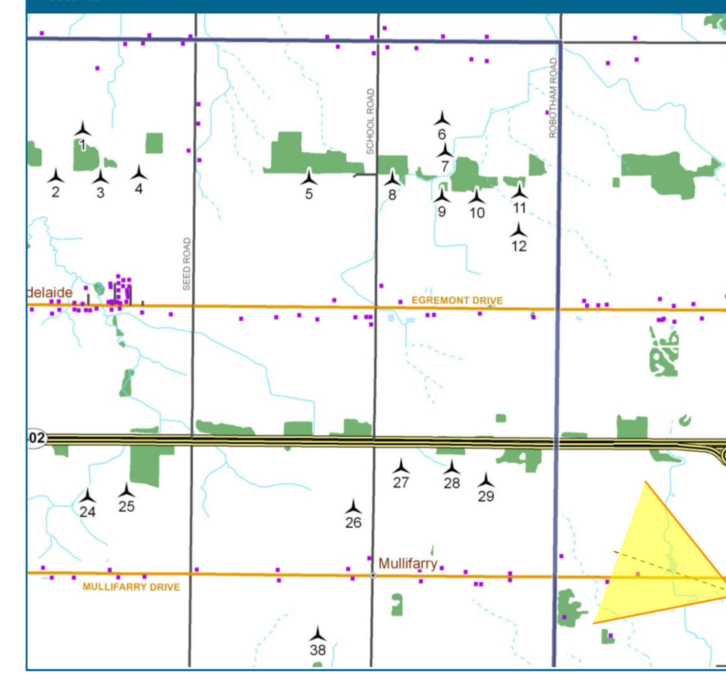
VISUAL SIMULATION

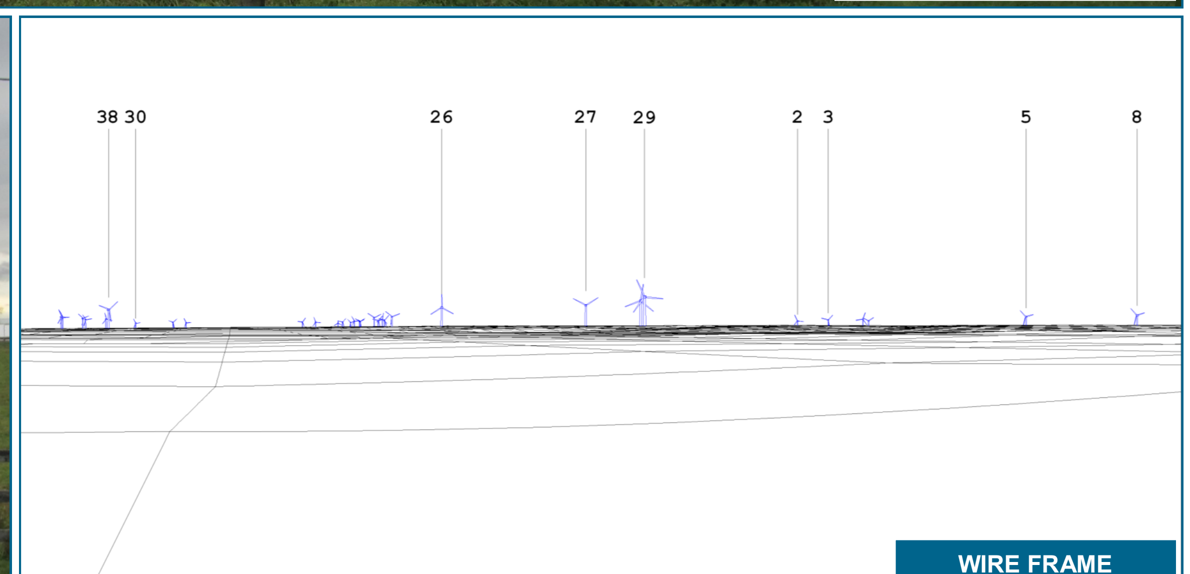
TECHNICAL DATA

PHOTOGRAPH - VIEW POINT		
Photograph Number:		43
Coordinates (UTM 17 NAD83) :	448567 E	4758701 N
Altitude with respect to mean sea level:		241 m
Date Photograph was taken :		November 3rd, 2011
Direction :		290 degrees T.N.
Focal Length :		28 mm
View span :		65 degrees
Altitude of photograph with respect to ground :		1.8 m
WIND TURBINES USED		
Model :		GE 1.6 100
Height of nacelle—mid point :		80 m
Rotor Diameter :		100 m
SIMULATION		
Visual Simulation No. :		PM04-1009ADE-43-E448567_N4758701-L01-T02-D290-MLR01.WFV
Configuration No. :		L01-1009ADEL-PHOM-20111102-AN.WFL
Total number of wind turbines for the project:		38
Total number of visible wind turbines in visual simulation:		8
Closest visible wind turbine :		No 29 at 2.8 km
Furthest visible wind turbine :		No 2 at 8.1 km

MAP



ORIGINAL PHOTO



WIRE FRAME

Note:
* The Wire Frame Technical drawing does not take into consideration vegetation. It is possible that wind turbines are visible on the wire frame drawing but not on the visual simulation.

Prepared for :

NEXTera ENERGY

Prepared by :

GL Garrad Hassan

Date : April 19th, 2012
Version 01

VISUAL SIMULATION

As viewed from 100 m south of the intersection of Centre Road and Mullifarry Drive

Adelaide Wind Farm

Next Steps

REA Process

- The final REA reports will be submitted following the public open houses which will initiate the Ministry of the Environment's review.

- Final reports will be available online at www.NextEraEnergyCanada.com

- Comments received on or before August 17, 2012 will be included in our Public Consultation report to the Ministry of the Environment. Should you wish to provide comments after this date, they can be forwarded directly to the Ministry of the Environment

Other Approvals Required Before Construction

- In addition to the REA, permits and certificates of approval may be required from approval agencies before construction can begin. These may include:
    - Archaeological Clearance from the Ontario Ministry of Tourism, Culture and Sport (MTCS);
    - Fisheries Act Authorizations from the Federal Department of Fisheries and Oceans (DFO);
    - Aeronautical Obstruction Clearance from Transport Canada;
    - Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Permit from the Ausable Bayfield Conservation Authority (ABCA); and
    - Other permits or authorizations from the Ontario Ministry of Natural Resources (MNR) and North Middlesex and Middlesex County.

Please visit www.NextEraEnergyCanada.com
for more details on the progress of the project

Adelaide Wind Energy Centre

NEXTera ENERGY CANADA

OPEN HOUSE COMMENT FORM

• Adelaide Metcalfe Municipal Hall • 2340 Egremont Dr • Strathroy, ON • August 14, 2012 •

Your comments will be considered. We are collecting this information to help us understand and address your concerns about the Project. Comments will become part of the public record with the exception of personal information.

1. Did the information presented tonight meet your expectations?
   - [x] Yes
   - [ ] Somewhat
   - [ ] No

   Please explain: ______________________

2. If you asked questions during the Open House, did you get a satisfactory response?
   - [x] Yes
   - [ ] Didn't speak to anyone
   - [ ] Somewhat
   - [ ] No

   Please explain: ______________________

3. After attending the Open House, how do you feel about the Project?
   - [ ] Positive
   - [x] Neutral
   - [ ] Negative

   Please explain: There are questons about the studies being world wide and NOT in Ontario or in Canada.

4. What topics would you like to learn more about? (check all that apply)
   - [x] Aboriginal Interests
   - [x] Socio-economic
   - [x] Environment
   - [x] Human Health
   - [x] Community Partnerships
   - [x] Transmission
   - [ ] Project Details

   Other: ______________________

Adelaide Wind Energy Centre

NEXTera ENERGY CANADA

5. Please provide your comments or questions in the space provided below:

I am questionable about the health effects it causes humans. No studies of any sort have been completed in Ontario or even in Canada for that much

If you would like to be kept informed about the status of the Adelaide Wind Energy Centre, please provide your contact information below.

Name: [redacted]

Street [redacted]

City/Pr [redacted]

Postal [redacted]

To learn more about the Project, or to send your completed comment form to us, please contact:

Josie Hernandez
Sr. Communications Specialist
NextEra Energy Canada, ULC
5500 North Service Road, Suite 205
Burlington, Ontario L7L 6W6

Toll Free: 1-877-257-7330
Website: www.NextEraEnergyCanada.com

Please submit by Aug. 21/12

Adelaide Wind Energy Centre

NEXTera ENERGY CANADA

OPEN HOUSE COMMENT FORM

• Adelaide Metcalfe Municipal Hall • 2340 Egremont Dr • Strathroy, ON • August 14, 2012 •

Your comments will be considered. We are collecting this information to help us understand and address your concerns about the Project. Comments will become part of the public record with the exception of personal information.

1. Did the information presented tonight meet your expectations?
   - ☐ Yes
   - ☐ Somewhat
   - ☐ No

   Please explain: ______________________

2. If you asked questions during the Open House, did you get a satisfactory response?
   - ☐ Yes
   - ☐ Didn't speak to anyone
   - ☐ Somewhat
   - ☒ No

   Please explain: you still don't know where the hydro lines are going and this is suppose to be your final meeting.

3. After attending the Open House, how do you feel about the Project?
   - ☐ Positive
   - ☐ Neutral
   - ☒ Negative

   Please explain: ______________________

4. What topics would you like to learn more about? (check all that apply)
   - ☐ Aboriginal Interests
   - ☐ Socio-economic
   - ☐ Environment
   - ☐ Human Health
   - ☐ Community Partnerships
   - ☐ Transmission
   - ☐ Project Details

   Other: ______________________

Adelaide Wind Energy Centre

NEXTera ENERGY CANADA

5. Please provide your comments or questions in the space provided below:

- danger to birds, bats, wildlife & domestic
- no thought to people health
- no thought to the people that own the land.
- what is happening to the water table -
- what about the farmers whose well ~~[illegible]~~ dry up. & who pays.
- who pays if cut our tiles
- what about stray voltage
- what about the noise from the lines.

If you would like to be kept informed about the status of the Adelaide Wind Energy Centre, please provide your contact information below.

Name: ______

Street Address: ______

City/Province: ______

Postal Code: ______ Email: ______

To learn more about the Project, or to send your completed comment form to us, please contact:

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Full cost accounting for the life cycle of coal

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Each stage in the life cycle of coal—extraction, transport, processing, and combustion—generates a waste stream and carries multiple hazards for health and the environment. These costs are external to the coal industry and are thus often considered "externalities." We estimate that the life cycle effects of coal and the waste stream generated are costing the U.S. public a third to over one-half of a trillion dollars annually. Many of these so-called externalities are, moreover, cumulative. Accounting for the damages conservatively doubles to triples the price of electricity from coal per kWh generated, making wind, solar, and other forms of nonfossil fuel power generation, along with investments in efficiency and electricity conservation methods, economically competitive. We focus on Appalachia, though coal is mined in other regions of the United States and is burned throughout the world.

Keywords: coal; environmental impacts; human and wildlife health consequences; carbon capture and storage; climate change

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Introduction

Coal is currently the predominant fuel for electricity generation worldwide. In 2005, coal use generated 7,334 TWh (1 terawatt hour = 1 trillion watt-hours, a measure of power) of electricity, which was then 40% of all electricity worldwide. In 2005, coal-derived electricity was responsible for 7.856 Gt of CO_2 emissions or 30% of all worldwide carbon dioxide (CO_2) emissions, and 72% of CO_2 emissions from power generation (one gigaton = one billion tons; one metric ton = 2,204 pounds.)[1] Non–power-generation uses of coal, including industry (e.g., steel, glass-blowing), transport, residential services, and agriculture, were responsible for another 3.124 Gt of CO_2, bringing coal's total burden of CO_2 emissions to 41% of worldwide CO_2 emissions in 2005.[1]

By 2030, electricity demand worldwide is projected to double (from a 2005 baseline) to 35,384 TWh, an annual increase of 2.7%, with the quantity of electricity generated from coal growing 3.1% per annum to 15,796 TWh.[1] In this same time period, worldwide CO_2 emissions are projected to grow 1.8% per year, to 41.905 Gt, with emissions from the coal-power electricity sector projected to grow 2.3% per year to 13.884 Gt.[1]

In the United States, coal has produced approximately half of the nation's electricity since 1995,[2] and demand for electricity in the United States is projected to grow 1.3% per year from 2005 to 2030, to 5,947 TWh.[1] In this same time period, coal-derived electricity is projected to grow 1.5% per year to 3,148 TWh (assuming no policy changes from the present).[1] Other agencies show similar projections; the U.S. Energy Information Administration (EIA) projects that U.S. demand for coal power will grow from 1,934 TWh in 2006 to 2,334 TWh in 2030, or 0.8% growth per year.[3]

To address the impact of coal on the global climate, carbon capture and storage (CCS) has been proposed. The costs of plant construction and the "energy penalty" from CCS, whereby 25–40% more coal would be needed to produce the same amount of energy, would increase the amount of coal mined, transported, processed, and combusted, as well as the waste generated, to produce the same amount of electricity.[1,4] Construction costs, compression, liquefaction and injection technology, new infrastructure, and the energy penalty would nearly double the costs of electricity generation from coal plants using current combustion technology (see Table 2).[5]

Adequate energy planning requires an accurate assessment of coal reserves. The total recoverable reserves of coal worldwide have been estimated to be approximately 929 billion short tons (one short ton = 2,000 pounds).[2] Two-thirds of this is found in four countries: U.S. 28%; Russia 19%; China 14%, and India 7%.[6] In the United States, coal is mined in 25 states.[2] Much of the new mining in Appalachia is projected to come from mountaintop removal (MTR).[2]

Box 1.

Peak Coal?

With 268 billion tons of estimated recoverable reserves (ERR) reported by the U.S. Energy Information Administration (EIA), it is often estimated that the United States has "200 years of coal" supply.[7] However, the EIA has acknowledged that what the EIA terms ERR cannot technically be called "reserves" because they have not been analyzed for profitability of extraction.[7] As a result, the oft-repeated claim of a "200 year supply" of U.S. coal does not appear to be grounded on thorough analysis of economically recoverable coal supplies.

Reviews of existing coal mine lifespan and economic recoverability reveal serious constraints on existing coal production and numerous constraints facing future coal mine expansion. Depending on the resolution of the geologic, economic, legal, and transportation constraints facing future coal mine expansion, the planning horizon for moving beyond coal may be as short as 20–30 years.[8–11]

Recent multi-Hubbert cycle analysis estimates global peak coal production for 2011 and U.S. peak coal production for 2015.[12] The potential of "peak coal" thus raises questions for investments in coal-fired plants and CCS.

Worldwide, China is the chief consumer of coal, burning more than the United States, the European Union, and Japan combined. With worldwide demand for electricity, and oil and natural gas insecurities growing, the price of coal on global markets doubled from March 2007 to March 2008: from $41 to $85 per ton.[13] In 2010, it remained in the $70+/ton range.

Coal burning produces one and a half times the CO_2 emissions of oil combustion and twice that from burning natural gas (for an equal amount of energy produced). The process of converting coal-to-liquid (not addressed in this study) and burning that liquid fuel produces especially high levels of CO_2 emissions.[13] The waste of energy due to inefficiencies is also enormous. Energy specialist Amory Lovins estimates that after mining, processing, transporting and burning coal, and transmitting the electricity, only about 3% of the energy in the coal is used in incandescent light bulbs.[14]

Thus, in the United States in 2005, coal produced 50% of the nation's electricity but 81% of the CO_2 emissions.[1] For 2030, coal is projected to produce 53% of U.S. power and 85% of the U.S. CO_2 emissions from electricity generation. None of these figures includes the additional life cycle greenhouse gas (GHG) emissions from coal, including methane from coal mines, emissions from coal transport, other GHG emissions (e.g., particulates or black carbon), and carbon and nitrous oxide (N_2O) emissions from land transformation in the case of MTR coal mining.

Coal mining and combustion releases many more chemicals than those responsible for climate forcing. Coal also contains mercury, lead, cadmium, arsenic, manganese, beryllium, chromium, and other toxic, and carcinogenic substances. Coal crushing, processing, and washing releases tons of particulate matter and chemicals on an annual basis and contaminates water, harming community public health and ecological systems.[15–19] Coal combustion also results in emissions of NO_x, sulfur dioxide (SO_2), the particulates PM_{10} and $PM_{2.5}$, and mercury; all of which negatively affect air quality and public health.[20–23]

In addition, 70% of rail traffic in the United States is dedicated to shipping coal, and rail transport is associated with accidents and deaths.[20] If coal use were to be expanded, land and transport infrastructure would be further stressed.

Summary of methods

Life cycle analysis, examining all stages in using a resource, is central to the full cost accounting needed to guide public policy and private investment. A previous study examined the life cycle stages of oil, but without systematic quantification.[24] This paper is intended to advance understanding of the measurable, quantifiable, and qualitative costs of coal.

In order to rigorously examine these different damage endpoints, we examined the many stages in the life cycle of coal, using a framework of environmental externalities, or "hidden costs." Externalities occur when the activity of one agent affects the well-being of another agent outside of any type of market mechanism—these are often not taken into account in decision making and when they are not accounted for, they can distort the decision-making process and reduce the welfare of society.[20] This work strives to derive monetary values for these externalities so that they can be used to inform policy making.

This paper tabulates a wide range of costs associated with the full life cycle of coal, separating those that are quantifiable and monetizable; those that are quantifiable, but difficult to monetize; and those that are qualitative.

A literature review was conducted to consolidate all impacts of coal-generated electricity over its life cycle, monetize and tabulate those that are monetizable, quantify those that are quantifiable, and describe the qualitative impacts. Since there is some uncertainty in the monetization of the damages, low, best, and high estimates are presented. The monetizable impacts found are damages due to climate change; public health damages from NO_x, SO_2, $PM_{2.5}$, and mercury emissions; fatalities of members of the public due to rail accidents during coal transport; the public health burden in Appalachia associated with coal mining; government subsidies; and lost value of abandoned mine lands. All values are presented in 2008 US$. Much of the research we draw upon represented uncertainty by presenting low and/or high estimates in addition to best estimates. Low and high values can indicate both uncertainty in parameters and different assumptions about the parameters that others used to calculate their estimates. Best estimates are not weighted averages, and are derived differently for each category, as explained below.

Climate impacts were monetized using estimates of the social cost of carbon—the valuation of the damages due to emissions of one metric ton of carbon, of $30/ton of CO_2equivalent (CO_2e),[20] with low and high estimates of $10/ton and $100/ton. There is uncertainty around the total cost of climate change and its present value, thus uncertainty concerning the social cost of carbon derived from the total costs. To test for sensitivity to the assumptions about the total costs, low and high estimates of the social cost of carbon were used to produce low and high estimates for climate damage, as was done in the 2009 National Research Council (NRC) report on the "Hidden Costs of Energy."[20] To be consistent with the NRC report, this work uses a low value of $10/ton CO_2e and a high value of $100/ton CO_2e.

All public health impacts due to mortality were valued using the value of statistical life (VSL). The value most commonly used by the U.S. Environmental Protection Agency (EPA), and used in this paper, is the central estimate of $6 million 2000 US$, or $7.5 million in 2008 US$.[20]

Two values for mortality risk from exposure to air pollutants were found and differed due to different concentration-response functions—increases in mortality risk associated with exposure to air pollutants. The values derived using the lower of the two concentration-response functions is our low estimate, and the higher of the two concentration-response functions is our best and high estimate, for reasons explained below. The impacts on cognitive development and cardiovascular disease due to mercury exposure provided low, best, and high estimates, and these are presented here.

Regarding federal subsidies, two different estimates were found. To provide a conservative best estimate, the lower of the two values represents our low and best estimate, and the higher represents our high estimate. For the remaining costs, one point estimate was found in each instance, representing our low, best, and high estimates.

The monetizable impacts were normalized to per kWh of electricity produced, based on EIA estimates of electricity produced from coal, as was done in the NRC report tabulating externalities due to coal.[2,20] Some values were for all coal mining, not just for the portion emitted due to coal-derived electricity. To correct for this, the derived values were multiplied by the proportion of coal that was used for electrical power, which was approximately 90% in all years analyzed. The additional impacts from nonpower uses of coal, however, are not included in this analysis but do add to the assessment of the complete costs of coal.

To validate the findings, a life cycle assessment of coal-derived electricity was also performed using the Ecoinvent database in SimaPro v 7.1.[25] Health-related impact pathways were monetized using the value of disability-adjusted life-years from ExternE,[26] and the social costs of carbon.[20] Due to data limitations, this method could only be used to validate damages due to a subset of endpoints.

Box 2.

Summary Stats

1. Coal accounted for 25% of global energy consumption in 2005, but generated 41% of the CO_2 emissions that year.
2. In the United States, coal produces just over 50% of the electricity, but generates over 80% of the CO_2 emissions from the utility sector.[2]
3. Coal burning produces one and a half times more CO_2 emissions than does burning oil and twice that from burning natural gas (to produce an equal amount of energy).
4. The energy penalty from CCS (25–40%) would increase the amount of coal mined, transported, processed, and combusted, and the waste generated.[4]
5. Today, 70% of rail traffic in the United States is dedicated to shipping coal.[20] Land and transport would be further stressed with greater dependence on coal.

Life cycle impacts of coal

The health and environmental hazards associated with coal stem from extraction, processing, transportation and combustion of coal; the aerosolized, solid, and liquid waste stream associated with mining, processing, and combustion; and the health, environmental, and economic impacts of climate change (Table 1).

Underground mining and occupational health

The U.S. Mine Safety and Health Administration (MSHA) and the National Institute for Occupational Safety and Health (NIOSH) track occupational injuries and disabilities, chronic illnesses, and mortality in miners in the United States. From 1973 to 2006 the incidence rate of all nonfatal injuries decreased from 1973 to 1987, then increased dramatically in 1988, then decreased from 1988 to 2006.[27] Major accidents still occur. In January 2006, 17 miners died in Appalachian coal mines, including 12 at the Sago mine in West Virginia, and 29 miners died at the Upper Big Branch Mine in West VA on April 5, 2010. Since 1900 over 100,000 have been killed in coal mining accidents in the United States.[14]

In China, underground mining accidents cause 3,800–6,000 deaths annually,[28] though the number of mining-related deaths has decreased by half over the past decade. In 2009, 2,631 coal miners were killed by gas leaks, explosions, or flooded tunnels, according to the Chinese State Administration of Work Safety.[29]

Black lung disease (or pneumoconiosis), leading to chronic obstructive pulmonary disease, is the primary illness in underground coal miners. In the 1990s, over 10,000 former U.S. miners died from coal workers' pneumoconiosis and the prevalence has more than doubled since 1995.[30] Since 1900 coal workers' pneumoconiosis has killed over 200,000 in the United States.[14] These deaths and illnesses are reflected in wages and workers' comp, costs considered internal to the coal industry, but long-term support often depends on state and federal funds.

Again, the use of "coking" coal used in industry is also omitted from this analysis: a study performed in Pittsburgh demonstrated that rates of lung cancer for those working on a coke oven went up two and one-half times, and those working on the top level had the highest (10-fold) risk.[31]

Mountaintop removal

MTR is widespread in eastern Kentucky, West Virginia, and southwestern Virginia. To expose coal seams, mining companies remove forests and fragment rock with explosives. The rubble or "spoil" then sits precariously along edges and is dumped in the valleys below. MTR has been completed on approximately 500 sites in Kentucky, Virginia, West Virginia, and Tennessee,[32] completely altering some 1.4 million acres, burying 2,000 miles of streams.[33] In Kentucky, alone, there are 293 MTR sites, over 1,400 miles of streams damaged or destroyed, and 2,500 miles of streams polluted.[34–36] Valley fill and other surface mining practices associated with MTR bury headwater streams and contaminate surface and groundwater with carcinogens and heavy metals[16] and are associated with reports of cancer clusters,[37] a finding that requires further study.

The deforestation and landscape changes associated with MTR have impacts on carbon storage and water cycles. Life cycle GHG emissions from coal increase by up to 17% when those from deforestation and land transformation by MTR are included.[38] Fox and Campbell estimated the resulting emissions of GHGs due to land use changes in the Southern Appalachian Forest, which encompasses areas of southern West Virginia, eastern Kentucky, southwestern Virginia, and portions of eastern Tennessee, from a baseline of existing forestland.[38] They estimated that each year, between 6 and 6.9 million tons of CO_2e are emitted due to removal of forest plants and decomposition of forest litter, and possibly significantly more from the mining "spoil" and lost soil carbon.

The fate of soil carbon and the fate of mining spoil, which contains high levels of coal fragments, termed "geogenic organic carbon," are extremely uncertain and the results depend on mining practices at particular sites; but they may represent significant emissions. The Fox and Campbell[38] analysis determined that the worst-case scenario is that all soil carbon is lost and that all carbon in mining spoil is emitted—representing emissions of up to 2.6 million tons CO_2e from soil and 27.5 million tons CO_2e from mining spoil. In this analysis, the 6 million tons CO_2e from forest plants and forest litter represents our low and best estimates for all coal use, and 37 million tons CO_2e (the sum of the high bound of forest plants and litter, geogenic organic carbon, and the forest soil emissions) represents our high, upper bound estimate of emissions for all coal use. In the years Fox and Campell studied, 90.5% of coal was used for electricity, so we attribute 90.5% of these emissions to coal-derived power.[2] To monetize and bound our estimate for damages due to emissions from land disturbance, our point estimate for the cost was calculated using a social cost of carbon of \$30/ton CO_2e and our point estimate for emissions; the high-end estimate was calculated using the high-end estimate of emissions and a social cost of carbon of \$100/ton CO_2e; and the low estimate was calculated using the point estimate for emissions and the \$10/ton low estimate for the social cost of carbon.[20] Our best estimate is therefore \$162.9 million, with a range from \$54.3 million and \$3.35 billion, or 0.008¢/kWh, ranging from 0.003 ¢/kWh to 0.166 ¢/kWh.

The physical vulnerabilities for communities near MTR sites include mudslides and dislodged boulders and trees, and flash floods, especially following heavy rain events. With climate change, heavy rainfall events (2, 4, and 6 inches/day) have increased in the continental United States since 1970, 14%, 20%, and 27% respectively.[39,40]

Blasting to clear mountain ridges adds an additional assault to surrounding communities.[16] The blasts can damage houses, other buildings, and infrastructure, and there are numerous anecdotal reports that the explosions and vibrations are taking a toll on the mental health of those living nearby.

Additional impacts include losses in property values, timber resources, crops (due to water contamination), plus harm to tourism, corrosion of buildings and monuments, dust from mines and explosions, ammonia releases (with formation of ammonium nitrate), and releases of methane.[41]

Methane

In addition to being a heat-trapping gas of high potency, methane adds to the risk of explosions, and fires at mines.[20,42] As of 2005, global atmospheric methane levels were approximately 1,790 parts per billion (ppb), which is an 27 ppb increase over 1998.[43] Methane is emitted during coal mining and it is 25 times more potent than CO_2 during a 100-year timeframe (this is the 100-year global warming potential, a common metric in climate science and policy used to normalize different GHGs to carbon equivalence). When methane decays, it can yield CO_2, an effect that is not fully assessed in this equivalency value.[43]

According to the EIA,[2] 71,100,000 tons CO_2e of methane from coal were emitted in 2007 but

Table 1. **The life cycle impact of the U.S. coal industry**

	Economic	Human health	Environment	Other
Underground coal mining	1. Federal and state subsidies of coal industry	1. Increased mortality and morbidity in coal communities due to mining pollution	1. Methane emissions from coal leading to climate change	
		2. Threats remaining from abandoned mine lands	2. Remaining damage from abandoned mine lands	
MTR mining	1. Tourism loss	1. Contaminated streams	1. Loss of biodiversity	
	2. Significantly lower property values	2. Direct trauma in surrounding communities	2. Sludge and slurry ponds	
	3. Cost to taxpayers of environmental mitigation and monitoring (both mining and disposal stages)	3. Additional mortality and morbidity in coal communities due to increased levels of air particulates associated with MTR mining (vs. underground mining)	3. Greater levels of air particulates	
	4. Population declines	4. Higher stress levels	4. Loss and contamination of streams	
Coal mining	1. Opportunity costs of bypassing other types of economic development (especially for MTR mining)	1. Workplace fatalities and injuries of coal miners	1. Destruction of local habitat and biodiversity to develop mine site	1. Infrastructure damage due to mudslides following MTR
	2. Federal and state subsidies of coal industry	2. Morbidity and mortality of mine workers resulting from air pollution (e.g., black lung, silicosis)	2. Methane emissions from coal leading to climate change	2. Damage to surrounding infrastructure from subsidence
	3. Economic boom and bust cycle in coal mining communities	3. Increased mortality and morbidity in coal communities due to mining pollution	3. Loss of habitat and streams from valley fill (MTR)	3. Damages to buildings and other infrastructure due to mine blasting
	4. Cost of coal industry litigation	4. Increased morbidity and mortality due to increased air particulates in communities proximate to MTR mining	4. Acid mine drainage	4. Loss of recreation availability in coal mining communities

Continued

Table 1. *Continued*

	Economic	Human health	Environment	Other
	5. Damage to farmland and crops resulting from coal mining pollution	5. Hospitalization costs resulting from increased morbidity in coal communities	5. Incomplete reclamation following mine use	5. Population losses in abandoned coal-mining communities
		6. Local health impacts of heavy metals in coal slurry	6. Water pollution from runoff and waste spills	
	6. Loss of income from small scale forest gathering and farming (e.g., wild ginseng, mushrooms) due to habitat loss	7. Health impacts resulting from coal slurry spills and water contamination	7. Remaining damage from abandoned mine lands	
	7. Loss of tourism income	8. Threats remaining from abandoned mine lands; direct trauma from loose boulders and felled trees	8. Air pollution due to increased particulates from MTR mining	
	8. Lost land required for waste disposal	9. Mental health impacts		
	9. Lower property values for homeowners	10. Dental health impacts reported, possibly from heavy metals		
	10. Decrease in mining jobs in MTR mining areas	11. Fungal growth after flooding		
Coal transportation	1. Wear and tear on aging railroads and tracks	1. Death and injuries from accidents during transport	1. GHG emissions from transport vehicles	1. Damage to rail system from coal transportation
		2. Impacts from emissions during transport	2. Damage to vegetation resulting from air pollution	2. Damage to roadways due to coal trucks
Coal combustion	1. Federal and state subsidies for the coal industry	1. Increased mortality and morbidity due to combustion pollution	1. Climate change due to CO_2 and NO_x derived N_2O emissions	1. Corrosion of buildings and monuments from acid rain
	2. Damage to farmland and crops resulting from coal combustion pollution	2. Hospitalization costs resulting from increased morbidity in coal communities	2. Environmental contamination as a result of heavy metal pollution (mercury, selenium, arsenic)	2. Visibility impairment from NO_x emissions

Continued

Table 1. *Continued*

	Economic	Human health	Environment	Other
		3. Higher frequency of sudden infant death syndrome in areas with high quantities of particulate pollution	3. Impacts of acid rain derived from nitrogen oxides and SO_2	
		4. See Levy *et al.*[21]	4. Environmental impacts of ozone and particulate emissions	
			5. Soil contamination from acid rain	
			6. Destruction of marine life from mercury pollution and acid rain	
			7. Freshwater use in coal powered plants	
Waste disposal		1. Health impacts of heavy metals and other contaminants in coal ash and other waste	1. Impacts on surrounding ecosystems from coal ash and other waste	
		2. Health impacts, trauma and loss of property following coal ash spills	2. Water pollution from runoff and fly ash spills	
Electricity transmission	1. Loss of energy in the combustion and transmission phases		1. Disturbance of ecosystems by utility towers and rights of way	1. Vulnerability of electrical grid to climate change associated disasters

only 92.7% of this coal is going toward electricity. This results in estimated damages of \$2.05 billion, or 0.08¢/kWh, with low and high estimates of \$684 million and \$6.84 billion, or 0.034¢/kWh, and 0.34¢/kWh, using the low and high estimates for the social cost of carbon.[20] Life cycle assessment results, based on 2004 data and emissions from a subset of power plants, indicated 0.037 kg of CO_2e of methane emitted per kWh of electricity produced. With the best estimate for the social cost of carbon, this leads to an estimated cost of \$2.2 billion, or 0.11¢/kWh. The differences are due to differences in data, and data from a different years. (See Fig. 1 for summary of external costs per kWh.)

Impoundments

Impoundments are found all along the periphery and at multiple elevations in the areas of MTR sites; adjacent to coal processing plants; and as coal combustion waste ("fly ash") ponds adjacent to coal-fired power plants.[47] Their volume and composition have not been calculated.[48] For Kentucky, the number of known waste and slurry ponds alongside MTR sites and processing plants is 115.[49] These

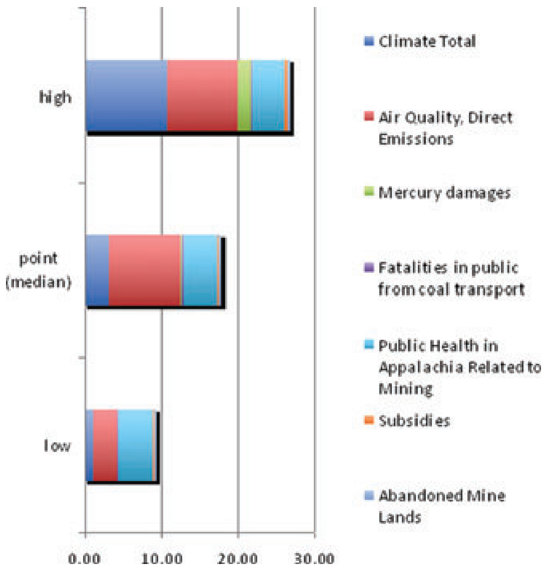

Figure 1. This graph shows the best estimates of the externalities due to coal, along with low and high estimates, normalized to ¢ per kWh of electricity produced. (In color in *Annals* online.)

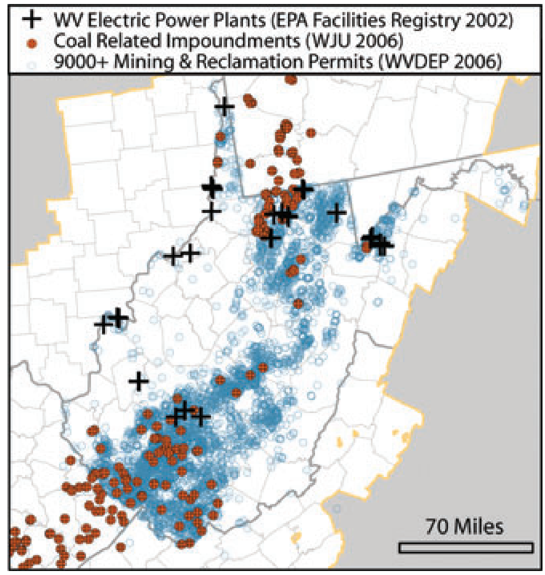

Figure 2. Electric power plants, impoundments (sludge and slurry ponds, CCW, or "fly ash"), and sites slated for reclamation in West Virginia.[44–46] (In color in *Annals* online.) Source: Hope Childers, Wheeling Jesuit University.

sludge, slurry and coal combustion waste (CCW) impoundments are considered by the EPA to be significant contributors to water contamination in the United States. This is especially true for impoundments situated atop previously mined and potentially unstable sites. Land above tunnels dug for long-haul and underground mining are at risk of caving. In the face of heavier precipitation events, unlined containment dams, or those lined with dried slurry are vulnerable to breaching and collapse (Fig. 2).

Processing plants

After coal is mined, it is washed in a mixture of chemicals to reduce impurities that include clay, non-carbonaceous rock, and heavy metals to prepare for use in combustion.[50] Coal slurry is the byproduct of these coal refining plants. In West Virginia, there are currently over 110 billion gallons of coal slurry permitted for 126 impoundments.[49,51] Between 1972 and 2008, there were 53 publicized coal slurry spills in the Appalachian region, one of the largest of which was a 309 million gallon spill that occurred in Martin County, KY in 2000.[48] Of the known chemicals used and generated in processing coal, 19 are known cancer-causing agents, 24 are linked to lung and heart damage, and several remain untested as to their health effects.[52,53]

Coal combustion waste or fly ash

CCW or fly ash—composed of products of combustion and other solid waste—contains toxic chemicals and heavy metals; pollutants known to cause cancer, birth defects, reproductive disorders, neurological damage, learning disabilities, kidney disease, and diabetes.[47,54] A vast majority of the over 1,300 CCW impoundment ponds in the United States are poorly constructed, increasing the risk that waste may leach into groundwater supplies or nearby bodies of water.[55] Under the conditions present in fly ash ponds, contaminants, particularly arsenic, antimony, and selenium (all of which can have serious human health impacts), may readily leach or migrate into the water supplied for household and agricultural use.[56]

According to the EPA, annual production of CCW increased 30% per year between 2000 and 2004, to 130 million tons, and is projected to increase to over 170 million tons by 2015.[57] Based on a series of state estimates, approximately 20% of the total is injected into abandoned coal mines.[58]

In Kentucky, alone, there are 44 fly ash ponds adjacent to the 22 coal-fired plants. Seven of these ash ponds have been characterized as "high hazard" by the EPA, meaning that if one of these impoundments spilled, it would likely cause significant property damage, injuries, illness, and deaths. Up to 1 in 50 residents in Kentucky, including 1 in 100 children, living near one of the fly ash ponds are at risk of developing cancer as a result of water- and air-borne exposure to waste.[47]

Box 3.

Tennessee Valley Authority Fly Ash Pond Spill

On December 2, 2008 an 84-acre CCW containment area spilled when the dike ruptured at the Tennessee Valley Authority Kingston Fossil Plant CCW impoundment, following heavy rains. Over one billion gallons of fly ash slurry spilled across 300 acres.

Local water contamination

Over the life cycle of coal, chemicals are emitted directly and indirectly into water supplies from mining, processing, and power plant operations. Chemicals in the waste stream include ammonia, sulfur, sulfate, nitrates, nitric acid, tars, oils, fluorides, chlorides, and other acids and metals, including sodium, iron, cyanide, plus additional unlisted chemicals.[16,50]

Spath and colleagues[50] found that these emissions are small in comparison to the air emissions. However, a more recent study performed by Koornneef and colleagues[59] using up-to-date data on emissions and impacts, found that emissions and seepage of toxins and heavy metals into fresh and marine water were significant. Elevated levels of arsenic in drinking water have been found in coal mining areas, along with ground water contamination consistent with coal mining activity in areas near coal mining facilities.[16,17,60,61] In one study of drinking water in four counties in West Virginia, heavy metal concentrations (thallium, selenium, cadmium, beryllium, barium, antimony, lead, and arsenic) exceeded drinking water standards in one-fourth of the households.[48] This mounting evidence indicates that more complete coverage of water sampling is needed throughout coal-field regions.

Carcinogen emissions

Data on emissions of carcinogens due to coal mining and combustion are available in the Ecoinvent database.[25] The eco-indicator impact assessment method was used to estimate health damages in disability-adjusted life years due to these emissions,[25] and were valued using the VSL-year.[26] This amounted to \$11 billion per year, or 0.6 ¢/kWh, though these may be significant underestimates of the cancer burden associated with coal.

Of the emissions of carcinogens in the life cycle inventory (inventory of all environmental flows) for coal-derived power, 94% were emitted to water, 6% to air, and 0.03% were to soil, mainly consisting of arsenic and cadmium (note: these do not sum to 100% due to rounding).[25] This number is not included in our total cost accounting to avoid double counting since these emissions may be responsible for health effects observed in mining communities.

Mining and community health

A suite of studies of county-level mortality rates from 1979–2004 by Hendryx found that all-cause mortality rates,[62] lung cancer mortality rates,[60] and mortality from heart, respiratory, and kidney disease[17] were highest in heavy coal mining areas of Appalachia, less so in light coal mining areas, lesser still in noncoal mining areas in Appalachia, and lowest in noncoal mining areas outside of Appalachia. Another study performed by Hendryx and Ahern[18] found that self-reports revealed elevated rates of lung, cardiovascular and kidney diseases, and diabetes and hypertension in coal-mining areas. Yet, another study found that for pregnant women, residing in coal mining areas of West Virginia posed an independent risk for low birth weight (LBW) infants, raising the odds of an LBWs infant by 16% relative to women residing in counties without coal mining.[63] LBW and preterm births are elevated,[64] and children born with extreme LBW fare worse than do children with normal birth weights in almost all neurological assessments;[65] as adults, they have more chronic diseases, including hypertension and diabetes mellitus.[66] Poor birth outcomes are especially elevated in areas with MTR mining as compared with areas with other forms of mining.[67] MTR mining has increased in the areas studied, and is occurring close to population centers.[62]

The estimated excess mortality found in coal mining areas is translated into monetary costs using the VSL approach. For the years 1997–2005, excess age-adjusted mortality rates in coal mining areas of Appalachia compared to national rates