Appendices: Include data sources, analysis and explanatory notes

Mild winter biggest factor in 20-year low for US CO2 emissions

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Appendix-1: Changes in electricity generation mix and impact on CO2 emissions

Here we describe the data and calculations needed to estimate the quantity of CO2 saved when coal generation is replaced by natural gas. As discussed earlier, coal generation lost 95 million MWh, and nuclear and hydro together lost 17 million. At the same time, natural gas added 68.7 million and wind 8.7 million MWh.

Most of the increase in natural gas generation replaced coal, but a small fraction also replaced hydro and nuclear. We use share weighted average to estimate the quantity of natural gas generation that replaced coal. The calculations below show that out of the 68.7 million MWh increase in natural gas generation between the first quarter of 2011 and 2012, 57 million (83%) replaced coal and the remainder (12 million MWh) filled in for the generation lost by hydro and nuclear.

Regarding the impact on CO2 emissions, each MWh of coal replaced by gas leads to a *decrease* of 0.5 metric tons in CO2. But for each MWh of hydro or nuclear that is replaced by natural gas, there is an *increase* of 0.5 metric tons of CO2. The total decrease in CO2 emissions by the increased use of natural gas in electricity generation is the sum of these two factors. On net increased natural gas generation saved 23 million metric tons of CO2. The calculations below provide additional explanation.

	Description	Data	Remark/Source
1.0	**Total Decline in Electricity Generation**		
1.1	Total generation loss by coal (million MWh)	95	MER July 2012; Table 7.2a
1.2	Total generation loss by hydro and nuclear (million MWh)	17	MER July 2012; Table 7.2a
1.3	Total generation loss by petroleum (million MWh)	2.4	MER July 2012; Table 7.2a
1.4	Total generation loss-all sources [1]+[2]+[3] (million MWh)	114	Calculation
1.5	Share of coal in lost generation [1.1]/[1.4]	83%	Calculation
2.0	**Total Increase in Electricity Generation**		
2.1	Total generation gains by natural gas (million MWh)	68.7	MER July 2012; Table 7.2a
2.2	Total generation gains by wind (million MWh)	8.7	MER July 2012; Table 7.2a
2.3	Total generation gains by other sources (million MWh)	1.5	MER July 2012; Table 7.2a
2.4	Total generation gains—all sources (million MWh)	79	Calculation
2.5	Share of increase due to natural gas: [2.1]/[2.4]%	87%	Calculation
3.0	**Net Changes in Electricity Generation**		
3.1	This is the difference between total generation lost (item [1.4] and total generation increase (item [2.4]) (million MWh)	35	Calculation
3.2	Share of electricity generation that was eliminated due the decline in end use demand, regulations and other factors: [3.1]/[1.4]%	31%	Calculation
3.3	Share of lost generation that was replaced by new sources [2.4]/[1.4]%	69%	Calculation
3.4	Total generation lost (35 million MWh) includes some from coal and the rest from hydro, nuclear and petroleum. We estimate the share of generation lost by each source using the weight of each source in the total of 114 million MWh of lost generation. Using weighted average is most reasonable way to estimate the		Explanatory note

	Description	Data	Remark/Source
	components within the total lost generation.		
3.5	Coal accounts for 95 million of the 114 million MWh. That amounts to 83%. Therefore, the 35 million net generation loss includes 0.83*35 million MWh of coal generation.	29	Calculation
4.0	**Replacement of coal by natural gas & wind**		
4.1	Quantity of coal to be replaced by other sources of electricity [1.1]-[3.2] or (95-29 million MWh)	66	Calculation
4.2	Most of the 66 million MWh of coal generation was replaced by gas—a small fraction by wind and other sources. We use the share of each source to allocate new generation. We know that natural gas represents 87% of the total generation gains from all sources (item [2.5]. Therefore, 87%*66 million MWh of coal was replaced by natural gas.	57	Calculation
4.3	Again using share of wind in the total electricity increase ([2.2]/[2.4]) or 11% as the weight, the estimate of wind replacing coal comes to 11%*66 = 7 million MWh	7	Calculation
4.4	The remainder of coal was replaced by other sources of electricity entering the grid—this is a very small number	~1	*total may not add up to 66 due to rounding*
5.0	**Replacement of hydro and nuclear by natural gas & wind**		
5.1	Replacement of hydro and nuclear: these sources lost a total of 17 million MWh ([1.2]). As shown in [3.3], 69% of this generation loss was replaced. This comes to 69% of 17 =12	12	Calculation
5.2	Replacement by natural gas: this accounts for 87% of the new generation; so the share of hydro and nuclear replaced by natural gas is 87%*12 = 10	10	Calculation
5.3	The remainder of hydro and nuclear was replaced by wind and other sources. This comes ~2 million MWh [5.1]-[5.2]	2	Calculation
6.	**Replacement of petroleum by natural gas**		
6.1	Petroleum lost 2.4 million MWh; if 31% was never replaced, it leaves 1.7 million that was replaced by natural gas because of easy substitutability between the two fuels	1.7	Calculation
7.0	**Summary of changes in electricity generation mix**		
7.1	Natural gas increased generation by ~69 million MWh [2.1]. The allocation of this increase is as follows: coal replacement—57 million [4.2]; hydro and nuclear replacement: 10 million [5.2]; and petroleum replacement: 1.7 million [6.1]		Explanatory note
7.2	Wind increased its generation by 8.7 million MWh. The allocation of this increase is as follows: 7 million filled in for coal [4.3] and ~2 million for hydro and nuclear [5.3]		Explanatory note
8.0	**Savings in CO2 emissions due to natural gas generation**		
8.1	Each MWh of electricity from coal that was replaced by gas saved 0.5 metric tons of CO2. Therefore, replacement of 57.5 million MWh of coal [4.2] will save 0.5*57 million metric tons of CO2	29	Calculation
8.2	Each MWh of electricity from hydro and nuclear that gas replaced, it generated 0.5 metric tons of CO2. For 10 million MWh [5.2] it replaced, it generated 0.5*10 = 5 million metric tons of CO2	5	Calculation
8.3	Net savings in CO2 from increased electricity generation from natural gas [8.1]-[8.2] (29-5 = 24)	24	Calculation
8.4	Contribution of natural gas generation to total co2 reduction of 114 million metric tons (23/114 = 20%)	21%	Calculation
9.0	**Savings in CO2 emissions due to increased wind generation**		
9.1	Wind replaced 7 million MWh of electricity generation gap left by coal [4.3]. Each MWh replacement saves 0.9 metric ton of CO2.	7	Calculation

	Description	Data	Remark/Source
	Total savings in CO2 from wind is 0.9*7 = 7 million metric tons		
9.2	Wind also replaced 2 million MWh of hydro and nuclear. Since these are all zero-carbon electricity sources, net CO2 savings is zero	0	Calculation

Appendix-2: Space heating from natural gas

Basic framework: Both natural gas (direct energy) and electricity (indirect energy) are used for space heating in residential and commercial sectors. Most of the heating needs are in the first and the last quarters of each year. The first quarter typically accounts for around 52% of the total annual heating degree days. This can be verified from the EIA data on heating degree days (link).

To quantify the amount of CO2 reduction in the first quarter of 2012 that can be attributed to the mild winter, we need an estimate of the quantity of natural gas and electricity used for space heating in the base period—the first quarter of 2011. Next we estimate the reduction in the demand for natural gas and electricity in the first quarter of 2012 using the relationship that each percent decrease in HDD leads to an equal percent decrease in energy needed for space heating (see EIA's section "Adjusting for Weather and Climate").

End use data on space heating using natural gas and electricity are available for residential and commercial sectors from the Annual Energy Outlook 2012 Early Release. The most recent data includes 2010 and it is reasonable to use it to estimate the shares natural gas and electricity used for space heating in the first quarter of 2011 because the first quarter HDD for 2010 and 2011 were almost identical. The Calculation steps are shown below.

2.1.0	**Space heating>> residential sector >> natural gas**		
2.1.1	Direct use of natural gas in homes includes space heating and other end uses including water heating, cooking and clothes dryers. Space heating is seasonal while the other end uses remain steady through the year. Since 52% of the heating degree days are in the first quarter, the same proportion of annual energy for space heating is consumed in the first quarter.		Explanatory note
2.1.2a	Total annual (2010) consumption of natural gas for space heating (quadrillion Btu)	3.5	AEO 2012 Early Release; residential/reference case
2.1.2b	Consumption of natural gas for space heating in the first quarter = 52% of 3.5	1.82	Calculation
2.1.3a	Total annual (2010) consumption of natural gas for other end uses (quadrillion Btu)	1.57	AEO 2012 Early Release; residential/reference case
2.1.3b	Consumption of natural gas for other uses in the first quarter = 25% of 1.57 (these end uses are not seasonal like space heating, and are expected to be uniform across sectors. Hence the first quarter estimate just one fourth of the total)	0.39	Calculation
2.1.4	Total natural gas consumption in the first quarter [2.1.2b]+[2.1.3b]	2.21	Calculation
2.1.5	Share of natural gas used for space heating in the first quarter [2.1.2b]/[2.1.4]	82%	

2.1.6	We apply the same percentage to the first quarter data for 2011 because the heating degree days for 2010 and 2011 are comparable (2,312 in Q1-2010 and 2,315 in Q1-2011)		Explanatory note
2.1.7	Quantity of natural gas consumed in the residential sector in Q1-2011 (billion cubic feet)	2,350	MER June 2012, Table 4.3
2.1.8	Share of natural gas used for space heating in Q1-2011 is [2.1.5]*[2.1.7] or (82% of 2,350 billion cubic feet)	1,933	Calculation
2.1.9	Heating degree days in Q1-2012 was 23% lower compared to Q1-2011. Therefore, natural gas needed for space heating in Q1-2012 will be 23% lower.		Explanatory note
2.1.10	Reduction in natural gas use due to the mild winter of 2012 is estimated as 23% of 1,927 billion cubic feet	445	Calculation
2.1.11	Now we compare the predicted decline in natural gas use for Q1-2012 with the actual decline in natural gas between the first quarters of 2011 and 2012. If the two values are close, it means that it is appropriate to allocate the entire decline in natural gas consumption to the mild weather of 2012.		Explanatory note
2.1.12	Total natural gas consumption in Q1-2012 (billion cubic feet)	1,879	Calculation
2.1.13	Decline in natural gas consumption between Q1-2011 and Q1-2012 [2.1.7] – [2.1.12] or (2,350 –1,879)	471	Calculation
2.1.14	Since the predicted value of 445 is very close to the actual value of 471, we can conclude that the entire decline in natural gas in the residential sector between the first quarters of 2011 and 2012 is attributable to the mild winter.		Explanatory note
2.1.15	Total CO2 decline due to reduced natural gas consumption in residential sector (first quarter change between 2011 and 2012) Q1-2011 total of 127 million metric tons versus 102 million in Q1-2012. This reduction in CO2 can be attributed to the mild winter	25	MER June 2012, Table 12.2
2.2.0	**Space heating>> commercial sector >> natural gas**		
2.2.1	Direct use of natural gas in the commercial sector includes space heating and other end uses listed by the EIA covers water heating, cooking and miscellaneous uses like pumps, emergency generators, combined heat and power. Like the residential sector, space heating is seasonal while the other end uses remain steady through the year. Since 52% of the heating degree days are in the first quarter, the same proportion of annual energy for space heating is consumed in the first quarter.		Explanatory note
2.2.2a	Total annual (2010) consumption of natural gas for space heating (quadrillion Btu)	1.65	AEO 2012 Early Release; commercial/reference case
2.2.2b	Consumption of natural gas for space heating in the first quarter = 52% of 1.65	0.86	Calculation
2.2.3a	Total annual (2010) consumption of natural gas for other end uses (quadrillion Btu)	1.6	AEO 2012 Early Release; commercial/reference case
2.2.3b	Consumption of natural gas for other uses in the first quarter = 25% of 1.6	0.4	Calculation
2.2.4	Total natural gas consumption in the first quarter [2.2.2b]+[2.2.3b] or (0.86 + 0.4)	1.26	Calculation
2.2.5	Share of natural gas used for space heating in the first quarter [2.2.2b]/[2.2.4] or 0.86/1.26	68%	Calculation
2.2.6	We apply the same percentage to the first quarter data for 2011 because the heating degree days for 2010 and 2011 are comparable (2,312 in Q1-2010 and 2,315 in Q1-2011)		Explanatory note
2.2.7	Quantity of natural gas consumed in the commercial sector in Q1-	1,326	MER June 2012, Table 4.3

	2011 (billion cubic feet)		
2.2.8	Share of natural gas used for space heating in Q1-2011 is [2.2.5]*[2.2.7] or (68% of 1,326 billion cubic feet)	904	Calculation
2.2.9	Heating degree days in Q1-2012 was 23% lower compared to Q1-2011. Therefore, natural gas needed for space heating in Q1-2012 will be 23% lower.		Explanatory note
2.2.10	Reduction in natural gas use due to the mild winter of 2012 is estimated as 23% of 902 billion cubic feet	208	Calculation
2.2.11	Now we compare the predicted decline in natural gas use for Q1-2012 with the actual decline in natural gas between the first quarters of 2011 and 2012. If the two values are close, it means that it is appropriate to allocate the entire decline in natural gas consumption to the mild weather of 2012.		Explanatory note
2.2.12	Total natural gas consumption in Q1-2012 (billion cubic feet)	1,103	Calculation
2.2.13	Decline in natural gas consumption between Q1-2011 and Q1-2012 [2.2.7] – [2.2.12] or (1,326 –1,103)	223	Calculation
2.2.14	Since the predicted value of 208 is very close to the actual value of 223, we can conclude that the entire decline in natural gas in the commercial sector between the first quarters of 2011 and 2012 is attributable to the mild winter.		Explanatory note
2.2.15	Total CO2 decline due to reduced natural gas consumption in commercial sector (first quarter change between 2011 and 2012) Q1-2011 total of 72 million metric tons versus 60 million in Q1-2012.	12	MER June 2012, Table 12.3

Appendix-3: Space heating from electricity

EIA's monthly energy review provides aggregate data on retail electricity end use for residential, commercial, industrial and other sectors—not the detailed data on the sub-components of end uses. Detailed data at the space heating and other uses are reported in the Annual Energy Review. The most recent data on electricity consumption for space heating in residential and commercial sectors are available for 2010. Since 2010 and 2011 are almost identical in terms of the heating degree days, we use the 2010 data to estimate the quantity of electricity used for space heating in 2011. Then we use the change is heating degree days between 2011 and 2012 to estimate the reduced demand for electricity to heat up homes and commercial buildings. The calculations and data sources are described below.

3.1.0	**Space heating>> residential sector >> electricity**		
3.1.1	According to the EIA, 5.8% of electricity in homes was used for space heating in 2010. We apply the same share to the 2011 data on residential electricity end use. Since 52% of the heating degree days are in the first quarter, the same proportion of electricity for space heating is consumed in the first quarter.	5.8%	Explanatory note; EIA Frequently Asked Questions
3.1.2	Total 2011 consumption of electricity in the residential sector (million MWh)	1,424	MER June 2012, Table 7.6
3.1.3	Estimate of electricity used for space heating (5.8% of 1,424) million MWh	83	Calculation
3.1.4	Estimate of electricity used for space heating in the first quarter of	43	Calculation

	2011 (52% of [3.1.3] since 52% of HDD are in the first quarter; million MWh		
3.1.5	To estimate the quantity of electricity used for space heating in the first quarter of 2012, we use the HDD to energy demand relationship described above—the same methodology that the EIA uses for its projections and analysis. Since HDD in the first quarter of 2012 was 23% less than 2011, we expect the demand for electricity also to be 23% lower.		Explanatory note; EIA's HDD–space heating energy use relationship
3.1.6	Decline in residential electricity end use for space heating due to the mild winter in 2012 is 23% of 2011 electricity or 23% of 43 million MWh [3.1.4]	10	Calculation
3.1.7	Since 83% of electricity generation lost is accounted by coal, (see [1.5] in Appendix-1) estimate of loss in coal generation attributable to lower demand for space heating due to mild winter is 83% of 10 million MWh ([3.1.6])	8	Calculation
3.1.8	**Estimate of CO2 reduction from reduced electricity use for space heating in the residential sector**		
3.1.9	Each MWh of coal generation lost saves around 0.9 ton of CO2. Therefore, reduced generation of 8 million MWh from coal will save 0.9*8 million metric tons of CO2	7.4	Calculation
3.2.0	**Space heating>> commercial sector >> electricity**		
3.2.1	Unlike the residential sector, the EIA does not provide an estimate of annual electricity used for space heating in the commercial sector. But the share of electricity used for space heating can be estimated using the 2010 data from the early release of the Annual Energy Outlook.		Explanatory note; EIA Frequently Asked Questions
3.2.2a	Total annual (2010) consumption of electricity for space heating (quadrillion Btu)	0.18	AEO 2012 Early Release; commercial/reference case
3.2.2b	Consumption of electricity for space heating in the first quarter = 52% of 0.18	0.094	Calculation
3.2.3a	Total annual (2010) consumption of electricity for other end uses including water heating, ventilation, cooking lighting, refrigeration and other. Space cooling is excluded from this total because there is none in the first quarter of the year (quadrillion Btu)	3.79	AEO 2012 Early Release; commercial/reference case
3.2.3b	Consumption of electricity for other uses in the first quarter = 25% of 3.79 (these end uses are not seasonal like space heating or space cooling, and are expected to be uniform across sectors. Hence the first quarter estimate is just one fourth of the total)	0.95	Calculation
3.2.4	Total electricity consumption in the first quarter [3.2.2b]+[3.2.3b] or (0.094 + 0.95)	1.04	Calculation
3.2.5	Share of electricity in the commercial sector used for space heating in the first quarter [3.2.2b]/[3.2.4] or 0.094/1.04	9%	Calculation
3.2.6	We apply the same percentage to the first quarter data for 2011 because the heating degree days for 2010 and 2011 are comparable (2,312 in Q1-2010 and 2,315 in Q1-2011)		Explanatory note
3.2.7	Quantity of electricity consumed in the commercial sector in Q1-2011 (million MWh)	311	MER June 2012, Table 4.3
3.2.8	Estimate of electricity used for space heating in the first quarter of 2011 in the commercial sector 9% of 311 [3.2.7] million MWh	28	Calculation
3.2.9	Decline in commercial electricity end use for space heating due to the mild winter in 2012 is 23% of 2011 electricity or 23% of 28 million MWh [3.2.8]	6	Calculation
3.2.10	Since 83% of electricity generation lost is accounted by coal, (see [1.5] in Appendix-1) estimate of loss in coal generation	5	Calculation

	attributable to lower demand for space heating due to mild winter is 83% of 6 million MWh ([3.2.9])		
3.2.11	**Estimate of CO2 reduction from reduced electricity use for space heating in the commercial sector:** Each MWh of coal generation lost saves around a ton of CO2. Therefore, reduced generation of 5 million MWh from coal will save 5 million metric tons of CO2	5	Calculation
3.3.0	**Total CO2 reduction due to the mild winter of 2012**		
3.3.1	This is equal to CO2 saved due reduced: [2.1.15] natural gas use for space heating in residential sector + [2.2.15] natural gas use for space heating in commercial sector + [3.1.9] reduced electricity demand in residential sector + [3.2.11] reduced electricity demand in commercial sector -- = 25+12+7+5 = 49 million metric tons of CO2	49	Calculation

Appendix-4: Decline in electricity end use

4.0	**Electricity>>Total end use**		
4.1	We use the total electricity retail sales to quantify the decline in end use in residential, commercial, and other sectors. The data comes from Monthly Energy Review June 2012, Table 7.6 titled Electricity End Use		Explanatory note
4.2	Total electricity retail sales Q1-2011 (million MWh)	918	MER June 2012, Table 7.6
4.3	Total electricity retail sales Q1-2012 (million MWh)	879	MER June 2012, Table 7.6
4.4	Decline in electricity end use [4.3]-[4.2] (million MWh)	39	Calculation
4.5	Total decline in end use electricity attributed to reduced need for space heating due to mild winter [3.1.6]+[3.2.9] (million MWh)	16	Calculation
4.6	Decline in end use due to other factors including structural change in economy, higher prices, standards and improved efficiency [4.4]-[4.5] or (39-16) million MWh	23	For the list of four factors behind end use decline see AEO 2012 Reference Case, slide # 29
4.7	Since 83% of electricity generation lost is accounted by coal, (see [1.5] in Appendix-1) estimate of loss in coal generation attributable to lower end use demand is 83% of 23 million MWh ([4.6])	19	Calculation
4.8	**Estimate of CO2 reduction from reduced electricity:** Each MWh of coal generation lost saves around a ton of CO2. Therefore, reduced generation of 19 million MWh from coal will save 19 million metric tons of CO2	18	Calculation