

# Washington State Carbon Tax

## Fiscal and Environmental Impacts

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**July, 2011**

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## Acknowledgement

This thesis was submitted in partial fulfillment of the requirements for the degree of the Master of Public Administration (MPA) at the University of Washington.

This thesis has not been possible without countless advice and encouragement of my faculty advisor at the University of Washington, Professor David Layton, and my supervisors at the Washington State Department of Commerce, Roel Hammerschlag and Greg Nothstein. I owe my deepest gratitude to them to their continuous support as well as technical assistance from the beginning to the end of my research.

I am also heartily thankful to other staff at the Washington State Department of Commerce, other faculties at the University of Washington, particularly Professor Yoram Bauman who is an authority in carbon tax research, officials at BC provincial government who gratefully shared their experiences in implementing the carbon tax with me, and Eric de Place at Sightline Institute who provided me an opportunity to shared the study's finding with other researchers and advocates. Their guidance and support at various stages of the research enabled me to develop an understanding of the subject.

Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of the project. For questions regarding this research and programmed spreadsheets, please contact me at my permanent email address [keibun.mori@gmail.com](mailto:keibun.mori@gmail.com).

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## Executive Summary

Energy policy makers have long proposed a carbon tax as an economy-wide policy tool to curb greenhouse gas (GHG) emissions<sup>1</sup>. As the federal government continues to struggle in implementing comprehensive policy solutions to reduce GHG emissions, policy makers in Washington State have shown interests in a state carbon tax. However, little quantified information is available for policy makers to examine its environmental and fiscal impacts in Washington State. At the request of the Washington State Department of Commerce this study therefore aims at developing a new open-source model to quantify the environmental and fiscal impacts of a carbon tax on each sector and to provide policy recommendations for Washington State based on the model's results.

The study begins with a theoretical discussion on a carbon tax. The discussion finds a carbon tax to have four major strengths: (1) comprehensiveness as an economy-wide solution, (2) price certainty, (3) administrative simplicity, and (4) welfare enhancement. Its weaknesses include but are not limited to: (1) high impacts on low income households and small businesses, (2) uncertainty in the environmental impacts, (3) public perception as "just another tax," and (4) a leakage effect, or the shift of demand for fossil fuels to other regions. British Columbia (BC) has implemented the first economy-wide carbon tax at a regional level; their analysis show the BC carbon tax to lower emissions by 3.9% from a business-as-usual (BAU) scenario in 2020 at a modest tax rate capped at \$30 per metric ton of CO<sub>2</sub>-equivalent (MTCO<sub>2</sub>), with exemptions for most aviation and marine fuels. BC faced few implementation difficulties due to support from the business community, but its revenue recycling scheme is not functioning well as the revenue offset required by law significantly exceeds the actual revenues from the carbon tax.

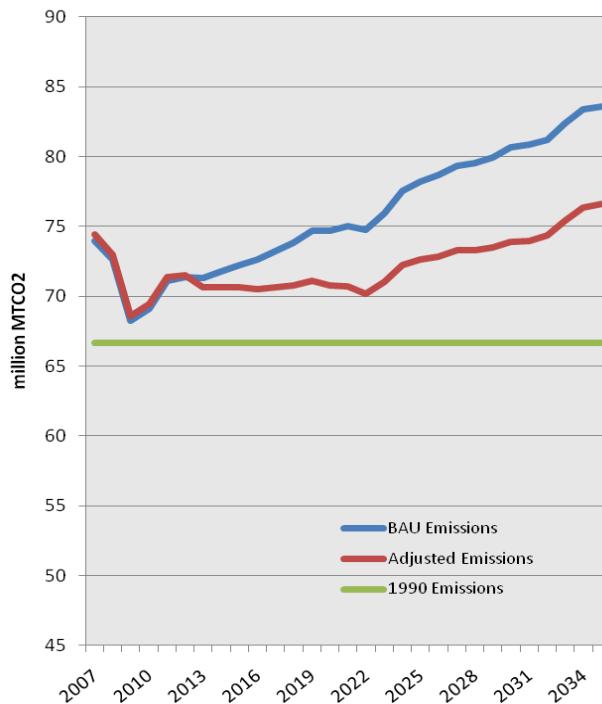
This study then introduces the frameworks and parameters used to build the Carbon Tax Analysis Model (C-TAM). C-TAM is an open-source model based on three major elements: (1) carbon tax rates, (2) the US Energy Information Administration (EIA)'s energy price and demand forecasts, and (3) price elasticities of demand (indicators of how consumer demand responds to price changes). The primary advantage of C-TAM over more sophisticated models such as the National Energy Modeling System (NEMS) is to provide policy makers opportunities to better understand the model and change various assumptions to explore the best design elements. C-TAM is also able to estimate the effect of a local carbon tax in other states or nationwide implementation when the baseline dataset is adjusted.

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The model projects that the carbon tax modeled after the BC carbon tax will, as of 2035, reduce energy-related GHG emissions by 8.4% from a BAU scenario for Washington State (see Table 1 and Figure 1). The nationwide implementation will curb the emissions by a far larger margin (23.3%) for the US, due largely to the higher use of coal and heating fuels in other regions. For both cases, the impacts on fossil fuel consumption are high for the electric sector due to its effects on the fuel mix of the electric sector, with far less impacts on the transportation fuel consumption. The revenues would amount to \$2.1 billion in 2035 for Washington State, with the majority collected from the transportation sector, and households and businesses will be responsible for roughly half of the revenues each.

**Table 1: Summary of the Projected Environmental and Fiscal Impacts at \$30/MTCO<sub>2</sub> in Washington State**

	GHG Change from the BAU Scenario			Carbon Tax Revenues (in millions)		
	2015	2025	2035	2015	2025	2035
Residential	-4.9%	-15.7%	-20.8%	\$219	\$217	\$216
Commercial	-6.4%	-20.3%	-26.6%	\$195	\$194	\$200
Industrial	-6.8%	-15.2%	-17.5%	\$417	\$407	\$415
Transportation	-1.4%	-3.2%	-2.8%	\$1,085	\$1,128	\$1,219
<b>Total</b>	<b>-2.2%</b>	<b>-7.1%</b>	<b>-8.4%</b>	<b>\$1,916</b>	<b>\$1,945</b>	<b>\$2,050</b>



**Figure 1: Projected GHG Emissions in Washington with \$30/MTCO<sub>2</sub> Carbon Tax**

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This level of reduction however is insufficient to achieve the state GHG reduction target to reduce emissions to 25% below 1990 levels in 2035; in fact, the emissions with the carbon tax will be 14.9% higher than 1990 levels. These model results are based on standard energy price and economic growth forecasts as well as the assumption that fuel mix for electric generation will change in

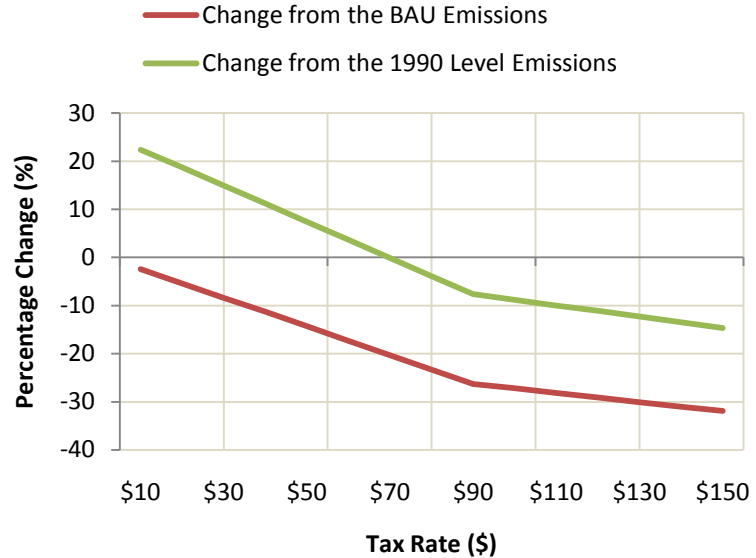
response to the introduction of the carbon tax. Additional analysis suggests a tax rate of \$70/MTCO<sub>2</sub> to stabilize the energy-related emissions at 1990 levels in 2035, \$90/MTCO<sub>2</sub> to shut down all fossil fuel power plants, and \$240/MTCO<sub>2</sub> to achieve the state GHG reduction target (see Figure 2).

Based on these findings and discussion on political feasibility, this study recommends that Washington introduce a carbon tax with the following parameters:

- Base rate: \$10/MTCO<sub>2</sub>
- Annual incremental rate: \$5/MTCO<sub>2</sub>
- Cap rate: \$70/MTCO<sub>2</sub> (approximately \$70/gallon of gasoline)
- Exemptions: aviation (jet) and marine (residual) fuel for interstate and international trips
- Revenue fate: 45% to offset retail sales tax, 45% to offset business & occupation (B&O) tax, and 10% to a contingency fund

With these parameters, Washington should be able to reduce its emissions to 1990 levels in 2035 while maintaining economic competitiveness and equity with the revenue recycling package. Achieving the state target would require complementary measures to target the emissions from transportation and heating system, such as electrification of transportation system, transportation demand management (TDM), and enhanced building energy codes. Lastly, Washington should provide explicit price information on future energy costs as it is likely to prompt consumers and businesses to invest in energy-saving technologies and therefore maximizes the effect of the carbon tax.

Figure 2: Emission Changes in 2035 with Various Rates



## Chapter 1: Introduction

### *Climate Change*

Modern societies have relied on fossil fuel such as coal, oil, and natural gas to produce electricity and power transportation since the onset of industrialization. The massive combustion of fossil fuel has caused observable accumulation of carbon dioxide (CO<sub>2</sub>) in the earth's atmosphere. CO<sub>2</sub> is one of the greenhouse gases (GHG) which increases the earth's average surface temperature by trapping heat from outer space within its atmosphere. The scientific consensus by the International Panel of Climate Change (IPCC) suggests that the accumulation of manmade CO<sub>2</sub> in the atmosphere is the leading cause of global warming<sup>2</sup>. Even with a few degrees of temperature change, global warming can cause substantial effects on the environment such as sea-level rise from icecap melting and water shortage from change in precipitation patterns. According to the estimate by an economist Nicholas Stern, these effects alone could reduce the US GDP by 0.13% and world's GDP by 0.5-1.0% in 2050 if the emissions continue to increase at the projected pace<sup>3</sup>. Locally in the Pacific Northwest, sea-level rise could threaten various infrastructures ranging from port facilities to individual homes, and the change in precipitation patterns may permanently alter the regional ecosystem. Furthermore, the rise in temperature is expected to reduce the snowpack on the Cascade Mountains, which is likely to induce widespread shortage in water supplies<sup>4</sup>.

### *International and Federal Response*

In response to the warning by the IPCC, the international community established the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 to examine policy options to curb GHG emissions, primarily from fossil fuel combustion. After a series of negotiations, the Kyoto Protocol was signed in 1997, mandating industrialized nations to reduce their emissions with specific targets by 2012. The Clinton Administration signed the Kyoto Protocol, but the United States was unable to complete the ratification process due to resistance from Congress. The Kyoto Protocol has been ineffective in reducing GHG emissions because of the lack of U.S. participation and mandatory reduction targets for developing nations. The G.W. Bush Administration was unable to take stringent actions to curb the emissions, but the Obama Administration made a major push for the passage of comprehensive climate bills in 2009 and 2010; however, Congress once again failed to take action. So far, the federal government has taken

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limited actions such as higher vehicle fuel efficiency standards, direct regulation on stationary emission sources, and increased spending on renewable energy sources. These policies are however unlikely to significantly cut the overall emissions.

### *Washington's Response*

In the midst of the struggle to implement stringent policies at federal level, Washington State began to explore its own policy options in the early 2000's. Washington formed the Western Climate Initiative (WCI) in 2007 with five other states in the US and four provinces in Canada. Later in the year, the state legislatures enacted HB 2815 (RCW 70.235.020) to mandate the state to reduce its GHG emissions with specific reduction targets. The voters also demonstrated strong commitments in cutting the emissions by approving the Initiative 937 in 2006, setting renewable energy standards for electric utilities to include a certain share of renewable energy sources into their power supply mix. Building on this momentum, the Washington's Climate Advisory Team (CAT) drafted a roadmap to implement various policies, such as stringent building efficiency codes and minimum renewable fuel content requirements, to meet the reduction targets. Furthermore, the governor Christine Gregoire issued executive order 09-05 to direct the state agencies to accelerate actions to meet the state reduction targets on May 21<sup>st</sup>, 2009<sup>5</sup>.

### *State Energy Strategy*

Washington has drafted its first comprehensive energy plan as the State Energy Strategy in 1993. The primary purpose of the State Energy Strategy was to ensure that the state to meet its future energy needs at least cost. The Washington State Energy Office (WSEO) has been responsible for updating the State Energy Strategy every two years, but the update has been limited to addressing minor issues such as data revision. The environment surrounding energy policy has changed drastically since 1993, and the state legislatures have enacted E2SHB 2658 in 2010 to direct the full revision of the State Energy Strategy with the following three goals: 1) maintain competitive energy prices, 2) foster a clean energy economy and jobs, and 3) meet obligations to reduce GHG emissions. The legislation also established nine principles to guide the revision process and directed the Washington State Department of Commerce to submit the revision by December 31<sup>st</sup>, 2011. As a part of this full revision of the State Energy Strategy, the Department of Commerce requested the author to conduct feasibility study of carbon pricing in Washington State from an academic perspective, with the emphasis on quantification

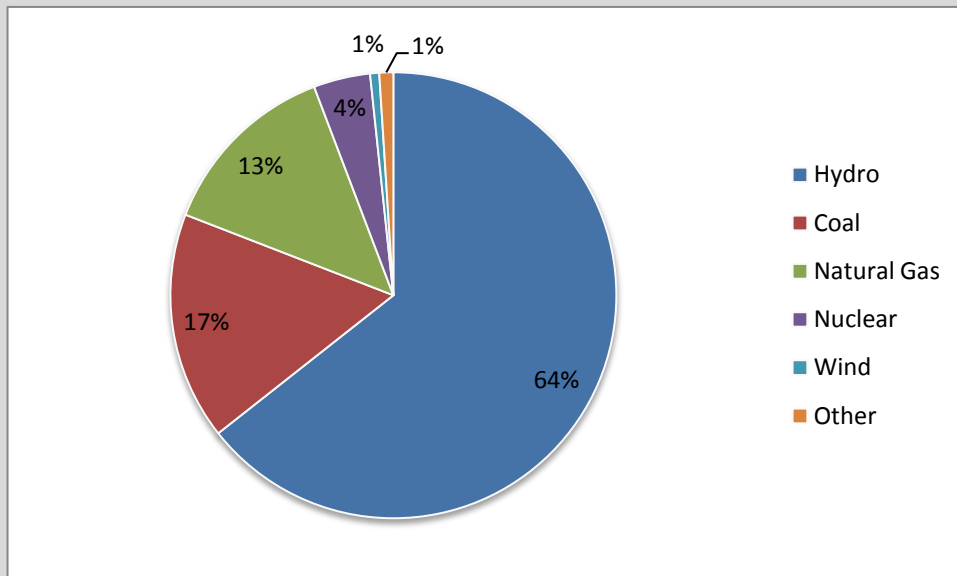
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of its fiscal and environmental impacts. The central scope of the study was the development of a model to compute the effects of a carbon tax on the GHG emissions in Washington. This paper begins with theoretical discussion of a carbon tax, including the case study of the BC carbon tax, followed by the introduction of the model. It then analyzes the results of the modeling, including the effects on the GHG emissions by sector and on the state revenues, and concludes with the policy implication and recommendation for the Department of Commerce.

### **Box: Washington's Energy Profile**

Washington has a unique energy profile in the sense that it has abundant and inexpensive supply of hydropower. This has historically attracted various energy intensive industries ranging from aerospace manufacturers to aluminum smelters. The majority of the hydropower comes from dams in the Cascade Mountains. In 2009, this hydropower supplied 62% of Washington's electricity needs, with the rest primarily coming from coal (17%), natural gas (13%), and nuclear power (4%)<sup>6</sup>. This unique energy profile enabled Washington to have per capita GHG emissions much lower than the national average<sup>7</sup>. Furthermore, the dependence on hydropower also resulted in skewed composition of emissions sources where transportation sector is responsible for nearly half (47%) of the state's emissions<sup>8</sup>.

**Figure 3: Washington's Electricity Generation by Fuel Sources**



## Chapter 2: Carbon Tax Theory

### *Overview*

A carbon tax is a type of pollution tax imposed on fossil fuel to correct market failures associated with its use. The primary market failures of fossil fuel products are negative environmental externalities such as climate change and air pollution. In the absence of a carbon tax (or other regulatory approaches), consumers do not bear the full costs of using the product, which is the sum of production and distribution costs and social costs such as economic loss from climate change and air pollution. In theory, the increased costs associated with levying a tax lower the demand for fossil fuel. For this reason, the absence of a carbon tax leads to over consumption, and a carbon tax aims at correcting this market failure by internalizing the social costs of the negative externalities into its retail price. The internalized social costs then make the retail price of fossil fuel higher, and as a result, lower the quantity of fossil fuel demanded by consumers.

In practice, a carbon tax is levied on fossil fuels at a fixed rate per its physical unit, and the rates are usually subject to carbon contents, or emission factors, of the fuel. For example, if a carbon tax is set at \$30/MTCO<sub>2</sub>, it translates into \$2.13 per million Btu (energy unit), or \$0.29 per gallon, of motor gasoline by using the emission factor of 70.88 kg of CO<sub>2</sub> per million Btu<sup>9</sup>. The average gasoline retail price for Washington was \$3.82 per gallon as of the latest data on April 4, 2011<sup>10</sup>, so the carbon tax would cause 7.6% of price increase at \$30/MTCO<sub>2</sub>. It is normally added to retail price, and retailers are responsible for collecting it in the same way as other taxes.

### *Advantages*

There are three primary advantages of a carbon tax over other major policies to control GHG emissions. First of all, a carbon tax is an economy-wide policy that can cut the emissions from every major source, while other policies tend to target the emissions from a particular source, such as electricity, heating, or transportation. For instance, renewable portfolio standards (RPS) and carbon trading scheme proposed at federal level are aiming at cutting emissions from electricity generation, while the goal of Corporate Average Fleet Efficiency (CAFE) is to decrease them from transportation sector. In contrast, a carbon tax applies to all types of fossil fuel and so it covers all of the major emissions sources except for agriculture

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and deforestation. For this reason, a carbon tax can complement, or at least supplement a complex patchwork of various policy options, easing the administrative burden of reducing GHG emissions.

Secondly, a carbon tax provides clear price signal to firms and households, which enables them to make better purchasing and investment decisions<sup>11</sup>. For other policies, the effect on product price is almost always uncertain. For example, it is generally difficult to predict the effect of carbon trading on the cost of coal, and improved CAFE may or may not induce substantial change in the retail vehicle price. As lifecycle costs of physical capital are one of the most important attributes when making investment or purchasing decisions, the lack of good price signal may prevent optimal decision making for firms and households. In contrast, by its definition, the financial cost of a carbon tax is fixed for the quantity of fuels. Several studies suggest that consumers and businesses are likely to engage energy-saving measures and invest on energy-saving technologies more with explicit price information<sup>12</sup>. Hence, a carbon tax can maximize its effect on consumer behavior by sending a clear price signal.

The administrative simplicity is also an important advantage for a carbon tax. Its collection mechanism can be similar or identical to existing taxes such as gas taxes, so there are little administrative difficulties in implementing a carbon tax. In contrast, traditional forms of regulation and carbon trading scheme requires new or novel forms of government oversight and enforcement. This often necessitates substantial administrative costs associated with the creation of new government agencies. Such complex regulatory framework poses administrative costs not only to government agencies but also to producers. The administrative complexity is often a critical factor for a policy option to be effective and long-lasting, which favors a carbon tax over other options.

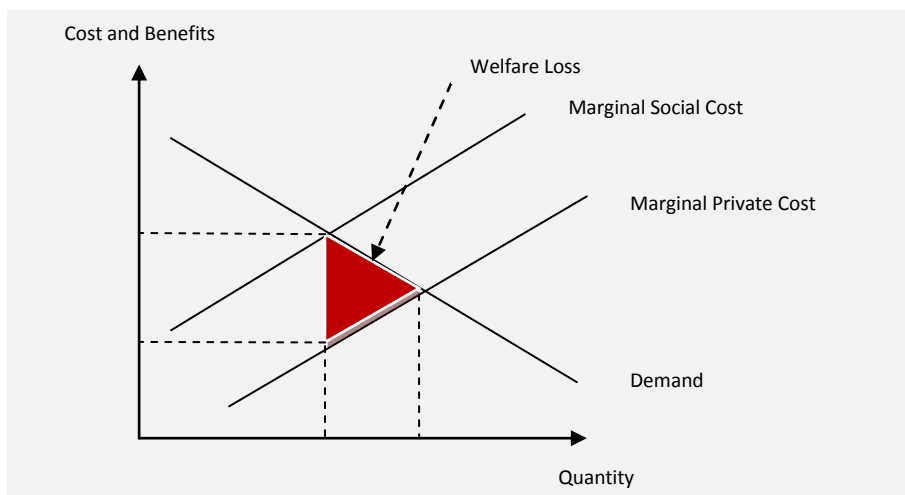


Figure 4: Economic Loss from Overconsumption

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Lastly, and most importantly, a carbon tax can bring two economic benefits<sup>13</sup>. One benefit comes from eliminating the negative externalities of fossil fuel. As shown in Figure 4, in the absence of pollution tax, marginal private cost (the retail cost) is lower than marginal social cost simply because the marginal private cost does not include the negative externalities. In this case, the equilibrium of the marginal private cost and the demand curve is at an optimal point for individuals but at a suboptimal point for the society. This causes substantial welfare loss from overconsumption, commonly referred as dead weight loss by economists and shown in red on Figure 4. A carbon tax however shifts the cost curve to the left and moves the equilibrium along the demand curve. If the rate is set at an optimal level, it can completely eliminate the welfare loss and enhance the social welfare. The other benefit arises when using the revenues from a carbon tax to offset other tax revenues. In principle, taxes such as an income tax and a property tax distort the market and reduce social welfare as they apply to all the goods. When the goods do not have negative externalities (or other public goods characteristics), the marginal private cost is identical to the marginal social cost, so the pretax equilibrium is already at the optimal point both for individual and the society. Therefore, these taxes can push the equilibrium away from the optimal point, resulting in welfare loss. This welfare loss is often called marginal excess tax burden, and Ballard et al (1985) estimate it to be between 0.12 and 0.23 for the US tax system<sup>14</sup>, meaning that one dollar of typical taxes in the US results in \$0.12 to \$0.23 of welfare loss. A carbon tax, however, can avert this welfare loss if used to offset other taxes. In this way, a carbon tax can enhance the social welfare by eliminating the welfare loss from pollution (climate change) and by offsetting the other taxes imposing welfare loss. These benefits are sometimes referred as “double dividend,” and they are an important attribute of a carbon tax<sup>15</sup>.

### *Disadvantages*

Despite these advantages, a carbon tax has not been widely implemented due to a variety of concerns and drawbacks. Of these concerns and drawbacks, policy makers need to pay attention to the following four major drawbacks. First of all, a carbon tax has negative effects on equity, particularly on income equity. As low income households must dedicate the larger proportion of their income for energy-related expenditures such as utility payments and motor fuel purchases, a carbon tax would inevitably pose disproportionate financial burden to the low income households.

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Secondly, there are substantial uncertainties regarding policy outcomes. Unlike cap and trade or efficiency standards, a carbon tax regulates price, not the quantity of GHG emissions. It is therefore relatively difficult to quantify the effect of a carbon tax on GHG emissions and its associated revenues, making policy makers to pursue this option.

The third disadvantage is the strong public resistance to new taxes, even pollution taxes such as cigarette taxes. This is because the general public tends to see new taxes just a way to bring more revenues to the government regardless of the actual intent. As seen in recent election results throughout the United States, the lasting economic recession has certainly deteriorated the public acceptance of new taxes further. Washington State is not an exception to such sentiment, and in the past few years its voters rejected a variety of ballot initiatives to adopt new taxes such as a personal income tax. For this reason, the political feasibility can be a major roadblock for policy makers pursuing the carbon tax option.

Lastly, it is possible that a carbon tax could cause leakage, or a shift of the GHG emissions when implemented in limited regions or countries. In this case, a carbon tax geographically alters the relative price of fuels and may bring adverse impacts on overall production activities, particularly on energy-intensive industries such as refining and metal manufacturing. Morgenstern et al (2007) suggest that the impact is fundamentally tied to the type and level of energy use of a particular industry and to their ability to pass the increased costs to the consumers<sup>16</sup>. Using an input-output model they estimated that a carbon tax at \$10/MTCO<sub>2</sub> would reduce output by less than 1% for most industries in the near-term in the US, but will be greater for industries such as vehicle manufacturing (1%), chemicals and plastics (1%), and primary metals (1.5%). Using historical data, they concluded that impacts of a carbon tax will be larger for some industries, but that the effects can be reduced by as much as 50% with a broader implementation or a border tax. This analysis suggests that a carbon tax does have distributional effects; however, they may not be as significant as some argue and can be minimized with careful policy design such as a border tax and revenue recycling.

These drawbacks often become a major roadblock to the introduction of a carbon tax, but policy makers can address them with careful policy design. For instance, a revenue recycling scheme to offset carbon tax revenues with the emphasis on low-income households and energy-intensive industries can mitigate

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the concerns on income equity, public perception, and leakage problems. In addition, flexible rate setting can ensure that a carbon tax is adequately high to meet the GHG emission targets.

### *Examples*

A limited number of nations have implemented a carbon tax. While the scope and magnitude varies, many northern European nations, including Denmark, Finland, Ireland, the Netherlands, the United Kingdom, Norway, Sweden and Switzerland, introduced energy taxes based on fuel's carbon intensity<sup>17</sup>. Furthermore, the European Union as a whole is currently examining the possibility of a regional carbon tax. Looking at the other parts of the world, Japan has historically imposed fuel taxes on fossil fuels at high rates and is planning to begin levying additional fuel taxes based on carbon contents in 2011. Other nations in Asia-Pacific regions actively examining the carbon tax option as of April 2011 are Australia, China, India, South Korea, and Taiwan. In the United States, the Obama Administration is generally in favor of cap and trade, but the regional taxation on GHG emissions has started in some areas such as Bay Area in California, Boulder in Colorado, and Montgomery County in Maryland. In Canada, Quebec and Alberta impose an energy tax on large emitters, and BC introduced an economy-wide carbon tax in 2008. Since Washington's carbon tax is likely to be an economy-wide carbon tax, the following chapter examines BC's experiences to better understand the potential obstacles, problems, and outcomes.

## Chapter 3: BC Carbon Tax

### Background

BC introduced a revenue-neutral provincial carbon tax in July 2008 as a central strategy in its Climate Action Plan. It is likely to be a model for Washington because it is the only economy-wide carbon tax in North America. Quebec and Alberta have similar taxes, but these apply to a limited number of large emitters such as power generators. BC and Washington are geographically contiguous and share many socioeconomic characteristics such as fuel mix of electricity generation, land use patterns, economic structure, and dependence on international trade. These similarities enable a relevant comparison of forecasted and actual effects of the BC carbon tax, to forecasted effects in Washington.

The BC carbon tax is a core policy option of BC's comprehensive climate policy package, *the BC Climate Action Plan*. It applies to a broad set of fossil fuels such as gasoline, diesel, natural gas, heating oil, propane, and coal, but excludes jet and marine fuel for international and interprovincial trips<sup>181</sup>. The intent for the exemption was to ease the concern that a carbon tax could shift the demand for jet and marine fuel to other geographic areas, since aircraft and ship operators have the ability to choose to fuel in other areas. The tax rate started at C\$10/MTCO<sub>2</sub> in 2008 and is increasing at C\$5/MTCO<sub>2</sub> every year until it achieves the ceiling of C\$30/MTCO<sub>2</sub> in 2012. The purpose of this phase-in structure was to ease public concern regarding a sudden price hike on fuel and to give the users more time to adapt to the price signal. The effective tax rate depends on the carbon content of the fuel as described in the previous section. Table 2 summarizes the initial effective rates by fuel types at C\$10/MTCO<sub>2</sub>.

**Table 2: Selected Carbon Tax Rates by Fuel Type at \$10/MTCO<sub>2</sub>**<sup>19</sup>

	Units	Initial Tax Rate
Gasoline	¢/liter	2.34
Diesel	¢/liter	2.69
Jet Fuel	¢/liter	2.61
Natural Gas	¢/gigajoule	49.66
Propane	¢/liter	1.54
Coal (high heat value)	¢/ton	20.77
Coal (low heat value)	¢/ton	17.77

\* The monetary value is in Canadian dollar

<sup>1</sup> Since jet and marine fuel usage for intra-provincial trips is insignificant, the remainder of the study assumes that BC exempts all jet and marine fuels from the carbon tax

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The BC carbon tax is collected mostly at the wholesale level simultaneously with motor fuel taxes. The exceptions are marketable natural gas and propane; for these fuels the tax is collected at the retail level in the same way as a sales tax. BC chose these collection mechanisms to minimize the cost of administration to government and minimize the compliance cost to those collecting the tax on the government's behalf.

**Table 3: Financial Plan<sup>20</sup>**

(\$millions)	2008/09	2009/10	2010/11
Carbon tax revenue	-338	-631	-880
Personal Tax Cuts			
Low income refundable tax credit	104	145	146
Reduce bottom two tax bracket rates by 2% for 2008 and by 5% for 2009	113	230	244
Additional personal income tax rate cuts	0	40	157
Total tax cuts for individuals	217	415	547
Business Tax Cuts			
Reduce general corporate rate to 11% (2008)	75	128	133
Reduce general corporate rate to 10.5% (2010) and to 10% (2011)	0	6	73
Reduce small business corporate income tax rate to 3.5% (2008)	46	79	82
Reduce small business income tax rate to 3% (2010) and to 2.5% (2011)	0	3	45
Total tax cuts for businesses	121	216	333
Total tax cuts	338	631	880

Revenue collected from the carbon tax must, by law, be recycled into the economy in the form of tax cuts. As Table 3 suggests, BC offsets the revenues primarily by cutting rates on existing taxes. For personal taxes, BC directs carbon tax revenues to provide low income tax credit and personal income tax. Furthermore, BC distributed a Climate Action Dividend, a one-time check of \$100, for each resident upon introducing the carbon tax. Combined with the tax credit to low-income residents, the dividend was aimed at addressing the equity concern of a carbon tax. For business taxes, BC reduced general corporate tax rates as well as small business corporate tax rates in two phases. The aim of these tax cuts was to maintain economic competitiveness by offsetting the increased cost of business activities caused by the carbon tax. As a public education tool, *the BC Climate Action Plan* includes a set of tables describing the financial impacts at a household level in various cases. Table 4 shows a sample of these tables, indicating that a family of four with C\$90 of annual income will have a net gain from the carbon tax.

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**Table 4: A Sample Carbon Tax and Tax Cuts: Net Savings (\$) for a Family of Four (\$90K of income)<sup>21</sup>**

	2008	2009
One-Time Climate Action Dividend	400	
Personal Income tax cut	85	224
Van: 10l/100km fuel Efficiency driving 20,000 km/year	-24	-59
Sedan: 9L/100km driving 15,000 km/year	-16	-40
Natural gas for heat and hot water (102.6 GJ in Lower Mainland)	-26	-64
<b>Annual Savings</b>	<b>419</b>	<b>61</b>

### *Impact Estimate*

BC estimated the carbon tax impact on GHG emissions based on an energy-economy equilibrium model called CIMS<sup>22</sup>. The model is specifically designed to measure the effects of energy policy on energy, economic, physical, and GHG outputs in Canada, but it excludes agriculture and land use change. The model essentially takes a bottom-up approach tracking changes in capital stocks, which necessitates numerous modules for each sector. This approach is almost identical to the National Energy Modeling System (NEMS) used by the Energy Information Administration (EIA) at the US Department of Energy. The CIMS analysis forecasts that the carbon tax would curb BC's GHG emissions by three million tons in 2020<sup>23</sup>, about 3.8% of the emissions expected in reference case with low energy price<sup>24</sup>.

The Ministry of Finance was responsible for forecasting the carbon tax revenues. Due to the uncertainty in the effects on short-term consumption, the Ministry made a conservative assumption that the carbon tax does not have any effect on the level of consumption in the short run. Instead, based on past trends, it assumed that natural gas consumption will grow at 2% annually, while gasoline consumption will decline at 1% annually. The Ministry derived the revenue estimate simply by multiplying these forecasted baseline consumptions by each fuel.

This assumption was perhaps reasonable for the initial period due to the low starting rates. The Ministry reports in its *Budget and Fiscal Plan 2010* that the actual revenues for 2009/2010 was slightly lower than the forecast in Sep, 2009 (-2.6%)<sup>25</sup>, but it is unclear if it was due to the economic recession, carbon tax, or the combination of the two. *Budget and Fiscal Plan 2011* has updated forecast for FY 2010/2011 and beyond, which is higher than the forecast in the previous budget plan, but it does not identify the causes for the forecasted change<sup>26</sup>. BC does not have a formal monitoring protocol to measure the effects of the policies, but the province reports GHG emissions in a biannual inventory and carbon tax revenues in

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an annual budget report. Overall, at this point, the BC officials contend that it is challenging to isolate the effect of the carbon tax on overall consumption of fossil fuels and GHG emissions because (1) it has been in place only for two years, (2) the economic recession was the major disturbance to the overall consumption trends, (3) the winter Olympic games in 2010 also caused anomaly through active construction and tourist activities, and (4) the rates were in the process of escalation. However, the basic assumption is unlikely to be justified in the long run as CIMS predicts 3.8% decline in the GHG emissions by 2020.

### *Public Perception*

The Liberal Party who introduced the BC carbon tax maintained the majority in the provincial election in 2009 when the primary opposition party, the New Democratic Party (NDP), campaigned against it<sup>27</sup>. Judging from the Liberal Party's defeat in the 2008 national election with a proposal for a federal carbon tax, the level of public support was fairly high in BC. After three years of implementation, the level of public support has increased by 10 percentage points, and the NDP, who opposed the carbon tax in the general election of 2007, changed its position in favor of the carbon tax<sup>28</sup>. However, the carbon tax remains unpopular in rural areas as the rural communities are more dependent on automobiles.

Upon implementation, the response from the business community as a whole was generally supportive. For instance, the BC Chamber of Commerce expressed its support on BC carbon tax, because it not only reduces overall consumption of fossil fuels but also shifts the tax burden from income to consumption. However, there was some minor resistance from energy-intensive industries such as cement, metal, and natural gas, whose costs would increase at much higher rates than other industries. Furthermore, there were some frustrations from the business community on the revenue recycling mix that gives disproportionate benefits to individuals. For this reason, the BC Chamber of Commerce suggests that the revenue fate should be altered to solve the geographical inequity and individual-industry imbalance of the current revenue recycling scheme<sup>29</sup>.

### *Lesson*

Despite the success in initial implementation, one large problem has emerged: revenue shortfall. The top row of Table 5 lists the revenues and offsets planned in the 2008 Climate Action Plan. The second row of Table 5 shows that the collected revenues have been lower than the plan, and the third row that distributed offsets have been lower or higher than the plan. As a result, the "revenue neutral" carbon

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tax has in fact been revenue negative, with the latest forecast suggesting more of the same in the coming years.

**Table 5: Carbon Tax Revenues and Offsets**

	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Climate Action Plan	\$331	\$631	\$880	N/A	N/A	N/A
Collected Revenues	\$306	\$542	\$740	\$950	\$1,166	\$1,232
Distributed Offsets	\$313	\$729	\$862	\$1,141	\$1,494	\$1,474
Sum	(\$7)	(\$187)	(\$122)	(\$191)	(\$328)	(\$242)

\*in million Canadian dollar

\*\*collected revenues and distributed offsets for fiscal years after 2010/11 are based on the latest forecast as of Feb 15, 2011

\*\*\* There is only one row representing the Climate Action Plan's revenues and offset estimates because, by the definition of a revenue neutral tax, the planned revenues and offsets are equal.

The global economic recession is obviously a cause of the decline in revenues. However, the fundamental problem is that the offsets are indexed to the other taxes, not to the carbon tax revenues. For instance, businesses received their offsets in the form of rate cuts for on general corporate income tax: the offsets depend on their business income, not on the collected carbon tax revenues. For this reason, it is imperative to design the revenue-recycling scheme such that the offsets indexed to the actual revenues.

## Chapter 4: Carbon Tax Analysis Model (C-TAM)

### *Overview*

This chapter introduces the Carbon Tax Analysis Model (C-TAM) that estimates the impacts of a potential state carbon tax on GHG emissions and revenues. C-TAM was developed at the request of the Energy Office at the Washington State Department of Commerce to estimate a potential carbon tax in the state. The major determinants of the model's behavior are carbon tax rates, price elasticities of demand by fuel sources, and energy prices and demands forecasted by the EIA. The EIA's forecast is the basis for energy consumption and emissions in the BAU scenario. The model is programmed in Microsoft Excel, with a special focus on creating an attractive user interface. This provides the opportunities for policy makers to easily run C-TAM with their own assumptions and quickly check the results. This is an important feature of the model since the results are highly sensitive to various assumptions such as the price elasticity of demand. Lastly, note that all the monetary values in the model are in 2008 dollars.

### *Concept*

The basic concept of C-TAM differs substantially from the energy-economy general equilibrium models such as CIMS and NEMS, in the sense that the prediction does not rely on modules for each fuel and sector with numerous input variables such as technologies, capital stocks, and economic growth. Instead, C-TAM depends on the price elasticity of demand, an indicator of the degree to which a change in price induces a change in quantity demanded. By applying the price elasticity of demand to the percentage change in price caused by a carbon tax, the model can predict the adjusted quantity demanded. For example, if a carbon tax increases price of a certain energy product by 10%, and the energy product has an elasticity of -0.5, then demand would decline by 5%. Given a price change, the conceptual equation to predict the adjusted demand is<sup>2</sup>:

*Adjusted Demand*

*= Baseline Demand \* % Price Change \* Price Elasticity of Demand + Baseline Demand*

The right hand side of the equation consists of two terms; the first represents the change in quantity demanded; the second represents the baseline quantity demanded. Although this model takes a very

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<sup>2</sup> The relationship expressed in the equation is approximate as it does not take other effects such as substitution effect into consideration.

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simplistic approach, many of the complex dynamics in actual energy demand are already addressed in the EIA baseline forecast which contains the effects of numerous parameters needed to predict the demand. The remainder of the chapter discusses each variable used in the model, and introduces its overall mathematical process.

### *Baseline Energy Price and Demand Forecast*

The baseline energy price and quantity demanded comes from the EIA's Annual Energy Outlook (AEO). AEO data are generated by NEMS, the energy-economy general equilibrium model developed by the EIA<sup>30</sup>. The forecast predicts future energy price and quantity demanded, by fuel source, for each year up to 2035 in the latest edition (AEO 2010)<sup>31</sup>. It also forecasts energy price and demand for the following four major sectors: residential, commercial, industrial, and transportation sector. There is also an electric sector, but in most EIA data tables the demand of electricity is allocated to the other four sectors. The forecast accounts for all major legislated or scheduled policies and regulations (*e.g.* CAFE standards through 2016), but not proposed or probable regulations. Fuels used to generate electricity are accounted on a production basis, meaning that the fuel used in another state to generate electricity consumed in Washington is not included from the forecast. Due to the large uncertainties in energy price and economic growth, the EIA produces multiple scenarios for the AEO. The reference case is the standard scenario, using average oil price and economic growth projections. C-TAM is built on EIA's reference case projection, but the model uses the AEO's other four cases, high and low growth cases and high and low oil price cases, for sensitivity analysis.

The AEO's maximum geographical resolution is at regional level, and Washington State belongs to the Pacific region, including California, Oregon, Alaska, and Hawaii. The ratios between regional consumption and Washington's consumption, reported in the State Energy Database System (SEDS)<sup>32</sup>, are used to prorate the regional consumption forecast. In order to minimize the effect of annual variability, the ratios are the average ratios for three years between 2006 and 2008. The ratios by fuel are summarized in *Proration Ratio* tab in the spreadsheet model. The ratios vary significantly across fuel sources, primarily due to the unique fuel mix for electricity generation in Washington State<sup>3</sup>.

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<sup>3</sup> Since these minor fuel sources have little effect on overall energy demand, it is assumed that a simple ratio of the total energy demand of the two sources can be a proxy for these fuels. The SEDS provides data for all major fuel sources but not minor fuel sources such as liquefied hydrogen and petrochemical feedstock. Coal consumption is prorated separately for the industrial and electric sectors, so that the industrial forecast is not driven by trends in the overwhelmingly larger coal demand in the electric sector.

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### *GHG Emissions*

With the baseline and adjusted demand, the GHG emissions are estimated by multiplying the demand of each fuel by the respective emission factors for each fuel. The EIA classifies the emission factors of each fuel by use<sup>33</sup>, but this model uses a single emission factor for each fuel source for convenience as the differences by use are minimal. The model assumes the emission factor to be zero for the following fuel sources: renewable energy, petrochemical feedstock, other petroleum (*e.g.* lubricant, asphalt), biofuel, liquid hydrogen, nuclear power, and hydropower. The EIA does not provide emission factors for these fuel sources as the emissions occur only at the time of construction for renewable energy, nuclear power, and hydropower, and the projected level of demand is minimal for the rest of these fuel sources.

The baseline emissions computed using these methods is substantially lower than the GHG emissions inventory compiled by the Washington State Department of Ecology in 2007<sup>34</sup>, for two reasons. The first reason is that the baseline emissions in this model do not cover emissions from non-fossil fuel sources such as cement production, waste management, and agriculture. The other reason is that the AEO accounts electricity on a production basis while the state inventory accounts it on a demand basis. Washington consumes a substantial amount of electricity produced in other states using fossil fuels, which explains why the use of the AEO forecast results in lower emissions. As it is unlikely that Washington can levy a carbon tax on fuel used in other states, the AEO production-basis forecast fits the purpose of the model.

### *Carbon Tax Rate*

The default carbon tax rate to run C-TAM starts at \$10/MTCO<sub>2</sub>, increasing at \$5/MTCO<sub>2</sub> per year, capped at \$30/MTCO<sub>2</sub>. These values duplicate the starting rate and cap of the BC carbon tax, and the cap neatly matches the externalities of gasoline usage estimated by the National Research Council (\$0.30 per gallon)<sup>35</sup>. Multiplying these base rates by emission factors used to calculate the baseline GHG emissions yields the individual tax rates for each fuel.

### *Price Elasticity of Demand*

In theory, price elasticity of demand is a powerful tool to predict demand response to price change because it isolates the effect of price change by fixing the effects of other variables such as income and

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demographic change. However, in practice elasticity-based methods of economic modeling have been controversial, due largely to unreliable estimates of elasticity values associated with the lack of a standardized method to estimate. Espey (1996) demonstrates that methodological differences in data treatment, estimation technique, and demand specification can substantially affect the elasticity estimates for gasoline consumption<sup>36</sup>. For this reason, it is necessary to carefully examine a variety of studies against each other for each fuel source as well as to discuss the following issues to understand the drawbacks and limitations of using elasticity to estimate the impacts.

**Time frame.** The elasticity can be significantly different in the short run and long run. For instance, Dahl and Sterner (1991) suggest the short-term elasticity of gasoline consumption to be -0.26 and the long-term elasticity to be -0.86<sup>37</sup>. Such a difference arises because short-term elasticity normally represents minor changes such as driving habits while long-term elasticity represents more fundamental changes such as capital replacement (purchase of more fuel efficient vehicles) and land use change (housing choice to reduce the commute distance or live near transit stops)<sup>38</sup>. Since the purpose of the study is to find the long-term effects of the carbon tax, the model needs to focus on long-term elasticity.

**Temporal change.** The second issue is that the elasticity can change over time. Hughes et al (2007) documents this temporal dynamics in detail. The study finds that the short run elasticity was -0.335 between 1975 and 1980 but changed to -0.041 between 2001 and 2006, using a standard regression model with double-log form<sup>39</sup>. Although the study focuses on the short run elasticity, this implies that to produce a reliable forecast, the elasticity used in the model needs to come from relatively new studies. The literature research for this study therefore focused on studies published after 1990, with a few exceptions needed to cover data gaps among the recent studies.

**Location.** Differences in price elasticities of demand are observable between countries, often between states, and occasionally within a state. In the case of residential electricity demand, a meta-analysis by Espey (2004) suggests that US consumers are less elastic than non-US consumers in the long run<sup>40</sup>, and Bernstein and Griffin (2007) document that in the US the elasticity varies dramatically across regions and states<sup>41</sup>. It is therefore better to avoid using the elasticity estimates based on global data and to prioritize state-level or regional-level elasticity estimates if available.

Table 6 summarizes the selection of elasticities for each fuel source, providing three important findings. First, there are significant differences in elasticity estimates among studies for a single fuel. Second,

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studies for minor fuel sources such as jet fuel and residual fuel are scarce, and there was no elasticity estimate for industrial natural gas usage. The likely cause is the lack of interests for the minor fuel sources, and the industry-by-industry variation for the industrial natural gas usage. Third, the demands for most fuel sources are inelastic, meaning the quantity demanded declines less quickly than the price increases.

**Table 6: Summary of Elasticity Estimates**

Type	Author	Year	Transportation Fuels				Electricity			Natural Gas			
			Gasoline	Diesel Fuel	Jet Fuel	Residual Fuel	Res.	Com.	Ind.	Res.	Com.	Ind.	
Meta-Analysis	EIA <sup>42</sup>	2003					-0.49	-0.45		-0.41	-0.40		
	Goodwin <sup>43</sup>	2004	-0.64										
	Espey <sup>44</sup>	1996	-0.58										
	Brons <sup>45</sup>	2006	-0.53										
	AVG		-0.58				-0.49	-0.45		-0.41	-0.40		
Individual Studies	Council <sup>46</sup>	1982					-0.40	-0.53	-0.22				
	WSU <sup>47</sup>	1982					-0.09	-0.32	-0.82				
	BPA <sup>48</sup>	1982					-0.28	-0.42	-0.93				
	Dahl <sup>49</sup>	1991	-0.86										
	Greene <sup>50</sup>	1984		-0.47									
	Bernstein <sup>51</sup>	2006					-0.25	-1.37		-0.45			
	Small <sup>52</sup>	2007	-0.40										
	Agras <sup>53</sup>	1999	-0.92										
	Maddala <sup>54</sup>	1997					-0.23			-0.20			
	Maddala <sup>55</sup>	1997					-0.26			-0.28			
	Azevedo <sup>56</sup>	2011					-0.25						
	Sipes <sup>57</sup>	2001	-0.60										
	Sterner <sup>58</sup>	2006	-0.80										
	Goodwin <sup>59</sup>	1992	-0.71										
	Hewlett <sup>60</sup>	1980				-0.43							
	Hagler Baily <sup>61</sup>	1999	-0.60	-0.40	-0.30	-0.30							
	Silk <sup>62</sup>	1997					-0.60						
	Gately <sup>63</sup>	1988			-0.15								
	AVG			-0.70	-0.44	-0.23	-0.37	-0.30	-0.52	-0.49	-0.31	-0.24	
	Weighted AVG			-0.62	-0.44	-0.23	-0.37	-0.43	-0.47	-0.49	-0.38	-0.35	

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Table 6 lists individual studies and meta-analyses separately. Since meta-analysis incorporates the results from various individual studies, the meta-analyses are based on larger data pools and reduce bias in data selection and specification. For those fuels that have been subject to at least one meta-analysis, the model computes the final elasticity by first calculating separate averages of the individual studies and meta-analyses, and then taking the weighted average of both, doubling the weight of the average from meta-analyses. In the absence of meta-analyses, the model simply uses the average from individual studies. The final elasticities are summarized in the bottom of Table 6.

It is assumed that the elasticity is zero for the following fossil fuel sources as the level of consumption is almost zero and unlikely to change with the carbon tax: kerosene, coal (residential and commercial), motor gasoline (commercial and industrial), petrochemical feedstock, other petroleum, and biofuels and heat coproducts. Some of these elasticity estimates applies to others minor fuels **within the sector** as summarized below:

- Gasoline: liquefied natural gas (LPG), compressed natural gas, pipeline fuel natural gas, and ethanol (E85)
- Residential natural gas: LPG and distillate fuel oil
- Commercial natural gas: LPG, residual fuel oil, distillate fuel oil
- Industrial electricity: LPG, residual fuel oil, distillate fuel oil, natural gas, and coal

Lastly, the elasticity is phased in over time, rather than applied all at once, to represent the nature of the long run elasticity, which is in accordance with capital stock replacement. The U.S. Department of Transportation reports the average life span of a vehicle is 12 years<sup>64</sup>, and the EIA assumes the life expectancy of home appliances is about 10 to 20 years while the buildings last much longer, about 50 years<sup>65</sup>. NEMS assumes capital replacement to take place in a linear fashion. For these reasons, the elasticity is phased in over a ten-year period for transportation (2012 – 2022) and a twenty-year period for other fuel usage (2012-2032) in a linear fashion.

### *Impact Estimation*

Recall the equation for adjusted demand after application of a carbon tax:

*Adjusted Demand*

*= Baseline Demand \* % Price Change \* Price Elasticity of Demand + Baseline Demand*

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With the adjusted energy demand, the model can easily project the adjusted GHG emissions for Washington by multiplying the emission factors by the energy demand. Carbon tax revenues are the multiple of the carbon tax rates for each fuel by the energy consumption.

Since policymakers will wish to test revenue-neutral approaches in which the revenues are used to offset other taxes, it is useful to provide projected levels of other state revenue sources. The Washington State Office of Financial Management (OFM) provides a long-term forecast on the state economy up to 2030<sup>66</sup>. According to this forecast, Washington's total personal income will grow at 3.1% annually on average between 2011 and 2030. Although tax revenues may not grow at the same rate as personal income, it does offer a reasonable proxy. The model assumes that the other tax rates and structure are static. Since the state revenues are currently much lower than usual due to the economic recession, the base year for the projection is FY 2008, as reported by the Washington State Department of Revenue<sup>67</sup>. Using these assumptions, the model projects the levels of three major state revenue sources: retail sales tax, property tax, and B&O tax.

### *Electric Sector*

The electric sector requires a different modeling approach than the residential, commercial, industrial, and transportation sectors due to several factors. First, consumers pay for electricity, not for fuel. The elasticity of demand for electricity therefore cannot be applied directly to any fuel. Second, the sector's emissions and tax burdens must be reallocated to the other sectors because the electric sector is not a consumer but a provider of energy to other sectors. Third, each sector has different baseline prices of electricity (large industrial users, for example, are eligible for volume discounts) and different price elasticities of demand. These unique features imply that the model must perform a sequence of allocations and aggregations.

This process starts with the allocation of the GHG emissions from the electric sector to the other sectors. The emissions from each fuel source are aggregated for the electric sector to create a total for all fuels, and the total is then allocated to the other sectors based on the sectors' forecasted share of the electric consumption in each year. The second step is to find the price effect of the carbon tax. The electricity price change caused by the carbon tax is the weighted average of price increases of each fuel source. With this price change, the same equation used for non-electric fuels can find the adjusted electricity

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demand for each sector based on the electricity price elasticity of demand; finally, the adjusted demands are aggregated to find the adjusted energy demand for the electric sector.

The allocation of the adjusted total electricity demand to each fuel source in the electric sector is very challenging, because the effect of the carbon tax on fuel mix for electricity generation is uncertain. In theory, a carbon tax should change the fuel mix as it disproportionately alters the fuel price in favor of non-fossil fuel sources such as hydropower and nuclear power. However, power generation normally involves a large sum of capital costs to build power plants, and the lifetime of these plants typically stretches over half a century or longer. This is particularly the case for hydropower and nuclear power, and their operating costs to produce additional output are relatively low. For these reasons, the model includes two distinctive scenarios. One scenario assumes that the carbon tax does not affect the output of nuclear power and renewable energy, mostly hydropower, and natural gas and coal demand in the electric sector decreases with the same margin to meet the reduced demand as follows:

$$\begin{aligned} & \textit{Adjusted Demand (electric coal/natural gas)}^4 \\ & = \textit{Baseline Demand * \% Change in (Total Electricity Demand – Baseline Output from Nuclear and} \\ & \quad \textit{Renewable Energy) + Baseline Demand} \end{aligned}$$

The alternative scenario in contrast assumes that the fuel mix remains as projected in the AEO, so the following simple equation will apply to all fuel sources:

$$\begin{aligned} & \textit{Adjusted Demand (all electric fuels)} \\ & = \textit{Baseline Demand * \% Change in Total Electricity Demand + Baseline Demand} \end{aligned}$$

Now that the model is able to estimate the adjusted level of demand for each fuel source, the adjusted emissions can be derived in the same manner as the first step in this series of allocations and aggregations.

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<sup>4</sup> Adjusted Demand (electric coal/natural gas)

= Baseline Demand \* {(Adjusted Electricity Demand – Baseline Output from Nuclear and Renewable) – (Total Electricity Baseline Output – Baseline Output from Nuclear and Renewable)} / (Total Baseline Electricity Output – Baseline Output from Nuclear and Renewable) + Baseline Demand

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After constructing this model, however, the state made an agreement with the operator of the coal power plant in Centralia; the operator will shut down the entire plant of two coal-fired boilers in two phases, one boiler by 2020 and the other by 2025<sup>68</sup>. The power plant is the only coal power plant in Washington and is responsible for approximately 10% of the Washington's GHG emissions. The likely scenario is to replace these coal-fired boilers with natural gas boilers, so the model has an alternative assumption that the two boilers are replaced with natural gas boilers in the manner described above.

### *Summary of Limitations*

The discussion above reveals various limitations of C-TAM. In summary, these limitations are:

- **Accuracy of elasticity estimate.** The elasticity estimates are highly sensitive to estimation technique, data scope, and demand specification, and there are insufficient elasticity estimates available for some energy sources. Furthermore, as time goes on, the elasticity approximation is likely to be more error prone.
- **Fuel mix for the electric sector.** The effect of the carbon tax on the fuel mix for electricity generation is uncertain due to complex rate setting systems and high capitalization. Although the model allows the user to assume either that the fuel mix responds very strongly to the price signal or doesn't respond at all, the most likely scenario is somewhere between the two, likely closer to the former scenario.
- **Baseline forecast.** The EIA's baseline forecast is based on the best information available today, but the forecasted price and demand changes may be quite different from that forecast by EIA. In fact, the forecast made ten years ago was unable to predict the recent spike in crude oil price.
- **Capital stock replacement.** The demand change is assumed to be driven by capital stock replacement and phased in over the average lifetime of the capital stocks, but some behavioral changes take longer (*e.g.* land use change) or shorter (*e.g.* modal shift in the transportation sector).

In addition to these limitations, the model does not take the following factors into consideration:

- **Substitution effect.** A substitution effect may occur due to the changes in relative prices of fuels. In the face of relative prices changes, holding income fixed, consumers may attempt to maintain their utility (or welfare) by substituting away from goods with higher prices towards goods with relatively lower prices. This change in the relative price could trigger a substitution effect, shifting demand upward for the product with less price increase if it can be replaced. For instance, the model assumes that the demand of renewable energy would remain the same with the carbon tax, but it may in reality increase as it gains price competitiveness.

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- **Electric vehicle.** The EIA's forecast is based on the assumption that the market penetration of alternative vehicles, most importantly electric vehicles, will remain small for the analysis period. However if electric vehicles substantially replace today's conventional (internal combustion engine) vehicles, the fuel demand in the transportation sector will dramatically deviate from the forecast.

These limitations may lower the accuracy of the impact estimates. It is however difficult to quantify and incorporate the effects of these limitations, which are subject to further research.<sup>5</sup>

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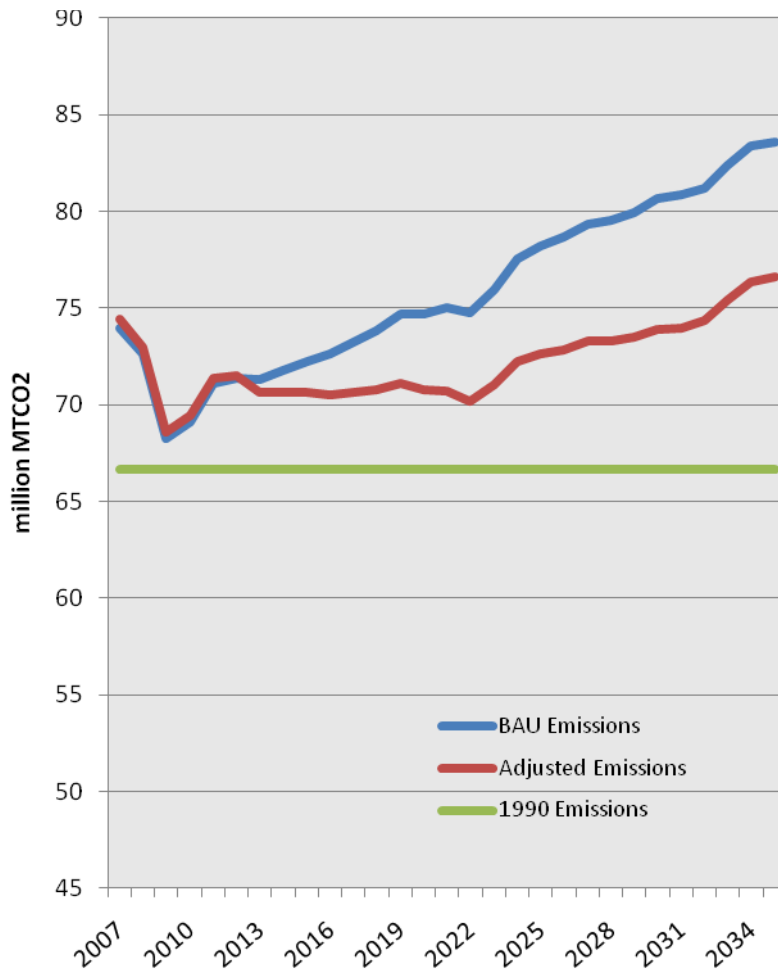
<sup>5</sup> Please contact the author to request the actual spreadsheet model at [keibun.mori@gmail.com](mailto:keibun.mori@gmail.com).

## Chapter 5: Results and Analysis

### Overview

C-TAM shows that a carbon tax can have substantial impacts on GHG emissions in Washington even duplicating the relatively low rates used in BC. Starting at \$10/MTCO<sub>2</sub> 2012, increasing by \$5/MTCO<sub>2</sub> each year until reaching the \$30/MTCO<sub>2</sub> cap in 2016, with exemptions for aviation and marine fuels, the change in emissions from the BAU scenario is estimated to be -1.8% in 2015, -7.1% in 2025, and -8.4% in 2035 (see Figure 1 and Table 7).

Figure 1: Changes in the GHG Emissions in Washington State with \$30/MTCO<sub>2</sub>



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**Table 7: Summary of GHG Impacts in Washington State with \$30/MTCO<sub>2</sub>**

	2015	2025	2035
GHG Change from the BAU Emissions			
Residential	-4.9%	-15.7%	-20.8%
Commercial	-6.4%	-20.3%	-26.6%
Industrial	-6.8%	-15.2%	-17.5%
Transportation	-1.4%	-3.2%	-2.8%
<i>all sectors</i>	-2.2%	-7.1%	-8.4%
GHG Change from 1990 Levels	+5.9%	+9.0%	+14.9%

With these baseline parameters the effect will increase rapidly in the first four years due to the annual rate increments. The effect is expected to increase further even after the rate reaches the cap because capital stock replacement will continue to take place. Once the full impacts of price change and stock turnover have been achieved as of 2032, the effect will gradually diminish due largely to increasing energy prices that deflate the relative value of the capped tax. Fuel cost is expected to continue to increase over time faster than the rate of inflation, so the cap decreases the relative value of the carbon tax in comparison to the retail price over time.

### *Comparison to Washington's Goals*

In 2008 Washington enacted HB 2815, which mandated the state to reduce the emissions to 25% below 1990 levels by 2035. According to the *Washington State GHG Inventory*, the total emissions in Washington were 88.4 million ton in 1990<sup>69</sup>. This is different than the estimates used in the carbon tax model because the *Washington State GHG Inventory* is accounted on a consumption basis and includes the emissions from non-energy sources such as agriculture and land use change. The estimated emissions from fossil fuel combustion in Washington were 66.7 million metric ton in 1990, projected to grow to 83.6 million metric ton by 2035 in the BAU scenario, a 25.3% increase from the 1990 level. The carbon tax would cut the emissions down to 76.6 million ton in 2035, still a 14.9% increase from the 1990 level. C-TAM therefore suggests that duplicating the rates and restrictions of the BC carbon tax, the Washington's carbon tax alone will not lead Washington to achieve its GHG reduction goal.

### *Comparison to BC's Analysis*

As noted in the previous chapter, BC has estimated the long-term effect of its carbon tax on GHG emissions by using CIMS, an energy economy general equilibrium model. Its estimate shows the BC

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carbon tax to curb its emissions by 3.9% relative to a 2020 reference case, 12 years after beginning implementation. This is somewhat lower than the estimated change for Washington after 12 years of implementation, which is a 6.8% reduction from the BAU scenario in 2024. The major causes of the difference are Washington’s higher share of coal in its electric generation fuel mix and a lower retail price of gasoline and diesel. Coal consumption is particularly sensitive to the carbon tax due to its high carbon intensity and low baseline cost, and it in turn increases the cost of electric generation by a larger margin than BC, whose hydropower meets over 90% of its demand<sup>70</sup>. Washington’s retail price of gasoline and diesel is lower than BC’s primarily due to lower gas tax. This amplifies the effect as the carbon tax raises the adjusted price of gasoline and diesel more in Washington. Taking these factors into account, C-TAM seems to have returned reasonable results.

### *Results for Nationwide Carbon Tax*

C-TAM was also run with AEO’s aggregated forecast for the whole nation, and it shows that the carbon tax with the same parameters can reduce the national GHG emissions by 23.3% compared to the BAU scenario in 2035. This figure is substantially larger than the estimate for Washington (8.4%). The primary causes of the differences would be climate and electric generation’s fuel mix. The moderate climate in Pacific Northwest reduces the needs for home heating and cooling, and

Washington’s hydro-dominated electric fuel mix keeps the emissions from the electric sector low even in the BAU scenario. In contrast, larger use of heating oil and electricity and higher dependency on coal power plants elsewhere in the nation gives more opportunities for the carbon tax to curb the use of fossil fuel. The carbon tax therefore would be a more effective policy tool if implemented nationwide, and it is more effective in reducing the emissions from the electric sector than the transportation sector. This finding is consistent with other quantitative estimates from studies by EIA (2009)<sup>71</sup> and Morrow et al (2010)<sup>72</sup>.

### *Sectoral Analysis*

In general, the effect on GHG emissions is stronger in non-transportation sectors as shown in Table 7, primarily due to their dependency on

**Table 8: Price Change from Carbon Tax in 2035**

<b>Residential</b>	
Natural Gas	11.6%
Electricity	9.1%
<b>Commercial</b>	
Natural Gas	12.2%
Electricity	9.1%
<b>Industrial</b>	
Natural Gas	16.9%
Industrial Coal	79.4%
Electricity	9.1%
<b>Transportation</b>	
Motor Gasoline	6.4%
Diesel Fuel	7.1%
<b>Electric</b>	
Distillate Fuel Oil	8.8%
Natural Gas	19.4%
Steam Coal	125.9%

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natural gas and electricity. Although natural gas has a lower emission factor than gasoline, its lower baseline price increases the relative value of the carbon tax in the adjusted retail price. For example, whereas the carbon tax is expected to increase the price of gasoline by 6.3% in 2035 under a \$30 tax, it will increase the cost of industrial natural gas by 16.9% for the same year. Since the price elasticities of demand for gasoline and natural gas are similar, the effect of the carbon tax on the demand would be much larger for natural gas. The effect is strongest in the industrial sector, where process heat is often dependent on direct combustion of fossil fuels, including coal. Coal's combination of high carbon intensity with low baseline cost makes it particularly sensitive to a carbon tax, nearly doubling its price under a \$30 tax (see Table 8)<sup>6</sup>.

### *Revenues*

In contrast, the majority of carbon tax revenues will come from the transportation sector, about 60% as of 2035. This is simply because the transportation sector is the dominant source of GHG emissions in Washington, and it will become the primary revenue source of the carbon tax. Across all sectors, the carbon tax is expected to generate \$2.1 billion in 2035. The gross revenues could offset substantial portions of other state revenues forecasted for 2035 in the model: 52% of state property tax revenues, 8% of state retail sales tax, and 68% of B&O tax. These results are summarized in Table 9.

**Table 9: Carbon Tax Revenues (in millions)**

Carbon Tax Revenues	2015	2025	2035
Residential	\$219	\$217	\$216
Commercial	\$195	\$194	\$200
Industrial	\$417	\$407	\$415
Transportation	\$1,085	\$1,128	\$1,219
Total	\$1,916	\$1,945	\$2,050

Consumers eventually bear all the increased costs from the carbon tax through increased costs of final products, making it a theoretically reasonable option to return all revenues to individuals, for example in the form of a retail sales tax reduction or cash rebate. Many Washington products are however exported outside the state and in many cases outside the country, so the carbon tax can adversely affect

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<sup>6</sup> See *Price Change* tab on the spreadsheet for more information on the price effect

## Washington State Carbon Tax: Fiscal and Environmental Impacts

export industries if all the revenues are returned to Washington consumers alone. Furthermore, it is politically challenging to distribute the revenues from all four sectors to a more narrowly defined group. For these reasons, it is unlikely that the entire revenue stream will be used to offset just one existing tax, or to fund a cash rebate. The distribution of the revenues is more likely to reflect the proportional burden on each sector.

Washington's major revenue sources are retail sales tax and property tax, mostly paid by individuals, and B&O tax, paid by businesses. The model estimates the revenues by the four sectors (residential, commercial, industrial, and transportation), which requires the reallocation of the revenues to individuals and businesses. The revenues from the residential sector and a portion of the transportation sector will come from individuals, and the remainder will come from businesses and governments. To distribute the revenues from the transportation sector, it is assumed that individuals consume all of gasoline and ethanol (E85), and businesses are responsible for the rest of transportation fuels, mostly diesel. This is a reasonable assumption judging from the past trend. The result then is that individuals would pay \$0.99 billion, and businesses would pay \$1.07 billion in 2035. The two groups are therefore responsible for approximately half of the revenue each. The policy implication is that individuals and businesses should both receive about half of the revenues each.

### *Sensitivity Analysis*

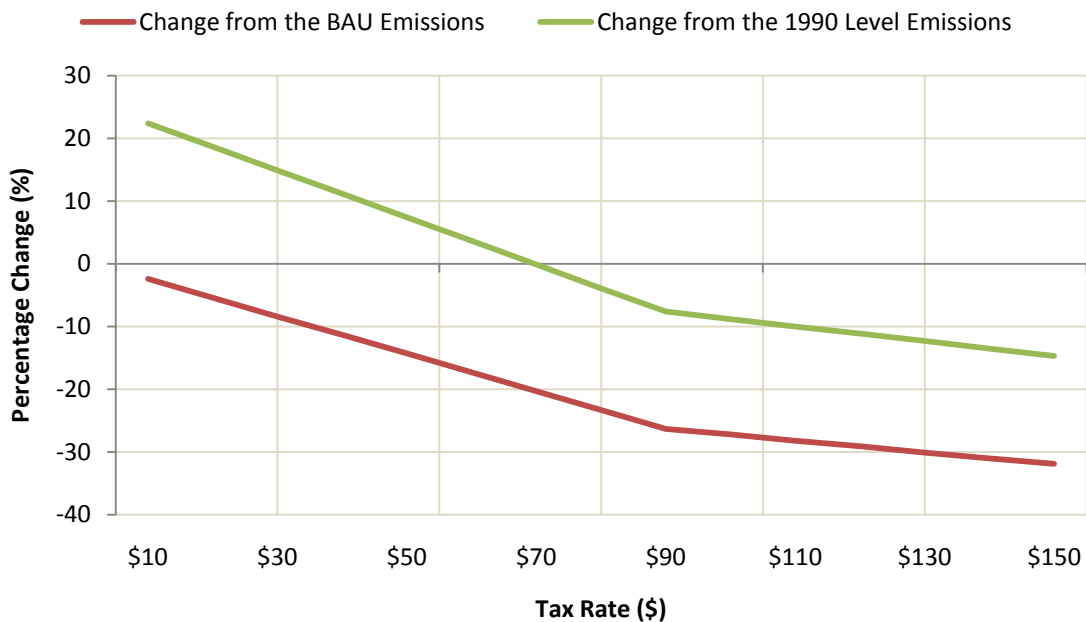
The results discussed up to this point are based on the rate structure used in the BC carbon tax (base model). Washington's carbon tax is certainly not restricted to be identical, so this section presents sensitivity analyses on two policy variables, the tax rates and the exemption of aviation and marine fuels. Additional sensitivity analyses explore the effects of three important assumptions made in the model: the scenario regarding electric fuel mix, the shutdown of the coal power plant in Centralia, and economic and energy price scenarios. The results from the sensitivity analyses can illuminate the effects of various policy decisions and assumptions for Washington.

**Carbon tax rates.** In the base model, the carbon tax is capped at \$30/MTCO<sub>2</sub> as in the BC carbon tax. Higher tax rates would impose additional costs on fuels and therefore reduce the GHG emissions further. The model was therefore run with various tax rates, and Figure 2 plots the effect on the total GHG emissions in 2035 as a function of different carbon tax rates. The policy implication is that the carbon tax rates must be very high to curb the emissions to the level set by the state law. For example,

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in order to stabilize the emissions at the 1990 levels, the tax rate must be as high as \$70/MTCO<sub>2</sub>. Figure 2 shows that the pace of GHG reductions will slow down at \$90/MTCO<sub>2</sub>, because \$90 carbon tax will reduce the demand for electricity to the level sufficient to retire all coal and natural gas power plants in the state<sup>7</sup>. Furthermore, the tax rate must increase to approximately \$240/MTCO<sub>2</sub> by 2035 to meet the state target for reducing emissions to 25% below the 1990 level. Such rate might be seen as too high by the general public as it is predicted to increase the gasoline retail price by \$2.4 per gallon.

Figure 2: Emission Changes in 2035 with Various Rates



**Aviation and marine fuel exemption.** The base model follows the example of the BC carbon tax and exempts aviation and marine fuel from taxation. BC exempted these fuels because of the concern that the demand can easily shift to the surrounding regions. However, from an equity standpoint, it is problematic as they are responsible for 16% of the energy-related GHG emissions in Washington as of 2007. When the model was run without this exemption, the reduction in the GHG emissions increased from 8.4% to 8.8% in 2035, and the revenues increased from \$2.1 billion to \$2.5 billion in the same year.

<sup>7</sup> In reality, however, some thermal plants need to be preserved to prepare for some weather conditions which adversely affect output from hydropower and other renewable energy sources. These conditions include a low precipitation year and a low wind day or time.

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This sensitivity analysis implicates that the exemption would not substantially undermine the environmental impacts of the carbon tax but lower the revenues. The cause of the contradictory results is that aviation and marine fuel consumption is believed to be inelastic when compared to other fuels. However, as discussed earlier, there aren't sufficient studies on the elasticity for these fuels, and policy makers need to take this lack of information into consideration prior to making a decision.

**Centralia shutdown scenario.** The previous chapter recognizes that the recent state law to phase-out the coal power plant in Centralia will have substantial impacts on the state GHG emissions. When replacing the coal-fired boilers at Centralia with a new natural gas plant, the projected emissions will be smaller than the base model as the electric generation from natural gas is less carbon intensive. When looking at the effects of the carbon tax, the reduction in the GHG emissions would be smaller, changing from 8.4% to 3.4% in 2035. The shutdown of the coal power plant reduces the impacts of the carbon tax because the shutdown will curb the BAU emissions. Although the change will be smaller in this scenario, both the BAU and adjusted emissions will be lower than the base model, and the carbon tax revenues will decrease from \$2.1 billion to \$2.0 billion in 2035.

**Fuel mix scenario.** In the base model, the fuel mix for the electric sector fully changes in response to the carbon tax in the base model; the output from renewable and nuclear power plants remain the same as projected in the AEO while the fossil fuel consumption in the electric sector declines to respond to the decreased electricity demand. The results with the alternative fuel mix scenario, in which all fuel sources decline by the same margin to meet the adjusted demand, shows that the reduction in the emissions will be considerably smaller; changing from 8.4% to 3.0%. This is dramatic change, indicates that the results are highly sensitive to scenarios about fuel mix change. While this alternative scenario is unlikely in theory, further research will be beneficial to provide more accurate forecasts.

**Energy price and economic growth scenarios.** The base model uses the reference case of the AEO, a standard scenario with moderate increases in energy price and economic growth. As introduced in the previous chapter, the AEO also provides energy price and demand forecasts for four other scenarios, high and low oil price cases and high and low growth cases. C-TAM can measure the effects of these cases by simply replacing the regional baseline consumption data and baseline price data from the reference case with the ones from the other cases. Table 10 summarizes the results of this sensitivity analysis for 2035. The results show that the effect of the carbon tax will be larger for the low oil price

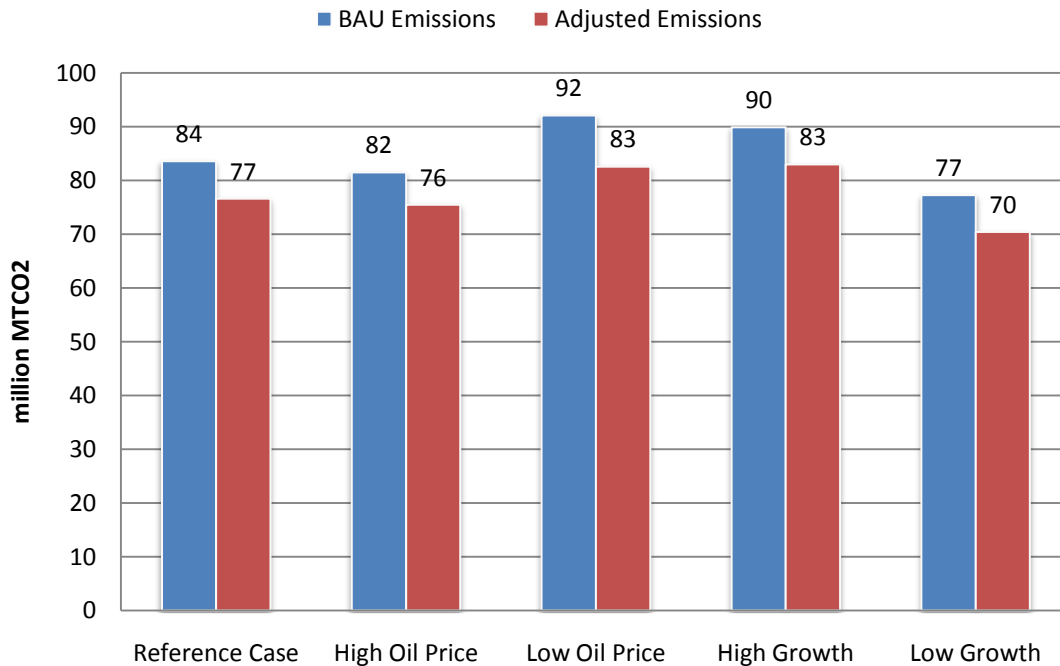
## Washington State Carbon Tax: Fiscal and Environmental Impacts

case than the high oil price case, because low oil price increases the relative value of the carbon tax in the final retail price. The actual reduction in GHG emissions will be the same for the low growth case and the high growth case, but the percentage change will be larger for the low growth case. This is simply due to the smaller BAU emissions for the low growth case, a denominator of the equation. Lastly, it is worth noting that since the emissions for the baseline forecast depend on the energy price and economic growth, the carbon tax rates needed to achieve the target reduction would change substantially.

**Table 10: Projected Emissions under Different EIA's Scenarios (in million MTCO<sub>2</sub>)**

<i>Scenario</i>	<i>BAU Emissions</i>	<i>Adjusted Emissions</i>	<i>% Change</i>
Reference Case	83.6	76.6	-8.4%
High Oil Price	81.5	75.5	-7.4%
Low Oil Price	92.1	82.6	-10.3%
High Growth	89.9	83.0	-7.7%
Low Growth	77.3	70.4	-8.9%

**Figure 5: Projected Emissions under Different EIA's Scenarios**



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### *Monte Carlo Simulation*

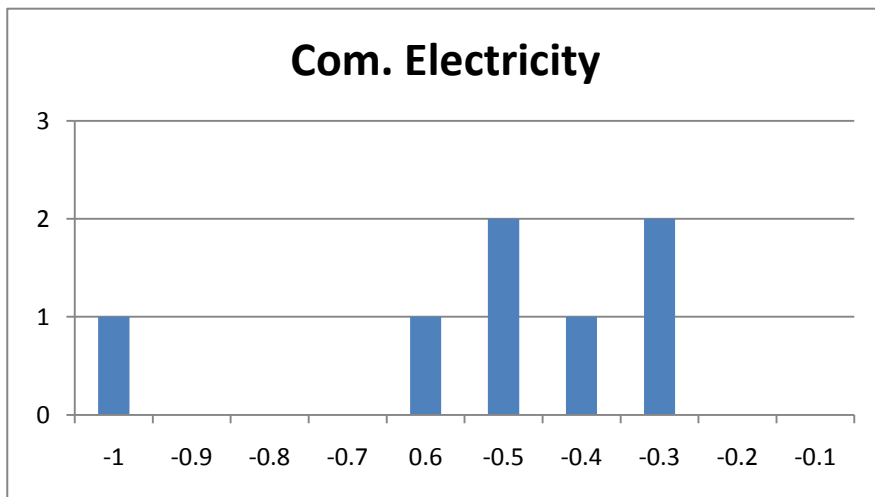
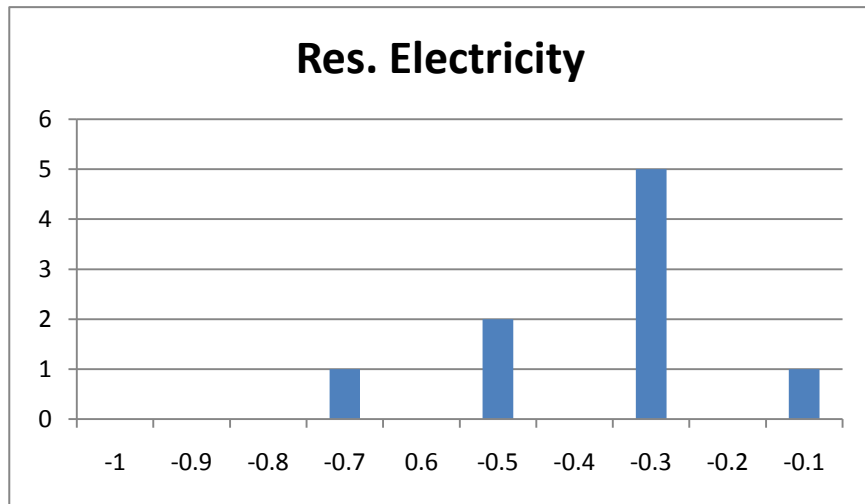
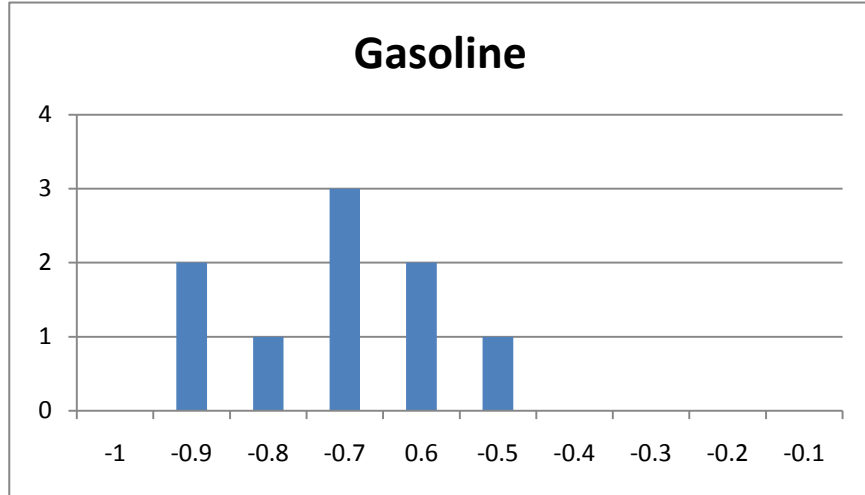
The sensitivity analysis in the previous section addresses the uncertainties in two of the three key drivers of the model, carbon tax rates and baseline forecast. It however does not address the significant uncertainties of the last driver, price elasticity of demand. The previous chapter discusses the variety of drawbacks of using the price elasticity of demand, and the discussion implies that the elasticity estimates are subject to uncertainties associated with the estimation techniques as well as the temporal and geographical scope of the dataset. Monte Carlo simulation can address the problem of uncertainty around elasticity estimates by running the model for a large number of times with various combinations of uncertain parameters. Rather than relying on a single-point estimate of elasticity or other variable, this simulation method provides a range and distribution of possible outcomes. Therefore, it helps decision makers understand the accuracy and range of the projected outcomes.

Oracle Crystal Ball is a specialized computer software program developed to run Monte Carlo simulations. It is in a spreadsheet-format and can easily import the data and model structure from Microsoft Excel. The software allows users to select the variables to include in the uncertainty analysis and assign the distribution patterns for the variables. This process requires additional inputs to shape the distribution pattern around the variable such as range, mean, and standard deviation.

Figure 6 shows the frequency of elasticity estimates, providing the distribution patterns for three well-studied energy demand: gasoline and residential and commercial electricity. The figures suggest that the elasticity estimates for gasoline are concentrated around the mean, those for residential electricity are more scattered across the figure, and those for commercial electricity are concentrated around the mean with an outlier. Although the sample size is not sufficiently large to arrive at a scientific conclusion about the distribution patterns, these findings suggest that a normal distribution can be a fit for the purpose of the Monte Carlo simulation. It is hence assumed that the estimates for gasoline and residential electricity simply follow the normal distribution, with a small standard deviation for gasoline and a larger one for residential electricity to represent the degree of concentration. The elasticity estimates for commercial electricity demand have an outlier of -1.37, so they are fitted by a lognormal distribution to model right-hand skew. There are a few elasticity estimates for the demand for other energy sources, but it is assumed that they can also be fitted by a normal distribution, with a standard deviation of 0.2. These assumptions are listed in Table 11.

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Figure 6: Distributions of Elasticity Estimates



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**Table 11: Parameters for Monte Carlo Simulation**

	Mean	Standard Deviation	Form
<b>Gasoline</b>	-0.62	0.2	Normal
<b>Diesel</b>	-0.44	0.2	Normal
<b>Jet Fuel</b>	-0.30	0.2	Normal
<b>Residual Fuel</b>	-0.37	0.2	Normal
<b>Res. Electricity</b>	-0.43	0.3	Normal
<b>Com. Electricity</b>	-0.47	0.2	Lognormal <sup>8</sup>
<b>Ind. Electricity</b>	-0.49	0.2	Normal
<b>Res. Natural Gas</b>	-0.38	0.2	Normal
<b>Com. Natural Gas</b>	-0.35	0.2	Normal

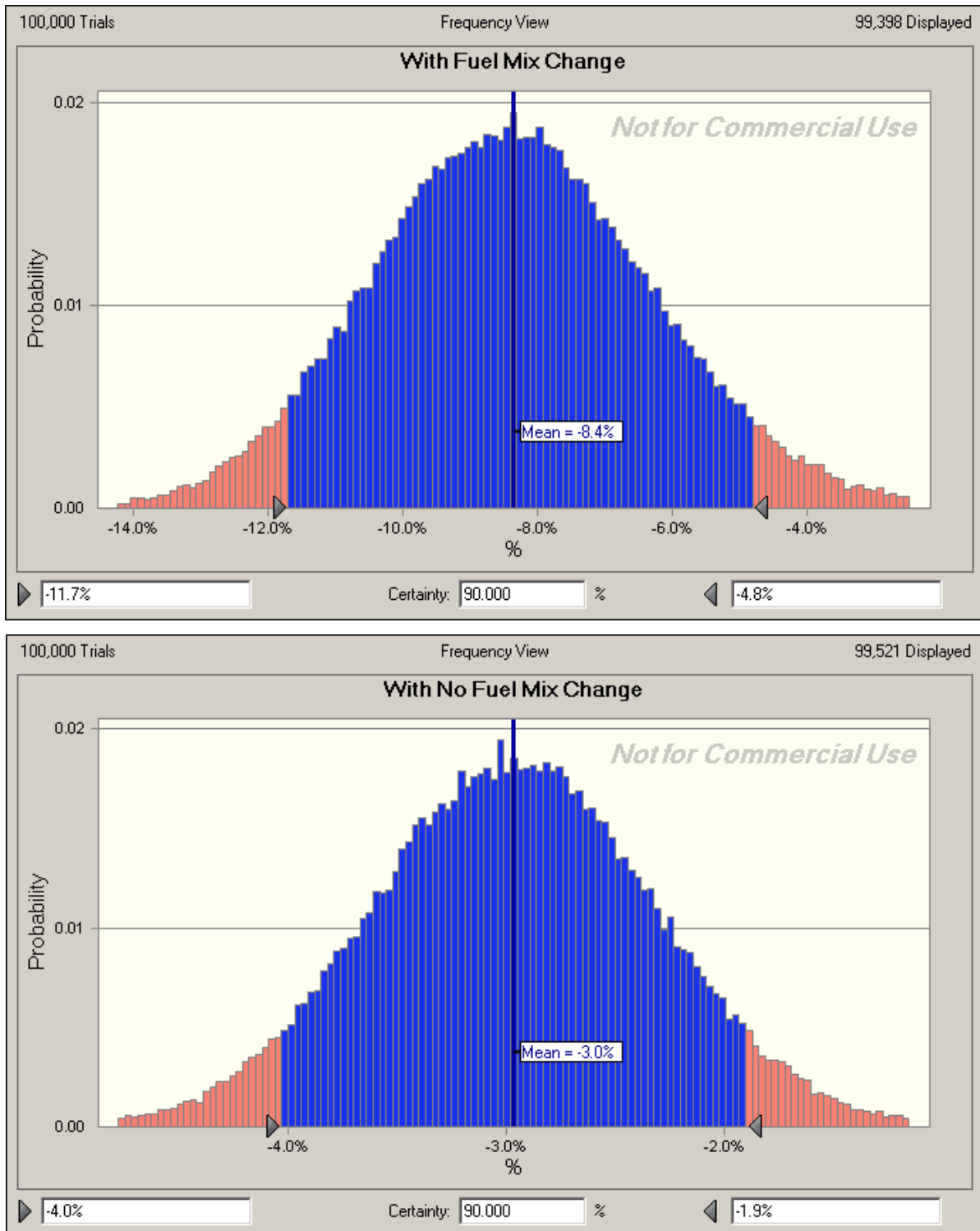
Monte Carlo simulations in this study use two different scenarios on fuel mix for electric generation. As described earlier, one scenario assumes that a carbon tax will alter the fuel mix in favor of non-fossil fuel energy sources, mostly hydropower and nuclear power, and the other scenario assumes that the consumption for the electric outputs from all energy sources will decrease by the same margin. Figure 7 shows the results of the simulations with 100,000 trials for the two scenarios. The blue bars represent the outcomes with 90% confidence intervals, ranging from -11.7% to -4.8% with the mean at -8.4% with the fuel mix change, and ranging from -4.0 to -1.9% with the mean at -3.0% without the fuel mix change. This simulation suggests that the uncertainty around the price elasticity of demand might have some effect on the outcome, but not large enough to alter the fundamental conclusion.

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<sup>8</sup> The location of the lognormal distribution is set at -1.37, based on the outlier mentioned in the main text.

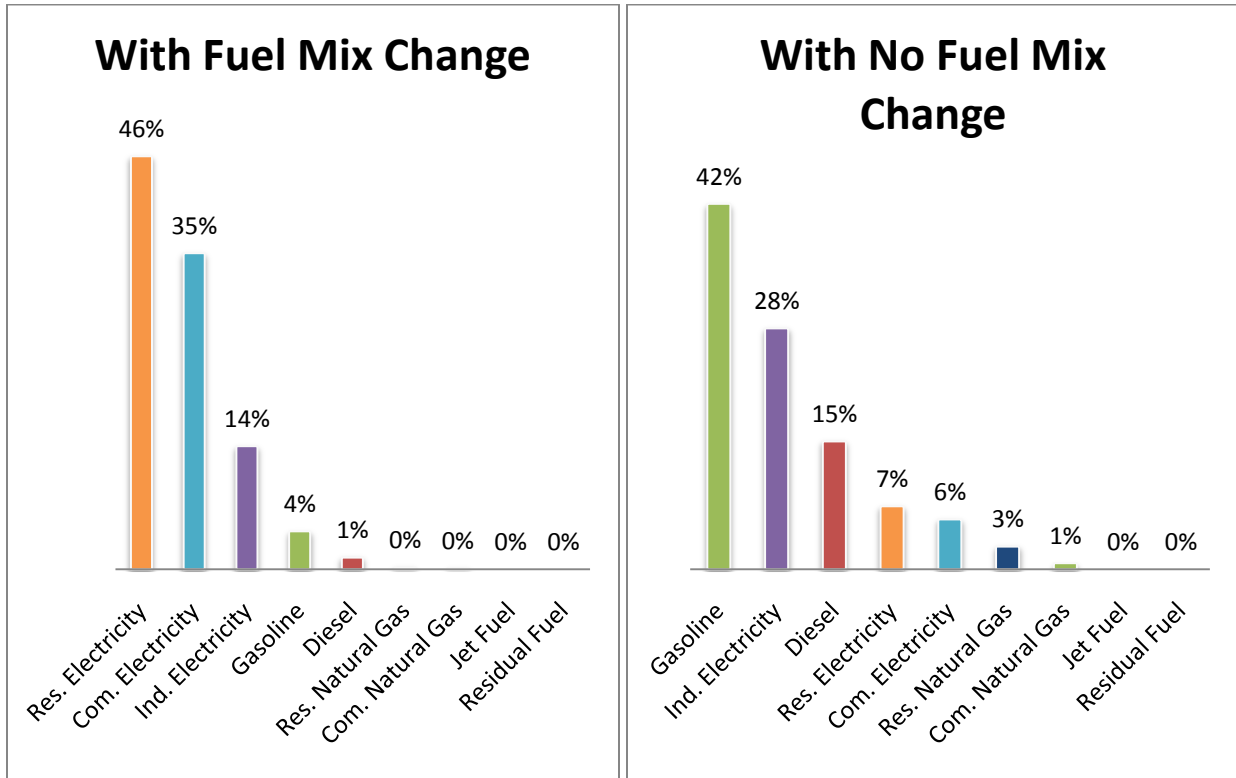
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Figure 7: Result of Monte Carlo Simulation



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Figure 8: Contributions of the Uncertain Variables to the Outcomes



The Monte Carlo simulations can also provide the model's sensitivity to various assumptions analyzing the contribution of uncertain variables to the variance in the outcomes in percentile. Figure 8 suggests that with fuel mix change, the variance is overwhelmingly driven by the elasticity of electricity consumption, because the effect of a small change in electricity consumption is amplified by the assumption that the fossil fuel consumption in the electric sector alone declines to respond to the decreased electricity demand. In contrast, in the case of no fuel mix change, the variance is caused primarily by the elasticity for gasoline consumption, largely due to its high consumption volume. However, electricity consumption remains a relatively important factor under the scenario with no fuel mix change. The jet and residual fuel make no contributions in both scenarios as they are exempted from the tax in the base model. An important implication from this analysis is that C-TAM is sensitive to the selection of the elasticity values of gasoline and electricity demand.

## Chapter 6: Conclusion and Recommendation

This study shows that a carbon tax can be an effective policy tool to curb GHG emissions in Washington. In the base model using BC's policy parameters, the carbon tax is expected to reduce emissions by 8.4% from the BAU scenario, with \$2.1 billion in revenues, as of 2035. This falls short of Washington's legislated GHG target; in fact, with the given assumptions, the rate must be allowed to climb to \$140/MTCO<sub>2</sub> (about \$1.40 per gallon of gasoline) for the state to achieve its 2035 emission reduction target. Although many other industrial nations have already levied such levels of tax on fossil fuels, the carbon tax with such a high rate may be politically infeasible in the U.S. due to the general public sentiment on taxes. Therefore, based on the preliminary results and subsequent sensitivity analyses, this study concludes with the following set of recommendations.

### *Identify a Politically Feasible Carbon Tax Rate*

As noted earlier, the rate must reach \$240/MTCO<sub>2</sub> to meet the state goal to reduce its emissions 25% below 1990 levels by 2035, but the carbon tax capped at \$70/MTCO<sub>2</sub> could reduce the emissions to the 1990 levels. This translates to approximately \$0.70 per gallon of gasoline, which may be seen as a much more realistic option by the general public. In addition, the sensitivity analysis suggests that the marginal effect of the carbon tax becomes significantly smaller at \$90/MTCO<sub>2</sub> due to the phase-out of thermal plants using fossil-fuel. When assuming that the state will also implement other policies to reduce emissions, I recommend the carbon tax capped at \$70/MTCO<sub>2</sub> as a politically viable and optimal policy option for Washington State. The annual incremental rate should remain small, probably around \$5/MTCO<sub>2</sub>/year like the BC carbon tax to provide adequate time for the public to prepare and respond. Lastly, it will be critical to provide explicit price information on future energy costs to prompt consumers and businesses to engage and invest in energy-saving measures and technologies.

### *Coordinate Complementary Policies*

To achieve the remainder of the emission reduction goal, Washington needs to carefully select a set of complementary emission reduction policies. Since the \$70 carbon tax eliminates most GHG emissions from electric sector, the complementary policies should target non-point source emissions, mostly from transportation system and direct combustion of fuels for building heating. These policies include but are

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not limited to the electrification of transportation system, transportation demand management (TDM), land use change, and building efficiency strategies such as enhanced building energy codes. As the focus of this study is on a carbon tax, I do not recommend specific policies to complement the carbon tax. I however do not recommend carbon trading (cap and trade) at state-level due to its duplicity with the carbon tax and administrative complexity. Therefore, Washington should prefer raising the carbon tax further over introducing a carbon trading scheme.

### *Duplicate the BC Exemptions*

The base model exempts jet and marine fuel as in the BC carbon tax. When this exemption is repealed, the margin of the emission reduction from the BAU scenario will increase from 8.4% to 8.8% in 2035. The effect of the exemptions is small due to their relatively small share of the total emissions and due to inelastic demand. This implies that it is not crucial to include these two fuels in the carbon tax from the perspective of climate policy. Although the exemption violates the simplicity principle and could open up a door for other exemptions, the exemption improves political feasibility by easing oppositions from the freight industry and could mitigate the potential leakage of demand for air and marine travel to nearby regions. These benefits should outweigh the moral issues, such that Washington's carbon tax should include exemptions for jet and marine fuel.

### *Design a Fair and Reliable Revenue Recycling Mechanism*

To maintain economic competitiveness and build political support, it would be crucial to offset the financial burden of the carbon tax. C-TAM results indicate that individuals and businesses will each bear about half of the tax burden, so they should each receive about half of the revenues. One of the drawbacks of the carbon tax is that it is a regressive tax, meaning the low-income households and small businesses operating on a small profit margin must dedicate a greater proportion of their disposable/net income to pay for the carbon tax. Looking at the three major revenue sources for Washington, the retail sales tax is also known to be regressive for individuals, and the B&O tax is disadvantageous for businesses operating on a small margin and/or not vertically integrated, while the property tax is relatively progressive as the property values are generally correlated with income. Taking these factors into consideration, Washington should use half of the revenues to offset the retail sales tax, and the other half to offset B&O tax. The sales tax offset would be about 5% of its revenues in 2035, so it can be

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lowered three tenths of a point from 6.5% to 6.2%. The B&O tax offset would be about 41% of its revenues in 2035, sufficient to cut its base rate nearly by half (the rates vary by industry).

Alternatively or additionally, it would be possible to use a portion of the revenues for a cash rebate. The cash rebate can be effective in mitigating the regressive nature of a carbon tax if it focuses on low income households. For instance, a portion of the revenues can be directed to increase the amount of the Earned Income Tax Credit (EITC), a form of cash rebate based on filing status and income level, in the same way that the American Recovery and Reinvestment Act (ARRA) provided economic relief for low income households by expanding the EITC. This required little administrative costs and burdens, and can be a direct and effective way to inequity of a carbon tax. It is also possible to redirect some revenues to the state general fund or the clean energy fund. However, the general public may begin to see the carbon tax as “just another tax” if Washington redirects even a small portion of the revenues, and these alternate uses may pose another hurdle to gain public support.

Lastly, it is critical to establish a mechanism to match the carbon tax revenues to the revenue offsets because BC is struggling with maintaining the revenue offset package as initially planned due to lower than expected carbon tax revenues. One obvious solution is to adjust the level of rate cut for sales and B&O tax every year, but frequent and unpredictable changes could confuse and frustrate residents and businesses. Alternatively, Washington could create the offset package with a conservative revenue estimate, and when surplus arises, it can be returned to the public in the form of a cash rebate and/or forwarded to other funds such as the state general fund or clean energy fund. Such a mechanism enables the carbon tax to have a better chance of survival in difficult economic or political situations in the future.

### *Final Recommendation*

In summary, I recommend that Washington implement a carbon tax with the following parameters:

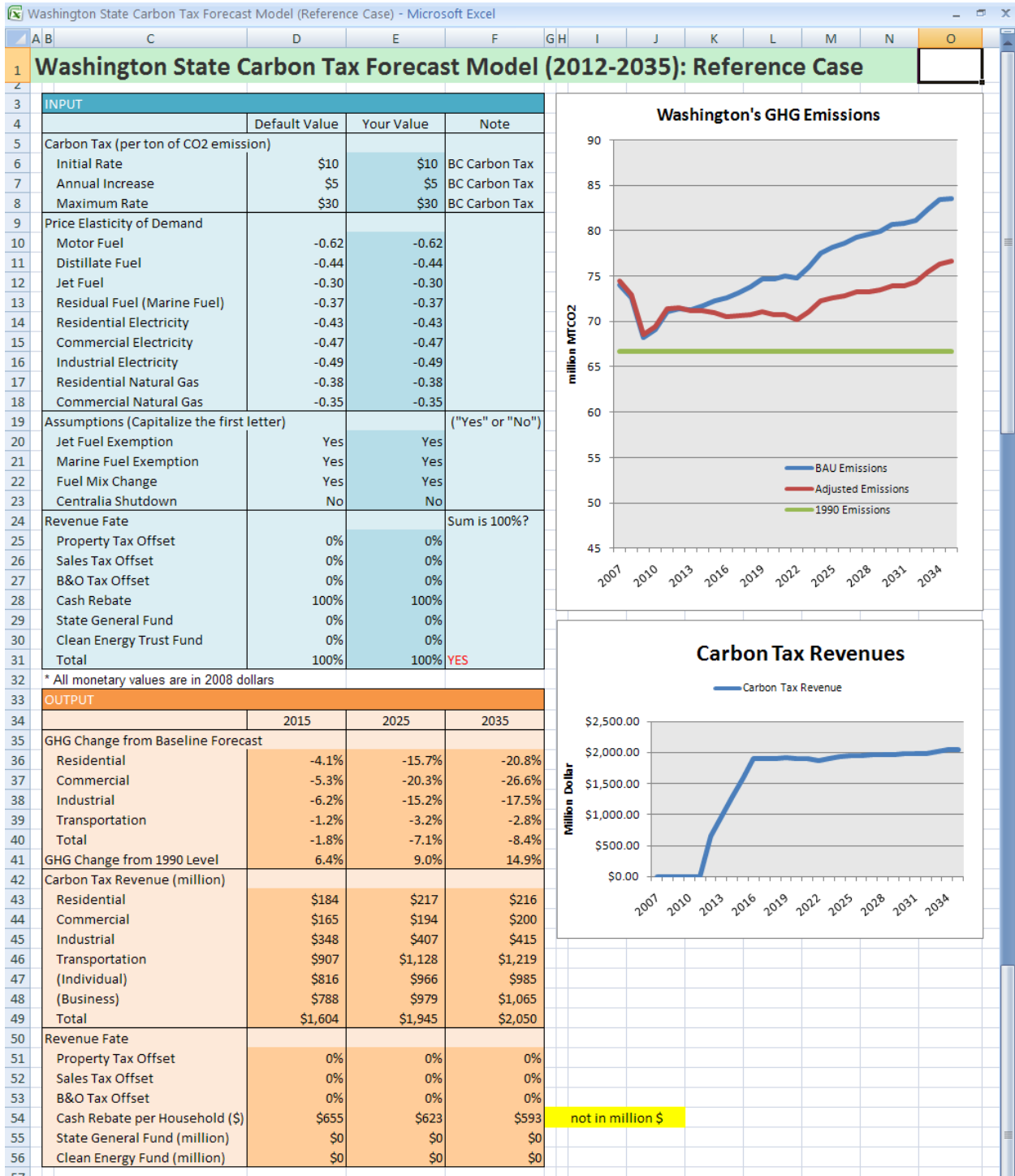
- Base rate: \$10/MTCO<sub>2</sub>
- Annual incremental rate: \$5/MTCO<sub>2</sub>
- Cap rate: \$70/MTCO<sub>2</sub>
- Exemptions: aviation (jet) and marine (residual) fuel for interstate and international trips
- Revenue fate: 45% to offset retail sales tax, 45% to offset B&O tax, and 10% to the contingency fund which is redirected for other uses such as cash rebate and forwarding to other funds

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These parameters should reduce Washington's GHG emissions by 16% from the business-as-usual scenario, or to the 1990 level. Meeting the state reduction goal for 2035 would require complementary emission reduction policies to target non-point sources such as automobiles and building heating systems.

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## Appendix A: Sample View of C-TAM



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