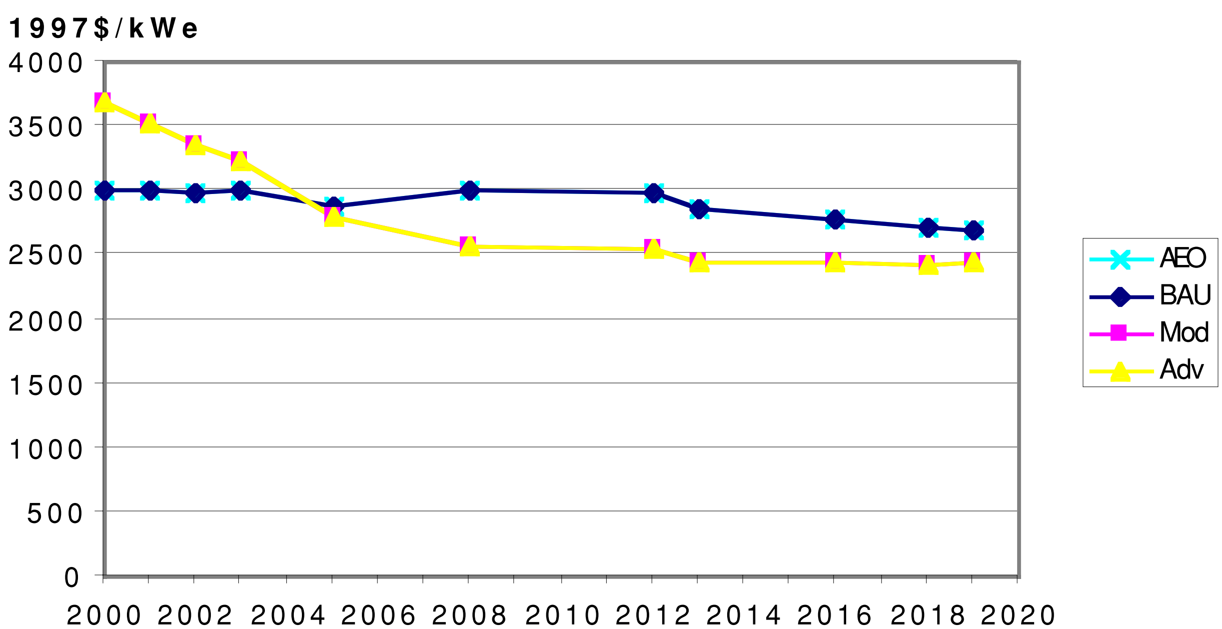
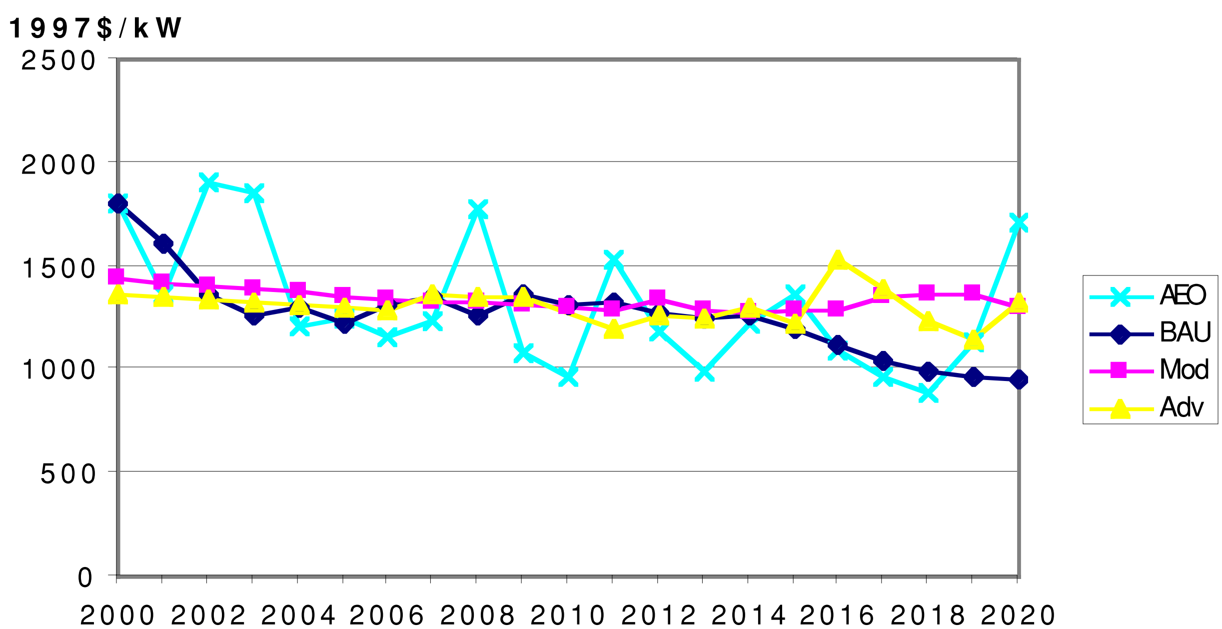


Table C-4-12: Geothermal Data for Each Scenario

	Capital Cost (1997$/kW)			Fixed O&M Cost (1997$/kW)		
	BAU[a]	Mod	Adv	BAU[a]	Mod	Adv
2000	2159	1447	1372	96.9	73.6	87.0
2001		1424	1348		71.5	84.6
2002		1407	1323		69.4	82.1
2003		1392	1299		67.4	79.7
2004		1375	1274		65.3	77.2
2005		1359	1250		63.1	74.8
2006		1343	1239		61.7	73.1
2007		1334	1228		60.4	71.4
2008		1324	1216		59.0	69.7
2009		1314	1205		57.6	68.0
2010		1304	1194		56.0	66.3
2011		1294	1185		55.3	65.5
2012		1284	1175		54.6	64.6
2013		1274	1166		53.9	63.8
2014		1264	1156		53.2	63.0
2015		1254	1147		52.6	62.2
2016		1247	1138		51.9	61.3
2017		1247	1128		51.2	60.5
2018		1247	1119		50.5	59.7
2019		1247	1109		49.8	58.8
2020		1247	1100		49.2	58.0

[a] BAU capital costs used a single value for the 5th of a kind plant, with contingency factor (1.053) and learning adjusting the value as a function of the capacity installed. BAU Fixed O&M cost was entered as a single value.

Fig. C-4-9: Capital Costs for Geothermal Capacity Including Regional Variations



The irregular geothermal cost output for the Reference case is not repeated in the BAU, Moderate, and Advanced scenarios. This was done by setting the LARGE and SMALL parameters of the wgeparm file to zero. These two parameters control the number of years that a site developer must wait between installations at the site. In NEMS this delay is implemented by increasing the capital cost of geothermal for LARGE (or SMALL if the site is small) years. By setting these parameters to zero, the capital cost does not jump up after each site installation as it does in the Reference case.

The constraints limiting wind in NEMS were altered in all scenarios as shown in Table C-4-13.

Table C-4-13: Modifications to NEMS Constraints on Wind

NEMS EMM	CEF-NEMS EMM
Maximum construction of 1GW in a region in a single year	Deleted
Short-term supply elasticity: 70% increase in capital costs for national growth above 14% per year	Reduced to 5% penalty for annual national growth between 20 and 30% and 15% penalty above 30% growth.
Intermittency: Max wind generation < 10% regional generation	Replaced by capital cost multiplier below
Capital cost increased by a factor of 3 for 90% of all wind resource due to site access, intermittency, & market factors	Capital cost increased by as much as 60% as regional market penetration rises from 10% to 20%

The limit of 1 GW of wind development in a single region in a year is duplicated by the later constraints related to wind intermittency and therefore, has been removed.

The capital cost penalty imposed at high annual growth rates has been modified to represent EIA s intent of a 1% penalty in capital costs for every 1% in annual growth above 20%, e.g., between 20 and 30% annual growth, the average is 25% growth or 5 percentage points above 20%, thus a 5% capital cost penalty. Implementation in CEF-NEMS requires that annual growth be roughly translated to orders for new wind systems whose construction won t be completed for 3 years. Table C-4-14 shows these CEF-NEMS input values.

Table C-4-14: Short-term Growth Constraint on Wind

Annual Growth Rate (%)	Equivalent 3-yr Order (%)[a]	Capital Cost Penalty (%)
0 - 20	0 — 35	0
20 — 30	35 — 65	5
30 — 40	65 — 95	15

a Percent of prior year s installed nationwide wind capacity that can be ordered for completion 3 years hence.

Rather than a binary constraint on wind that simply says no more than 10% of the generation in a region can come from an intermittent source like wind, we have substituted a cost penalty. The cost penalty captures the fact that if wind achieves penetration levels above 10% of the generation in a region, it may encounter charges for ancillary services and other backup capacity charges. Such charges are very grid and time specific (Wan and Parsons, 1993). As a simplifying surrogate, we assume that a wind system may have to purchase a dedicated natural gas turbine. The cost of the turbine is assumed to be 40% of the cost of a wind system per kW. This cost is appended to the cost of the wind system as the wind penetration grows from 10% of the generation within a region to 20% as shown below:

Table C-4-15: Fraction of the Wind Resource at Each Cost Multiplier Level

Wind Penetration %	Cost penalty as a percentage of the wind system cost
0-10	0
10-12.5	10
12.5-15	20
15-20	40

Since CEF-NEMS does not have a cost penalty function based on wind penetration, we combined the last two constraints in Table C-4-16. To do this we used the form of the last constraint in Table C-4-13 by translating the wind penetration fraction into a fraction of the wind resource in the region. The cost multiplier in CEF-NEMS can be as high as 60% because we added the 40% intermittency-driven turbine cost to the first level of NEMS penalties (20% cost penalty) to capture the access and market issues originally intended by the EIA. We did not retain the full 300% penalty of NEMS for such issues as site access and market factors as our market investigation did not reveal any evidence of penalties to actual wind installations above 20%. If there are market factors that would increase the cost of wind more than 20% in the future, we assume they are reduced in the moderate and advanced scenario both by the explicit policies and the change in public resolve relative to climate change assumed in those scenarios. The resulting constraint inputs are as shown in Table C-4-16 below:

Table C-4-16: Fraction of the Wind Resource at Each Cost Multiplier Level

	Long-term Capital Cost Multipliers				
Region	1	1.2	1.3	1.4	1.6
1	0.100	0.900	0.000	0.000	0.000
2	0.150	0.509	0.165	0.165	0.012
3	0.100	0.594	0.174	0.132	0.000
4	0.400	0.600	0.000	0.000	0.000
5	0.003	0.002	0.001	0.001	0.994
6	0.100	0.807	0.093	0.000	0.000
7	0.100	0.240	0.085	0.085	0.490
8	0.100	0.900	0.000	0.000	0.000
9	0.100	0.900	0.000	0.000	0.000
10	0.010	0.007	0.004	0.004	0.974
11	0.023	0.007	0.000	0.005	0.965
12	0.010	0.012	0.005	0.005	0.967
13	0.120	0.148	0.067	0.067	0.598

REFERENCES

Wan Y., and B.K. Parsons, 1993, Factors Relevant to Utility Integration of Intermittent Renewable Technologies, NREL/TP-463-4953, Draft, National Renewable Energy Laboratory, Golden, CO, August.

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