PNNL-14256

Appendices A – D for
Model Documentation for the SGM

Antoinette L. Brenkert
Ronald D. Sands
Son H. Kim
Hugh M. Pitcher

October 2004

Prepared for the United States Environmental Protection Agency under
Contracts AGRDW89939464-01 and AGRDW89939645-01

Joint Global Change Research Institute, College Park, MD
Pacific Northwest National Laboratory
Operated by Battelle for the US Department of Energy

LEGAL NOTICE

Printed in the United States of America

Table of Contents

List of Tables

Appendix A: Data Tables for the SGM

Input-Output Tables

The basic structure on which the SGM is built is a regional hybrid commodity-by-commodity input-output table. Table 1 shows a commodity-by-commodity hybrid input-output table. This table shows input for the base year for the USA ($X_{i,j}$ values for $t=0$ for the year 1990).

Table 2 shows the summations, $XS_{i,v}$, over all inputs for each of the regions for which the SGM is implemented, to illustrate the different regions' input breakdowns.

Table 3 shows for time $t=7$ a table similar to Table 1 to be solved for excess demand and related prices. The matrix cells contain the demand values ($Ed_{i,j}$ which for the base year are denoted by $X_{i,j}$) with diagonal elements (bolded) equaling values of demand ($Ed_{i,j}$) minus gross production ($PRD_{i,j}$). The point in time for which Table 3 is an illustration shows results in the form of carbon emissions.

A similar table is shown as Table 4 for $t=7$ when a carbon policy is implemented consisting of carbon-equivalent emission limits and inputs are given in Table 27 below. When Tables 3 and 4 are carefully compared, one can observe the shifts in values attributable to the carbon policy implemented.

When the market solves for market prices as described in the "The solution procedure" (see Chapter ten of the documentation), the values at time $t=7$ are as in Table 5 below. Table 5 contains the results of a model run implementing a carbon policy consisting of carbon-equivalent emission limits for which the full input-output table at $t=7$ is given in Table 4. The carbon price value at $t=7$ (year 2025) can be found in this table.

Table 1 An example of input as a commodity-by-commodity hybrid input-output table (first 12 columns)

	t=0	1	2	3	4	5	6	7	8	9	10	11	12
Region = USA		Agriculture	ETE	Crude Oil	Nat. Gas	Coal	Coke Prod.		Electricity	Oil refining	Gas T&D	Paper, Pulp	Chemicals
Other Ag.	1	8341	13334	4	4	10	0	0	25	16	13	94	445
ETE	2	8938	1137360	9551	10000	2524	100	0	13,939	14188	6214	23341	41715
C.Oil Prd.	3	0	0	0	0	0	0	0	0	70929	0	0	0
N.Gas Prd.	4	0	0	0	0	0	0	0	0	0	43865	0	0
Coal Prd.	5	0	144	0	0	0	838	0	16,659	0	0	307	810
Coke Prd.	6	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0
Elec Gen.	8	548	46167	0	0	0	0	0	16,215	0	0	5668	9516
Ref Oil	9	1012	2368	0	0	0	0	0	5,559	9171	62	845	7066
Gas T&D	10	744	10980	0	0	0	0	0	14,531	0	6439	2969	11227

Wood Prd.	11	1330	29157	9	9	77	0	0	93	284	43	56484	4612
Chemicals	12	4405	31028	686	719	217	0	0	477	2955	96	9785	65850
Cement	13	75	5681	270	283	106	0	0	18	565	21	805	1123
Steel	14	7	635	635	665	60	0	0	1	90	55	272	384
NFMetals	15	1	783	2	2	14	0	0	132	2	1	207	164
OthInd	16	2607	310184	1096	1148	2540	0	0	15,848	2828	4577	13908	18188
PassTran	17	624	32293	189	198	297	0	0	1,929	432	333	1477	1837
FrghtTran	18	1040	30291	333	349	1018	0	0	5,738	6626	594	7106	8083
Grains and Oil Seeds	19	91	55	0	0	0	0	0	0	1	0	1	156
Animal Products	20	1050	652	0	0	0	0	0	0	1	1	7	186
Forestry	21	35	86	0	0	0	0	0	0	1	0	6496	103
Food Processing	22	129	65638	1	1	0	0	0	1	105	58	513	1498
Carbon	23	0	0	0	0	0	0	0	0	0	0	0	0
Land rental	24	0	0	0	0	0	0	0	0	0	0	0	0
Labor income	25	17885	2179060	9789	10249	8412	2000	0	26,285	9046	9740	43107	50293
OVA (other value added)	26	22000	1143280	15436	16162	5060	500	0	78,043	9251	16356	30415	58979
IBT (indirect business taxes)	27	1177	360702	2058	2155	2277	100	0	11,218	6837	4495	2067	3722

Table 1 Extension (next 13 columns)

	t=0	13	14	15	16	17	18	18	20	21	22	23
Region = USA		Cement , etc.	Iron and Steel	NF Metals	Other Industry	Passeng er Transpo rt	Freight Transpo rt	Grains and Oil Seeds	Animal Product s	Forestry	Food Processi ng	Carbon
Other Ag.	1	24	18	19	8832	23	35	3094	4014	1951	12116	
ETE	2	6798	12698	11025	354937	26392	46233	12340	11037	883	46575	
C.Oil Prd.	3	0	0	0	0	0	0	0	0	0	0	
N.Gas Prd.	4	0	0	0	0	0	0	0	0	0	0	
Coal Prd.	5	311	0	13	193	0	0	0	0	0	0	
Coke Prd.	6	0	3563	0	0	0	0	0	0	0	0	
	7	0	0	0	0	0	0	0	0	0	0	
Elec Gen.	8	7201	3589	2271	24674	1212	0	425	1768	26	3655	
Ref Oil	9	129	169	40	11989	69830	22137	1093	477	48	218	
Gas T&D	10	1916	2158	1301	10893	0	0	1383	0	26	2581	
Wood Prd.	11	1823	217	302	77694	100	375	18	217	12	11813	
Chemicals	12	2551	1321	1568	62172	130	297	5335	628	187	3981	
Cement	13	7139	1193	400	44128	61	42	79	8	2	4522	
Steel	14	369	12346	716	64350	43	230	9	12	0	7	
NFMetals	15	92	1584	19542	42771	20	94	0	0	0	32	
OthInd	16	5728	7467	6445	518492	6531	14257	2673	2050	290	21774	
PassTran	17	522	661	387	13351	12357	6260	98	290	47	2179	
FrghtTran	18	4165	2887	2408	35871	3707	35514	1144	3040	56	8964	
Grains and Oil Seeds	19	0	0	0	564	0	13	2089	22876	32	19601	
Animal Products	20	0	0	0	368	1	5	671	13990	111	69394	
Forestry	21	4	0	7	849	0	0	0	0	215	83	

Food Processing	22	22	3	6	1761	303	152	0	14039	322	61555	
Carbon	23	0	0	0	0	0	0	0	0	0	0	
Land rental	24	0	0	0	0	0	0	0	0	0	0	
Labor income	25	17473	17071	11220	680626	40371	75956	1561	3928	1183	51466	
OVA (other value added)	26	10576	5231	3931	300289	11847	36366	23083	9885	1794	55597	
IBT (indirect business taxes)	27	769	859	676	25806	5595	6024	2220	1183	332	9077	

Table 1 Extension (demand sector columns)

	t=0	24	25	26	27
Region = USA		Net Exports	Investments	General Government Consumption	Household Consumption
Other Ag.	1	-2911	0	1980	20560
ETE	2	66545	57739	670812	2807997
C.Oil Prd.	3	-30870	0	0	0
N.Gas Prd.	4	-1923	0	0	0
Coal Prd.	5	3336	0	0	0
Coke Prd.	6	-25	0	0	0
	7	0	0	0	0
Elec Gen.	8	-145	0	15735	68185
Ref Oil	9	-6186	0	1667	5635
Gas T&D	10	0	0	3034	22780
Wood Prd.	11	-2587	2935	3754	17104
Chemicals	12	6117	1261	12348	71841
Cement	13	-4132	0	804	4416
Steel	14	-8146	10	258	27
NFMetals	15	-3846	230	377	75
OthInd	16	-119489	896796	119290	425387
PassTran	17	20012	1684	11874	69193
FrghtTran	18	28057	3180	7374	46444
Grains and Oil Seeds	19	10963	0	563	310
Animal Products	20	-674	0	141	3539
Forestry	21	-571	0	-1802	2011
Food Processing	22	-3165	2	8535	233708
Carbon	23	0	0	0	0
Land rental	24				
Labor income	25				
OVA (other value added)	26				
IBT (indirect business taxes)	27				

Table 1 Extension (Electricity production sector columns)

	Elec Gen.	Oil	Gas	Coal	Biomass	Nuclear	Hydro
	SUMMED	8.1	8.2	8.3	8.4	8.5	8.6
Other Ag.	25	1	2	14	0	5	3
ETE	13,939	582	1,314	7,761	0	2,871	1,410

C.Oil Prd.	0	0	0	0	0	0	0
N.Gas Prd.	0	0	0	0	0	0	0
Coal Prd.	16,659	0	0	16,659	0	0	0
Coke Prd.	0	0	0	0	0	0	0
Elec Gen.	16,215	677	1,529	9,029	0	3,340	1,641
Ref Oil	5,559	5,559	0	0	0	0	0
Gas T&D	14,531	0	14,531	0	0	0	0
Wood Prd.	93	4	9	52	0	19	9
Chemicals	477	20	45	265	0	98	48
Cement	18	1	2	10	0	4	2
Steel	1	0	0	1	0	0	0
NFMetals	132	6	12	74	0	27	13
OthInd	15,848	662	1,494	8,824	0	3,264	1,603
PassTran	1,929	81	182	1,074	0	397	195
FrghtTran	5,738	240	541	3,195	0	1,182	581
Grains and Oil Seeds	0	0	0	0	0	0	0
Animal Products	0	0	0	0	0	0	0
Forestry	0	0	0	0	0	0	0
Food Processing	1	0	0	0	0	0	0
Carbon	0	0	0	0	0	0	0
Land Rental	0	0	0	0	0	0	0
Labor Income	26,285	1,098	2,478	14,636	0	5,414	2,659
Capital	78,043	3,260	7,359	43,455	0	16,074	7,896
RIBT	11,218	700	1,693	6,028	0	1,876	922

Table 2 Summations of total inputs in the commodity-by-commodity input-output table based on industry technologies, $XS_{i,v}$, for all 14 regions of SGM, indicating which parts of the input-output tables are active

Regions	1	2	3	4	5	6	7	8	9	10	11	12	13
	Australia & New Zealand	Canada	China	FSU	India	Japan	South Korea	Mexico	MDE	ROW	USA	WEU	EEU
Other Ag.	27,061	40,322	969,989	349,553	2,100,342	19,554,283	10,814,696	91,546	60,561	222,910	72,060	1,671,002	27,227
ETE	528,182	950,743	831,846	1,477,124	6,120,061	377,778,588	276,149,065	1,002,115	809,433	2,548,301	5,399,562	10,292,799	378,347
C.Oil Prd.	2,778	26,991	49,602	15,786	50,462	10,507	0	26,282	128,747	124,946	40,075	63,598	3,751
N.Gas Prd.	2,007	12,400	1,307	8,853	26,556	87,918	0	4,051	16,825	28,250	41,960	36,976	6,250
Coal Prd.	6,287	2,083	54,823	20,423	64,969	112,976	1,274,446	1,419	64	11,660	22,481	67,440	16,269
Coke Prd.	0	0	11,791	0	0	2,286,462	0	0	0	0	3,759	0	0
[empty]	0	0	0	0	0	0	0	0	0	0		0	0
Elec Gen.	14,143	26,080	85,104	45,711	248,677	16,981,103	6,827,980	17,176	29,612	106,927	228,578	313,931	60,467
Ref Oil	12,714	37,722	65,801	20,190	169,702	8,338,786	6,649,080	19,971	68,909	157,349	133,433	327,922	35,968
Gas T&D	2,292	13,041	0	15,173	43,368	2,096,483	332,084	0	0	0	93,113	100,933	20,443
Wood Prd.	0	0	106,803	0	0	6,424,761	8,509,984	0	0	0	205,862	0	0
Chemicals	0	0	326,911	0	0	27,299,221	27,002,174	0	0	0	286,102	0	0
Cement	0	0	145,988	0	0	5,557,366	7,942,621	0	0	0	67,535	0	0
Steel	0	0	245,076	0	0	29,693,833	19,921,814	0	0	0	74,478	0	0
NFMetals	0	0	0	0	0	7,868,568	3,223,319	0	0	0	62,300	0	0
OthInd	0	0	1,438,143	0	0	348,222,337	0	0	0	0	2,282,075	0	0
PassTran	0	0	31,570	0	0	16,882,083	7,876,579	0	0	0	179,026	0	0
FrghtTran	0	0	119,862	0	0	16,911,496	5,760,163	0	0	0	244,213	0	0
Grains and Oil Seeds	0	0	0	0	0	0	7,222,013	0	0	0	57,366	0	0

Animal Products	0	0	0	0	0	0	3,138,767	0	0	0	89,463	0	0
Forestry	0	0	0	0	0	0	659,449	0	0	0	7,539	0	0
Food Processing	0	0	0	0	0	0	29,467,801	0	0	0	385,457	0	0
Carbon									0				
Land	4,222	2,093	54,142	4,458	127,206	0	0	43,216	2,032	7,003		66,169	641
Labor	183,272	357,083	799,554	520,069	3,060,807	249,831,202	79,690,214	211,910	399,324	1,077,713	3,266,745	4,658,161	155,245
OVA	113,934	222,038	679,664	571,881	1,104,168	172,910,645	81,997,961	414,768	249,913	612,276	1,854,112	2,332,359	86,871
IBT	16,316	81,595	220,007	26,761	576,065	23,415,106	16,629,256	69,004	68,500	155,569	449,375	454,525	21,577

Regions	3	8
	Germany-1995	Brazil
Other Ag.	86,640	3,572,435
ETE	3,457,558	25,173,102
C.Oil Prd.	634	374,670
N.Gas Prd.	4,516	79,282
Coal Prd.	20,287	27,335
Coke Prd.	3,213	0
[empty]	0	0
Elec Gen.	101,439	1,297,676
Ref Oil	44,963	1,806,015
Gas T&D	34,813	165,800
Wood Prd.	139,166	1,473,065
Chemicals	199,421	3,848,308
Cement	82,241	541,750
Steel	101,350	4,217,840
NFMetals	243,140	5,475,553
OthInd	1,708,312	15,578,483
PassTran	35,783	1,900,413
FrghtTran	214,599	1,160,931
Grains and Oil Seeds	0	0
Animal Products	0	0
Forestry	0	0
Food Processing	0	735,687
Carbon	0	0
Land	14,206	87,912
Labor	1,942,820	16,609,161
OVA	1,228,755	10,251,541
IBT	81,880	4,810,571

Over different value of *t* this matrix shows all model aspects in summary, *e.g.*, for time $t=7$ with carbon fees imposed of $100 per ton carbon with the demands ($Ed_{i,j}$ element) in the matrix cells and the gross output produced (PRD_j) values on the diagonal.

Table 3 An example of a commodity-by-commodity hybrid input-output table with gross production as diagonal elements at time *t=7* (first 12 columns)

T=7	1	2	3	4	5	6	7	8	9	10	11	12
Region = USA	Agriculture	ETE	Crude Oil	Nat. Gas	Coal	Coke Prod.		Electricity	Oil refining	Gas T&D	Paper, Pulp	Chemicals
Other Ag.	**-136664**	30703	4	4	10	0	0	35	17	20	162	780
ETE	14926	-11632900	9339	9778	2237	142	0	19293	15350	9753	39010	71095
C.Oil Prd.	0	0	-47747	0	0	0	0	0	92927	0	0	0
N.Gas Prd.	0	0	0	-49992	0	0	0	0	0	84584	0	0
Coal Prd.	0	164	0	0	-24772	1367	0	18263	0	0	299	803
Coke Prd.	0	0	0	0	0	-6162	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
Elec Gen.	921	98130	0	0	0	0	0	-394965	0	0	9624	16498
Ref Oil	1395	4202	0	0	0	0	0	4057	-166718	121	1174	10017
Gas T&D	970	18687	0	0	0	0	0	62672	0	-169295	3884	14971
Wood Prd.	2351	69451	9	10	72	0	0	130	313	68	-344164	8283
Chemicals	7698	72774	700	733	200	0	0	666	3244	153	17056	-506413
Cement	129	13040	271	284	97	0	0	25	617	33	1381	1966
Steel	13	1462	639	669	54	0	0	1	99	88	468	674
NFMetals	2	1906	2	2	13	0	0	186	2	2	370	299
OthInd	4545	725313	1115	1168	2344	0	0	22124	3101	7301	24193	32266
PassTran	1057	72744	187	196	267	0	0	2676	470	526	2503	3176
FrghtTran	1774	68802	332	348	920	0	0	7978	7220	940	12108	14045
Grains and Oil Seeds	161	130	0	0	0	0	0	0	1	0	1	279
Animal Products	1959	1669	0	0	0	0	0	0	1	1	13	352
Forestry	62	204	0	0	0	0	0	0	1	0	11443	185
Food Processing	237	163816	1	1	0	0	0	1	117	93	934	2781
Carbon	0	0	803	503	529	0	0	0	0	0	0	0
Land rental	0	0	0	0	0	0	0	0	0	0	0	0
Labor income	774	118864	253	265	194	79	0	1067	280	432	1890	2241
OVA (other value added)	0	0	0	0	0	0	0	0	0	0	0	0
IBT (indirect business taxes)	0	0	0	0	0	0	0	0	0	0	0	0

Table 3 Extension (next 13 columns)

	t=7	13	14	15	16	17	18	18	20	21	22	23
Region = USA		Cement, etc.	Iron and Steel	NF Metals	Other Industry	Passenger Transport	Freight Transport	Grains and Oil Seeds	Animal Products	Forestry	Food Processing	Carbon
Other Ag.	1	41	30	30	18409	34	50	4402	6869	2164	25689	
ETE	2	11480	20540	16862	718420	37944	63958	17053	18346	951	95919	

C.Oil Prd.	3	0	0	0	0	0	0	0	0	0	0	
N.Gas Prd.	4	0	0	0	0	0	0	0	0	0	0	
Coal Prd.	5	304	0	11	223	0	0	0	0	0	0	
Coke Prd.	6	0	6187	0	0	0	0	0	0	0	0	
	7	0	0	0	0	0	0	0	0	0	0	
Elec Gen.	8	12397	6019	3601	51354	1806	0	596	2984	29	7662	
Ref Oil	9	182	231	52	20359	84861	25618	1253	658	43	374	
Gas T&D	10	2530	2717	1548	17204	0	0	1497	0	22	4159	
Wood Prd.	11	3246	370	488	166054	152	547	26	380	13	25639	
Chemicals	12	4494	2232	2506	131376	196	429	7688	1089	210	8553	
Cement	13	-132010	1988	630	91928	91	60	113	13	2	9568	
Steel	14	642	-134011	1133	134495	64	328	13	21	0	15	
NFMetals	15	167	2762	-97752	93059	31	140	0	0	0	70	
OthInd	16	10069	12595	10279	-4907750	9792	20536	3844	3546	325	46679	
PassTran	17	894	1088	603	27452	-312487	8792	137	490	51	4551	
FrghtTran	18	7172	4759	3753	74027	5432	-376893	1612	5152	62	18821	
Grains and Oil Seeds	19	0	0	1	1203	0	19	-98651	39990	36	42472	
Animal Products	20	0	0	1	830	1	7	1027	-175752	133	158508	
Forestry	21	7	0	11	1810	0	0	0	0	-10205	179	
Food Processing	22	41	5	10	3896	477	230	0	25403	377	-922953	
Carbon	23	0	0	0	0	0	0	0	0	0	0	
Land rental	24	0	0	0	0	0	0	0	0	0	0	
Labor income	25	767	685	426	34983	1440	2694	57	171	33	2767	
OVA (other value added)	26	0	0	0	0	0	0	0	0	0	0	
IBT (indirect business taxes)	27	0	0	0	0	0	0	0	0	0	0	

Table 3 Extension (demand columns)

	t=7	24	25	26	27
Region = USA		Net Exports	Investments	General Government Consumption	Household Consumption
Other Ag.	1	-2911	0	9143	40979
ETE	2	91406	160303	3098190	7090590
C.Oil Prd.	3	-45180	0	0	0
N.Gas Prd.	4	-34592	0	0	0
Coal Prd.	5	3336	0	0	0
Coke Prd.	6	-25	0	0	0
	7	0	0	0	0
Elec Gen.	8	-145	0	61033	122458

Ref Oil	9	0	0	5435	6695
Gas T&D	10	0	0	9229	29207
Wood Prd.	11	-2587	8148	17339	43671
Chemicals	12	6117	3501	57028	177774
Cement	13	-4132	0	3712	10282
Steel	14	-8146	27	1192	64
NFMetals	15	-3846	640	1744	208
OthInd	16	-119489	2489800	550948	1045500
PassTran	17	20012	4676	54841	105119
FrghtTran	18	28057	8828	34058	70685
Grains and Oil Seeds	19	10963	0	2601	793
Animal Products	20	-674	0	653	11270
Forestry	21	-571	0	-8322	5195
Food Processing	22	-3165	5	39418	688275
Carbon	23	0	0	0	0
Land rental	24	0	0	0	0
Labor income	25	0	0	0	-170365
OVA (other value added)	26	-49639	2300210	0	-2250600
IBT (indirect business taxes)	27	0	0	0	0

Table 4 An example of a commodity-by-commodity hybrid input-output table with demand minus gross production as diagonal elements at time *t=7* (first 12 columns) with carbon-equivalent emission limits imposed

t=7	1	2	3	4	5	6	7	8	9	10	11	12
Region = USA	Agriculture	ETE	Crude Oil	Nat. Gas	Coal	Coke Prod.		Electricity	Oil refining	Gas T&D	Paper, Pulp	Chemicals
Other Ag.	-126257	28791	4	4	10	0	0	35	17	19	153	734
ETE	13759	-11654400	9339	9779	2419	142	0	19527	14979	9635	38612	70246
C.Oil Prd.	0	0	-47778	0	0	0	0	0	92430	0	0	0
N.Gas Prd.	0	0	0	-50025	0	0	0	0	0	81394	0	0
Coal Prd.	0	184	0	0	-27122	1287	0	20618	0	0	312	835
Coke Prd.	0	0	0	0	0	-5933	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
Elec Gen.	862	100597	0	0	0	0	0	-396061	0	0	9660	16511
Ref Oil	1315	4343	0	0	0	0	0	4102	-164565	117	1180	10035
Gas T&D	904	19003	0	0	0	0	0	59283	0	-164136	3862	14849
Wood Prd.	2168	69575	9	10	78	0	0	132	306	67	-340782	8184
Chemicals	7120	73220	702	735	217	0	0	675	3173	151	16928	-500882
Cement	120	13110	272	285	105	0	0	25	604	33	1370	1946
Steel	12	1470	641	671	59	0	0	1	97	86	464	667
NFMetals	2	1913	2	2	14	0	0	188	2	2	367	295
OthInd	4194	727401	1117	1169	2536	0	0	22400	3028	7211	23974	31913
PassTran	983	73660	189	198	290	0	0	2723	462	517	2491	3153
FrghtTran	1638	69065	333	348	997	0	0	8085	7060	927	11999	13893

Grains and Oil Seeds	149	130	0	0	0	0	0	0	1	0	1	276
Animal Products	1803	1669	0	0	0	0	0	0	1	1	13	347
Forestry	57	204	0	0	0	0	0	0	1	0	11287	182
Food Processing	218	164143	1	1	0	0	0	1	115	92	925	2748
Carbon	244	286	729	486	622	0	0	12	0	63	0	0
Land rental	0	0	0	0	0	0	0	0	0	0	0	0
Labor income	719	119214	253	265	212	80	0	1084	277	429	1872	2221
OVA (other value added)	0	0	0	0	0	0	0	0	0	0	0	0
IBT (indirect business taxes)	0	0	0	0	0	0	0	0	0	0	0	0

Table 4 Extension (next 13 columns) for time *t=7* with carbon-equivalent emission limits imposed

t=7	13	14	15	16	17	18	18	20	21	22	23
Region = USA	Cement, etc.	Iron and Steel	NF Metals	Other Industry	Passenger Transport	Freight Transport	Grains and Oil Seeds	Animal Products	Forestry	Food Processing	Carbon
Other Ag.	39	28	28	17221	32	47	4138	6407	1907	23965	0
ETE	11417	20427	16745	711806	38172	63669	16790	17951	878	94013	0
C.Oil Prd.	0	0	0	0	0	0	0	0	0	0	0
N.Gas Prd.	0	0	0	0	0	0	0	0	0	0	0
Coal Prd.	320	0	10	220	0	0	0	0	0	0	0
Coke Prd.	0	5959	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0
Elec Gen.	12464	5968	3565	51211	1811	0	595	2962	27	7604	0
Ref Oil	183	224	50	20101	82974	25581	1258	655	41	371	0
Gas T&D	2528	2617	1490	16855	0	0	1487	0	20	4090	0
Wood Prd.	3226	367	483	164319	152	544	25	372	12	25127	0
Chemicals	4480	2217	2486	130298	197	427	7593	1069	195	8403	0
Cement	-130812	1971	623	91066	91	60	111	13	2	9396	0
Steel	639	-132727	1121	133175	64	327	13	20	0	15	0
NFMetals	167	2745	-96985	92245	31	139	0	0	0	68	0
OthInd	10024	12531	10211	-4864610	9854	20461	3789	3474	300	45796	0
PassTran	893	1069	591	27146	-310542	8758	135	482	48	4482	0
FrghtTran	7141	4720	3717	73333	5449	-375374	1589	5049	57	18468	0
Grains and Oil Seeds	0	0	1	1190	0	19	-96981	39132	33	41615	0
Animal Products	0	0	1	821	1	7	1010	-171678	122	155094	0
Forestry	7	0	10	1786	0	0	0	0	-9330	175	0
Food Processing	41	5	10	3859	479	229	0	24864	348	-903224	0

Carbon	0	0	0	0	0	0	0	0	0	0	-2441
Land rental	0	0	0	0	0	0	0	0	0	0	0
Labor income	770	684	424	34747	1453	2686	56	168	31	2721	0
OVA (other value added)	0	0	0	0	0	0	0	0	0	0	0
IBT (indirect business taxes)	0	0	0	0	0	0	0	0	0	0	0

Table 4 Extension (demand columns) for time *t=7* with carbon-equivalent emission limits imposed

t=7	24	25	26	27
Region = USA	Net Exports	Investments	General Government Consumption	Household Consumption
Other Ag.	-2911	0	9540	36050
ETE	173518	157406	3232620	6910570
C.Oil Prd.	-44653	0	0	0
N.Gas Prd.	-31369	0	0	0
Coal Prd.	3336	0	0	0
Coke Prd.	-25	0	0	0
	0	0	0	0
Elec Gen.	-145	0	63681	118690
Ref Oil	0	0	5671	6366
Gas T&D	0	0	9629	27519
Wood Prd.	-2587	8000	18091	42120
Chemicals	6117	3438	59503	171538
Cement	-4132	0	3873	9869
Steel	-8146	27	1244	61
NFMetals	-3846	628	1819	202
OthInd	-119489	2444790	574853	1023080
PassTran	20012	4592	57220	100450
FrghtTran	28057	8669	35536	69249
Grains and Oil Seeds	10963	0	2714	757
Animal Products	-674	0	682	10780
Forestry	-571	0	-8683	4873
Food Processing	-3165	5	41128	667171
Carbon	0	0	0	0
Land rental	0	0	0	0
Labor income	0	0	0	-170365
OVA (other value added)	1171	2268460	0	-2269520
IBT (indirect business taxes)	0	0	0	0

Table 5 Variable values at the end of the last iteration of the market solving algorithms when carbon policies are based on carbon emission limits

For t=7 when carbon policies are based on carbon equivalent emissions and carbon fees of $100 ton C Region = USA	Mrk (m)	(j)	MrkEd = Excess Demand	MrkPrd (note energy in ExaJoules)	P_i	SalesV (note energy in monetary values)
Other Ag.	1	1	0.02328	138868.0	0.91327	138868.0
C.Oil Prd.	2	3	0.00000	20.8	1.00000	47777.9
N.Gas Prd.	3	4	0.00000	21.8	1.00000	50024.8
Coal Prd.	4	5	0.00000	27.8	0.89636	27122.8
Coke Prd.	5	6	0.00000	1.2	2.17083	5933.4
[empty]	6	7	0.00000	0.0	1.00000	0.0
Elec Gen.	7	8	0.00003	20.7	1.38707	425025.0
Ref Oil	8	9	0.00000	41.9	1.72712	176722.0
Gas T&D	9	10	0.00001	36.9	1.59899	176302.0
Wood Prd.	10	11	0.14703	439236.0	0.83425	439236.0
Chemicals	11	12	0.29714	616838.0	0.85995	616838.0
Cement	12	13	0.01484	143155.0	0.91768	143155.0
Steel	13	14	0.02649	153190.0	0.90411	153190.0
NFMetals	14	15	0.03776	128960.0	0.76174	128960.0
OthInd	15	16	6.44723	5948400.0	0.85386	5948400.0
PassTran	16	17	0.92306	328508.0	1.00436	328508.0
FrghtTran	17	18	0.55866	425260.0	0.95212	425260.0
Grains and Oil Seeds	18	19	0.05353	99969.7	0.84195	99969.7
Animal Products	19	20	-0.04671	196859.0	0.67687	196859.0
Forestry	20	21	-0.21275	9553.9	0.84770	9553.9
Food Processing	21	22	-2.90778	1038580.0	0.72144	1038580.0
Carbon market for fixed carbon fee of $100 per ton carbon	22	23	0.00081	2440.6	165.66	2440.6
	23	24	0.00000	0.0	0.00000	0.0
Land rental	24	25	-0.00001	170365.0	60.62	170365.0
Labor income	25	26	71.01880	2269550.0	0.08938	2269550.0
OVA (other value added)	26	2	0.00000	14169100.0	1.00000	14169100.0

Markup of Prices

After solving for market prices, as described in "The solution process" (see Chapter ten of the documentation) and illustrated in Table 5, the market prices are "marked up," for prices paid (Equation 9) and prices received (Equation 13). The marked-up prices are part of the calculations of expected prices paid and received (Equations 15 and 16). The marked-up prices are also part of the calculations of the technical change coefficients when imposing changes in elasticity (Equations 34 and 36), the Leontief technical change coefficients (Equations 39, 41, 44-45), the expected profit rates (Equations 55-57), profits (Equations 58 and 59 for old vintages; Equations

74 and 75 for new vintages), demands[1] (Equation 61 for old vintages; Equations 76 for new vintages) and gross production (Equation 63 for old vintages; Equation 76 for new vintages). In addition, marked-up prices are used in the calculations of additional costs upon demands (e.g., Equations 82 and 83). The necessary information for the markup of prices is listed below and described in “ Prices and expected prices” (see Chapter four of the documentation).

Table 6 Initial and future market prices

Supply sectors (i)	Region = USA Period	0	1	2	3	4	5	6	7	8	9	10	11	12	Extended through additional periods if necessary
1	Ag	1	1	1	1	1	1	1	1	1	1	1	1	1	
2	ETE	1	1	1	1	1	1	1	1	1	1	1	1	1	
3	CrudeOil	1	1	1	1	1	1	1	1	1	1	1	1	1	
4-22	Etc.	1	1	1	1	1	1	1	1	1	1	1	1	1	
23	Carbon	1	1	1	1	1	1	1	1	1	1	1	1	1	
24	Land	0	0	0	0	0	0	0	0	0	0	0	0	0	
25	Labor	25.96	25.96	25.96	25.96	25.96	25.96	25.96	25.96	25.96	25.96	25.96	25.96	25.96	
26	Capital	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	

Alternatively, crude oil prices are set exogenously:

3	CrudeOil	1	0.7068	0.7682	0.8118	0.8367	0.8636	0.8974	0.9325	0.9691	1.007	1.0464	1.0874	1.13

Table 7 Price overrides (*IPfix*)

Region = USA	T: Exogenous F: Endogenous
Start Period	1
Ag	F
ETE	T
CrudeOil	T
NatGas	T
Coal	F
Coke	F
Steel	F
Elect	F
RefOil	F
GasTD	F
Ind11	F
Ind12	F
Ind13	F
Ind14	F
Ind15	F
Ind16	F
Ind17	F
Ind18	F
Ind19	F

[1] Demands and gross production based on the Leontief production function are price-independent, except throught the Leontief technical scale coefficients (see Equations 64 and 78 for demands and Equations 65 and 79 for gross production).

Ind20	F
Ind21	F
Ind22	F
Carbon	F
Land	T
Labor	F
Capital	F

Table 8 Production-sector-specific indirect business taxes

Tax Rates on Production (Indirect Business Taxes) Region = USA		
Production Sectors	MSTART (t=0)	TXIBT(IS,L)
1	0	0.016604
2	0	0.071580
3	0	0.054166
4	0	0.054166
5	0	0.112005
6	0	0.029087
7	0	0
8	0	0.057385
9	0	0.054049
10	0	0.050808
11	0	0.010144
12	0	0.013186
13	0	0.011498
14	0	0.011895
15	0	0.010967
16	0	0.011445
17	0	0.032355
18	0	0.025316
19	0	0.040286
20	0	0.013398
21	0	0.046201
22	0	0.024134

Table 9 Transportation cost changes for each supply sector

Region = USA	For each supply sector Transportation Costs		
	TRI	TRZ	TTRZ
	equals 0 for all	equals 0 for all	equals 20 for all
Sector	0	0	20
Subsector	0	0	20
Ag	0	0	20
ETE	0	0	20
CrudeOil	0	0	20
NatGas	0	0	20
Coal	0	0	20
Etc.	0	0	
Ind22	0	0	20
Carbon	0	0	20
Land	0	0	20
Labor	0	0	20

Capital	0	0	20

Table 10 Additive taxes, proportional tax rates and transportation-export-import cost multipliers

Region = USA			For each supply sector		
			Proportional Tax Rates equals one for all For each supply	Transportation Cost Multiplier **For each supply sector**, but also used for each production sector	Additive Taxes equals 0 for all For each supply
Region	Input	Start Period	$TXPRO_{i,j,jj}$	$EXIMPORT_i$	$TXADD_{i,j,jj}$
	1	0	1	1	0
	2	0	1	1	0
	3	0	1	1	0
	etc	0	1	1	0
	26	0	1	1	0

Table 11 Adjustments to prices

Production (sub) sectors (j,jj)		Adjustment on Prices for supply sectors 1:22			Etc 2:22	Adjustment on Prices for supply sector 23			For land: labor	Adjustment on Prices for IR Interest rates (see Equation 13) (see also below for alternative values)			Adjustment on Prices for IR Retrofit		
		AD	ADJZ	TADJZ		AD	ADJZ	TADJZ		AD	ADJZ	TADJZ	AD	ADJZ	TADJZ
	Region = USA														
	Supply Sectors >	1				23				26			27		
1	Other Ag.	1	1	20		1	1	20		0.184440	0.184	20	0	0	20
2	ETE	1	1	20		1	1	20		0.013406	0.060	20	0	0	20
3	C.Oil Prd.	1	1	20		1	1	20		-0.037437	-0.037	20	0	0	20
4	N.Gas Prd.	1	1	20		1	1	20		0.036857	0.037	20	0	0	20
5	Coal Prd.	1	1	20		1	1	20		0.104267	0.104	20	0	0	20
6	Coke Prd.	1	1	20		1	1	20		0.246819	0.247	20	0	0	20
7	empty	1	1	20		1	1	20		0.000000	0.000	20	0	0	20
8.1	ElecOil	1	1	20		1	1	20		1.326267	15.000	20	0	0	20
8.2	ElecGas	1	1	20		1	1	20		0.265579	0.204	20	0	0	20
8.3	ElecCoal	1	1	20		1	1	20		0.034936	0.100	20	0	0	20
8.4	ElecBio	1	1	20		1	1	20		0	0.000	20	0	0	20
8.5	ElecNuc	1	1	20		1	1	20		0.066597	0.064	20	0	0	20
8.6	ElecHydro	1	1	20		1	1	20		0.089439	0.064	20	0	0	20
9	Ref Oil	1	1	20		1	1	20		0.056189	0.056	20	0	0	20
10	Gas T&D	1	1	20		1	1	20		0.027453	0.027	20	0	0	20
11	Wood Prd.	1	1	20		1	1	20		0.069210	0.069	20	0	0	20
12	Chemicals	1	1	20		1	1	20		0.152835	0.153	20	0	0	20
13	Cement	1	1	20		1	1	20		0.161308	0.161	20	0	0	20
14	Steel	1	1	20		1	1	20		0.012773	0.013	20	0	0	20
15	NFMetals	1	1	20		1	1	20		-0.005411	-0.010	20	0	0	20
16	OthInd	1	1	20		1	1	20		0.204431	0.204	20	0	0	20
17	PassTran	1	1	20		1	1	20		0.203327	0.203	20	0	0	20
18	FrghtTran	1	1	20		1	1	20		0.009212	0.009	20	0	0	20

19	Grains and Oil Seeds	1	1	20		1	1	20		0.088871	0.089	20	0	0	20
20	Animal Products	1	1	20		1	1	20		-0.009659	-0.010	20	0	0	20
21	Forestry	1	1	20		1	1	20		0.072629	0.073	20	0	0	20
22	Food Processing	1	1	20		1	1	20		0.322878	0.323	20	0	0	20
26	Capital interest rates	1	1	20		1	1	20		0	0	20	0	0	20
27	TxIBT	1	1	20		1	1	20		0	0	20	0	0	20

Conversion Tables

Information in the next three tables (12-14) are necessary for the conversion of energy units to monetary units.

Table 12 Emission coefficients and GWP

Fn	EMC (millions ton C/EJ)	GWP
Oil combined	20.43	1
Gas combined	13.65	1
Coal combined	24.08	1

Table 13 Energy conversion factors (exajoules per million 1990 dollars)

ENERGY		$PRCONVRT_{i\ or\ j}$
Region	Sector	
Ag	1	1
ETE	2	1
C.Oil Prd.	3	0.00043592
N.Gas Prd.	4	0.00043592
Coal Prd.	5	0.00102535
Coke Prd.	6	0.00020574
Empty	7	1
Electricity	8	0.00004878
Ref Oil	9	0.00023709
Gas T&D	10	0.00020927
Wood Prd.	11	1
Chemicals	12	1
Cement	13	1
Steel	14	1
NFMetals	15	1
OthInd	16	1
PassTran	17	1
FrghtTran	18	1
Grains and Oil Seeds	19	1
Animal Products	20	1

Forestry	21	1
Food Processing	22	1

Table 14 Exchange rates

Exchange rate	national currency per US dollar
Region	EXCHRATE (National currency/US dollar)
11	1
3	4.783

Technical Change Tables

For each region, technical change parameters for each sector *j*, each subsector *jj*, and each time period *t* determine the efficiency improvements in energy production, energy transformation (e.g., oil refining, gas processing, coal and electricity generation), industry, transportation and agriculture.

An example of technical change parameters for one production sector is listed in Table 15. The parameters are used as the base value for a multiplier (which changes over time; see Equations 19-21, 29, 43, 187 and 222) of the base year's technical scale coefficients ($\alpha_{i,j}$) extracted from an input-output table (Table 1 is the input-output table from which the $\alpha_{i,j}$'s are extracted). Thus, technical change parameters are inputs for modifications over time of the technical scale coefficients for inputs to production (that is, to capital (*KA)*, labor (*L)*, energy (*E)*, industry (*M)* (manufacturing), land (*land)*, oil refining, gas production and processing, coal production, and electricity towards the production processes, *j* and *jj*, for each region *l* and each time period *t*.

Technical change parameters also determine the efficiency of labor productivity, land productivity, and capital (see Table 15).

Tables 16 and 17 show technical change parameters for household and government fuel consumption.

Table 15 Technical change parameters for production sector 2, the Everything Else sector, for inputs of capital *KA*, labor *L*, energy production *E*, industry *M* (manufacturing), land *land*, oil refining, gas processing, coal and electricity

Region = USA														
Period t		0	1	2	3	4	5	6	7	8	9	10	11	12
Sector, **e.g.**:		2	2	2	2	2	2	2	2	2	2	2	2	2
Subsector, **e.g.**:		1	1	1	1	1	1	1	1	1	1	1	1	1
Parmname														
TECHNN (KA): capital	1	0	0	0	0	0	0	0	0	0	0	0	0	0
TECHNN (L): labor	2	0	0.03	0.025	0.005	0.015	0.02	0.02	0.02	0.015	0.015	0.015	0.015	0.015
TECHNN (E):	3	0	0	0	0	0	0	0	0	0	0	0	0	0

energy													
TECHNN (M); manufacturing	4	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TECHNN (land)	5	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TECHNN (Ref Oil)	6	0	0.03	0.025	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
TECHNN (Ref Gas)	7	0	0.02	0.02	0.02	0.02	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
TECHNN (Coal)	8	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
TECHNN (Electricity)	9	0	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Table 16 Technical change parameters for household fuel use

Household AEEI by fuel	HHAEEI	Region=11	Period												
		Period	0	1	2	3	4	5	6	7	8	9	10	11	12
		Ref Oil	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		Gas	0	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
		Coal	0	0	0	0	0	0	0	0	0	0	0	0	0
		Elec	0	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Table 17 Technical change parameters for government fuel use

Government AEEI by fuel	GVAEEI	Region=11	Period												
		Period	0	1	2	3	4	5	6	7	8	9	10	11	12
		Ref Oil	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		Gas	0	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
		Coal	0	0	0	0	0	0	0	0	0	0	0	0	0
		Elec	0	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Table 18 lists the elasticities of substitution for the reference case. In the headings of Tables 19 and 20 references are made to the equations describing the technical scale coefficient calculations. Tables 19, 20, and 21 show example outputs of the technical scale transformation processes captured. These transformations are dependent on the elasticities of substitution in the CES production function.

Table 18 Elasticities of substitution for the production sectors

Region = USA		sigma1, Long-run elasticities	sigma2, Short-run elasticities	rho1, ρ_1 is based on sigma1 $\rho = (\sigma-1)/\sigma$	mu1, μ_1 is based on sigma1 $\mu=\rho/(1-\rho)$	rho2, ρ_2 is based on sigma2	mu2, μ_2 is based on sigma2
Column headings of the production sectors ↓							
Agriculture	1	0.3	0.1	-2.333	-0.7	-9	0.111
ETE	2	0.4	0.1	-1.5	-0.6	-9	0.111
Crude Oil	3	0.276	0.1	-2.623	-0.724	-9	0.111
Nat. Gas	4	0.276	0.1	-2.623	-0.724	-9	0.111
Coal	5	0.276	0.1	-2.623	-0.724	-9	0.111
Coke Prod.	6	0.1	0.1	-9	-0.9	-9	0.111

Empty	7	0.276	0.1	-2.623	-0.724	-9	0.111
ElecOil	8.1	0.051	0	-9	-0.9		0
ElecGas	8.2	0.051	0	-9	-0.9		0
ElecCoal	8.3	0.051	0	-9	-0.9		0
[ElecBio]	8.4	0.3	0.3	-2.333	-0.7	-2.333	0.429
ElecNuc	8.5	0.1	0	-9	-0.9		0
ElecHydro	8.6	0.1	0	-9	-0.9		0
Oil refining	9	0.1	0	-9	-0.9		0
Gas T&D	10	0.1	0.1	-9	-0.9	-9	0.111
Paper, Pulp	11	0.276	0.1	-2.623	-0.724	-9	0.111
Chemicals	12	0.276	0.1	-2.623	-0.724	-9	0.111
Cement, etc.	13	0.276	0.1	-2.623	-0.724	-9	0.111
Iron and Steel	14	0.276	0.1	-2.623	-0.724	-9	0.111
NF Metals	15	0.276	0.1	-2.623	-0.724	-9	0.111
Other Industry	16	0.276	0.1	-2.623	-0.724	-9	0.111
Passenger Transport	17	0.276	0.1	-2.623	-0.724	-9	0.111
Freight Transport	18	0.276	0.1	-2.623	-0.724	-9	0.111
Grains and Oil Seeds	19	0.276	0.1	-2.623	-0.724	-9	0.111
Animal Products	20	0.276	0.1	-2.623	-0.724	-9	0.111
Forestry	21	0.276	0.1	-2.623	-0.724	-9	0.111
Food Processing	22	0.276	0.1	-2.623	-0.724	-9	0.111

Table 19 Example output of the vintaged alpha transformations, $\alpha_{i=1,j=1}$, over time (for supply sector 1 and production sector 1)

t= 0:12 ↓	Equation 28 results	Equation 31 results; used in operating new capital, t=1:12, in the Z equation (see Equations 72, 74, 76 and 77) and in the expected profit rate calculations in the Z equation (see Equation 55 and 57) and consequently in the new investment Z part of the equation (see Equation 133)		Equation 37 results; used in Z in demand function; for vintages (v=t–3:t-1) short-run elasticities override long-run elasticities when operating old vintages (see Equations 55, 58, 61 and 63)	
0	0.000769	at t=0 for v=0	0.116363	at t=0 for v=-3:-1	0.116363
1	0.000685	at t=1 for v=1	0.112380	at t=1 for v=-2:0; at t=2 for v=-1:0; at t=3 for v=0	0.112010
2	0.000610	at t=2 for v=2	0.108533	at t=2 for v=1; at t=3 for v=1; at t=4 for v=1	0.108177
3	0.000543	at t=3 for v=3	0.104819	at t=3 for v=2; at t=4 for v=2; at t=5 for v=2	0.104474
4	0.000483	at t=4 for v=4	0.101231	at t=4 for v=3; at t=5 for v=3; at t=6 for v=3	0.100898
5	0.000430	at t=5 for v=5	0.097766	at t=5 for v=4; at t=6 for v=4; at t=7 for v=4	0.097445
6	0.000383	at t=6 for v=6	0.094420	at t=6 for v=5; at t=7 for v=5; at t=8 for v=5	0.094110
7	0.000341	at t=7 for v=7	0.091188	at t=7 for v=6; at t=8 for v=6; at t=9 for v=6	0.090889
8	0.000304	at t=8 for v=8	0.088067	at t=8 for v=7; at t=9 for v=7; at t=10 for v=7	0.087778
9	0.000271	at t=9 for v=9	0.085053	at t=9 for v=8; at t=10 for v=8; at t=11 for v=8	0.084774
10	0.000241	at t=10 for v=10	0.082142	at t=10 for v=9; at t=11 for v=9; at t=12 for v=9	0.081872
11	0.000215	at t=11 for v=11	0.079331	at t=11 for v=10; at t=12 for v=10;	0.079070
12	0.000191	at t=12 for v=12	0.076615	at t=12 for v=11	0.076364

Table 20 Example output of capital stock technical coefficient transformations for all production sectors for one region and one point in time

		α_i=capital $cost_{s,j,jj,v}$ = $\alpha_{i=26,j,jj,v}*\alpha0^{\rho}$ Results from Equation 30	αcst_i=$capitalcost_{,j,jj,v}$= α_i=capital $costs_{j,jj,v}^{1/(1-\rho)}$ Results from Equation 31	α_i=capital $cost_{j,jj,v}$ Results from Equation 34	αcst_i=$capitalcost_{j,jj,v}$= $\alpha_{i=capital}$ $costs_{j,jj,v}^{1/(1-\rho2)}$ Results from Equation 37
Other Ag.	1	0.6534	0.8804	0.653953	1.1858
ETE	2	0.4903	0.9020	0.772669	1.7985
C.Oil Prd.	3	48.9650	2.9279	49.024200	4.7324
N.Gas Prd.	4	10.9379	1.9359	10.951200	2.8297
Coal Prd.	5	0.5958	0.8689	0.601115	1.1776
Coke Prd.	6	0.0002	0.4610	0.000434	0.4610
.	7	0	0.0000	82546	0.0000
Elec Gen	8.1 =8	95	1.7814	2559520	1.7849
	8.2 =9	119	2.1224	271993000	2.1271
	8.3 =10	2834	2.6925	33388	2.6979
	8.4 =11	0	0.0000	14171	0.0000
	8.5 =12	11704	2.8337	0.000402	3.1234
	8.6 =13	11704	2.6010	22.596700	2.8532
Ref Oil	9 =14	0.0004	0.4575	0.195348	0.5066
Gas T&D	10 =15	22.2536	1.3659	0.234395	1.3659
Wood Prd.	11 =16	0.1954	0.6372	0.078838	0.9068
Chemicals	12 =17	0.2340	0.6700	0.036424	0.8894
Cement	13 =18	0.0792	0.4960	0.032947	0.6548
Steel	14 =19	0.0339	0.4008	0.028394	0.6074
NFMetals	15 =20	0.0329	0.3899	0.002444	0.6053
OthInd	16 =21	0.0283	0.3742	0.561938	0.4810
PassTran	17 =22	0.0024	0.1901	5.777320	0.2437
FrghtTran	18 =23	0.5602	0.8529	0.274525	1.2955
Grains and Oil Seeds	19 =24	5.7653	1.6227	1.094720	2.2552
Animal Products	20 =25	0.2745	0.6999	0.017428	1.0927
Forestry	21 =26	1.0939	1.0253	0.653953	1.4453
Food Processing	22 =27	0.0174	0.3270	0.772669	0.3967

Table 21 Example output of the Leontief coefficients for the fixed factor production subsectors of electricity production and the refined oil production sectors for one region at one point in time for the first supply sector (agriculture; *i=1*) and for the 26th supply sector (capital; *i=26*)

Production (sub)sectors ↓		$\lambda_{0,j,jj,v}$ Equation 40	$\lambda_{i=1,j,jj,v}$ Results from Equation 41 for supply sector 1	$\lambda_{i=26=capital,j,jj,v}$ Results from Equation 42 for capital
8. 1 =8	ElecOil	1	0.00008063	1.9725
8.2 =9	ElecGas	1	0.00007521	2.3812
8.3 =10	ElecCoal	1	0.00012472	2.9777
8.4 =11	ElecBio	1		
8.5 =12	ElecNuc	1	0.00014823	3.4426
8.6 =13	ElecHydro	1	0.00014823	3.1299
9=14	Ref Oil	1	0.00011989	0.5609

Data Tables for the Operation of Vintaged Capital

Each capital stock has a specified lifetime of 4 time periods or 20 years, the so-called nameplate lifetime of a technology in the reference case for the USA. At the end of the capital stock lifetime, the capital is retired and no longer used. Capital stocks are operated across their lifetime with no decrease in technical efficiency (the alpha scale or technical scale parameters are constant over the life (vintages) of the producing sector). Four vintages are operating simultaneously at each point in time representing three operating old vintage technologies and one new technology. Initial capital stock is input (see Table 22 for the reference case). Table 23 shows the technology characteristics of vintaged capital for the reference case.

Table 22 Initial values of prior capital stock

Column headings of the production sectors	Production sectors ↓	Prior Capital Stocks			
Production Sectors	(Sub) sector	KAPRIOR: IVIN (-3)	KAPRIOR: IVIN (-2)	KAPRIOR: IVIN (-1)	KAPRIOR: IVIN (0)
Other Ag.	1	22966	24138	25369	26663
ETE	2	2831665	2976109	3127920	3287476
C.Oil Prd.	3	57692	60635	63728	66979
N.Gas Prd.	4	34113	35853	37682	39604
Coal Prd.	5	7332	7706	8099	8512
Coke Prd.	6	430	451	474	499
Empty	7	0	0	0	0
ElecOil	8.1	5890	6190	6506	6838
ElecGas	8.2	17206	18084	19006	19976
ElecCoal	8.3	76623	80531	84639	88956
ElecBio	8.4	0	0	0	0
ElecNuc	8.5	27571	28978	30456	32009
ElecHydro	8.6	12314	12942	13602	14296
Ref Oil	9	17325	18209	19138	20114
Gas T&D	10	36734	38608	40577	42647
Wood Prd.	11	52849	55545	58378	61356
Chemicals	12	69209	72739	76450	80349
Cement	13	12010	12623	13267	13943
Steel	14	13016	13680	14378	15111
NFMetals	15	11214	11786	12387	13019
OthInd	16	293112.20	308063.90	323778.30	340294.20
PassTran	17	11605.32	12197.31	12819.50	13473.42
FrghtTran	18	92856.04	97592.63	102570.80	107803.00
Grains and Oil Seeds	19	36102.39	37943.97	39879.50	41913.75
Animal Products	20	29163.57	30651.20	32214.72	33858.00
Forestry	21	3058.80	3214.83	3378.82	3551.17
Food Processing	22	39498.18	41512.98	43630.56	45856.16

Table 23 Technology characteristics

NTECHCHAR								
Region	Sector	Subsector	NTECH1 nameplate lifetime of the technology	NTECH2 number of periods between initial investment and first operation	NTEC H3 maximum allowable lifetime (np)	NTECH4 lifetime of the technology renovation	NTECH5 number of periods until initial investment	NTECH6 period in which investment is no longer allowed
	1	1	4	0	4	2	0	50
	2	1	4	0	4	2	0	50
	3	1	4	0	4	2	0	50
	4	1	4	0	4	2	0	50
	5	1	4	0	4	2	0	50
	Etc							
	8	5	4	0	4	2	0	50
	Etc							
	19	1	4	0	4	2	0	50
	20	1	4	0	4	2	0	50
	21	1	4	0	4	2	0	50
	22	1	4	0	4	2	0	50

Carbon Policies and Emissions

Essential information for carbon emission calculations can be found in Table 24, which is an extension of Table 12. Table 25 lists which gases *EMC3* may be emitted in the different production sectors processes (emission activities), the accompanying sector index *EMC4*, the values for the conversion of energy units to monetary units *PRconvrt* (as in Table 13), and policy switches (*EMC2* and *EMC5*).

Table 24 Global warming potential of different gases

				GWP
Region	Gas			1990
11	1	CO_2	Carbon dioxide	1
11	2	CH_4	Methane	5.727273
11	3	N_2O	Nitrous oxide	84.54545
11	4	HFCs	Hydrofluorocarbons	1982.668
11	5	PFCs	Perfluorocarbons	1864.123
11	6	SF_6	Sulfurhexafluoride	6518.182

Table 25 Greenhouse gas emission coefficients and related parameters

Region	Production sector index (j) (EMC4) indicator	$PRconvrt_i$	Emission activity sector	Index (ix) (Nsource)	Emission activity process	EMC_{ix} (EMC1)	Gas togle (EMC2)	Gas type (EMC3)	Switch (EMC5) if =-1 then not a GHG; if =1 then include in GHG calculations
11	3	0.00043592	Crude oil production	1	Oilcomb	16.26676	0	1	1
11	4	0.00043592	Natural gas production	2	Gascomb	13.53174	0	1	1
11	5	0.00102535	Coal production	3	Coalcomb	24.24744	0	1	1
11	5	0.00102535	Coal production	4	CoalPr	4.18	1	2	0
11	1	1	Agriculture	5	Enteric	5.71	1	2	0
11	10	0.00020927	Distributed gas production	6	NatGasSys	5.77	1	2	0
11	3	0.00043592	Crude oil production	7	OilSys	1.29	1	2	0
11	2	1	Everything Else	8	Landfills	10.2	1	2	0
11	1	1	Agriculture	9	Manure	2.61	1	2	0
11	1	1	Agriculture	10	OthAgMeth	0.444	1	2	0
11	2	1	Everything Else	11	OthNonAgMeth	0.707	1	2	0
11	2	1	Everything Else	12	Wastewater	0.15	1	2	0
11	2	1	Everything Else	13	HFC23	0.004988	1	4	0
11	2	1	Everything Else	14	ODSSub	0.000157	1	4	0
11	2	1	Everything Else	15	IndProcsN	0.117	1	3	0
11	1	1	Agriculture	16	ManureN	0.04	1	3	0
11	2	1	Everything Else	17	MobileN	0.163	1	3	0
11	1	1	Agriculture	18	SoilN	0.891	1	3	0
11	2	1	Everything Else	19	StationaryN	0.044	1	3	0
11	2	1	Everything Else	20	Aluminum	0.002897	1	5	0
11	2	1	Everything Else	21	Semiconductor	0.000429	1	5	0
11	8	0.0004970	Electricity generation/distribution	22	ElecDist	0.000859	1	6	0
11	2	1	Everything Else	23	Mg	0.000261	1	6	0

Cost curves can be defined for a variable number of points in each curve. The carbon price (level) relates to a corresponding percent reduction in emissions. The model finds the percentage reduction in emissions through linear interpolations based on the carbon fee. Note that all nitrogen sources share a common curve, as do all high GWP sources[2]. Additional carbon policy switches are listed in Table 26. Table 27 lists the data used in the carbon policy cases for which results are illustrated.

[2] See DeAngelo et al. (2004); Delhotal et al. (2004); Schaefer et al. (2004); Scheele and Kruger (2004); references can be found in the documentation

Table 26 Cost curves for calculations of the carbon-equivalent emissions in relation to carbon prices

Emission activity sector	Index (ix)	Region	level 1	level 2	level 3	level 4	level 5	level 6	level 7
Coal production	4	level	0	5	10	20	30		
		cc	0	0.36786	0.42857	0.46786	0.71429		
Agriculture/ Enteric Fermentation	5	level	0	5	20	40	100	200	
		cc	0	0.2	0.25	0.32	0.38	0.4	
Distributed gas production	6	level	0	5	25	65	140	220	
		cc	0	0.3	0.35	0.4	0.5	0.55	
Crude oil production	7	level	0	5	20	40	100	200	
		cc	0	0.2	0.25	0.32	0.38	0.4	
Everything Else/ Land fills	8	level	0	1	10	20	40		
		cc	0	0.2	0.3	0.38	0.42		
Agriculture/ Manure	9	level	0	5	20	40	75	150	
		cc	0	0.14	0.2	0.38	0.61	0.69	
Agriculture/ Other Ag Methane	10	level	0	5	20	40	100	200	
		cc	0	0.2	0.25	0.32	0.38	0.4	
Everything Else/ Other non-Ag Methane	11	level	0	5	20	40	100	200	
		cc	0	0.2	0.25	0.32	0.38	0.4	
Everything Else/ Waste water	12	level	0	5	20	40	100	200	
		cc	0	0.2	0.25	0.32	0.38	0.4	
Everything Else/ HFC23	13	level	0	5	20	40	80	150	200
		cc	0	0.19096	0.36765	0.52553	0.52563	0.56674	0.56684
Everything Else/ ODSSub	14	level	0	5	20	40	80	150	200
		cc	0	0.19096	0.36765	0.52553	0.52563	0.56674	0.56684
Everything Else/ Industrial N	15	level	0	5	20	40	80	150	200
		cc	0	0.00948	0.21124	0.21134	0.21592	0.21602	0.22489
Agriculture/ Manure N	16	level	0	5	20	40	80	150	200
		cc	0	0.00948	0.21124	0.21134	0.21592	0.21602	0.22489
Everything Else/ Mobile N	17	level	0	5	20	40	80	150	200
		cc	0	0.00948	0.21124	0.21134	0.21592	0.21602	0.22489
Agriculture/ Soil N	18	level	0	5	20	40	80	150	200
		cc	0	0.00948	0.21124	0.21134	0.21592	0.21602	0.22489
Everything Else/ Stationary N	19	level	0	5	20	40	80	150	200

		cc	0	0.00948	0.21124	0.21134	0.21592	0.21602	0.22489
Everything Else/ Aluminum	20	level	0	5	20	40	80	150	200
		cc	0	0.19096	0.36765	0.52553	0.52563	0.56674	0.56684
Everything Else/ Semiconductor	21	level	0	5	20	40	80	150	200
		cc	0	0.19096	0.36765	0.52553	0.52563	0.56674	0.56684
Electricity generation/distribution	22	level	0	5	20	40	80	150	200
		cc	0	0.19096	0.36765	0.52553	0.52563	0.56674	0.56684
Everything Else/ Magnesium	23	level	0	5	20	40	80	150	200
		cc	0	0.19096	0.36765	0.52553	0.52563	0.56674	0.56684

Table 27 Mitigation data

SGM Emissions mitigating technologies input tables					
N GAS PROD AND PROC				*O and M costs*	
Em Driver	Level	Mit. Pct.	Capital	Cost	*Cost*
7	1	0.0350012	0.0000797	0.0000054	*0*
	2	0.1389745	0.0008593	0.0000084	*0*
	3	0.2359669	0.0027236	0.0001607	*0*
	4	0.3107168	0.0056303	0.0004339	*0*
	5	0.4023341	0.0125880	0.0006406	*0*
	6	0.4399916	0.0139066	0.0013849	*0*
	7	0.4433727	0.0144586	0.0014050	*0*
N GAS TRANSMISSION AND DIST				*O and M costs*	
Em Driver	Level	Mit. Pct.	Capital	Cost	*Cost*
26	1	0.2348281	0.0001607	0.0000729	*0*
	2	0.3540385	0.0004834	0.0002228	*0*
	3	0.4241136	0.0013729	0.0003638	*0*
	4	0.4838602	0.0030017	0.0005423	*0*
	5	0.5533318	0.0060539	0.0006181	*0*
	6	0.5557796	0.0061375	0.0006468	*0*
	7	0.5568887	0.0061892	0.0006654	*0*
COAL				*O and M costs*	
Em Driver	Level	Mit. Pct.	Capital	Cost	*Cost*
8	1	0.1009039	0.0005048	0.0005250	*0.0000281*
	2	0.2072688	0.0011051	0.0011844	*0.0000891*
	3	0.3045475	0.0023189	0.0019252	*0.0001596*
	4	0.4017072	0.0033485	0.0035550	*0.0003475*
	5	0.4806272	0.0048686	0.0056830	*0.0005496*
	6	0.5121412	0.0062200	0.0077929	*0.0007098*
	7	*0.5230969*	*0.0070969*	*0.0092047*	*0.0008499*

Tables 28 - 30 summarize the carbon policy option impacts through the recycling of revenues obtained from the carbon fees and, if active, from carbon permit trade. The details of revenue recycling are described in the household and government sections in this document.

Table 28 Descriptions of switches and variables partaking in carbon policy

	Carbon policy options
$CarbFeeP_1$	Activate carbon policy:
	0 for no policy: no carbon price
	1 for policy: some kind of carbon pricing
$CarbFeeP_2$	Activate carbon pricing:
	0 for a fixed carbon price
	enter "0" under policy (PolType),
	enter start period, and
	enter carbon prices by period
	1 for a variable carbon price to be set to reach emissions goal
	internal target (enter year for reference period: $CarbFeeP_5$)
$CarbFeeP_3$	Determine emission limits based on CO_2 or Carbon equivalent basis:
	For user-defined target, enter "1" under Policy,
	0 only CO_2 emissions used to compute limit
	enter start period ($CarbFee_6$) and
	enter targets ($CarbFee_4$) by period
	1 all Carbon-equivalent emissions used to compute limit
	enter start period ($CarbFee_6$) and
	enter targets ($CarbFee_4$) by period
$CarbFeeP_4$	Set details of the emission limits:
	0 external carbon emissions limit
	enter carbon emission limits by period
	enter under policy a $CarbFeeP_3$ value of 0 or 1: CO2 or Ce,
	1 internal carbon emissions limit
	enter reference year for target (e.g., "1990")
	enter under policy a $CarbFeeP_3$ value of 0 or 1: CO2 or Ce,
	enter start period ($CarbFee_6$) and
	enter fraction of reference period emissions allowed in each period (eg, "0.95" for 5% reduction from reference period)
$CarbFeeP_5$	Reference period for internal target for carbon emission limit (e.g., 2005 for year => year-1990)/5 = n)
$CarbFeeP_6$	Start period for policy
	enter initial period for carbon fee to apply (must be after reference period; e.g., 3 for 2005)

Table 29 Policy options, carbon prices and emission limits

	Alternative 1 Reference case	Alternative 2 constant-carbon-price of $100/ton C-$CO_2$	Alternative 3 Emission limits	Alternative 4 Emission limits million tons C as a fraction of the emissions in the third period (CO2)	Alternative 5 Emission limits million tons C as a fraction of the emissions in the third period (CE)
PolType (for explanation see descriptions above and Table 28)	0	0	1	2000	2000
$CarbFeeP_3$ = Carbon dioxide or carbon-equivalent emissions	0	0	0	0	1
$CarbFeeP_6$ = START PERIOD	0	4	3	5	5

1990	$CarbVar_{t=0}$	0	0	1261	0	0
1995	$CarbVar_{t=1}$	0	0	1329	0	0
2000	$CarbVar_{t=2}$	0	0	1429	0	0
2005	$CarbVar_{t=3}$	0	0	1345	0	0
2010	$CarbVar_{t=4}$	0	100	1261	0	0
2015	$CarbVar_{t=5}$	0	100	1248	1.3	1.3
2020	$CarbVar_{t=6}$	0	100	1236	1.3	1.3
2025	$CarbVar_{t=7}$	0	100	1224	1.3	1.3
2030	$CarbVar_{t=8}$	0	100	1211	1.3	1.3
2035	$CarbVar_{t=9}$	0	100	1199	1.3	1.3
2040	$CarbVar_{t=10}$	0	100	1187	1.3	1.3
2045	$CarbVar_{t=11}$	0	100	1175	1.3	1.3
2050	$CarbVar_{t=12}$	0	100	1164	1.4	1.4

Table 30 Impacts of carbon policy options

Revenue Recycling Options: Select case (icrbfeeopt)	
Case 0: ICRBfeeOPT = 0 No carbon fees	
Case 1: ICRBfeeOPT = 1 Carbon fee to general revenues	Government tax revenues include a carbon fee option.
Case 2: ICRBfeeOPT = 2 Deficit reduction	All carbon fees ($CrbFeeTot_t$) are retrieved from government resources (Equation 214) and used for deficit reduction (Equation 215). **Note** that the deficit is treated as a positive number; the fee has therefore to be subtracted.
Case 3: ICRBfeeOPT = 3 Carbon fee to consumers	All carbon fees ($CrbFeeTot_t$) are retrieved from government resources (Equation 216) and returned to household income (Equation 171).
Case 4: ICRBfeeOPT = 4 40% Households, 60% Industry	All carbon fees ($CrbFeeTot_t$) are retrieved from government resources (Equation 216); 40% of carbon fees ($CrbFeeTot_t$) are returned to households (Equation 172); 60% of carbon fees and increases in ibt taxes ($CrbFeeTot_t$ and $ExIBT_t$ (Equation 217)) are returned to corporate earnings (TREte) (Equation 163).
Case 5: ICRBfeeOPT = 5 Domestic to consumers, permits to Deficit	For this option carbon permit trading ($CrbTrade_t$) is kept separate from domestic carbon permit fees ($CrbFeeTot_t$) and there are two paths: (a) if carbon trading ($CrbTrade_t$) is not occurring at a loss it will reduce government deficits (Equation 218), and it will be generated from personal income (Equation 173), while, at the same time, the domestic carbon fee ($CrbFeeTot_t$) is returned to households (Equation 173) and provided for by government resources (Equation 217); (b) If carbon trading provides for a net loss government resources provide for the carbon fees ($CrbFeeTot_t$) (Equation 219) and household income (Pinc) receives the fees (Equation 174).
Case 6: ICRBfeeOPT = 6 Revenue Recycling Options:	
ICRBfeeOP 0 = no tax	
ICRBfeeOP 1 = general revenue	$CrbFeeRcyPct_{3:}$ Revenue ($CrbFeeTot_t$) and increases in IBT taxes ($ExIBT_t$ (Equation 217) are recycled to corporate earnings (TREte) (Equation 172).
ICRBfeeOP 2 = deficit reduction	$CrbFeeRcyPct_{2:}$ Revenue is recycled to household income (Pinc)

	(Equation 175).
ICRBfeeOP 3 = consumption	CrbFeeRcyPct $_{1:}$ Revenue is recycled to government resources (Equation 219).

Demand Sectors

Investment Demands

Initial annual investments *KAflow* for the base year (*v=t=0*) and old vintages (*v=-1*) are input parameters, as are initial expected profit rates (see Table 31).

Table 31 Initial values of annual investments and expected profit rate

Column headings of the production sectors	Production (sub)sectors ↓	Annual Investment		EXPPROF (-1)	EXPPROF (0)
		KAFLOW (-1)	KAFLOW (0)		
Other Ag.	1	4620	5808	1	1
ETE	2	569663	716050	1	1
C.Oil Prd.	3	11606	14589	1	1
N.Gas Prd.	4	6863	8626	1	1
Coal Prd.	5	1475	1854	1	1
Coke Prd.	6	86	109	0	0
Empty	7	0	0	1	1
ElecOil	8.1	1185	1489	1	1
ElecGas	8.2	3461	4351	1	1
ElecCoal	8.3	15415	19376	1	1
ElecBio	8.4	0	0	0	0
ElecNuc	8.5	5547	6972	1	1
ElecHydro	8.6	2477	3114	1	1
Ref Oil	9	3485	4381	1	1
Gas T&D	10	7390	9289	1	1
Wood Prd.	11	10632	13364	1	1
Chemicals	12	13923	17501	1	1
Cement	13	2416	3037	1	1
Steel	14	2618	3291	1	1
NFMetals	15	2256	2836	1	1
OthInd	16	58967	74120	1	1
PassTran	17	2335	2935	1	1
FrghtTran	18	18680	23481	1	1
Grains and Oil Seeds	19	7263	9129	1	1
Animal Products	20	5867	7375	1	1
Forestry	21	615	773	1	1
Food Processing	22	7946	9988	1	1

Table 32 lists the three parameters that are used in the investment equations: *rinv* is the expected profit rate function exponential, which equals one in the reference case; *scaler* ─ an investment accelerator ─ is a scale coefficient with a value of 1.15 in the reference case; and *accinv* is the working age population ratio exponential, which equals one in the reference case.

Table 32 Investment accelerator equation parameters

Parameters for Investment Equation			
Region	scaler (accl)	accinv	Rinv
	1.2	1	1

Anticipated increases in investments for all production sectors in this formulation are determined by an exogenous parameter $Qproj_t$ in SGM 2000 (see Table 33).

Table 33 Production multiplier

PROJECTED OUTPUT MULTIPLIER (used for investment)													
QPROJ													
Region													
Period	0	1	2	3	4	5	6	7	8	9	10	11	12
Multiplier	1	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15

Some sectors or subsectors may have investment set exogenously (see last column in Table 34; note that when $ExoInvst_j$ equals one or less, no exogenous investment takes place). Before 2040 hydropower and nuclear power-generated electricity generated is determined by exogenously determined investments (see Table 34). The *rhoinv* parameter shown in Table 34 is the expected profit rate exponential, which equals one in the example run.

Table 34 Production sector-specific investment elasticities and exogenous investment demands

	Logit Exponential for Subsector Investment	Exogenous Investment Demand Start period 0
Region	RHOINV	EXOINVST
Ag	1	0
ETE	1	0
CrudeOil	1	14588.7306
NatGas	1	8626.26942
Coal	1	0
Coke	1	0
Steel	1	0
Elect	1.2	0
Ref Oil	1	0
Gas T&D	1	0
Wood Prd.	2	0
Chemicals	1	0
Cement	1	0
Steel	1	0
NFMetals	1	0
OthInd	1	0
PassTran	1	0
FrghtTran	1	0
Grains and Oil Seeds	1	0
Animal Products	1	0
Forestry	1	0
Food Processing	1	0

Table 35 Investment switches for electricity in nuclear and hydropower over time

EXOELEC			
	t	Exogenous Investment for Nuclear Power EXOELEC	Exogenous Investment for Hydro Power EXOELEC
8	0	6972.02379	3113.89224
8	1	9063.63093	3736.67069
8	2	9063.63093	4110.33776
8	3	8157.26784	4110.33776
8	4	8157.26784	4110.33776
8	5	8157.26784	4110.33776
8	6	8157.26784	4110.33776
8	7	8157.26784	4110.33776
8	8	8157.26784	4110.33776
8	9	8157.26784	4110.33776

A set of triggers function as indicators of implementation of resource-related investment functions in the oil, gas and coal production sector (Table 36).

Table 36 Resource characteristics: oil, gas and coal are depletable resources

Resource Characteristics		
NRSCHAR		
Region=11	Product	Ichar
	1	0
	2	0
	Oil production 3	2
	Gas production 4	2
	Coal production 5	2
	6	0
	7	0
	8	0
	Etc	0
	19	0
	20	0
	21	0
	22	0

Table 37 and 38 list the initial values of uninvested depletable resource $Drsce_{j,jj}$ or $DrsCtmp_{j,jj,t}$ and the vintage specific resource that is invested into and available for consumption $Drsve_{j,jj,t}$ or $DrsVtmp_{j,jj}$. No subsectors are active, which implies *jj* is always one. Units are exajoules.

Table 37 Data on oil, gas, and coal resources

	Sector	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Quantity of Uninvested Depletable Resources: DRSCE						
	3=oil	20000	0	0	0	0

	4=gas	20000	0	0	0	0
	5=coal	50000	0	0	0	0
Initial: Annual Growth Rate in Resource Base: RESGRO						
	3=oil	0	0	0	0	0
	4=gas	0	0	0	0	0
	5=coal	0	0	0	0	0
Terminal: Annual Growth Rate in Resource Base: RESGRZ						
	3=oil	0	0	0	0	0
	4=gas	0	0	0	0	0
	5=coal	0	0	0	0	0
Time to Terminal Resource Growth Rate: TRESGRZ						
	3=oil	115	115	115	115	115
	4=gas	115	115	115	115	115
	5=coal	115	115	115	115	115

Table 38 Data on investments in oil, gas, and coal resources

	Sector	Subsector	IVIN(-3)	IVIN(-2)	IVIN(-1)	IVIN(0)
Invested Capital in Depletable Resources: DRSVE						
	3=oil	1	42.64	89.64	141.32	198.04
Invested Capital in Depletable Resources: DRSVE						
	4=gas	1	44.65	93.86	147.96	207.35
Invested Capital in Depletable Resources: DRSVE						
	5=coal	1	59.73	125.55	197.92	277.36

Investments into available energy reserves are calculated with the CES production function with long-run elasticities σ1. Thus, the values of $\alpha_{i,=26,j,jj,v}$ used in calculating the reserves are as in Table 39. Also note that *jj=1* in the reference case.

Table 39 Example of the capital cost scale factor transformations for oil, gas and coal production

Production sectors ↓		$\alpha_{i=26=capital,j,jj,v} = \alpha_{i=26,j,jj,v} * \alpha_0^{\rho}$ (Results from Equation 30)	$\alpha cst_{i=26=capital,j,jj,v} = \alpha_{i=26,j,jj,v}^{1/(1-\rho)}$ (Results from Equation 31)
C.Oil Prd.	3	48.9650	2.9269
N.Gas Prd.	4	10.9379	1.9353
Coal Prd.	5	0.5958	0.8668

Table 40 shows intermediate results of the shares calculated by means of the sequence of equations and the resulting annual investments into the production sectors in the base year.

Table 40 Capital demands and share calculation results at the end of the base year calculations (*t=0*)

	m	Jj	j	v	capital	$Share_{j,jj,t=0}$ Results after execution of Equation 110	$Share_{j,jj,t=0}$ Results after execution of Equation 116	$Kaflow_{j,jj,v}$ Results after execution of Equation 117

							and resharing	through 130
	0	1	1	0	26	1		5808
	0	1	2	0	26	1		528683
	0	1	3	0	26	1		14589
	0	1	4	0	26	1		8626
	0	1	5	0	26	1		1854
	0	1	6	0	26	1		109
	0	1	7	0	26	0		0
ElecOil		1	8	0	26	0.027	0.0591	1489
ElecGas		2	8	0	26	0.08	0.1725	4351
ElecCoal		3	8	0	26	0.357	0.7684	19376
ElecBio		4	8	0	26	0	0	0
ElecNuc		5	8	0	26	0.268	0	6972
ElecHydro		6	8	0	26	0.268	0	3114
	0	1	9	0	26	1		4381
	0	1	10	0	26	1		9289
	0	1	11	0	26	1		13364
	0	1	12	0	26	1		17501
	0	1	13	0	26	1		3037
	0	1	14	0	26	1		3291
	0	1	15	0	26	1		2836
	0	1	16	0	26	1		74120
	0	1	17	0	26	1		2935
	0	1	18	0	26	1		23481
	0	1	19	0	26	1		9129
	0	1	20	0	26	1		7375
	0	1	21	0	26	1		773
	0	1	22	0	26	1		9988

Table 39 shows the investment share information that is input for sharing the production of capital in the SGM. The sharing of investment input is implemented as a vector of values, given that the full matrix $CapMat_{i,j}$ only consists of the row values *i* in the reference case.

Table 41 Investment shares vector

Investment Shares Vector			
Region=11		Input Sectors	SHAREINV
	Aggriculture	1	0
	ETE	2	0.05990578
	C.Oil Prd.	3	0
	N.Gas Prd.	4	0
	Coal Prd.	5	0
	Coke Prd.	6	0
	Empty	7	0
	Electricity	8	0
	Ref Oil	9	0
	Gas T&D	10	0
	Wood Prd.	11	0.00304478
	Chemicals	12	0.00130845
	Cement	13	0
	Steel	14	0.00001024
	NFMetals	15	0.00023904

	OthInd	16	0.93044316
	PassTran	17	0.00174750
	FrghtTran	18	0.00329912
	Grains and Oil Seeds	19	0
	Animal Products	20	0
	Forestry	21	0
	Food Processing	22	0.00000194

Households

The SGM keeps track of population within each region by gender and 5-year age cohort. Population data may be read in directly, using projections from either the World Bank or the United Nations for the model base year and for all future SGM time steps. Data for the reference case are listed in Tables 42 and 43.

Table 42 Projected male population

Projected Male Population													
Region													
Period	0	1	2	3	4	5	6	7	8	9	10	11	12
Age 0-4	9647	9993	9712	9786	10243	10844	11259	11525	11813	12243	12788	13348	13877
Age 5-9	9244	9772	10198	9899	9981	10446	11045	11459	11730	12027	12468	13018	13582
Age 10-14	8806	9632	10273	10655	10359	10455	10933	11547	11979	12269	12587	13047	13617
Age 15-19	9146	9365	10169	10776	11176	10875	10965	11448	12078	12526	12828	13155	13625
Age 20-24	9901	9311	9347	10209	10812	11188	10893	10978	11453	12070	12510	12805	13123
Age 25-29	10767	9572	8902	9055	9882	10454	10820	10542	10627	11080	11673	12097	12381
Age 30-34	10978	10941	9744	9070	9219	10049	10610	10974	10698	10788	11245	11839	12263
Age 35-39	9955	11141	11078	9852	9177	9329	10157	10717	11083	10816	10914	11376	11974
Age 40-44	8804	10039	11155	11091	9868	9201	9360	10183	10744	11116	10861	10965	11430
Age 45-49	6785	8582	9722	10817	10759	9592	8952	9105	9910	10463	10836	10596	10701
Age 50-54	5523	6638	8375	9492	10572	10532	9401	8779	8950	9751	10308	10683	10454
Age 55-59	5005	5322	6393	8085	9190	10262	10244	9158	8568	8755	9557	10117	10498
Age 60-64	4948	4727	5040	6081	7732	8816	9876	9890	8873	8333	8536	9342	9906
Age 65-69	4512	4505	4321	4654	5659	7239	8296	9334	9387	8470	7983	8232	9028
Age 70-74	3423	3835	3859	3755	4094	5034	6495	7492	8491	8601	7814	7399	7671
Age 75+	4628	5369	6166	6779	7135	7706	8986	11261	13840	16574	18625	19326	19377

Table 43 Projected female population

Projected Female Population													
Region													
Period	0	1	2	3	4	5	6	7	8	9	10	11	12
Age 0-4	9204	9533	9274	9341	9768	10330	10719	10973	11253	11670	12192	12727	13229
Age 5-9	8814	9311	9722	9439	9508	9941	10503	10897	11159	11447	11871	12394	12929
Age 10-14	8385	9166	9784	10154	9872	9953	10401	10984	11398	11680	11987	12426	12965
Age 15-19	8654	8800	9667	10237	10623	10335	10414	10872	11474	11905	12198	12509	12954
Age 20-24	9409	8825	9013	9853	10424	10790	10507	10590	11051	11650	12077	12363	12668
Age 25-29	10591	9444	8889	9071	9896	10451	10818	10546	10632	11085	11674	12092	12370
Age 30-34	11016	10951	9826	9237	9421	10256	10813	11185	10914	11006	11467	12061	12479
Age 35-39	10081	11190	11143	9991	9400	9585	10418	10978	11354	11088	11182	11642	12234

Age 40-44	9015	10234	11342	11289	10134	9542	9735	10572	11140	11524	11260	11354	11814
Age 45-49	7045	8887	10089	11176	11131	10007	9430	9617	10447	11013	11395	11135	11225
Age 50-54	5848	7010	8850	10027	11109	11071	9963	9394	9597	10428	10997	11378	11119
Age 55-59	5470	5770	6914	8714	9879	10951	10921	9836	9284	9501	10327	10896	11271
Age 60-64	5671	5323	5614	6726	8483	9622	10674	10658	9623	9102	9319	10134	10694
Age 65-69	5564	5417	5089	5383	6453	8142	9234	10248	10246	9273	8776	9015	9801
Age 70-74	4599	4991	4867	4578	4852	5828	7361	8350	9283	9300	8440	7996	8232
Age 75+	8510	9443	10408	11019	11216	11618	12849	15267	18132	21215	23595	24553	24750

Table 44 lists the male and female population summed between ages 16 and 65, representing age groups 4 through 13. It also lists income for time periods before the base year.

Table 44 Male and female working age population

Male and Female Working Age Population (15 - 65)				
Region	WorkingAGE' 80	WorkingAGE' 85		Working_Age_pop
	1	1	77984.75	Male working_age_population at t-1 (Wage(2,L,-1))
	1	2	79165.50	Female working_age_population at t-1 (Wage(2,L,-1))
	1	1	81811.31	Number of working-age males at t=0 (Wage(1,L,0))
	1	2	82799.92	Number of working-age females at t=0 (Wage(2,L,0))
				Wage(3,L,M) is the workforce
	2	4	5199.63	Income (GNP/workforce) at t=-2 Wage(4,L,-2)
	2	4	6146.42	Income (GNP/workforce) at t=-1 Wage(4,L,-1)

The number of households *Nhh* in a regional population is either a regional input parameter (Table 45) or calculated based on the average number of people per household.

Table 45 Number of households in the base year 1990

Number of households in base year	
Region	NHH
	100000

The labor force for the base year ($LB_{0,ng}$) is either fixed by an exogenous parameter (see Table 46: Fix labor switch) or calculated from data.

Table 46 Household labor supply fraction in base year

	ng	Household Labor Supply		FIX LABOR SWITCH
Region=11	Gender	LB(0)=$LB_{0,ng}$	Period	Rate
	1	0.8	0	0.764468
	2	0.8	1	0.768885
			2	0.777627
			3	0.785602
			4	0.795574
			5	0.809890
				Identical to period 5 thereafter

The demand for labor by households is set exogenously for the base year (see Table 47).

Table 47 Demand for household labor supply in the base year

	Number employed in base year
Region	ED(NIN-1)=$Ed_{i=25,j=27}$
	125840

Table 48 lists the total land area used as parameters in the reference case. Table 49 lists the maximum potential share of land supplied to the market for the base year R_0, and Table 50 lists the demand for land supply in the base year.

Table 48 Total land area over time

Total Land Area		
Region	Period	TLA
	0	1000
	1	1000
	2	1000
	3	1000
	4	1000
	5	1000
	6	1000
	7	1000
	8	1000
	9	1000

Table 49 Land supply function coefficient

Base year Land Supply Function Coefficient	
Region	R(0)=R_0
	1

Table 50 Demand for land in base year

Land used in base year	
Region	ED(NIN-2)=$Ed_{i=24=ls,j=27=hh}$
11	500

Personal income equals the sum of retained income, labor income, and land rental income, minus personal income tax to which government transfers are added and from which personal savings are subtracted. Data required for the calculations are listed in Tables 51 through 60.

Table 51 Personal income tax rate

Personal Income Tax Rate		
Region	Start Period	PITR
	0	0.1628223

Table 52 Corporate income tax rates in base year

Corporate Income Tax Rate		
Region	Start Period	CITR
	0	0.07577859

Table 53 Investment tax credit rates

Investment Tax Credit Rates		
Region	Production (sub)Sector	XITCR=XITCrate$_j$
	1	0
	2	0
	etc	0
	21	0
	22	0
Initial Period for Investment Tax Credit Policy		
PERIOD		
Region		
	100	

Table 54 Retained earnings fraction in the base year

Retained Earnings		
Region	Sector	RE(0)
	1	0.8
	2	0.8
	Etc	
	8	0.8
	9	0.8
	Etc	
	20	0.8
	21	0.8
	22	0.8

Table 55 Total regional household retained earnings

Total retained earning in base year	
Region	TRETE(L)
	624493.6

Table 56 Social security tax rate

Social Security Tax Rate		
Region	Start Period	SSTR
	0	0.15872188

Table 57 Government transfers in the base year

Government transfers in base year

Region	GOVTR
	808000

Table 58 Household savings in base year

Savings in base year	
Region	$Ed_{i=26,j=26}$
	221300

Table 59 Household savings function coefficient in base year

Household Savings Function Coefficient in base year	
Region	$S(0)=S_0$
11	0.4

Table 60 Household income and price elasticities in base year

Household Demand Function Coefficients; Region=11				
Supply sectors ↓		Start Period	Income ε1	Price ε2
Other Ag.	1	0	0.8	-0.3768
ETE	2	0	1.12	-1.0170756
C.Oil Prd.	3	0	0	0
N.Gas Prd.	4	0	1.099	-0.213
Coal Prd.	5	0	1.099	-0.213
Coke Prd.	6	0	1.099	-0.213
	7	0	0	0
Elec Gen.	8	0	1	-0.213
Ref Oil	9	0	0.75	-0.213
Gas T&D	10	0	0.9	-0.213
Wood Prd.	11	0	0.9	-1.0170756
Chemicals	12	0	0.9	-1.0170756
Cement	13	0	0.9	-1.0170756
Steel	14	0	0.9	-1.0170756
NFMetals	15	0	0.9	-1.0170756
OthInd	16	0	0.9	-1.0170756
PassTran	17	0	0.5	-0.5
FrghtTran	18	0	0.5	-0.5
Grains and Oil Seeds	19	0	0.9	-1.0170756
Animal Products	20	0	0.9	-1.0170756
Forestry	21	0	0.9	-1.0170756
Foods	22	0	0.9	-1.0170756

Government

The reference case of SGM 2003 contains only one general government service; the government preference function *GF* is, consequently, set to one, given that no government subsectors are simulated. Thus, the *GF* elasticity coefficient of Table 61 below is not used and *GF* is set to one.

Table 61 Government preference function coefficients

Government Preference Function Coefficients				
GF				
Region	Sector	Index	Start Period	Coefficients
	26	4	0	-0.5

Government deficits are input data with negative values (see Table 62).

Table 62 Government deficit over time

Government Deficit			
GOVDEF			
Region=11	Period	Deficit (listed as +)	
	0	-68404.69	1990
	1	-54723.75	1995
	2	-41042.81	2000
	3	-27361.88	2005
	4	-13680.94	2010
	5	0	2015
	6	0	2020
	7	0	2025
	8	0	2030
	9	0	2035
	10	0	2040
	11	0	2045
	12	0	2050

Trade

If trade is fixed, trade quantities can be input values ($Trade_{0,i=23}$: e.g., Table 63) and trade demand can be set equal to these initial trade values. Note that the SGM has the option to read in carbon trade (into either $Trade_{0,i=23}$ or into an additional trade vector $Trade_{1,i=23}$).

Table 63 Trade data

Region		Net Trade in Base Year		Net Trade when t=1	
	Input	Start Period t=0	$Trade_{0,i}$	t=1	$Trade_{0,i}$
Other Ag.	1	0	-2911.44	1	-2911.44
ETE	2	0	66544.70	1	66544.70
C.Oil Prd.	3	0	-30870.17	1	-30870.17
N.Gas Prd.	4	0	-1922.75	1	-1922.75
Coal Prd.	5	0	3336.18	1	3336.18
Coke Prd.	6	0	-25.47	1	-25.47
	7	0	0.00	1	0.00
Elec Gen.	8	0	-144.75	1	-144.75
Ref Oil	9	0	-6185.95	1	0.00
Gas T&D	10	0	0.00	1	0.00
Wood Prd.	11	0	-2587.47	1	-2587.47
Chemicals	12	0	6117.04	1	6117.04

Cement	13	0	-4131.90	1	-4131.90
Steel	14	0	-8145.91	1	-8145.91
NFMetals	15	0	-3845.95	1	-3845.95
OthInd	16	0	-119488.65	1	-119488.65
PassTran	17	0	20012.44	1	20012.44
FrghtTran	18	0	28057.27	1	28057.27
Grains and Oil Seeds	19	0	10962.83	1	10962.83
Animal Products	20	0	-674.20	1	-674.20
Forestry	21	0	-570.53	1	-570.53
Food Processing	22	0	-3164.53	1	-3164.53
[carbon market]	23	0	0.00	1	0.00
Land rental	24	0	0.00	1	0.00
Labor income	25	0	0.00	1	0.00
OVA (other value added)	26	0	-49639.22	1	-49639.22

Appendix B: Description of the Solution Algorithms

Bisection Routine

The bisection routine is a simple but robust approach to finding roots. To begin the bisection routine, the solution or the root must be bracketed. Bracketing is achieved when the price of a good is adjusted up or down until the excess demand (demand minus supply) changes sign. The two prices at which the sign change occurs represent the initial bracketing interval. Bracketing price intervals are found for all markets.

Once the bracketing price intervals are found, the midpoints of the price intervals are used to determine the sign of the new excess demands. The midpoint price is used to replace the initial bracketing price that has the same sign in excess demand. Each successive iteration reduces the bracketed price intervals by a factor of 2. After n iterations, if the solution is bound by an interval of size ε_n, then after the next iteration it will be bracketed by an interval of size

$$\varepsilon_{n+1} = \varepsilon_n/2 \qquad \text{Eq. A3.1}$$

From the initial bracketed interval, ε_o, to the desired tolerance, ε, the number of iterations to achieve the tolerance is given by

$$n = \log_2 (\varepsilon_o/\varepsilon) \qquad \text{Eq. A3.2}$$

Because there are multiple markets, however, the actual number of iterations to achieve the tolerance for all the markets is determined by the largest initial bracketed interval.

In certain situations, a market must be bracketed again and the bisection routine reapplied. Supply and demand for one market is dependent on the market prices of other goods. Thus, the solution may shift and no longer lie in the initial bracketing intervals. New bracketing intervals must be determined in such a case. In other situations, bracketing may not be possible at all, *e.g.*, when resources are exhausted and there are no longer any supplies. In such a case, the bisection routine cannot be applied.

Although the advantages of the bisection routine is its robustness and sureness in finding the solution price, its disadvantage is that it is slow. To improve the speed of finding solution prices, the bisection routine is combined with the Newton-Raphson routine, which relies on the use of derivative.

Newton-Raphson Routine

The Newton-Raphson routine is a numerical derivative approach to finding the solution. The advantage of this routine over the bracketing and bisection routine is that it converges quadratically near a solution as opposed to linearly and approaches the solution very quickly (Ref. Numerical Recipes). In the vicinity of the solution, each iteration of the routine approximately doubles the number of significant digits in the trial solution. The Newton-Raphson routine requires the evaluation of the function and its derivative at arbitrary points. The Newton-Raphson formula is given by

$$x_{i+1} = x_i + f(x_i)/f'(x_i) \qquad \text{Eq. A3.3}$$

where x_i is the trial solution, x_{i+1} is the next trial solution, and $f'(x_i)$ is the derivative of the function evaluated at x_i.

Graphically, the routine extends the tangent line of the function at a point until it crosses zero and sets the next trial solution to the abscissa of that zero-crossing. This is repeated until the solution is found.

The disadvantage of the Newton-Raphson routine is that it is unstable where there are discontinuities and therefore, the routine's global convergence properties are poor. For instance, at local discontinuities or extreme values, the tangent line of the trial point can move the next trial point hopelessly far away from the real solution.

An effective strategy for creating a solution algorithm that is both fast and robust it to utilize both the bracketing and bisection and the Newton-Raphson methods. This hybrid algorithm relies on bisection whenever Newton-Raphson takes the solution out of bounds, or whenever Newton-Raphson is not reducing the size of the brackets rapidly enough.

The bracketing and bisection routine is applied first to find the initial bracketing intervals and to come near the vicinity of the solution for all markets. The Newton-Raphson routine is then applied to quickly come to the solution. If the Newton-Raphson routine takes the solution out of bounds or does not find the solution within a set number of iterations, the bisection routine is called. This procedure is repeated until the solution is found.

Appendix C: Description of the Solution Algorithms

Input-Output Table Conversions

For detail on conversion from use tables, make tables, and energy balance tables to hybrid commodity by commodity tables see Fisher-Vanden 1993:4.

Let U be a commodity-by-industry use matrix[3] with the same number of columns as industries. Let g be a vector of production values by industry. V is an industry-by-commodity make matrix[4]. An input-output table based on industry technology[5] is created using the matrix equation

$$T = U\hat{g}^{-1}V$$

where $\hat{g}$ is a diagonal matrix with the elements of *g* on the diagonal and zeros everywhere else. Some notation will be set up to show why this works. Let s_{ik} be the value share of input i in the output of industry k , which is equal to the element in the i-th row and k-th column of a normalized use matrix $U\hat{g}^{-1}$. Let v_{kj} be an element of the industry-by-commodity make matrix V. i is an index that runs through all inputs, including value added. k is an index for industries and j is an index for outputs. Individual elements of the input-output table are given by

$$t_{ij} = \sum_k s_{jk} \upsilon_{kj}$$

where t_{ij} is the amount of input i used in the production of output j. Let k be any industry that produces some of output j. Then v_{kj} is the amount of output j produced by that industry. The amount of input i required by industry k is given by $s_{ik} v_{kj}$.

---

3 The use table has the commodities that industry uses as rows, and industries that use these commodities as column headings.
4 The make table has the industries that make commodities as rows and the produced commodities as column headings.
5 http://www.bea.gov/bea/industry/iotables/prod/table_list.cfm?anon=336: The input-output (I-O) accounts show how industries interact; specifically, they show how industries provide input to, and use output from, each other to produce Gross Domestic Product (GDP). These accounts provide detailed information on the flows of the goods and services that make up the production process of industries. The I-O accounts are presented in a set of tables: Use, Make, Direct Requirements and Total Requirements. The Use table shows the inputs to industry production and the commodities that are consumed by final users. The Make table shows the commodities that are produced by each industry. The three Requirements tables are derived from the Use and Make tables. The Direct Requirements table shows the amount of a commodity that is required by an industry to produce a dollar of the industry's output. The two Total Requirements tables show the production that is required, directly and indirectly, from each industry and each commodity to deliver a dollar of a commodity to final users. The Use table is the most frequently requested table because of its applications to the estimates of GDP.

Repeat this procedure for all industries that produce (re Make) any of output j and sum to get the total amount of input i used in the production of output j.

Final-demand vectors remain unchanged by these calculations, and can be appended to the derived input-output table. Note that this procedure will work *even if there are more industries than commodities*.

Postmultiplying by a normalized make table is a way to convert information categorizied by industry to a commodity categorization. This can be applied to all input rows of the use table *as well as energy consumption data* where the rows are fuels and the columns are industries.

Appendix D: Comparisons between the SGM and MiniCAM

The major characteristics of the two Integrated Assessment Models, the Second Generation Model (SGM) and the Mini-Climate Assessment Model (MiniCAM) developed and maintained by the PNNL Joint Global Change Research Institute (JGCRI) are listed below.

General versus partial equilibrium

- The MiniCAM is a partial equilibrium model; the energy sectors are tracked in MiniCAM's evolving Edmonds-Reilly-Barnes module (ERB)
- The SGM is a general equilibrium model, with an 'Everything Else' sector that encompasses all those sectors that are not explicitly simulated such that a general balance of supply and demand can be achieved.

The scope of the models

- The MiniCAM estimates the supply and demand of energy (in the ERB module), agricultural production and land use (using the Agriculture and Land Use model, AgLU), linking greenhouse gas and sulfur dioxide emissions with climate change and sea level rise (using the Model for the Assessment of Greenhouse-gas Induced Climate Change MAGICC) and determines the regional patterns of climate change (using the Regional Climate Change Scenario Generator SCENGEN).
- The SGM estimates a complete, albeit condensed set of economic accounts.

The time horizons of projections

- MiniCAM's time steps are 15 years. Parameters and variables are point estimates, *e.g.*, point estimates are found on the resource cost curves for the model solution.
- SGM's time steps are five years. *Transfers* or *flows* (profit rates, capital flows, investment rates, production rates, prices, technological change) are based on representative annual values of parameters or variables representative of 5-year time-period. Costs, stocks, resource values, etc. are integrated values over a 5-year period. The initial commodity-by-commodity hybrid input-output table is representative of the base year (1990); equilibrium solutions after each 5-year time step are representative of the number of time steps after the base year. Available energy resources are calculated based on investment, which, in turn are based on expected profit rates. Total resources consumed are subtracted from a raw resource stock that may grow independently.

Final demands versus providing energy services

- The MiniCAM simulates demands in the form of 'energy services' to three end-use sectors: transportation, industry and buildings.
- The SGM simulates the traditional economic concepts of factor markets in the form of 'value added' (land, labor, and capital); these factor markets supply factor services to the

production sectors and four components that play a role in SGM's final demand: households, government, investment and net exports.

Functional representation of demand

- In the MiniCAM demand functions are constant elasticity functions that are combined with logit share equations to calculate fuel and agricultural product demands. The demand functions have elasticities for general economic activity and the prices of the specific products demanded.
- In the SGM, demand is determined as the sum of intermediate and final demand sectors. Intermediate demands are determined by cost functions; final demands, in the form of investment-, household-, government-, and net exports-demand are each estimated separately, *e.g.*, household demand is formulated as a constant elasticity function.

Functional representation of production

- In the MiniCAM all goods are produced with a fixed-coefficient (Leontief) production function. These functions are combined with logit share equations to provide a means for competition, *e.g.*, implementation of the logit share equation results in different fuel modes competing in obtaining the lowest total cost of energy services to an end-sector (*e.g.*, the share of oil and gas for heating buildings).
- In the SGM all goods are produced with either a Constant-Elasticity-of-Substitution (CES) production function with vintaging, or a fixed-coefficient (Leontief) production function in combination with logit share equations (*e.g*., for electricity). The CES equations allow for maximum output, to any given vector of inputs. Moreover, as the SGM searches for equilibrium prices, technical coefficients remain invariant with respect to price while input-output coefficients will respond to changes in price. This response, governed by the elasticity of substitution, is important for climate policy since production process intensity ought to respond to changes in the price of fossil fuels.

Capital, investment, profit

- MiniCAM simulates neither capital investment nor profit.
- SGM simulates vintaged capital investment and profit.

Units

- MiniCAM's supplies are based on prices (costs) of supplies: \$/J for energy; \$/cal for agricultural products; $\$/m^3$ wood for wood products. MiniCAM's energy demands are based on energy units (Joules); agricultural demands on calories and wood demands on m^3 wood.
- The SGM calculates production in units that depend on the product unit demanded (*e.g.*, paper in tons, agricultural products in calories, energy in exajoules), and cost of production in monetary value (regional currency). Prices of supplies and of commodities produced are relative to the price of the numeraire sector, whose price equal unity (one).