Cost Benefit and Least Burden Analysis

Chapter 173-407 WAC
Carbon dioxide mitigation program for fossil-fueled thermal electric generating facilities

Chapter 173-218 WAC
Underground injection control program

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Table of Contents

TABLE OF CONTENTS **1**

CONCLUSION **3**

PURPOSE OF THIS ANALYSIS **4**

BACKGROUND **4**

REASON FOR THIS RULE 5

SCOPE OF ANALYSIS **5**

COMPARISON OF THE CURRENT AND FINAL RULES **6**

CURRENT RULE REQUIREMENTS 6
DESCRIPTION OF FINAL CHANGES 6
Who is affected? *6*
What is required? *9*
BASELINE FOR ANALYSIS 10
TIME PERIOD FOR ANALYSIS 10

SUMMARY OF RESULTS **12**

SUMMARY OF COSTS 12
SUMMARY OF BENEFITS 12
SUMMARY OF NET BENEFITS 13

THE COSTS **13**

FUEL VS. CARBON CAPTURE AND SEQUESTRATION COSTS 13
ECOLOGY'S SELECTED COST ESTIMATE 16
CONSUMER COSTS 17

THE BENEFITS **18**

CONCLUSIONS ON THE MARGINAL SOCIAL COST OF CARBON 18
The IPCC Literature Review as a Basis for the Benefit Values *19*
UNCERTAINTY AND THICK TAILS ON DISTRIBUTIONS 22
How Thick is the Temperature Change Probability Tail? *23*

LEAST BURDENSOME ANALYSIS **23**

Averaging of load *24*
Other cost reductions *24*

COMMENTS REQUESTED **28**

REFERENCES **30**

APPENDIX 1: USDOE COAL DATA **31**

APPENDIX 2 USDOE NATURAL GAS DATA **32**

APPENDIX 3: ELECTRICITY PRICING DATA **34**

APPENDIX 4: NATIONAL DISCUSSIONS ON LIMITS TO CO_2 EMISSIONS AND COAL **35**

APPENDIX 5: OTHER ITEMS THAT MAY AFFECT ENERGY PRICES **38**

Conclusion

The analysis shows it is likely that the benefits of the final rules and the law, taken together, are greater than the costs and the final rules are the least burdensome version of the rules which meets the requirements in the law.

All new power plants permitted for operation in Washington after June 2008 will need to demonstrate that they comply with the final rules. Ecology anticipates that new natural gas combined cycle turbine facilities will be able to comply easily. Coal, oil, and gas boiler facilities will find it difficult to comply without geological sequestration.

Given the existing economic environment and the cost of capturing carbon for sequestration, Ecology assumes companies will choose to maximize their use of the flexibility in the law and in the final rules. This makes it less likely that the final rules will cause any existing or hypothetical new power plants to capture and sequester carbon dioxide (CO_2).

Ecology's analysis compares the benefit of reducing carbon to the cost of a shift from coal to natural gas turbines. The reason for this is that capture and geological sequestration[1] of CO_2 is not economically viable now. In coming to this conclusion, Ecology relies on current information on the demand for electricity and assumes that:

1. There will be no unexpected near-term permanent increases in the demand for power.
2. The demand during low load periods of spring and fall power will not even out.
3. The cost of coal as fuel will not decrease relative to the cost of natural gas.[2]
4. New technology for carbon capture will not bring the cost down to the $10 per ton - the U.S. Department of Energy (USDOE) target before 2020.[3]
5. In Washington the technical feasibility of geologic carbon sequestration in basalts will not be demonstrated until the Wallula CO_2 injection test[4] is complete.

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[1] Geologic sequestration of CO_2 is the process in which CO_2 is removed from combustion exhaust gases, compressed, transported to a storage site, pumped underground for long-term storage and then monitored to prevent escape.

[2] The price ratio for natural gas relative to coal would need to change a fair amount in order to offset the cost of sequestration. Natural gas prices have been volatile. They have increased but not sufficiently to offset the cost of sequestration. The NWPPC forecast, The Fifth Northwest Power and Conservation Plan, *Current Status and Future Assumptions*, indicates: The medium case assumes that national wellhead natural gas prices will average about $5.45 in 2004 (2000$) and decrease to $4.00 by 2010. Prices are then assumed to further decrease gradually to $3.80 by 2015 and then grow back to $4.00 by 2025. http://www.nwcouncil.org/energy/powerplan/plan/(02)%20Current%20Status.pdf

[3] An industry analyst believes that there may be new, more innovative methods beyond IGCC with Selexol. If that happens then it would reverse this finding.

[4] There is an ongoing CO_2 injection test to be sited in the Wallula area of Washington to demonstrate the feasibility of injection of CO_2 into basalt. Part of the project is to determine if the chemical conversion of the rock minerals to carbonates that has been demonstrated in the laboratory will occur in the field. This test is anticipated to be completed in 2010.

Therefore, Ecology estimated the costs of the law and the final rules on foregone production of electricity from coal rather than reviewing changes in the cost of carbon capture and sequestration. Ecology requests comments and has included a section on the issues that remain in question.

Purpose of this analysis

The Washington State Department of Ecology (Ecology) is proposing to amend:

- Chapter 173-407 WAC Carbon dioxide mitigation program for fossil-fueled thermal electric generating facilities
- Chapter 173-218 WAC Underground injection control program

The Administrative Procedures Act (RCW 34.05.328 (1) (d) (e)) requires two types of analyses before adopting a significant legislative rule – a cost-benefit analysis and a least burdensome alternative analysis.

- The cost benefit analysis is used to "determine that the probable benefits of the rule are greater than its probable costs, taking into account both the qualitative and quantitative benefits and costs and the specific directives of the statute being implemented" as required in RCW 34.05.328 (1)(d).
- The least burdensome alternative analysis is used to "determine, after considering alternative versions of the rule and the analysis required under (b) and (d) of this subsection, that the rule being adopted is the least burdensome alternative for those required to comply with it that will achieve the general goals and specific objectives stated under (a) of this subsection" as required in RCW 34.05.328 (1) (e).

This report provides the results of these analyses and shows the potential costs associated with the final rules.

Background

In 2007, state lawmakers passed new climate change legislation that Governor Christine Gregoire signed into law on May 3, 2007. The new law (Chapter 80.80 RCW) requires Ecology, in coordination with the Energy Facility Site Evaluation Council (EFSEC), to adopt rules setting a greenhouse gases emissions performance standard. The rules will set standards for:

- Baseload generation and cogeneration facilities[5] in Washington.
- Baseload[6] electric generation for which electric utilities enter into long-term financial commitments[7] on or after July 1, 2008.

[5] A cogeneration facility is a fossil-fueled thermal power plant in which the heat or steam is also used for industrial or commercial heating or cooling purposes and that meets federal energy regulatory commission standards for qualifying facilities under the public utility regulatory policies act of 1978.
[6] Baseload electric generation (Ch. 80.80 RCW) means electric generation from a power plant that is designed and intended to provide electricity at an annualized capacity factor of at least sixty percent.

Reason for this rule

Carbon dioxide (CO_2) is the main source of the greenhouse gas emissions that are contributing to climate change. Electricity generation is the third leading contributor of greenhouse gases in Washington, behind transportation and the direct use of fuel. Ecology is proposing rule amendments that will:

- Implement an emission performance standard of 1,100 pounds of greenhouse gases per Mega Watt hour (MWh) of power generated for baseload power plants.
- Establish an output-based methodology for calculating greenhouse gas emissions from a cogeneration facility.
- Establish performance standards to protect the quality of ground water associated with a carbon capture and sequestration project.
- Establish criteria for evaluating carbon capture and sequestration plans submitted by power plants.

All of these are necessary to implement the new law and they will help us begin to address the impacts of climate change in Washington and support the Governor's Climate Change Challenge Executive Order (07-02).

Scope of Analysis

Although the energy sector has broad impacts, Ecology has defined a narrow scope for this analysis.

- This analysis does not deal with energy and economy interactions. It only addresses change to the electrical sector for electricity sold to the grid.
- Generally, this kind of analysis only covers the final rule. Since the benefits of the law cannot be realized without the final rule to implement them, Ecology had to analyze how the law and the rule interact with each other to estimate the costs and benefits of the final rules.
- The price data in this document are from the market and include the impacts of all existing subsidies. Most energy sources are subsidized. Hydro, wind, solar, and fossil fuels all receive different forms of subsidies. Ecology has not attempted to net out the price effect of subsidies from the cited data because the market interactions are too complex to allow it.[8] The USDOE estimates do not appear to include

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[7] Long-term financial commitments (Ch. RCW 80.80) means a) Either a new ownership interest in baseload electric generation or an upgrade to a baseload electric generation facility or b) A new or renewed contract for baseload electric generation with a term of 5 or more years for the provision of retail power or wholesale power to end-use customers in this state.

[8] The energy sector affects and is affected by every sector of the economy. The subsidy with the most direct impact on fossil fuels is the depletion allowance. However indirect effects taken together may swamp the more direct effects of this subsidy. A couple of examples will suffice to illustrate the complexity. The ability of homeowners to write off interest on home loans when paying income tax may

subsidies, except that the modeled price of coal and natural gas come from a market that is affected by subsidies. The price data used to determine the viability of carbon capture in this document are from the market and therefore include the impacts of all subsidies.

Comparison of the Current and Final rules

Two rules are affected by this adoption. This analysis covers both rules. The first rule is WAC 173-407, implementing the requirements of RCW 80.70. The second rule is WAC 173-218, implementing provisions of RCW 90.48 to protect groundwater quality.

Current rule requirements

The existing rules of WAC 173-407 implement the provisions of RCW 80.70 which are not activities or permitting requirements of Energy Facility Site Evaluation Council (EFSEC). EFSEC is adopting rules for 80.70 as part of this rule making process. The existing rule requires ***mitigation*** "of the emissions of CO_2 from all new and certain modified fossil-fueled thermal electric generating facilities with station-generating capability of more than 25 MWe.[9]" The law and existing rule require that the mitigation cover the expected emissions for the 30 year expected lifetime of a power plant. Carbon capture and sequestration is one option for accomplishing this.

The existing rules of WAC 173-218 WAC do not include specific requirements for using underground injection control wells for underground geologic sequestration of carbon dioxide, but they do regulate the discharge of fluids into the wells to prevent ground water contamination. Permits for these types of projects are required under RCW 90.48 RCW, Water Pollution Control and WAC 173-216, the State Waste Discharge Permit Program.

Description of final changes

Who is affected?

The rule applies in a complex manner and would apply to power plants only in specific cases. This is laid out in Table 1. Any plant that meets the criteria in the table must comply, however it will be easier for the new natural gas turbines and gas/oil turbines to meet the requirements. Given the 1,100 pounds of greenhouse gasses per MWh emission performance standard, the law and the final rule are most likely to affect coal-based power plants. Affected coal power and old style natural gas boilers are likely to need carbon capture and sequestration to comply. Based on recent project permitting history, only natural gas combined cycle power plants are likely to be proposed and permitted for baseload operation in Washington. However, the law and the rule have flexibility which limits who is affected.

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mean larger homes and more demand for electricity. Property taxes may mean smaller homes. Subsidies for roads from municipalities may create more demand for gasoline, which in turn means a smaller share of fossil fuel goes into heating oil, which increases demand for electricity. Other things operate in the opposite direction. Even general equilibrium models have trouble handling all these interactions. Ecology has therefore not attempted to sort them out.

[9] WAC 173-407-010(1)

Baseload generation

According to the definition of baseload generation in WAC 173-407-110 if a new generator finds it is viable to operate *less than* 60 percent of the time so that they are not part of baseload generation, then the final rules would not affect them. This means a new generator could purposely build a facility to be permitted for operating at only 60 percent to avoid having to meet the requirements of the final rules. This is true even if the facility provided power on an emergency basis for *more than* 60 percent of a year.

The other side of this scenario is that the law and final rules are likely to limit the development of any new large coal or inefficient fossil fuel power plants.

For plants outside Washington, selling power into Washington, the law and rule limit emissions from baseload facilities that are subject to contracts for more than five years and they must weight power from unspecified sources on the system as the dirtiest form of fuel.

Short-term contracts

Because the law only covers long-term contracts the final rule (WAC 173-407-300, 310 and 320) can only addresses long-term contracts. Therefore, short-term contracts for purchases of less than five years are not covered. This means entities who want to buy electricity from a new coal or another fossil fuel source (that is not required to comply with the new law or final rules) will be able to do so, but only based on short-term contracts. This creates some uncertainty for any new coal or other fossil fuel generators who prefer long-term contracts to guarantee payoff of construction loans. This uncertainty may limit their willingness to develop this resource in Washington.

Distributed Generation

Distributed generation is when power is generated but no power is sold to the grid. Instead it is used to supply only the electrical needs of the facility for where it is located. This is not cogeneration. Even if these types of generators end up providing power to the grid during peak or emergency times, via short-term contracts, they would be unaffected by the final rules.

Emergency Generation

Emergency generators are designed to come on if grid power is lost. These generators will be unaffected.

Averaging of load

WAC 173-407-300 allows the load from specified and unspecified sources in a contract that provides a mix of types of power generation (such as a Bonneville Power Authority contract) to be averaged based on a formula.

Bonneville Power Authority (BPA) provided comments expressing concerns that they would have difficulty contracting with Washington Public Utility Districts

(PUDs) if they had to specify all sources of power.[10] Therefore, section 300 of Chapter 173-407 WAC is included in the final rule. When an entity signs a contract that includes electricity from unknown sources, they are allowed to average the CO_2 emissions from all of the sources. In practice, this means that if a contract is for a specified share of power from renewables, up to 42 percent of their sources can be unspecified. Given that the Northwest has a very large current supply of renewable power, in practice this means they may be able to include as much existing and new fossil fuel-based power as necessary under long-term BPA contracts.

[10] "BPA will make decisions on rate design, power products to be offered, and power resources to be acquired based on the Regional Dialogue process. There are so many uncertainties as to how a rule on "unspecified sources" will affect the Regional Dialogue process. BPA believes it would be reasonable to allow more time for interested parties to consider this matter because an ill conceived rule could jeopardize the ability of consumer-owned utilities to acquire long-term power from the FCRPS. For these reasons, BPA believes the prudent and "practicable" course is for the Department not to implement a rule on "unspecified sources" at this time."

Table 1: When would a power plant be required to meet the emission performance standard?

			Instate				Out of state			
			upon startup	new ownership interest	non-exempt upgrade	new long term baseload contract	upon startup	new ownership interest	non-exempt upgrade	new long term baseload contract
Baseload generation										
	Stand-alone									
		New	X	X	X	X				X
		Existing		X	X	X				X
	Cogeneration									
		New	X	X	X					X
		Existing		X	X					X
	Distributed generation									
		New				X				X
		Existing				X				X
Non-baseload										
	Seasonal									
		New				X				X
		Existing				X				X
	Emergency									
		New				X				X
		Existing				X				X
	Peaking power									
		New				X				X
		Existing				X				X

Table assumes that the facility is not powered exclusively by renewable fuels

Distributed generation is generation installed to supply the electrical needs of the facility it is located within. No power is sold to the grid. This is not cogeneration.

thermal energy. On or both forms of energy may be sold. Cogeneration facilities must meet FERC requirements to qualify

Emergency generation are emergency generators designed to operate in the event of a loss of grid power.

Peaking power plants are designed, intended, and permitted to operate at less than full time.

Seasonal power plants are designed, intended, and permitted to operate during portions of the year with high power demand. They are not permitted for full time operation.

Once non-baseload generation becomes baseload through a new contract to supply baseload power, such

What is required?

Chapter 80.80 RCW, created additional requirements with respect to greenhouse gases emissions. The law itself has a substantial impact without the final rules. However, it would be difficult for new power contracts in the state to be signed or new power plants sited and permitted for operation without adopting the final rules. The law and final rules adds a requirement for *permanent sequestration* of greenhouse gases above the 1,100 pounds of allowable emissions per megawatt hour (MWh) of electricity generated. The law does not define *permanent sequestration* or the specific plan requirements for designing, building, and monitoring a sequestration site or project. This is covered in the final rules.

The law and final rules also require that a new long-term financial commitment to buy electricity must meet the 1,100 pounds per MWh emissions performance standard. The rule specifies how a purchaser of electricity would determine if the proposed long-term financial commitment would meet the emissions performance standard.

WAC 173-218 is amended to include specific provisions for the design, permitting, implementation, closure and financial assurance requirements of an underground geologic sequestration project.

Baseline for Analysis

The baseline for this analysis excludes the law it implements because it can't be implemented without the existing rules or the final amendments.

Time Period for Analysis

This analysis is limited to a 12 year span reviewing likely choices available to power plants up to 2020. Ecology typically uses a 20 year period when evaluating rules. For major investments such as industrial plants, a longer period could be used. The law and the final rules allow CO_2 emissions to be reduced through perpetual storage, which would also require a longer time span for analysis. However, major potential changes make extending the time span less viable:

- The time span of the analysis affects not just discounting[11], but in this case, what should be evaluated. At the 2007 Electric Power Research Institute (EPRI) summer seminar,[12] only five percent of the participants (industry professionals) indicated they thought CO_2 capture would be commercially available by 2015. Only 24 percent thought it would be available by 2020, and only 15 percent by 2025. Over half of the participants do not expect it to be available for at least 20 years. The final rules limit CO_2 emissions for long-term baseload, but allow carbon capture and sequestration. If carbon capture and sequestration is not viable within the next 20 years, then it is the foregone energy that must be valued.

- On the other hand, 42 percent of the EPRI participants[13] believe mandatory CO_2 controls will be placed on the energy sector by 2010. Another 31 percent believe it will happen by 2012. The market forces that will affect the U.S. economy under carbon constraints and/or carbon pricing make 20 years too long a period to evaluate. It will change both the rules in the markets and the prices.

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[11] Discounting uses an interest rate to reduce the value of costs and benefits which accrue in the future.

[12] Electric Power Research Institute, Electricity Solutions for a Carbon Constrained Future, http://mydocs.epri.com/docs/CorporateDocuments/EPRI_Journal/2007-Fall/1016127_2007SummerSeminar.pdf

[13] Ibid.

- Results from Wallula sequestration testing may change our understanding of geological sequestration.

- At the end of the five-year period, the law directs the Department of Community Trade and Economic Development (CTED) to revise the emission performance standard to reflect the capabilities of combined cycle natural gas fired turbine equipment available at that time. Based on current combined cycle power plant equipment, the standard would be revised downward to 830 – 860 lb/MWh if this update were to occur today. However, we don't know what will be viable five years from now. When revisions occur they must be evaluated. A change of this magnitude would likely alter the market outcome and therefore Ecology would count those costs for this analysis.

- As part of the 2008 legislative session, the legislature passed a bill adding a greenhouse gas reporting requirement to RCW 70.94. The bill directs Ecology to develop recommendations to implement a greenhouse gas regional multi-sector market based system program that would become effective by 2012. If cap and trade laws come out of this, the economic landscape of power plants and their greenhouse gas emissions will be very different than what exists today.

Finally, if the rule has a short-term of action because changes in state law significantly alter the constraints on the market, then the rule would only affect a very limited number of plants. This makes the unit costs of electricity and carbon a better mechanism for comparison.

Discount rates (interest rates) are used to compare values that accrue over time. This document relies heavily on the United Nation's Intergovernmental Panel on Climate Change (IPCC) analysis of the economic literature on the cost of global warming,[14] and the USDOE analysis of the cost of carbon dioxide capture.[15] These documents use different discount rates. The USDOE models do not state the discount rate for modeling efforts that provide the unit cost of carbon capture and electricity. In this situation a shorter term analysis also makes more sense.

[14] Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos and R.T. Perez, 2007: Perspectives on climate change and sustainability. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 811-841.

[15] Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity, DOE/NETL-2007/1281, Final Report (Original Issue Date, May 2007), Revision 1, August 2007.

Summary of Results

Summary of Costs

Ecology estimates that baseload power plants with long-term contracts may experience anything from a savings of $6.05 per MWh (if coal options were more expensive than a natural gas substitute[17]), up to a cost of approximately $5.10 per MWh. This converts to a maximum cost of $11.58/tonne of CO_2 based on the least expensive energy production per MWh, Supercritical Pulverized Coal.

Table 2 shows each value stated in four different ways, which are mathematically equivalent, so that it will be easy to compare to different measures in quoted material.

Table 2: Cost and Benefit Calculations[16]

Basis for Calculations	Average	High Cost	
Average of Coal	$ 74.45		
Supercritical Pulverized Coal		$ 63.30	$/MWH
Natural Gas Combined Cycle	$ 68.40	$ 68.40	$/MWH
Cost Increase	$ (6.05)	$ 5.10	$/MWH
Coal	1,525		lbs CO2
Supercritical Pulverized Coal		1,681	lbs CO2
Natural Gas Combined Cycle	712	712	lbs CO2
CO2 decrease	813	969	lbs CO2
Cost per Tonne and Conversions			
	Low	High	
$/tonne CO2	**$ (16.37)**	**$ 11.58**	
$/ton CO2	$ (14.88)	$ 10.52	
$/Tonne C	$ (60.02)	$ 42.45	
$/ton C	$ (54.56)	$ 38.59	
Conversion: Benefit for Reduced CO2			
	Low	Expected	
$/tonne CO2	**$ 11.73**	**$ 27.27**	
$/ton CO2	$ 10.66	$ 24.79	
$/Tonne C	$ 43.00	$ 100.00	
$/ton C	$ 39.09	$ 90.91	

Summary of Benefits

The benefit of the final rules comes from reducing CO_2 emissions. CO_2 are valued based on estimated current damages from CO_2 in the air. To analyze the benefits of the final rules, Ecology selected a low and a mid range value from the IPCC's literature review.

- **The low estimate**: The mean value derived from refereed sources[18] is $43 per tonne of carbon. This converts to $11.73 per tonne of CO_2 emissions. It is the lowest value found in the IPCC's review of articles about the "marginal social cost"[19] of CO_2 emissions.
- **The expected value**: Ecology selected $27 per tonne of CO_2.
- **The high estimate**: No high estimate is selected because the cost of a 6°C (10.8°F) shift is not knowable and has a three percent chance of happening by 2105.

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[16] All the values in the top half of this table come from USDOE, 2007, Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity, USDOE/NETL-2007/1281, Final Report (Original Issue Date, May 2007), Revision 1, Exhibit ES-7.

[17] Assumes 90,360MMbtu/day at a unit cost of 6.75 generating a cost of $.04536 without capture and $.05274 per kWh- net with capture. This is lower than current cost but within the range for the NWPPC forecast.

[18] Sources in published journals that have referees who evaluate the work.

[19] The marginal social cost is the estimated total cost to all societies on the planet of a very small change in CO_2 emissions.

NOTE: These values are expected to rise at 2.4 percent per year.

Summary of Net Benefits

Ecology expects net benefits.

- The cost increase of $11.58/tonne of CO_2 is less than the low-end estimated benefit of $11.73 per tonne from reducing CO_2 emissions.
- The expected benefit of $27.27/tonne is significantly higher than the cost.
- No high end benefit can be estimated because the value would be very large and is not knowable.

The Costs

The primary question for the cost analysis is whether the law and the final rules will cause a fuel shift or carbon capture and sequestration.

Fuel vs. Carbon Capture and Sequestration Costs

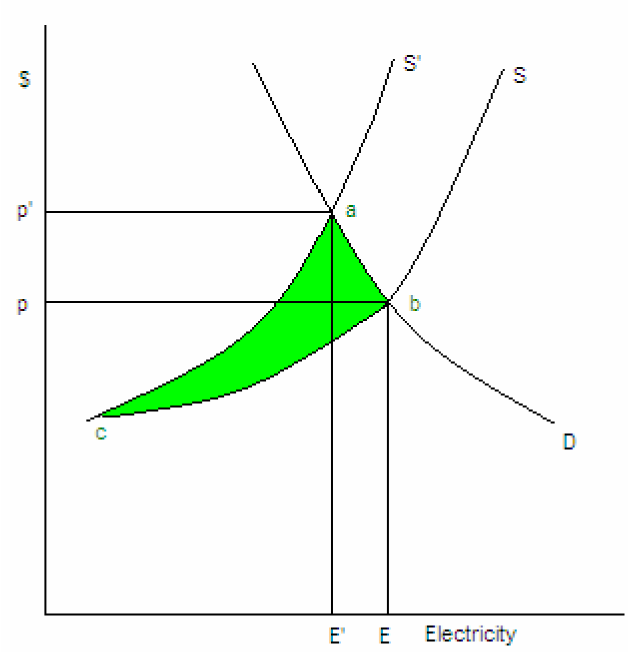
If a new baseload generator wanted to locate in Washington or a PUD wanted a long-term contract with an identified source then the question is what impact would the law and final rules actually have? A profit maximizing generator would prefer the lowest cost option and the utilities could also force the generator to select the lowest cost option carbon capture and sequestration costs or switching to a fuel and design that meets the emission performance standard.

Figure 1 shows the supply curves for a generator with coal (S) and without coal (S'). If carbon capture and sequestration were cheap then they might have gained (the area abc) the difference between costs of creating electricity with and without coal. If carbon capture and sequestration is not cheap the generator will use some other fuel (natural gas) and society will face a higher price and will reduce their consumption from E to E'. There will be a cost increase to consumers from p to p'. We can not know the marginal cost curve shift from coal or other fuel based boilers to combined cycle combustion turbines because it is highly variable based on the kind of plant affected. We can use a worst-case scenario, and estimate the per-unit cost of a shift from the cheapest coal plant[20] modeled by USDOE to a natural gas combined cycle plant.[21]

[20] Supercritical or Ultra-supercritical Pulverized Coal

[21] While abc is the correct measure of total costs the per unit measure implies a constant cost shift across the entire quantity of electricity purchased. In other words the largest cost differential is extrapolated to all purchases. It is therefore likely that this overstates the cost impact of the rule. Offsetting this is the fact that natural gas prices will probably move up more rapidly than the prices of coal. This is in part due to the expected impacts of global warming on taxation of fossil fuel and the potential for a cap-and-trade program.

Figure 1: Foregone resource income from coal or other high CO_2 fossil fuel based electricity



Is Carbon Capture and Sequestration Cheaper than a Substitute Fuel?

No. Due to the unproven nature of sequestration, the uncertainties over risk and long-term liability, the cost of carbon capture and sequestration is now too high. In the future it may decrease but it is unclear how much or when. The USDOE has a goal of reducing the cost of carbon capture and sequestration to $10 per ton of CO_2.

There are indications that sequestration can be successful. Today there are three well-established large-scale injection projects with an ambitious scientific program:

1. Sleipner (Norway): Sleipner began injection of about 1Mt CO_2/yr into the Utsira Formation in 1996. This was accompanied by time-lapse reflection seismic volume interpretation (often called 4D-seismic) and the SACS scientific effort.
2. Weyburn (Canada): Weyburn is an enhanced oil recovery effort in South Saskatchewan that served as the basis for a four-year, $24 million international research effort. Injection has continued since 2000 at about 0.85 Mt CO_2/yr into the Midale reservoir. A new research effort has been announced as the Weyburn Final Phase, with an anticipated budget comparable to the first.
3. In Salah (Algeria): The In Salah project takes about 1Mt CO_2/yr stripped from the Kretchba natural gas field and injects it into the water leg of the field.

None of these projects has detected CO_2 leakage of any kind, each appears to have ample injectivity and capacity for project success, operations have been transparent and the results largely open to the public." [22] [23]

However, the current cost differential between a new coal or other fossil fuel plant with capture and a new coal or another fossil fuel plant without capture ranges from $32 to $83 per ton of CO_2.[24] The cost of capture per kWh ranges from 24 to 55 mills (where a mill is $.001).[25] The change in cost created by capture would be expensive and would preclude its use. Further these costs do not include the compression of the gas, its transport[26] to a sequestration facility, its injection,[27] its long-term monitoring,[28] or the cost of financial assurance that the sequestration will not fail. However, the lions' share of the cost accrues to capture.

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[22] Ansolabehere, Stephen, Janos Beer, John Deutch, A. Denny Ellerman, S. Julio Friedmann, Howard Herzog, Henry D. Jacoby, Paul L. Joskow, Gregory Mcrae, Richard Lester, Ernest J. Moniz, Edward Steinfeld, James Katzer, 2007, The Future of Coal, Massachusetts Institute of Technology, http://web.mit.edu/coal/.

[23] While these are the sequestration specific projects, the injection of CO_2 for enhancing oil and gas recovery is a well practiced technology in the Texas/Oklahoma area of the US and in other parts of the world. Most of the existing CO_2 pipelines in the US (about 600 of the thousand + miles in the US) are for the transport of CO_2 from underground reservoirs to oil and gas fields for enhanced recovery.

[24] The IPCC has similar estimates of cost per tonne of CO2. The only option where they estimated a savings is for an Integrated Coal Gasification Combined Cycle Power Plant where CO2 can be injected as a part of enhanced oil recovery and included an 81% to 91% CO2 capture and injection. See table 8.3a. IPCC, Carbon Dioxide Capture and Storage, Working Group III, 2005.

[25] Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity, USDOE/NETL-2007/1281, Final Report (Original Issue Date, May 2007), Revision 1, August 2007.

[26] The IPCC estimates the cost per tonne to transport CO2 by pipeline 250 km could be as low as $1 if the volume is sufficient. See Fig. 8.1 in IPCC, Carbon Dioxide Capture and Storage, Working Group III, 2005.

[27] The IPCC estimates the cost per tonne to store CO2 could be as low as $0.50 ($2/tonne for carbon) under the correct circumstances. IPCC, Carbon Dioxide Capture and Storage, Working Group III, 2005.

[28] The IPCC estimates the cost per tonne to monitor CO2 could be as low as $0.10 ($0.40/tonne for Carbon) under the correct circumstances. IPCC, Carbon Dioxide Capture and Storage, Working Group III, 2005.

Table 3: USDOE Data on Cost of removing CO_2 in \$/MWh and Tonnes [29]

Source	Price \$ /MWh	\$/MWh + Capture	\$/MWh for Capture	% Increase for Capture	\$ /Tonne for Capture	CO2 Tonnes Produced /MWh	Capture CO2 Tonnes /MWh
GE Energy	\$ 78.00	\$102.90	\$24.90	32%	\$ 35.20	0.66	0.59
Conoco Phillips	\$ 75.30	\$105.70	\$30.40	40%	\$ 45.10	0.66	0.57
Shell	\$ 80.50	\$110.40	\$29.90	37%	\$ 46.20	0.64	0.57
Subcritical Pulverized Coal	\$ 64.00	\$118.80	\$54.80	86%	\$ 74.80	0.81	0.71
Supercritical Pulverized Coal	\$ 63.30	\$114.80	\$51.50	81%	\$ 74.80	0.76	0.67
Natural Gas Combined Cycle	\$ 68.40	\$ 97.40	\$29.00	42%	\$ 91.30	0.36	0.32

The removal and avoided costs in the USDOE document are in cost per ton of CO_2 for 90% removal.

This tends to indicate that the cost shift for coal or another fossil fuel with carbon capture and sequestration is likely to be well above the current prices. Capture alone increases the price of electricity from 37% to 86% depending on the type of plant chosen. There is a problem with this analysis in that these are costs for 90% removal. For a new pulverized coal plant, the law and the final rules would only require a removal of about 50% in order to comply. Designing a plant for partial removal of CO_2 will be cheaper. But there are no estimates for these costs. Thus these cost figures may overstate the cost of capture, which would be imposed by the final rules. However, the cost estimates will also rise because they do not include costs for CO_2 transport, injection, or long-term monitoring.

Thus the carbon capture and sequestration scenarios are cost prohibitive at this time. So the most likely cost is the loss of coal as an energy source (the area abc in figure 1), until the cost of carbon capture and sequestration comes down. If this were to change, then this analysis would need to be revised (see the request for comments below).

Ecology's Selected Cost Estimate

Ecology is using a shift from pulverized coal to natural gas combined cycle plants as the estimated cost if the final rules should happen to have an impact.[30]

The USDOE estimates of base cases without carbon capture and sequestration can be used to estimate the cost of new pulverized coal generation. [31] These costs include capital costs, fixed costs, variable costs, and fuel costs. Depending on the plant, there

[29] One mill is equal to one-tenth of one cent. A cost expressed in mills/kWh (i.e. 10 mills) converts to the same value in \$/MWh (i.e. \$10).
[30] New technology may eventually be available that would change these costs.
[31] Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity, USDOE/NETL-2007/1281, Final Report (Original Issue Date, May 2007), Revision 1, August 2007, Exhibit ES-7.

may be a savings from switching to natural gas combined cycle or a cost. Ecology has chosen $11.58 per CO_2 Tonne from switching from Supercritical Pulverized Coal to Natural Gas Combined Cycle.

Table 4: Calculating the Cost of Foregone Energy

Basis for Calculations	Average	High Cost	
Average of Coal	$ 74.45		
Supercritical Pulverized Coal		$ 63.30	$/MWH
Natural Gas Combined Cycle	$ 68.40	$ 68.40	$/MWH
Cost Increase	$ (6.05)	$ 5.10	$/MWH
Coal	1,525		lbs CO2
Supercritical Pulverized Coal		1,681	lbs CO2
Natural Gas Combined Cycle	712	712	lbs CO2
CO2 decrease	813	969	lbs CO2
Cost per Tonne and Conversions			
	Low	High	
$/tonne CO2	**$ (16.37)**	**$ 11.58**	
$/ton CO2	$ (14.88)	$ 10.52	
$/Tonne C	$ (60.02)	$ 42.45	
$/ton C	$ (54.56)	$ 38.59	

Note: if the cost of natural gas goes up with the cost of other fuels, this analysis will understate the cost.

Consumer Costs

Most of the cost will be passed on to consumers.[32] The demand for energy is "inelastic" and not very sensitive to price change in the short-term and probably still in the long-term.[33] If there is an impact from the law and the final rules, then even in a competitive setting it is likely that 100% of the cost will be passed on to consumers.

- If there were a power provider getting 100% of their power from a source that made this particular fuel shift, then this would be an 8% increase. For a family with a $200 per month power bill, the impact would be about a $16.20 increase in the monthly power bill.
- For consumers in general, if part of their electricity comes from such a plant, then their rates will rise based on the share of their electricity coming from that source, not by 8%. Suppose this occurred for a 100 MW plant operating at, at least 61% capacity. The total cost for consumers would be $2.7 million per year.

[32] Whether the plant is in Washington or outside Washington and complying for purposes of a long-term contract, consumers in more than one state may obtain electricity from them.
[33] James A Espey, *Turning on the lights: A Meta Analysis of Residential Electricity Demand Elasticities*, Journal of Agriculture and Applied Economics, April 2004

The Benefits

Burning fossil fuels creates greenhouse gases. Our society has been acting as if there is no cost to future generations from fossil fuel. In economic terms, we must estimate the externality cost for future populations from current greenhouse gas emissions. This social cost of carbon defines whether net benefits exist if the final rules help to restrict them.

Ecology selected a range of $11.73 to $27.27 as being the minimum and midrange values of eliminating one tonne of CO_2.

No high-end value is estimated. The reason for this is that the cost of a temperature shift over 6°C is so large it can not be known. The probability of this temperature range is 3% in the next 100 years and is higher than 3% in the 22nd century.

Conclusions on the Marginal Social Cost of Carbon

The social cost of carbon is the present value of the social costs of carbon at the time of emission. Given the IPCC's review of the literature and the wide range of assumptions put into the models and given the uncertainties about the shape of the probability distribution for higher temperature events, Ecology has selected:

Conversion	Low	Expected
$/tonne CO2	$ 11.73	$ 27.27
$/ton CO2	$ 10.66	$ 24.79
$/Tonne C	$ 43.00	$ 100.00
$/ton C	$ 39.09	$ 90.91

Table 5: The Social Cost of Carbon

- $43 per tonne of carbon from the IPCC summary of peer reviewed values as the minimum value of CO_2 because the IPCC found that these studies assume lower climate sensitivity.[34]

- $100 per tonne of carbon as a central value. This is a rounded value that lies in a common range from the IPCC literature review of Tol[35] ($93 as the mean) and Clarkson and Deyes[36] ($105 as the central value). It straddles values that would be created by Stern[37] if interest rates were adjusted. However, this selection probably underestimates some of the possible impacts.

- Ecology did not select a high-end value because existing studies deal with a subset of the impacts. Further, uncertainty about the impact of high temperatures reduces

[34] "Peer-reviewed studies generally reported lower estimates and smaller uncertainties than those which were not; their mean was US$43 per tonne of carbon with a standard deviation of US$83. The survey showed that 10% of the estimates were negative; to support these estimates, the climate sensitivity was assumed to be low and small increases in global mean temperature brought benefits…"

[35] Quoting from IPCC: "Tol (2005) gathered over 100 estimates of the MSCC from 28 published studies and combined them to form a probability density function; it displayed a median of US$14 per tonne of carbon, a mean of US$93 per tonne and a 95th percentile estimate equal to US$350 per tonne."

[36] Quoting from IPCC: "After surveying the literature, Clarkson and Deyes (2002) proposed a central value of US$105 per tonne of carbon (in year 2000 prices) for the MSCC, with upper and lower values of US$50 and $210 per tonne." These used a lower interest rate.

[37] Quoting from IPCC: "Stern (2007) calculated, on the basis of damage calculations described above, a mean estimate of the MSCC in 2006 of US$85 per tonne of CO2 (US$310 per tonne of carbon).

certainty about the probability distribution being used for the events we view as likely (see the section on distributions with thick tails).

Ecology also did not select a different value for carbon in different forms. Methane, for example has more impact and the value in the literature is higher. However, the CO_2 generation from coal dominates the equations and methane[38] turns into CO_2 eventually, therefore methane was not evaluated separately.

Important: The estimated values increase with the concentration of carbon.[39] The reader should expect that the values selected will rise over time as the amount of carbon in the atmosphere increases. The IPCC found these values will rise at about 2.4% per year.

The IPCC Literature Review as a Basis for the Benefit Values

The IPCC literature review on the economic impacts of global warming[40] and the social cost of carbon is extensive. The IPCC's Graphic 20.4 illustrates the segmentation of the types of literature. The IPCC's review of the literature found the following problems:

- The market based analysis only characterizes a limited set of gains (reduced losses) from reducing CO_2e.[41]
- The discount rate selected (3%, 1%, 0%) has a significant impact on the present value of future impacts.
- The analyses depend on assumptions regarding the impact scenarios. This includes, risk, a different model, an older model, or newer models of global impacts.
- More global valuations required significant extrapolation.
- Most of the literature missed some impacts.
- The literature indicated non-linear impacts as CO_2 levels increase.
- The cost per tonne may grow 2.4% per year.[42]

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[38] Methane is reported to have an atmospheric half live of 7 to 25 years depending on the reference with the carbon ending up as CO_2.

[39] Carbon as CO2, methane, PFCs, HCFCs in the atmosphere.

[40] **All quotes in this section are verbatim from this literature review unless it is footnoted as being from another source.** The reader is encouraged to read the source because this is a very short summary of what is discussed in the document. Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos and R.T. Perez, 2007: Perspectives on climate change and sustainability. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 811-841.

[41] CO2e includes the global warming potential of the chemicals and chemical classes that have been targeted. The value does not include the warming potential of water vapor. It is not equivalent to carbon or carbon dioxide.

[42] Quoting from IPCC Summary: "It has been known since IPCC (1996) that the MSCC will increase over time; current knowledge suggests a 2.4% per year rate of growth."

- Serious equity issues exist for poor regions where development or subsistence may be affected.
- Willingness to pay imposes limits on the value of losses because ability to pay is limited, which reduces the value of "free" environmental services. Property rights are not clear. Willingness to accept damages would provide still higher values.

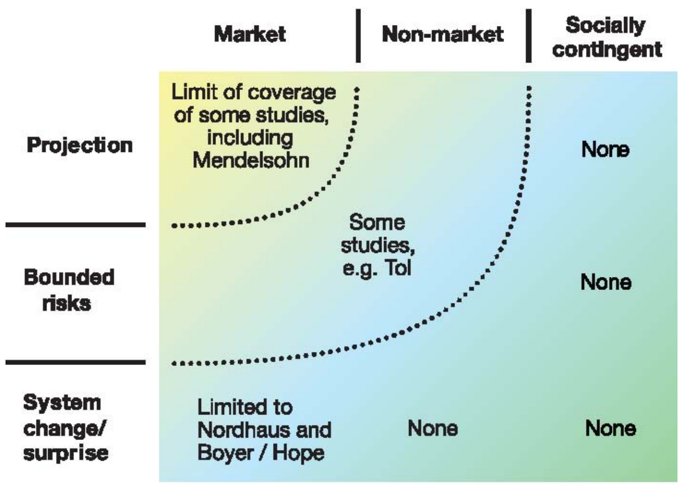

Figure 20.4. *Coverage of studies that compute estimates of the social cost of carbon against sources of climate-related risk. Coverage of most studies is limited to market-based sectors, and few of them move beyond the upper left corner to include bounded risks and abrupt system change. Source: Watkiss et al., 2005.*

Figure 2: The IPCC's graphic 20.4

As displayed in the IPCC's 20.4 most estimates are the product of work that limits impacts based on subsets of impacts that could be incorporated. However, some minimum values can be obtained; and Ecology seeks to use the third type of value, the Social Cost of Carbon. The IPCC identified impacts as follows:

> "Three types of aggregate impacts are commonly reported.
>
> - In the first, impacts are computed as a percent of gross domestic product (GDP) for a specified rise in global mean temperature.
> - In the second, impacts are aggregated over time and discounted back to the present day along specified emissions scenarios" … about economic development, changes in technology and adaptive capacity. Some of these estimates are made at the global level, but others aggregate a series of local or regional impacts to obtain a global total.
> - A third type of estimate has recently attracted the most attention. Called the social cost of carbon (MSCC), it is an estimate of the economic value of the extra (or marginal) impact caused by the emission of one more tonne of carbon (in the form of carbon dioxide) at any point in time; it can, as well, be interpreted as the marginal benefit of reducing carbon emissions by one tonne. Researchers calculate MSCC by summing the extra impacts for as long as the extra tonne remains in the atmosphere – a process which requires a model of

atmospheric residence time and a means of discounting economic values back to the year of emission."

Estimates are often stated in terms of potential GDP losses. In their section 20.6.1 the IPCC presents the history and present state of aggregate impact estimates. THE IPCC indicates that Type 1 estimates:

> "monetised the likely damage that would be caused by a doubling of CO_2 concentrations. For developed countries, estimated damages were of the order of **1% of GDP.** Developing countries were expected to suffer larger percentage damages, so mean global losses of **1.5 to 3.5%** of world GDP were therefore reported." [emphasis added]

The IPCC indicates that Stern (2007), which attempted to incorporate more impacts than other reports, generated much higher values:

> "unmitigated climate change could reduce welfare by an amount equivalent to a persistent average reduction in **global per capita consumption of at least 5%**. Including direct impacts on the environment and human health (i.e., 'non-market' impacts) increased their estimate of the total (average) cost of climate change to **11% GDP**; including evidence which indicates that the climate system may be more responsive to greenhouse gas emissions than previously thought increased their estimates to **14% GDP**. Using equity weights to reflect the expectation that a disproportionate share of the climate-change burden will fall on poor regions of the world increased their estimated **reduction in equivalent consumption per head to 20%**"… reflects the "PAGE2002 model and a focus on risks associated with higher temperatures." [emphasis added]

Equity and the Discount Rate

The IPCC's Figure 20.3 illustrates the divergence of the reductions in GDP and GDP per capita based on different models.

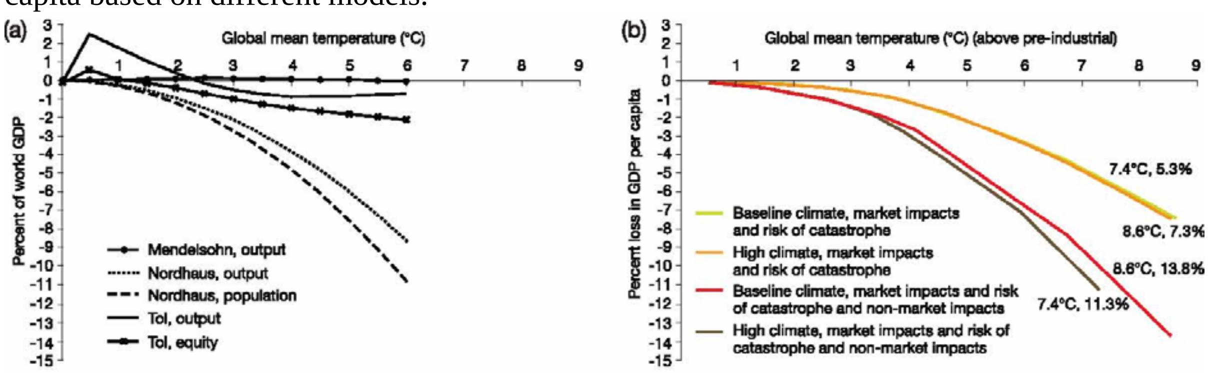

Figure 20.3. *(a) Damage estimates, as a percent of global GDP, as correlated with increases in global mean temperature. Source: IPCC (2001b). (b) Damage estimates, as a percent of global GDP, are correlated with increases in global mean temperature. Source: Stern (2007).*

Figure 3: The IPCC's Damage Estimates

The inclusion of non market values or equity creates substantial divergence. However, the selection of the discount rate creates the largest ranges in the literature reviewed. The range of values is heavily affected by the selected discount rate. Later review by

Weitzman[43] indicates that Stern has chosen the correct interest rate but perhaps for the wrong reasons.

Table 6: Range of Values from Literature as Reviewed by the IPCC

Characterization	Dates	US $/Tonne Carbon	Issues
Early calculations		$5 to $125 ($1990)	
Clarkson and Deyes literature summary	2002	$50 to $210, $105 central value ($2000)	
Pearce	2003	$4 to $9	3% discount rate
Tol literature review	2005	$14 Mean $93 95th percentile $350	
Peer Reviewed Studies		Mean $43 SD $83, includes negative range	10% of estimates negative; climate sensitivity was assumed to be low; small increases temperature brought benefits
Effect of interest rate		$62 $162 $1610	3% 1% 0%
DICE model ($2000)	1990 1995 2000	$10 $7 $6	
FUND model ($2000)	2000 2005	$9 to $23 -$15 to $110	
PAGE model ($2000)	1995 2005	$12 to $60 $4 to $51	

Uncertainty and Thick Tails on Distributions

The social cost of carbon could be larger than expected. Ecology can not place a high value on the Social Cost of Carbon.

Weitzman argues that the valuation of a probability distribution with a thick tail[44] tends to be difficult to evaluate with standard techniques, including a Monte Carlo. Economists

[43] Martin L. Weitzman, *A Review of the Stern Review of the Economics of Climate Change*, The Journal of Economic Literature, Vol. 45, Issue 3, September 2007, pgs. 703-724.
[44] Martin L. Weitzman, draft paper, Structural Uncertainty and the Value of Statistical Life in the Economics of Catastrophic Climate Change, Dept. of Economics, Harvard, 8/16/07. Most cost benefit analysis is based on probability distributions that have a thin tail and the average or median values fairly reflect the costs and benefits. The existence of a thick tail and uncertainty about how thick it is must also

doing evaluations have truncated the low probability/high value tails in order to make analysis easier. Statistically, we are in a Bayesian setting, trying to learn about "extreme bad tail probabilities from finite samples…" the economic results of which are impossible to fully describe because, by definition, we don't get to observe the tail.

He indicates that the willingness to trade off consumption now against catastrophic impacts to the natural world, as we understand it, given a thick tail of uncertain depth, may be even more important than the discount rate. "Reasonable attempts to constrict the length or fatness of the 'bad' tail still can leave us with uncomfortably big numbers whose exact value depends non-robustly on artificial constraints or parameter settings that we do not really understand."

The reduction in consumption now can be viewed as the premium on an insurance policy against the catastrophic losses. Given this the willingness to pay may be "very big." But we do not know what it is.

How Thick is the Temperature Change Probability Tail?

"The recently-released Fourth Assessment Report of the IPCC (2007) predicts for one hundred years from now a mean temperature change of further planetary warming... of $E[\Delta T] \approx 2.8^{o}C$ with a thick-tailed upper-end standard deviation of $\approx 1.6^{o}C$ … the probability $\Delta T \geq 4.5^{o}C$ is approximately 15% and the probability of $\Delta T > 6^{o}C$ is very roughly 3%. … but it seems unavoidable that the reduced-form probability of $\Delta T > 6^{o}C$ increases substantially above 3% after the next century…"[45] This would create unknowable scenarios that have not existed for tens of millions of years. In other words, as we move past 2105, there is more than a 3% chance that the estimated MSCC chosen here is much too low.

Least Burdensome Analysis

RCW 34.05.328(1)(e) requires Ecology to "determine, after considering alternative versions of the rule and the analysis required under (b), (c), and (d) of this subsection, that the rule being adopted is the least burdensome alternative for those required to comply with it that will achieve the general goals and specific objectives stated under (a) of this subsection."

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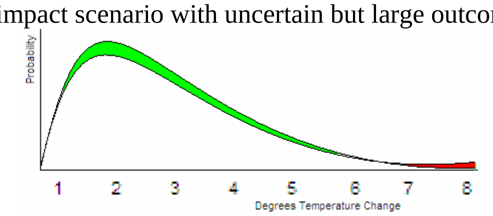
reduce certainty about the probabilities in the range we feel we understand. Thus a low probability/high impact scenario with uncertain but large outcomes is hard to value.



[45] Martin L. Weitzman, A Review of the Stern Review of the Economics of Climate Change, The Journal of Economic Literature, Vol. 45, Issue 3, September 2007, pgs. 703-724.

Averaging of load

The most significant cost reduction in the final rules is the section that allows averaging of the load for contracted power supply involving multiple sources of electrical power. Section WAC 173-407-300 allows the load from specified and unspecified sources to be averaged based on a formula. The formula has been revised based on comment.

- Bonneville Power Administration provided comments expressing concerns that they would have difficulty contracting with Washington PUDs if they had to specify all sources of power.[46] Therefore section 300 of Chapter 173-407 is included in the final rule. When an entity signs a contract that includes purchases of electricity from unknown sources they are allowed to average the CO_2 emissions from all the sources. In practice this means that if the contract includes a specified share of power from renewables, they can have up to 42% of their sources be unspecified. Given that the Northwest has a very large current supply of renewable power, in practice this means they may be able to include as much existing and new fossil fuel based power as they find to be necessary under long-term BPA contracts.

Other cost reductions

In addition the following items are believed to have created reduced burden for those who would be required to comply:

- Ecology considered a wide range of options for requiring a demonstration of compliance with the performance standard. Some advocated for regular and some for a one time action when rule applicability is triggered while others advocated for a continuing compliance requirement based on annual reporting of compliance. Ecology chose to propose an annual compliance and reporting approach to be consistent with other air quality program requirements, including current emission inventory program requirements.
- The performance standard applicability to contracts (section 300) uses default values for some generation sources and for unspecified sources to simplify the effort of a utility to determine compliance for contracts. This allows the use of actual emission information, in the calculation for specified sources, but does not require actual emission information to be used.
- At one point the draft rule required monitoring of greenhouse gas emissions by all baseload power plants in Washington, as of the date the rule would go into effect, regardless of whether the facility was required to demonstrate compliance with the performance standard. The rule has reduced the monitoring and reporting requirement to only those facilities and units that are subject to the applicability

[46] "BPA will make decisions on rate design, power products to be offered, and power resources to be acquired based on the Regional Dialogue process. There are so many uncertainties as to how a rule on "unspecified sources" will affect the Regional Dialogue process. BPA believes it would be reasonable to allow more time for interested parties to consider this matter because an ill conceived rule could jeopardize the ability of consumer-owned utilities to acquire long-term power from the FCRPS. For these reasons, BPA believes the prudent and "practicable" course is for the Department not to implement a rule on "unspecified sources" at this time."

criteria - i.e. those which are new baseload plants, enter into a new long-term financial commitment, upgrade, new ownership interest, etc.

- The law does not contain a de minimis criterion for a new ownership interest (which triggers the requirement to comply with the standard). We propose a de minimis ownership interest change to trigger applicability. This will reduce work associated with the trading of a few shares or small percentages of a facility's output.
- The law does not include a de minimis usage of fossil fuel in a renewable resource generation facility. We have provided a de minimis fossil fuel use to qualify as a renewable resource fueled generator. This de minimis is based on a criterion in several federal regulations. We have also defined what a renewable resource fuel is and utilized that definition in the final rule text. A de minimis fossil fuel usage is necessary for biomass fueled generation plants, because (1) you need to light the fire and fossil fuel (oil or natural gas) is usually used, (2) the cogeneration plants based on renewable fuels often have mandatory steam or electricity production contracts and need some sort of back-up fuel, and (3) occasionally the renewable fuel (especially wood waste) is too wet and needs supplemental fuel to properly burn. Without this de minimis, no electric generation facility that uses renewable fuels (biomass, landfill gas, etc) could qualify for the renewable energy source exemption in the law.
- The final rules will allow sequestration pilot projects to be permitted before meeting all of the data gathering requirements for a full permit.
- The final rules will allow the use of all existing geologic data previously collected for other activities to be used for site characterization.
- Geologic carbon sequestration projects will be permitted using the existing State Waste Discharge Permit Program instead of creating a unique permit program. Very few geologic sequestration permit applications are expected so if there were a unique permit program, the few projects would require permit fees that covered the total cost of the program.
- If a geologic sequestration project is associated with a fossil fuel power plant, which is likely, the same wastewater permit fee would cover all discharges including the carbon sequestration.
- During the discussions Ecology considered requiring:
    - Monitoring for each potable aquifer at a sequestration project and the unsaturated zone above the uppermost aquifer but chose to only require monitoring of the groundwater as close as practicable to the geologic sequestration formation.
    - Evaluation and monitoring within 6 miles beyond the project boundary but chose to require this evaluation and monitoring 1 mile beyond the project boundary.
    - The project boundary to include the area of 100% of the carbon dioxide injected but chose to define the boundary as the calculated extend of 95 percent of the injected carbon dioxide mass 100 years after the end of injection.

- A minimum number of deep characterization wells before permitting any site but chose to allow the number of wells to be determined based on site-specific considerations.
- Annual pressure testing of all injection wells but chose to require these tests every 5 years.
- The post-closure period to extend for a set number of years after injection is complete but chose to allow the post-closure period to end once monitoring and modeling indicate that there is little continued environmental risk.

- During the discussions Ecology considered not allowing sequestration projects:
    - Within 10 miles of any jurisdictional boundary, but chose to allow it as long as the project proponents addressed issues related to boundaries.
    - Within 10 miles of marine shorelines, but chose to allow as long as the project proponents addressed issues related to the shorelines.
    - With more than 25 percent of the project area within a 100 year flood plain, but chose to allow as long as the project proponents addressed issues related to flood plains.
    - Where more than 25 percent of the land overlying is not physically accessible, but chose to allow as long as the project proponents addressed issues related to accessibility.
    - With more than a low risk of seismic events, but chose to allow as long as the project proponents addressed issues related to seismic risks of the site.
    - Within 5 miles of any active faults, but chose to allow as long as the project proponents addressed any active (Holocene) faults within 5 miles. continuous monitoring for N2O at large plants, instead propose that large plants (above 25MW) do periodic emissions testing for the first year to establish a plant specific emission factor, and use that factor until an upgrade or other rule applicability triggering action occurs. For smaller plants, only emission factors derived from an authoritative source used, subject to ECY approval. For methane the same approach as for N2O is used.
    - The injection of carbon dioxide with any contaminants but chose to allow carbon dioxide as long as all known treatment technologies are used to remove contaminants.
- In the monitoring and recordkeeping and reporting requirements Ecology considered continuous stack monitoring of CO_2, and exhaust flow rate for all plant sizes. The rule only requires this for facilities subject to the EPA Acid Rain program requirements, and allows the use of emission factor calculations as allowed by that program for natural gas combustion units. For all units not subject to the federal Acid Rain program it allows the use of emission factors.

- For all plant sizes, an annual reporting requirement to Ecology, done electronically for Acid Rain Program sources, piggybacked on their 4th quarter report to EPA, for all others a separate submittal to Ecology containing the required information.
- The minimum reporting requirements for geologic sequestration projects is the same as the minimum required for all state waste discharge permits.
- For compliance with the emission performance standard, no inspections are required. However, the facilities subject to the federal Acid Rain program requirements to monitor CO_2 emissions already and will continue to have required quality assurance and substitute data provisions to be followed. This final rule does not add new requirements but rather references those existing requirements. The federal program already requires this, and a different state program would be more burdensome on the facilities due to having to maintain duplicate and differing data.
- There is no set schedule for Ecology inspection of geologic sequestration projects.
- There are no compliance dates in this rule, just applicability dates in the law. Except for the enforcement of the sequestration plan requirements. The source is required to submit the sequestration plan or the sequestration program at the time of the submittal of the notice of construction application. The approval of this plan or program will be issued at the same time as the permit. If there is an instance of non-compliance with the emissions performance standard (EPS), there is a requirement to revisit the program or plan. There is a requirement to submit the new plan or program as soon as possible, but no later than 150 days after the annual report that compares actual performance with the EPS. We could have made the deadline sooner, but we decided to make it this length of time. The source should have enough internal information on meeting the EPS some months before the end of the reporting period, and as such would prudently start work on a plan or program.
- Geologic sequestration projects may begin with a pilot project prior to complying with all of the permitting requirements for a full-scale project.

Comments Requested

Ecology requested comments on the following aspects of this analysis and received none.

1. **Literature:** This document relies heavily on the IPCC analysis of the economic literature on the cost of global warming[47] and the USDOE analysis of the cost of carbon dioxide capture for sequestration.[48]
2. **Economic Viability of carbon capture and sequestration**: Evaluation of the viability of a new technology is especially difficult when the technology is still largely in the idea phase. It is clear that once carbon capture and sequestration is economically viable, the market will be huge.[49] For this analysis the question is whether it is viable now or soon enough to make a difference for this rule adoption. The law and final rule bans emissions that exceed 1,100 pounds per MWh but allows new power plant development by not counting pounds that are sequestered. However, until carbon capture and sequestration is economically viable this analysis must count the cost of foregone power.

   The analysis finds that capture and sequestration is not economically viable now and therefore the costs of the final rule are based on foregone production of electricity from coal rather than on small changes in the cost of sequestration which would be created by the rule. In coming to this conclusion Ecology relies on current information. Ecology assumes:

   (a) No major long-term unexpected surges in demand
   (b) Nothing that will even out demand during low load periods of spring and fall (e.g. electric vehicles)
   (c) No general market shift that reduced the price of coal relative to natural gas.

Ecology requested information on the following but received none:

- Scenarios of the effect of electric cars on price, total demand, and relative seasonal peak load or some other likely scenario with a similar impact and
- Information that would indicate that sequestration is now viable in Washington's economy.

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- Whether a reduction in the price of the coal could sufficiently offset the cost of sequestration to make coal with CCS economically viable.
- Whether carbon trading is likely to drive down the real price of fossil fuels enough to make CCS economically viable nationally or world wide.
- Flexibility provided by the law: Wallula Energy Resource Center proponents plan to test sequestration in basalts as the means to reduce the CO2 emissions from their proposed facility in order to comply with the performance standard. However, Ecology expects some proponents to use the flexibility in the law coupled with the flexibility provided by the final rule to avoid the need to sequester CO2. This limits the possible cost impact.

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Appendix 1: USDOE Coal Data

Source:
http://tonto.eia.doe.gov/cfapps/STEO_Query/steotables.cfm?periodType=Annual&startYear=2005&startMonth=1&endYear=2009&endMonth=12&tableNumber=18
Download 1/16/2008

Table 6. U.S. Coal Supply, Consumption, and Inventories

	2005	2006	2007	2008	2009
Supply					
(Million short tons)					
Production	**1131.5**	**1162.7**	**1154**	*1144.5*	*1155.9*
Appalachia	**397.3**	**391.9**	**380.1**	*375*	*379.6*
Interior	**149.2**	**151.4**	**150.9**	*148.4*	*154.6*
Western	**585**	**619.4**	**623.1**	*621.1*	*621.7*
Primary Inventory Withdrawals	**6.2**	**-1.6**	**5.8**	*3.4*	*2.6*
Imports	**30.5**	**36.2**	**36.7**	*37.9*	*39*
Exports	**49.9**	**49.6**	**56.9**	*62.2*	*65.9*
Metallurgical Coal	**28.7**	**27.5**	**31.5**	*33.8*	*36.1*
Steam Coal	**21.3**	**22.1**	**25.4**	*28.3*	*29.7*
Total Primary Supply	**1118.2**	**1147.8**	**1139.6**	*1123.7*	*1131.6*
Secondary Inventory Withdrawals	**3.5**	**-41.1**	**-11.5**	*-0.2*	*4.1*
Waste Coal[a]	**13.4**	**14.4**	**14.2**	*15*	*15*
Total Supply	**1135.1**	**1121.1**	**1142.3**	*1138.4*	*1150.7*
Consumption					
(Million short tons)					
Coke Plants	**23.4**	**23**	**23.3**	*24*	*22.5*
Electric Power Sector[b]	**1037.5**	**1026.6**	**1047.9**	*1046*	*1053.4*
Retail and Other Industry	**65.1**	**62.7**	**64.8**	*68.4*	*68.7*
Residential and Commercial	**4.7**	**3.2**	**3.5**	*4.3*	*4.4*
Other Industry	**60.3**	**59.5**	**61.4**	*64*	*64.3*
Total Consumption	**1126**	**1112.3**	**1136**	*1138.4*	*1150.7*
Discrepancy[c]	**9.1**	**8.8**	**6.2**	*0*	*0*
End-of-period Inventories					
(Million short tons)					
Primary Inventories[d]	**35**	**36.5**	**30.8**	*27.3*	*24.7*
Secondary Inventories[e]	**109.3**	**150.4**	**161.9**	*162.2*	*158.1*
Electric Power Sector	**101.1**	**141**	**153.3**	*153.9*	*149.9*
Retail and General Industry	**5.6**	**6.5**	**6.2**	*6*	*6*
Coke Plants	**2.6**	**2.9**	**2.3**	*2.2*	*2.2*
Coal Market Indicators					
Coal Miner Productivity *(Tons per hour)*	**6.36**	**6.26**	**6.16**	*6.06*	*6*
Total Raw Steel Production *(Million short tons per day)*	**0.285**	**0.289**	**0.293**	*0.292*	*0.286*
Cost of Coal to Electric Utilities *(Dollars per million Btu)*	**1.54**	**1.69**	**1.77**	*1.81*	*1.85*

Appendix 2 USDOE Natural Gas Data

Source:
http://tonto.eia.doe.gov/cfapps/STEO_Query/steotables.cfm?periodType=Annual&startYear=2005&startMonth=1&endYear=2009&endMonth=12&tableNumber=16
Download: 1/16/2008

Table 5c. U.S. Regional Natural Gas Prices

Dollars per Thousand Cubic Feet

	2005	2006	2007	2008	2009
Wholesale/Spot					
U.S. Average Wellhead	7.26	6.4	6.37	6.87	7.09
Henry Hub Spot Price	8.85	6.93	7.17	7.78	7.92
Residential					
New England	15.49	17.55	16.62	16.82	17.23
Middle Atlantic	13.54	15.64	15.27	16.03	16.1
East North Central	11.76	12.38	11.87	12.15	12.35
West North Central	11.85	12.57	12.35	12.38	12.98
South Atlantic	15.61	17.18	16.81	16.78	17.19
East South Central	13.87	15.48	14.5	15.04	14.92
West South Central	12.56	13.46	12.61	13.28	13.72
Mountain	10.9	12.02	11.03	11.55	12.07
Pacific	11.75	12.02	11.99	12.37	12.74
U.S. Average	12.7	13.75	13.27	13.65	13.95
Commercial					
New England	13.63	14.93	14.03	14.29	14.59
Middle Atlantic	12.01	12.75	12.18	13.39	13.46
East North Central	10.66	11.41	10.76	11.25	11.61
West North Central	10.6	10.93	10.53	10.92	11.32
South Atlantic	12.9	13.63	12.84	13.1	13.34
East South Central	12.55	13.45	12.51	12.97	13.2
West South Central	10.62	10.68	10.29	10.77	11.03
Mountain	9.46	10.63	9.75	10.45	10.81
Pacific	10.52	10.9	10.92	11.08	11.48
U.S. Average	11.34	11.99	11.41	11.87	12.26
Industrial					
New England	12.54	12.92	12.21	12.59	12.77
Middle Atlantic	10.61	11.01	10.91	11.39	11.47
East North Central	9.83	9.74	9.62	9.88	10.17
West North Central	8.86	8.44	8	8.5	8.78
South Atlantic	10.41	9.72	9.27	9.82	9.97
East South Central	9.68	9.64	8.72	8.4	8.48
West South Central	7.97	6.89	6.95	7.57	7.82
Mountain	8.37	9.49	8.98	8.4	8.56
Pacific	7.14	7.96	8.3	8.22	8.61
U.S. Average	8.56	7.86	7.67	8.24	8.5

Table 5a. U.S. Natural Gas Supply, Consumption, and Inventories

	2005	2006	2007	2008	2009
Supply					
(Billion cubic feet per day)					
Total Marketed Production	51.86	53.1	54.43	55.28	55.41
Alaska	1.34	1.22	1.24	1.28	1.27
Federal GOM[a]	8.58	7.95	7.67	8.27	8.04
Lower 48 States (excl GOM)	41.94	43.93	45.52	45.73	46.1
Total Dry Gas Production	49.45	50.62	52.04	52.8	52.92
Gross Imports	11.89	11.47	12.47	12.07	12.4
Pipeline	10.16	9.87	10.33	9.51	9.18
LNG	1.73	1.6	2.14	2.56	3.23
Gross Exports	2	1.98	2.03	1.96	1.87
Net Imports	9.9	9.49	10.44	10.11	10.53
Supplemental Gaseous Fuels	0.17	0.18	0.17	0.18	0.18
Net Inventory Withdrawals	0.14	-1.2	0.46	0.09	0.03
Total Supply	59.67	59.09	63.11	63.18	63.67
Balancing Item[b]	0.64	0.23	-0.23	0.07	0.21
Total Primary Supply	60.3	59.32	62.88	63.24	63.88
Consumption					
(Billion cubic feet per day)					
Residential	13.22	11.97	12.96	13.21	13.22
Commercial	8.22	7.77	8.27	8.34	8.38
Industrial	18.07	17.79	18.07	18.15	18.18
Electric Power[c]	16.08	17.05	18.68	18.73	19.26
Lease and Plant Fuel	3.05	3.08	3.14	3.1	3.14
Pipeline and Distribution Use	1.6	1.6	1.68	1.64	1.62
Vehicle Use	0.06	0.07	0.07	0.08	0.08
Total Consumption	60.3	59.32	62.88	63.24	63.88
End-of-period Inventories					
(Billion cubic feet)					
Working Gas Inventory	2635	3070	2840	2807	2794
Producing Region[d]	748	953	910	895	868
East Consuming Region[d]	1511	1726	1525	1542	1558
West Consuming Region[d]	376	391	405	370	368

Appendix 3: Electricity Pricing Data

Source: http://tonto.eia.doe.gov/cfapps/STEO

Downloaded 1/16/08

Table 7c. U.S. Regional Electricity Prices

Cents per Kilowatthour

	2005	2006	2007	2008	2009
Residential Sector					
New England	13.4	16	16.6	*17*	*17.6*
Middle Atlantic	12.5	13.4	14	*14.2*	*14.6*
East North Central	8.4	9.1	9.7	*9.8*	*10.1*
West North Central	7.8	8.1	8.2	*8.3*	*8.5*
South Atlantic	8.8	9.8	10	*10.1*	*10.4*
East South Central	7.4	8.2	8.2	*8.3*	*8.6*
West South Central	10	11.5	11.2	*11.5*	*11.9*
Mountain	8.7	9	9.2	*9.4*	*9.6*
Pacific	10.4	11.6	11.8	*12*	*12.4*
U.S. Average	9.4	10.4	10.6	*10.8*	*11.1*
Commercial Sector					
New England	11.9	14.5	14.6	*15.1*	*15.7*
Middle Atlantic	11.8	12.7	13.1	*13.3*	*13.7*
East North Central	7.7	8.2	8.6	*8.7*	*8.8*
West North Central	6.3	6.6	6.7	*6.8*	*6.9*
South Atlantic	7.5	8.5	8.7	*8.9*	*8.9*
East South Central	7.2	7.9	8	*8.1*	*8.4*
West South Central	8.4	9.3	9.4	*9.6*	*10*
Mountain	7.4	7.6	7.7	*7.9*	*8*
Pacific	10.4	11.2	11.2	*11.5*	*11.9*
U.S. Average	8.7	9.5	9.6	*9.9*	*10.1*
Industrial Sector					
New England	9.1	11.6	12.5	*13.1*	*13.5*
Middle Atlantic	7.3	7.8	8	*8.1*	*8.3*
East North Central	4.9	5.4	5.8	*5.8*	*6*
West North Central	4.7	4.9	5.1	*5.2*	*5.3*
South Atlantic	5.3	5.5	5.6	*5.8*	*5.9*
East South Central	4.4	4.8	5.1	*5.2*	*5.4*
West South Central	6.6	7.2	7.1	*7.3*	*7.6*
Mountain	5.5	5.5	5.7	*5.8*	*5.9*
Pacific	7.5	7.9	7.9	*7.8*	*8.1*
U.S.Average	5.7	6.2	6.4	*6.5*	*6.7*
Average All Sectors*					
New England	12	14.5	15	*15.4*	*16*
Middle Atlantic	11.1	11.9	12.4	*12.6*	*13*
East North Central	6.9	7.5	7.9	*8*	*8.2*
West North Central	6.4	6.6	6.8	*6.9*	*7*
South Atlantic	7.6	8.4	8.6	*8.8*	*9*
East South Central	6.2	6.8	7	*7.1*	*7.3*
West South Central	8.5	9.4	9.4	*9.6*	*10*
Mountain	7.3	7.5	7.7	*7.8*	*8*
Pacific	9.7	10.6	10.7	*10.9*	*11.3*
U.S.Average	8.1	8.9	9.1	*9.3*	*9.6*

Appendix 4: National Discussions on Limits to CO_2 Emissions and Coal

Part of this analysis indicates that national discussions on a greenhouse gas tax or a cap-and-trade program have had a chilling effect on investment in coal. This relies on the assumption that industry is aware that there will be in the future, some significant form of restriction on CO_2 emissions and further that the expectations are already having an effect on coal development. This comes partly from The Future of Coal. [50]

As MIT observed:

> "Any serious efforts by government or industry to address greenhouse gas emissions and global warming in the near term would impose a price or charge on carbon or constrain the use of CO_2-emitting fuels in some manner."

Their second finding in the conclusions section is that:

> "Finding #2: A global carbon charge starting at $25 per ton of CO_2 emitted (or nearly $100 per tonne of carbon), imposed initially in 2015 and rising at a real rate of 4% per year, will likely cause adjustments to energy demand, supply technologies and fuel choice sufficient to stabilize mid-century global CO_2 emissions from all industrial and energy sources at a level of 26 to 28 gigatons of CO_2 per year. Depending on the expansion of nuclear power, the use of coal increases from 20% to 60% above today's level, while CO_2 emissions from coal are {96 MIT STUDY ON THE FUTURE OF COAL} reduced to half or a third of what they are today. This level of carbon charge implies an increase in the bus bar cost of U.S. electricity on average of about 40%, or about 20% of the retail cost. A significant contributor to the emissions reduction from coal is the introduction of CCS, which is utilized as an economical response to carbon charges at these levels. In the EPPA model simulations, approximately 60% of coal use employs CCS by 2050 with this carbon charge."

They further evaluate the trend in citizen willingness to pay for greenhouse gas reductions and find it to be significant:

> "As interesting as the levels of support for the taxes are the changes over time. We repeated the survey in 2006 and found a 50 percent increase in willingness to pay. The median response was approximately $15 more a month (or a 15 percent levy on the typical electricity bill), compared with just $10 in 2003. The average amount came to $21 per month. The rising amount that the typical person would pay was matched by a decline in the percent unwilling to pay anything. In 2003,

[50] Ansolabehere, Stephen, Janos Beer, John Deutch, A. Denny Ellerman, S. Julio Friedmann, Howard Herzog, Henry D. Jacoby, Paul L. Joskow, Gregory Mcrae, Richard Lester, Ernest J. Moniz, Edward Steinfeld, James Katzer, 2007, The Future of Coal, Massachusetts Institute of Technology, http://web.mit.edu/coal/.

> 24 percent of those surveyed said they were unwilling to pay anything. Three years later, a similarly constructed sample answered the identical series of questions, and the percent unwilling to pay anything fell to 18 percent, a statistically significant drop. The rise in willingness to pay resulted in large part from the increased recognition of the importance of the problem. The percentage of those who consider global warming a top-tier environmental concern rose from 20 percent to 50 percent. Those who did not rank global warming as one of the top two environmental problems in 2006 were willing to pay, on average $16 per month in 2006, while those who did rank global warming as one of the top environmental concerns in the country {Public Attitudes Towards Energy, Global Warming, and Carbon Taxes 91} were willing to pay $27 a month. In addition, willingness to pay among those who are concerned with this problem has risen considerably. Among those who consider global warming one of our chief environmental problems willingness to pay rose from $17 a month in 2003 to $27 a month in 2006. If global warming continues to rise as a concern, we expect to see growth, possibly very rapid growth, in willingness to pay fuel taxes that target greenhouse gas emissions."

Part of the confusion in the market comes from the expectation that coal plants may be grandfathered in and obtain large grants for CO_2 emissions. Doing this for new plants that are currently only "in the pipeline" would reduce assistance for populations that depend on plants that exist now. MIT indicates:

> "There is, however, a serious policy problem in that prospective investors in either SCPC or IGCC plants without CO_2 capture, may anticipate that potentially they will be "grandfathered" or "insured" from the costs of future carbon emission constraints by the grant of free CO_2 allowances to existing coal plants, including those built between today and the start of the cap-and-trade system. The possibility, indeed political likelihood of such grandfathering, means that there is a perverse incentive to build coal plants early—and almost certainly these will be SCPC plants—to gain the potential benefits of these future allowances while also enjoying the higher electricity prices that will prevail in a future control regime. The net {100 MIT STUDY ON THE FUTURE OF COAL} effect is that early coal plant projects realize a windfall from carbon regulation and thus investment in these projects will raise the cost of future CO_2 control.

Recommendation #6b: Congress should act to close this potential "grandfathering" loophole before it becomes a problem for new power plants of all types that are being planned for construction."

Given the concerns in the industry over the cost of dealing with carbon, some have suggested federal support for the construction of capture ready coal plants. However MIT indicates:

> "Some suggest that the uncertainty about the imposition of a future carbon charge justifies offering federal support for a portion of the initial investment cost

required to build new coal combustion plants without carbon capture and sequestration today, so that if a carbon emission charge were imposed in the future, the carbon capture and sequestration retrofit cost would be lower. We do not believe that sufficient engineering knowledge presently exists to define the relationship of the extent of pre-investment to the cost of future retrofit, and the design percentage of CO_2 removed. Moreover, the uncertainty about when a carbon charge might be imposed makes it difficult (for either a private investor or the government) to determine the value of incurring a cost for a benefit that is realized, if at all, at some uncertain future time. Other than a few low-cost measures such as providing for extra space on the plant site and considering the potential for geologic CO_2 storage in site selection, the opportunity to reduce the uncertain eventual cost of CCS retrofit by making preparatory investment in a plant without CO_2 capture does not look promising. In sum, engineering and policy uncertainties are such that there is no meaningful basis to support an investment decision to add significant "capture ready" features to IGCC or pulverized coal plants, designed and optimized for operation without CO_2 capture."

Appendix 5: Other Items that May Affect Energy Prices

Natural Gas Price Shifts

There have been increases in the price of natural gas so this may understate the cost of shifting from coal to natural gas. The expected price shift for natural gas may be somewhat higher than for coal.[51] The USDOE is forecasting an increase in the price of natural gas in the Pacific region of 3.7% to 5.1% between 2007 and 2009.[52] The increase in the price for coal is forecast to be 4.5% for the same time period. But the highest estimated price shift differential is not large. Therefore 8.1% seems a safe increase to estimate.

Rates are Averages

For comparison purposes the average retail cost of electricity for Washington was $63.60 per MWh in 2007.[53] Puget Power's residential rate including both their conservation and green power programs was $87.42 per MWh. This price includes wheeling power to the customers. For example, in the USDOE's Pacific Region they forecast the price of industrial electricity supplied to be 81 mills per kWh. This would cover the cost of coal power but not the cost of CO_2 capture. The 2005 WECC[54] average wholesale price of power was $48 per MWh. Note that this includes low cost hydropower and nuclear. The marginal cost is higher. Another possible comparison is to alternatives such as Wind, which USDOE indicates may cost $40 to $60 per MWh.[55] This latter is for comparison only because intermittent power supplies such as wind are less useful than supply that can meet baseload. Intermittent power can reach a tipping point somewhere between 15% and 30% of the load where it becomes less viable and more expensive to absorb it into the system. Until the supply of intermittent power swamps the ability of the grid to offset it, it is a lower price than that reported in USDOE's evaluation of coal. If it is necessary to use batteries to store the wind power, then the cost doubles.

Prices for Viable carbon capture and sequestration in the Future

As the literature looks for a price at which sequestration becomes viable, high prices are cited.

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[51] http://www.eia.doe.gov/steo data queries on left hand side of the page allow access to tables 5a, 5c, and 6 for comparison purposes.
[52] Day to day price movements may have been more volatile than this implies but averages necessarily smooth this.
[53] Table 5.6.B. Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State, Year-to-Date. Downloaded 1/23/08, http://www.eia.doe.gov/cneaf/electricity/epa/epat7p4.html
[54] Western Systems Coordinating Council.
[55] http://www1.eere.energy.gov/windandhydro/wind_ad.html Downloaded 1/22/08. Note: it is unclear whether this is with or without subsides.

- An MIT study estimates the carbon tax or charge that would be necessary to make sequestration viable. For future uses of coal the MIT study[56] finds that:

  > "Successful implementation of CCS will inevitably add cost for coal combustion and conversion. We estimate that for new plant construction, a CO_2 emission price of approximately $30/tonne (about $110/tonne C) would make CCS cost competitive with coal combustion and conversion systems without CCS. This would be sufficient to off set the cost of CO_2 capture and pressurization (about $25/tonne) and CO_2 transportation and storage (about $5/tonne). This estimate of CCS cost is uncertain; it might be larger and with new technology, perhaps smaller."

- Bohm et al [2007] examines the effects of carbon prices on optimal investment at three types of plants:

  > "The results of the analysis show that a baseline PC plant is the most economical choice under low CO_2 prices, and IGCC plants are preferable at higher CO_2 prices (e.g., an initial price of about $22/t CO2 *{$24/tonne CO2}* starting in 2015 and growing at 2%/year). Little difference is seen in the lifetime NPV costs between the IGCC plants with and without pre-investment for CO_2 capture. … The difference in lifetime emissions become significant only under mid-estimate CO_2 price scenarios (roughly between $20 and 40/t CO_2 *{$22 and $44/tonne CO2}*) where IGCC plants will retrofit sooner than a PC plant."[57]

- The IEA places the cost of CO_2 avoided at just under $30 for IGCC slurry feed plants.[58]

With an additional $24 to $30/tonne CO_2 however coal may not be able to compete with other sources of electricity.

Costs of Offsets vs Sequestration

The only proposal brought before EFSEC indicated they wanted to explicitly cut off the option of sequestration at $5 per ton. This tends to imply that a sequestration cost above $5 per ton is not competitive.

> "The measure of technological and economic feasibility for geological or other permanent sequestration, including carbon capture, compression, transport and storage, is a cost of $5/tonne CO_2 ($240-270 million) inclusive of the $50 million carbon capture investment."[59]

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[56] Ansolabehere, Stephen, Janos Beer, John Deutch, A. Denny Ellerman, S. Julio Friedmann, Howard Herzog, Henry D. Jacoby, Paul L. Joskow, Gregory Mcrae, Richard Lester, Ernest J. Moniz, Edward Steinfeld, James Katzer, 2007, The Future of Coal, Massachusetts Institute of Technology, http://web.mit.edu/coal/.

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[58] http://www.ieagreen.org.uk/glossies/co2capture.pdf, Capturing CO2, Figure 4.

[59] Pacific Mountain Energy Center Greenhouse Gas Reduction Plan, Submitted to Washington Energy Facility Site Evaluation Council, Application 2006-01, pg 7 item i.

EU Actions as an Indicator of Long-term Possible Costs

The EU is proceeding with reductions in CO_2 that are quite expensive. "It is estimated that acting now will limit the inevitable cost of curbing climate change to well below 1% of GDP, as opposed to the 5-20% needed if no action is taken (Stern report). This works out at roughly 150 euros {$223} per person each year until 2020 {total of $2,905 per person over 13 years}. What's more, savings on oil and gas imports alone – as the EU reinforces energy security - could amount to as much as €50bn {$74.5 billion} per year."[60]

[60] http://ec.europa.eu/news/energy/080123_1_en.htm downloaded 1/24/08.