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Biofuel Economics and Policy for Washington State

Jonathan Yoder
Project Leader and Principal Investigator
yoder@wsu.edu
509-335-8596
203G Hulbert Hall

Richard Shumway, Co-Principal Investigator
Philip Wandschneider, Co-Principal Investigator
Douglas Young, Co-Principal Investigator

School of Economic Sciences
Washington State University
Pullman, WA 99164-6210
http://www.ses.wsu.edu

Primary Contributing Authors* by Chapter

- Executive summary and Chapter 1: Phil Wandschneider and Jonathan Yoder
- Chapter 2: Hayley Chouinard, Eric Jessup, Jeffrey LaFrance, Kim Lyons (WSU Extension Energy Program), Richard Shumway, and Phil Wandschneider
- Chapter 3: Ana Espinola-Arredondo and Jonathan Yoder
- Chapter 4: Craig Frear (Dept. of Biological Systems Engineering, WSU), Suzette Galinato, Kate Painter, and Douglas Young
- Chapter 5: Jonathan Yoder (CGE analysis team: David Holland, Michael McCullough (Appendix A5), Leroy Stodick)
- Chapter 6: Eric Jessup, Richard Shumway, and Jonathan Yoder
- Chapter 7: Phil Wandschneider and Jonathan Yoder

* Authors are listed in alphabetical order by chapter and affiliated with the Washington State University School of Economic Sciences unless otherwise noted.

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Note to readers: Most of this research report is up-to-date as of December 2008 when its predecessor was submitted to the Washington State Legislature. However, Chapter 4 of this document was substantially updated in October 2009, and references were amended as needed immediately prior to finalization in February 2010.

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Executive Summary

In April 2007, the Washington State Legislature passed HB 1303, an "act relating to providing for the means to encourage the use of cleaner energy." This omnibus bill is divided into 5 parts, the fourth of which contains a number of research and planning initiatives for energy markets and climate change. Part 4, Section 402, is addressed to Washington State University to provide recommendations for market incentives and research and development grants for biofuels in the state.

In response to this legislation (which is outlined in Ch. 1), we have provided estimates of feedstock availability by region in the state of Washington based on economic feasibility (Ch. 4). In addition, a comparative analysis of policy alternatives in terms of their efficacy for meeting the stated goals above is included, which provides recommendations for market incentives for the development of biofuel and feedstock markets in the state of Washington (Ch. 5). Recommendations for public investment in research and technology development, promotion of new technology adoption, and infrastructure investment to support Washington State biofuel market development can be found in Ch. 6. Chapter 2 includes supporting material on current market conditions, Chapter 3 a description of the policy approaches being pursued at the national and state levels in the Pacific region, and Chapter 7 overall recommendations and a conclusion.

Market conditions for Washington biofuels and feedstocks

Washington's farmers and ranchers and the agricultural industry produce many profitable and high-value crops, including apples, potatoes, livestock products, hops, wheat, and wine. These crops provide high quality food for the state's six million consumers and profitable exports to the rest of the country and the world. However, Washington has only one high-value ethanol feedstock (wine grapes). In contrast, corn, sugar beets, soybeans, canola, and other biofuel feedstocks for today's markets are grown more competitively in the midwestern states and Canada.

In order for state policy to induce biofuel market competitiveness and the provision of significant quantities of fuel crops in today's markets, it would likely come at significant cost to either biofuel consumers or Washington. The results from our analysis of feedstocks and Washington's energy economy are consistent with this conclusion.

For the long run, Washington State shows promise as a potential producer of biomass-based fuels in second-generation biofuels markets. Indeed, Washington ranks 4th among 19 western states (after California, Texas, and Oregon) for estimated available biomass. Biomass-based fuels may, within a well-designed policy environment, be able to supply energy with reduced net carbon emissions and compete less with food crops for agricultural land.

In general then, the state has limited short-term prospects for a state-based biofuel industry, but strong long-term prospects. This situation has two major implications:

- If the state chooses to promote in-state production of biofuels, the most cost-effective approach would likely be to implement policy actions now to set the stage for competing in an advanced biofuels industry in the long run.

- However, the shortage of regionally-produced feedstocks in the short run does not prevent the state from adopting policies to reduce dependence on petroleum and mitigate greenhouse gas (GHG) emissions now and in the immediate in the future.

There are policy options that would have both an immediate effect on reducing petroleum dependence and GHG emissions and also set the stage for a developing bioenergy industry. On the other hand, some of these policies would impose costly short-run requirements. For example, suppose the state required that biofuels consumed in the state also be produced in the state. If so, our analysis shows that Washington would have to either accept low levels of biofuel production and consumption, adopt costly subsidies, or pass mandates onto the consumer for in-state feedstock use. Suppose tax credits are provided for in-state production of feedstocks or fuels to compete in today's biofuel markets. These tax credits would almost certainly cost the state more than the economic benefits that the tax credit would generate for in-state producers and consumers in the biofuel industry.

In the short run, in-state production requirements or subsidies will lead to more costly biofuels for consumers or state taxpayers. Policies that might seem to promote one goal can have negative impacts on other goals. Moreover, the short-run (immediate) and long-run impacts of policies can easily conflict. Therefore, it is important that the goals of this legislation be considered together and in conjunction with the goals and mandates of other related Washington State legislation. It is also important that the policies integrate effectively into broader state and federal energy policy as it develops. For example, Washington State can take advantage of an infrastructure for tracking biofuel and or biofuel characteristics that has already been developed as part of the federal renewable fuel standard. Furthermore, many states, as well as the federal government, are currently developing policies to promote biofuels and reduce carbon emissions and energy dependence. Coordinating with these other policy efforts would make Washington policies more effective.

Market incentives

If Washington State decides to implement a market incentive policy approach to pursue the objectives in HB 1303 §402, we recommend following a price incentives approach based on a carbon intensity tax. This is a tax that is progressively higher the greater are the "life-cycle" GHG emissions from the fuel. Such a tax could be implemented in a number of ways to make it revenue neutral and non-regressive depending on how it interacts with existing fuel excise taxes. For instance, it could generate a renewable fuels fund for tax credits to those who use fuels with low carbon intensities.

It is important to make 3 points clear immediately. First, although taxes are never popular, a carbon emissions tax[1] can be designed to alleviate concerns. In principle, the tax structure could be neutral with respect to both revenue and final fuel price in the long run by coupling the carbon tax on high carbon fuels with tax credits on low-carbon fuels. The tax revenues could also be used for biofuel investment incentives or to reduce other preexisting regressive or burdensome taxes such as sales taxes or business and occupation taxes. Further, other policy alternatives such as

[1] We will refer to the proposed tax by a number of terms, including carbon emissions tax, carbon intensity tax, or simply carbon tax. The idea put forward in this report is for a kind of tax related to life-cycle emissions and measured in carbon-equivalents.

renewable fuel standards or low carbon fuel standards may not entail explicit taxes, but they do impose a penalty which amounts to an implicit tax due to their effects on fuel supply and demand.

Second, a GHG–based approach may appear at first to be a climate change policy rather than a biofuels policy. However, our analysis shows that the most streamlined and direct way to approach all of the goals noted in our enabling legislation given Washington State's comparative advantages is through a policy linked to GHG emissions. Pursuing multiple goals is inherently complicated because no one policy instrument can address all goals perfectly. However, the carbon emissions–based policy that we recommend simultaneously addresses biofuels market development, petroleum dependence, as well as reductions in GHG emissions.

Third, we recommend the use of carbon emissions taxes over quantity-based fuel taxes. While volume-based taxes, subsidies, or standards can be used to (more or less) effectively reduce petroleum dependence and promote biofuel and feedstock markets in Washington, they do not provide direct incentives to produce and consume low-carbon fuels. We argue that a carbon-based policy can better target all 3 primary policy goals outlined in the legislation. The second reason is that quantity-based fuel taxes actually can penalize some biofuels. In particular, because ethanol has low energy content (hence a reduced number of miles-per-gallon), the effective quantity-based tax is higher than for other liquid fuels.

We recommend against a Washington-specific renewable fuel standard because our analysis suggests that it would not be as effective as a tax incentive for reducing carbon emissions, and it entails up-side cost risk. For similar reasons, we also recommend against a carbon-based renewable fuel standard such as that under development for California. Based on our findings, we support a price-based (tax and tax credit) system over a carbon cap-and-trade program, but given the inertia behind this approach under the Western Climate Initiative, we provide recommendations for both approaches.

Subsidies are costly both in terms of taxes to citizens and burden on the Washington economy. If policymakers choose to implement subsidies (tax credits) for renewable fuels produced in-state, we suggest using tax credits based on carbon emission intensity, and funding them only with carbon emissions tax revenues. Similarly, we recommend against feedstock subsidies, except perhaps for specific feedstocks where there additional benefits are garnered by the subsidy. Examples include municipal solid wastes (which reduce public waste disposal costs) and forest thinning (where wildfire risk is reduced and for public land where forest productivity is improved). Some incentive measures will be required to meet the biofuel feedstock and production objectives of the legislation. However, we recommend that these be cautious and oriented toward the long term.

Research, new technology adoption, and infrastructure

Our analysis identifies market conditions that may justify public investment in such activities as biofuels research and development (R&D), late stage market development, and market infrastructure. We discuss a set of management principles to guide these public investments, along with specific recommendations for near-term acquisitions.

Because there are already large private and national government efforts in place to develop the technology for advanced biofuels and other forms of biomass energy, Washington State should focus on research investments that support the state's infrastructure or economic sectors in which the state has existing or potential comparative advantage. Investment in late-stage development should focus on projects that provide significant potential for market-wide benefits from new technology that lends itself to Washington's specific comparative advantages. Such choices will likely position the state to facilitate private-sector initiation of cost-sharing arrangements, with a significant portion of risk borne by the private sector and substantive information-sharing requirements.

Because fuel markets are currently in flux, we recommend that the state pay particular attention to maintaining rail infrastructure and exercise caution when deciding to invest in specific biofuel plant or distribution-logistic projects. Where possible, Washington should strive to help facilitate market-based outcomes through public/private partnerships from all vested parties.

Biofuels in evolving energy markets

Our legislative mandate calls for us to focus our analysis primarily on the biofuel market. Biofuel policy to date across the United States has developed with a degree of isolation from most other energy policy developments. To reach state energy goals in a cost-effective and sustainable way, it is important to balance the economics of biofuel markets and their environmental consequences with the other energy sectors. Washington State policy and investment in biofuel markets should be approached with a goal of integration into other energy markets, and with a deliberate intent to allow for adaptation to technological change in these sectors.

Chapter 1: Introduction

Interest in biofuel market development within the United States has exploded due to a broad set of concerns and opportunities related to our reliance on fossil energy sources. Some of these issues are high oil and gasoline prices, dependence on oil imports, energy security in the face of geopolitical instability in oil-producing regions, and the potential for domestic rural economic development through biofuel production.

In response to these concerns, the state of Washington has enacted a series of laws and regulations. In April 2007, the Washington State Legislature passed HB 1303, an "act relating to providing for the means to encourage the use of cleaner energy." This omnibus bill contains 4 parts. The first focuses on clean air legislation, the second on public sector fuel use, the third on amending the Energy Freedom Program, and the fourth on a number of research and planning initiatives for energy markets and climate change.

Section 402 of Part 4, addressed specifically to Washington State University (WSU), is the foundation for this report and is included in full as follows:

Washington State University is directed to analyze the availability of biofuels in the state and to make best estimates to indicate, by percentage, the types and geographic origins of biofuel feedstock sources that contribute to biofuel production and use in the state, and to recommend models for possible implementation by the legislature or the executive office for at least the following potential biofuels incentive programs:

(a) Market incentives to encourage in-state production of brassica-based biodiesel, and cellulosic ethanol, including such market methods as direct grants, production tax credits, contracting preferences, and the issuance by the state of advance guaranteed purchase contracts;

(b) Possible preferred research programs, grants, or other forms of assistance for accelerating the development of in-state production of cellulosic ethanol and in-state biodiesel crops and their coproducts; and

(c) The following should be considered when evaluating potential biofuel incentive programs:

(i) Assisting Washington farmers and businesses in the development of economically viable, environmentally sustainable in-state biofuel and biofuel feedstock production;

(ii) Leveraging and encouraging private investment in biofuel production and distribution and biofuel feedstock production; and

(iii) Assisting in the development of biofuel feedstocks and production techniques that deliver the greatest net reductions in petroleum dependence and carbon emissions.

Interim and final reports on the work required under this section were provided to the legislature and governor on December 1, 2007, and 2008, respectively. WSU worked closely with the Department of Community, Trade, and Economic Development (CTED)[2] on these reports.

As is generally true with multiple goals, the goals of this legislation are partly complementary, but harbor potential

[2] As per 2009 legislation, CTED was changed to the Department of Commerce.

conflicts. In particular, policies which enhance goals in one sector of the economy (e.g., feedstocks in agriculture) may harm parts of other sectors (e.g., transportation). Similarly, policies may have different effects on urban compared to rural areas.

More concretely, a policy of increasing in-state biofuel feedstocks may produce less carbon reduction than a policy that encourages low carbon fuel use, regardless of origin.

Despite citing these potential conflicts, we do not accept the often-assumed conflict between environmental protection and economic growth and efficiency. To the contrary, expanding a green energy sector can create jobs, and reducing carbon emissions can employ conservation measures that reduce economic costs. Conflicts between goals are often more subtle than the supposed growth versus environment competition. For instance, a policy that reduces fuel taxes on biofuels to encourage their use may inadvertently increase petroleum use (hence carbon emissions) if the tax reduction results in a lower effective total gas price. In this report, we will attempt to be clear about where goals are mutually supporting, and where they conflict. Because there are tradeoffs inherent in choosing among any policy alternatives, our recommendations will keep 3 types of tradeoffs in mind:

- Potential trade-offs among the goals laid out in the legislation and other important social goals.
- Potential trade-offs between short- and long-run goals. The economic differences between a focus on first generation bio-energy and second generation bio-energy are likely to be substantial for Washington State.
- The trade-offs among regional, national, and global policies. A policy may look attractive from a local perspective, but might be ineffective or weak in the context of national or global policies and conditions.

It is important that the goals of this legislation be considered in conjunction with the goals and mandates of other related legislation, including the rest of HB 1303, HB 2815, and Washington Climate Action Team policy developments, which focus largely on greenhouse gas emissions reduction. It is also important that Washington's biofuel policy be designed to integrate effectively into broader state and federal energy policy as it develops. Most biofuel policy to date has been developed as if in isolation from other energy and even other motor fuel policy. Washington State's biofuel policy will operate within the context of a larger energy market, under the federal Renewable Fuel Standard (RFS), and possibly within the guidelines of the Western Climate Initiative (WCI). Washington is currently a partner in the WCI, which is developing a broadly applied carbon cap-and-trade system.

The WSU study

This report provides estimates of feedstock availability by region in the state of Washington based on economic feasibility, wherever possible. The report includes a comparative analysis of a set of policy alternatives in terms of their efficacy for meeting the stated goals above, and provides recommendations for market incentives for the development of biofuel and feedstock markets in the state of Washington. The last section of the report provides recommendations for public investment in research and technology development, promotion of new technology adoption, and infrastructure investment to support Washington State biofuel market development.

The project is managed in the School of Economics Sciences (SES) at WSU. A research team of faculty, staff, and students in various departments within the WSU system coordinated this report with CTED, WSDA, and the University of Washington. It is one of at least nine studies requested by the governor and legislature regarding bioenergy and biofuels.

The remaining chapters build on each other. The first 3 provide context for addressing the questions issued in the enabling legislation regarding feedstock availability, market incentives, and R&D investment. The next 3 address these primary questions.

Chapter 2 sets the stage in terms of economic and market conditions that will influence Washington's biofuel markets into the future. It examines the role of bioenergy in broader energy markets, the characteristics of the biofuel supply chain, the recent and current status of biofuel production facilities and refueling facilities in the state, transportation and infrastructure issues, and the characteristics of the primary biofuels that affect demand.

Chapter 3 provides a synopsis of biofuel policy at the national level, and examines the biofuel policies of the Pacific states and British Columbia. This chapter includes some of the context within which we approach our policy recommendations. Because Washington State's policy will have to function within the national policy context, it is important to design Washington's policy approach to complement national biofuel and energy policy to minimize administrative and economic burdens for state firms, taxpayers, and government. We examine the policies of the Pacific states and British Columbia in particular because these governments have pursued substantially different approaches. As a whole, they provide a fertile source of examples for comparative analysis.

Chapter 4 and its appendix (Appendix A4) provide the primary feedstock analysis called for in the enabling legislation. This chapter forecasts what Washington farmers will profitably grow under current and projected market conditions and current biofuel policies. Forecasts are made for the state's irrigated cropland and 4 dryland regions with differing precipitation levels.

Because biofuel markets are evolving rapidly and Washington's agricultural feedstock outlook varies substantially depending on the timeframe of consideration, the analyses are broken down into short-run, intermediate-run, and long-run periods. The short- and intermediate-run analyses for agricultural feedstocks utilize linear programming to project farmer acreage allocation based on the relative profitability for relevant crops in different regions. The long-run analysis utilizes yield growth trends and supply responsiveness to prices for different crops, as well as Washington's comparative advantage in producing versus importing different feedstock crops.

In contrast, the analysis of forest-based feedstocks, municipal solid wastes, and several other cellulosic sources focuses on current inventories. This approach is more appropriate given our available information because these feedstocks usually do not compete for a common land base as do crops. Also, the early stage of technology for converting these cellulosic feedstocks to biofuel precludes identifying demand prices for the feedstocks.

Chapter 5 provides recommendations for market incentives. The chapter begins with a summary of the recommendations followed by a more detailed discussion of them. The second half of the chapter provides the justifications for our recommendations, including an extensive review of the existing and rapidly evolving economics literature on policy design for biofuels, energy and fuel policy more generally, and policy for greenhouse gas emissions reduction. The chapter finishes with results and discussion based on our Computable General Equilibrium (CGE) model of Washington

State and its energy and biofuel markets.

Chapter 6 focuses on research and development recommendations. Unlike the previous chapter, we begin with the economic foundations of public investment in research, market development, and infrastructure, and then follow with specific examples for short-run investment approaches.

Chapter 7 provides an overview of our recommendations and some final thoughts.

Appendices to this report, which are cited occasionally in the text, are available electronically by request from Jonathan Yoder at yoder@wsu.edu or (509) 335-8596.

Chapter 2: Washington and biofuels in a global economic and policy context

Washington in the context of current biofuel and energy markets

Washington State is a small economy within the global economic system that includes worldwide energy markets and biofuel markets specifically. Hence, most current market conditions for biofuels in Washington depend in large part on the larger regional, national, and global markets. Moreover, biofuels themselves are a small part of the total market in energy and liquid fuels. Biofuels will likely remain a niche within energy markets for the foreseeable future in Washington, the nation, and the world. However, the magnitude of energy markets in the global economy today and the increasing importance of energy market diversification imply that niche markets such as biofuels can play an important role in both energy markets and the markets of local and regional economies such as that of Washington State.

The purpose of this chapter is to clarify how the Washington biofuel market fits into the context of global and regional markets; that is, to discuss the demand and supply for biofuels at global, national, and state/regional levels.

The role of bioenergy in energy markets

Fundamental market forces will drive the long-term relative prices and contributions of the energy markets. These are the realities within which policy will evolve.

Currently the energy market is largely driven by fossil hydrocarbons (Figure 2.1). Among the many reasons for this is the fundamental reality that over the last 150 years or so, fossil hydrocarbons consistently have been the least costly source of energy for many purposes. In 2008, renewable energy accounted for just 7% of the U.S. energy supply (Energy Information Administration, 2009c). In contrast, petroleum (37%), coal (22%), and natural gas (24%) provided the overwhelming bulk of the nation's energy use. Nuclear power (9%) still provides more energy than all renewable sources combined.

The implication is that energy markets as a whole are dominated by the fossil hydrocarbon markets. Hydrocarbon fuels drive energy prices at retail and production levels in the short- and intermediate-run. Hence, any policy or investment related to other energy resources, including biofuels and biomass, must come to terms with this fact. Policy for any energy sector must take into consideration its relationship to the abundance or scarcity of hydrocarbons and the prices these supplies generate when confronted with current energy demands.

On the other hand, if society hopes to eventually achieve a more sustainable energy balance, fossil hydrocarbon fuels eventually must be replaced and/or their negative effects must be mitigated. Current policy concerns include several sustainability issues: the inevitable scarcity of fossil hydrocarbons, local pollution effects, and the climate change effects of

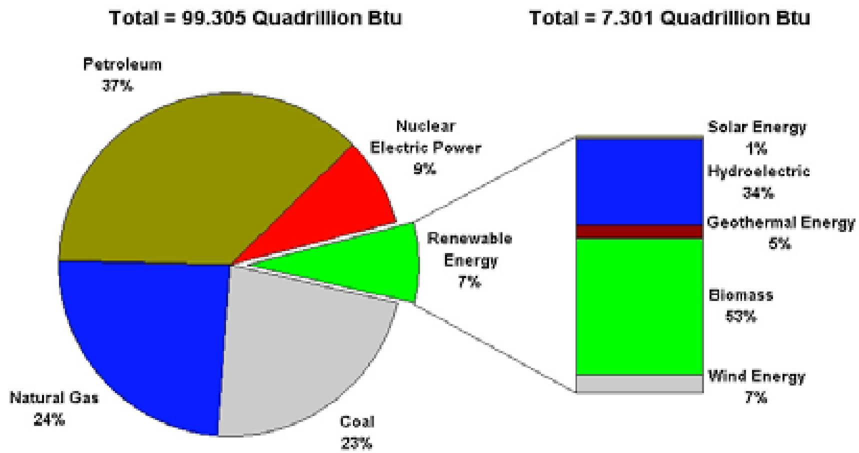

Figure 2.1: Major components of energy use (EIA, 2009a).

greenhouse gas emissions concomitant with hydrocarbon use. In this report we pay particular attention to energy scarcity/dependency and climate change as required in our mandate.

The energy dependence problem is a combination of energy scarcity intertwined with geopolitics. Concerning the potential for fossil hydro-carbon scarcity, there are mixed omens in the energy markets. While conventional petroleum production shows signs of decline, unconventional oil and coal reserves are plentiful, and there is substantial potential for growth in the nuclear power sector. Hence, the degree to which biomass energy will be drawn into energy markets to replace declining production of conventional oil is affected by the possible substitution of other fossil fuels and nuclear power, as well as any limits to production in the renewable sectors themselves.

Non-renewable energy options

Hydrocarbon energy feedstocks are fossil deposits. They are necessarily limited and non-renewable no matter how large the present stocks. While exact dates are under debate, most oil experts believe that we are approaching the time of "peak oil" for conventional sources. However, oil production will continue for decades after peak oil production is reached. For reference, peak oil production occurred in the United States in the early 1970s and in Europe (North Sea) in just the last few years. Because conventional oil will at some point become increasingly scarce, the price is expected to trend upwards, probably with large short-run fluctuations.

In the intermediate run (over the next few decades), some fraction of conventional oil consumption will likely be replaced by some mix of other. These alternative fuels are likely to include such abundant non-renewable energy sources as nuclear, coal, and unconventional oil stocks, as well as emerging renewable energy supplies. Economists refer to such substitutes as "back-up" resources. So, the longer-run market question is (assuming impending peak oil), what are the back-up resources for conventional fossil petroleum fuels, and which of the sources, if any, will dominate energy prices?

Of the other major hydrocarbon supplies, natural gas is relatively scarce and will follow a similar path as conventional oil. And although the supplies of unconventional (heavy) petroleum and coal are large (enough to last decades to several hundred years), they are costly in terms of environmental mitigation and/or extraction costs. Moreover, coal contains large amounts of carbon and other potential pollutants, and producing heavy oil (such as from the oil sands of Alberta) takes large quantities of water. Hence, we are facing a continuing increase in the extraction and environmental costs of these hydrocarbon supplies, particularly their per unit carbon emissions.

Nuclear power has both good and bad attributes and prospects. On the positive side, uranium fuel, especially when reprocessing technology (e.g., breeder reactors) is used, is relatively abundant. Although the operation of nuclear plants is virtually carbon neutral, their construction requires large amounts of cement, the production of which is a major source of greenhouse gas emissions. The large supplies of water needed to operate nuclear plants is another concern due to shortages throughout the world. More generally, the nuclear technology of the present tends to be large-scale and costly. The biggest concern about nuclear power is safety, both in terms of plant operations and storage of nuclear waste. Until the nuclear waste storage problem is resolved, there will be political and operational limits to the expansion of nuclear power in the United States and many other areas of the world. Although no major new nuclear plants have been built in the United States since 1996, several applications have been filed since for the development of new nuclear power plants (Energy Information Administration, 2009b). The future role of nuclear energy depends on the potential for 1) resolving the political and technical safety problems, and 2) developing more cost-efficient and scalable production technology.

Renewable energy options

The other long-term motivation for biofuels concerns the potential for global climate change. Renewable fuels generally, and biofuels in particular present a potential "twofor" solution in terms of addressing both the energy scarcity issue just discussed and the global climate change issue listed at the beginning of the chapter. Indeed, reducing carbon emissions is an explicit goal of the legislation underlying this study.

While biofuels and other renewable energy sources are ideal solutions for meeting these problems, in general, they may turn out to be too scarce to meet energy needs (at least in the short- and medium-term). Moreover, biofuels and other renewable fuels comprise a portfolio of resources, and each type of energy source has its own characteristics, limits, costs, and benefits. Hence, the potential value of biofuels must be seen in the context of other renewable fuel options.

The renewable energy market is complex, comprising a number of "niche" supplies. Many renewable energy supplies are linked to particular locations or uses. Wood and hydropower, the major traditional renewable energy supplies, are both relatively location-specific. The Northwest has a relative abundance of both, whereas southern California has little of either. More generally, much of the conventional supplies of wood biomass and hydropower were tapped in the 1970s, and these sources have grown little since.

Wind energy and solar power markets are increasing rapidly, but from an extremely small base. Again, both of these energy sources have specialized characteristics. The best sites for wind energy are location-specific. Moreover, wind energy is highly variable; it requires some storage and/or integration with other energy supplies in order to supply reliable power. The potential for solar power is large, but it is a diffuse energy source, difficult to link into the conventional power grid. It too has location-specific characteristics that must be addressed for efficient use. Despite these issues, both wind and solar energy are increasingly relied on as technology improvements lower their costs. However, these sources need to be thought of as long-term prospects for energy production because of their current economic limitations.

That leaves us with biomass as a source of energy. The basic technology for producing plant material is as old as agriculture, and the basic technology for producing ethanol is as old as wine and beer making. What is relatively new is the attempt to ramp up the production of biomass for explicit and direct conversion to liquid fuel to power machines.

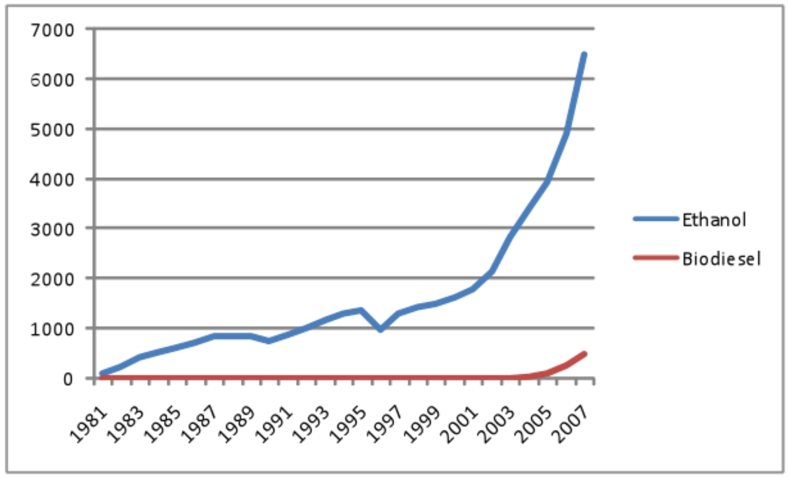

Figure 2.2: U.S. biofuel consumption, 1981–2007 (EIA, 2009b).

The absolute and relative contribution of biofuels has grown steadily over the last few years (Figure 2.2). In another section of this report, we delve more deeply into the potential U.S. supply of biofuels and their feedstocks. We now turn to a closer look at biofuel demand and supply.

The biofuel supply chain in Washington State

Washington has an existing biofuel market. Most Washington residents use biofuels presently as an additive to regular (petro-) gasoline to improve performance with respect to air pollution. Markets for more extensive use of biofuels are still embryonic and ill-defined.

In the remainder of this chapter we trace Washington State's market supply and demand through the supply chain (see Figure 2.3). The supply chain starts with feedstocks, continues with processing, and then is sold in retail markets inside and outside Washington. The whole chain is knit together by the transportation and distribution sector, and it ends with consumers. Markets balance demand and supply at each stage in the supply chain (within the government regulatory structure).

Note that the supply chain includes feedstocks from outside Washington as well as final demand from outside Washington. Washington is an *open economy*, which means its people and firms purchase and sell products from both inside and outside the state. Hence, the production and utilization of biofuels in Washington State should be viewed in the context of broader geographical market and national distribution–transportation realities.

Feedstock markets

Regional markets are essentially a product of the interaction between regional comparative advantage in production, regional transportation, and storage infrastructure and costs. Hence, understanding the following features of the Washington economy is crucial to understanding state biofuels prospects:

- The potential for feedstock production in the region (See Chapter 3)
- The final demand for biofuel products in the region
- The proximity and transportation costs among likely feedstock production, biofuel processing, distribution, and final demand

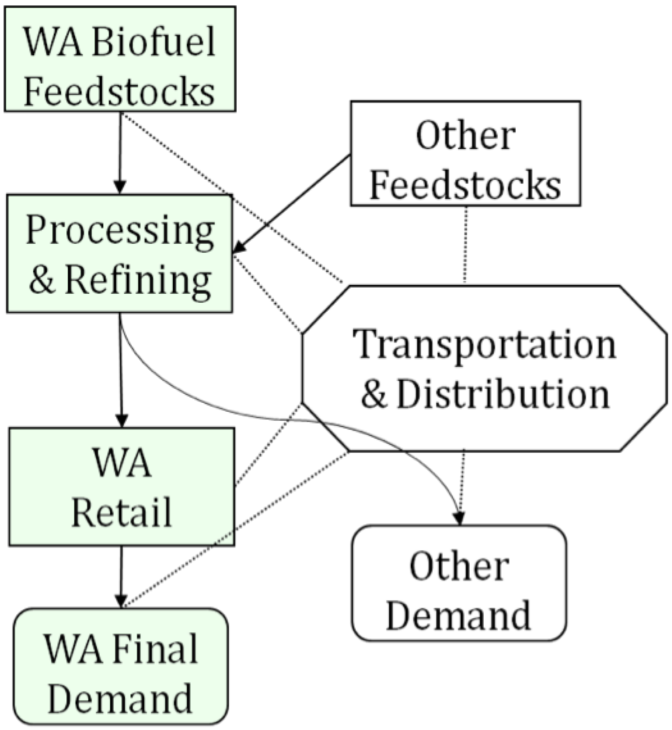

Figure 2.3: Basic biofuel supply chain.

locations

All regions in the United States and Canada have some potential to produce biomass feedstock. However, regions differ greatly in the quantity and quality dimensions of potential for the production of biomass feedstocks. As discussed in Chapter 4, the Pacific Northwest exhibits moderate concentrations of potential biomass production, mostly west of the Cascade mountains and primarily from forest and municipal waste. The region has some potential for eventually supplying significant amounts of raw biomass for energy production. However, these are mostly lignocelluosic feedstocks for direct conversion or production of advanced (second generation) biofuels. Washington has lower prospects for producing the feedstocks for conventional bio-ethanol. In contrast, the upper Midwest—also known as the Corn Belt—has large supplies of its namesake for producing conventional bio-ethanol.

Biofuel production in Washington State

There is currently a small biofuel processing industry in Washington and the Northwest, with several ethanol plants in the works. The tables below detail the current status of ethanol and biodiesel processing capacity in the state. They document the planning, construction, and operational status of biofuel facilities under known private sector consideration. It should be emphasized that many of these are speculative proposals and may not have a realistic chance of being built. Biodiesel plants and oilseed crushing facilities are farther along than ethanol plants, and the total capacity of production plants either constructed or under consideration in 2008 is much less than in 2007.

Ethanol plant projects

Table 2.1 provides a summary of plans for ethanol production facilities in Washington from 2007 to mid-2008. In 2007, no operational ethanol plants existed in the state, but 14 (the majority of which were on the Eastside) were in some stage of consideration between concept and construction. For example, 2 were in actual or impending construction, 4 in the permitting stage, 2 in planning, 2 in concept, and 1 was focusing on cellulosic ethanol production. If all plants were constructed as then contemplated, they would have produced at least 650 million gallons of ethanol per year (MGY).

By mid-2008, business plans had changed markedly. Startup was delayed on both plants under construction, 3 of those in

Table 2.1: Change in status of Washington ethanol plants from 2007 to 2008 (Lyons, 2008; Domby and Young, 2008).

Location	Developer	Capacity	2007	Mid-2008
Longview	U.S. Ethanol Northwest Renewable	55 MGY	Construction begun, 2008 startup	Project undergoing redesign to improve economics—planned startup 4th quarter 2009
Finley	Columbia Renewable Energy	55 MGY	Construction planned for summer 2007	Delayed—planned startup 2nd quarter 2010
Moses Lake	Liquafaction Corporation	Phased capacity @ 12-36-60 MGY	Air permit complete for 12 MGY	On-hold pending refinancing. Air permit completed for 12 MGY
Ritzville/Keyston/ Tokio	Cilion/Khosla Ventures/Premier Bio Energy	55 MGY	Permitting underway	On-hold as company works through California plant startup issues
Plymouth	Pacific Ethanol	55 MGY	Permitting	On-hold
Cherry Point	Vitality Fuels Corp	100 MGY	Not Reported	Feasibility study out 8/2008
Vancouver	Rappaport Energy Consulting LLC	25 MGY	Not Reported	Planning—looking at alternative sites
Othello	Evergreen Biofuels	50 MGY	Not Reported	Concept stage
Moses Lake	Global Ethanol	40-80 MGY	Permitting	Cancelled
Wallula	E_{85} Inc (tech provider VogelBusch)	100 MGY—corn	Proposal to Port of Walla Walla, in planning stage	Cancelled
Vancouver	Great Western Malting (tech provider Delta-T)	55 MGY—Barley feedstock	Planning	Cancelled
Bruce	Evergreen Biofuels	50 MGY	Concept	Not Reported—no information
St. John	St. John Ethanol	N/A	Concept	Not Reported—no information
Cowlitz County	Pure Energy	N/A	N/A Cellulosic	Not Reported—no information

the permitting phase were put on hold and 1 was cancelled, and both in the planning phase were cancelled. Of the 3 for which the development stage was not reported in 2007, 1 is now in the concept phase, 1 in the planning phase, and 1 in the feasibility study phase. The total production capacity of those not cancelled or placed on hold is about half the 2007 potential.

Biodiesel plant projects

Table 2.2 provides a summary of plans for biodiesel production facilities in Washington during the same years as covered in Table 2.1. In 2007, there were far more (24) biodiesel plants in some stage of consideration than ethanol plants, but the total potential production capacity (about 300 MGY) was less than half that for ethanol. Both the number of potential plants and their production capacity were approximately evenly divided between the Westside and Eastside. Of the 24 potential plants, 8 were in commercial operation by 2007, 3 were in the permitting stage, 3 were in planning, 6 in the concept stage, and 4 were not reported.

By 2008, only 5 biodiesel plants were in commercial operation, 3 of which were operating below capacity, and 1 had shifted to renewable diesel (which is not the same as biodiesel by Washington State's definition). Two were operating as R&D facilities, 2 were in the permitting or concept stages, 7 were either on hold or had no activity, and 8 were cancelled or closed. Like the prospective ethanol plants, the total production capacity of biodiesel plants not closed, cancelled, or placed on hold in 2008 was less than half the 2007 potential.

Table 2.3 provides a summary of current plans for oilseed crushers[3] in Washington. Four crushers are currently in operation and have a production capacity of 24,255 tons per year. Two of these were constructed with financial support from the Washington Energy Freedom Program (EFP). Another 2 crushers are being planned, each of which has received support from the EFP, while a third crusher was cancelled. Five oilseed crushing facilities that are on-line or under development are on the Eastside, while 1 is located on the Westside. Their combined potential crushing capacity is estimated at 418,000 tons per year.

Biodiesel blends and E_{85} fueling stations

As of January 25, 2010, the National Biodiesel Board has records for 51 retail sites selling biodiesel in Washington. Station information can be viewed at www.biodiesel.org/buyingbiodiesel/retailfuelingsites/showall.aspx. The actual number of stations in Washington selling biodiesel is probably higher, according to preliminary sampling conducted by WSDA.

Economic conditions for biofuel production in Washington State

As summarized above, slower development of in-state biofuel production has occurred over the past few years than many expected. It is beyond the scope of this project to perform a detailed analysis of these outcomes, but an overview of the prevailing market conditions for current markets will help provide context.

We can categorize these conditions into 1) national biofuel market conditions and 2) the relationship of Washington to these national markets. National and even international biofuel markets have had a tumultuous couple of years due to volatile corn and other biofuel input commodity prices. Higher fossil fuel prices have cut both ways for renewable fuel producers by making renewable fuels more competitive, but also increasing the costs of renewable

[3] Oilseed crusher scale can be measured in several ways. Two of the most common are gallons of oil produced per year and tons of seed crushed per year, which we chose because that is the form in which we received the data.

Table 2.2: Change in status of Washington biodiesel plants from 2007 to 2008 (Lyons, 2008; Domby and Young, 2008).

Location	Developer	Capacity# MGY	2007 Status	Mid-2008 Status
Grays Harbor	Imperium Renewables	100	Under construction—startup mid summer 2007	Operational August 2007. Supplies local markets, also export sales to Europe and marine/cruise ship markets. Production has been limited, with recent shutdowns.
Seattle	Seattle Biodiesel (aka Imperium Renewables)	5	Operational—mainly soybean oil	Operational. Closed down commercial production—operates as R&D facility.
Creston	Columbia BioEnergy LLC	8-10	Operational—mainly soybean oil	Operating below nameplate capacity. Varied feedstock—primarily canola. Collecting/processing glycerin for value added sales.
Ellensburg	Central Washington Biodiesel	<1	Operational ramp up phase using WA canola to start. Proposed 3-5 MGY capacity.	Operational—below 100,000 gallons current production. Transitioning from virgin oils to recycled oils/fats.
Arlington	Standard Biodiesel	8	Operational—waste vegetable oils	Operational. Feedstock—recycled vegetable oil/fats. No longer producing biodiesel—shifting production to "renewable diesel."
Burbank	Gen-X	5	Startup summer 2007 recycled vegetable oils/fats	Operational. Feedstock—recycled vegetable oils/fats. Production currently @ 0.5 MGY. Expansion plans on hold.
Odessa	Inland Empire Oilseed—Fred Fleming, Green Star Products	8	Planning—Energy Freedom Fund	Energy Freedom Program funding for joint crushing/biodiesel production plant. Biodiesel plant installed 4/2008, crushing not yet operational.
Port of Sunnyside	Natural Selection Farms—Ted Durfee	0.5	Operational—Energy Freedom Program support	Energy Freedom Program funding for joint crushing/biodiesel production plant. Biodiesel plant construction on hold, focus on crushing operation.
Richland	TriCity & Olympia Railroad Company	1	Not Reported	Startup summer 2008. Pilot scare, could expand based on economics. Oils supplied by Con-Agra. Open to R&D.
Anacortes	Whole Energy	10	Permitting/financing underway	Lost partner—project development on hold. Concentrating near term on wholesale. Currently moving about 150,000 gallons/month.

Table 2.2, Cont.

Location	Developer	Capacity# MGY	2007 Status	Mid-2008 Status
Port of Warden	Washington Biodiesel	35	Planning—Energy Freedom Fund	Energy Freedom Program funding for joint crushing/biodiesel production plant. Biodiesel plant construction on hold, focus on crushing operation.
Seattle	General Biodiesel	14	Not Reported	Relocated to Seattle from Mt. Vernon. Started permit process.
Vancouver	Rappaport Energy Consulting LLC	N/A	Not Reported	Concept
Poulsbo	Olympic Biofuels	0.5	Operational—waste vegetable oil	Closed production down—still distributing biodiesel.
Addy	Advanced Biodiesel	N/A	Concept	No activity
Toppenish	Agri Systems	N/A	Concept	No activity
Chelan County	Robert Steward	N/A	Concept	No activity
Spokane	Spokane Conservation District/Palouse Bio	5	Planning—Energy Freedom Fund	Energy Freedom Program funding for joint crushing/biodiesel production plant. Project cancelled.
Tacoma	Baker Commodities	10	Concept	Project cancelled. Baker Commodities sold biodiesel development business to Tellurian Biodiesel, February 2008.
Bruce	Columbia BioEnergy/Air Energy	25	Concept	Project cancelled
Tacoma	Sound Refining	30	Concept	Project cancelled
Colfax	Losonoco	N/A	Not Reported	Project cancelled
West Seattle	Planetary Fuels	6	Permitting underway	Project cancelled. New startup Planetary NRG, will focus on recovery and processing of low value, high FFA waste grease as feedstock material.
Burbank	NorthWest BioFuels, Inc.	30	Permitting underway	Project cancelled

Note: There are a number of smaller biodiesel facilities (<10,000 gallons/yr) that may be operational. These include Beavercreek Bioproducts of Twisp, GloCal Network Corporation of Seattle, and Biodiesel Works of Bellingham.

#Capacity often exceeds actual production by a considerable margin. Information on production was not always accessible (Kim Lyons, personal communication, December 2008).

Table 2.3: Oilseed crusher facility status in Washington (Lyons, 2008)

Location	Developer	Capacity (tons crushed/yr)#	Status
Spokane	Spokane County Conservation District/ Palouse BioEnergy	Range from 25,500 to 340,000 tons per year (TPY). 25,000 TPY facility most likely near term.	Cancelled
Port of Warden	Washington Biodiesel	350,000 TPY	Planning—$2,915,397 Energy Freedom Program
Odessa	PDA/Inland Empire Oilseeds LLC (2 co-ops, Rearden Seed and Fred Fleming)	44,200 TPY	Planning—$3,500,000 Energy Freedom Program
Sunnyside	Port of Sunnyside/ Natural Selections (Ted Durfee)	8,000 TPY—contract w/ Imperium for 1 MGY. Delivered 6K gallons 1/30/07.	Operational—$750,000 Energy Freedom Program
Colfax	NRCS/Whitman Conservation District	255 TPY—portable crusher @ 3/4 tons per day	Operational
Snohomish	Snohomish County	8,000 TPY	Operational
Touchet	Touchet Seed and Energy	8,000 TPY	Operational

#Capacity often exceeds actual production by a considerable margin. Information on production was not always accessible (Kim Lyons, personal communication, December 2008).

fuel production.

Although relatively few ethanol and biodiesel plants have stopped operations in the United States (around 10), some firms are going into bankruptcy, and industry development has slowed substantially not only in Washington State, but nationally and even internationally (Galbraith, 2008). Credit markets are increasingly tight, which is also likely to affect not only existing firms and plant operations, but the development of new plants. These impacts are being felt even in the Midwest, where biofuel markets have a comparative advantage.

The biofuel industry in Washington State has not been able to successfully compete on a large scale with the Midwest, indicating that production costs are generally higher due to current market and energy policy conditions. The extent to which current development projects have slowed in Washington is consistent with the larger industry trends, but is further indication that the state's position in current biofuel markets continues to be relatively weak.

One industry participant, Warren Shoemaker, a past employee of Pacific Ethanol Inc. and currently of Pursuit Dynamics Inc., speculates it is likely that none of the planned ethanol projects in Washington will be continued based on grain as the feedstock. He suggests that these Washington State developments, if they are not abandoned, are more likely to become cellulosic ethanol projects because developers are refocusing the technology and funding to secure an alternative feedstock supply. Discussions with several other market participants, agency personnel, and researchers with knowledge of the local terrain for biofuels generally support this conclusion.

Transportation and distribution

The infrastructure required for processing, refining, and distributing biofuels and petrofuels mediates between the raw production of feedstocks and consumption of the final product. The regions where domestic fuel consumption activities will occur in the United States depends upon a host of consumer demand attributes, including population concentration, income, and the price/availability of alternative transportation services.

While the Pacific Northwest is an important growth region for the United States, it is relatively smaller than most of the other large regional agglomerations in the nation. Moreover, except for California and Arizona, other market areas are long distances from the Pacific Northwest. The location of Washington and the Pacific Northwest relative to feedstock supplies and final demand, together with transportation costs and infrastructure, will shape the final form of the Washington biofuel market.

Comparison of the location of potential feedstock availability and likely geographic markets for fuel demand reveals that the Pacific Northwest is at a comparative disadvantage compared to the Midwest. In the Midwest, feedstock availability is close to the market demand centers, which helps to explain the growth of corn-based ethanol processing plants here.[4] Of course, mere proximity of potential demand and supply sites does not guarantee development of a market. Many other factors influence the potential viability of firms and their locations, including national incentive policies, state regulatory framework, and transportation costs (which is only partially dependent on physical distance).

Comparison of the location of feedstock supplies relative to the location of regional centers of demand generates several important questions and observations regarding the potential for developing a viable biofuels industry in the Pacific Northwest. These questions illustrate the type of considerations that need to be dealt with when undertaking development and/or expansion of biofuel markets in Washington State:

- How does feedstock availability compare to demand for biofuels in the Pacific Northwest (or Washington State)?
- How do these demand–supply balances compare to the scale efficiencies needed to create a viable biofuel processing plant?
- Are there sufficient supplies of regional feedstocks (in aggregate, and at various times), or must the feedstocks be imported to support a regional processing industry (at least sometimes)?
- If feedstocks must be imported, do scale economies in processing versus transportation costs favor importing feedstocks to local processors, or importing the finished product from distant processors?
- If the regional market is too limited to support a processing industry, what are the comparative advantages, counting transportation costs, of local processors accessing more distant U.S. markets?
- Given the likelihood that long distance transport may be necessary for either feedstock collection or fuel distribution, is there sufficient and cost-effective rail and barge transportation infrastructure available?

The existing ethanol plant at Boardman, Oregon, offers some insight into business operations, transportation, logistics, and long-term economic viability. This 40-million-gallon-capacity plant converts corn into ethanol that is sold to blending terminals in the Portland/Seattle markets. Corn is purchased from elevators and grain merchandising companies throughout the

[4] Up-to-date maps of ethanol plant locations in the United States can be found at http://www.ethanolproducer.com/plantmap/.

Midwest and shipped via unit train to the Boardman plant.

According to the Upper Great Plains Transportation Institute, the transportation rate to ship grain from Minneapolis, Minnesota, to Portland, Oregon, on unit trains varies from $1.25 to $1.75 per bushel of grain (approximately 1,500 miles). The comparison for grain shipped from the Pacific Northwest (Washington, Idaho, Oregon) via truck–barge combination utilizing the (directly adjacent) Snake/Columbia river system to Portland, Oregon, is $.25 to $.75 per bushel. Ethanol produced at the plant is shipped weekly down the Columbia River, and gasoline is then hauled back upriver to the Tri-Cities area.

The operational flexibility of the Boardman ethanol plant is significantly dependent upon the shipping rate provided by the railroad for delivering feedstock. This makes the plant somewhat captive to the shipper, because the only feasible transportation alternative for the feedstock is via truck from the Midwest. Nonetheless, the Boardman location is likely among the most economically viable settings in the Northwest for grain ethanol production.

The decision regarding where to locate this particular plant was likely based upon access to 1) water for ethanol processing, 2) feedlots/dairies for byproduct distribution, and 3) inexpensive transport of ethanol fuel to Portland/Seattle markets via barge. The long distance transportation for obtaining feedstocks decreases the long run relative competitiveness of this plant compared to a location which also possessed these attributes yet can obtain the feedstock locally. The Boardman location would also be less advantageous outside the demand markets of Portland/Seattle given the long distance to other concentrated demand markets for biofuel. The Boardman plant highlights the critical nature of the transportation infrastructure in determining the viability of biofuel market in Washington. The relevant transportation infrastructure for biofuels comprises a combination of barge, rail, and truck, which is in decreasing order of variable costs and increasing order of fixed costs (see Figure 2.4).

Distance and location can affect plant economics in highly idiosyncratic ways. In addition, the specific practices and requirements of the different transportation modes influence the possible industry development paths. The long run viability of the biofuel industry in the state of Washington will therefore depend on coordinated developments in the transportation infrastructure as well as the economics of size in processing and blending plants, feedstock supplies, and final demands.

It is also worthwhile to notice how railroad companies (Class I) view the emerging biofuel markets in terms of their business plans. Because railroad firms are not currently investing in specialized cars to transport ethanol or biofuel, the investment risk is on the prospective shipper, which conveys a pessimistic view of this market for transportation demand in the long run.

In summary, the following transportation factors are likely to affect the pattern and viability of any long term biofuel industry emerging in Washington:

- Location of feedstock, plant, and market relative to transportation modes
- Distance from feedstock to plant and plant to market
- Quantities of commodity (feedstock, by-products, final products)
- Attributes of commodity (liquid, solid, hydrophylic, corrosive, etc.)
- Specific modal and transportation service attributes
- Ability to negotiate service/rate

contracts with Class I railroads (related to plant and firm size/scale)

Demand for conventional and renewable automobile fuels[5]

Any biofuels policy in the state of Washington will be effective only if the ultimate consumers of transportation services find it in their self interest to purchase and use alternative fuels. This places an important focus of the biofuels policy debate on consumers of gasoline and diesel fuels.

Ethanol has been considered an alternative automobile fuel for more than a century. However, a combination of factors early in the development of the automobile industry caused gasoline to be generally favored over ethanol (Dimitri and Effland, 2002). The reasons include a $2.08/gallon alcohol tax from 1861 to 1906, high farm prices during an important developmental period of the automobile industry (1910–1919), the need to use much more alcohol than gasoline to generate the same horsepower (Strong, 1909), the higher compression ratio required for alcohol (15:1) than for gasoline (8:1) to combust efficiently, a corporate

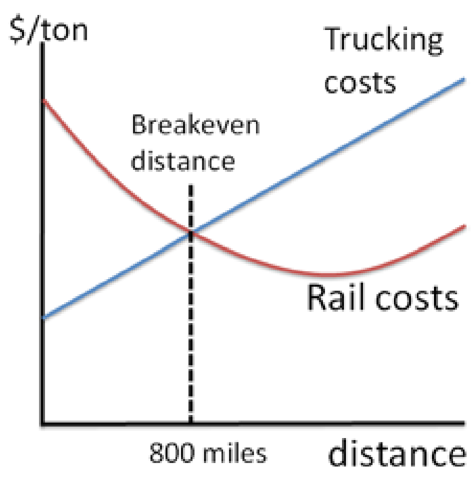

Figure 2.4: General modal transportation cost comparison.

agreement (between Standard Oil, Dupont, and General Motors), and submissive accommodation by the government. Today many of the same issues are again a focus of the debate on government policies toward the subsidization and development of the biofuel market. Long-standing positive arguments are that it is a clean and lead free fuel that can reduce our dependence on foreign oil, lower the cost of energy for transportation, and provide a means to solve farm surplus problems.

Consumer demand for a given type of fuel is conditional on the choice of vehicles in the automobile fleet and preferences for a host of automobile characteristics. The average usable life of a typical new car is now more than 10 years, which will impact short- to intermediate-term fuel demand.

Once an automobile is chosen, fuel options for that vehicle have historically been limited to a narrow range. Recently developed flex-fuel cars are an important exception. Once a vehicle is chosen, the demand for fuel depends on a variety of factors in addition to price.[6] Economic analyses of gasoline demand typically find it to be price inelastic, a normal good, and an economic necessity (e.g., Graham and Glaister, 2004). In lay terms, this means that consumers are relatively unresponsive to price changes, that consumption increases with income, and that low-income consumers forego many other products before giving up gasoline. Hence, although consumers can modify demand somewhat in response to price, the change is small; more substantial changes will only come as they start to replace their fleet of cars. Consequently, the demand for biofuels can also be expected to be price inelastic. Only when and if biofuels become viable substitutes for petroleum fuel in the existing vehicle fleet will this change. Only

[5] See Appendix A2 for a more detailed analysis that supports this section.

[6] They include such things as the distance to work, public transportation sources, and the quality and quantity of roads.

when fleets are well adapted to biofuels, and biofuels are available at competitive prices, would one expect to see widespread adoption of biofuels.

The other factor that will certainly affect demand for ethanol as vehicles are able to accommodate higher blends is the fact that its heating value is about 64% that of gasoline. Thus, a gallon of high-blend ethanol will not provide a vehicle the same mileage as a gallon of gas. An individual driver's primary interest in purchasing automobile fuel is the energy content per dollar paid at the fuel pump—that is to say, the number of miles driven per dollar of fuel purchased. In a market setting without a renewable fuel standard (RFS) or subsidy, the point at which ethanol becomes price competitive in consumption with gasoline (assuming that they are otherwise perfect substitutes, which they are not) is when the price of ethanol is about 64% of the gasoline price.

For illustration, suppose that gasoline and ethanol were the same price per gallon in the marketplace, but for purposes of reducing greenhouse gas emissions or reducing petroleum fuel dependence, the state imposed a renewable fuel standard or subsidized ethanol (the revenues for which are paid for through taxes) until it was cost-competitive in terms of energy content per gallon with gasoline. Consumers would then be paying a price penalty equivalent to an implicit energy tax on consumers (in the case of an RFS) or taxpayers (in the case of a subsidy). This means that a mandatory fuel portfolio policy where petro-gas and ethanol have the same price is equivalent to imposing a 36% tax. The effect of this implicit energy tax is illustrated in Figure 2.5, where an E_{20} biofuel blend standard is roughly equivalent to a 6% retail sales (energy) tax on regular gasoline, an E_{50} biofuel standard is equivalent to nearly a 20% energy tax, and an E_{85} standard would have the same effect on drivers of gasoline-powered automobiles as a 42% energy tax. Given the potential supplies of first-generation ethanol, high price penalties are not expected in the near future, but even at low levels the cumulative effect on individual annual expenditures and consumers in aggregate can be huge.

While energy content may be a critical issue for consumer acceptance of ethanol and ethanol blends, fleet replacement will almost certainly dramatically affect the technical aspects associated with the biofuel success. The various types of biofuels have different combustion characteristics, interact differently with combustion engines, and have different emissions characteristics from petroleum-based fuels. Each of these characteristics affect the degree to which biofuels are substitutable for petroleum fuels in the existing vehicle fleet and the potential environmental benefits from this substitution. For instance, ethanol use is optimized at higher compression ratios than petro-gas and is relatively water-loving. The latter feature means it cannot use

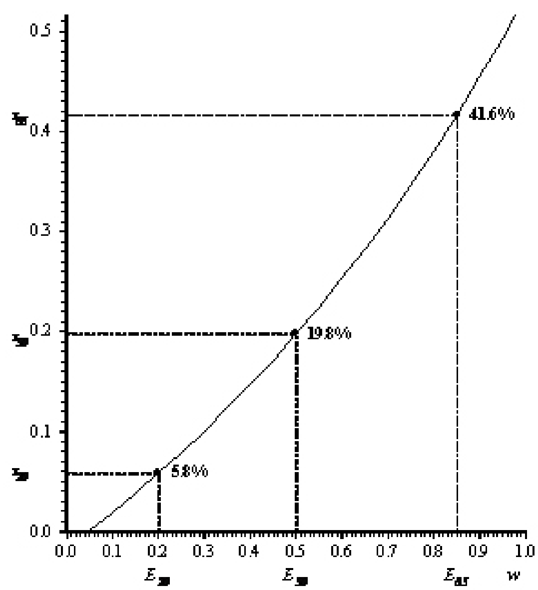

Figure 2.5: Implicit energy tax from a binding RFS given equal per-gallon prices of gasoline and ethanol.

the same distribution system as petro-gas in high concentrations. Biodiesel fuels also coagulate at lower temperatures than petro-diesel, creating problems in cold temperatures (depending on the feedstock base). Further details on these issues are provided in Appendix A2.

Figure 2.6 shows ethanol and biodiesel use in Washington between July 2007 and September 2008 fluctuating substantially but in general trending upward. There was also a large spike in ethanol use in the early 1990s (Energy Information Administration, 2009d), attributed to both the federal oxygenated fuel requirement and the state's ethanol incentive, which was discontinued in 1994.

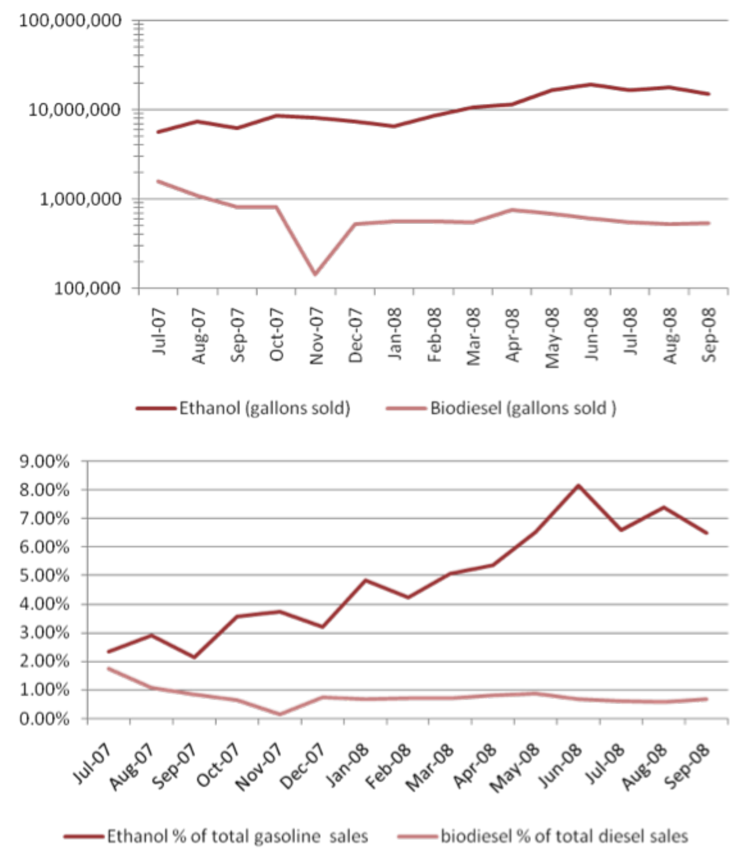

Figure 2.6: Ethanol consumption (top) and biodiesel consumption (bottom) in Washington State (Ann Diaz, Washington State Department of Licensing, personal communication, 2008).

Since 2003, biodiesel consumption in Washington has risen from a few thousand gallons to millions of gallons per year. According to Washington Department of Licensing data, from October 2007 through September 2008, ethanol sales totaled 146.6 million gallons (an average of 5.43% of total fuel sales). Biodiesel sales amounted to 6.8 million gallons (0.67%) of total sales. In addition to the growing number of retail locations, municipal and fleet use continues to increase (Lyons, 2008).

After biofuels are produced, fuel producers and distributors (oil companies) combine these products with petroleum-based fuels to generate the blended products sold to final consumers. Common examples of these blended products include E10 and E_{85}, fuels that contains 10 and 85 percent ethanol, respectively, with petroleum gasoline making up the remainder, and B_{20}, which is 20% biodiesel and 80% petroleum diesel.

Biofuels can be used as complements or substitutes for fossil fuels. For example, fuel producers may provide blended products to improve or change specific fuel characteristics. Small amounts of ethanol can improve emissions quality and energy extraction efficiency. Including small amounts of ethanol in gasoline increases fuel oxygen content and lowers vehicle carbon monoxide emissions. Generally, there are oxygenation benefits from using ethanol (in place of other oxygenators such as MTBE, methyl tert-butyl ether) up to around 5%. Because of health risks, MTBE is now banned in many states, which is an important factor in driving up demand for ethanol.

Adding ethanol to gasoline also increases fuel octane. Fuels with greater octane can be used in engines with higher compression to improve the efficiency of energy extraction and improve the performance and value of the base fuel. However, the higher engine compression required for such fuels to work is a basic characteristic which must be designed and built into engines. Most existing vehicles are built for the octane ranges of standard gasoline and hence would not be able to capture the benefit of considerably higher octane from higher ethanol blends over the small concentrations used currently.

Adding small amounts of biodiesel to petroleum diesel also can generate advantages. It helps with fuel lubricity. In these cases, biodiesel and bio-ethanol are complements to petroleum fuels. To the extent that biofuels are used in this way, the demand levels for biofuels will be driven by the overall demand for the basic petroleum fuel. However, once the biofuel additive provides the desired oxygenation or lubrication properties, increasing the percent of biofuel to the blended product replaces petroleum fuel.

When biofuel becomes a replacement or substitute for petroleum fuels, the economics change. Where a biofuel is used as a complement, its use level depends on the least-cost combination of feedstocks required to meet technical requirements. In these cases, biofuels can have higher prices than petrofuels if their additive value is worth the price. When blends increase the ratio of biofuel, biofuel becomes a direct rival to (substitute for) petrofuel. In this case, biofuel must compete directly on price or be promoted by non-price policy measures.

There were approximately 4.7 million licensed drivers in Washington during 2005 (U.S. Department of Transportation, 2006b). In 2004, Washington consumers purchased over 3.3 billion gallons of gasoline and gasohol combined (U.S. Department of Transportation, 2006c). Ethanol accounted for about 23.5 million gallons (less than 1%) of that consumption (U.S. Department of Transportation, 2006a), while biodiesel sales ranged between 1 and 1.5 million gallons (Lyons, 2005).

Final demand and supply logistics

Four main players interact along the fuel supply chain to determine the final demand for biofuels: oil refiners and distributors, retailers, final consumers, and policy makers. The oil refiners blend feedstocks to produce fuels, and the distributors blend biofuels with petroleum fuel to generate the final biofuel products. Some retailers face the decision of whether or not to offer biofuels for sale. Final consumers must choose which fuel product to purchase. Various Washington State regulations impact the decisions of each of these players. Each group must be considered to provide a complete picture of the demand for biofuels. We focus next on retailers and consumers.

Retailers

Independent retail gasoline station owners decide what products to provide, and they may have concerns with some biofuels. The B_{20} and E_{85} blends often involve costly changes to storage and dispensing equipment. The National Renewable Energy Laboratory (2008) estimates that converting an existing tank and dispenser to allow for E_{85} fueling averages about $21,000, with a median of about $11,000. To install a new tank, the average is almost $72,000 (with a median of almost $60,000). It is also often necessary to coat metal components, provide different plastic parts, and make other modifications.

Additionally, biofuels represent new products for many consumers, which means warning signs need to be posted to ensure appropriate use. Some retailers may not want to risk customer confusion. Quality issues associated with biofuels may also raise concerns with final users and therefore retailers. The uncertain future of biofuels may cause many retailers to wait until some of these concerns are resolved.

Consumers

Commercial road vehicles represent a significant portion of the fuel consumed in Washington. Organizations operating large numbers of vehicles to transport goods within and across Washington's highway system may increasingly become purchasers of biofuels. Transport companies may market their use of more environmentally friendly fuel or be primarily driven by relative costs. This sector's interest in biofuels is at present unknown.

Users of marine vehicles also constitute a significant potential market for biofuels. Recreational boaters, public transportation vehicles such as state ferries, and other transport boats such as barges and cargo carriers may become users of biofuels. Biofuels have the potential for reducing environmental damages because they generally degrade more easily than petrofuels.

Washington State Ferries investigated the use of biodiesel as part of its Clean Air Initiative. In June 2005, they suspended a pilot test of biodiesel because the fuel clogged the vessels' engine filters. However, preliminary results from research underway at Washington State University indicates that protocols developed since then correct the problem. Future use of biofuels could occur as these technical problems are solved.[7]

[7] Personal communication with Craig Frear, Washington State University Department of Biosystems Engineering and member of the research team examining the issue. December 8, 2008.

Private motor vehicle drivers are expected to provide the largest demand for biofuels. Washington had over 3 million private and commercial registered vehicles in 2005. For the most part, all of these could burn low percentage blends of ethanol or biodiesel. However, the use of higher blend fuels, such as E_{85}, would require changes in the fueling infrastructure. In 2002, there were 2,700 flexible-fuel vehicles (FFVs) capable of using E_{85} fuel (U.S. Department of Energy, 2007c) in Washington. There are now more than 102,000 FFVs registered in Washington that could run on E_{85} fuel (BioEnergy Washington, 2008).

Note, however, that while FFVs could run on higher concentrations of biofuels, their compression settings are still generally set to optimize use of standard gasoline. While the percent of registered vehicles capable of burning E_{85} is not large, the number of FFVs is growing because automakers have committed to building these vehicles. More than 6 million are currently on the road nationally. Consumers typically make their consumption decisions based on some function of the price of the good, the price of substitute goods, the quality of the good, and other attributes such as the environmental impact of the product.

No studies characterize or calculate the specific demand for biofuels. However, several recent studies found a short-run price elasticity of demand for gasoline of about -0.25 (Graham and Glaister, 2004; Goodwin, 2004; Espey, 1998). This implies that a 1% increase in price will only result in a 0.25% reduction in the quantity of gasoline demanded. In other words, the quantity of gasoline consumed is not very responsive to price in the short run.

Ultimately, price differences between petroleum fuel and biofuels will play a key role in determining the demand for biofuels. For consumers, biofuels represent a substitute for petroleum fuel. As the price of petroleum fuel increases relative to biofuel, more consumers will switch to biofuels. However, it is important to recall that equal volumes of standard gasoline and ethanol (for example) contain different amounts of energy, which will affect price. Consumers might initially believe that a lower volumetric price for ethanol means a cost savings, but it will not take long for most to notice the drop in fuel economy and come to understand that they must assess fuel prices on an energy content basis.

The volatility of prices will also be important for many consumers. Large fuel consumers, such as transport companies, may have a particular interest in avoiding price volatility as they plan for future consumption. In an empirical study, Vedenov et. al. (2006) suggest that significant increases in levels and volatility of petroleum gasoline prices may create incentives for consumers to switch to biofuels because these blends will likely have lower price volatility (due in part to the "portfolio effect" of combining products with different volatility patterns). In another study, Tareen et. al., (2000) found that the price volatility of alternative diesel fuels was lower than that of petroleum diesel.

In addition to prices and energy content differences, consumers may base their fuel consumption decisions on the cost and need for vehicle component conversions and effects on the environment. For example, filters and hoses need to be replaced and other vehicle changes may be required to use some biofuel blends. Finally, some consumers are motivated by environmental concerns as well as the other factors mentioned. However, in the short run, environmentally-conscious consumers are likely to opt for higher mileage vehicles as much or more than for biofuel-capable vehicles.

Chapter 3: Current policy environment

In this chapter we examine the biofuel policies of the federal government and the Pacific Coast states as well as British Columbia. We do this for 2 reasons. First, Washington State biofuel markets will operate within the context of federal biofuel programs and other regional and national policies. Washington State's policy should therefore be designed to make the best possible use of these federal and regional programs. Second, California, Oregon, Washington, and British Columbia have very different policy approaches, and they span a broad set of biofuel policy options. An examination of these policies provides context for understanding the policy recommendations in subsequent chapters.

Federal biofuel programs

Yacobucci (2008) provides a summary of federal programs as of March 2008. These include a renewable fuel standard for biofuels administered by the EPA, tax credits administered by the IRS, several grant and reimbursement programs administered by the USDA to promote biofuel production, and DOE grants and loan guarantees primarily for biomass utilization research and development. In addition, Farm Bill H.R. 6124, passed in June 2008, modified the tax credit for corn-based ethanol and provides several other grant and incentive programs.

Federal production tax incentives and grant programs.

Before the 2008 Farm Bill was passed, gasoline suppliers who blended ethanol with gasoline were eligible for a 51¢ tax credit for each gallon of ethanol blended. Small ethanol producers (60 MGY ethanol production) were eligible for a 10¢ tax credit as well. Producers could receive a tax credit of $1.00 per gallon of biodiesel or renewable diesel as defined by law.[8] In the 2008 Farm Bill (H.R. 6124: Food, Conservation, and Energy Act of 2008), tax credits for corn-based ethanol are reduced from 51 cents to 45 cents per gallon (Section 15331), while the tax credits for cellulosic are $1.01 per gallon (Section 15321). Sections 9001–9005 of the 2008 Farm Bill provide a program for federal procurement of biomass-based products and advanced biofuels, biorefinery development assistance up to 30% of the cost of the project, assistance to upgrade biorefinery power systems, a rural energy program, and other programs. Through the IRS, a taxpayer can take a depreciation deduction of 50% on a new cellulosic biomass plant in the first year of production, and biofuel producers can receive reimbursements through the USDA for production capacity enhancements to existing plants.[9] Under the Biomass Research and Development Initiative, the DOE funds grants for biomass demonstration projects, research, and development, as well as loan guarantees for biofuel projects that utilize cellulosic feedstocks and/or that reduce greenhouse gas emissions. More detail on these programs will be discussed in Chapter 6.

8 The DOE is authorized to offer per gallon tax credits for cellulosic biofuels until 2015 or until production reaches one billion gallons, whichever is first. However, these have not yet been implemented.

9 The USDA also has several other programs that provide benefits for biofuel industry development but are not limited to biofuel production per se.

Federal Renewable Fuel Standard

The federal Energy Policy Act of 2005 (EPAct 2005, P.L. 110-58) and the Energy Security and Independence Act of 2007 (P.L. 110-140, H.R. 6), hereafter the EISA, together mandate consumption requirements for biofuels.[10] The requirements increase to 36 billion gallons in 2022 based on fuel type and carbon emissions characteristics. The America Coalition for Ethanol provides a useful summary of RFS characteristics, which we utilize below:

- Conventional biofuels are defined as ethanol produced from corn starch. New construction of corn ethanol plants must provide at least a 20% reduction in GHGs over conventional gasoline.
- Advanced biofuels are renewable fuels other than corn ethanol with at least a 50% reduction in greenhouse gas emissions over conventional gasoline and biodiesel, respectively, and include cellulosic biofuel, biomass-biobased diesel, and undifferentiated advanced biofuel defined below.
- Cellulosic biofuels are renewable fuels derived from cellulose, hemicellulose, or lignin derived from renewable biomass and provide a 60% emissions reduction from baseline gasoline and diesel, respectively (40% of baseline emissions).

Undifferentiated biofuels include fuels made from sugars or non-corn starches, crop residues, and various waste materials, crop residues; as well as biogas, butanol, and related fuels; that provide at least a 50% reduction in GHGs relative to baseline gasoline and diesel emissions.

The required 9 billion gallons for 2008 corresponds to an aggregate requirement that 7.76% of fuel sold in the U.S. must be biofuel based on calculations published in the *Federal Register* (2008). Although the RFS requires 36 billion gallons by 2022, the corn ethanol contribution to the RFS is capped at 15 billion gallons per year beginning in 2015, with the remainder being advanced biofuels as described above. The EPA is required by the federal RFS legislation to report the RFS in percentage terms each November for the upcoming calendar year.[11]

The final EPA rule for the federal RFS (EPA, 2007b) provides the compliance and enforcement program for the federal renewable fuel standard.[12] Renewable identification numbers (RINs) act as both the accounting mechanism and trading currency used by obligated parties to satisfy the RFS. The agency has determined that different types of renewable fuels have different equivalence values. For instance, corn ethanol has an equivalence value of 1, so that one gallon of corn ethanol is associated with one RIN. A gallon of cellulosic ethanol, however, is associated with 2.5 RINs. These RINs are created by renewable fuel producers or importers, and generally sold along with the renewable fuel to gasoline refiners or importers. These refiners then use their accumulated RINs to demonstrate compliance with their volume obligation.

The rules require obligated parties—primarily companies who act as refiners and importers of petroleum based fuel—to acquire enough RINs to satisfy the RFS. They can do this either by buying renewable fuel (and their associated RINs) to generate blended fuel or buying RINs on an open market. Although the market for RINs is in

[10] A host of information about the federal RFS is available at http://www.epa.gov/otaq/renewablefuels/index.htm#regulations.

[11] EPA (2007a) provides a summary of projected regulatory impacts of the federal RFS.

[12] Note that the consumption requirements in this rule are already out of date, but there is a great deal of information in this report that pertains to implementation.

Table 3.1: RFS schedule under the Energy Independence and Security Act of 2007 (American Coalition for Ethanol, 2008).
(Numbers are in billions of gallons per year.)

Calendar Year	Conventional Biofuel	Advanced Biofuel	Cellulosic Biofuel	Biomass-Biobased Diesel	Undifferentiated Advanced Biofuel	Total Renewable Fuel
2008	9					9
2009	10.5	0.6		0.5	0.1	11.1
2010	12	0.95	0.1	0.65	0.2	12.95
2011	12.6	1.35	0.25	0.8	0.3	13.95
2012	13.2	2	0.5	1	0.5	15.2
2013	13.8	2.75	1		1.75	16.55
2014	14.4	3.75	1.75		2	18.15
2015	15	5.5	3		2.5	20.5
2016	15	7.25	4.25		3	22.25
2017	15	9	5.5		3.5	24
2018	15	11	7		4	26
2019	15	13	8.5		4.5	28
2020	15	15	10.5		4.5	30
2021	15	18	13.5		4.5	33
2022	15	21	16		5	36

its infancy, there is one primary RIN trading service in operation, the RinXchange. Trading by any registered party is possible at http://rinxchange.com/.

Obligated parties for the federal RFS

Any party that produces gasoline for use in the United States, including refiners, importers, and blenders (other than oxygenate blenders), is considered an "obligated party" under the RFS program. All obligated parties are expected to meet the renewable fuel standard as of 2007, with 2 important exceptions: 1) small refiners and small refineries through 2010,[13] and 2) all gasoline producers located in Alaska, Hawaii, and noncontiguous U.S. territories are exempt from the RFS program indefinitely.

The EISA allows small refiners and refineries to voluntary join the program before 2011. Additionally, if a study by the Secretary of Energy determines that compliances with the requirement would impose a huge economic hardship on the small refinery, then the exemption period shall be extended for a period of not less than 2 years.

Under the final rule, any person who meets the definition of refiner under the fuel regulations, which includes any blender who produces gasoline by combining blendstocks or blending blendstocks into finished gasoline, is subject to the renewable fuels obligation. Any person who brings gasoline into the 48 contiguous states from a foreign country or an area that has not opted into the RFS program or brings gasoline from a foreign country

[13] The EISA defines a small refinery as not exceeding an average aggregate daily crude oil throughput of 75,000 barrels.

or an area that has not opted into the RFS program into an area that has opted into the RFS program, is considered an importer under the RFS program and is subject to the renewable fuels obligation.

A blender who only blends renewable fuels downstream from the refinery or importer is not subject to the renewable fuel obligation. A refiner or importer located in a noncontiguous state or U.S. territory is not subject to the renewable fuel obligation and thus is not an obligated party (unless the noncontiguous state or territory opts into the RFS program). A party located within the contiguous 48 states is an obligated party if it imports into the 48 states any gasoline produced or imported by a refiner or importer located in a noncontiguous state or territory.

Definitions of renewable fuel and related terms for the RFS

The statutory definition of renewable fuel includes biodiesel, all motor vehicle fuels produced from biomass material, cellulosic ethanol, and waste derived ethanol. The term "biodiesel"[14] means a diesel fuel substitute produced from nonpetroleum renewable resources that meets the registration requirements for fuels and fuel additives established by the EPA under Section 7545 of the EISA, which includes: animal wastes (including poultry fats and poultry wastes), municipal solid waste and sludges, oils derived from wastewater and the treatment of wastewater, and other waste materials. The definition of renewable fuel also includes "all motor vehicle fuels produced from biomass material," such as grain, starch, oilseeds, animal or fish materials (including fats, greases, and oils), sugarcane, sugar beets, tobacco, potatoes or other biomass (such as bagasse from sugar cane, corn stover, algae, and seaweed), or the feedstock of natural gas if produced from a biogas source (such as a landfill, sewage waste treatment plant, feedlot, or other place where decaying organic material is found).[15]

On the other hand, the term "cellulosic biomass ethanol" means ethanol derived from any lignocellulosic or hemicellulosic matter that is available on a renewable or recurring basis, including dedicated energy crops and trees, wood and wood residues, plants, grasses, agricultural residues, animal wastes and other waste materials, and municipal solid waste.

Both animal and municipal solid waste are also listed as allowable feedstocks for the production of ''cellulosic biomass ethanol.'' When such feedstocks do not contain cellulose, however, the resulting ethanol is waste-derived.

Within the context of the EISA, the term "renewable biomass" means each of the following:

- Planted crops and crop residue harvested from agricultural land cleared or cultivated at any time prior to the enactment of EISA that is either actively managed, fallow, or nonforested
- Planted trees and tree residue from actively managed tree plantations on non-federal land cleared at any time prior to enactment of EISA, including land belonging to an Indian tribe or an Indian individual, that is held in trust by the United States or subject to a restriction against alienation imposed by the United States
- Animal waste material and animal

[14] Notice that the regulation divided the definition of biodiesel into 2 separate categories: 1) Biodiesel (mono-alkyl esters) and 2) Non-ester renewable diesel. The combination of these 2 categories in the regulation fulfills the Act's definition of biodiesel.

[15] For purposes of the renewable fuel program, EPA considers a fuel to be based on its potential to operate a highway or nonroad vehicle, without regard to whether it in fact is used in a vehicle application.

byproducts

- Slash and pre-commercial thinnings that are from non-federal forestlands, including those belonging to an Indian tribe or an Indian individual that are held in trust by the United States or subject to a restriction against alienation imposed by the United States, but not forests or forestlands that are ecological communities with a global or state ranking of critically imperiled, imperiled, or rare pursuant to a State Natural Heritage Program, old growth forest, or late successional forest
- Biomass obtained from the immediate vicinity of buildings and other areas regularly occupied by people or a public infrastructure at risk from wildfire
- Algae
- Separated yard waste or food waste, including recycled cooking and trap grease

"Additional renewable fuel" is produced from renewable biomass and is used to replace or reduce the quantity of fossil fuel present in home heating oil or jet fuel. On the other hand, advanced biofuel is renewable fuel other than ethanol derived from corn starch that has lifecycle greenhouse gas emissions at least 50% less than baseline lifecycle greenhouse gas emissions.

The following fuels are considered advanced biofuel:

- Ethanol derived from cellulose, hemicellulose, or lignin
- Ethanol derived from sugar or starch (other than corn starch)
- Ethanol derived from waste material, including crop residue, other vegetative waste material, animal waste, and food waste and yard waste
- Biomass-based diesel
- Biogas (including landfill gas and sewage waste treatment gas) produced through the conversion of organic matter from renewable biomass
- Butanol or other alcohols produced through the conversion of organic matter from renewable biomass
- Other fuel derived from cellulosic biomass

The definition of renewable fuel in the Act is not limited to fuels that can be blended with gasoline. Various fuels that meet the definition of renewable fuel can be used in their pure form, such as ethanol, biodiesel, methanol, or natural gas. The Act is unclear on whether other fuels that meet the definition of renewable fuel, but are not used in gasoline, could also be used to demonstrate compliance towards the aggregate national use of renewable fuels.

The EISA's definition of renewable biomass has also generated some conerns. Specifically, since it excludes the biomass that could be made available from private land, Wong (2008) argues that the federal RFS substantially limits the amount of biomass that may be used for compliance. As Wong notes (p. 5), all forest materials harvested from national forests and public lands are excluded, except for materials immediately surrounding buildings and infrastructure at risk of wildfire, and a potentially substantial portion of forest biomass from private land. Mill residues and may also be excluded, although the language is unclear. The EISA also does not include organic materials from municipal solid waste in its definition of renewable biomass to be counted toward the RFS.

These exclusions are particularly important for the state of Washington because they comprise a substantial proportion of the available biomass in the state. In addition, as discussed later in this section, the utilization of municipal solid waste and certain forest residues in wildfire-prone areas represent potential markets that warrant consideration for supplementary support.

Compliance under the federal RFS

Compliance with the RFS program is demonstrated through the acquisition of unique renewable identification numbers (RINs) assigned by the producer or importer "to every batch"[16] of renewable fuel. The RIN shows that a certain volume of renewable fuel was produced or imported.

Each year the refiners' obligated parties must acquire sufficient RINs to demonstrate compliance with their volume obligation. RINs are valid for the calendar year they are generated or the following calendar year. RINs can also be traded, thereby functioning as the credits envisioned in the Act. A system of recordkeeping and electronic reporting for all parties that have RINs ensures the integrity of the RIN pool.

Each obligated party is required to use current-year RINs to meet at least 80% of its renewable volume obligation (RVO), with a maximum of 20% derived from previous-year RINs. Any previous-year RINs that an obligated party may have in excess of the 20% cap can be traded to other obligated parties that need them. If the previous-year RINs in excess of the 20% cap are not used by any obligated party for compliance, they will expire. The net result will be that, for the market as a whole, no more than 20% of a given year's renewable fuel standard can be met with RINs from the previous year.

[16] There is debate about when RINs should be assigned. Some institutions argue that it should be at the point of renewable fuel blending into motor vehicle fuel, but the final program design assumes that all but a negligible quantity of renewable fuel will eventually be consumed as motor vehicle fuel. Therefore, the EPA does not think it is necessary to verify that blending has occurred in order to guarantee a program that adequately ensures it occurs. They argue that tracking renewable fuel blending into gasoline will complicate the compliance system.

The EPA will verify an obligated party's compliance with its RVO through annual compliance demonstration reports that include the following information:

- Demonstration of compliance with the previous calendar year's RVO
- A list of all transactions involving RINs
- Tabulation of the total number of RINs owned, used for compliance, transferred, retired, and expired

In its annual reports, an obligated party is required to include a list of all RINs held as of the reporting date, divided into a number of categories. For instance, a distinction must be made between current-year RINs and previous-year RINs.

The EISA allows other parties, including brokers, to own and transfer RINs. The main objective is to create a fluid and free market that increases the venues for RINs to be acquired by the obligated parties that need them.[17] The means through which RIN trades occur is at the discretion of the parties involved. For instance, they can create open auctions, contract directly with those obligated parties who seek RINs, use brokers to identify potential transferees and negotiate terms, and/or transfer the RINs to another party[18] RIN transaction reports must be submitted by the end of the quarter in which the transaction occurred, while gallon-RIN activity reports should be submitted quarterly.

[17] There is concern that the design of the RFS program relies on the assumption of abundance of RINs available to buyers. For instance, if the supply of renewable fuel is very close to the demand, trading of RINs could be constrained, making it more difficult for obligated parties to obtain RINs from parties who have excess. The EPA argues that an open market maximizes competition and minimizes cost.

[18] Brokers involved in RIN transfer can either operate in the role of arbitrator without owning the RINs or take custody of the RINs from one party and transfer them to another.

Fuel equivalence values in the RFS program

One question that EPA needed to address in developing the regulations was how to count volumes of renewable fuel in determining compliance with the RVO. The Act stipulates that every gallon of waste-derived ethanol and cellulosic biomass ethanol should count as if it were 2.5 gallons for RFS compliance purposes. The Act does not stipulate similar values for other renewable fuels.

The EPA requires that the "equivalence values" for renewable fuels other than those for which specific values are set forth in the Act be based on their energy content in comparison to the energy content of ethanol, adjusted as necessary for their renewable content. The results are:

- 1.0 for corn ethanol
- 1.3 for biobutanol
- 1.5 for biodiesel (mono alkyl ester)
- 1.7 for non-ester renewable diesel

This methodology can be used to determine the appropriate equivalence value for any other potential renewable fuel as well.

Washington's current biofuel programs

A summary of biofuel incentives and policy is provided at BioEnergy Washington (2009). The primary elements of Washington State policy applying specifically to biofuels are a set of tax incentives, a renewable fuel standard, and a fund for awarding competitive grants for research and development of technology, facilities, and infrastructure for renewable energy sources.

Tax incentives

As of December 2008, Washington State provided several tax incentives for biofuel market participants (WSDR, 2008):

- A 71% reduction in Business and Occupation (B&O) tax, from 0.484% to 0.138%, for manufacturers of E_{85} fuel, biodiesel fuel, biodiesel feedstock, or wood biomass fuel (RCW 82.04.260.
- Income attributable to the sale of biodiesel fuel, wood biomass fuel, or alcohol fuel as a component of blended fuel sold may be deducted from the measure of B&O taxes received by retail sellers and distributors of biodiesel fuel, E_{85} fuel, and wood biomass fuel. Applies only to the percent of motor fuel that is biofuel (RCWs 82.04.4334, 82.04.4335, 82.29A.135).
- Property and leasehold tax exemptions for manufacturers of E_{85} fuel, biodiesel fuel, biodiesel feedstock, or wood biomass fuel (RCWs 84.36.635, 84.36.640).
- Sales/use tax exemption for machinery/equipment, delivery vehicles, and construction of facilities for retail sellers and distributors of biodiesel fuel, E_{85} fuel, and wood biomass fuel (RCWs 82.08.955, 82.12.955, 82.08.960, 82.12.960).

Energy Freedom Program

Financial assistance in the form of low-interest loan and grants may be awarded through the Energy Freedom Program (EFP, RCW 15.110) for research and development of new and renewable energy and biofuel sources, renewable energy and biofuel infrastructure and facilities including refueling stations, and markets for alternative fuel byproducts. The Energy Freedom Program was allotted $23 million from the state general fund, but it expires

June 30, 2016 (BioEnergy Washington, 2009). As of November 30, 2008, WSDA through the EFP had contracted to provide $103 million in low-interest loans for the development of 3 oilseed processing and biodiesel production facilities and one anaerobic digester facility WSDA (2009). CTED manages 1.5 million in recent grants for another crusher/biodiesel processor and a wood-fired boiler project.

Renewable Fuel Standard

In August 2007, the Washington State Biofuels Advisory Committee recommended that the 2% RFS be pursued (WSBAC, 2007).

The critical elements of these RFS rules for our purposes are:

- For both fuels, the RFS applies to fuel sold in Washington State.
- Implementation and ratcheting of the standards are based on the economic capacity for in-state feedstock production.
- Licensees are required to provide evidence of meeting a minimum aggregate content standard. No individual licensee is necessarily bound or required to satisfy the standard themselves. For this and other reasons, the standard is for practical purposes not enforceable.

The first 2 elements are basically an in-state supply condition The last relates to the onus of responsibility. We discuss these below in more detail, and examine the economic consequences and importance of each for implementation.

In-state biofuel production requirement

The RFS applies to fuel sold by licensees in Washington, which include importers, suppliers, refiners, and blenders of motor fuels. Because distributors are not considered licensees, fuel sales relate most closely (but not exactly) to fuel consumption in Washington State. However, increasing the ethanol content requires evidence that there are sufficient raw materials to support in-state production of ethanol, and increasing the RFS for biodiesel requires that in-state production capacity (including both crushing and feedstock production) can support a 3% standard.

Thus, implementation for what amounts to consumption fuel standards is tied closely to in-state production capacity. Presumably, the legislature imposed this connection to "Stimulate creation of a new industry in Washington that benefits our farmers and rural communities" (SB 6508; WSBAC, 2007).

Regulated entities and the RFS target

As written in RCWs 19.112.110 and 19.112.120, the Washington State RFS mandates the reporting of biofuel sales as the basis of an aggregate standard. Although the intent of the legislation may have been to impose an enforceable renewable fuel standard, the legislation wording does not target anyone in particular other than to report sales. Further, the legislation does not apparently provide the state agencies involved the authority to enforce a binding standard. The standard therefore plays no direct role in increasing the blending rates in the state of Washington. The ethanol RFS is currently satisfied because the aggregate ethanol content of gasoline sales in the state is currently greater than 2%.[19] If the state were to adopt a more aggressive and binding standard, an enforcement mechanism would be necessary.

The Western Climate Initiative

[19] The ethanol RFS is currently met because of market conditions, including the existing applicable federal and state incentives and policies).

The Western Climate Initiative (WCI) was signed in February of 2007 by the governors of Arizona, California, New Mexico, Oregon, and Washington State, who thereby agreed to identify, study, and implement ways to reduce GHG emissions. Each of the partners has joined the newly formed GHG (Climate) registry, which builds on the existing California Climate Action Registry. It began accepting data in early 2009. The Climate Registry will play an important role in establishing an accurate reporting mechanism and accounting infrastructure on which to base the WCI cap-and-trade program.

Currently there are 11 WCI partners and 13 observers.[20] The initiative is open to participation by other U.S. states, tribes, Canadian provinces, and Mexican states as partners (those that expect to implement the cap-and-trade program designed by WCI) or observers. New partners must have adopted a greenhouse gas reduction goal that is equivalent to the WCI regional GHG reduction goal and have a plan for reaching the targeted reduction levels.

The main regional goal of the WCI is the "reduction of regional greenhouse gas emission by 15% below 2005 levels by 2020." GHG obligations are based on the six greenhouse gases reported to the UN Framework Convention on Climate Change by the USEPA in the U.S. Greenhouse Gas Inventory and by Environment Canada in the Canada National Inventory Report.[21]

State and provincial goals for GHG reduction

Cap-and-trade programs are one of the ways WCI partners target emissions reductions for stationary sources, energy supplies, and residential, commercial, industrial, and transportation fuels. Table 3.2 provides a list of goals by participating state in the WCI.

Entities or facilities with compliance obligation in the cap-and-trade program include:

- Industrial sources (both process and combustion) with emissions above the threshold at the point of emission.
- Electricity sources/facilities: first jurisdictional deliverer, or the generator for sources within WCI jurisdictions and the first entity over which a partner has regulatory authority that delivers electricity generated outside the WCI into a WCI partner jurisdiction for consumption in that partner jurisdiction.
- Residential, commercial, and industrial fuel combustion at facilities with emissions below the threshold: where the fuels enter commerce in the WCI partner jurisdictions; generally at a distributor; precise point to be determined and may vary by jurisdiction.
- Transportation fuel combustion sources/facilities: where the fuels enter commerce in the WCI partner jurisdictions; generally at the terminal rack, final blender, or distributor; precise point to be determined and may vary by jurisdiction.
- Cogeneration facilities: How to

[20] WCI partners include Arizona, California, Montana, New Mexico, Oregon, Utah, Washington, British Columbia, Manitoba, Ontario, and Quebec, while observers are Alaska, Colorado, Idaho, Kansas, Nevada, Wyoming, Saskatchewan, and the 6 Mexican border states of Sonora, Baja California, Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas.

[21] carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). These estimates are presented in terms of CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas to global average radictive forcing on a 100-year Global Warming Potential (GWP) weighted basis.

Table 3.2: WCI targets, by participating partner

Partners	Short Term (2010-2012)	Medium Term (2020)	Long Term (2040-2050)
Arizona	not established	2000 levels by 2020	50% below 2000 by 2040
British Columbia	not established	33% below 2007 by 2020	not established
California	2000 levels by 2010	1990 levels by 2020	80% below 1990 by 2050
Manitoba	6% below 1990	6% below 1990	not established
New Mexico	2000 levels by 2012	10% below 2000 by 2020	75% below 2000 by 2050
Oregon	arrest emissions growth	10% below 1990 by 2020	>75% below 1990 by 2050
Utah	not established	2005 levels by 2020	not established
Washington	not established	1990 levels by 2020	50% below 1990 by 2050

handle emissions associated with cogeneration facilities is still under consideration by the partners.

Relationship to the biofuel and motor fuel industry

The transportation fuel industry will have to fulfill the emissions requirements established by the WCI. However, the cap-and-trade program excludes carbon dioxide emissions from the combustion of biomass, biofuel, pure biofuels, or the proportion of carbon dioxide emissions from the combustion of biofuel in a blended fuel (e.g., B_{20} or E_{85}) provided these sources are determined to be carbon neutral by the WCI partner in which the emissions occur.

The WCI considers the emissions produced by the combustion from transportation and the combustion from the industrial source. The fact that the emissions from qualified biofuel or biomass are excluded indirectly promotes the consumption of renewable fuels. Similarly, this distinction supports the Federal Renewable Fuels Standard program since it is mainly focused on promoting biofuels production.

The WCI final design has been presented by the partners as the framework for the regional cap-and-trade program. Much of the detail must still be completed. All annual caps through 2020 will be established before the program starts in 2012, but revisions are scheduled for 2015.

Given the preliminary stage of the current cap-and-trade program, it is impossible to accurately measure the impacts that these actions will have on the motor fuel industry. However, the motor fuel industry will have incentives to increase its production of biofuels, and this will be complemented by an increase in biofuel demand from industrial and commercial facilities. These effects are not expected until after the second compliance period.

Accounting for emission levels

Each partner will update the other WCI partners on their climate action plan and GHG emissions inventories every 2 years to ensure that actions are underway at levels consistent with full achievement of the 2020 goal. As members of the board of directors for the Climate Registry, participating states and provinces set standards for the measurement, verification, and public reporting of GHG emissions throughout North America. Partners also provide meaningful information to reduce GHG emissions, and embody the highest levels of environmental integrity. Within the WCI cap-and-trade design, the entities and facilities subject to reporting are those with annual emissions equal or greater than 10,000 metric tons of CO_2e. The Registry is currently voluntary, but is in the process of developing a system to support mandatory reporting programs.

Each WCI partner will have an emission allowance budget under the cap-and-trade program that is consistent with its jurisdiction-specific emissions goal for 2020; they will also have the flexibility to decide how best to allocate this allowance budget. For instance, a partner could give allowances to the emitters operating within its jurisdiction, auction the allowances to a willing buyer, or provide for some combination of the two. The WCI design calls for a minimum auction level of 10% at the start of the program, increasing to at least 25% by 2020.

Compliance under the WCI

Each WCI partner will retain and/or enhance its regulatory and enforcement authority and responsibilities to enforce compliance with the cap-and-trade program within its own jurisdiction. The regulated sources are required to ensure the data are accurate and complete by undergoing third party validation of reported emissions from entities and facilities under the cap.

The WCI requires that at the end of each compliance period, facilities and entities with emissions submit the same number of emission allowances to the government as the emissions they had during the compliance period. If they do not have sufficient emission allowances to cover their emissions, a penalty of 3 allowances will be assessed.

Summary of status

The WCI released its final design for the regional cap-and-trade program in 2008 (WCI, 2009). Work will continue to refine the design through the development of model rules. The timeline agreed to by the WCI partners is that each will begin reporting previous-year emissions in 2011. The first phase of the cap-and-trade program will begin January 1, 2012, with 3-year compliance periods. The second phase will begin in 2015, when the program expands to include transportation, residential, commercial, and industrial fuels.

Washington's Climate Initiatives

The state of Washington is analyzing different alternatives to reduce GHG emissions and thereby face the challenges imposed by climate change. Washington's Climate Advisory Team (CAT) has prepared an interim report that includes recommendations to achieve the state's environmental objectives. Among the CAT goals are job creation and energy independence. In another document (Washington Climate Advisory Team, 2008), CAT recommends considering a low carbon fuel standard such as that which California is pursuing, but also suggests other approaches.

One of these Washington State initiatives is SB6001, "Mitigating the Impacts of Climate Change," effective July 2007. It provides a package of measures to reduce GHG emissions, including getting back to 1990 levels by 2020. By 2035 GHG emissions have to be reduced to 25% below 1990 levels and by 2050, to 50% below 1990 levels. Other measures aim to add 25,000 jobs in the clean energy sector and reduce the expenditure on imported fuel by 20%.

Another important initiative is HB 2815. This Act introduces a framework for reducing GHG emissions in the Washington economy. The main objective is to design a multi-sector, market-based system for regulating GHG emissions. Furthermore, it authorizes a reporting system and establishes a process for maintaining a comprehensive inventory of GHG emissions to track the state's progress in achieving its reduction goals.

The CAT has proposed the following measures to significantly reduce transportation-related emissions:

- Transit, ridesharing, and commuter choice programs
- State, regional, and local VMT (vehicle miles traveled) reduction goals and standards
- Transportation pricing
- Promotion of compact and transit-oriented development
- Improvements to freight railroads and intercity passenger railroads
- Promotion and incentives for improved community planning, building design, and construction in the private and non-state public sectors

For cleaner vehicles and fuels, the CAT recommends:

- Diesel engine emission reductions and fuel efficiency improvements
- Acceleration and integration of plug-in hybrid electric vehicles
- Low carbon fuel standard
- In-state production of biofuels and biofuel feedstocks
- Improved commercialization of advanced lignocellulosic processes

Pacific state and provincial biofuel policies

Identifying the policy actions of Oregon and California regarding biofuel market development is important for understanding the broader context in which Washington State biofuels policies exist. The 3 Pacific states have taken somewhat different approaches to biofuel market development and examining these differences is informative. This section discusses the policies enacted and planned in Oregon and California and how they might relate to the development of recommendations for Washington State.

California

In January of 2007, an executive order from the governor of California (S-01-07) established a low carbon fuel standard (LCFS) on transportation fuel producers, blenders, and importers in the state of California, with an initial goal of reducing carbon emissions from the transportation sector at least 10% (below 1990 emissions levels) by the year 2020. This standard is based on carbon emissions with a full fuel cycle basis, so fuels that have lower net lifecycle carbon emissions count more toward fulfilling the standard than those with higher lifecycle carbon emissions. California's LCFS was initially implemented such that it achieved only modest reductions in carbon emissions, but is now requiring more stringent requirements. The LCFS allows for banking and trading of credits much like the fuel standard specified in the federal Energy Policy Act of 2005.

California's LCFS is designed to achieve 2 primary goals. The first is to encourage investment in current technologies that can help the state meet the 2020 goal of lowering transportation carbon emissions by 10%. The second is to stimulate innovation in transportation fuel technologies that will allow the state to meet a long-term goal of dramatically lowering transportation carbon emissions 80% by 2050. Additionally, the LCFS is designed to attain related goals such as increased economic growth, improved air quality, and greater diversity and reliability of energy sources.

The LCFS requires accounting for all GHG emissions from all the electricity consumed in the state (including transmission and distribution line losses generated within the state or imported from outside the state). In addition, California's LCFS specified that before January 1, 2009, the state board needed to prepare a scoping plan for achieving the maximum technologically-feasible and cost-effective reductions in GHG emissions by 2020. The plan also had to identify and make recommendations on direct emission reduction measures, alternative compliance mechanisms, market-based compliance mechanisms, and potential monetary and nonmonetary in order to achieve the goals specified in the Act. Before January 2011 the state board has to define its GHG emission limits and reduction measures to become operative on January 1, 2012.

An analysis developed by UC Berkley (Farrell and Sperling, 2007) concluded that the LCFS should not be seen as a singular policy. In fact, they propose that the LCFS should be coordinated with other climate change policies. Since the LCFS may have implications for broader issues such as environmental justice and sustainability, it should be implemented within this context. The study indentifies a considerable increase in the administrative capability of the regulating agencies in order to successfully implement the LCFS.

The above study proposes 22 recommendations to be implemented in California's LCFS. They can be summarized as follows:

- The LCFS should apply to all gasoline and diesel used in California for use in transportation, including freight and off-road applications. The LCFS should also allow providers of non-liquid fuels (electricity, natural gas, propane, and hydrogen) sold in California for use in transportation to participate in the LCFS or have the associated emissions covered by another regulatory program.
- Heavy and light duty diesel fuels should be treated differently to prevent the possibility that unrelated increases in diesel consumption could lead to compliance without achieving LCFS goals.
- The LCFS regulation should be imposed on entities that produce or import transportation fuel for use in California.
- GHG emissions from the production of fuels should be included in the LCFS.
- There should be no limit on the ability of any legal entity to trade or bank (hold) LCFS credits. Compliance using banked LCFS credits is allowed with no discount or other adjustment. Borrowing should not be allowed.
- Obligated parties should have the option to comply with the LCFS by paying a fee, which is different from paying a fine for non-compliance.
- Methods and protocols need to be established to verify that claimed credits are accurate.
- If carbon capture and storage (CCS) technologies that are safe and

adequately monitored are developed, CCS projects directly related to the supply of transportation energy should be included within the LCFS.

- Develop a non-zero estimate of the global warming impact of direct and indirect land use change for crop-based biofuels, and use this value for the first several years of LCFS implementation.
- Conduct a 5 year review beginning in 2013 of data, methods, fuel production technologies, and advanced vehicle technologies.

Oregon

Oregon has implemented a suite of biofuels policies (OR HB 2210) that include a 50% tax credit on eligible costs for new renewable energy facilities (such as ethanol production facilities), tax credits for producers and collectors of biofuel feedstocks, tax credits for consumers of biofuels, and a renewable fuel standard for biodiesel and ethanol.

Each of these policies has some aspect that is unique to Oregon State. The facility investment tax credit is notable for its size alone. The credit originally covered 35% of eligible costs, but in 2007 was increased to 50% on projects up to $20 million in size.

To be eligible for the Business Energy Tax Credit under Section 2 of OR HB 2210, the biomass must be produced or collected in Oregon as a feedstock for bioenergy or biofuel production in Oregon. The credit rates are as follows:

- For oil seed crops, $0.05 per pound.
- For grain crops, including but not limited to wheat, barley, and triticale, $0.90 per bushel.
- For virgin oil or alcohol delivered for production in Oregon from Oregon-based feedstock, $0.10 per gallon.
- For used cooking oil or waste grease, $0.10 per gallon.
- For wastewater biosolids, $10.00 per wet ton.
- For woody biomass collected from nursery, orchard, agricultural, forest, or rangeland property in Oregon, including but not limited to prunings, thinning, plantation rotations, log landings, or slash resulting from harvest or forest health stewardship, $10.00 per green ton.
- For grass, wheat, straw, or other vegetative biomass from agricultural crops, $10.00 per green ton.
- For yard debris and municipally generated food waste, $5.00 per wet ton.
- For animal manure or rendering offal, $5.00 per wet ton.

The tax credit for producers and collectors of biofuel feedstocks is based on the energy content of the feedstock; in subsequent amendment to the law, corn grain was excluded and wheat grain delayed from eligibility for 2 years. The credit is only available for feedstocks that are sold or provide for biofuels production. The ethanol fuel standard was dependent on the Oregon Department of Agriculture certifying a statewide annual production capacity of at least 40 million gallons of ethanol, which it did after monitoring ethanol production, use, and sales in Oregon (Oregon Department of Agriculture, 2007).

Implementation of Oregon's RFS for ethanol is also conditional on a minimum volume of in-state ethanol production (40 million gallons); for biodiesel, the RFS of 2% is conditional on 5 million gallons of production per year from sources in Oregon, Washington, Idaho, or Montana; the 5% RFS will be implemented based on production of at least 15 million gallons per year from these states. The upper production minimum has already been met.

Once statewide production capacity reaches that minimum level, all gasoline must contain at least 10% ethanol by volume. That is, a retail dealer may not sell any gasoline unless it is at least 10% ethanol. A similar fuel standard was created for biodiesel. Once the annual biodiesel production capacity of Oregon, Washington, Idaho, and Montana reaches 5 million gallons (15 million gallons), all diesel fuel sold in the state must be 2% (5%) by volume. The definition of biodiesel used in the legislation enacting the RFS is "a motor vehicle fuel consisting of mono-alkyl esters of long chain fatty acids derived from vegetable oils, animal fats, or other nonpetroleum resources, not including palm oil," which means it excludes renewable diesel.

Finally, the consumer tax credit for transportation biofuels is equal to $0.50 per gallon, and may not exceed $200 per registered motor vehicle per year. HB 2210 also requires the development of dispenser labeling.

British Columbia Carbon Tax (BCCT)

The British Columbia carbon tax, effective July 1, 2008, is a consumer tax like the motor fuel tax and provincial sales tax (PST). Table 3.3 provides the tax schedule. All businesses, individuals, and visitors to British Columbia who purchase or use fuel in the province or burn combustibles (tires and peat) for heat or energy will pay the carbon tax (with exemptions) at the time of purchase or use. For instance, it is payable on combustibles such as tires or peat at the time of use. The tax rates are based on $10 per ton of carbon dioxide equivalent (CO_2e) emissions from the combustion of each fuel. The tax rate will increase over the next 4 years as follows:

- July 1, 2009—$15 per ton of CO_2e emissions
- July 1, 2010—$20 per ton of CO_2e emissions
- July 1, 2011—$25 per ton of CO_2e emissions
- July 1, 2012—$30 per ton of CO_2e emissions

There are a number of exemptions from the fuel tax. Of particular relevance to this report is that biofuels and renewable energy such as biodiesel, ethanol, biomass, pulping liquor, and wood are exempt.

One of the main characteristics of the BCCT is that it is revenue neutral, which means that revenues from the carbon tax will be returned to taxpayers through reductions in other provincial taxes. The fact that the carbon tax is revenue neutral can be interpreted as a low income climate action tax credit. The maximum annual tax credit is $100 per adult plus $30 per child. Single parent families can claim the adult amount for the first child instead of the child amount. The maximum annual credit is reduced by 2% of net family income in excess of $30,000 for single individuals and in excess of $35,000 for families. The maximum credit amounts increased to $105 per adult and $31.50 per child starting July 2009.

The credit will be paid together with the federal Goods and Services Tax Credit payments. As such, eligible recipients will receive 25% of the credit each quarter. Individuals who are 18 years of age who meet the residency requirement and who are not incarcerated will be eligible for the tax credit. Table 3.4 shows the impact of the tax rate changes to British Columbia personal income taxes payable by a single individual with wage income and claiming basic credits only.

Finally, the government of British Columbia has declared its commitment to integrating

Table 3.3: British Columbia carbon tax rates (British Columbia Ministry of Finance, 2010).

July 1 of year:		2008	2009	2010	2011	2012
Liquid Fuels						
Gasoline	US¢/gallon	11.59	17.40	23.17	28.99	34.81
Diesel	US¢/gallon	13.27	19.90	26.54	33.12	39.76
Light Fuel Oil	US¢/gallon	13.27	19.90	26.54	33.12	39.76
Heavy Fuel Oil	US¢/gallon	14.95	22.45	29.90	37.40	44.85
Aviation Gasoline	US¢/gallon	11.78	17.64	23.56	29.42	35.29
Jet Fuel	US¢/gallon	12.60	18.89	25.24	31.54	27.83
Kerosene	US¢/gallon	12.31	18.46	24.61	30.77	36.92
Gaseous Fuel						
Natural Gas	¢/GJ*	239.80	359.69	479.59	599.49	719.39
Propane	US¢/gallon	7.36	11.06	14.71	18.41	22.11
Butane	US¢/gallon	8.46	12.74	16.97	21.20	25.43
Ethane	US¢/gallon	4.71	7.02	9.37	11.73	14.09
Pentane	US¢/gallon	8.46	12.74	16.97	21.20	25.43
Coke Oven Gas	¢/GJ*	203.40	305.13	406.81	508.53	610.21
Solid Fuels						
Coal—Canadian Bituminous	$/Ton	20.79	31.18	41.58	51.97	62.36
Coal—Sub-Bituminous	$/Ton	17.72	26.58	35.44	44.30	53.15
Coal—U.S. Bituminous	$/Ton	24.39	36.58	48.78	60.97	73.16
Coke	$/Ton	24.87	37.30	49.74	62.17	74.60
Petroleum Coke	¢/Liter	17.64	26.49	35.29	44.13	52.93
Tires—shredded	$/Ton	23.91	35.87	47.82	59.78	71.73
Tires—whole tires	$/Ton	20.80	31.20	41.60	52	62.40

* GJ means GigaJoule

the carbon tax and cap-and-trade system in order to prevent double taxation. The precise form that integration takes depends on the specific details of the cap-and-trade system created as the result of the multi-party negotiations within the WCI. However, the Carbon Tax Act currently contains provisions which will allow for exemptions from the payment of carbon tax or full or partial refunds of carbon tax paid with respect to fuel, tires, or peat subject to the Greenhouse Gas Reduction (Cap and Trade) Act under which the cap-and-trade system within the WCI will be implemented in British Columbia.

Table 3.4: Income tax reductions ($Canadian) due to British Columbia's carbon tax.

Taxable Income	2008 tax Before cuts	Reduction in 2008 tax	Reduction in 2009 tax
$20,000	$233	$11	$28
$30,000	$1,015	$20	$55
$40,000	$1,654	$34	$90
$50,000	$2,455	$51	$134
$60,000	$3,270	$68	$179
$70,000	$4,085	$85	$224
$80,000	$5,134	$85	$224
$100,000	$7,642	$85	$224
$120,000	$10,582	$85	$224
$150,000	$14,992	$85	$224

Chapter 4: Feedstock availability and economic potential for Washington State[22]

Section 402 of Washington House Bill 1303 directs Washington State University "to analyze the availability of biofuels in the state and to make best estimates ....[of] the types and geographic origins of biofuel feedstock sources that contribute to biofuel production and use in the state...." The legislation directs specific attention to "in-state production of brassica-based biodiesel, and cellulosic ethanol...." In response, this chapter attempts to answer the question: To what extent will Washington farmers grow biofuel feedstocks?

Table 4.1 outlines the organization of the analysis in this chapter. Initially we project state availability of feedstocks from agricultural food and feed crops. These are partitioned between biodiesel feedstocks such as oilseeds and ethanol feedstocks such as field corn and sugar beets. Later in the chapter we project state availability of cellulosic or non-food/feed sources for ethanol and biodiesel. Consistent with the legislative mandate, we trace the origin of these feedstocks among geographic regions within Washington.

We forecast the availability of crop feedstocks for 3 periods: for 2008, a medium future period of 2009-2011, and a longer run period of 2012-2020 under projected market scenarios. Naturally, a much greater degree of certainty is associated with the nearer term projections.

Furthermore, because the development of cellulosics to biofuels is less technologically mature than crop feedstocks, projections for cellulosic feedstocks will emphasize current inventories of these biofuel sources. Finally, the crop feedstock availability projections in this chapter are based on specified market/policy conditions and agro-climatic potential. Estimates of state-level economic impacts, measured as changes in economic

[22] Unlike the rest of this report, Ch. 4 was substantially updated in October 2009 after the original report was submitted to the Washington State Legislature in December 2008.

Table 4.1: Organization of Washington State biofuel feedstock analysis (by geographic region).

Feedstock Source	Current & Short Run (2008)	Medium Run (2009-2011)	Long Run (2012-2020)
Washington State Food and Feed Feedstocks	For Biodiesel (Canola and other oilseeds)		
	Numerical Projections	Numerical Projections	Numerical Projections
	For Ethanol (Corn and sugar beets)		
	Numerical Projections	Numerical Projections	Numerical Projections
Washington State Cellulosic (or non-Food and Feed Feedstocks)	For Ethanol (Wood products, municipal solid waste, etc.)		
	Numerical Projections	None	None
	For Biodiesel (Recycled greases, etc.)		
	Numerical Projections	None	None

welfare and gross state product for new state biofuel incentive policies, are generated from an economic simulation model reported in Chapter 5.

Current and short-run crop feedstock availability

Washington is recognized worldwide for its high quality apples, cherries, wine grapes, pears, potatoes, alfalfa hay, hops, and wheat. However, the state produced less than 1% of the nation's oilseeds (i.e., canola) during the last 2 agricultural censuses (NASS, 2008a, 2008b). Washington's canola yields averaged 1,436 lbs/ac during this period. North Dakota produced over 90% of America's canola in the last 2 agricultural censuses. With limited oilseed production, most Washington biodiesel plants import soy oil from the U.S. Midwest and canola from Canada, or use local recycled cooking oils (Lyons, 2008).

Because they are minor crops in Washington, the U.S. Dept. of Agriculture-National Agricultural Statistics Service (USDA-NASS) does not report annual production statistics for most oilseeds in the state. However, the USDA-NASS Agricultural Census reports statewide harvested oilseed acreages and other statistics each 5 years (NASS, 2008a, 2008b, 2009a). The census data show an average of 17,577 acres for all oilseeds (including canola/rapeseed, mustard, flaxseed, and safflower) over 1997, 2002, and 2007, with an average of 10,448 acres of canola alone (Table 4.2). The relatively high 2002 oilseed acreage represented only one fourth of 1% of Washington's cropland. Washington's oilseeds are used for cooking oils, food condiments, cover crops, biodiesel, and animal feed.

It is useful to place the potential crop feedstock production of Washington State and the United States in an international perspective (Table 4.3). On the world

Table 4.2: Washington State harvested acreage of canola[a] and other oilseeds[b] (NASS, 2008a, 2008b, 2009a).

Year	WA oilseeds	WA canola	Canola as % of WA oilseeds
1997	16,791	13,239	79
2002	20,379	7,776	38
2007	15,561	10,449	67
Average	17,577	10,448	61

[a] Canola and rapeseed, nearly all canola
[b] Mustard seed, flaxseed, and safflower

scene, the U.S. is a minor canola/rapeseed producer with annual production of 0.66 million metric tons in 2007, only 7.4% of Canada's production. As shown in Table 4.3, the U.S. leads in soybean production, but soybean acreage in Washington State averaged only 609 acres over 2006–2008 (FSA, 2008). While soy oil is the primary source of biodiesel in the U.S., its potential is limited by strong food demands for soy and the fact that soy has half the oil content by weight of canola (offset in part by higher yields).

Corn is a potential ethanol feedstock, but Washington averaged only 0.15% of the nation's field corn in recent years (Table 4.4). Washington lacks the high 24-hour temperatures and summer precipitation of the Midwest that permits profitable corn production without irrigation. Consequently, large Pacific Northwest ethanol producers such as Pacific Ethanol's plants at Boardman, Oregon, and Burley, Idaho, import corn from the U.S. Corn Belt.

While only about 1,600 acres of sugar beets were produced in 2008 in Washington, this crop is also a potential ethanol feedstock in Washington. As shown in Figure 4.1, Washington produced 1.5 to 2.5 million

Table 4.3: Leading national producers of potential crop biofuel feedstocks, 2007 (FAO, 2009).

Crop	Country	Production: mill. Metric tons	Crop	Country	Production: mill. Metric tons
Ethanol			Biodiesel		
Corn	USA	332	Soybeans	USA	71
	China	152		Brazil	58
	Brazil	52		Argentina	46
	Mexico	23		China	16
Sugar Cane	Brazil	514	Palm Oil Fruit	Malaysia	75
	India	335		Indonesia	70
	China	106		Nigeria	8
	Thailand	64		Thailand	7
Sugar Beets	France	32	Canola (Rapeseed)	China	10
	USA	32		Canada	9
	Russia	29		India	7
	Germany	26		Germany	5

Note: Not all of these feedstocks are used for biofuel production. For example, virtually none of the sugar beets produced in the United States are used for ethanol. Similarly, most corn and soy go to livestock feed and human food, respectively. Cooking oil absorbs most canola oil. On the other hand, much of Brazil's sugar cane is devoted to ethanol.

tons (60,000–90,000 acres) of sugar beets from 1970 to 1978 before the U&I Sugar Plant closed. This represented 4–7% of U.S. sugar beet production at the time. In contrast, the neighboring state of Idaho, which retains processing facilities, produced 14% of the nation's sugar beets in 2008 (NASS, 2008). The U.S. ranks among the world's top 4 sugar beet producers (Table 4.3). A recent report concludes that sugar beets are an unlikely ethanol source in Washington due to current competition from other irrigated crops, high production costs, and transportation disadvantages (Yoder et al., 2009).

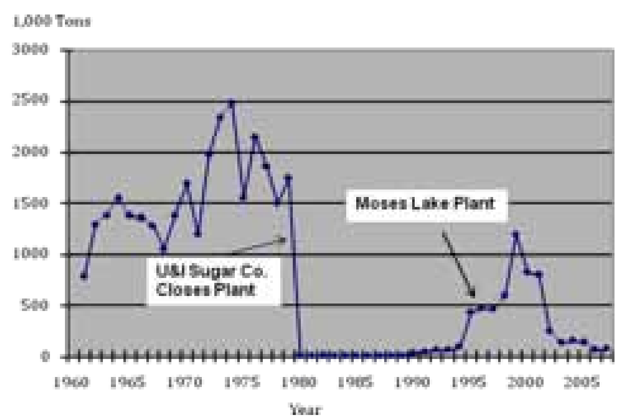

Figure 4.1: Washington sugar beet production (1,000 tons), 1960–2007 (NASS, 2010).

Table 4.5 provides a sharper measure of the adequacy of Washington's current canola, field corn, and hypothetical sugar beet production in relation to specified biofuel targets. The state's 2007 canola could meet only 9/100 of 1% of the state's diesel consumption as biodiesel. An additional 5,112 acres of other oilseeds (Table 4.2) could add to the biodiesel supply, but a considerable amount would be diverted to cooking oils, condiment foods, or other uses as in the past.

Ethanol from Washington's field corn could satisfy 1.99% of the state's gasoline consumption. However, local livestock

Table 4.4: Washington field corn and sugar beet production, 2005–2008 (NASS, 2009b).

Field Corn

	Million Bushels		Thousand Harvested Acres	
Year	WA	WA as % USA	WA	WA as % USA
2005	16.40	0.15	80	0.11
2006	15.75	0.15	75	0.11
2007	25.20	0.19	120	0.14
2008	15.75	0.13	91	0.12
Avg '05-'08	18.28	0.15	91	0.12

Sugar Beets

	Thousand Tons		Thousand Harvested Acres	
Year	WA	WA as % USA	WA	WA as % USA
2005	69	0.25	1.70	0.13
2006	74	0.22	2.00	0.15
2007	84	0.27	2.00	0.16
2008	67	0.25	1.60	0.15
Avg. '05-'08	76	0.25	1.83	0.15

feeders might outbid ethanol producers for local field corn. Livestock feeders would either need to do that, reduce livestock production, or find other feed. Ethanol from sugar beet acreage at 1970's levels could provide 2.64% of the state's gasoline consumption. Again, sugar producers might outbid ethanol producers for sugar beets. Current Washington field corn and historical sugar beet production could supply less than 2 40-million-gallon-per-year (MGY) plants each if the entire production were diverted to this purpose. Only 0.02% of the feedstock requirements of a 40 MGY biodiesel plant could be met by current in-state canola production.

Projections of crop feedstocks by region

Profit-maximizing linear programming (LP) models were used to project crop acreages, diesel and nitrogen use, breakeven prices for biofuel feedstock crops, and grain straw supply for 5 Washington production regions and 2 lengths of run. LP models calculate farmers' profit maximizing land use, input use, and technology selection subject to the quantity and quality of their land and other

Table 4.5: Adequacy of Washington canola, sugar beet, and corn production to meet specified demands.

Item	Canola	Sugar Beets	Corn
Washington 2007-2008 acres for canola and corn, but 1970-1978 average acres for sugar beets	10,449	76,911	90,000
In-state production as % of Washington diesel or gasoline consumption per year	0.09	2.64	1.99
Number of 40 MGY plants supplied by in-state production	0.02	1.78	1.34

Notes: Canola acres are from the 2007 Agricultural Census. The estimated Washington average yield of 1,629 lbs/ac is a 2008 trend projection from census data. Biodiesel from canola requires 18.3 lbs canola/gal of biodiesel (Mattson et al., 2007). The Washington sugar beet acreage is based on the 1970-1978 average when the state produced sugar beets extensively. The estimated 2008 Washington sugar beet yield of 74,600 lbs/ac assumes yield growth proportionate to Idaho. Ethanol from sugar beets requires 80.6 lbs of sugar beets/gal of ethanol (Salassi, 2007). The Washington average yield of 215 bu/ac is a 2008 trend projection from NASS (2008) data; the 2008 corn acres are from the same source. Ethanol from field corn requires 0.36 bu corn/gal of ethanol (Lyons, 2009b). MGY is million gallons per year. Washington consumes about 1 and 2.7 billion gal/yr of diesel and gasoline, respectively.

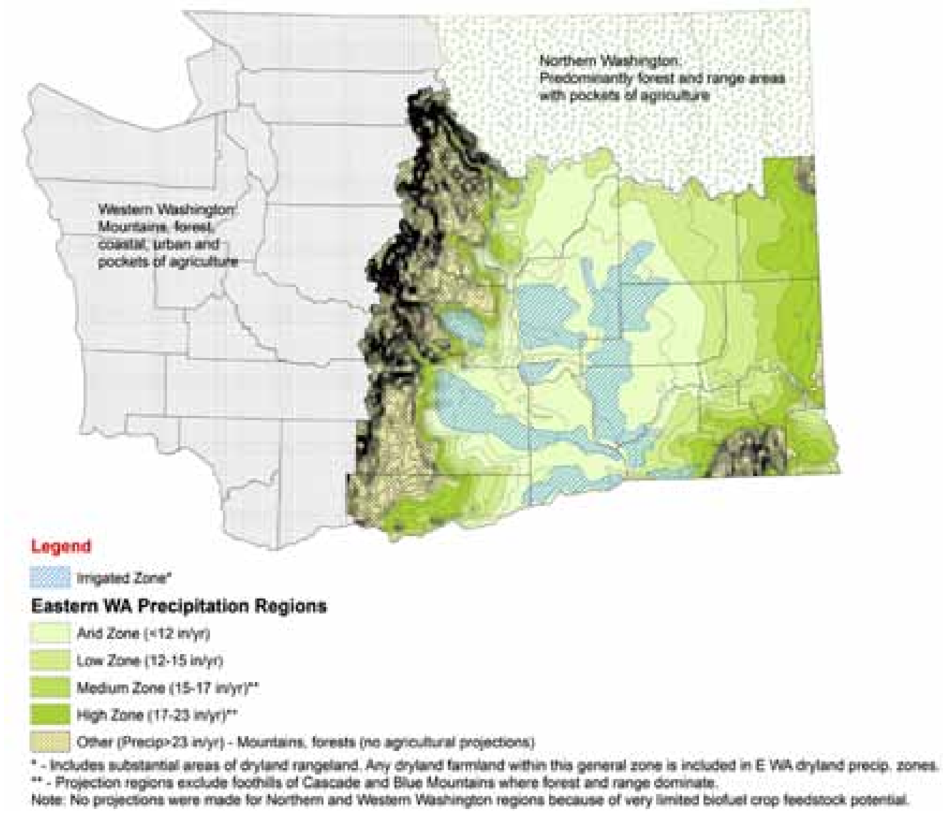

Figure 4.2: Washington State geographic regions for agricultural projections (PRISM Climate Group, 2008; Rupp, 2008; Washington State Department of Ecology, 1999). The mapped areas are meant for general illustration only.

resources, agro-climatic conditions, and policy constraints. The theory, data, and assumptions of the utilized LP models are described in Appendix A4.1.

Four eastern Washington dryland farming regions examined in this chapter include a high precipitation region averaging 17–22 inches/year, a medium precipitation region averaging 15–17 inches/year, a low precipitation region averaging 12–15 inches/year, and an arid precipitation region averaging 7–12 inches/year. A fifth region includes Washington's irrigated farmland (see Figure 4.2), while a sixth region comprising the 19 counties entirely or partially west of the Cascade Mountain Range was not modeled because its current and past production of crop biofuel feedstocks is miniscule (NASS, 2009b). Furthermore, western Washington experimental oilseed production results have been disappointing (personal communication and experiment reports, T. Miller, 2008). The cool and moist summers in western Washington hinder maturation and harvesting of the crop. On the positive side, future research to breed oilseed cultivars suitable for western Washington could improve yields. Furthermore, expanded agronomic experiments and farm trials to identify geographic niches in this region, such as Snohomish County where oilseeds appear to be more productive, should be encouraged (Ryan Hembree, as quoted by Jeff Caanan, December 2008).

Currently, pasture, hay, silage, cane berries, and other high-value fruit and vegetable crops dominate cropland uses in this region. Field crop acreage has been ceding to urban development in some western Washington counties. However, as discussed in the cellulosics feedstocks section later in this chapter, feedstock projections from forestry residues, municipal waste, and other non-food or feed sources are promising for western Washington.

Some special assumptions underlying the feedstock projections merit highlighting. First, the projections include total cropland acres grown for all purposes, both biofuel feedstock and other end uses. Second, total regional cropland acreage is constrained at current levels (Appendix Table A4.1.D3), with the exception of moving land to or from the Conservation Reserve Program (CRP). Third, farmers in these regions have demonstrated they can shift cropping patterns with relatively minor adjustments in their current machinery and labor supplies, with opportunities for custom hiring, so these resources are not constraining. Fourth, the projections assume that crops grown in the dryland regions, including spring wheat, winter wheat, barley, grain legumes (peas, lentils, and garbanzos), and canola, are grown in agronomically sound rotations. Canola, which dominates oilseed production in eastern Washington (Table 4.2), represents all oilseeds in the projections. Past canola research successes such as "Roundup© ready" canola and greater research funding for canola are likely to sustain its dominance. Camelina is an experimental oilseed for arid cropping regions, but it has not been fully cleared by regulatory bodies as a safe meal for livestock feed or biodiesel additive at higher blends (Montana Department of Agriculture, 2009). It may have promise as a blended feedstock with recycled cooking oils (Jeff Caanan, personal communication, December 2008). Washington averaged only 451 acres of camelina in 2007 and 2008 (FSA, 2008).

Crop acreage in the irrigated region is typically dictated by processing plant contracts and relative profitability, so there is less adherence to strict agronomic rotations. For example, wheat or corn can substitute as a rotation crop with potatoes. Consequently, individual crops are modeled within historic bounds in this region (Appendix A4.1: Data and Assumptions for LP Model, Other Modeling Notes). Spring contract prices for autumn harvest are employed for 2008 projections in all regions. New government biofuel incentive programs and changing world energy conditions could induce different market prices. Exceptions to the pricing assumptions occur for land retained in the Conservation Reserve Program (CRP) or planted to a crop with which most growers have no experience.

Economic theory specifies that risk-averse farmers will discount profit or price expectations for crops or land uses they perceive as more risky than average, or equivalently add a bonus to expectations for crops or land uses they see as less risky than average (Anderson et al., 1977; Barry, 1977). Because CRP rents are guaranteed by the U.S. Treasury and thereby have zero risk, they receive a 20% price bonus in the model. Because new crops generally present farmers and scientists with a risky learning curve (Zaikin et al., 2008; F. Young and C. Hennings, personal communications, 2008), expected canola price is discounted by 20%.

Short run (year 2008) projections

Table 4.6 presents 2008 projections for profitable feedstock crop acreage, straw production, and fuel and fertilizer usage for feedstock production for each of the 5 modeled production regions. Of course, projected production of a biofuel feedstock does not mean that the crop will be processed into biofuels since the output

Table 4.6: Projected profitable biofuel feedstock acres, energy and fertilizer use, and harvestable grain straw by geographic region, 2008, Washington State.

Region	Canola	Grain corn	Sugar beets	Diesel use (1000s gal)	Dry Nitrogen use (1000s lbs)	Liquid Nitrogen use (1000s lbs)	Harvest-able Grain Straw (tons)
			acres				
Dryland Zones							
High (17-22 in/yr)	0	0	0	4,074	47,267	0	552,773
Med (15-17 in/yr)	0	0	0	1,509	23,608	0	330,521
Low (12-15 in/yr)	0	0	0	2,276	18,143	0	0
Arid (7-12 in/yr)	0	0	0	2,754	44,422	0	0
Irrigated	0	105,000	0	8,221	82,155	81,454	203,347
WA Total	0	105,000	0	18,334	215,595	81,454	1,086,641

Notes: Crop prices used for projections were May-June contract offers for August 2008, as detailed in Appendix A4 Table A4.1.D4. These were $7.28/bu for grain corn (which was a high contract price spike at the time of analysis), $38/ton for sugar beets, and $21.10/cwt for canola (including a 20% risk discount). Projected prices for other crops as well as available cropland acres, common crop rotations, expected crop yields, crop rotation production costs excluding diesel and nitrogen, diesel and nitrogen input use rates and prices, harvestable straw rates, and other data for each region's model projections are summarized in Appendix Tables A4.1.D1-A4.1.D5. Projected acres of wheat, barley, and grain legumes are reported in Appendix Table A4.1.R1. Harvestable straw is from wheat and barley.

will be distributed among competing uses. Breakeven prices required for feedstock crops to be produced are reported next.

Table 4.6 projects no biofuel crops that are typically irrigated (i.e., grain corn and sugar beets) in dryland eastern Washington in 2008. Of greater importance, no canola production is projected in the short run for these zones. Of course, small canola acreages at recent levels (Table 4.2) can be expected to continue being grown to meet rotational needs, special contracts, or agro-climatic niches. But on the whole, canola rotations do not compete with the dominant rotations of winter wheat-spring grain-spring legumes (or fallow) in the 2 higher precipitation regions or with winter wheat-fallow in the 2 lower precipitation regions (see Appendix Table A4.1.R1 for projections of all dryland crops).

The breakeven prices to make spring canola profitable in the high and medium precipitation regions are $33.68/cwt and $146.31/cwt, respectively (Appendix Table A4.1.R6).[23] These compare to a risk-discounted 2008 spring contract price of $21.10. How realistic are these low 2008 canola acreage forecasts? FSA (2008) showed planted acreage of canola was down in 2008 compared to 2007. Some other oilseeds were higher, but some of these are destined as condiment food crops or cover crops. NASS 2008 surveys also report that Washington wheat, a competing crop, was up in 2008 (NASS, 2009b).

No canola was projected in 2008 for the irrigated zone, but the oilseed is somewhat more competitive there; the breakeven price falls short of the risk-discounted contract price by only $3.45/cwt (24.55 – 21.10) (Appendix Table A4.1.R6). The low-irrigated canola projections square with field reports.

[23] Breakeven prices are viewed in a multiple crop context. The breakeven price is required to make the crop compete successfully with other candidate crops. It does not mean that the crop breaks even with its total costs of production viewed alone.

One canola grower reports that the number of 160-acre irrigation circles of canola in the Columbia Basin dropped from 25 in 2007 to only 7 in 2008 (Jeff Schibel, personal communication, 2008). The "wait and see" attitude of farmers with respect to canola, despite record prices, would seem to justify the risk discounts previously noted. More importantly, record high prices for traditional crops in this region (alfalfa, wheat, corn) discouraged production of alternative crops (Painter and Young, 2008). Similarly, no sugar beet acres were projected for the irrigated zone in 2008. The breakeven price of sugar beets is $43.32/ton, which is about $5 more than its projected price.

Table 4.6 shows a projected 105,000 acres of irrigated grain corn in 2008. The USDA ultimately estimated Washington grain corn growers harvested only 90,000 acres in 2008 (Appendix Table A4.1.R3). This compares to 120,000 acres in 2007 and about 80,000 in the previous 2 years. Our model over-projected grain corn acreage due to the short-lived high contract corn price used in the analysis. Harvestable grain straw production is tabulated as a potential cellulosic source of ethanol. However, some agricultural scientists discourage removing any straw because of the adverse effects on long-run soil quality (Kennedy, 2008).

Potential feedstock availability: medium run (2009-2011)

Except for crop prices and production costs, all assumptions and data sources for the 2009-2011 medium run remain the same as those outlined for the short run. Historically, agricultural commodity price booms have been followed by a return to long run real prices, or sometimes depressed prices, as a result of vigorous supply response. Some commentators argued that the combined momentum of increasing demands from the Chinese and Indian economies and world thirst for biofuels would perpetuate the extremely high agricultural commodity prices of late 2007 and early 2008 (*The Economist*, 2007). However, this report assumes that price patterns will follow historic cyclical patterns, albeit with return to a higher plateau. As an example, farm gate mid-November 2008 prices for soft white wheat in eastern Washington had dropped to $5/bu from the $15/bu spike in January 2008. This late-2008 wheat price was still above historic averages.

For the medium run, it is assumed that all crop prices retreat to a simple 3-year moving average of the 2006, 2007, and 2008 prices. We assume all production costs, except diesel and nitrogen, will increase 7% by the 2010 medium run midpoint compared to 2008 levels, and diesel and nitrogen will increase by 20.3% and 19.4%, respectively (See Appendix A4.1, Prices and cost assumptions, for details).

Table 4.7 presents projections for the 2009-2011 medium run. Again, canola and sugar beets fail to compete profitably with other Washington crops (see Appendix Tables A4.1.R4 and A4.1.R5 for more detail). Due to the cyclical downturn in projected crop prices in the medium run, breakeven prices for canola and sugar beets exceed projected market prices by a greater margin than in the short run (Appendix Table A4.1.R6). Again, the price shortfall for canola is smallest in the irrigated region with a breakeven of $27/cwt compared to a risk-adjusted expected price of $12.45/cwt. The sugar beet breakeven price of $47.14/ton exceeds the projected price of $38.5/ton. With crop prices falling and costs increasing, Washington agriculture shows a return to the historical "cost-price squeeze" in the medium run. The deteriorating profit outlook reduces projected grain corn production from 105,000 acres in 2008 to only 55,000 acres in the medium run (Tables 4.6 and 4.7). This is consistent with Washington's history of wide swings for

Table 4.7: Projected profitable biofuel feedstock acres, energy and fertilizer use, and harvestable grain straw by geographic region, medium run (2009-2011), Washington State.

Region	Canola	Grain corn	Sugar beets	Diesel use ('000 gal)	Dry Nitrogen ('000 lbs)	Liquid Nitrogen ('000 lbs)	Harvestable Grain Straw (tons)
				acres			
Dryland Precipitation Zones							
High (17-22 in/yr)	0	0	0	4,074	40,821	0	552,773
Med (15-17 in/yr)	0	0	0	1,509	23,608	0	330,522
Low (12-15 in/yr)	0	0	0	964	15,551	0	0
Arid (7-12 in/yr)	0	0	0	2,754	44,427	0	0
Irrigated	0	55,000	0	7,824	74,655	73,954	203,347
WA Total	0	55,000	0	17,125	199,062	73,954	1,086,642

Notes: Crop prices used for projections were 2006-2008 averages. These were $5.18/bu for grain corn, $38.5/ton for sugar beets, and $12.45/cwt for canola. The canola projection used a contract price of $15.56/cwt with a 20% risk discount. Projected prices of other crops as well as available cropland acres, common crop rotations, expected crop yields, crop rotation production costs excluding diesel and nitrogen, diesel and nitrogen input use rates and prices, harvestable straw rates, and other data for each region's model projections are summarized in Appendix Tables A4.1.D1-A4.1.D5.

1960–2008 grain corn production (NASS, 2009b).

Potential crop feedstock availability: long run (2012-2020)

Linear programming is an inherently inappropriate tool for long run projections because of the lack of general equilibrium adjustments in all prices. In place of integrated quantitative modeling, long run Washington crop feedstock availability will be discussed qualitatively based on technology trends, statistical supply elasticities, and trade relationships.

Current and future Washington canola yield prospects

Canola. Although some irrigated canola in Washington has yielded up to 3,600 lbs/ac (Painter and Roe, 2007), a recent statewide average is 1,436 lbs/ac (NASS, 2008b, 2009a). Washington canola yields are modest for several reasons. Canola prefers cooler temperatures during flowering than those prevalent in eastern Washington. Stand establishment is difficult. A WSU scientist conducting an irrigated canola experiment at Lind, Washington, found it necessary to replant winter canola to lower-yielding spring canola due to stand failure in 5 of 6 years (Zaikin et al., 2008). A USDA-Agricultural Research Service researcher experienced similar stand establishment problems with dryland canola at Ralston, Washington, as did a nearby grower (Young et al., 2008; F. Young and C. Hennings, personal communications, 2008). Canola is vulnerable for as long as 6 years to carryover damage from wheat herbicides commonly used in Washington, including imidazolinone- and sulfyurea-types (Pursuit©, Glean©, Finesse©). Canola, dry peas, and barley showed no yield growth over the past 20 years at the modest 10% statistical significance level. In contrast, alfalfa, potatoes, wheat, and grain corn yields grew at significant rates of 0.9, 0.6, 0.8, and 0.9% per year, respectively. Research breakthroughs could accelerate canola yield growth in Washington. However, given the much greater economic importance of canola in North Dakota and Canada, these areas may outpace Washington in yield and acreage growth and depress the canola market. The central Canadian prairies offer a more suitable climate for canola and Canada has pursued a more active research and regulatory program to improve canola yields and quality (Mattson et al., 2007).

Despite the discouraging prospects for canola and other oilseeds in Washington, it is important to recognize that oilseeds have received little or no previous agronomic and genetic research to make them regionally adaptable. This stands in stark contrast to the 100 years of focused research on wheat and potatoes in the Pacific Northwest. The projections in this chapter do not incorporate potential future oilseed research breakthroughs that could improve their economic competitiveness.

Comparative advantage of Washington sugar beets and field corn

Washington farmers' responses to market signals speak clearly about the state's lag in sugar beet production (recall Table 4.4 and Figure 4.1). In contrast to Idaho, Washington has struggled to maintain profitable sugar beet processing facilities over the past 3 decades. The American sugar beet industry has been downsizing. Idaho's acreage declined by 22% in 2008 compared to 2007. In 2008 it stood at its lowest level since 1977 (Wilkins, 2008). Strict import quotas and tariffs protect the American sugar industry from lower-cost foreign producers. Any trade reform would further shrink the U.S. sugar industry. Nonetheless, production records from the 1970s in the irrigated Columbia Basin show that Washington growers have the capacity to grow large quantities of sugar beets if economic incentives return (Figure 4.1).

As noted in Table 4.4, Washington produces only 0.15% of the nation's field corn. Lacking the favorable climate of the Corn Belt for dryland corn production, and possessing a portfolio of higher value crops for its irrigated cropland, Washington will continue to be a small field corn producer. However, Washington growers can expand production of this irrigated crop, as shown by past fluctuations in production.

Statistical supply response to price of Washington biofuel feedstocks and competing crops

According to the analysis above and empirical estimates by Zheng and Shumway (2008), corn and sugar beets could respond to higher prices induced by market forces or public subsidies and become viable sources of biofuel feedstock. Zheng and Shumway find that sugar beets demonstrate the largest short-run supply elasticities (responsiveness to price changes). However, this result is based on very low production levels for much of the estimation period (recall Figure 4.1), so its reliability is unclear. The elasticity estimates for irrigated field corn in Washington are considered more reliable because they are based on continuous production of this crop at substantial levels. Although the short-run elasticity estimates for corn are somewhat smaller than for sugar beets, long-run elasticity estimates are greater (Zheng and Shumway, 2008). Thus, corn could be more responsive to price and subsidy stimuli over the long run.

Supply responsiveness for canola is hard to judge due to the limited quantity produced in the state, the short time period for which reliable state-level data are available, and the lack of promising production experience in the state. Consequently, we draw no conclusions about the prospects for this source of in-state biofuel feedstock responding to price or subsidy incentives.

International trade opportunities

It should be borne in mind that Washington is an open economy with the other 49 United States and a partially open economy with the rest of the world. As shown by Pacific Ethanol's early experience in the Pacific Northwest, midwestern corn can be imported in sufficient quantities to sustain large plants, albeit with profitability challenges. Washington's proximity to the Canadian prairies offers a transportation advantage in purchasing canola from the world's largest exporter of this crop. Its location on the Pacific Rim also offers transportation advantages for importing southeast Asian palm oil.

Long-run prospects

Given Washington's comparative advantage in non-feedstock crops, weak yield growth for most feedstock crops, and inconclusive data for feedstock supply response, we conclude that in-state production of oilseeds, sugar beets, and field corn is likely to account for only a small fraction of state fuel needs in the long run. Current production of oilseeds, field corn, and sugar beets is extremely small by national standards. Large ethanol and biodiesel processors in the Pacific Northwest currently import nearly all of their virgin feedstocks. We do not see regional and international comparative advantages for feedstock and non-feedstock crops changing markedly.

Cellulosic biomass feedstock potential

This section covers Washington's biomass feedstock potential. The analysis below utilizes different methods from the economic approaches applied above. We begin by explaining these differences and the reasons for applying different methods for biomass assessment.

Inventory analysis versus profit-maximizing response

Potential supplies of Washington's cellulosic feedstocks will list current inventories rather than project profit-maximizing production as in the previous crops section. There are 3 reasons why an inventory rather than an economic response approach is appropriate for analyzing Washington's cellulosic feedstocks:

- Cellulosic feedstock sources like forestry residues and municipal waste do not compete for a common cropland resource as in the LP profit-maximizing methodology described in Appendix A4.1 (Economic Theory Underlying Linear Programming Projections).[24]
- Some cellulosic sources like grain straw and food processing residue can be derived from the crop projections in the previous section, plus end use allocations.
- The technologies to convert cellulosic feedstocks to biofuels are relatively immature, making it difficult or impossible to obtain demand prices for these feedstocks.

There currently are no commercial cellulosic ethanol plants in Washington. However, substantial research is underway to develop commercially feasible technology to convert cellulosic sources to biofuel. Two major examples are Pacific Ethanol's pilot plant funded by the U.S. Department of Energy and Washington State University's Center for Bioproducts and Bioenergy at its Richland campus. As biofuel conversion technologies mature, these sources could provide potentially large biomass feedstock for Washington. The inventory of Washington's potential cellulosic feedstocks in this chapter is a first step in answering

[24] However, they compete with other land uses, so care must be made to avoid imputation of potential output when it would require changes in land use. The inventory approach does not formally consider alternative land uses (in contrast to, say, linear programming approaches used to estimate potential crop production). Note also that the inventory approach measures the technically feasible quantities, and hence does not speak to what might be economically possible.

important questions for policy-makers, business people, and researchers concerning future research and development.

Another team of researchers has recently provided economic response projections integrated over crop and cellulosic feedstocks for several multi-state regions (Biomass Research and Development Board, 2008). We feel the strong assumptions regarding immature cellulosic conversion technologies and transportation costs required for this integrated approach make it inappropriate for Washington State.

Overview of cellulosic inventories for Washington

In December 2005, Washington State University researchers in cooperation with the Washington State Department of Ecology completed a county-level inventory for Washington across 45 different biomass feedstocks identified by the Ecology "beyond waste" program (Frear et al., 2005).

The inventory of cellulosic feedstocks for Washington State, derived from that study, is sub-divided into 4 main categories: municipal waste, forestry biomass, field residue, and dedicated energy crops (Figure 4.3). The total available lignocellulosic biomass in Washington is approximately 17 million dry tons, where 66% comes from forestry residues.

A considerable portion of this biomass is unlikely to be economically useful to a future biofuels industry, primarily because of transportation and collection/conversion costs. In addition, new and existing uses will compete for the available tonnage in the marketplace.

The key findings of the cellulosic inventory are that:

- Washington is rich in annual production of under-utilized cellulosic biomass (~17 million dry tons/yr).
- The quantity inventoried contrasted sharply to the lower numbers reported by Perlack et al. (2005) in the federally funded Billion Ton Report (<10 million dry tons/yr).
- Cellulosic material represents the overwhelming majority of the total inventory (~85%).

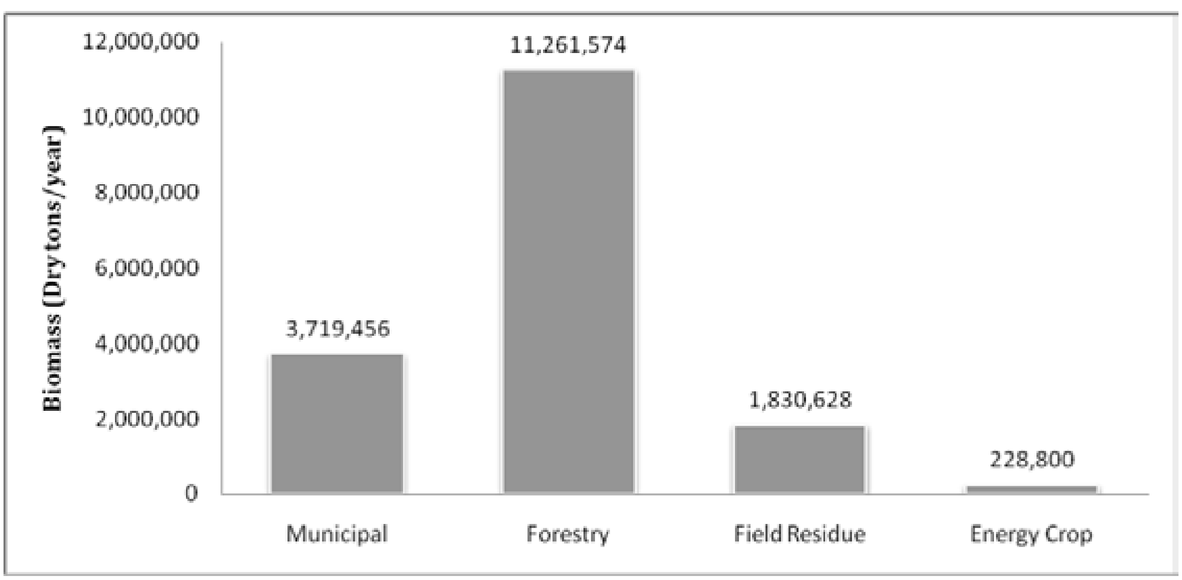

Figure 4.3: Washington's potential biomass and bioenergy by group.

To make the inventory more valuable as an assessment of the likely cellulosic biofuel feedstock supply, the original inventory was modified in several important respects (Frear, 2008):

- Because biofuel production facilities will undoubtedly face economies of scale, they will need reliable sources of feedstock within reasonable transportation distances. Consequently, small quantities of cellulosic biomass that are too far from potential biofuel production facilities were excluded.
- The forest thinning inventory was revised based on unpublished preliminary data compiled at Oregon State University through their contract for the second version of the Billion Ton Report (Skog, 2008).
- The potential for cellulosic biomass from dedicated energy crops was added. The cellulosic energy crops inventoried were switchgrass and poplar.

The above modifications provided important refinement to the inventory for purposes of cellulosic biofuel feedstock measurement. However, it is important to note that limitations remain in the biomass inventory. For example, it does not account for environmental impacts of biomass removal, the inventory is county rather than mileage-based, the economics of competing markets were not included, and it ignores a number of issues regarding collection, pre-treatment, and transportation. The importance of developing decentralized energy densification and pretreatment strategies that can fit in with large-scale fuel conversion plants will be discussed in Chapter 6.

This section presents the county-level estimates modified by Frear (2008) as benchmark upper bound levels of cellulosic feedstocks in Washington State. The methods used for these estimates are detailed in Appendix A4.2. After presenting these estimates, we include a brief comparison of forestry resource biomass from different data sources to provide perspective on the results.

Field residues

Sixty-one percent, or 1,116,683 tons per year of the total field residue listed in Table 4.8, is from wheat straw. This inventory is similar to the 2008 LP projection in Table 4.7 of 1,086,642 tons of grain straw. The top 3 wheat-producing counties in Washington—Whitman, Lincoln, and Adams—account for 46% of field residue. The assumed 25% collection rate for widely dispersed low energy density crop residues reduces the total biomass available for energy use.[25] Estimates of crop residues by the Western Bioenergy Assessment Team, (2008) were within 18% of Frear (2008).

Forest residues from logging, tree thinning, mills, and land clearing

Six western Washington counties—Grays Harbor, Lewis, Cowlitz, Snohomish, Pierce, and Clallam—account for 4,267,239 tons per year, or 38% of the state's forest residues. Stevens and Yakima Counties in eastern Washington also possess substantial forest residues.

As with field residues, the forestry biomass listed in Table 4.9 is disperse and of relatively low energy density. These facts make economical utilization for biofuel challenging. Of additional concern is the terrain where these feedstocks are located, as they require extensive infrastructure improvements and associated cost. Another important factor in this inventory is the use of mill residue which already has an

[25] Available crop residue depends critically on how much residue is and should be left for soil conservation practices.

Table 4.8: Biomass from wheat, barley, grass seed straw, corn stover, and other crop residues by Washington State county for 2007 (Frear, 2008). Numbers are in tons per year.

Adams	178,219	Franklin	72,207	Lewis	0	Snohomish	4,427
Asotin	13,249	Garfield	60,733	Lincoln	250,511	Spokane	133,158
Benton	50,863	Grant	178,476	Mason	0	Stevens	5,884
Chelan	2,266	Grays Harbor	0	Okanogan	13,462	Thurston	0
Clallam	0	Island	0	Pacific	0	Wahkiakum	0
Clark	0	Jefferson	0	Pend Oreille	0	Walla Walla	163,936
Columbia	68,008	King	0	Pierce	0	Whatcom	45
Cowlitz	0	Kitsap	0	San Juan	0	Whitman	415,992
Douglas	68,154	Kittitas	881	Skagit	4,326	Yakima	130,107
Ferry	0	Klickitat	15,724	Skamania	0	Statewide TOTAL	1,830,628

approximate 95% utilization rate in existing markets. Hence, while these residues are undoubtedly biomass energy sources, they are not net new sources. Care should be made not to double count when the objective is to inventory potential new sources.

Although there are numerous other feedstocks with existing competitive uses (for example, straws to Asian markets), forest residue stands out in its overwhelming utilization rate and therefore the degree to which new or existing markets will be impacted by the introduction of new uses. An important economic consideration involved with tree thinning are the ancillary benefits of forest health restoration and productivity, along with reduced wildfire risk and suppression costs (Mason et al., 2006).

Table 4.10 compares Frear's (2008) forestry residues estimates to those from Skog (2008) and the Western Bioenergy Assessment Team (WBAT, 2008). The lower total residue of 8,540,515 tons/yr for Skog versus 11,261,574 tons/yr for Frear arises from Skog's omission of logging residue and lower estimate from thinning. WBAT's much lower estimate for total forestry residues arises in part because they included only a conservative estimate of available mill residue for biofuels, while the other 2 data sources included all mill waste, even though much of this might be allocated to other uses. Note however, if this waste were to be switched to biofuels, there would be a loss of the direct conversion of waste to energy in co-generation which is extensively used. Hence, net energy increases from mill wastes are likely to be small. Conservatism regarding the availability of materials for biofuels characterized WBAT's assumptions for all types of forestry residues. However, WBAT was the only source to provide an estimate for orchard and vineyard prunings (363,672 tons/yr).

Municipal solid waste

Municipal solid waste relevant for cellulosic biofuel feedstock amounts to an estimated 3,719,456 tons per year. Three populous Puget Sound counties—King, Pierce, and Snohomish—account for 53% of Washington's municipal solid waste (Table 4.11). As with mill waste, there are existing competitive and well-entrenched markets for paper waste which will need to be considered for any potential biofuel project. Other important issues deal with the economics of collection and rerouting woody waste from landfills. WBAT (2008) estimated Washington generated 168,059

Table 4.9: Forest residues from logging, tree thinning, mills, and land clearing by Washington State county for 2007 (Frear, 2008). Numbers are in tons of dry biomass per year.

Adams	277	Franklin	1,350	Lewis	910,463	Snohomish	905,969
Asotin	118,256	Garfield	6,692	Lincoln	8,132	Spokane	98,279
Benton	3,941	Grant	1,966	Mason	361,103	Stevens	642,904
Chelan	171,776	Grays Harbor	1,110,488	Okanogan	256,150	Thurston	437,870
Clallam	661,090	Island	10,860	Pacific	312,646	Wahkiakum	96,012
Clark	137,609	Jefferson	254,180	Pend Oreille	305,118	Walla Walla	8,899
Columbia	7,644	King	376,045	Pierce	679,418	Whatcom	255,814
Cowlitz	905,780	Kitsap	235,591	San Juan	19,557	Whitman	713
Douglas	805	Kittitas	158,713	Skagit	407,625	Yakima	586,462
Ferry	228,157	Klickitat	207,412	Skamania	369,808	Statewide TOTAL	11,261,574

Table 4.10: Comparison of total Washington forestry residues by data source.

Data Source	Type	Dry Tons	Cost ($/dry ton)
Skog, 2008	Thinning	2,720,865	40
Skog, 2008	Other Removals	10,319	30
Skog, 2008	Urban Wood Residue	530,980	N/A
Skog, 2008	Mill Residue	5,278,351	N/A
Total		8,540,515	
WBAT, 2008	High Case	1,855,034	30
Total	N/D		
Frear, 2008	Logging Residue	1,901,072	42-122
Frear, 2008	Forest Thinning	3,663,554	42-122
Frear, 2008	Mill Waste	5,278,353	20-60
Frear, 2008	Land Clearing	418,595	N/A
Total		11,261,574	

N/A: Not Available
N/D: Not Disaggregated by Type
Note: All estimates are preliminary and subject to revision.

tons/yr of sewage sludge. Frear (2008) excluded this municipal waste feedstock.

Switchgrass and hybrid poplar

Switchgrass, Indiangrass, big bluestem, and arundo grass were not included in the crop feedstock projections because a) Washington has no commercial forage grass ethanol plants to establish demand prices for these potential feedstocks and b) increases in these irrigated grasses would imply decreases in other irrigated land uses. A recent study showed that on irrigated lands with appropriate water and nutrient supply, 2 annual cuttings of a suitable variety of 3rd year switchgrass produced a combined yield of 25,400 lbs/acre (Collins, 2007). At a conversion rate to ethanol of 80 gallons/dry ton, this amounts to 1,016 gallons of ethanol/acre, an impressive yield. However, the question is whether switchgrass can compete with other irrigated crops once conversion technology is perfected and a demand price is determined. The most likely land to be converted to switchgrass is that currently used to produce forage—especially alfalfa hay and grass—which currently has a low value.

Considerable research, breeding, and commercialization of hybrid poplar are underway in the Pacific Northwest. National Agricultural Statistics Service (NASS, 2009b) data show approximately 40,000 acres planted in Washington. Frear (2008) estimates present and future production could be 28,800 dry tons/yr. It takes about $58/dry ton to farm and harvest poplar. Presently, the industry utilizes the majority of the wood for high-value products and services, and the residue for pulp or heat. It is unlikely the entire harvest would be committed to energy production.

Frear (2008) assumed that 50% of the hybrid poplar harvest tonnage would be available as residue for fuel production, even though present industry business plans do not include biofuels. Thus, the maximum and minimum numbers for Washington State hybrid poplar production are 28,800 to 14,400 dry tons/yr wood for fuel. Since a dry ton produces 75 gallons, 1–2 MGY of ethanol could be produced from this feedstock. Hybrid poplar was not included in the linear programming projections due to lack of market prices as a biofuel feedstock.

Recycled cooking oils and surplus fats

Recycled cooking oils and surplus fats are not a lignocellulosic biomass feedstock, but they currently are an important niche biodiesel feedstock. Frear (2008) did not inventory this relatively small feedstock; however, the Western Bioenergy Assessment Team (2008) estimated Washington could supply 65 million pounds/yr of edible and inedible animal tallow plus 13 million pounds/yr of recycled yellow grease. Combined, these 2 sources could provide an estimated 10.4 MGY of biodiesel. A survey of biodiesel refineries in Washington found that small refineries relying on this feedstock were among the most economically durable in the state (Lyons, 2008; Domby and Young, 2008).

Table 4.11: Municipal solid waste: Non-wood yard waste, paper, and urban wood waste by Washington State county for 2007 (Frear, 2008). Numbers are in tons of dry biomass per year.

Adams	8,100	Franklin	42,957	Lewis	22,422	Snohomish	360,220
Asotin	10,025	Garfield	1,348	Lincoln	12,261	Spokane	282,768
Benton	80,402	Grant	36,946	Mason	59,158	Stevens	35,745
Chelan	48,080	Grays Harbor	46,257	Okanogan	3,342	Thurston	101,010
Clallam	39,276	Island	31,671	Pacific	21,287	Wahkiakum	1,875
Clark	156,657	Jefferson	13,454	Pend Oreille	14,368	Walla Walla	39,761
Columbia	1,914	King	1,053,312	Pierce	570,127	Whatcom	87,045
Cowlitz	120,433	Kitsap	129,483	San Juan	6,253	Whitman	23,415
Douglas	15,972	Kittitas	7,267	Skagit	53,233	Yakima	150,553
Ferry	2,835	Klickitat	3,936	Skamania	3,638	Statewide Total	3,719,456

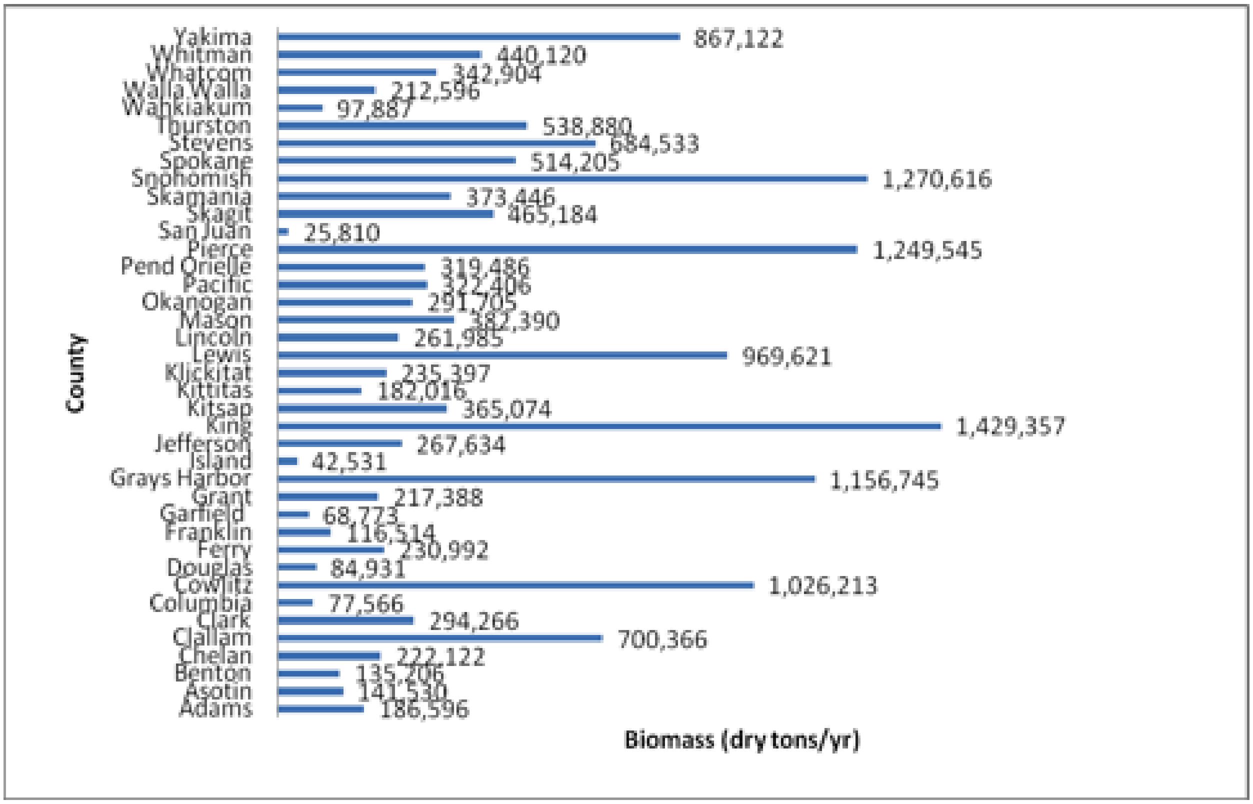

Figure 4.4: Lignocellulosic biomass by Washington State county for 2007 (Frear, 2008). Numbers are in tons per year.

The Puget Sound region has a transportation advantage for recycled cooking oils attributable to its population density. In the past, used cooking oils presented a disposal cost for restaurants, so acquisition prices are often close to zero. If households sorted recycled oils and greases at the source and these products were collected by existing recycling services, the supply of these feedstocks could be increased at relatively low cost. However, processing costs for recycled cooking oils are higher than for virgin feedstocks due to the need to remove contaminants.

Total lignocellulosic biomass in Washington State per year

The total available lignocellulosic biomass/yr in Washington is estimated to be approximately 17 million dry tons, with 66% of this coming from forestry residues (Figure 4.3).

Figure 4.4 shows substantial concentration of this biomass in King and other counties with large urban populations and/or forest resources. If one assumes a rough conversion factor of 75 gallons of ethanol/dry ton of lignocellulosic biomass utilized, the biofuel potential represented amounts to 1.275 billion gallons of ethanol. This is obviously an impressive number, but there are several challenges to overcome.

First, the cost of collection, transportation, and distribution of such disperse, energy-dilute biomass could be quite high. Second, there are many scientific and engineering hurdles yet to be overcome involving pre-treatment, fermentation, thermal processing, distillation, catalysis, purification, and mass distribution. Third, existing and new markets for some biomass, such as fiber board for wood products and recycled paper and co-generation for mill residues, will reduce quantities available for biofuel production. Finally, water and nutrient usage may limit conversion of some biomass to biofuels. These constraints will permit utilizing only some fraction of this biomass for biofuels. There also remains the need to assess supply, collection, transportation, and distribution costs, as well as competitive markets for these feedstock sources.

Conclusions

With respect to crop feedstocks such as oilseeds, sugar beets, and field corn, in-state production is likely to account for only a very small fraction of Washington's fuel needs. The current production of oilseeds and sugar beets is extremely small by national standards and the projected breakeven prices for Washington farmers to profitably produce these crops exceed current and projected prices. Large ethanol and biodiesel processors in the state import nearly all of their virgin feedstocks.

This is not to say that Washington agriculture is impoverished. Quite the contrary: Washington is the second largest agricultural state by value in the Pacific and Mountain regions after national leader California, and 11th in the nation. Washington is recognized worldwide for its high quality apples, cherries, potatoes, hops, wheat, sweet corn, wine grapes, and livestock products. These high-value products with a local comparative advantage maximize income to Washington's farmers and ranchers. Based on competitive markets, the gains from producing and exporting these crops to the rest of the country and the world maximize the state's agricultural income.

The outlook for exceeding a 2% ethanol blend target in gasoline based on in-state feedstocks is less demanding. Indeed, Washington's 2007 field corn production could satisfy a 2.39% ethanol blend if it were all diverted to biofuels. However, local livestock feeders might outbid ethanol producers for local field corn. Similarly, sugar beet acreage at 1970s levels with trend increases in yields would provide a 2.64% ethanol blend if beets were diverted entirely to biofuels. Of course, increases in sugar beets imply decreases in some other crop. The biodiesel picture is less promising since the state's 2007 canola acreage would meet only 9/100 of 1% of the state's biodiesel consumption.

In comparison to crop biofuel feedstocks, the long-run potential for biofuel production from lignocellulosic biomass in Washington State is promising. Washington ranked fourth after California, Texas, and Oregon among 19 western states in available biomass (Western Bioenergy Assessment Team, 2008). The total annual lignocellulosic biomass in Washington State is estimated at approximately 17 million dry tons. This biomass could theoretically produce an estimated 1.275 billion gal/yr of ethanol, or 47% of Washington's 2.7 billion gal/yr gasoline consumption (Frear, 2008). However, only a fraction of this biomass would be converted to biofuel in the current technological environment due to the high costs of collection and processing. In addition, competing and existing markets for some biomass would reduce the available tonnage for biofuels.

While the lack of technological maturity for producing biofuel from lignocellulosic biomass precludes a reliable estimate of the biofuel fraction at this point, our assessment is that vigorous ongoing research, such as that at DOE's pilot plant in Boardman, Oregon, and WSU's Richland campus, has promise to solve the engineering, biochemical, and logistics barriers to exploiting Washington's abundant lignocellulosic biofuel feedstocks. Chapter 6 provides additional research and development recommendations to accelerate that process.

Chapter 5: Market incentives for Washington biofuels & feedstocks

This chapter includes our market incentive recommendations and a discussion of the strengths and weaknesses of various related general policy approaches.

Part I: Market incentive recommendations

The goals in Section 402 of the biofuel incentive legislation and our economic analysis in Part II of this chapter and elsewhere have led us to the following recommendations:

- The use of a carbon emissions intensity tax on fuel for renewable and nonrenewable fuels.
- That revenues from the carbon-emission tax be used in one (or both) of 2 ways:
    - For a renewable energy fund such as the Energy Freedom Fund to support tax credits and research and development for low carbon fuels. We recommend tax credits only to the extent that they are offset by carbon emissions tax revenues.
    - To reduce other taxes such as (in Washington State) sales taxes and B&O taxes.
- Where there is public investment in infrastructure and R&D, it should be targeted to complement private investment and funded from an alternative energy fund, not from general funds.
- Direct incentives for in-state feedstocks or co-products, should not be provided, with specific exceptions.
- A binding state-level renewable fuel standard should not be imposed.

It might appear at first glance that carbon emissions are prioritized over in-state biofuel/feedstock production and reducing petroleum dependence, but we argue below that while purely volume-based biofuel policy instruments can be relatively effective in reducing dependence on petroleum fuels and promoting in-state production of biofuels and feedstocks, they will not necessarily be effective at reducing carbon emissions.

In contrast, we argue that given the nature of petroleum fuels and Washington's characteristics, carbon-based incentive instruments will provide the most effective foundation for addressing all 3 primary goals. As such, a carbon-based policy suite can be thought of as an umbrella under which the other policy goals can be addressed.

The carbon emissions intensity tax would tend to depress the quantities of high-carbon fuels consumed, thus reducing dependence on petroleum fuels. The carbon tax would also promote in-state biofuel and feedstock production to the extent that it induces substitution away from high-carbon to low-carbon renewable fuels. However, this shift toward renewable fuels would be partially offset by lower blended fuel consumption due to higher blended after-tax fuel prices.

Of the 2 basic targets for carbon tax revenues, direct support of renewable fuel markets is preferred over reductions in existing taxes given that one of the primary stated objectives of the enabling legislation is to support the biofuel industry. Reductions in existing taxes would likely be a less costly approach for reducing petroleum dependence and reducing greenhouse gas emissions, but it would have a weaker effect on support for biofuel market development.

If the state chooses to provide direct support for the biofuel industry based on carbon tax revenues, it can do so by providing tax credits (subsidies) to low-carbon renewable fuels, and/or it can invest carbon tax revenues in research and development into advanced biofuels. The tax/subsidy combination will reduce the price increase of blended fuels due to the carbon tax and reduce the price of biofuels relative to all other goods in the economy. It can also better target in-state fuel production and strengthen private incentives for research, development, and adoption of advanced biofuel production technologies. The carbon emission tax revenues can be used to help support early development of Washington State's biofuel industry by funding R&D for advanced biofuels, feedstocks, and infrastructure.

As the economics literature shows for the corn market, energy feedstock producers benefit substantially from biofuel subsidies. Therefore, this tax/subsidy program is likely to benefit feedstock producers also. Alternatively, the second target mentioned above is to use carbon tax revenues to offset existing distortionary taxes such as business and occupation or sales taxes. This can be beneficial to the economy as a whole by improving the private after-tax returns to labor and capital in Washington State industries in general.

Below we consider the components of our recommendations in more detail, including implementation issues, an extended review of the literature that compares policy alternatives, and the results of our computable general equilibrium model and analysis of Washington State and its energy markets.

Some pros and cons of pursuing carbon-based policies

Following Farrell and Sperling (2007, p. 7), the carbon intensity of a fuel is defined as the total life-cycle global warming intensity per unit of fuel energy measured in net CO_2 equivalent (CO_2e) emissions of greenhouse gasses of the fuel, measured over its life-cycle. Life-cycle analysis (LCA) is the term used to describe the methods of estimating the life-cycle characteristics of a good.

Focusing policy directly on life-cycle carbon emissions reduction can provide a foundation for motor fuel diversification and market development, and can help target the most environmentally benign fuels in both the short- and long- run to spur further development of low-carbon fuels and the feedstock production to support them.

However, estimating the net carbon emissions over the life of the fuel from inception to combustion is a complicated problem, especially for biofuels.[26] The analysis entails consideration of both the direct combustion emissions, the emissions due to the production, and distribution of the biofuels and feedstocks. It is beyond the scope of this report to discuss the details of these estimation procedures, but among the complications of most recent concern is how to estimate the indirect GHG emissions from land use conversion (and associated biomass disturbance) that can result from feedstock production

[26] See our interim report at http://www.ses.wsu.edu/research/EnergyEcon.htm, Section 4, and Appendix 4 for a more detailed review of LCA as it applies to life-cycle carbon emissions estimation.

acreage expansion (Searchinger et. al., 2008; Fargione et. al., 2008).

Introducing carbon accounting into policy provides benefits, but also results in costs. One of the primary potential benefits of biofuels is greenhouse gas emissions reduction relative to fossil motor fuels. It is also a benefit that is not generally accounted for in the marketplace except through the effects of environmental regulation. Further, biofuels do not necessarily provide greenhouse gas emissions reduction. There is substantial variation in production processes and combustion characteristics relative to fossil fuels and a concomitant wide range of life-cycle greenhouse gas emissions (Farrell et al., 2006; Wang et al., 2007).

The extent to which a carbon-emission based policy helps reduce carbon emissions cost-effectively depends on how accurate the carbon emissions estimates are. The less precise or accurate the estimates, the less effective will be the policy. In addition, there will be substantive administrative costs associated with this policy approach. It entails estimating and tracking carbon for categories and perhaps even individual batches of biofuels. Protocols must be developed and updated, and for the foreseeable future, the process will be prone to substantial error and disagreement in terms of emission intensity estimates.

Despite their current weaknesses, we argue in favor of immediate implementation of LCA carbon accounting for 3 reasons. First, an unavoidable fact is that *any* approach for weighting the relative efficacy of one fuel over another relative to an objective is necessarily choosing equivalence values. For example, traditional volumetric ethanol subsidy programs place no explicit weight on carbon intensity. Often, they treat biofuels by type or class, such as corn ethanol or soy biodiesel. More refined versions simply treat all ethanol as equal, though ethanol can vary greatly in its carbon emission intensity depending on feedstock and production process. The current federal equivalence values use an ad hoc approach that has implied carbon intensity weightings, but it is based on fuel type and feedstock source, not directly on an estimated carbon intensity index. Consequently, this approach is weaker as an incentive mechanism for promoting the development and use of low-carbon fuels than would be a carbon index.

Second, although ad hoc approaches for setting equivalency values provide no inherent foundation for systematically improving the measurement of carbon intensity, adopting a carbon-based instrument and a well-designed regulatory environment will accelerate the development of LCA because it becomes more than just an academic exercise for both the public and private sectors.

Third, even within this framework, it is practical to compartmentalize LCA analysis. For example, among the biggest challenges for LCA are land use changes that affect fuel carbon intensities. Farrell and Sperling (2007), Section 4.5.1, suggest that in the short run at least, indirect land use effects should be assumed zero for a limited set of feedstock types and sources, such as municipal wastes and biomass residues that do not lead to competition for productive agricultural land.

In summary, because *any and every* policy is based on implicit value weightings, and these values define the incentives for economic agents working within the policy framework, it is better to adopt a system of carbon accounting for motor fuels now rather than later.

A carbon emissions tax

As a starting point, consider British Columbia's carbon tax adopted in July of

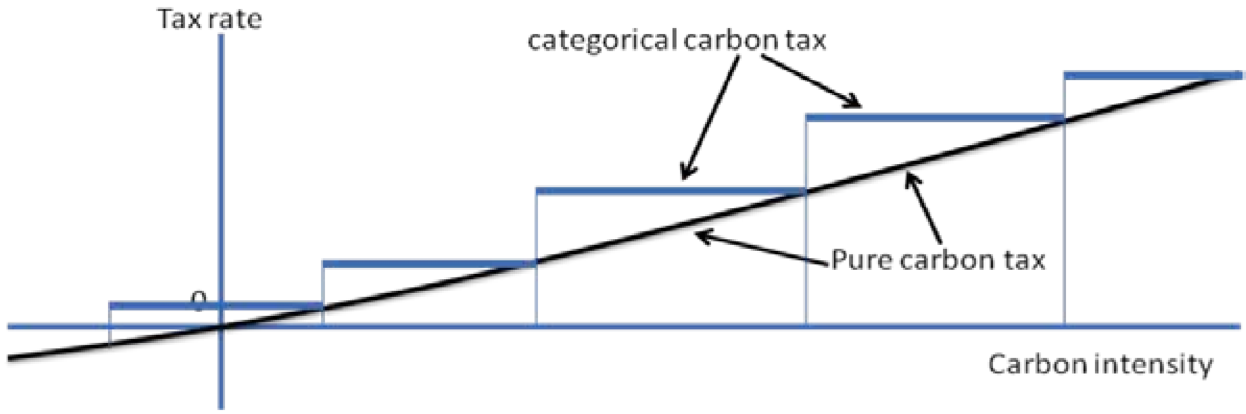

Figure 5.1: A pure (proportionate) carbon emissions tax and a categorized carbon emissions tax.

2008. The tax is imposed only on non-renewable fuels, including, but not limited to, gasoline, diesel, aviation fuel, natural gas, and various categories of coal (see Ch. 3 for a more complete overview). Notably, renewable fuels such as biofuels are exempt from the carbon emissions tax.

In contrast, our proposed carbon-based tax (or modified tax and subsidy program discussed later) puts a price on life-cycle carbon even for renewable fuels, which means it distinguishes among the types of renewable fuels rather than just fossil and non-fossil fuels.[27] This in turn provides the incentive for firms to invest in and move toward production of lower carbon renewable fuels, not just move away from non-renewable fuels. The BC program provides little or no incentive for firms to distinguish between low and high carbon renewable fuels.

Later in this chapter we compare the economic performance of these different types of instruments. RFSs and carbon-based fuel standards are *quantity-based instruments,* while taxes and subsidies are *price-based instruments*. Our recommendation for carbon-based price instruments is detailed later in this chapter. Here we briefly summarize the reasons that we recommend a carbon emissions tax over a renewable fuel standard:

- A carbon emission tax provides revenues that can be applied toward explicit support to renewable fuel tax credits or subsidies and toward R&D for renewable fuel technologies and infrastructure.
- A tax and tax credit program will likely be more easily implemented (less onerous administrative costs) than a carbon-based fuel standard with trading, or a carbon cap-and-trade program.
- A carbon emission tax results in lower carbon price volatility relative to a carbon cap-and-trade mechanism, and a lower risk of unexpectedly high compliance costs for firms.
- In conjunction with low-carbon emissions tax credits, a carbon emissions tax can more easily complement the Federal RFS. At the least, a carbon emissions tax can also facilitate the transition of Washington State toward being

[27] This statement oversimplifies the issues somewhat. In fact, non-renewable fuels will have embedded carbon taxes to the degree that their production process and distribution uses fossil fuels—depending on exactly how and where the tax is assessed. This potential embedded tax means that the proposed life-cycle carbon intensity tax must take care to avoid double taxation.

competitive under the Western Climate Initiative. In contrast, a binding state-level RFS would amount to a third major standard under which state energy markets would have to operate.

Execution of a carbon emissions tax

The most direct way to implement a carbon-based tax is to construct it similar to the excise tax on motor vehicle fuels, but based on fuel carbon intensity, not fuel volume. The state excise tax on motor fuels is now implemented by RCW 82.36.020 and RCW 82.36.025). As of July 1, 2008, the state excise tax for motor vehicle fuels was 37.5¢ (in addition to the federal fuel tax of 18.4¢ for gasoline and 24.4¢ for diesel). This is among the largest state fuel excise tax burdens in the country.[28] The motor vehicle fuel tax also applies to the ethanol and biodiesel in blended fuels. Ethanol and biodiesel are considered taxable fuels and are taxed at the same rate regardless of blend (i.e., 100% ethanol is taxed at the same rate as gasoline, but this means it is taxed per unit of energy more than gasoline).

As discussed by Parry and Small (2005), there are 2 main reasons to tax fuels. One is to raise revenues, and the other is to alter per-gallon prices to account for non-market costs of fuel usage and transportation such as pollution, congestion, and infrastructure costs. The explicit motivation for Washington's fuel excise tax as stated in the biofuels legislation and state constitution is to pay for transportation infrastructure.

Imagine, then, a 2-part tax applied to fuels: one tax component based on volume (i.e., the current gas excise tax) that accounts for transportation infrastructure and congestion costs, and one carbon emissions tax component that varies by estimated net life-cycle greenhouse gas emissions of the fuel. If the current base of 37.5¢ is to be maintained for transportation infrastructure, then a carbon emissions tax would have to be in addition to this base tax. However, there is no practical reason why this base fuel tax could not be reassessed and changed either up or down.

Figure 5.1 shows a pure, continuous carbon emissions tax (black curved line) that in principle represents the cost of carbon emissions from a unit of fuel (e.g., a gallon). This line is increasing with carbon intensity. It passes through the intercept so that a fuel with zero net CO_2e emissions would have no tax and a fuel that provides net reductions in emissions would receive a subsidy.[29] The blue step function represents a categorization of fuels with tax rates set to correspond to the maximum carbon intensity for the category. A firm can in principle then attempt to get their fuel certified as low carbon intensity and receive a lower tax rate.

The Western States Petroleum Association (WSPA, 2008) argues that the carbon intensity default values should represent the central measure of the default category, not an upper bound on fuel intensity for the category of fuel. Our assessment is that if the private sector were not given the opportunity to be granted lower ACFI status for their fuel based on successful provision of evidence, we would concur with the WSPA. However, given the opt-in option, only firms who believe their fuel has a lower

[28] The excise tax is paid by motor vehicle fuel licensees other than motor vehicle fuel distributors (see RCW 82.36.026), but the incidence of this tax is likely to be borne almost entirely by consumers (Chouinard and Perloff, 2004; Chouinard and Perloff, 2007; Alm et al., 2005). State and federal gas taxes are passed onto retailers but are included in the pump price paid by consumers. Persons who use motor vehicle fuel off public highways may claim a refund of the gas tax. However, retail sales tax is deducted from this refund.

[29] This is in principle possible if during the life-cycle of the fuel more carbon were sequestered than emitted.

ACFI than the categorical standard will apply. The consequence of this self-selection is that *actual* average carbon emissions tax rates would decline below the average ACFI target. We therefore argue, as Farrell (2007) and Yeh (2008) do, that the fuel category standards should be set conservatively (i.e., that tax rates be based on an ACFI that corresponds to a high value for each fuel category.

The accounting mechanism for these taxes (and as discussed later, tax credits) could rely in part on the infrastructure of the federal RFS for volumetric accounting, with carbon accounting integrated into it in a complementary way. The obligated parties and recipients of the taxes and subsidies can be either the same as the obligated parties for the federal RFS or some modification of that set.

The accounting mechanism for the tax system described above would need to be augmented in order to keep track of fuel carbon intensity (once a carbon index value has been assigned to a fuel). The problem amounts to keeping track of fuel differentiation so as to be able to tax differentially.[30] Several accounting frameworks are under development for product differentiation in fuels.

The federal renewable identification number (RIN) system discussed in Chapter 3 is one model that could be utilized in principle, although it does not specifically identify the carbon content of fuels. In order to facilitate federal RFS goals, the RIN will have to differentiate between biomass-based and corn ethanol fuels.

The WCI and California are also developing accounting systems for fuels to be utilized within cap-and-trade frameworks that can be useful for carbon/price-based instruments. Yeh (2008) suggests the following reporting requirements that presumably would be attached through a tracking number like the federal RIN: batch number, fuel type, fuel quantity, feedstock type, feedstock origin, processing characteristics, fuel carbon intensity, fuel carbon intensity accuracy level, and sustainability information.

To implement the measurement and labeling fuel carbon intensity, we recommend considering (and perhaps modifying) a general framework proposed for California's low carbon fuel standard that allows firms to play an active and constructive role in carbon intensity measurement. The "default and opt-in" program would have fuel types assessed and assigned to a general carbon intensity category, and the fuel would carry a carbon intensity level equal to the highest carbon intensity value for the category (Farrell, 2007; Yeh, 2008). Obligated parties who show that the fuel they are producing has a carbon intensity lower than the assigned default value would have their fuel reclassified to the (presumably) lower carbon intensity level. This process would require a certification process, and indeed a certification industry, but it would also provide market incentives that promote the further development of carbon intensity measurement.[31]

One final note about imposing a carbon emissions tax structure on both non-renewable and renewable fuels is that care must be taken not to double count carbon emissions when assessing life-cycle emissions. To best understand this point,

30 Note that the tax is not on the fuel per se, but on the externality associated with the fuel. Hence the tax varies with carbon intensity/per unit. This has important implications in relation to existing Washington Law, which we discuss in more detail below.

31 Gustavo Collantes of the Washington Department of Community, Trade, and Economic Development is in the process of developing ideas for a fuel certification process that would work either alone or in conjunction with LCA to measure fuel carbon intensity (G. Collantes, personal communication, October 2, 2008).

consider a hypothetical case in which all fossil oil faced a carbon tax to account for potential emissions as it was taken from the ground.[32] This tax would then be a cost of carbon accounted for in the marketplace throughout the marketing process not only by final consumers, but intermediate consumers such as feedstock and biofuel producers to the extent that these taxed fossil fuels are used in feedstock and biofuel production. Thus, if the oil carbon tax reflects emissions from fossil-based products in the production of feedstocks and biofuels, these carbon emissions should not be in the LCA emissions base to calculate the biofuel carbon emission tax. If they were, these emissions would be double counted, leading to excessive taxation of biofuels relative to other goods.

Potential restrictions on the use of carbon emissions tax revenues

Carbon emissions taxes provide revenues that could support research and development, funding for demonstration projects, biofuel infrastructure development, tax credits for renewable fuels, and/or for offsetting existing taxes. But a potential complication associated with imposing a carbon emissions tax on motor fuels is that motor fuel excise tax revenues in Washington State seem to be earmarked by the constitution and related legislation for funding transportation infrastructure investment. Article II, Section 40 of the Washington State Constitution states

"All fees collected by the State of Washington as license fees for motor vehicles and all excise taxes collected by the State of Washington on the sale, distribution or use of motor vehicle fuel and all other state revenue intended to be used for highway purposes, shall be paid into the state treasury and placed in a special fund to be used exclusively for highway purposes."

This language does not preclude a carbon emissions tax on fuels, but implies that the revenues from such a tax would need to be spent on transportation infrastructure. However, Section 40 also states that

"…this… shall not be construed to include revenue from general or special taxes or excises not levied primarily for highway purposes…,"

This provision suggests that if the intent of the tax were to mitigate carbon emissions, such revenues would not necessarily need to be applied to transportation infrastructure. An opinion issued by the Washington State Office of the Attorney General (Collins, 2001) supports this option, and we are unaware of any subsequent challenges to this section.

Alternatively, a carbon intensity tax is not strictly speaking a motor vehicle excise tax. The fuel is simply the medium for what amounts to a by-product of fuel use: greenhouse gas emissions. Further, the tax is not based on volume per se, but the carbon intensity of the fuel. It is an emissions or effluent tax, not an excise tax in the usual sense. As such, it might be argued that the constitutional language pertaining to motor fuel revenue destinations does not apply at all. There also appear to be precedents for taxing intermediate petroleum products and using revenues for other purposes. A petroleum products tax was imposed for one fiscal year (2003-2004) to finance affordable insurance for underground petroleum storage tanks (RCW 82.23A).[33]

[32] Such a tax structure is not ideal, because emissions are a better target, but oil extraction is used here for clarity.

[33] If using revenues from excise taxes on motor fuels turns out to be problematic, it might be feasible to use the Washington State Business and Occupation (B&O) tax structure to pursue these objectives. B&O taxes are "measured on the value of products, gross proceeds of sale, or gross income of the business" (Washington State Department of Revenue, n.d.). The problem with this approach is that gross sales change as prices changes, so that a carbon tax on gross sales would changes as prices change, even though price change in itself engenders no change in carbon content. To be a consistent carbon tax,

Why not a low carbon fuel standard?

There is quite a bit of political inertia associated with the Low Carbon Fuel Standard (LCFS) under development in California (California Air Resources Board, 2008). Washington's Climate Action Team has recommended considering a similar standard for Washington State (Climate Action Team, 2008, p. 52 of Appendix 4), but also state that other approaches warrant further consideration. We argue in favor of taxes and a tax credit system rather than a low carbon fuel standard.

As noted earlier in this chapter, a carbon intensity tax has 2 economic effects: it increases the cost of high carbon fuel relative to the cost of low carbon fuel, and it increases the cost of both of these fuels relative to other goods. This means that it will lead to a substitution away from high carbon toward low carbon fuels and thus reduce total blended fuel consumption.

California's LCFS is an intensity *standard*, which means that for any given quantity of blended fuel used, the average CO_2e content must be at or below a certain amount; it is basically a blend requirement based on carbon (not fuel type and volume) such that for any given quantity of blended fuel consumed, the average carbon intensity must not be above a certain level.

The difference between the intensity standard and a carbon tax is that the carbon-based standard primarily imposes a substitution among fuels leading to more low-carbon fuel use. It reduces total blended-fuel consumption only to the extent that the low-carbon fuel price is higher than the high-carbon fuel price. Indeed, Holland et al. (2008) show that in principle, total carbon emissions can increase under a low-carbon fuel standard if the increase in low-carbon fuel use overpowers the decrease in high-carbon fuel use. Their simulations indicate this is unlikely to be the case, but a related consequence is that the carbon-based standard is likely to be relatively cost-ineffective.

Holland et al. (2008) conclude that an intensity standard based on historical baseline energy production levels is the least costly carbon-based standard that they consider. The primary difference between these 2 types of intensity standards is that increases in the quantity of fuels produced and consumed is accounted for in the baseline, and any increases in carbon due to increases in the quantity of blended fuels counts against the standard. This, however, is basically equivalent to a standard carbon cap-and-trade program.

The results of Holland et al. (2008), as well as our own assessment of the broader literature on the comparative efficacy of content standards versus overall caps, leads us to recommend carbon cap-and-trade programs over low carbon fuel standards. However, we argue below in favor of a tax and tax credit system over a cap-and-trade program.

A tax credit to promote in-state production of low-carbon biofuels

The carbon intensity tax instrument proposed above shifts the relative price of blendstock fuels toward low-carbon renewable fuels, which in turn provides incentives for low-carbon renewable fuel production in general. However, given our legislative charge, there are 2 primary concerns with a carbon emissions tax alone:

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sales price changes would need to be accounted for.

Currently the state provides a reduction in B&O tax from 0.484% to 0.138% for manufacturers of E_{85} fuel, biodiesel fuel, biodiesel feedstock, or wood biomass fuel. This deduction has apparently seen relatively little use to date. Although it is a 71% reduction in the B&O rate, it amounts to a decrease of only about one third of one percent of gross revenues.

- It does not provide positive price incentives to low-carbon renewable fuels, and will make blended fuels more expensive.
- It does not provide any benefits targeted specifically to support in-state production of fuels or feedstock because fuels can (and are) imported into the state for consumption and blending.

Each of these concerns can be addressed by using the tax revenues to provide positive support for in-state production of low-carbon biofuels. Thus, the revenues can be used to support tax credits for biofuel production, and/or to support public funding for research, development, and infrastructure to promote the Washington State biofuel industry. We proceed under the assumption that the possible constitutional and statutory constraints on using carbon emissions taxes can be overcome.

A stable promise of tax credits for producing low-carbon fuels, based on tax revenues on high-carbon fuels would provide an incentive for private investment in low-carbon fuel production in the state (Galinato and Yoder, in press). However, such an approach would require modification to a pure carbon emissions tax In order to maintain a tax and subsidy schedule that continues to change relative prices in favor of low-carbon fuels, consider what we call a "shifted" carbon emissions tax, such that a zero tax is applied to fuels with some benchmark carbon intensity. Producers of fuels with a carbon intensity higher than this benchmark would pay a carbon emissions tax proportional to the carbon intensity of the fuel, while producers of fuels with lower carbon intensity than the benchmark would receive tax credits proportional to the carbon intensity of the fuel. Figure 5.2 shows the shifted carbon emissions tax (bottom) and the basic, zero-normed carbon emissions tax. In the figure, CI* is the baseline carbon intensity, such that fuels with higher carbon intensity pay a tax, and fuels with lower carbon intensity receive a subsidy. Categorical default tax rates are shown as the blue step functions.

For comparison, again consider British Columbia's carbon emissions tax discussed in Chapter 3, which excludes renewable fuels from a carbon emissions tax, and therefore provides no incentives for firms to distinguish between or favor low-carbon renewable fuels over higher-carbon renewable fuels. Although a shifted carbon emissions tax imposes taxes for high-carbon fuels and subsidies for fuels with low carbon intensities, the tax/subsidy schedule is still proportional to carbon intensity for all of these fuels, including renewable fuel. As a result, firms producing and using renewable fuels would have an incentive to account for differences in carbon intensity among renewable fuels as well as non-renewable fuels.

What would the benchmark CI* be, and how would this approach be designed quantitatively? There are many alternatives. An ad hoc example might be to set CI* to be equal to the bureaucratically-accepted carbon intensity of corn ethanol under current production settings, and then categorizing fuels around that point. Presuming that this carbon intensity measure is lower than that of petroleum-based gasoline, then gasoline blendstock would be subject to a carbon emissions tax, perhaps of the magnitude that BC is imposing. Biodiesel and biomass-based fuels may likely receive a tax credit, again, depending on LCA determinations of carbon intensity.

Note that we are referring to fuel types as categories. This is reasonable to the extent that these categories are substantially (positively) correlated with carbon intensity. For example, for our CGE analysis discussed later, we use gasoline as the baseline against which compare the other fuels. We

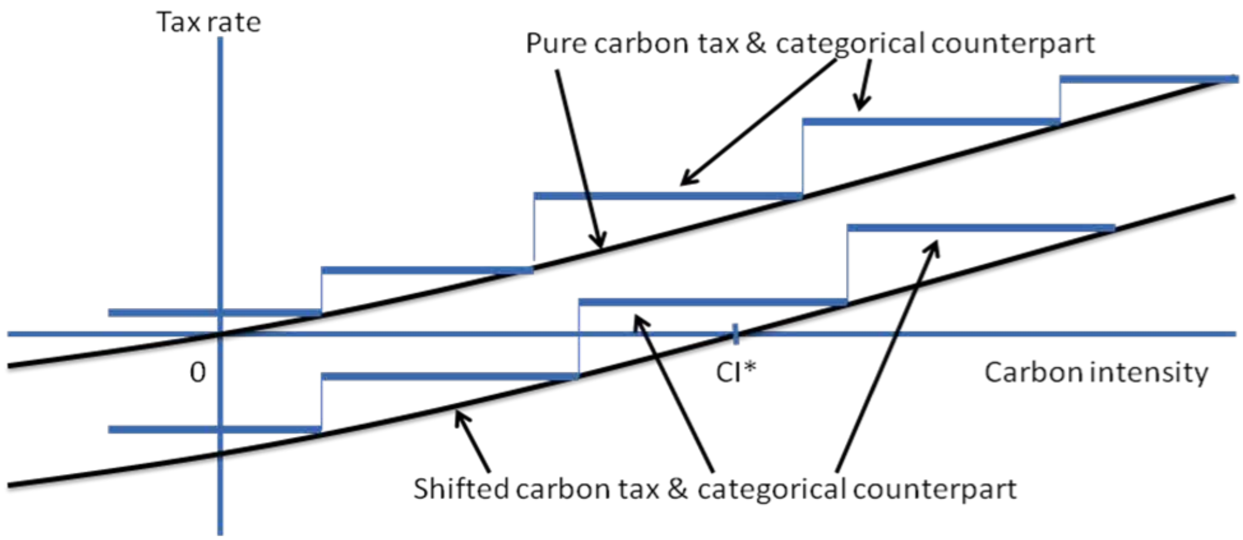

Figure 5.2: Shifted carbon emissions tax use of revenues from high-carbon fuels to subsidize low-carbon fuels.

utilized a modified average of existing LCA estimates, and imposed the following CO_2e emissions in kilograms/gallon (percent of corn ethanol emissions in parentheses for comparison): gasoline, 10.75 (105.3%); diesel 11.35 (111.2%); corn ethanol, 10.21 (100%); cellulosic ethanol, 7.19 (70.4%); and biodiesel, 6.13 (60.0%).[34] Estimates such as these can be part of the foundation of a tax/subsidy.[35]

The issue of double counting carbon emissions is worth mentioning here again. If a carbon tax is applied to gasoline and diesel in the state, and these taxes are paid by producers of biofuels in the state, then in-state biofuel tax liability should account for this in some way. One example would be to apply a carbon emissions tax on the life-cycle emissions and allow biofuel-producing firms to deduct the cost of the emissions tax imposed on fossil fuels.[36]

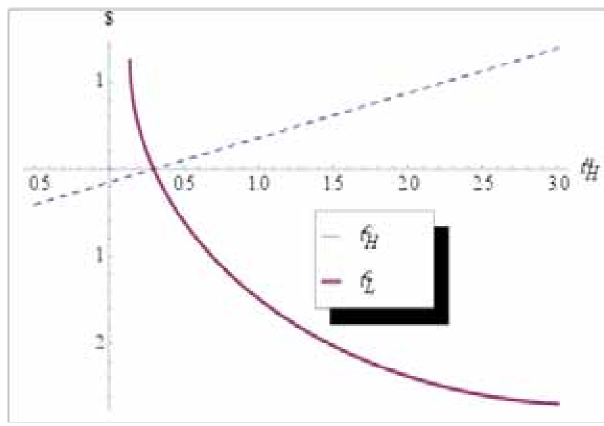

Figure 5.3: Relationship between a revenue-neutral carbon emissions tax on a high-carbon fuel and a subsidy on a low-carbon fuel.

Revenue neutrality of carbon emission taxes and subsidies

In principle, a tax/subsidy program such as the one described above could be revenue-neutral in the sense that all carbon emissions tax revenues from high-carbon fuels are directed to exactly offset subsidy costs for low-carbon fuels. This implies a tight relationship between tax revenues and subsidy expenditures, but using estimates of market price response in fuel markets

[34] These estimates are used for expository purposes only.

[35] Note that in principle the tax credit can in fact provide negative taxation. For example, the current federal subsidy of 46 cents is larger than the federal fuel tax of about 18.4 cents, providing a net subsidy.

[36] This suggested approach is imprecise, but is included as an example.

and a fund for storing tax revenues, an approximately tax-neutral program can be implemented. Figure 5.3 shows a hypothetical relationship between the tax on a high-carbon fuel and a subsidy on a low-carbon fuel, conditional on spending all tax revenue from one high-carbon fuel to pay for tax credits on one low-carbon fuel. Of course, this relationship could be extended to several categories of fuels (Galinato and Yoder, in press).

Unclaimed tax credits for R&D in the short and intermediate run

Given the current low levels of Washington biofuel production and the remaining challenges for second-generation biofuel technologies, it is likely that carbon revenues from virtually any non-zero level of carbon emissions tax (e.g., on gasoline and diesel) would go unused as tax credits for low-carbon biofuel production initially. If unused, this would lead to a buildup in a fund of revenues.

The question is, what should be done with these funds? Options include 1) save them to offset future carbon-based tax credits, 2) invest in R&D to support low-carbon renewable fuels, or 3) use them to offset existing regressive or burdensome taxes. We do not discuss the first option further. We discuss the third option in the section below on revenue recycling, and the prospects and direction for public investment of R&D in the next chapter. Investing in R&D will likely be most expedient for the development of biofuel markets in Washington State, but using the revenue to offset other distortionary taxes may be the best economically from an economy-wide perspective.

Long-run strategy for low-carbon subsidies based on net revenue constraints

If a revenue-neutral tax and subsidy program is successful in the sense that it moves the aggregate share of motor fuel use away from high-carbon petroleum-based fuels toward low-carbon renewable fuels, then the tax balance will shift over time (because the ratio of gasoline consumption to biofuel consumption will also change over time).

If carbon emissions tax revenues based on a shifted tax structure are used to promote in-state development and infrastructure needs for the state's nascent biofuel industry, as the industry develops and low-carbon fuel production and consumption increases in the state, revenues from carbon emissions taxes would be increasingly directed toward supporting the tax credits for low-carbon fuels over time. This will entail alteration of the tax/subsidy schedule on occasion, analogous to cap adjustments in a cap-and-trade program. Work is in progress to extendthe static model in Galinato and Yoder (in press) to characterize the appropriate dynamic time path of policy adjustments implied by this framework.

Using carbon tax revenues to offset other distortionary taxes

The previous subsections recommend recycling carbon tax revenues toward tax credits and R&D support for low-carbon renewable fuels. In contrast, British Columbia has a revenue-neutral carbon emissions tax in the sense that carbon emissions tax revenues are used to offset other taxes.[37] This approach has been receiving increasing attention in the literature (Fullerton and Metcalf, 2001; Parry, 1997; Parry, 1995; Bovenberg and Mooji, 1994). The basic argument is that traditional taxes such as income taxes and payroll taxes are imposed solely to collect revenue, and their imposition reduces after-tax returns to labor and business investments, leading to reductions in these activities below economically efficient levels

[37] Refer to http://www.sbr.gov.bc.ca/documents_library/notices/BC_Carbon_Tax_Update.pdf.

(in principle). This is why traditional taxes tend to be costly in terms of overall societal welfare.

Environmental taxes, on the other hand, are prescribed to correct a market failure so as to improve social welfare (by internalizing the environmental costs of people's actions). So, if environmental tax revenues (which can improve welfare) can be recycled to reduce other traditional "distortionary" taxes (those which reduce total social output), then this combination provides "double dividends," and if applied appropriately, can improve social welfare relative to traditional revenue-raising taxes. We discuss this issue in more depth later in this chapter.

If our enabling legislation was limited to recommendations for reducing petroleum dependence and carbon emissions, this type of revenue recycling approach would be our recommendation, because it would likely allow the state to pursue these goals at the least social cost. However, the third goal, which is arguably the primary impetus of the legislation, is to promote in-state biofuel production. To pursue this goal in conjunction with the other 2 goals, we recommend directing carbon tax revenues (at least in part) toward low-carbon renewable fuel tax credits and/or research, development, and technology adoption as discussed previously and in the next chapter.

Policy for in-state feedstock production

Providing incentives for low-carbon fuels will boost demand for feedstock production that supports low-carbon fuel production. Therefore, direct incentives for feedstock production are not a necessity to promote these markets. Biofuel tax credits and blend mandates will tend to increase the derived demand and market price of feedstocks. de Gorter and Just (2007) find that in the case of corn ethanol when the price of oil is sufficiently high (as it was, for example in the summer of 2008), the average federal and state ethanol tax credit of $1.08/gallon translates to approximately a $2.23 subsidy per bushel of corn if the tax credit is fully applicable and utilized.[38] So for corn ethanol, the feedstock price is very sensitive to the price of ethanol. Thus, focusing on biofuel subsidies promotes feedstock prices quite substantially in general. However, the resulting price increases do not apply solely to in-state feedstock production and therefore do not provide a price advantage to in-state feedstocks. This will result in an increase of feedstock imports.

Subsidies targeting feedstocks would also likely not be a cost-effective way of promoting the biofuel industry in Washington. Washington State has a comparative advantage at producing high-value crops other than those used as biofuel feedstocks in the current market environment, so providing subsidies to current "first generation" agricultural feedstocks would be costly. Further, such price incentives would either compete with or supplement federal agricultural incentives and provide further pressure on agricultural land and probably water use. Competition with land for food crops is probably not politically wise in the current atmosphere of concern over the possible impact of biofuel production on food prices and availability.

However, policymakers may wish to provide support for feedstocks that

[38] The average market price of corn used in the study is about $2.33 per bushel. That all but 10 cents per bushel is due to the subsidy seems at first blush to be unlikely. However, this does not mean that if the ethanol subsidy were removed, the price of corn would drop to 10 cents per bushel. If this were to occur, there would be an excess supply, and the quantity of corn grown and supplied would decline, leading to a price somewhere between $0.10 and $2.33. de Gorter and Just (2007) estimate that the price of corn would settle to about $2.00 per bushel.

address environmental issues (i.e., market imperfections) other than those surrounding climate change. For instance, tax credits may be used to promote the use of waste flows and forest residues that contribute to wildfire risk.[39] Wildfire risk reduction provides public benefits to adjacent and other local landowners by reducing the risk of ignition and fire movement across property boundaries. Because landowners do not bear the full benefit of wildfire risk reduction, their incentives for reducing it are therefore too weak from an economic efficiency perspective. Other factors, including fire insurance and public wildfire suppression, exacerbate these incentive problems (Yoder, 2004). Coordinating wildfire risk with biofuel feedstock utilization seems an obvious and important synergy.

Cap and trade vs. taxes

We argue in favor of tax instruments over carbon-based cap-and-trade programs based on a growing economic literature, which we discuss in detail later. However, because we recognize there is momentum in this state and elsewhere for carbon cap-and-trade programs, we provide some fundamental recommendations for how such a system should be structured.

The most important recommendation is that if the state chooses to pursue a cap-and-trade program for carbon-based fuels, carbon credits should be auctioned, not given outright, to obligated parties.[40] The auction revenue can then be utilized in the same way as we recommend that carbon emissions tax revenues be used.

More specifically, if renewable fuels are exempt from the cap-and-trade program (as is often the case in carbon cap-and-trade proposals), the auction revenues should be used to provide carbon-based tax credits for low-carbon renewable fuels and support for R&D and technology adoption in advanced renewable fuel industries. Taken together, this approach is similar to the tax and subsidy program which comprises our primary proposal, and in principle targets all 3 primary goals of our enabling legislation (promote in-state biofuel industries, reduce petroleum dependence, and reduce carbon emissions). Alternatively, auction revenues could be directed toward offsetting other taxes such as B&O taxes or sales taxes, which would more cost-effectively reduce petroleum dependence and carbon emissions. Finally, a combination of taxation and cap-and-trade programs might be implemented either sequentially or, with care not to double-tax for carbon emissions, simultaneously.

The cap-and-trade program being developed under the Western Climate Initiative will take several years to implement (transportation fuels will be integrated at the earliest in 2012). The use of a carbon tax such as that of British Columbia could be implemented in the interim. This would in principle “jump start” the process and provide incentives for the affected industries to begin preparing for cap-and-trade obligations.

There is some evidence (discussed in Part II below) that the integrated use of both price and quantity instruments (i.e., taxes and cap-and-trade) can be more cost-effective than the use of either in isolation (though there are pitfalls, also discussed in Part II). If a carbon tax and a cap-and-trade program were to be implemented such that obligated parties had to fully participate in both programs, it could amount to double taxation (i.e., paying for carbon credits and taxes on the same ton of CO_2e emissions). Were a cap-and-trade program

[39] Currently, the federal RFS does not count fuels made from feedstocks from federal land. This should not be a restriction imposed in Washington State policy.

[40] Alternatively, these credits should be auctioned to the greatest politically feasible degree.

to be implemented for Washington State in conjunction with a carbon tax, we recommend that obligated parties under the cap-and-trade program be provided a full or partial carbon tax exemption so they are not taxed twice for the same fuel carbon content.

Washington policy in the context of the federal biofuel policy

The Energy Independence and Security Act of 2007 (EISA; H.R. 6) and Food, Conservation, and Energy Act of 2008 (2008 Farm Bill; H.R. 6124) have increased the emphasis on advanced biofuels substantially by placing minimum requirements for the fraction of biomass-based fuels eligible to satisfy the federal RFS, by increasing the difference between the subsidy provided to starch-based versus biomass-based ethanol, and by emphasizing advanced biofuels in both biofuel market development and research. For example, EISA dictates that in the year 2015, the amount of conventional biofuels eligible to satisfy the federal RFS will be capped at 15 billion gallons, but the consumption requirements will continue to grow up to 36 billion gallons by 2022, and cellulosic biofuels will need to increase from 3 to 16 billion gallons. This development is important, because the state of Washington has a potential comparative advantage in biomass-based fuels relative to the starch-based fuel being relied upon now. Hence, the federal programs are increasingly supportive of Washington State biofuel markets.

Consider again Washington State's decision calculus in light of this development in federal biofuel policy. As noted previously, Washington is a small open economy within the context of national and global markets. A substantial fraction of the benefits from Washington's investments will be borne globally, nationally, and regionally, while the costs of the state's policies will be borne primarily by its residents.

Taken together, the federal movement toward mandating consumption of more biomass-based fuels, providing larger subsidies for producing biomass-based fuels, and funding development of fuels that lean toward Washington's apparent comparative advantage in biomass-based fuels suggests that the state should work in the short run to facilitate a long-run strategy to make the best use of federal support programs for the industry. This federal direction points to emphasis on R&D as discussed in Chapter 6 and implies that states will be able to rely less on expensive tax credit programs to support biofuel market goals.

How aggressive should the policy be?

For climate change mitigation, the problem is a difficult one that revolves in part around what the appropriate discount rate is to use for future benefits from current carbon emissions reduction. The economic discussion surrounding this issue is very active and far from being resolved. Among the most widely known assessments relating to this question is the Stern Review on the Economics of Climate Change (Stern, 2006). Tol (2005, 2007) provide meta-analyses of the social costs of carbon (the latter paper includes Stern's estimates in the analysis). The range of estimates of the marginal cost of carbon is large due to substantial uncertainty about and difference in the discount rates applied across studies. Nonetheless, it is instructive to consider the numbers. The mode (i.e., most likely) and mean (i.e., average) of all published estimates of the marginal cost of a ton of carbon emissions are \$35 and \$129, respectively. For peer-reviewed research, the mode and median are \$20 and \$71, respectively.[41] So for the sake of discussion, suppose the true cost per ton of carbon emitted were \$30 (this

[41] See Tol (2007), Table 1, based on the Fisher-Tippett kernel density estimator.

amounts to approximately 29¢/gallon). From an economic perspective, a carbon emissions tax of $30 per ton would in principle (subject to perfect markets and enforcement, etc.) induce an efficient level of carbon emissions reduction. In a simple world with no uncertainty and no differences in enforcement costs, a standard that produces carbon emissions reduction equivalent to that of a $30 carbon emissions tax would provide an equivalently efficient outcome.[42] The economically efficient amount of carbon emissions reduction would be such that the cost of the last unit of emissions reduction (from each emissions source) is exactly equal to the expected social cost of carbon emissions.

The bottom line is that the net present expected cost of a ton of carbon is at best a judgment call highly dependent on assumptions about the appropriate discount rate; however, it is one that must be made. Recall again British Columbia's tax schedule outline in Chapter 3. This seems a reasonable starting point, at least as a foundation for modification.

Modification of Washington's RFS

Although we have argued against imposing a binding renewable fuel standard, we recognize that the state may nonetheless choose to proceed with it. We therefore provide policy recommendations for the state's RFS.

A summary of Washington's current biofuel incentives and policy is provided in Chapter 3 of this report and in BioEnergy Washington (2009). The primary elements of Washington State policy applying specifically to biofuels are a set of tax incentives, a renewable fuel standard, and a fund for awarding competitive grants for research and development of technology, facilities, and infrastructure for various renewable energy sources, including biofuels. The critical elements of the current Washington State RFS for our purposes are:

- For both fuels (ethanol and biodiesel), the RFS applies to fuel sold in Washington State.
- Implementation and ratcheting of the standard are based on the (economic) capacity for in-state raw material (feedstock) production.
- Licensees are required to provide evidence of meeting a minimum aggregate content standard. However, no individual licensee is bound or required to satisfy the standard themselves, so for practical purposes, it is not enforceable.

The first element pertains to consumption, because in-state sales can be supplied by both imports and in-state production. The second element is one approach for imposing an in-state supply requirement. The last relates to the onus of responsibility for meeting the RFS. We discuss these below in more detail, and examine the economic consequences and importance of each for implementation.

In-state biofuel production requirement

The RFS applies to fuel sold by licensees in Washington, which includes importers, suppliers, refiners, and blenders—but not distributors—of motor fuels. So fuel sales relates more closely (but not exactly) to fuel *consumption* in Washington State. However, increasing the ethanol content requires evidence that there are sufficient "raw materials" to support [in-state] production of

42 $30 is high relative to most summary statistics of the trading prices of the EXC carbon market futures given current exchange rates. See the European climate exchange Web site at http://www.ecx.eu for the most current price data. Note that the carbon futures price is a result of the current and expected total carbon cap that applies (which may or may not a have been set with an equilibrium market price in mind). If the overall cap is applied appropriately and the carbon market works well, the ideal trading price would equal the marginal damage of a ton of carbon.

ethanol, and increasing the RFS for biodiesel requires that in-state production capacity (including both crushing and feedstock production) can support a 3% standard. Thus, the implementation for what amounts to a consumption fuel standard is tied closely to in-state production capacity. To the extent that the standard promotes the demand for ethanol and biodiesel, the derived demand for in-state production of both ethanol and feedstocks would be increased as well, and drawn along with the increased sale of the 2 biofuel types. Presumably the legislature imposed this connection to satisfy the goal to "stimulate creation of a new industry in Washington that benefits our farmers and rural communities" (WSBAC, 2007; RCW 19.112.110, SB 6508).

Several economic issues regarding this feedstock and raw materials supply condition have important implications for the end result of a binding RFS, and these are best discussed in the context of the other stated goals in SB 6508. In particular, the supply constraint affects both the physical and economic feasibility of implementing the standard, as well as the magnitude and distribution of the costs and benefits that accrue from the standard. It may act to promote in-state production, but at a potential cost in terms of consumption.

If the supply constraint were to be satisfied automatically under prevailing market conditions (as would be the case, say, in Iowa), it would be effectively non-binding.[43] As indicated by the discussion in Chapter 4 of this report relating to feedstocks, under current market conditions and biofuel technologies, Washington State has a comparative advantage for growing crops other than the current winning biofuel feedstocks (i.e., corn, canola, and soybeans), and currently imports virtually all biodiesel feedstocks as well as all ethanol, little to none of which is produced with Washington corn.

As a result, in the short run, most feedstocks for Washington-sold biofuels will come from out of state unless and until market conditions and/or the related policies change. If *any* biofuel feedstock or raw materials are produced in-state but at a level too low to satisfy SB 6508, the RFS would be rescinded, and there would be *no* system to support the small but positive feedstock and raw material market in the state.

Thus, for Washington State there is a tradeoff between the stated goals of the adopted legislation SB 6508: support the feedstock markets explicitly by imposing these feedstock supply constraints, or abandon the biofuel RFS for one or both fuel types. The latter is an outcome that would satisfy none of the 3 RFS goals that relate to building a biofuel industry.[44] We recommend that if the state continues to pursue an RFS, it should not impose an in-state production constraint for implementation.[45]

Regulated entities and the RFS target

As written in RCW 19.112.110 and RCW

[43] Implementation of Oregon's RFS for ethanol was conditional on a minimum volume of in-state ethanol production (40 million gallons); for biodiesel, the RFS of 2% is conditional on 5 million gallons of production per year from sources in Oregon, Washington, Idaho, and Montana; the 5% RFS is being implemented based on production of at least 15 million gallons per year from these states.

[44] This regulatory uncertainty introduced by a conditional standard can be viewed as an example of the regulatory uncertainty discussed in Karp (2008).

[45] The Washington State Biofuels Advisory Committee recommended in August 2007 that the governor proceed with the 2% standard slated for implementation in December 2008 (WSBAC, 2007). This recommendation was made despite the fact that virtually all feedstocks for biodiesel and all raw materials for ethanol consumption were being imported, even though a minimum in-state production was a stated condition for continuation.

19.112.120, the Washington State RFS mandates the *reporting* of biofuel sales as the basis of an aggregate standard. It does not impose the burden of satisfying the standards on anyone in particular. As such, it is a goal, not an enforceable standard, and plays little or no direct role in increasing the blending rates in the state of Washington. The ethanol RFS is currently satisfied because the aggregate ethanol content of gasoline sales in the state is currently greater than 2%.[46] If the state wishes to adopt a more aggressive and binding standard, however, an enforcement mechanism would be necessary for it to be effective.

Two basic questions must be answered before a binding standard can be imposed: who should be held responsible for meeting the standard, and at what level of fuel volume aggregation must this standard be binding.[47] The current RFS requires reporting by licensees, including suppliers, refiners, importers, and blenders, all of which are upstream of the final emitters. This set of entities is currently responsible for remitting fuel tax revenues (see RCW 82.36.026), so are a natural focus for a fuel standard (Arimura et al., 2007; Farrell and Sperling, 2007).

The exact target of the RFS can range from a per-unit content requirement such that each gallon of fuel contains at least x% renewable fuel (e.g., Oregon's approach), to a statewide aggregate standard such as that of Washington. As mentioned above, Washington's statewide aggregate standard is not enforceable without more specificity regarding who is responsible for satisfying what part of the standard. On the other hand, it is likely that allowing more flexibility than a per-gallon volumetric standard would both reduce the costs of attaining the aggregate standard and increase the value of motor fuels for a given aggregate content goal.

It is widely documented in the economics literature on environmental regulation that allowing flexibility in reaching a standard translates to more leeway for the industry to reduce the aggregate costs of attaining an aggregate standard. For example, it is possible that joint production of a biofuel and a petroleum fuel may in some cases be the least-cost method of ending up with a blended fuel. Flexibility in end-use content from gallon to gallon in turn is likely to allow more flexibility for responding to market demand for various blended fuels (e.g., E10 for most vehicles and E_{85} for flex fuel vehicles), thereby increasing the aggregate value of blended fuels for a given aggregate average content requirement (Arimura et al., 2007). On the demand side this is because of differences in the way renewable fuels are used by different end users, and on the supply side because of differences in production and distribution costs across firms.

We recommend that if an RFS is implemented, each firm must, on average, satisfy the blend requirement. We do not recommend a gallon-by-gallon blend requirement such as Oregon's because it allows further cost-saving arrangements via tradable credits, as discussed below.

Credit trading among licensees

Allowing trading among licensees and using federal RFS obligated parties and RINs will in principle allow for lower compliance costs. It will also economize on administration costs because it uses a largely intact federal system. We recommend that if a binding RFS is imposed, the obligated

[46] The ethanol RFS is now being met because current market conditions (inclusive of the existing applicable federal and state incentives and policies) are such that ethanol prices have recently been relatively lower, and this has most likely played a part in induced higher blending rates.

[47] See the Interim report, Section 4, for more general discussion of these issues.

parties are allowed to trade credits via the federal RIN system using developing RIN exchange markets.[48]

This credit trading process will provide information to regulators as well. As we have mentioned before, one of the concerns about quantity-based instruments is that the upside costs of a standard may end up being substantially higher than expected. Credit markets provide information about how costly (at the margin) the standard is for firms to satisfy. It also provides a basis for a safety valve such that the average blend requirements can be relaxed by the sale of credits by regulators.

Part II: Economic fundamentals of policy alternatives

The following section is included for readers who want a more in-depth understanding of the economic foundations of our recommendations. The specific nature of market imperfections, economic sustainability, and market dependence and risk as discussed in the previous section can provide important guidance for the design of policy. Below we briefly discuss the market impacts of implementing biofuel subsidies, renewable fuel standards, fossil fuel taxes, feedstock subsidies, and finally, we examine performance-based instruments rather than volume-based instruments. These discussions will not be exhaustive, but rather focused on the important consequences of each policy alternative for the purposes of this report.

Economic motives for regulation and public support

We begin with the perspective that, when markets are working well within the context of existing property rights institutions, they provide private firms and consumers with the incentives to make production and consumption decisions that are consistent with social economic development in general. We presume that market-mediated processes generally are more effective at recognizing and using time and place-specific information for these ends than are well-intentioned government entities. However, market outcomes are not always consistent with social goals.

Three fundamental economic concerns are fundamental to the policy recommendations we make in this report: concerns over market imperfections, economic equity and sustainability, and petroleum dependence and energy market risk.

We address at least 5 important market imperfections (sometimes called market failures) that can reduce societal economic well-being and may justify the external support of developing biofuels markets. These include market externalities, knowledge spillovers, network externalities, market power, and induced innovation. Economic efficiency (non-waste, high levels of economic wellbeing) is presumed to be good in its own right, and elucidating market failures can often help provide guidance to design policy that corrects these market failures. Successfully doing so allows us in principle to reach societal goals in the least-cost, most effective way.

The *distribution* of economic welfare and development within and across state and national borders matters, and public involvement in markets can be motivated on equity grounds as well. *Economic sustainability* relates to the distribution of welfare over generations, and just like contemporaneous equity, it is not guaranteed even by an efficient market. Finally, although economic and political *volatility and uncertainty* are inescapable, public policies are often called upon to

[48] Note that the credits would apply to a specific volume of renewable fuel, not the average blend percentage itself. However, it is an easy calculation to find a blend rate based on total renewable and non-renewable fuel volume.

reduce them.

The market issues mentioned above that guide our policy recommendations are discussed in more detail in section 4 of our interim report, which can be downloaded from http://www.ses.wsu.edu/research/EnergyEcon.htm.

Biofuel subsidy

A tax credit provided to producers of biofuels (as with the federal tax credit discussed in Chapter 3) is effectively equivalent to a subsidy, and will have the same effect on an industry as a permanent increase in price received by producers.[49] As long as the subsidy induces ethanol to be a competitive substitute for petroleum in blended fuel, it will lead ethanol producers to accept lower market prices (net of the subsidy) for their biofuel. The equilibrium market price paid by blenders of the target biofuel will decrease, but not by as much as the subsidy, so that the price (including the subsidy) received by ethanol producers will increase. This equilibrium-subsidized price will therefore theoretically be accompanied by an increase in the quantity of biofuels produced and blended into motor fuels (de Gorter and Just, 2008b).

The subsidy also increases profits for firms in the biofuel industry, especially in the short run. This provides an incentive for firms to invest in additional plants and durable inputs to expand long-run industry output, which will carry over to increase investment in research and development into technologies that reduce production costs.

From the perspective of the consumer, a subsidy on a good has 2 effects: an *income effect* and a *substitution effect*. A subsidy on a biofuel provides a lower retail price for renewable fuel for consumers, leading them to substitute away from fossil fuels to the now-cheaper biofuel. The subsidy will also lead to a decrease in the price of blended fuel to the extent that there is substitution toward the cheaper blendstock. This leads to a related substitution effect: an increased use of blended fuel relative to other goods, because the relative price of blended fuel declines. This decrease in blended fuel price increases the real purchasing power of consumer income. The income effect of a subsidy is that consumers are likely to purchase more blended fuel. Thus, in the case of a subsidy for renewable fuels, the income and substitution effects will both in principle lead to an increase in renewable fuel. However, whether or not fossil fuel use declines or increases is uncertain, and it depends on the relative strength of the substitution effect away from fossil fuel, the substitution effect toward blended fuel, and the income effect which could induce more fossil fuel use.

If the price of oil, gasoline, and diesel is set primarily in a world market and biofuel production quantities do not affect these petroleum markets, a biofuel subsidy sufficient to induce biofuel use would lead to a one-for-one displacement of non-renewable fuels for renewable fuels (de Gorter and Just, 2008b). But as discussed before, Du and Hayes (2008) estimate that the U.S. ethanol blending has led to a reduction in retail gasoline prices from $0.29 to $0.40 per gallon due

[49] Tyner and Taheripour (2007) consider several variations on subsidies as future policy alternatives given 2 policy goals: increasing national security through reducing energy independence and reducing carbon emissions to mitigate global warming. They first consider a variable rate subsidy to reduce energy independence that kicks in when the price of a barrel of oil drops below $60, and increases as oil prices decline. This approach in principle will help keep the biofuel more competitive relative to oil-based fuels while reducing the required tax revenues when oil prices are higher. They next consider a 2-part subsidy that contains one component that does not vary across renewable fuel types (for the energy security goal) and one component that is proportional to net carbon emissions in order to incentivize the production of low-carbon biofuels.

to an (implied) reduction in demand for petroleum-based gasoline.

Subsidies are often provided by states and countries to increase the relative competitiveness of their local industry relative to the regional or world market competitors, and the urge to do this is particularly strong when a local industry is less competitive than producers elsewhere. It is important in this situation to consider the economic effects on a small open economy that provides these subsidies. First note that if local producers are not competitive, it basically means that others can produce the good or service at lower cost elsewhere. A subsidy will reduce these costs and help a local industry become more competitive. However, in order to make a high-cost local industry competitive, the government expenditures must be used to support local production. These government expenditures are funded by taxes on local consumers. Thus, if a subsidy is used to make a local (high-cost) producer exactly as competitive as other producers, consumers will be buying goods at the world market price *and* paying taxes to support the local high-cost producer. This represents a transfer of wealth from taxpayers to local producers, and the state as a whole (consumers, producers, and taxpayers) is worse off than if the subsidy were not provided and the goods were imported.

A subsidy for biofuels also affects the markets for feedstocks and co-products. Inducing more biofuels to be produced by providing a subsidy calls for more feedstock to produce it, and the equilibrium price and quantity of feedstock used will increase as well (Rubin et al., 2008). For example, de Gorter and Just (2008d) estimate that the 51¢ ethanol tax credit indirectly results in a corn subsidy as high as $2.04 per bushel. Gardner (2007) estimates that the long-run effect of subsidies is a corn price increase of 6.5%, or about 24 cents. Among other things, this close relationship between ethanol subsidies and corn prices leads Rubin et al. (2008) to argue that ethanol subsidies are very effective at increasing farm incomes, though not as effective for supporting other stated objectives of the federal biofuel program.

In terms of the benefits of a biofuel subsidy to the agricultural sector, Gardner (2003) finds the intriguing result that under plausible market conditions, ethanol subsidies can provide larger benefits to corn growers than deficiency payments.

The effect of a biofuel subsidy on the co-product market is somewhat different. If a biofuel is subsidized, the quantity of both the biofuel and its co-product will increase for any given market price of the co-product. If the demand for the co-product remains constant, the price of that co-product will decline. In fact, if a large amount of a co-product with little economic value is produced, prices can go from positive to negative to the degree that it costs to dispose of the co-product. Economic returns from co-products are often touted as being very important to the viability of biofuel markets, but it is crucial to recognize that when local and regional markets are flooded with biofuel co-products, prices will tend to decline. The extent of price decline depends on the extent of the market for co-products. This in part depends on how well these biofuel co-products may act as substitutes for similar products in different markets.

There are also, of course, environmental effects that occur through changes to biofuel markets. In terms of carbon emissions, there are 2 effects of a biofuel subsidy. First, it increases biofuel's share of total fuel consumed, and second, all else equal, it decreases the price of the blended fuel and therefore increases consumption of the blended fuel. Even given the assumption that the biofuel provides CO_2e emissions savings over petroleum-based fuels, the effect of a renewable fuel subsidy on total blended fuel carbon emissions is ambiguous because the increased aggregate use of blended fuel may outweigh the per-unit emissions reduction that results from blending low-carbon fuel into petroleum-based fuel.

Feedstock subsidy

A subsidy for feedstocks has the same type of effects on feedstock markets as a biofuel subsidy has on biofuels: it leads to a higher price received by producers, and a lower price paid by consumers of the feedstock—who in this case are biofuel producers. In general, the subsidy is shared, because some will be passed on to biofuel producers through lower feedstock prices. Feedstock costs are generally a major component of biofuel production costs, so a feedstock subsidy can in principle substantially reduce the costs of biofuel production. These economic effects are very similar to those of a biofuel subsidy because the markets are so tightly integrated.[50]

It is important to consider the fiscal effects of a subsidy in the context of feedstocks. In order for Washington State to induce Washington producers to produce biofuel feedstocks for current markets, it will have to subsidize to the point that feedstock prices are competitive with the crops currently grown. Because these crops are in many cases high-value crops, subsidies will likely have to be relatively large to make local feedstocks competitive at world and regional prices (see the feedstock assessment in Ch. 3). And this means that Washington taxpayers will have to pay additional taxes to support the subsidy.[51]

Thus, because of the relative richness of Washington agricultural land for other uses, an effective biofuel feedstock subsidy to support in-state feedstock production would likely be especially costly. An important corollary to this argument is that even if a subsidy for in-state biofuel production were provided, the costs to the state would be much higher if this production required the use of feedstocks produced in the state.

Fossil fuel tax

A tax levied on the producer or consumer of petroleum fuels will increase the market price of petroleum fuels relative to biofuels, and in doing so will reduce market production and consumption of petroleum fuels. As with subsidies, a tax leads to substitution effects and income effects. The substitution effect induces consumers to substitute renewable fuels for fossil fuels due to the higher relative after-tax price of fossil fuels. However, unlike the subsidy, the tax will make blended fuels more expensive, leading to substitution away from blended fuel use toward other goods. The income effect of a tax, in contrast to the income effect of a subsidy, leads to less consumption of blended fuel because fuel users will conserve and spend less on all goods. Thus, a tax on fossil fuels is different than a subsidy on either biofuels or feedstocks in that it will tend to reduce consumption of blended fuels, all else equal.

The interplay between the effects of a gasoline tax is illustrated in a paper entitled "Does Britain or the United States Have the Right Gasoline Tax?" (Parry and Small, 2005) that outlines the main reasons often voiced for taxing gasoline consumption: (a) to reduce gasoline use to reduce local

[50] This result is an illustration of the common textbook result that a subsidy or tax is shared by producers and consumers in the same amounts regardless of whether the subsidy (or tax) is placed on the producer or consumer. The characteristics of the market determine who receives what share of benefits from a subsidy (or costs of a tax), not who the government targets.

[51] These arguments are also valid at a larger scale for federal support programs of agriculture as well as in the context of world markets.

air pollutants and CO_2 emissions, (b) to reduce driving to reduce congestion and traffic accidents, and (c) to raise government revenues. Incidentally, Parry and Small find (with a focus around year 2000) that Great Britain's fuel tax rate of about US$ 2.80 was about twice the optimal tax rate for Great Britain, whereas the average U.S. federal plus state tax rate at the time was US$ 0.40, less than half of the optimal rate for the U.S.

But Parry and Small (2005) also point out the argument that fuel taxes such as these are imperfect instruments for addressing air pollution, congestion, and other traffic-related costs. For example, a fossil fuel tax will only reduce carbon emissions because carbon emissions are incidental to fossil fuels. If there are differences in motor fuel pollution emission rates through automobile use, such a tax will not help incentivize consumption of low-polluting fuels.

The economic incidence of fuel taxes is also worth noting. Chouinard and Perloff (2004) show that when gasoline taxes are imposed at the federal level, consumers and wholesale distributors of gasoline each pay about one half of the tax. In contrast, almost all of the burden of state taxes is borne by (local) consumers because of the flexibility with which wholesalers can respond by moving fuel between states. Furthermore, a fuel tax, like most sales taxes, tends to be regressive, imposing higher real costs on lower income households.

Renewable fuel standards (RFS)

In a static model that includes the biofuel, blended gasoline, and corn markets, de Gorter and Just (2007) show the basic economic effects of an enforced renewable fuel standard. For brevity, we will omit much of the background explanation and focus on the results of most interest for our purposes.[52]

Consider imposing a binding blend mandate such that some fixed fraction of motor fuel purchased by consumers in Washington is made up of biofuel. Imposing or increasing a blend requirement causes the average ethanol price received by ethanol producers and paid for by blenders to increase, as well as the average consumer price paid for blended fuel.

Basically, the blend mandate imposes a de facto subsidy to ethanol producers paid for by consumers of blended fuel. Quantities of ethanol consumed increase, quantities of fossil fuel decrease, and because the price of blended fuel increases (at least in terms of per unit energy), total consumption of blended fuel decreases. For illustration, de Gorter and Just (2007) estimate that a mandate for a 3 billion gallon increase in 2006 would have increased the price of ethanol by 8% and the quantity by 50%. The price and quantity of gasoline consumption would have declined by 1.4% and 2.4%, respectively, relative to what they would be if the mandate were not imposed. As with a biofuel subsidy, demand for biofuel inputs will also increase in response to an RFS, leading to an increase in market price and input quantities (Tyner, 2007; McPhail and Babcock, 2008).

The U.S. ethanol program and ethanol market as a whole can have impacts on national and regional gasoline markets. Du and Hayes (2008) estimate that ethanol production in the U.S. has led to decreases in retail gasoline prices from \$0.29 to \$0.40 per gallon, and may have "significantly" reduced the profit margin of the oil refinery

[52] A few fundamental assumptions are worth noting here. The below assumes that the production costs of the biofuel are larger than those of the gasoline (including feedstock costs), and that the fossil fuel and biofuel are basically perfect substitutes (recognizing that this is not the case complicates things, but would not change the basic results discussed here). We also primarily discuss the case in which there is a competitive world market for oil in which the state has no capacity for altering the world oil price.

industry. Similar to the effect of a federal gas tax, the effect of a blend mandate on sales is that blended fuel prices will be higher, and the lion's share of the extra cost of fuels will be passed on to the consumer rather than producers to the extent suggested by Du and Hayes (2008).[53]

Economists have been recommending since the 1960s the implementation of cap-and-trade programs as an alternative to pure quantity-based standards to reduce the aggregate compliance costs of environmental standards (Crocker, 1966). Such programs have now been implemented widely, from the SO_2 trading program developed under the 1990 Clean Air Act to the EU Emissions Trading Scheme for CO_2 (Burtraw and Evans, 2008). A cap-and-trade mechanism comprises 2 parts: 1) a cap on total emissions among the effected parties, and 2) emissions allowances, or credits, owned by firms that consume said credits by emitting pollution at a point in time, either bank the credits for future emissions, or sell the credits to another firm that can then produce the amount of emissions associated with the credits.

In the context of a renewable fuel standard, fuels are physical and tradable commodities. In principle, if one firm can produce ethanol more cheaply than another, the high-cost firm could simply purchase the biofuel from the low-cost firm until their total obligations are met. This is the foundation for the tradable RINs of the federal renewable fuel standard. Flexibility in end-use content from gallon to gallon in turn is likely to allow more flexibility for responding to market demand for various blended fuels (e.g. E_{10} for most vehicles and E_{85} for flex fuel vehicles), thereby increasing the aggregate value of blended fuels for a given aggregate average content requirement (Arimura et al., 2007 among others). On the demand side this is because of differences in the way renewable fuels are used by different end-users, and on the supply side because of differences in production and distribution costs across firms (the supply side).

The cost savings from a cap-and-trade program relative to an across-the-board cap in emissions at the firm level results from allowing firms that can reduce emissions at low cost to sell their right to emit to firms who find it more costly to reduce emissions. In principle, this allows the emissions reductions to be generated by only those firms who can do so at the least cost. Therefore, these cost savings will only be substantive if there is substantive variability in the cost of satisfying the standard across firms. Newell and Stavins (2003) show that the cost savings from allowing trade are larger as the variance in firm's costs of meeting the standard increases relative to their baseline market allocation were the standard not imposed.[54]

However, developing and carrying out a trading scheme is not a costless process, and the first question to consider is whether the benefits of allowing trade are worth the administration and transaction costs of an emissions market.

Performance-based instruments

A carbon emissions tax on motor fuels could be applied based on a carbon index at either the retail level or various stages of production. Such a tax would support a biofuels market for basically the same reason a petroleum tax would, and especially for those biofuels that have low net carbon emission life-cycles. One particular advantage of such a tax is that it

[53] One implication of this result is that if an objective of supporting alternative fuels is to increase the competitiveness in traditional fuel markets, a concerted regional or national level approach would be more effective than a state-level approach.

[54] Newell and Stavins (2003) focus on emissions reduction, which is different from meeting a standard.

would support biofuels that are lower net carbon emitters than others. For example, corn ethanol produced in a plant powered by coal would be taxed more than corn ethanol produced in a facility that burned corn stover. In this manner, producers would have an incentive to develop new technologies that emit less carbon and possibly result in greater levels of sequestered carbon.

Furthermore, a carbon emissions tax would lead the fuel sectors to reduce emissions at relatively low cost.[55] A tax on all emitting fuels helps renewable fuel markets only by changing the relative price to favor low-carbon fuels. The substitution away from high-carbon fuels toward biofuels would help, but there would also be an offsetting effect of a reduction of the total quantity of fuel demanded. The ultimate use of the tax revenues affects the economy as well.

There is increasing interest in carbon-based fuel standards. California's low carbon fuel standard and the United Kingdom Renewable Transport Fuel Obligation Programme are examples of policies that allow carbon mitigation trading based on a carbon index of some sort (Farrell and Sperling, 2007; Department for Transport, 2009). Rather than fuel volume, these standards apply to net carbon emissions per unit of energy (or related measure). For California, the metric is termed "global warming intensity," and is measured in carbon-dioxide-equivalent magajoule of energy, with the onus of satisfying the cap on fuel producers, blenders, and importers.

Much like a blend standard, California's low carbon fuel standard (LCFS) regulates the average carbon emissions per unit energy of fuel (carbon intensity) regardless of the amount of fuel produced and consumed. Holland et al. (2008) is among the only economic analyses that focus specifically on the structure of California's LCFS, Which they find is likely to reduce carbon, but is not economically cost-effective relative to alternatives like carbon cap-and-trade programs that limit total carbon emissions rather than intensity.

Price versus quantity instruments

Previously, we examined some of the important effects of basic policy instruments. In this section, we examine the basic strengths and weaknesses of these approaches in more detail. We have found that taxes, standards, and subsidies can all be used to favor renewable fuels. Below we provide a comparative analysis of the relative performance of these instruments to reach the goals of the legislation supporting this report. We then argue that for biofuels in Washington State, price instruments such as taxes and subsidies should primarily be used rather than quantity instruments such as renewable fuel standards and cap-and-trade programs.

The foundations of this conclusion come from several lines of economic literature, the larger policy environment in which Washington will likely be operating, and results from our own Washington State Economic model, all of which will be discussed below. To be clear, the economics literature is not entirely settled regarding the relative merits of price or quantity instruments in general. Our conclusion to recommend focusing on price instruments draws from what we see as important idiosyncrasies of Washington's market and policy setting as a whole.

It is useful to start by summarizing some of the basic arguments for or against price and quantity instruments in the form of

[55] In well-functioning markets, the carbon emissions tax outcome and distribution of carbon emissions across firms would be very similar to that under a carbon standard set for the same aggregate emissions. As such, a tax program can lead to cost-effective emissions reduction in the same sense that a cap-and-trade program does, assuming the implementation costs are similar.

carbon emissions taxes and carbon cap-and-trade programs as important and timely representatives of price and quantity instruments. Stavins (2007, pp. 50-53) provides a useful and concise summary of the relative strengths and weaknesses of these approaches.

In summary, The potential strengths of carbon emissions taxes over cap-and-trade include 1) simplicity in implementation for regulators and firms, 2) reduced political difficulties with allocating allowances, 3) revenues that can be used elsewhere in the economy, and 4) no introduced carbon price volatility.

The potential disadvantages of taxes relative to cap-and-trade programs include 1) political resistance to new taxes, 2) more expense to firms, 3) requests and battles for tax exemptions that might reduce the effectiveness of a tax system, 4) more uncertainty over carbon emissions, and 5) difficulty harmonizing with cap-and-trade programs.

Stavins (2007, p. 53) suggests that the 2 approaches, after modifying them to account for each of their weaknesses, can become increasingly similar in effect. This appears true to an extent, but the uncertainty and market dynamics of real-world conditions leave substantive differences.

Uncertainty and relative economic efficiency

A line of research beginning with Weitzman (1974) shows that price and quantity policy instruments behave differently in terms of expected social welfare when there is uncertainty in markets. In particular, Weitzman shows that quantity-based instruments are more effective than price-based instruments if the benefits from further emissions reductions (that is, the marginal benefits) increase more with pollution increases than do the costs of further pollution reductions.

Fischer et al. (2003) examine instrument choice, but explicitly allow technological innovation to be endogenous such that it responds to policy incentives in a 3-stage static analysis. Their findings extend Weitzman's approach in several ways. In particular, quotas (i.e., cap-and-trade programs) are favored over taxes when marginal abatement cost curves are relatively flatter (and marginal benefit curves are relatively steeper). Dietz and Stern (2008) argue that this is likely to be the case for GHG emissions, and so quantity instruments would tend to out-perform price instruments for climate change mitigation.

Because GHGs are stock pollutants, dynamic models that incorporate stock effects are generally more appropriate and can provide insights that static models cannot. A rapidly growing literature on the economic dynamics of climate change and mitigation is shedding light on the relative efficacy of quantity versus price instruments. Hoel and Karp (2002) and Newell and Pizer (2003) extend Weitzman (1974) to include the stock effects of GHG accumulation, but based on several different assumptions about the characteristics of uncertainty and policy adjustment. Despite their differences, both find that taxes tend to dominate standards for controlling greenhouse gasses. Newell and Pizer (2003) in particular find the net benefits of using emissions taxes are several times larger than for standards, and the dominance of taxes over standards is very robust over a reasonable range of parameter values. Karp and Zhang (2008) argue based on their results that price instruments are likely to out-perform quantity restrictions for 3 reasons: 1) rapidly changing markets and rapidly changing (endogenous) policy targets tend to favor the use of taxes; 2) given that GHGs are a stock pollutant, the magnitude of the slope of damage function would have to be "implausibly large to favor quotas" (Hoel and Karp, 2002); and 3) market investment in abatement capital in response to both market conditions and policy instruments favors price instruments (taxes on GHGs) further.[56]

Fischer and Newell (2008) develop a dynamic model and generate numerical estimates of the relative efficacy of 6 different policy instruments for GHG mitigation. Under what they consider to be a plausible parameterization of the GHG mitigation problem as applied to the electricity sector, they rank the effectiveness of these instruments as follows: 1) emissions price [tax], 2) emissions performance standard [i.e., a carbon-based standard], 3) fossil power tax [roughly equivalent to a fossil fuel tax], 4) renewable share requirement [roughly equivalent to a renewable fuel blend standard], 5) renewable subsidy, and 6) R&D subsidy.[57]

Fischer and Newell (2008) also find that an optimally tuned policy portfolio tends to achieve emissions reduction at lower cost than any single policy alone. Another example of this growing literature is Pizer (2002), who finds based on a stochastic computable general equilibrium model that expected welfare gains from an optimal price policy are 5 times that of an optimal quantity-based policy for mitigating climate change. He also finds that a hybrid policy provides substantial improvements over both. This possibility will be discussed later.[58]

Price-based instruments are not universally better than quantity instruments even when considering a narrow expected net benefit criterion, but a rapidly growing literature examines the conditions under which each approach tends to do better than the other.

This literature review presented here is not exhaustive, but our reading of the recent literature tends to supports the use of price instruments such as carbon emissions taxes for GHGs mitigation over quantity instruments such as standards and even cap-and-trade regimes.

Cap-and-trade credit price volatility versus tax stability

Parry and Pizer (2007) focus on 2 practical distinctions between price polices and cap-and-trade programs. First, cap-and-trade programs fix the total carbon emissions cap, but allow prices of the regulated product (such as carbon) to vary over time (e.g., European Climate Exchange data). In contrast, with a price instrument, the tax or subsidy remains constant, but emissions adjust over time subject to changing market conditions. Thus, a price instrument provides lower price uncertainty for the targeted industry than a cap-and-trade method.[59]

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[56] We are considering the utilization of renewable fuels versus fossil fuel and life-cycle emissions from fuel production and use. The question in our case is how will the costs of reducing net greenhouse gasses change in the long run? If costs drop substantially through technology change, the long-run marginal abatement cost curves will be relatively flat.

[57] We discuss the issue of R&D subsidies in Chapter 6.

[58] Karp (2008) and Von Dölland en Requate (2008) have implications for regulatory uncertainty induced by multiple equilibria in market settings with investment incentives. Karp (2008) shows that under certain conditions when firms face uncertain quantity-based targets such as non-tradable emissions allowances, it can induce uncertainty for firms about whether or not and to what extent they should invest in pollution-reduction technology, because their competitiveness depends on the investment levels of other firms. In contrast, Von Dölland en Requate (2008) show that for some specific policy commitments, price instruments can lead to multiple equilibria where cap-and-trade policies do not. This is a new area of research, and the conditions under which these issues of regulatory uncertainty arise through multiple potential market equilibria are under debate.

[59] Green (2008) points out that when there are several different industries—in his case, natural gas, coal, and nuclear electrical power generation—correlations between energy and carbon prices in a

For a traditional cap-and-trade arrangement, there is also arguably a more substantial risk of bearing upside costs higher than expected because if a cap or standard is set ex ante and the costs of reaching that standard turn out to be much higher than expected, either these costs must be borne by producers or the standard must be adjusted to address the higher costs. Adjusting the standard in an ad hoc way introduces uncertainty into the process, and if there is a risk of standards being diminished by policymakers, the credibility of the standard is undermined and firms will face this additional policy uncertainty. In the case of a price instrument, if the costs of reaching an environmental goal turn out to be higher than expected, the consequence is that the goal will not be met precisely because firms are able to optimize with respect to emissions by paying for additional emissions if the control costs are higher than originally expected.

Recently, cap-and-trade designs and proposals have begun addressing this volatility and upside cost risk. As noted by Arimura et al. (2007), some carbon cap-and-trade programs provide for a safety valve such that emitters can purchase credits from the regulator if the credit price reaches some specified value. This is effectively a price ceiling for allowances. Some of the new cap-and-trade programs also allow for credit banking (saving and borrowing), which means firms can deal more flexibly with credit price variation.

Immediate incentives versus immediate market response

In their commentary on achieving low-cost GHG emission targets, Schneider and Goulder (1997) make an important distinction between immediate abatement of GHGs and immediate implementation of policy for GHG abatement. They argue that while it may be economically optimal to delay the actual abatement of GHGs because it may lower the costs of climate change mitigation, this does not imply that implementation of policy to set the process in motion should be delayed as well. To the contrary, even if the goal were to focus on long-run, low-cost GHG reductions the bulk of which to be performed in the distant future, policy must be implemented immediately to induce the necessary changes in technology and capital.

There is a potentially important distinction between price-based instruments such as fossil fuel taxes or renewable fuel subsidies and renewable fuel standards as generally implemented. Many renewable fuel standards, including Washington's (RCW 19.112.110) and Oregon's, are introduced in such a way that the standard is not implemented unless and until a certain amount of production is realized in the state. The weakness of this approach is that it provides no direct incentives to invest in the renewable fuel industry until dates for the RFS become clear.[60] Prior to that, there is substantial regulatory uncertainty and little to no incentive to invest in production or distribution capital. This is similar to the regulatory uncertainty discussed in Karp (2008).[61] In contrast, a stable renewable fuel subsidy, for example, provides an incentive not only for producers to produce more renewable fuel than if the subsidy were not in place, but it also provides a tangible positive incentive for firms who are not in the industry to consider entering in order to receive the subsidy. Thus, even if the subsidy is not utilized by firms in the short

cap-and-trade system can reduce the overall price volatility that a firm faces.

[60] Once the RFS implementation dates are clear, firms can infer what to expect in terms of the increased demand for renewable fuels that follow from the standard.

[61] The foundation of the regulatory uncertainty that Karp (2008) points out is a strategic conundrum that firms face. In Karp's analysis there are 2 strategic equilibria because the incentive for one firm to invest is dependent on what other firms do.

run, it provides an incentive to invest in production capital to begin production as long as the subsidy is stable. This weakness of standards relative to subsidies or fossil fuel taxes to induce investment in future production capacity of renewable fuel is especially important in an emerging market where most of the market and non-market benefits are expected to follow from future technology and market development, as is the case with biomass-based second-generation fuels.

Revenue raising and revenue recycling

Price-based instruments provide flexibility in the source of funds to support subsidies and the end use of revenues from taxes. Cap-and-trade programs can generate public revenues also if the credits are auctioned off to obligated parties, but historically, credits have been given to obligated parties.

There is a longstanding debate in the economics literature about whether revenue-generating policies are better than non-revenue-generating policies because the revenue from the tax can be put to use (Parry, 1995, 1997; Bovenberg and Mooji, 1994). Two conclusions are increasingly clear from this literature that are relevant for this report: First, if cap-and-trade programs are used (for carbon or other pollutants), the credits should be auctioned to polluters, not simply given to existing polluters prior to allowing credits to be traded. Second, there are at least 3 important destinations for revenues from either taxes or cap-and-trade credit auctions: 1) marginal subsidies for low carbon and/or renewable fuels, 2) research and development for low carbon and/or renewable fuels, and 3) offsetting other major distortionary taxes such as income or payroll taxes.

The revenue recycling literature generally focuses on option 3 above. Fullerton and Metcalf (2001) examine the question of whether public revenue generation matters for the relative effectiveness of a given environmental policy. They argue that if an environmental policy generates "privately-retained scarcity rents," it will tend to exacerbate pre-existing tax distortions.[62] In contrast, if these rents are not retained privately, but captured as revenues and reinvested appropriately, tax distortions can be reduced.

An important class of privately-retained scarcity rents is the benefits that firms receive when cap-and-trade credits are simply given to them rather than auctioned. Thus, in terms of environmental policy distortions, this and related literature on revenue recycling suggest that if a cap-and-trade program is implemented, credits should initially be auctioned, not given away (Sorrell and Sijm, 2003; Burtaw et al., 2001; Crampton and Kerr, 2002).[63] The importance of auctions over grandfathering for credit (pollution allowance) allocation is also catching on in the policy arena. According to Armuri et al. (2007), all but one cap-and-trade scheme being proposed at the national level propose to distribute a portion of allowances by auction.

Taxing high-carbon fuels to subsidize low-carbon fuels uses the taxes from one blendstock (e.g., unfinished gasoline) to pay for the subsidy of another blendstock (e.g., pure denatured ethanol). There are several politically palatable characteristics of this approach. First, the net price effect on blended motor fuel for a given blend

[62] Mankiw (2007) provides a brief synopsis of the arguments in a popular press format.

[63] There are tradeoffs, however. For another important perspective, see Burtaw and Palmer, 2007. They examine various ways of free distribution that reduce the efficiency and distributional issues that accompany free distribution of credits in general. However, even though the paper focuses on methods for free distribution, they find efficiency gains from applying auctions.

rate will be lower than that if a pure carbon emissions tax is used. This is a characteristic of the policy that is likely to improve its palatability in the U.S. at a time when gasoline prices have reached historic highs even when adjusted for inflation. Secondly, policymakers are more amenable to new tax structures when an increase in a tax in one sector is offset by a decrease in tax in another sector.

In principle, a revenue-neutral tax and subsidy instrument could be developed such that the increase in the tax on high-carbon fuels is offset entirely by the subsidy for low-carbon fuels. As such, the 2 most politically unsavory aspects of a carbon emissions tax (higher fuel prices and higher taxes in general) are alleviated to some extent. If the petroleum or high-carbon fuel tax revenues are used entirely to provide marginal subsidies for renewable low carbon fuel, the approach is revenue-neutral with respect to fuel taxes.[64]

Galinato and Yoder (in press) provide a theoretical foundation for this type of tax/subsidy approach. de Gorter and Just (2007) show that in a static model with zero administration costs, a consumption mandate such as that of the federal government is equivalent to a consumption tax on gasoline that is fully used to subsidize biofuels.[65] That is, under restrictive conditions, a renewable fuel consumption mandate is equivalent to a revenue-neutral tax/subsidy program for fuels. Allowing for offsets to a cap-and-trade (such as firms buying credits from entities not covered by the carbon cap) is also closely analogous to using carbon emissions tax subsidies in part to purchase carbon offsets in addition to providing subsidies for low-carbon fuel.

Subsidies and tax credits for low-carbon renewable fuels

From simulations applied to the electricity sector, Palmer and Burtraw (2005) compare the cost-effectiveness of a renewable energy tax credit, a renewable energy portfolio standard, and a carbon cap-and-trade policy. They find that the carbon cap-and-trade program is the most effective of the 3 (carbon emissions taxes were not considered), followed by a renewable energy portfolio standard.

Integrated policy programs

There is a theoretical foundation and empirical evidence to support the idea that multiple policy instruments such as the joint use of quantity and price instruments can and sometimes should be used to effectively address policy goals. On the other hand, the use of multiple instruments can lead to complications and unintended consequences as well.

Moreover, federal and state governments often apply regulation and legislation that interact with each other in terms of their effectiveness. For example, the state of Washington will be operating within the context of an existing federal renewable fuel standard and subsidy program when developing its biofuel policy, and may also be operating under the Western Climate Initiative's proposed carbon cap-and-trade program. Below we examine what we consider to be among the most important fundamental issues both in support of and as a warning for the inevitability of a complex policy mix.

The benefits of multiple policy instruments

[64] That is not to say it is revenue-neutral for the economy as a whole. Because this approach will change fuel prices, it will affect other sectors of the economy, and total government revenues are likely to change.

[65] The federal program amounts to a consumption mandate and a subsidy for biofuels, which is not equivalent to a revenue-neutral tax and subsidy approach. In fact, the federal combination of an RFS and a subsidy for renewable fuel leads to some surprising and troubling results, as discussed later.

From a theoretical perspective, if there is more than one policy goal (as is the case with HB 1303 and related legislation), or if there is more than one market imperfection, the use of multiple policy instruments is often called for. In particular, one basic theoretical result is that to restore efficiency in an economic system, it generally takes at least as many policy instruments as there are categories of externalities. For example, if there are emissions externalities, weak incentives for basic research and development, and learning-by-doing spillover effects, 3 targeted instruments might be used, such as a carbon emissions tax, public support of basic research, and public cost sharing for demonstration projects (Sorrell and Sijm, 2003).

Fischer and Newell (2008) find that an optimally-tuned policy portfolio of policy instruments tends to achieve emissions reduction at substantially lower cost than any single policy alone. Another example from this growing literature is Pizer (2002), who finds that a hybrid policy provides substantial improvements over both. This possibility will be discussed later.

Pitfalls of integrating policy instruments

Although there may be some benefits to the simultaneous use of more than one policy instrument, there are also potential problems, some of which can be overcome with careful integration of the use of multiple instruments, and some that are more difficult to overcome without more extensive policy design. We consider 2 important cases: 1) the joint use of renewable fuel standards and subsidies for renewable fuels—an approach that describes the current federal renewable fuel program, and 2) the joint use of carbon cap-and-trade programs and carbon emissions taxes, a situation that applies to some participants in the EU Emissions Trading Scheme. Sorrell and Sijm (2003) discusses some of the interaction effects between cap-and-trade programs and other policies. Here we will focus our examples on the interaction between current renewable fuel standards, tax credits, and farm programs at the national level.

There are 2 interesting working papers by de Gorter and Just that examine important, and probably unintended, policy interactions. de Gorter and Just (2008c) examine the effect of joint use of an ethanol subsidy and a renewable fuel standard. The central result of this paper is that when a consumption or blend standard is imposed in conjunction with an ethanol subsidy, it end up being a gasoline consumption subsidy. In a nutshell, this is because the standard itself induces consumption of ethanol, so ethanol producers (and corn producers) bid away to blenders the excess profits they would otherwise accrue from the subsidy. Blenders in turn pass this savings on to consumers of gasoline (again, because the ethanol consumption mandate is already binding).

Thus, the addition of an RFS to a subsidy removes much of the potential benefits of a subsidy to ethanol producers and feedstock growers, and exacerbates gasoline consumption due to the price effect. This is 1 of 3 related reasons why we argue strongly that if subsidies are provided for (low-carbon) biofuels, the revenues to offset these subsidies should come from (high-carbon) fuels rather than general funds. This is important because the federal RFS will likely be binding, and it would be especially important if the state pursues an RFS of its own.

de Gorter and Just (2008a) discusses the interaction between ethanol policies and farm subsidy programs. As they point out, proponents of ethanol subsidies argue that the ethanol subsidy reduces the tax costs of corn price support programs. However, de Gorter and Just find that the corn subsidies increase the costs of the ethanol subsidy, and the ethanol subsidy increases the costs of the traditional corn subsidies. In addition, in some cases the corn subsidies themselves lead to ethanol production and corn producers do not benefit from the ethanol subsidies. It is important therefore to realize that if Washington State chooses to provide tax credits for renewable fuels, federal farm programs may increase the costs of these subsidies to the extent that they apply to feedstocks produced in the state.

CGE results for Washington State

The general literature review of comparative policy effects above is generally applicable to Washington, but not specifically targeted to the state. In this section, we provide a summary of results from a computable general equilibrium (CGE) model calibrated for Washington State as a foundation for comparing the impacts of different policy alternatives on Washington's biofuel and feedstock markets and economy as a whole. These results should be viewed as complements to the general discussion of policy instruments above. Appendix A5 provides a detailed report of how the CGE model was constructed and is run, as well as a full report of counterfactual results.

Computable general equilibrium models are multi-sector models of the economy. The application of different biofuel policies in a CGE framework allows for a relative comparison between impacts of different policies over the entire state economy in aggregate terms. We rely on the IMPLAN (Impact Analysis for Planning) 2006 database for most of the data, but have added more specificity and updates (as late as June 2008) for the energy sector. Results can be interpreted as the economic reactions to policy changes that a small open economy like Washington is likely to make under the given conditions, holding all else constant. This CGE implementation is static, so each policy result can be thought of as a short-run snapshot of a new economic equilibrium that would result from the application of a new policy.

CGE models of this sort, along with their associated assumptions, can only shed light on certain aspects of the questions we are addressing in this report. These results are not meant to be interpreted as accurate quantitative estimates of what an effect a given policy would have, but rather should be used to help understand the relative qualitative impact when comparing the effects of different policies.

To examine the effects of policy changes on the markets for different types of biofuels, we developed the model around corn-based ethanol, cellulosic ethanol, and biodiesel. Each of these has unique characteristics of interest, and behaves differently under different policy approaches. We consider several different policy approaches to illustrate the most important results from the model:

- Renewable fuel standard (RFS)
- Fossil fuel taxes (FFTax)
- Renewable fuel subsidies (RFSub)
- Revenue Neutral fossil fuel taxes used to fund renewable fuel subsidies (RNTaxSub)
- Carbon-based taxes and subsidies (CTax, CSub, RNTaxSub)

We examine the impact of each of these policy types on the following economic indicators:

- State gross domestic product (GDP),[66] which represents the value of production by the state's industry and government sectors, and can be calculated as C+I+G+E-M, where these terms represent expenditures

[66] GDP can also be measured as the sum of incomes related to production, such as wages and salary accruals and gross operating surplus (see IMPLAN vocabulary, http://implan.com/v3/index.php?option=com_glossary&Itemid=164).

relating to consumption, investment, government, exports, and imports, respectively

- Equivalent variation (EV), which is the amount of money in (approximately) millions of dollars that would make households as well off as the specified change in the economy
- Changes in fuel quantities in (approximately) thousands of gallons per day (Q)
- Changes in carbon emissions in kilograms per gallon (CE)

State GDP and EV differ in a couple of important ways. GDP relates to industry and government productivity. One aspect of this that becomes important in our results is that state government revenues are constrained to equal state expenditures, so that if industry productivity is constant but state revenues (and therefore state expenditures) increase, so does state GDP.

On the other hand, EV, which represents the net economic value to households of the policy change (which could be negative), including the effects of price and income changes, does not include the potential benefits from state expenditures. EV is the net benefits of a policy change to households through their employment activities. To the extent that government leads to expenditures that increase the welfare of households, EV underestimates the total net value of a policy change.

Currently, the production of corn-based or cellulosic ethanol does not exist in the state of Washington. Further, successful private markets for cellulosic ethanol are basically non-existent. To assess the net carbon emissions of each fuel type, we rely on debatable life-cycle estimates of carbon emissions. The following are important assumptions that we rely on with relatively little confidence in their validity as applied to Washington State's future. However, they do allow us to compare the effects of different market structures on different policy alternatives:

- Cellulosic ethanol is assumed to be produced following the process described in Aden (2008).[67]
- Net carbon emissions for each fuel type are an unweighted average of existing LCA carbon emissions estimates from easily applicable studies from 2006 onward (see Appendix A5).
- Given the great uncertainty in the nature of these future markets, we developed model parameters in such a way as to yield multidimensional variation across fuel characteristics.

Our approach to calculating net carbon-equivalent emissions (CO_2e) from each fuel type accounts for differences in energy content of fuels and provides the following emissions ranking per gallon from high to low:

Diesel > gasoline > corn ethanol > cellulosic ethanol > biodiesel

The comparisons below are based on market data from about June 2008 and before, as well as the initial production assumptions necessary to implement the CGE. The base case average ethanol blend rate for consumption is about 1.76%, and 2.37% for biodiesel.

These do not match current consumption rates, and the ethanol percentages tend to be higher than the biodiesel average blend rates. Further, the current aggregate ethanol content of blended fuels consumed

[67] This is only one of many cellulosic production processes vying for economic acceptance in advanced biofuel markets. It is based on utilization of corn stover, which is clearly not the biomass of choice for Washington State. However, Aden (2008) is among the few studies that provide the type of information needed for the CGE model.

in the state is above 7.5%, so in reality, an enforced 5% RFS would not be binding at all, nor would it cost the state anything. However, although we have calibrated the model as well as possible given the already dated data we have available to us, the model is designed only for qualitative comparisons of the relative effects of different policies.

Renewable Fuel Standard

Table 5.1 shows the effects of an RFS held at 4 levels (5%, 8%, 10%, and 12%) on fuel quantities. The numbers corresponding to both types of ethanol quantities and gasoline are in response to an ethanol RFS. The biodiesel and diesel responses are the result of a biodiesel RFS.[68]

In response to an ethanol standard of 8%, for example, ethanol volume increases by about 770%, while gasoline volume decreases by 6.79%. Perhaps somewhat more realistically (because some production of biodiesel exists in the state currently), an 8% biodiesel RFS increases biodiesel production by 300% and decreases diesel production by 7.93%. Because the RFSs force a move from high-carbon non-renewable fuels to lower-carbon renewable fuels, CO_2e emissions decrease as the standard is ramped up. Note, however, that each renewable fuel is treated identically under the RFSs for ethanol and biodiesel.

Although mandatory RFSs can be effective for targeting and implementing a blend mandate, they can also be costly. For instance, a 5% biodiesel fuel consumption standard reduces GDP by -$9.98 million, and average EV by 0.45 million over all households. For ethanol, the decline in GDP reaches $70 million, and this is allowing for a (small) cellulosic ethanol industry that out-competes the corn ethanol given current world and state market conditions. If cellulosic ethanol were excluded, the costs of reaching these standards would be larger still. Given the hypothetical comparative advantage that cellulosic ethanol has over corn ethanol, all of the increase in ethanol comes from cellulosic sources, and there is a slight decline in corn ethanol from the base level. While this magnitude of industrial growth is allowed in a CGE model, it is likely to not be feasible in the short-run open economy (see Appendix A5).

Fossil fuel taxes

Table 5.2 shows the effects of a fossil fuel tax. It is important to realize that the magnitude of the numbers in Table 5.2 are

Table 5.1: Base and in-state fuel production response to a Washington State consumption RFS (assuming existing production under base conditions).†

RFS level*		5%	8%	10%	12%
Base Q**		% change in quant. produced			
Biomass Eth	40.21	409.4	771.7	1012	1253
Corn Eth	8.03	-0.04	-0.07	-0.09	-0.12
Gasoline	8331	-3.60	-6.79	-8.91	-11.0
ΔGDP#		-37.5	-70.8	-92.9	-115
EV		-0.94	-1.8	-2.3	-2.9
Carb Emiss		-0.92	-1.74	-2.28	-2.83
Biodiesel	56.22	105.1	309.0	512.5	715.5
Diesel	3652	-2.70	-7.93	-13.1	-18.3
ΔGDP#		-9.98	-30.3	-50.9	-71.5
EV		-0.45	-1.35	-2.26	-3.16
Carb Em		-0.40	-1.18	-1.96	-2.73

†Quantities in this table are not directly comparable to quantities in the following Tables 5.2 and 5.3, but they are qualitatively comparable.

*The ethanol numbers are in-state production levels in response to an in-state consumption RFS on ethanol regardless of type. Biodiesel RFS pertains to biodiesel as a fraction of diesel only.

**Base Q is the imposed starting quantity. Q approximates millions of dollars in revenue per year.

#ΔGDP is the change in GDP in millions of dollars.

[68] In order to sharply define the effects, we impose the ethanol RFS independently of the biodiesel RFS; only one of them at a time were used per model run.

not directly comparable to the numbers in Table 5.1 and Table 5.2 because they are not normalized to any given baseline objective. However, the comparisons of numbers within tables and qualitative comparisons across tables are valid and useful.[69]

The 2 most striking effects of a fossil fuel tax on the CGE economy are that these taxes are the most effective way of reducing the consumption of fossil fuels, and they actually increase the state's GDP.[70] Not surprisingly, EV is negative for every household income class because household income declines from the fuel taxes and the price of most commodities increases. The shock causes a decrease in welfare as expected, even as GDP goes up.[71]

Whether or not an increase in GDP would actually result from an increase in fossil fuel tax is questionable, but the result does suggest that such taxes are effective in reducing petroleum fuel use, reducing carbon emissions, and to some extent shifting the aggregate fuel blend away from fossil fuels and toward renewable fuels. Fossil fuel taxes reduce fuel consumption across the board, but they reduce fossil fuel consumption more, even in percentage terms, than renewable fuels because some fossil fuels are substituted for relatively less expensive biofuels. These taxes lead to overall lower fuel use because fossil fuels are a very important input into the production of all goods in the economy, and therefore affect the costs of biofuel production.

Although taxes increase GDP according to the model, there are substantial negative effects on EV because the prices of all goods tend to increase in response to higher after-tax gas prices. Again, however, EV does not account for the potential public benefits from using the tax revenues to provide other benefits to the public, including the reduction of other tax rates. Further, of all the policy options, fossil fuel taxes are the only revenue-generating policy we consider here.

Table 5.2: Base and in-state fuel production response to a Washington State fossil fuel excise tax on consumption.

Tax level		0.1%	0.3%	0.5%	0.73%
Base Q*		% change in quant. produced			
Biomass Eth	40.21	-0.04	-0.13	-0.21	-0.31
Corn Eth	8.03	-0.05	-0.14	-0.24	-0.35
Gasoline	8331	-0.05	-0.16	-0.27	-0.39
Biodiesel	56.22	-0.05	-0.15	-0.24	-0.36
Diesel	3652	-0.05	-0.16	-0.27	-0.40
ΔGDP#		17.3	52.1	86.7	126.3
EV		-0.67	-2.02	-3.39	-4.96
Carb Em		-0.05	-0.14	-0.24	-0.35

*Base Q is the imposed starting quantity. Q approximates millions of dollars in revenue per year.

#ΔGDP is the change in GDP in millions of dollars.

69 Because of the restricted nature of the model, the highest fossil fuel tax that we could impose was 0.73%. We scaled the remaining tax schedules back as a result.

70 The unusual result regarding the increase in state GDP from fuel taxes stems mainly from an increase in state government revenues and expenditures. State government excise tax revenues increase for the excise tax on gasoline and diesel as expected, but there is an unexpected increase in indirect business taxes (IBT) because one type of tax usually causes other sources of state revenue to fall. However, IBT increases mainly because the fuel tax causes a shift in electricity production away from the public power sector to the private power sector. The production function for public power shows higher use of gasoline and diesel in that sector than is the case for private power, so when gasoline and diesel become more expensive, there is a substitution of private power for public power. Both industries produce the same commodity, but private power pays much higher IBT per unit of output than public power, which increases IBT for the whole economy even though production declines for every industry in the economy except private power. Thus, we get an estimated increase of state GDP even though factor income declines.

71 Recall, however, that no benefits accrue to households from the increase in public goods and services associated with the larger government expenditure. This is a weakness of the underlying theory.

Renewable fuel subsidies

Table 5.3 includes results for renewable fuel subsidies funded by from the general tax base. Unlike fossil fuel taxes, renewable fuel subsidies stimulate positive growth in the targeted renewable fuel markets. However, they are also costly in terms of the state's GDP.

For example, a 5% renewable fuel subsidy induces a 21.65% increase in domestic biofuel output. It also leads to a 0.19% increase in producer price, which is an index of producer costs. In contrast to biodiesel, a subsidy of this level for corn ethanol will lead to an increase in producer price by 4.76%, but output only increases by 1.12%. This is an illustration of the comparative disadvantage that the state has in the production of corn ethanol. Subsidizing the (hypothetical) cellulosic ethanol industry provides very different effects: a decreased producer price of 0.001% and a 12.56% increase in production. Simply put, not all biofuel technologies are created equal.

State GDP is negative throughout[72] because state revenues are used to fund the subsidy, and the increased productivity of the renewable fuel sector does not fully offset these tax expenditures. EV is positive because the subsidies make blended fuel prices decline, making household purchasing power increase (though again, the opportunity costs of using state revenue for subsidies is not accounted for in EV).

Even though there is a substantial substitution away from non-renewable fuels toward lower-carbon renewable fuels, non-renewable fuel quantities change very little. In fact, diesel quantities actually increase. Blended fuel quantities increase because the subsidies lower blended fuel prices by lowering renewable fuel quantities. The implication of these results is that subsidies alone are not very effective for reducing utilization of petroleum-based fuels.

[72] Due to the structure of the CGE model, the subsidy does not distinguish between in-state produced fuel and imported fuel. However, when import frictions (Armington elasticities) are set to minimize importation, the effects are minimal.

Table 5.3: Effects of a subsidy from general tax funds.

Subsidy level		5%	10%	15%	20%
Base Q*		% change in Q			
Biomass Eth	40.21	12.6	27.3	44.7	66.2
Corn Eth	8.03	1.12	6.78	5.11	29.25
Gasoline	8331	-0.004	0.04	0.08	0.13
Biodiesel	56.22	21.65	52.6	100.7	186.1
Diesel	3652	0.03	0.06	0.011	0.16
ΔGDP#		-11.7	-26.8	-47.7	-80.5
EV		0.12	0.21	0.22	0.08
Carb Em		0.03	0.06	0.09	0.15

*Base Q is the imposed starting quantity. Q approximates millions of dollars in revenue per year.

#ΔGDP is the change in GDP in millions of dollars.

Carbon emissions increase as subsidies are provided because the total amount of fuel consumed increases more than enough to offset the substitution effects on carbon emissions.

Fossil fuel taxes to fund renewable fuel subsidies

Using fossil fuel tax revenues to fund subsidies for renewable fuels leads to CGE results somewhat comparable to RFS results. This should be no surprise, because an RFS effectively imposes a negative shift in the intermediate demand for fossil fuels (which is what a fossil fuel tax does) and a positive shift in intermediate demand for renewable fuels (which is what a subsidy does). Table 5.4 shows the effects of using an increasing proportion of revenues from a fixed fossil fuel tax to subsidize biofuels.

The size of fossil fuel tax required to fund a 20% renewable fuel subsidy is quite small given that a 0.1% gasoline tax will approximately fund a 20% subsidy of cellulosic and corn ethanol and a 0.2% diesel tax will approximately fund a 20% biodiesel subsidy.

Table 5.4 provides some examples of the effects of increasing a biodiesel subsidy based on a fixed volumetric tax of 0.2% on diesel from 0% of the tax revenues to 100% of the tax revenues (which approximately provides a 20% subsidy). Not surprisingly given our previous results, the tax causes both diesel and biodiesel quantities to decline. As subsidies for biodiesel increase, biodiesel quantities increase substantially, while diesel quantities increase very slightly because blended fuel price decreases, leading to a higher aggregate biodiesel aggregate blend. This increase in blend, however, is accompanied by lower GDP than when the subsidy is not provided.

One additional effect of taxes and subsidies that we have not examined yet are changes in prices. Figure 5.4 shows that a fossil fuel tax increases the price of gasoline (so the price change is positive on the left side of the graph). As subsidies increase, not only do the net revenues from the tax subsidy program decline, but the price of gasoline blendstock decreases as well. This result of the model is consistent with several studies of the effects of ethanol on gasoline prices (e.g., Sexton et al., 2008).

Carbon-based vs. volume-based taxes & subsidies

If policy instruments are based on carbon intensity, the CGE model results change because technologies are rewarded for reduced CO_2e emissions, not just for changing fuel quantities. The easiest way to see the differences in these effects is to compare the effect of a renewable fuel subsidy to the effect of a carbon-based subsidy on the quantities of cellulosic vs. corn ethanol. Because cellulosic ethanol was specified to have a lower CO_2e intensity than corn ethanol, we expect cellulosic ethanol to receive a larger subsidy than corn ethanol.

Table 5.5 shows that under the fossil fuel subsidy, the cellulosic ethanol quantity consumed increases approximately 23 times more than corn ethanol. Under the carbon-based subsidy, the cellulosic ethanol quantity consumed increases over 50 times more than corn ethanol. This difference between the relative effects of the volumetric subsidy over the carbon-based subsidy is even more pronounced in terms of quantities produced. Cellulosic ethanol increases about 11 times more than corn ethanol under the volumetric subsidy, but almost 250 times more under the carbon subsidy. Again, the sole difference between these 2 policies is that under the volumetric subsidy, both types of ethanol are subsidized the same. Under the carbon-based program, cellulosic ethanol is subsidized at a greater rate.

Feedstock subsidies

Feedstock subsidies can influence not only feedstock production, but also fuel production and prices. Figure 5.5 shows some of the effects of a 20% feedstock subsidy on oilseeds, corn, and switchgrass.[73]

[73] We chose these feedstocks only because we have associated production information and they represent a broad spectrum of feedstock types.

Table 5.4: Percent changes in biodiesel quantities as the fraction of a 0.2% diesel tax applied to support biodiesel subsidies increases.

Subsidy (approx)	% of tax revenues	State GDP	% change in quantity Biodiesel	Diesel
0%	0%	22.53	-0.06	-0.08
4%	20%	13.38	16.66	-0.06
8%	40%	2.31	38.66	-0.03
12%	60%	-11.67	68.97	0.00
16%	80%	-30.36	113.55	0.03
20%	100%	-57.78	185.80	0.08

State GDP declines in all cases because these subsidies require tax revenues and cost more than the value they add to the economy.

EV increases for oilseed and switchgrass subsidies because feedstock subsidies lower the price of feedstocks, which in turn lowers the price of biofuels, which in turn increases the purchasing power of consumers.

Table 5.5: Change in low-carbon to high-carbon quantities consumed and produced in response to volumetric versus carbon subsidies (lowest subsidy rate for each).

Q=quantity	Volumetric	Carbon-based
Cellulosic Ethanol Q consumed	3.00	3.86
Change in corn Ethanol Q consumed	0.13	0.08
O (cellulosic)/Q (corn) consumed	23.20	50.37
Cellulosic Ethanol Q produced	26.61	36.34
Change in corn Ethanol Q produced	2.35	0.15
Q (biodiesel)/Q (diesel) produced	11.32	246.62

Corn subsidies, in contrast, reduce EV for a couple of reasons. First, increasing corn production draws capital and labor away from other high-value production processes, and in this case the benefits in terms of corn and ethanol price are not enough to outweigh these other price effects. The tax burden to support the subsidy exacerbates this problem.

Carbon emissions increase in all cases because the increase in blended fuel (from a lower price) outweighs the substitution effects toward renewable fuels with lower carbon intensity.

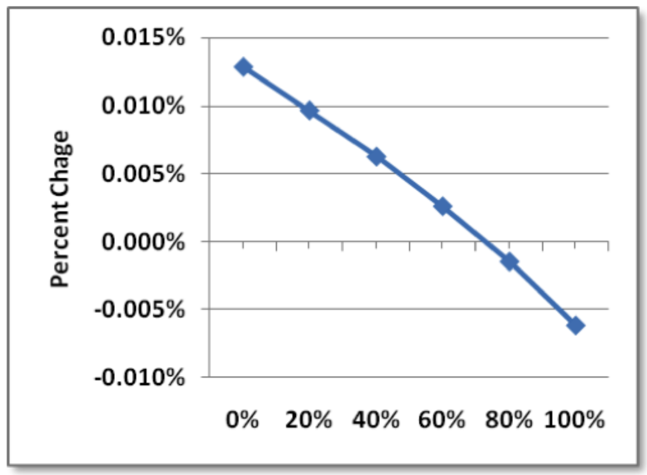

Figure 5.4: Percent change in the price of gasoline blendstock for a subsidy fraction of fossil fuel tax.

Table 5.6 provides a comparison of the effectiveness of renewable fuel subsidies to feedstock subsidies. The first and second line show the effects of an ethanol subsidy and a switchgrass subsidy, respectively, on the value production (sales) of cellulosic ethanol and switchgrass. A switchgrass subsidy of 20% increases ethanol sales by $13.59 million, and feedstock sales by $18.09 million. An ethanol subsidy of 20% increases cellulosic ethanol sales by $26.61 million and switchgrass sales by $20.53 million. Most importantly, the ratio of fuel to feedstock sales is higher for a subsidy to cellulosic ethanol (1.30) than a subsidy to the feedstock (0.75). This result holds across all 3 types of fuel/feedstock combinations. The implication is one we have seen with when comparing volumetric versus carbon-based instruments: if the goal is to increase renewable fuels, target renewable fuels; if the goal is to increase feedstock production, target feedstocks.

The CGE modeling approach is useful to help understand some of the fundamental effects of different policy options on various economic indicators of interest. Because of information deficiencies and the fact that there is currently no ethanol production in the state of Washington against which to calibrate the model, and because cellulosic ethanol is still not produced commercially and the technology is in rapid development, the results should only be used to help understand the relative qualitative effects for policy comparison.

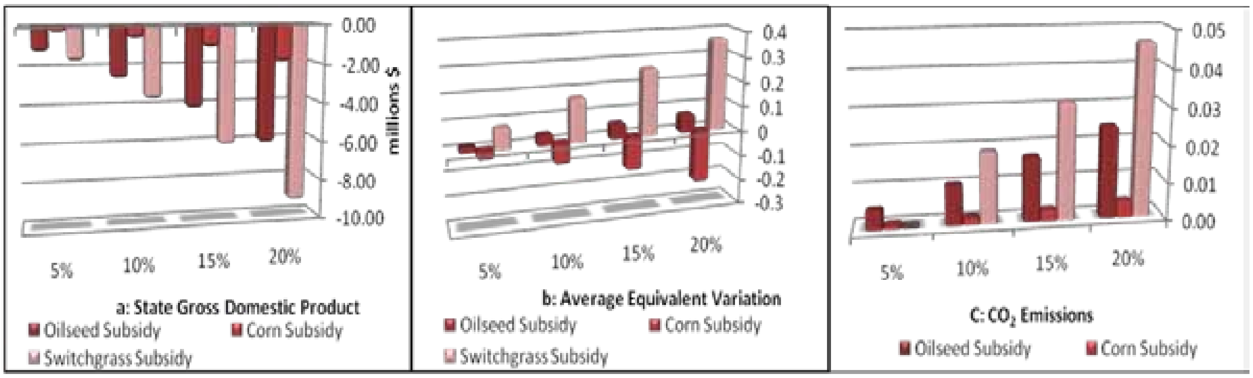

Figure 5.5: Effects of feedstock subsidies on GDP, EV, and CO_2e emissions.

Table 5.6: Relative effect of renewable fuel subsidies and feedstock subsidies on the value of fuel and feedstock production.

20% subsidy to	Change in value fuel sales (dVfuel)	Change feed-stock sales (dVfeed)	Ratio dVfuel/ dVfeed
Cellulosic Ethanol	26.61	20.53	1.30
Switchgrass	13.59	18.09	0.75
Corn Ethanol	4.16	3.92	1.06
Corn	2.08	3.77	0.55
biodiesel	105.13	2.33	45.14
oilseeds (canola)	0.77	0.49	1.56

The actual numbers as values and levels are not reliable predictions of market response.

Summary of implications from the economics literature and CGE analysis for Washington State

As discussed in the first section of this chapter, we conclude that a carbon tax is the best foundation for our policy approach. In the theory section of this chapter, we found that recent literature points to several advantages of price instruments over quantity instruments in our context. The most important of these include improved economic efficiency from taxes in emerging, technology-intensive industries; lower price (tax) volatility relative to cap-and-trade programs; and more flexibility in revenue distribution and use.

Our CGE analysis suggests that taxes are less onerous for the economy as a whole than subsidies (which are costly for the state), but subsidies allow a more targeted approach to promote biofuel markets, and carbon-based instruments target carbon better than volume-based instruments, and they happen to target those fuels and feedstocks that Washington is best situated to produce as advanced biofuels become increasingly important within national and international fuel contexts.

Chapter 6: Research, development, and infrastructure recommendations

Market incentive policies such as renewable fuel standards, fossil fuel taxes, and volumetric subsidies are generally tied to inputs and outputs of functioning firms and consumers such that they affect production and consumption at the margin. They provide incentives for private firms to invest (or not invest) in an industry in much the same way as product prices do. These policy instruments will strengthen the incentives of private firms to invest in research and development (R&D) in order to better compete in these markets (Kverndokk and Rosendahl, 2007; Popp, 2004; Buonanno et al., 2000).

There is a growing induced innovation literature focusing on environmental policy that examines the capacity for policy instruments such as carbon taxes and cap-and-trade programs to induce private innovation and investment toward lower-cost cleaner technology (Hicks, 1932; Popp, 2006; Mohr, 2002; Ambec and Barla, 2002).[74] However, even with well-designed market incentives targeted at production or consumption, several characteristics of technology-based emerging markets may lead to weak incentives for private investment. These market imperfections combined with other social objectives may warrant public investment in R&D in addition to, or in conjunction with, other policies. Therefore, public policy toward research, infrastructure, and other investment dimensions of market development can be viewed as another policy tool.

The economic fundamentals of private investment are relatively straightforward, at least at a conceptual level. It is often useful to consider 2 related conditional objectives: 1) invest in options that provide the highest expected net present value for a given level of risk, or 2) invest in options that best reduce risk for a given expected return.

These economic fundamentals concerning private investment are only part of the picture when considering public investment decisions. Another important dimension of the investment decision relates to the appropriate mix of public and private investment (Gardner and Lesser, 2003). As discussed in more detail below, public investment in research and development (R&D) and infrastructure can be justified if:

- There is a high expected net social return from the investment,
- There are clear reasons why an unregulated private sector is unlikely to invest at socially-optimal levels (e.g., non-exclusivity, non-rivalry, tendency toward monopoly and/or inadequate risk-transfer markets), *and*
- The likely social benefits of the investment will be broadly distributed within the society.

As an example, it is often argued that each of these criteria has been satisfied for research in a number of areas, including agriculture. Estimates of historical rates

[74] This is just one specific example of the general economics of technology, exploration, and capital input investment.

of return to public investment in all agricultural research are consistently relatively high, with some more than 25% per year (Huffman and Evenson, 2006). Innovation firms are unable to capture the full economic benefit of their discoveries, and the effect of discoveries that lower the cost of production has been to lower the price of food and fiber by nearly as much (e.g., it took 37% as many inputs to produce the same agricultural output in 2004 as in 1948, and consumers spent only 43% as much of their personal disposable income on food in 2004 as in 1948 even though the portion of total food expenditures from purchases away from home more than doubled [Economic Research Service, 2008a, 2008b]). Consequently, improved standards of living were made possible for the entire public because of public investment in agricultural research. Because energy generally, and motor fuels specifically, are so fundamental to the costs of production of not only food, but virtually all goods in today's economy, and because the development of renewable fuel markets—especially advanced biofuels—are so dependent on technology development, we argue that well-targeted public investment is likely to be constructive. We also argue that targeting this public investment is crucial if it is to complement rather than crowd out private investment in biofuel technologies.

Public Investment in Innovation

We first examine the economic foundations for public investments in research and development, and then public support for late-stage technology.

Research and development

Concepts from economics, particularly notions of market failure, provide tools for analyzing the needs and possibilities for public action in research and development. We outline 4 issues below: information spillovers from R&D, comparative advantage of public research institutions, welfare redistribution effects through market prices, and returns to investment relative to the market's technological maturity.

Information and technology spillover

Consider technology as a package of information rather than a physical good. To the extent that technology is embodied information, it can be characterized as a joint use, classic public good. In economic jargon, public goods are not the same as publicly-provided goods. Public goods are defined as commodities whose services can be used by more than one individual simultaneously, such as movies on a large screen, scenic vistas, national defense, and general information. Two people can simultaneously benefit from clean air or a reduction in risks from global warming, each without affecting the other's level of benefit.[75] Economic analysis shows that such joint-use situations lead to inefficiency, and has thus been widely used to justify public support of R&D (Byerlee and Echeverría, 2002).

Comparative advantage of public research institutions

A closely related argument motivating public involvement in R&D is examined by Aghion et al. (2005). They argue that even if all benefits from R&D are fully appropriable (i.e., both public and private

[75] More precisely, a classic public good has the potential for undiminished simultaneous use and inability to exclude access. Interestingly, patents and copyrights are legal means of promoting private R&D (innovation) by privatizing the inherently public good nature of information by granting property rights to specific information and technology. Although the provision of such property rights provides an incentive for innovation ex ante, the tradeoff is that it can limit the economic benefits to society after development of the technology.

research organizations retain full rights to research output), the structures of university and non-profit organizations provide a comparative advantage for basic, early-stage research. In contrast, private firms have a comparative advantage in development of late-stage technology. Further, Aghion et al. argue that these differences are such that much critical basic research would never be pursued except in the public sector.

In the context of canola research, Mall and Gray, (2005) find that public basic research promotes private applied (later-stage) research, and that public applied research has a long-run crowding-out effect on private applied research. The implication of each of these studies is that public institutions have a comparative advantage for doing basic research.

Distribution of economic effects

A third argument for public research investment in markets such as agriculture is that, for competitive markets, benefits from public investments tend to be broadly distributed among consumers (Shumway, 1998). To the extent that bioenergy markets are competitive and consumption is broadly distributed, public investment in biofuels research tends to reduce energy prices, which benefits low-income individuals proportionately more, and so can be thought of as a distributive public policy instrument.

Addressing market imperfections and improving market performance

The market incentive programs discussed in the previous chapter such as carbon taxes are motivated and shaped by market imperfections such as environmental externalities and market power. Two characteristics of those policies are important here. First, they require information to implement effectively. The most pressing example of this from the previous chapter is the need to measure carbon intensities of fuel. The better the measure, the better the economic performance of a carbon tax, and developing these measures requires substantive research.

Second, a carbon tax, even if it targets carbon emissions effectively, does not account for other environmental effects. Understanding the range of environmental effects from biofuel market development is important for understanding the full consequences (market and non-market effects) of biofuel production and consumption, and to account for it as policy evolves. Water utilization and water quality impacts from production and consumption relative to other fuels are a couple of examples.

Returns to public investment in technology and adoption

The returns to public investment in R&D, technology implementation, and infrastructure depend on the characteristics of the markets in question, and in particular on the technological maturity of those markets. Kverndokk and Rosendahl (2007) study the effectiveness of technology subsidies for climate change mitigation by examining the dynamics of technology adoption decisions and experience effects ("learning by doing"). They find that optimal subsidies for new technology implementation are highest at first adoption and decline over time. This is consistent with the findings of Duke and Kammen (1999), who examine 3 energy market transformation programs (MTPs): the U.S. EPA's Green Lights program to promote energy efficient lighting, the World Bank Group's Photovoltaic Market Transformation initiative, and the U.S. federal grain ethanol subsidy. They find (along with others) that the incentives for corn ethanol (which are based solely on volume, not performance) have been ineffective in helping to induce technological change in ethanol markets, primarily because the low-cost production process based on corn is a mature technology with little likely potential for major cost reductions.

As discussed in the market incentives chapter of this report (4), Fischer and Newell (2008) find that an R&D subsidy is the least effective of several policy instruments for addressing climate change in the electricity markets.[76] They conclude that this result is in large part due to the fact that other policy instruments incentivize immediate energy sector market behavior change, whereas R&D investments take considerable time to lead to improved competitiveness in the energy sector.

One important difference between the Washington State biofuels market and the developed electricity industry is that policy instruments that might have immediate or near-immediate impact in the electricity sector will have only minor impact in terms of boosting in-state low-carbon fuel production simply because of the time required for industry development. Thus, R&D in this nascent market has greater comparative advantage over carbon taxes than in the developed electricity industry.

Public support for late-stage technology

The 2 primary justifications often given for public support of late-stage development are both based on potential market imperfections—information spillover effects somewhat like those relating to research, and liquidity constraints for venture capital. These reasons are founded on a complementarity between private and public investment in the utilization of new technologies. But there are also reasons to be cautious about allocating public investment to late-stage technologies. They include the potential to surmount technology lock-in and the risk of crowding out rather than promoting private investment.

Economic spillover effects of technology adoption

Early adopters of new fully operational technology such as methods of turning biomass into bio-crude or ethanol provide broad economic spillover effects. Some aspects of the strengths and weaknesses of new technology and the successes and failures of early technology adopters are observable by other actors in the economy, who can learn from these observations and pass them on to other potential adopters. Because producers cannot capture all the positive effects of developing or adopting a new technology (i.e., they have no incentive to account for the spillover benefits in their investment), they will invest less in technology than is socially optimal (Stokey, 1988). This result favors some form of subsidies or cost sharing for the adoption of new technologies when broad-based industry learning is likely.

Poorly functioning venture capital markets

Mason and Harrison (2004) examine the issue of market failure in private, early-stage venture capital. The possibility of market failure in this context suggests that public investment in R&D can be justified, even for risky late-stage investment, if venture capital is not sufficiently available for market development in a new industry. In contrast to Aghion et al. (2005), this argument suggests a place for public financing to support risky ventures where there is evidence of market inefficiency.[77]

[76] The other instruments that Fischer and Newell (2008) consider are emissions taxes, performance standards, fossil power taxes, renewable share requirements, and renewable subsidies.

[77] These arguments are similar to those in favor of the emergency finance package promoted by the Treasury and the Federal Reserve in September

However, the non-existence of willing venture capital is not always evidence of market failure. It may simply be a market that is correctly assessing excessive risk relative to expected return in comparison to other investment options. Also, when offering public financing to support late-stage private ventures, the consequence is that it reduces risk to the firm (residual claimant). This can lead to excessive failures ex post to the extent that private firms choose to accept the public support to finance ventures that they otherwise would not pursue without public financing.

Antidote for technology lock-in

A third argument for public involvement and investment in biofuel R&D, including late-stage development for renewable and/or low-carbon fuel technology, is the idea of technology lock-in. Based on a more general literature about technology path dependence and "sticky" technology evolution, Unruh (2000, 2002) and Sandén and Azar (2005) argue that we are currently in a state of "carbon lock-in" in which mature fossil fuel-based technology and infrastructure have a substantial comparative advantage. Jumping from one technological trajectory to another (presumably to move to a preferable local economic optimum) may require a public boost through direct involvement in R&D or institutional change due to market coordination problems, public infrastructure needs, and regulatory and institutional inflexibilities.

The potential for technology lock-in is a double-edged sword. Although it can motivate public investment in new technology, public policy in the form of regulation and public investment can contribute to future technology lock-in that can hold back continued development.

2008 and passed by Congress in October 2008 in response to credit constraints in the wake of the subprime mortgage crisis.

The degree of this risk depends on the structure of public involvement and the characteristics of the technology involved (Kverndokk and Rosendahl, 2007).

Crowding out private investment

Just as public applied research can either promote or crowd out private applied research, investment by the public sector can either promote or crowd out private sector investment in late-stage technology. López and Galinato (2007) provide an aggregate, economy-wide perspective on the interactions between public and private investment. They examine the effect of government investment in, and subsidies for, private goods that otherwise might be provided effectively by the private sector and public goods that tend to be non-rivalrous, non-exclusive, and under-invested in by the private sector. They find that as the share of government support for private goods investment increases relative to public goods investment, 1) it crowds out private investment in private goods, 2) it crowds out government investment in public goods, and 3) the crowding out of private investment in private goods may persist in the long run if there are complementarities between private goods and public goods. The implication of studies such as this one is that the public sector should focus on R&D targets that otherwise would not be provided by the private sector, and especially those that are complementary with private sector investment in basic research.

Infrastructure development

Biofuel use in motor fuels is relatively widespread now for low-biofuel content blends. For fuel blends with low biofuel content, current infrastructure is relatively adaptable to support both biofuel supply and demand. Most vehicles can utilize low-percentage blends of biofuels, and biofuels are often useful as complements to petroleum fuels as oxygenates or lubricants. This adaptability is evidenced by the recent widespread adoption of ethanol blends and to a lesser extent biodiesel blends. However, in order to successfully increase the use of biofuel at higher content blends, the current public and private fleet of vehicles must change through modification of existing vehicles and the production of new flex-fuel vehicles.

For the private sector to have the incentive to invest in flex-fuel or other biofuel-friendly vehicles, the availability of refueling centers must develop across the state. On their own, however, it is likely that most private refueling stations will have little incentive to be early adopters of high-blend refueling capacity if the private sector does not demand biofuels. In the transportation literature this is described as a "chicken or egg" problem (Button, 1993) that may justify coordination in early market development. The wrong incentive structure can lead to situations where an inefficient or otherwise socially undesired path is taken. The legislative support (though not yet funded) for refueling projects under the Green Energy Incentive Account (RCW 43.325.040) is an example of public efforts to provide incentives to help overcome these coordination problems and start development along a socially desired and presumably efficient industrial path.

Many of the transportation and infrastructure challenges faced by Washington State for the development of a biofuel industry are similar to those faced nationwide. The U.S. General Accounting Office (2007) lists several issues that are a concern nationally, including limited rail capacity, inadequate pipeline capacity, and few refueling stations for higher biofuel blends. Each of these issues is relevant to Washington.

The question of infrastructure investment raises concern about another form of market failure. In dealing with infrastructure investment, an inherent potential problem is market concentration. Infrastructure often exhibits increasing physical or financial returns to scale such that bigger enterprises and larger plants experience lower average costs and are able to develop the financial muscle to invest in key controlling aspects of the sector. This can lead to small numbers of firms. Hence, one ends up with an efficiency vs. market power dilemma where larger size may create a lower-cost industry structure, but the small number of firms may develop market power that captures most or all the benefits of the economies of scale, and consumers are left paying higher prices.[78] There are clearly economies of scale in the refinery sector of the traditional oil economy, but the extent of economies of scale in some of the potential biofuel industries is not yet clear. Currently, a small number of oil companies control virtually the entire distribution infrastructure in Washington.

The existence of unregulated market power is generally considered "bad" based on its associated upward impact on consumer prices and downward impact on quantities produced and consumed. However, the nature and implications of the current potential market power of oil firms in Washington are not well understood. In one sense, monopolies are positive for conservation because monopolies have lower production rates (and thus lower carbon emissions, other factors equal) due to higher prices than competitive firms. However, firms with monopoly power can also exercise control over the growth path of their industries if they have network externalities. Certainly one would expect oil firms to use their market power to promote industrial development favorable to their asset values. For instance, such firms might have an incentive to slow development in biofuel markets to retain market share of their primary asset.

[78] In the extreme, economists call this type of concentration a "natural monopoly."

Where such market actions are expected, an increase in independent biofuel production capacity and infrastructure development that reduces the market power of the oil industry may improve long-run market efficiency, lower consumer prices, and benefit the environment if sufficient economies of scale are captured.

Washington State within the context of a national research environment

Continuing the above discussion in the context of federalism with regard to public investment, the national government should be promoting public R&D that has broad geographic applicability. Indeed, the Department of Energy recently invested over $1.2 billion for cellulosic technology development (U.S. General Accounting Office, 2007).[79] Some of those funds are targeted for long-run broad benefits to the industry. In other cases, the funds are likely to have regional benefits.

Viewing Washington as one economic entity within a larger economic environment, the state might expect to gain higher local rates of return on public investments targeted toward R&D opportunities that provide primarily local benefits. There are 2 closely related reasons for this: first, focusing on local market idiosyncrasies tends to ensure that a higher proportion of investment benefits are received locally. Second, a federal perspective suggests that the national government will pursue more widely applicable R&D, so the most cost-effective approach for Washington would be to focus on complementary research.

[79] For example, Pacific Ethanol received approximately $24 million in matching funds to build a cellulosic pilot project alongside their corn ethanol plant at Boardman, Oregon (http://www.pacificethanol.net/site/index.php/news/news_article/285/).

Although state-focused research efforts are appealing because they aim to primarily benefit in-state residents, 2 important facts caution against this approach. First, documented rates of return on investment are often lower for regionally-targeted research than for research with national or international relevance. Second, many important research discoveries can be adapted for use in other geographic regions, so it is difficult to prevent technological spillovers to those who don't share in the cost of research. This second factor suggests that state-level research investments can often be more fruitful when pursued collaboratively with the private sector, other states, and national public entities.[80]

These are very general and initial guidelines from which to proceed toward final recommendations. As outlined in the plan of work, we build on these fundamentals to provide a systematic approach for targeting R&D and making a specific set of near-term recommendations. First, however, we examine what the preceding analysis suggests about the content and application of Washington State's Energy Freedom Program, which is designed to promote private investment in biofuel market facilities and infrastructure.

Modifying and utilizing Washington's Energy Freedom Program and Green Energy Incentive Account

The legislation for Washington's Energy Freedom Program (EFP, RCW 15.110) provides a fund into which revenues can be placed and used to support the types of public investment that this report recommends. As noted in Chapter 3, $23 million was allocated to the EFP to provide low-in-

[80] For a useful example, see the proposal for technical collaboration between WSU and the Pacific Northwest National Laboratories for basic research in biofuels and bioproducts (Chen and Stevens, 2006).

terest loans and grants for the development of oilseed processing and biodiesel production facilities, an anaerobic digester facility, and a wood-fired boiler project.

The Green Energy Incentive Account (GEIA, a subaccount of the Energy Freedom Account) was created to provide cost sharing for refueling stations and pilot projects related to plug-in hybrids (RCW 43.325.040). However, this account has not yet been funded.

Recommendations for additional EFP selection criteria

Sections RCW 43.325.020 and RCW 43.325.070 provide criteria for supporting R&D projects under the Energy Freedom Account. This account was developed when there were no other substantive market incentives provided for biofuel market development in Washington State. If, on the other hand, the tax and subsidy programs recommended in this report (or alternative market incentives) are implemented or a binding RFS is imposed, they will lead to increased private investment in the local renewable fuel industry that satisfies most of parts 3(a) through (i) of RCW 43.325.020 and several elements of Section RCW 43.325.070, Part 1. To the extent they induce the private sector to pursue the types of investments the legislation was meant to support, they would do so without shifting additional investment risk onto taxpayers.

Our findings suggest that the emphasis of the selection criteria should be modified to provide a sharper focus on new, emerging technologies that are not well established anywhere, for which there is high potential value as well as high risk. Further, Section 3(j), which requires certain reporting requirements, should also include stipulations regarding information sharing to provide benefits to other potential market entrants.[81] Additional criteria should focus on potential benefits from surmounting market imperfections such as environmental externalities.

The federal 2008 Farm Bill includes a useful example of a framework that incorporates some of these points. For example, Section 9003 (d) (page 2073), which provides for cost sharing up to 30% for biorefinery investments, requires an advisory committee and the Secretary of Agriculture to consider several of the same criteria that the EFP considers. It also requires explicit consideration of the following [original numbering included for comparison to original document]:[82]

(ii) the level of financial participation by the applicant

(iii) whether the applicant is proposing to use a feedstock not previously used in the production of advanced biofuels

(iv) whether the applicant is proposing to work with producer associations or cooperatives

(v) whether the applicant has established that the adoption of the process proposed in the application will have a positive impact on resource conservation, public health, and the environment

(viii) whether the project can be replicated

(ix) scalability for commercial use

These additional considerations are consistent with a focus on projects with broadly distributed potential benefits, with contributions to technology development, and with cost sharing by multiple sources.

81 These types of stipulations will likely not be viewed favorably by firms to the extent that information disclosure increases the competition they face. However, information spillover is one of the primary justifications for public investment support. To not pursue this type of contract provision would negate an important reason for public cost sharing.

82 There are other useful examples of project selection criteria in sections 9001-9008 of the Farm Bill.

With regard to the Green Energy Incentives Account, the economic problems discussed in the previous section of this chapter on network externalities, the bi-directional causality of fueling opportunities, and incentives for investment in flex-fuel vehicles and plug-in hybrid pilot projects support the efforts of sections (4) and (5)(b) of the code providing cost-sharing arrangements for refueling. It is likely that funding this program will be economically justifiable as argued above, and may well help jump-start demand for and use of flex-fuel vehicles and plug-in hybrids if market conditions are conducive. We have no reason to argue that the 50% maximum cost-sharing arrangement should be set at a different level. Targeting funds toward those highways with the most potential demand is likely to be appropriate.[83] Valuable information about changing fuel use and demographics in the state could come by inviting applications from any location that is accompanied by evidence that sufficient demand is likely to develop in that area. A review board would have to assess the likelihood of substantial use of a refueling station.

An assessment of the EFP to date

The EFP has funded 4 oilseed crushing facilities, 3 of which have biodiesel production capacity, 1 wood-fired boiler system for a public school, and 1 anaerobic digester facility (WSDA, 2008). By some accounts, the anaerobic digester project was more successful than the oilseed crushing facilities in terms of the economics of operation after production commenced.[84]

There are 2 important differences between the oilseed crushers and anaerobic digester facilities. First, the anaerobic digester project had positive net revenue projections in the business plan but faced high capital costs. Conversely, the biodiesel projects appeared to face less onerous capital costs but did not have convincing positive net revenue projections. To the extent that reality was consistent with the business plans, even if public support were justified for other reasons, the crusher facilities would have been less appropriate for public support on the grounds that they were less likely to succeed after initiation than the anaerobic digesters.

Secondly, by some accounts the technology for anaerobic digestion is less mature, with more substantive potential gains to be had through the experience of implementation than appears to be the case with oilseed crushing facilities. Thus, on these grounds, the anaerobic digestion facilities are stronger candidates for public demonstration project support than are oilseed crushing facilities.[85]

With this example in mind, we turn to some other examples of R&D directions that are consistent with the economic fundamentals for public investment discussed above.

Recommendations for Public Investment in the Near Term

We have argued in previous chapters that if the state of Washington invests in the development of a biofuel production industry, it should focus primarily on advanced biofuel markets. Although advanced biofuel markets have yet to develop, the diversity and scope of current technological research, development, and pilot projects is staggering. It is useful to provide some examples of possible R&D areas that are consistent with the foregoing discussion. Omissions should not be taken as

[83] Presumably, if demand for higher blends increases in other areas of the state, additional motorways will be defined as Green Highways to allow a broader application of the fund. Although it may not be necessary, it would add clarity to legislatively limit the location of EFP funds to high-demand areas.

[84] Craig Frear, personal communication, October 2008.

[85] As a demonstration project, enforceable and enforced information sharing agreements should apply.

a vote of no confidence in any given research direction.

Below we adopt (with modifications) a categorization of investment areas used by the Biomass Research and Development Technical Advisory Committee (2007), including a) feedstock development, b) processing and conversion, c) infrastructure, and d) end-use markets.

Feedstock production and distribution

The state should continue research on environmental impacts of biomass production and utilization, especially on water use, water quality, and long-run soil quality.

Of particular importance is early-stage research into new biofuel technologies that are both well suited for the types of feedstocks in development and feedstocks that are unique to and/or prevalent in Washington, including cellulosic conversion technologies.

As covered in Chapter 4, the most likely productive types of feedstocks for Washington are municipal solid waste, agricultural field crops and residues, and forest residues.

Municipal solid waste

As a major producer of municipal waste and sewage sludge in the densely populated Puget Sound region, Washington should closely monitor technologies for converting this potential feedstock to biofuel. The state could likely benefit from spillover research on densely populated areas in California and the East Coast.

Agricultural field crops and residues

Washington's agro-climatic advantages favor thinking "outside the box" of traditional corn, sugar beet, and oilseed feedstocks. Put simply, most past and foreseeable market conditions indicate that Washington growers are likely to make the most money from high-value and adaptive crops like tree fruit and wheat. Oilseeds can be more cheaply imported from the Canadian prairies and corn from the U.S. Midwest.

In Chapter 5 we recommend that subsidy or tax credits should not be provided for feedstocks directly (relying instead on fuel incentives to induce appropriate demand for feedstocks). However, public agricultural research has often provided relatively high returns to investment. Many potentially viable cropping approaches are currently under research in Washington State (e.g., Washington State University Biofuels Cropping Systems Research and Extension Project, 2008). It remains to be seen whether or which of these and other feedstock possibilities are economically viable. As mentioned in Chapter 4, oilseeds (to take but one example to represent many potential biofuel feedstocks) have received little or no previous agronomic and genetic research to make these crops regionally adaptable. This stands in stark contrast to wheat and potatoes that are targets of up to 100 years of focused research in the Pacific Northwest.

We recommend continued research into cropping systems that have high potential for development into regionally and nationally competitive feedstocks. However, it is important to be cognizant that biofuel crops currently established elsewhere have shown themselves to be less competitive here (such as canola and corn) are to face an uphill battle, as varieties elsewhere are similarly funded for improved productivity.

Washington's abundant surface water available for irrigation should permit it to efficiently grow switchgrass, Indiangrass, big bluestem, and arundo grass[86] with relatively

[86] Sweet sorghum (not to be confused with grain sorghum) is one of several other possible feedstocks in the U.S. being researched by Oklahoma State University, Texas A&M University, and Iowa State University (James Simpson, Impact Center, WSU, personal communication, 2008).

low life-cycle energy requirements. The technologies for converting these feedstocks to biofuels are much less developed than those for corn, oilseeds, and recycled cooking oils. Nonetheless, promising yields and fertilizer efficiencies indicate that these forage grasses warrant further agronomic and conversion technology research.

The utilization of wheat straw and field residues more generally is an important possibility for biomass utilization in eastern Washington. However, there are also pressing concerns due to its effect on soil quality and future production yield. This is an area of research with long-run environmental and economic consequences that needs research attention given that the Palouse is among the most highly erodible farmland in the nation.

Biochemistry-related plant productivity is another area of research with potential regional and global benefits, making it ideal for cost sharing and leveraging with federal funds or cooperating states.

The Biomass Research and Development Board (2008) provides 2 basic recommendations regarding research and development for feedstocks from a national perspective: 1) increasing productivity of first-generation feedstocks and 2) moving toward a portfolio of feedstocks. Although a feedstock portfolio at the state level would be useful, at this stage of market development it is likely best to pursue the feedstock options that provide this region a comparative advantage, and let the variation across the geography of the United States lead to a national portfolio.

Forest residues

As shown in Chapter 4, approximately 66% of Washington's lignocellulosic biomass can potentially come from forestry resources, and forest residues are likely the largest categorical source of biomass in the state.

One of the primary challenges of utilizing forest residues is the costliness and difficulty of collection and transportation, and thus we recommend pursuing research to make these more efficient. In addition to developing low-cost collection of forest biomass and adopting small-scale biomass processing, we suggest that the state focus their efforts on biomass removal to reduce wildfire risk in fire-prone areas and provide forest health benefits. As discussed earlier in this report, the non-market spillover effects of these activities on private land provide economic motivation for public R&D support of these activities on both public and private land.

The University of Washington is currently working on characterizing barriers to the use of forest resources for biofuel. This report will likely be useful as a means to identify other areas of research, as well as possible technology adoption collaborative arrangements.

Biofuel processing and conversion

We recommend early-stage research investment in new biofuel technologies that are both well suited for the types of feedstocks in development and that are unique to and/or prevalent in Washington.

We also recommend entering into joint public private ventures (perhaps via the Energy Freedom Fund) to support early adoption of processing and conversion technologies, particularly those which show promise for overcoming what will be significant logistical and transportation problems with biomass-based fuels. One example of such technology is the use of small scale, mobile, or semi-mobile pyrolysis units to produce bio-oil and nutrient/carbon co-products that remain on site as enhancements to forest health and reduce transportation to only the energy-dense bio-oil for refinement (Laird, 2008). Bio-oil can in principle be used as a crude oil to produce bio-gasoline, biodiesel, and ethanol. However, a lack of refinery capacity would likely be a substantial bottleneck.[87] Research and development into the technology and economics of refining bio-oil into bio-gasoline, bio-diesel, and ethanol therefore seems to be another promising target for public support.

The previous example is consistent with many of the characteristics we recommend looking for as a target for public investment. In principle, it has the potential for allowing the utilization of a wide range of biomass under a wide variety of conditions due to small-scale onsite first-stage processing. Moreover, because this area of biofuel technology processing and conversion is both actively developing and complex, there is likely to be a substantial learning curve during pilot projects and commercialization that will progress from information sharing agreements as part of public-private ventures. More generally, research and development on decentralized energy densification and pretreatment strategies will strengthen the prospects for all lignocellulosic biomass feedstock sources.

Much attention has been given to plucking the "low-hanging fruit" in the form of waste products for biofuel feedstocks. The discussion has largely centered on wastes that have very limited quantities (e.g., cull potatoes) or are highly dispersed (e.g., crop residues). However, there are other waste streams that are both concentrated and in high quantity, including human wastewater and carbon dioxide recycling in a broad range of settings in which concentrated carbon dioxide could be used to augment plant productivity. For example, Washington presently has 11 algae fuel start-up companies in the state, which is one of the largest concentrations in the world. It would be difficult right now to directly convert carbon dioxide into algae, separate the oil, and then sell it profitably. A 90% decrease in costs would be required for current technology to become viable. However, one might take an existing anaerobic digester on a confined animal facility and harness the carbon dioxide and heat to grow algae. The algae could be used not only for oil, but also for protein to be sold as animal feed. The economics could prove very different than current efforts that concentrate only on biofuel production. Cost-sharing grants could specifically be targeted toward such demonstrations or niche projects to accelerate the overall development of the technology and industry.

[87] Manuel Garcia-Perez, WSU research scientist, personal communication, November 2008.

In Chapter 5 we did not discuss providing market incentives to support the development of markets for biofuel co-products because nothing suggests that this is necessary given a direct focus on renewable fuel markets. However, markets for co-products are often pivotal for the economic viability of renewable fuel markets, and the same market problems that apply to R&D for biofuel development apply to the development of co-products, and may provide progress toward the 3 basic goals of promoting the Washington State biofuel and feedstock industry, reducing petroleum dependence, and reducing greenhouse gas emissions. Nevertheless co-product markets should not be the target of policy to address these goals. Rather, efforts should target the biofuel market directly.

Infrastructure and transportation

The 2 primary objectives of infrastructure development are to facilitate 1) demand and consumption and 2) bulk distribution of intermediate fuels such as neat ethanol and biodiesel as blendstock for future blending.

Given the important role that transportation plays in the economics of biofuel collection and distribution, including the efficiencies to be gained from bulk utilization of rail and water (barge), the state should invest in maintaining right-of-way ownership from abandoned rail lines and supporting the viability of existing shortline rail and the lock/dam system on the Columbia/Snake River. Given the uncertain potential for biofuel market development, this provides option value at a low cost relative to rebuilding infrastructure or attempting to re-purchase right-of-way in the future.

To the extent that the state does invest in infrastructure such as fueling stations and other distribution systems that can handle the idiosyncrasies of specific fuels such as ethanol, we recommend required substantive private leadership and cost sharing. Any plans must be robust to market fluctuations in terms of enough flexibility to consider the viability of alternative uses of infrastructure.

Facilitating the use of federal programs and other joint ventures

We also suggest that the state serve as a facilitator and link between private industry, universities, federal government, and regulatory agencies.

The 2008 Farm Bill (Section 9009, Cooperative Research and Extension Projects) and U.S. Department of Energy have allocated funds for research and development directed at the biofuel industry. The state should work to acquire, utilize, and complement these funds. The U.S. Department of Energy has noted that companies are having a hard time obtaining funding for commercial-scale development demonstrations of their technologies, which will only get worse with the current credit crisis and recession.

The state could use Energy Freedom Program funds to support the development of substantial proposals for federal grant monies. The following represents a potential scenario: Round A "proof of concept" research could be funded by the state through the Department of Ecology or Agriculture and federal Small Business Research Innovation Research (SBIR) grants, with both requiring a full private match; Round B "pilot" development could be funded by the biofuel zone through its dedicated incubator of large corporations such as Boeing and Microsoft with competitive cost-sharing and matching SBIR Phase II funds; and Round C "large pilot or demonstration" funding could be supplied by federal grants and Energy Freedom Fund no-interest loans.

There are also some interesting possibilities for promoting information sharing among and between private firms and public entities. One example is joint patenting (Hagedoorn, 2003; Lerner and Tirole, 2004), which is a process by which firms agree to share their technological advances to their mutual benefit.[88]

Markets and policy

For the state of Washington, biofuel markets can be described as emerging, technology-intensive industries in continuing need of policy and market assessment. This report provides a foundation for a proposed set of market incentive and approaches to R&D. There are, however, many issues beyond the scope of this relatively broad study.

First, although we develop a general approach for carbon emissions taxation and tax credits, a great deal of research should be applied to life-cycle analysis of fuels and into the details of developing taxation and tax credit schedules across fuels to minimize double counting and resolve complications from interstate and international trade across jurisdictions with varying biofuel policies.

[88] Apparently, a U.S. federal program during WWII created a patent-sharing system among aircraft industries to accelerate the development of needed fighters and bombers. Given the current national priority for renewable fuels, Washington could promote a similar program for biofuels. Source: 2008 Algae Summit, Seattle, WA.

Second, although estimates of supply characteristics are beginning to emerge for biofuel and feedstock markets, very little has been done to understand the many characteristics of demand that warrant attention. For example, at lower blend levels, gasoline and ethanol can be considered economic complements to the extent that ethanol acts as an oxygenate. However, at higher blends, this benefit becomes outweighed, and they become (imperfect) consumption substitutes. These issues are virtually unstudied in any formal way.

Management Principles and Selection Models to Guide Public Investment

For review purposes, public investment is justified when 3 criteria are met:

1. There is a high expected social return from the investment,
2. There are clear reasons why the private sector is unlikely to invest at socially optimal levels (e.g., non-exclusivity, non-rivalry, and/or inadequate risk-transfer markets), and
3. The likely social benefits of the investment will be broadly distributed within society.

Satisfaction of these 3 elements also means that little oversight is usually needed to attain high public value. Outright grants may be the best practice in this case. Even when the criteria are not fully satisfied, social benefits from public investment may still be greater than social costs when the investment is carefully implemented. High rates of return to total R&D investments are documented for many sectors (Salter and Martin, 2001). The second criterion is also often valid for investments in basic and early-stage applied research.

Public investment is less easily justified the further along the innovation life-cycle the activity is (i.e., the closer it is to actual development of new technology for individual firm use). Because there is less risk and time required for implementation, a private firm is typically able to capture a larger share of the social benefits of innovation than in earlier stages of R&D. Firms in many industries are able to exercise some degree of market power, so it is the third criterion that is most often not fully satisfied, even for basic and early applied research. However, public investment could still be justified in this case as long as a public–private contractual business arrangement assures that the public sector will capture benefits in proportion to its share of the investment.

In addition to the criteria noted above, management principles relevant for public investment in R&D depend on overall goals. For example, if a targeted mission (e.g., getting a person to the moon as was NASA's charge in the 1960s) is the overriding objective, a very hierarchical, focused, and highly coordinated management of the entire R&D enterprise is warranted. In such a case, individual scientists or research organizations would be given less flexibility in designing a research program and pursuing independent research inquiries than if the goal was to discover new knowledge that may someday have practical value. In the principles noted below, we give high priority to the programmatic goal of developing new technology that will reduce the cost of vehicular fuel in Washington, lower carbon emissions, be environmentally sustainable, and increase the comparative advantage of Washington businesses to engage in feedstock production and biofuel production and distribution. Since some of these goals are competitive with each other, trade-offs will be required. However, their pursuit would require greater coordination and focus than a general quest for new knowledge that could ultimately have practical value.

The production process for R&D is very different than in most other sectors of the economy. For example, it is non-repetitive; once new knowledge is discovered, it does not need to be re-discovered. It is also inherently risky, especially early in the R&D life-cycle. Further, the value of the R&D product is dependent both on the level of investment and creativity of the scientists (Ladd, 1979), which is often enhanced by less rather than more management (Shumway, 1981).

This unique production process must guide the management approach taken to capture the most benefit from the R&D sector. It implies the need for longer-term funding and less-frequent accountability than in typical public grant processes. It also implies the need for information from scientific experts as well as the organization applying for public support.

To capitalize on scientist creativity, some "unfettered" block allocations of public funds could be provided to those scientists/R&D organizations with proven track records in areas with clearly documented high historical rates of return to public investment. To reduce the high transaction costs for creative scientists, most funds could be made available through 2-part 5-year conditional grants. The allocation decision should consider scientific merit, the predicted social value pertinent to Washington's technology goals if the effort is successful, and the probability of it being successful.

Scientific merit and estimates of predicted value and probability of success require verification by scientific experts. While essential, this step poses a particular challenge since knowledgeable experts can also be competitors for funding. Mid-period performance documentation should be required to secure the second part of the grant so that continued funding is based on demonstrated progress and maintained high potential value and likelihood of success.

Because the aim of this public investment is to secure high value to the citizens of the state, there must be demonstrated political will to discontinue it. Unless all 3 of the criteria that justify public investment in R&D are met unconditionally, benefits accruing from R&D discoveries should be shared by the public in proportion to the share of the total investment.

A substantial number of R&D project selection models have been developed and reported in the literature. Poh et al. (2001) compared and evaluated 6 of the most common classes of models against 7 criteria for an ideal evaluation method. The model classes consisted of 3 weighting-and-ranking methods (scoring, comparative, and analytic hierarchy) and 3 benefit-contribution methods (economic, benefit-cost, and decision tree). Their criteria included the ability of the method to accommodate multiple objectives, incorporate risk and uncertainty in the analysis, be simple to use and interpret, rely on readily available data, adapt to the experience and knowledge of many experts and decision-makers, consider both quantitative and qualitative data, and be inexpensive to implement. They found that the scoring model dominated the others, and the economic model was the next highest ranked.

We develop 2 models in Appendix A6 that are particularly relevant for Washington government agencies in selecting projects and organizations for biofuel R&D investment. The models simulate practical evaluation procedures which public policy-makers can use to rank R&D projects, programs, and organizations. The first is a scoring model, while the second is our recommended modified economic model.

Chapter 7: Conclusions and Summary of Recommendations

In April 2007, the Washington State Legislature passed HB 1303, an "act relating to providing for the means to encourage the use of cleaner energy." The fourth chapter of this omnibus bill contains the section (402) which directs Washington State University to provide recommendations for market incentives and research and development grants.

The goals specified in the legislation were aimed at the development of a viable in-state (biodiesel and cellulosic ethanol) biofuel and biofuel feedstock industry. Additional goals were to help develop a biofuels industry which would reduce carbon emissions and petroleum dependency.

The analysis in this report provides estimates of feedstock availability by region in the state of Washington based on economic feasibility, wherever possible. The report includes a comparative analysis of policy alternatives in terms of their efficacy for meeting the stated goals, and market incentive recommendations for the development of biofuel and feedstock markets in the state of Washington. Additional recommendations are for public investment in research and technology development, promotion of new technology adoption, and infrastructure investment to support Washington State biofuel market development.

This report makes 2 major recommendations. First, we recommend policies that position the state for the long run over policies that respond to the short-run, current situation. Energy prices, feedstock prices, technology and so forth have one thing in common: they will change. However, there are some long-run trends that the state can respond to and help prepare its industry and citizenry.

The second major recommendation is to employ flexible, market-oriented incentive programs rather than direct state action such as direct regulation and specific investments wherever possible. The report assumes that markets are generally more effective and responsive than governments in matters of industrial investment and production. In cases where markets tend to stray from social goals and interests, such as pollution reduction, aspects of sustainability, and wealth/income distribution concerns, the state is most likely to be successful when focusing on the design of an effective general institutional framework that leaves most operational-level decisions in the hands of firms, consumers, and taxpayers. Our recommendations focus largely on general policy and institutional design.

Feedstock assessment

Chapter 4 examines the economic viability and availability of a wide variety of feedstocks, as requested in our enabling legislation. We find that under likely biofuel and agricultural market conditions, crop feedstocks including oilseeds, sugar beets, and field corn are likely to account for only a very small fraction of state agricultural production and state fuel needs. Large ethanol and biodiesel processors in the state and region import nearly all of their virgin feedstocks. Current production of oilseeds and sugar beets is small and the projected breakeven prices for Washington farmers to profitably produce these crops exceed current and projected prices. This market outcome is partly due to the particular agronomic conditions of Washington and largely due to the fact that Washington is very competitive in markets for myriad other high-value crops, which would be costly to give up.

This is not to say that new crops and cultivars will not emerge. Many potentially viable biofuel feedstocks have received little research for variety development in Washington State relative to traditional crops like wheat, apples, and potatoes. New cultivars and agronomic techniques with high biofuel potential may be devised for any of a number of these crops in the future. What emerges depends on a combination of research funding, the serendipities of research, and the effects of economic inducements.

In comparison to crop biofuel feedstocks, the long-run potential for biofuel production from Washington's abundant lignocellulosic biomass is promising. Progress is also being made in the development of agricultural crop biomass productivity.

While the lack of maturity in the technology for producing biofuel from lignocellulosic biomass precludes a reliable estimate of the biofuel fraction at this point, our assessment is that vigorous ongoing research has promising potential to solve the related engineering, biochemical, and logistic barriers.

Recommendations for market incentives

We argue in Chapter 5 that the most effective approach to meeting the short-run goals specified in the legislation is to use market incentives that focus on the demand side of biofuel markets. That is, in the immediate future, we recommend that the state target consumer incentives that promote substitution away from petroleum-based fuel consumption and toward bio-based fuel consumption.

For the longer run, Washington State shows promise as a potential producer of biomass-based fuels and second-generation biofuels. Advanced biomass-based fuels may be able to supply alternative energy with reduced net carbon emissions given appropriate technology and policy. Moreover, the state is well situated to utilize lignocellulosic sources that compete less directly with food crops for agricultural land than the current first-generation biofuels. Nonetheless, the state's biofuel policies should flexibly provide opportunities and incentives for all biofuel and feedstock types with favorable market and environmental performance to compete in these emerging markets and strengthen their performance over time.

Basic policy recommendations

- We recommend a price incentives approach taking the form of a tax based on a carbon emission index for renewable and non-renewable fuels.
- We recommend a revenue-neutral or revenue-recycling implementation of the price incentive policy. Revenues from the carbon emissions–based fuel tax create a renewable energy fund which can be used in 1 or all of 3 ways:
    1. For offsets to the fuel taxes on low emission fuels.
    2. To support tax credits and research and development for low carbon fuels.
    3. To reduce other taxes such as sales taxes and B&O taxes.

- We recommend that where there is public investment in infrastructure and R&D, it should be targeted to complement private investment, not replace it.
- We recommend against direct state-funded tax credits or subsidies for in-state feedstocks or co-products, with the minimal, targeted exceptions discussed in this report.
- We recommend against a binding state-level renewable fuel standard.

Support for price incentives

We argue that targeting greenhouse gasses is the most effective way to address the largest number of the legislative objectives as directed in our mandate. Research results show that different fuels can vary substantially in their net greenhouse gas emissions due to differences in feedstock efficiencies, production processes, and combustion characteristics.

Focusing policy directly on the net contribution of fuels to carbon emissions reduction will help assure that the adopted policies are constructive for the long run as well as the short run. GHG-targeted policies will provide a foundation for motor fuel diversification and will encourage development of the most environmentally-benign fuels in both the short and long run. Such policies will also spur further development of low-carbon fuels on both demand and supply sides. This policy incentivizes a state energy industry that continues to be shaped by the issues of increasing energy scarcity and mitigation of global warming.

Second, advanced biofuels and biomass-based fuels show more environmental and economic promise in the long run than do the first generation biofuels (though we are confident that even these first-generation fuels can improve their environmental performance if firms are given tangible incentives to do so). Moreover, Washington State has a better potential market position for biomass-based fuels relative to current starch- and even oilseed-based biofuels. Implementing a carbon-based policy approach will work in favor of Washington's comparative advantage, especially in the context of developing regional, national, and global carbon policies. Nonetheless, it will allow all renewable fuel types to compete on the same playing field.

Third, while we recognize the pitfalls of relying on life-cycle carbon emission estimates in the short run, early integration of carbon intensity measurement and tracking into policy will spur its rapid improvement. While the carbon content of fuel at the retail level can be easily measured, the carbon footprint or overall flows of carbon are much more difficult to track at this stage.

Based on a whole economy modeling technique, results from other models of our own, literature findings, and the experiences reported by political entities, our analysis favors taxes over subsidies as a foundational policy instrument due to the difficulty in targeting subsidies to the goals and the larger state costs of subsidies.

Another feasible policy instrument is a renewable fuel standards (RFS). However, we found that it is not as effective as price policies and has greater up-side cost riskd to businesses. While renewable fuel standards do provide reductions in carbon emissions, they lead to decreases in GDP, state revenue, and consumer market welfare. Renewable fuel standards also force a decrease in the supply of blended fuel that ultimately results in fewer indirect business taxes and decreased returns to labor.

A cousin of the renewable fuel standard is a carbon-based fuel standard such as that under development for California in which the average CO_2e emissions level for a firm must satisfy a specified level. This approach, which includes credit trading, targets GHG emissions better than an RFS, but it has some of the same problems. One of these is that reductions in total blended fuel production and consumption are not directly addressed. Hence, the economic effectiveness of this approach for the goals of our enabling legislation is diminished.

Beyond the above reasons weighing against alternative policy mechanisms such as subsidies or renewable fuel standards, there are positive, direct reasons for favoring a price incentive policy built around a carbon emissions standard as the foundation of the state's market incentives program. These direct reasons include the following:

- A carbon emissions tax increases the price of GHG emissions relative to all other goods. This will help accomplish the goals of a) reducing carbon emissions cost-effectively, b) reducing the use of imported petroleum, and c) increasing the relative competitiveness of low-carbon alternative fuels.
- Our Computable General Equilibrium analysis suggests that fuel-based taxes are the most cost-effective instrument in terms of state GDP to reach petroleum reduction and carbon emissions reduction goals.
- Relative to a carbon cap-and-trade mechanism which allows carbon prices to fluctuate, a carbon tax will result in lower or zero price volatility and lower risk of unexpectedly high carbon control costs.
- A carbon emissions tax provides revenues that can be applied toward explicit support to renewable fuel tax credits or subsidies and toward R&D for renewable fuel technologies and infrastructure.[89]
- Compared to some policy alternatives, a carbon-based tax may create fewer and less onerous regulatory burdens on the private sector. Moreover, the carbon-based tax may work more effectively in conjunction with national and regional RFS policies.

Implementing price-based incentive policies

Our analysis suggests that the most cost-effective way to pursue our enabling legislation's stated goals would be to impose a tax on all fuels (and for that matter, energy sources generally) in proportion to their life-cycle carbon emissions intensity. Fuels with net negative life-cycle emissions would receive a tax offset. To maximize the economic cost-effectiveness of this approach, the carbon emissions portion of the fuel tax could have a net zero fuel cost impact by making net tax increases for high carbon emission fuels equal to net fuel credits to negative carbon emission fuels. Any net revenues from the carbon emissions tax subsidy could be used to offset existing taxes such as B&O taxes or sales taxes.

Tax credits and subsidies

The carbon emissions tax would directly address the goals of reducing carbon emissions and lowering dependence on petroleum fuels. However, this approach would make it difficult to cleanly target the promotion of in-state biofuel production, the other basic goal of the legislation.

Despite the weaknesses of tax credits (i.e., subsidies), they may still be the most effective way to target in-state production of biofuels and feedstocks. If policymakers choose to implement subsidies for renewable fuels produced in-state, we recommend the following:

[89] Note, however, that carbon-based fuel taxes tend to be regressive, and hence policymakers may wish to use some revenues generated by the tax to rectify the regressive features of the tax.

- Base tax credits on carbon emissions intensity.
- Finance the subsidy/credit programs from a fund generated by the carbon emission tax revenues.
- Limit feedstock subsidies to those that might generate additional benefits (e.g., municipal solid wastes to reduce public waste disposal costs and forest biomass to reduce wildfire risk on private and public land).

Appropriately designed, this price-based approach will (a) reduce incentives for high-carbon fuel consumption; (b) augment incentives for the production and consumption of low-carbon fuels; (c) provide lower price risk to producers than a carbon-based fuel standard; (d) avoid the potentially costly pitfalls of implementing a hard standard for low-carbon biofuels in a highly volatile, developing market; and (e) reinforce RFS standards or cap-and-trade policies set at national or multi-state levels.

We argue that this combination of a carbon tax imposed on both in-state and imported high-carbon fuels, the revenues from which would be used to fund tax credits for low-carbon renewable fuels produced in the state of Washington, is the most effective way of addressing all of the primary goals of the enabling legislation of this report.

Support for subsidy policy to promote in-state production of biofuels

Using a regional economic model known as a Computable General Equilibrium (CGE) model to examine the effects of subsidies and the other policies we recommend that tax credits or subsidies be provided only when offset by tax revenues on high-carbon fuels. We make this recommendation for 3 reasons:

1. Subsidies alone would tend to promote rather than reduce blended motor fuel consumption.
2. Subsidies without offsetting taxes would create weaker incentives for consumers to invest in more fuel-efficient vehicles and consumption technology.
3. Taxing high-carbon emissions fuel rather than subsidizing low-carbon emission fuels (or even fossil fuels categorically) tends to be less costly to the state in terms of GDP.

Policy for feedstock markets

We recommended against state provision of production tax credits or subsidies for Washington biofuel feedstocks, with exceptions based on targeted and well-justified conditions. The new biofuel market for feedstocks can benefit crop producers substantially even without direct feedstock subsidies. While estimates of the actual impact vary widely, it is clear that there is major political concern about the potential for biofuel production to impact food prices.

Another factor is that feedstock subsidies would likely not be a cost-effective way of promoting the Washington biofuel industry. Because Washington has a comparative advantage for producing high-value crops other than those used as biofuel feedstocks in the current market environment, shifting its production would be costly both in terms of required taxes to effect the change and net economic losses to the state's economy. Furthermore, such price incentives would either compete with or supplement federal incentives and provide additional pressure on agricultural land and probably water use, either of which could have adverse environmental impacts.

However, feedstock incentives such as tax breaks can be applied to promote certain niche feedstocks, the use of which provides additional benefits. In the cases of municipal waste and forest residues, tax credits or cost-sharing programs can produce net benefits if they can be designed to provide incentives to redirect waste away from landfills or boost incentives for reducing wildfire risk in forests and elsewhere. However, in these cases we recommend that the magnitude of the tax credit or cost share be designed to reflect the public cost savings associated with these additional social benefits, and let the social benefits of renewable fuel market development be reflected in policy sharply directed at fuel markets themselves.

Another area of study and debate for such credits or cost-sharing would be in reducing local water pollution or water use. However, while these cases may (or may not) have merit, close study of them was beyond the scope of the present mandate. Further analysis of potential environmental or economic benefits is warranted before any policy action is taken.

Beyond Biofuels

Our legislative mandate calls for us to focus our analysis primarily on biofuel markets, but a broader perspective on energy markets is imperative for an economically effective energy policy. Biofuel policy to date across the United States has developed with a degree of isolation from most other energy policy developments. To reach our energy goals in a cost-effective and sustainable way, it is important to balance the economics of biofuel markets and their environmental consequences with the other important energy sectors.

Washington State policy and investment in biofuel markets should be approached with integration into the larger energy markets in mind, and with a deliberate intent to allow for adaptation to technological change. Setting aside the risks of prognostication, consider, for example, the consequences of the current level of investment by automakers in electrical hybrid vehicles. Indeed, Washington's most recent Climate Action Team (2008) report recommends facilitating the promotion of plug-in hybrid development. From a transportation cost and carbon impact framework, greater utilization of the electrical grid to provide power to passenger vehicles may prove more environmentally and economically viable in the future. The movement toward electric vehicles would reduce many network inefficiencies associated with moving heavy, bulky products such as feedstocks long distances and instead create electricity from local resources such as forestry residues.

While it is likely that biofuels will play a part in fulfilling Washington's energy needs in the foreseeable future, these broader developments should be kept in mind as the state develops its biofuel policies. In particular, if policy is implemented without integration, the costs of meeting our alternative energy goals could vary widely across sectors.

Finally, most of the reasons that the state of Washington is interested in pursuing the development of renewable fuels relate to global, or at least national, problems. For the state to pursue these goals independently of other jurisdictions would almost certainly be a costly process. Actively developing cooperation and coordination across states, multi-state regions, and countries will help ensure that the costs of the state's efforts are more commensurate with the shared benefits that its energy and environmental policies create.

References

Aden, A. 2008. Biochemical Production of Ethanol from Corn Stover: 2007 State of Technology Model. Technical Report NREL/TP-510-43205. National Renewable Energy Laboratory (NREL), Golden, CO. http://www.osti.gov/bridge/product.biblio.jsp?query_id=1&page=0&osti_id=928256

Aghion, Phillipe, Mathias Dewatripont, and Jeremy Stein. 2005. Academic Freedom, Private-Sector Focus, and the Process of Innovation. Working Paper 11542. National Bureau of Economic Research. http://www.nber.org/papers/w11542

Alm, James, Edward Sennoga, and Mark Skidmore. 2005. Perfect Competition, Spatial Competition, and Tax Incidence in the Retail Gasoline Market. Working Paper No. 05-09. http://academics.uww.edu/business/economics/wpapers/05_09_skidmore.pdf

Ambec, S. and P. Barla. 2006. Can Environmental regulations be good for business? An assessment of the porter hypothesis. *Energy Studies Review* 14 (2): 42 – 62. http://en.scientificcommons.org/37548486

American Coalition for Ethanol. 2008. RFS Schedule under the Energy Independence and Security Act of 2007. http://www.ethanol.org/index.php?id=78&parentid=26#Franchise

Anderson, J.R., J.J. Dillon, and J.B. Hardaker. 1977. *Agricultural Decision Analysis*. Ames, IA: Iowa State University Press. http://www.amazon.com/Agricultural-Decision-Analysis-Jock-Anderson/dp/0813804000

Arimura, Toshi H., Dallas Burtraw, Alan Krupnick, and Karen Palmer. 2007. U.S. Climate Policy Developments. RFF discussion paper 07-45. http://www.rff.org/documents/RFF-DP-07-45.pdf

Barry, Peter J., editor. 1977. Risk Management in Agriculture. Ames, IA: Iowa State University Press. http://www.amazon.com/Risk-Management-Agriculture-Peter-Barry/dp/0813815231

BioEnergy Washington. 2008. Biofuel Availability. Washington State Government. http://bioenergy.wa.gov/BiofuelAvailability.aspx

__________________. 2009. Washington State Government. http://www.bioenergy.wa.gov/BiofuelIncentives.aspx

Biomass Research and Development Board. 2008. Increasing Feedstock Production for Biofuels: Economic Drivers, Environmental Implications, and the Role of Research. Biomass Research and Development Initiative. http://www.brdisolutions.com/Site%20Docs/Increasing%20Feedstock_revised.pdf

Biomass Research and Development Techical Advisory Committee. 2007. Roadmap for Biomass and Biobased Products in the United States. Biomass

Research and Development Initiative. October. http://www1.eere.energy.gov/biomass/pdfs/obp_roadmapv2_web.pdf

Bovenberg, A. Lans and Ruud A. de Mooij. 1994. Environmental Levies and Distortionary Taxation. *The American Economic Review* 84(4): 1085-1089. http://www.jstor.org/stable/2118046

British Columbia Ministry of Finance. 2010. British Columbia Carbon Tax Update. Notice 2008-023, January. http://www.sbr.gov.bc.ca/documents_library/notices/BC_Carbon_Tax_Update.pdf

Buonanno, Paulo, Carlo Carraro, Efram Castelnuovo, and Marzio Galeotti. 2000. Efficiency and Equity of Emissions Trading with Endogenous Environmental Technical Change. In *Efficiency and Equity of Climate Change Policy*, pp. 121-162. C. Carraro, ed. Norwell, MA: Kluwer Academic Publishers. http://www.springer.com/economics/environmental/book/978-0-7923-6262-3

Burtraw, Dallas and David A. Evans. 2008. Tradable Rights to Emit Air Pollution. RFF discussion paper 08-08. http://www.rff.org/Documents/RFF-DP-08-08.pdf

Burtaw, Dallas and Karen Palmer. 2007. Compensation Rules for Climate Policy in the Electricity Sector. RFF discussion paper 07-01. http://www.rff.org/rff/Documents/RFF-DP-07-41.pdf

Burtraw, Dallas, Karen Palmer, Ranjit Bharvirkar, and Anthony Paul. 2001. The Effect of Allowance Allocation on the Cost of Carbon Emission Trading. RFF discussion paper 01-30. http://www.rff.org/Documents/RFF-DP-01-30.pdf

Button, Kenneth J. 1993. *Transport Economics*. 2nd Edition. Northampton, MA: Edward Elgar Publishing.

Byerlee, Derek and Ruben Echeverría, eds. 2002. *Agricultural Research Policy in an Era of Privatization*. New York: CABI Publishing. http://www.cabi.org/bk_BookDisplay.asp?PID=1571

California Air Resources Board. 2008. The California Low Carbon Fuel Standard Regulation. Draft. October. http://www.arb.ca.gov/fuels/lcfs/101008lcfsreg_draft.pdf

Chen, Shulin and Don Stevens. 2006. Strategic Plan for the Technical Collaboration between Washington State University and Pacific Northwest National Laboratory: Report of the Bioproducts Focus Group. April.

Chouinard, Hayley H. and Jeffrey M. Perloff. 2004. Incidence of federal and state gasoline taxes. *Economics Letters* 83(1): 55-60. http://www.sciencedirect.com/science/article/B6V84-4B9K84P-1/2/aa8c3aed037a11dc8fc2cdf376644567

____________________. 2007. Gasoline price differences: Taxes, pollution regulations, mergers, market power, and market conditions. *The B.E. Journal of Economic Analysis & Policy* 7(1). http://www.bepress.com/bejeap/vol7/iss1/art8

Climate Action Team. 2008. Leading the Way: Implementing Practical Solutions to the Climate Change Challenge. November. http://www.ecy.wa.gov/climatechange/2008CATdocs/ltw_app_v2.pdf

Collins, William B. 2001. Office of the Attorney General of the State of Washington. 2001 Wash. AG LEXIS 2; 2001 Op. Atty Gen. Wash. No. 2.

Cramton, Peter and Suzi Kerr. 2002. Tradeable carbon permit auctions: How and why to auction not grandfather. *Energy Policy* 30(4): 333-345. http://www.sciencedirect.com/science/article/B6V2W-457VJ10-8/2/e5ee1f6418d6d3c87a5dba393fae5823

Crocker, T. D. 1966. The structuring of atmospheric pollution control systems. In *Economics of Air Pollution*, pp. 61-86. New York: W.W. Norton and Company. http://www.amazon.com/Economics-Air-Pollution-Harold-Wolozin/dp/B000K4QNDO/ref=sr_1_3?ie=UTF8&s=books&qid=1226031378&sr=8-3

de Gorter, Harry and David R. Just. 2007. The economics of a biofuel consumption mandate and excise-tax exemption: An empirical example of U.S. ethanol policy. MPRA Working Paper No. 5503.

__________________. 2008a. The Welfare Economics of an Excise-Tax Exemption for Biofuels and the Interaction Effects with Farm Subsidies. Social Science Research Network, Working Paper No. 2007-13. http://ssrn.com/abstract=1015542

__________________. 2008b. Water in the U.S. Ethanol Tax Credit and Mandate: Implications for Rectangular Deadweight Costs and the Corn-Oil Price Relationship. Social Science Research Network. http://ssrn.com/abstract=1071067

__________________. 2008c. The Law of Unintended Consequences: How the U.S. Biofuel Tax Credit with a Mandate Subsidizes Oil Consumption and Has No Impact on Ethanol Consumption. Social Science Research Network, Working Paper No. 2007-20. http://ssrn.com/abstract=1024525

__________________. 2008d. The Social Cost and Benefits of U.S. Biofuel Policies. Paper presented at the National Agricultural Biotechnology Council 20, Reshaping American Agriculture to Meet its Biofuel and Biopolymer roles, Columbus, OH. http://nabc.cals.cornell.edu/pubs/nabc_20/NABC20_Part_3_4b-DeGorter.pdf

Department for Transport. 2009. Renewable Transport Fuel Obligation (RTFO). United Kingdom government. http://www.dft.gov.uk/pgr/roads/environment/rtfo/

Dietz, Simon and Nicholas Stern. 2008. Why economic analysis supports strong action on climate change: A response to the Stern Review's critics. *Review of Environmental Economics and Policy* 2(1): 94–113. http://reep.oxfordjournals.org/cgi/content/short/2/1/94

Domby, A. and D. Young. 2008. Change in Status of Washington Biodiesel and Ethanol Plants from 2007 to 2008. Working paper, Washington State University School of Economic Sciences biofuels project, June.

Du, Xiaodong and Dermot J. Hayes. 2008. The Impact of Ethanol Production on U.S. and Regional Gasoline Prices and on the Profitability of the U.S. Oil Refinery Industry. Center for Agricultural and Rural Development Working Paper 08-WP 467. http://www.econ.iastate.edu/research/webpapers/paper_12929.pdf

Duke, R. D., and Daniel M. Kammen. 1999. The economics of energy market transformation initiatives. *The Energy Journal* 20(4): 15–64. http://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryID=80487

Economic Research Service. 2008a. 1 in the United States. U.S. Department of Agriculture. http://www.ers.usda.gov/Data/AgProductivity/

__________________. 2008b. Food Expenditures by Families and Individuals as a Share of Disposable Personal Income. U.S. Department of Agriculture. http://www.ers.usda.gov/briefing/CPIFoodandExpenditures/Data/table7.htm

The Economist. 2007. The end of cheap food. December 6. http://www.economist.com/opinion/displaystory.cfm?story_id=10252015

Energy Information Administration (EIA). 2009a. Renewable Energy Consumption in the Nation's Energy Supply, 2008. In Renewable Energy Consumption and Electricity: Preliminary Statistics 2008, Figure 1. U.S. Department of Energy. http://www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/figure1.html

___________________. 2009b. Status of Potential New Commercial Nuclear Reactors in the United States. http://www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/reactorcom.html

___________________. 2009c. U.S. Energy Facts Explained: Consumption and Production. U.S. Department of Energy. http://www.eia.doe.gov/basics/energybasics101.html

___________________. 2009d. Washington Consumption, Prices, Expenditures, and Production, 1960-2007. U.S. Department of Energy. http://www.eia.doe.gov/emeu/states/state.html?q_state_a=wa&q_state=WASHINGTON

Environmental Protection Agency (EPA). 2007a. Regulatory Impact Analysis: Renewable Fuel Standard Program. Technical Report # EPA420-R-07-004, April. http://earth1.epa.gov/OMSWWW/renewablefuels/420r07004chap2.pdf

___________________. 2007b. Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program; Final Rule. 40 CFR Part 80. *Federal Register* 72(83): 23900-24014. http://www.epa.gov/otaq/renewablefuels/rfs-finalrule.pdf

___________________. 2008. Revised Renewable Fuel Standard for 2008, Issued Pursuant to Section 211(o) of the Clean Air Act as Amended by the Energy Independence and Security Act of 2007. *Federal Register* 73(31): 8665-8667. http://www.epa.gov/fedrgstr/EPA-AIR/2008/February/Day-14/a679.pdf

Espey, M. 1998. Gasoline demand revisited: An international meta-analysis of elasticities. *Energy Economics* 20(3): 273-296. http://dx.doi.org/10.1016/S0140-9883(97)00013-3

Fargione, Joseph, Jason Hill, David Tilman, Stephen Polasky, and Peter Hawthorne. 2008. Land clearing and the biofuel carbon debt. *Science* 319(5867): 1235-1238. http://www.sciencemag.org/cgi/content/abstract/1152747

Farm Service Agency (FSA). 2008. Planted Acreage of Oilseeds in Washington State. U.S. Department of Agriculture. http://www.fsa.usda.gov/FSA

Farrell, Alexander. 2007. Implications of California's Low Carbon Fuel Standard. International Life Cycle Assessment & Management, 2007, Portland, OR, October 2. http://www.lcacenter.org/InLCA2007/presentations/LCFS-Farrell.pdf

Farrell, Alexander E., Richard J. Plevin, Brian T. Turner, Andrew D. Jones, Michael O'Hare and Daniel M.Kammen. 2006. Ethanol Can Contribute to Energy and Environmental Goods. *Science* 311(5760): 506-508. http://www.sciencemag.org/cgi/content/short/311/5760/506

Farrell, Alexander, and Daniel Sperling. 2007. A Low-Carbon Fuel Standard for California, Part 2: Policy Analysis - FINAL REPORT. http://www.energy.ca.gov/low_carbon_fuel_standard/UC_LCFS_study_Part_2-FINAL.pdf

Fischer, Carolyn and Richard G. Newell. 2008. Environmental and technology policies for climate mitigation. *Journal of Environmental Economics* and Management 55(2): 142-162. http://www.sciencedirect.com/science/article/B6WJ6-4R33527-1/1/dc7333b2da5fd029fa9608ce2ab15e58

Fischer, Carolyn, Ian W. H. Parry, and William A. Pizer. 2003. Instrument choice for environmental protection when technological innovation is endogenous. *Journal of Environmental Economics and Management* 45(3): 523-545. http://www.sciencedirect.com/science/article/B6WJ6-48712N5-1/2/aec180468dd621e365b863ea3bdc9af7

Food and Agricultural Organization of the United Nations (FAO). 2009 FAOSTAT. http://faostat.fao.org/site/567/default.aspx

Frear, C. 2008. Cellulosic Feedstock Availability by County in Washington State. Working Paper. Washington State University, Biological Systems Engingeering.

Frear, C. B. Zhao, G. Fu, M. Richardson, S. Chen and M. Fuchs. 2005. Biomass Inventory and Bioenergy Assessment: An Evaluation of Organic Material Resources for Bioenergy Production in Washington State. Washington Department of Ecology Publication number 05-07-047. http://www.ecy.wa.gov/biblio/0507047.html (A web-based Visual Basic interface of all associated tables and graphs is available at http://www.pacificbiomass.org.)

Fullerton, Don and Gilbert E. Metcalf. 2001. Environmental controls, scarcity rents, and pre-existing distortions. *Journal of Public Economics* 80(2): 249-267. http://www.sciencedirect.com/science/article/B6V76-42T4F1V-4/2/50f0cb01c8a933779213f11773a6751f

Galbraith, Kate. 2008. Economy shifts, and the ethanol industry reels. *The New York Times*, November 4. http://www.nytimes.com/2008/11/05/business/05ethanol.html?emc=eta1

Galinato, Gregmar and Jonathan Yoder. In press. An integrated tax-subsidy policy for carbon emission reduction. *Resource and Energy Economics*. http://dx.doi.org/10.1016/j.reseneeco.2009.10.001

Gardner, Bruce and William Lesser. 2003. International agricultural research as a global public good. *American Journal of Agricultural Economics* 85(3): 692-697. http://www.jstor.org/stable/1244996

Gardner, Bruce. 2007. Fuel ethanol subsidies and farm price support. *Journal of Agricultural & Food Industrial Organization* 5(2): Article 4. http://www.bepress.com/jafio/vol5/iss2/art4

__________________. 2003. Fuel Ethanol Subsidies and Farm Price Support: Boon or Boondoggle? University of Maryland, Department of Agricultural and Resource Economics. Working Paper 03-11. http://www.arec.umd.edu/publications/papers/Working-Papers-PDF-files/03-11.pdf

Goodwin, P., J. Dargay, and M. Hanley. 2004. Elasticities of road traffic and fuel consumption with respect to price and income: A review. *Transport Reviews* 24(3): 275-292. http://eprints.ucl.ac.uk/1262/

Graham, D. and S. Glaister. 2004. Road traffic demand elasticity estimates: A review. *Transport Reviews* 24(3): 261–274. http://www.ingentaconnect.com/content/routledg/ttrv/2004/00000024/00000003/art00002

Green, Richard. 2008. Carbon tax or carbon permits: The impact on generators' risks. *The Energy Journal* 29(3): 67-89. http://goliath.ecnext.com/coms2/gi_0199-8142251/Carbon-tax-or-carbon-permits.html

Hagedoorn, John. 2003. Sharing intellectual property rights—An exploratory study of joint patenting amongst companies. *Industrial and Corporate Change* 12(5): 1035-1050. http://icc.oxfordjournals.org/cgi/content/abstract/12/5/1035

Hicks, J. 1932. *The Theory of Wages*. London: Macmillan.

Hoel, Michael and Larry Karp. 2002. Taxes versus quotas for a stock pollutant. *Resource and Energy Economics* 24(4): 367-384. http://www.sciencedirect.com/science/article/B6VFJ-46RKR3H-1/2/a519fb0c97d49d9aa37e2e58d0c755d9

Holland, Stephen P., Christopher R. Knittel, and Jonathan E. Hughes. 2007. Greenhouse Gas Reductions under Low Carbon Fuel Standards? University of California, Davis, Institute of Transportation Studies. Research Report UCD-ITS-RR-08-01. http://pubs.its.ucdavis.edu/publication_detail.php?id=1128

Huffman, Wallace E. and Robert E. Evenson. 2006. *Science for Agriculture: A Long-Term Perspective*. 2nd Edition. Ames, IA: Iowa State University Press. http://www.blackwellpublishing.com/book.asp?ref=9780813806884&site=1

IMPLAN. 2008. Economic Impact Modeling Solutions. http://implan.com/

Karp, Larry. 2008. Correct (and Misleading) Arguments for Using Market Based Pollution Control Policies. CUDARE Working Papers 1063. http://purl.umn.edu/42868

Karp, Larry and Jiangfeng Zhang. 2008. Taxes Versus Quantities for a Stock Pollutant with Endogenous Abatement Costs and Asymmetric Information. CUDARE Working Papers 1064. http://purl.umn.edu/42877

Kennedy, Ann. 2008. Cited in Wheat residue too valuable to lose. *Seattle Times* July 25. http://seattletimes.nwsource.com/html/businesstechnology/2008069989_apfarmscenewheatresidue.html

Kverndokk, Snorre and Knut E. Rosendahl. 2007. Climate policies and learning by doing: Impacts and timing of technology subsidies. *Resource and Energy Economics* 29(1): 58-82. http://www.sciencedirect.com/science/article/B6VFJ-4KCPV50-1/2/df8f8f72ecc33af717c5c05fa9fc9421

Ladd, G.W. 1979. Artistic research tools for scientific minds. *American Journal of Agricultural Economics* 61(1): 1-11. http://myresearchspace.grs.uwa.edu.au/files/folders/robynowenspublicfolder/entry862.aspx

Laird, David A. 2008. The charcoal vision: A win–win–win scenario for simultaneously producing bioenergy, permanently sequestering carbon, while improving soil and water quality. *Agronomy Journal* 100(1):178-181. http://agron.scijournals.org/cgi/content/abstract/100/1/178

Lerner, J. and J. Tirole. 2004. Efficient patent pools. *American Economics Review* 94(3): 691-711. http://www.atypon-link.com/AEAP/doi/abs/10.1257/0002828041464641

López, R. and G. Galinato. 2007. Should governments stop subsidies to private goods? Evidence from Rural Latin America. *Journal of Public Economics* 91(5-6): 1071-1094. http://dx.doi.org/10.1016/j.jpubeco.2006.10.004

Lyons, John Kim. 2005. Biodiesel in Washington: A Snapshot. Washington Community Trade and Economic Development Energy Policy Division. May. http://www.cted.wa.gov/DesktopModules/CTEDPublications/CTEDPublicationsView.aspx?tabID=0&ItemID=3180&MId=863&wversion=Staging

Lyons, Kim. 2008. Biofuel Development in Washington. Washington State University Extension Energy Program. http://www.bioenergy.wa.gov/documents/biofuelactivities.pdf

Mall, S. and R. Gray. 2005. The crowding effects of basic and applied research: A theoretical and empirical analysis of an agricultural biotech industry. *American Journal of Agricultural Economics* 87(2): 423-438. http://www.ingentaconnect.com/content/bpl/ajae/2005/00000087/00000002/art00012

Mankiw, N. Gregory. 2007. One answer to global warming: A new tax. *The New York Times,* September 16. http://www.nytimes.com/2007/09/16/business/16view.html

Mason, C. Larry, Bruce R Lippke, Kevin W Zobrist, and Thomas D Bloxton Jr. 2006. Investments in fuel removals to avoid forest fires result in substantial benefit. *Journal of Forestry* 104(1):27-31. http://www.ingentaconnect.com/content/saf/jof/2006/00000104/00000001/art00006

Mason, Colin M. and Richard T. Harrison. 2004. Improving access to early stage venture capital in regional economies: A new approach to investment readiness. *Local Economy* 19(2): 159-173.

Mattson, J.W., W.W. Wilson, and C. Duchsherer. 2007. Structure of the Canola and Biodiesel Industries. Agribusiness & Applied Economics Report No. 606. North Dakota State University, Department of Agribusiness & Applied Economics. August. http://ageconsearch.umn.edu/handle/7644

McPhail, Lihong Lu and Bruce A Babcock. 2008. Short-Run Price and Welfare Impacts of Federal Ethanol Policies. Iowa State University, Center for Agricultural and Rural Development. Working Paper 08-WP 468. http://www.econ.iastate.edu/research/webpapers/paper_12943.pdf

Mohr, R. 2002. Technical change, external economies and the porter hypothesis. *Journal of Environmental Economics and Management* 43(1): 158-168. http://www.ingentaconnect.com/content/ap/ee/2002/00000043/00000001/art01166

Montana Department of Agriculture. 2009. Camelina Development Efforts. http://agr.mt.gov/camelina/default.asp

National Agricultural Statistics Service (NASS). 2008a. 1997 Census of Agriculture. U.S. Department of Agriculture.

__________________. 2008b. 2002 Census of Agriculture. U.S. Department of Agriculture.

__________________. 2008c. Data and Statistics: U.S. and State Data – Crops. http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp#top/

__________________. 2009a. 2007 Census of Agriculture. U.S. Department of Agriculture.

__________________. 2009b. Washington Statistics. http://www.nass.usda.gov/Statistics_by_State/Washington/index.asp

__________________. 2010. Quick Stats: U.S. & All States County Data. U.S. Department of Agriculture.

National Biodiesel Board. 2008. Retail Fueling Sites in Washington State. http://www.biodiesel.org/buyingbiodiesel/retailfuelingsites/showstate.asp?st=WA

National Renewable Energy Laboratory. 2008. Cost of Adding E_{85} Fueling Capability to Existing Gasoline Stations:

NREL Survey and Literature Search. March. http://www.afdc.energy.gov/afdc/pdfs/42390.pdf

Newell, Richard G. and William A. Pizer. 2003. Regulating stock externalities under uncertainty. *Journal of Environmental Economics and Management* 45(2): 416-432. http://www.sciencedirect.com/science/article/B6WJ6-47YY389-2/2/65e6ab338464718a5d87d565d3f28b0b

Newell, Richard G. and Robert N. Stavins. 2003. Cost heterogeneity and potential savings from market-based policies. *Journal of Regulatory Economics* 23(1): 43-59. http://www.springerlink.com/content/q1vp610650q63153/

Oregon Department of Agriculture. 2007. Implement HB 2210 mandate to blend gasoline with 10% by volume ethanol. *Oregon Bulletin*.

Painter, K.M. and D. Roe. 2007. Economics of Canola Production in the Pacific Northwest. Washington State University, School of Economic Sciences. http://www.ses.wsu.edu/PDFFiles/WorkingPapers/WP2007-17_BiofuelsDec11.pdf

Painter, K.M. and D.L. Young. 2008. A Rising Price Tide Has Raised All Commodities, but Winter Canola Still Nets Less than Soft White Winter Wheat in the Irrigated Columbia Basin. In *2008 Dryland Field Day Abstracts: Highlights of Research Progress*, pp. 20-21. Washington State University Department of Crop and Soil Sciences. Technical Report 08-1. http://css.wsu.edu/proceedings/2008/2008_Field_Day_Abstracts.pdf

Palmer, Karen and Dallas Burtraw. 2005. Cost-Effectiveness of Renewable Electricity Policies. Resources for the Future. Discussion Paper 05-01. http://www.rff.org/rff/Documents/RFF-DP-05-01.pdf

Parry, Ian W. H. 1995. Pollution taxes and revenue recycling. *Journal of Environmental Economics and Management* 29(3): S64-S77. http://www.sciencedirect.com/science/article/B6WJ6-45S92WM-16/2/ea5ee19f7891079bc1ff3ecb601e96e7

____________________. 1997. Revenue Recycling and the Costs of Reducing Carbon Emissions. Climate Issues Brief No. 2. Resource for the Future. http://www.rff.org/rff/Documents/RFF-CCIB-02.pdf

Parry, Ian W.H. and William A. Pizer. 2007. Combating global warming: Is taxation or cap-and-trade the better strategy for reducing greenhouse emissions? *Regulation* 30(3): 18-22. http://www.cato.org/pubs/regulation/regv30n3/v30n3-4.pdf

Parry, Ian W.H., and Kenneth A. Small. 2005. Does Britain or the United States have the right gasoline tax? *The American Economic Review* 95(4): 1276-1289. http://www.ingentaconnect.com/content/aea/aer/2005/00000095/00000004/art00017

Perlack, Robert, Lynn Wright, Anthony Turhollow, Robin Graham, Bryce Stokes, and Donald Erbach. 2005. Biomass as Feedstock for A Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply. Oak Ridge National Laboratory. Sponsored by the U.S. Departments of Energy and Agriculture. April. http://www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

Pizer, William A. 2002. Combining price and quantity controls to mitigate global climate change. *Journal of Public Economics* 85(3): 409-434.

http://www.sciencedirect.com/science/article/B6V76-4679PR4-5/2/d1d67c0d68ec28e7664504ef60997dc1

Poh, K.L., B.W. Ang, and F. Bai. 2001. A comparative analysis of R&D project evaluation methods. *R&D Management* 31(1): 63-75. http://www3.interscience.wiley.com/journal/119015697/abstract

Popp, D. 2004. ENTICE: Endogenous technological change in the DICE model of global warming. *Journal of Environmental Economics and Management* 48(1): 742-768. http://dx.doi.org/10.1016/j.jeem.2003.09.002

__________________. 2006. Innovation in climate policy models: Implementing lessons from the economics of R&D. *Energy Economics* 8(5-6): 1-14. http://cat.inist.fr/?aModele=afficheN&cpsidt=18207557

PRISM Climate Group. 2008 Washington State precipitation data. Oregon State University. www.prism.oregonstate.edu

Reidy, Susan. 2008. Credit crisis hits biofuel industry. *Biofuels Business* November-December: pp. 54-57.

Renewable Identification Numbers Exchange. 2008. http://rinxchange.com/

Rubin, Ofir, Miguel A. Carriquiry, and Dermot J. Hayes. 2008. Implied Objectives of U.S. Biofuel Subsidies. Iowa State University, Center for Agricultural and Rural Development. Working Paper 08-WP 459. http://ideas.repec.org/p/isu/genres/12866.html

Rupp, R. 2008. GIS data layer of irrigated areas created by digitizing aerial photos. Washington State University, Department of Crop and Soil Sciences.

Salassi, M.E. 2007. The economic feasibility of ethanol production from sugar crops. *Louisiana Agriculture Magazine*, Winter. http://www.lsuagcenter.com/en/communications/publications/agmag/Archive/2007/Winter/The+Economic+Feasibility+of+Ethanol+Production+from+Sugar+Crops.htm

Salter, A.J. and B.R. Martin. 2001. The economic benefits of publicly funded basic research: A critical review. *Research Policy* 30(3): 509-32. http://www.ingentaconnect.com/content/els/00487333/2001/00000030/00000003/art00091;jsessionid=1ehvu93snm1ul.alice

Sanden, Bjorn A. and Christian Azar. 2005. Near-term technology policies for long-term climate targets—Economy wide versus technology specific approaches. *Energy Policy* 33(12): 1557-1576. http://www.sciencedirect.com/science/article/B6V2W-4BY3WR1-1/2/8cba9172ecd9becae4566634f17f7b53

Schneider, S.H. and Lawrance H. Goulder. 1997. Achieving low-cost emissions targets. *Nature* 389: 13-14. http://stephenschneider.stanford.edu/Publications/PDF_Papers/Nature-SHS-Goulder-Cmmtry.pdf

Searchinger, Timothy, Ralph Heimlich, R. A. Houghton, Fengxia Dong, Amani Elobeid, Jacinto Fabiosa, Simla Tokgoz, Dermot Hayes, and Tun-Hsiang Yu. 2008. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science* 319(5867): 1238-1240. http://www.sciencemag.org/cgi/content/abstract/1151861 http://www.sciencemag.org/cgi/content/abstract/1151861

Sexton, Steven, Deepak Rajagopal, David Zilberman, and Gal Hochman. 2008. Food versus fuel: How biofuels make food more costly and gasoline cheaper. *Agricultural and Resource Economics Update*. University of California, Giannini Foundation of Agricultural

Economics. September/October. http://www.agecon.ucdavis.edu/extension/update/articles/v12n1_1.pdf

Skog, K.E. 2008. Preliminary estimates of wood biomass supply from U.S. forests for the revision to the Perlack et al., 2005—Billion Ton Annual Supply report. U.S. Forest Service.

Shumway, C.R. 1981. Subjectivity in ex ante research evaluation. *American Journal of Agricultural Economics* 63(1): 169-173.

__________________. 1998. Values, changing forces, choices, and the profession. *American Journal of Agricultural Economics* 80: 887-897. http://www.jstor.org/stable/1244181?seq=2

Sorrell, Steven and Jos Sijm. 2003. Carbon Trading in the Policy Mix. *Oxford Review of Economic Policy* 19(3): 420-437. http://oxrep.oxfordjournals.org/cgi/content/abstract/19/3/420

Stavins, Robert N. 2007. A U.S. Cap-and-Trade System to Address Global Climate Change. Harvard University, John F. Kennedy School of Government, Working Paper RWP07-052, October. http://belfercenter.ksg.harvard.edu/publication/17657/us_capandtrade_system_to_address_global_climate_change.html

Stern, Nicholas. 2006. The Economics of Climate Change. http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_Report.cfm

Stokey, Nancy L. 1988. "Learning by Doing and the Introduction of New Goods." *Journal of Political Economy* 96(4): 701-717. http://ideas.repec.org/a/ucp/jpolec/v96y1988i4p701-17.html

Strong, R.M. 1909. Commercial deductions from comparisons of gasoline and alcohol tests on internal combustion engines. *U.S. Geological Survey Bulletin* 392.

Tareen, I.Y., M.E. Wetzstein, and J.A. Duffield. 2000. Biodiesel as a substitutute for petroleum diesel in a stochastic environment. *Journal of Agricultural and Applied Economics* 32(2): 373–381. http://ssrn.com/abstract=244759

Tol, Richard S.J. 2005. The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties. *Energy Policy* 33(16): 2064-2074. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V2W-4CJCVJ8-2&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=71c17d94104e19b7f20939da2733bda3

__________________. 2007. The Social Cost of Carbon: Trends, Outliers and Catastrophes. Economics. Discussion Paper 2007-44. http://ideas.repec.org/p/zbw/ifwedp/6171.html

Tyner, Wallace E. 2007. Policy alternatives for the future biofuels industry. *Journal of Agricultural & Food Industrial Organization* 5(2): Article 2. http://econpapers.repec.org/article/bepbjafio/v_3A5_3Ay_3A2007_3Ai_3A2_3Ap_3A1189-1189.htm

Tyner, Wallace E. and Farzad Taheripour. 2007. Renewable energy policy alternatives for the future. *American Journal of Agricultural Economics* 89(5): 1303-1310. http://findarticles.com/p/articles/mi_hb6673/is_/ai_n29398067

Unruh, Gregory C. 2000. Understanding carbon lock-in. *Energy Policy* 28(12): 817-830. http://www.sciencedirect.com/

science/article/B6V2W-40T9HJ3-1/2/8ff1f7385f1fef1c62be6851af59746e

___________________. 2002. Escaping carbon lock-in. *Energy Policy* 30(4): 317-325. http://www.sciencedirect.com/science/article/B6V2W-457VJ10-6/2/ac0d68f476e5ded60393ae05603bac92

U.S. Department of Transportation. 2006a. Estimated Use of Gasohol: 2004. Highway Statistics 2004. Table MF-33e, October. http://www.fhwa.dot.gov/policy/ohim/hs04/pdf/mf33e.pdf

___________________. 2006b. Licensed Total Drivers, by Age: 2005. Highway Statistics 2005. Table DL-22, sheet 3 of 3, October. http://www.fhwa.dot.gov/policy/ohim/hs05/pdf/dl22.pdf

___________________. 2006c. Motor Fuel Use: 2005. Highway Statistics 2005. Table MF-21, October. http://www.fhwa.dot.gov/policy/ohim/hs05/pdf/mf21.pdf

U.S. General Accounting Office. 2007. Biofuels: DOE Lacks a Strategic Approach to Coordinate Increasing Production with Infrastructure Development and Vehicle Needs. Report GAO-07-713. June. http://www.gao.gov/new.items/d07713.pdf.

Vedenov, Dmitry V. , James A. Duffield, and Michael E. Wetzstein. 2006. Entry of alternative fuels in a volatile U.S. gasoline market. *Journal of Agricultural and Resource Economics* 31(1): 1-13. http://ageconsearch.umn.edu/handle/10144

von Döllen, Andreas and Till Requate. 2008. Environmental policy and uncertain arrival of future abatement technology. *The B.E. Journal of Economic Analysis & Policy* 8(1): Article 30. http://www.bepress.com/bejeap/vol8/iss1/art30

Wang, Michael, May Wu, and Hong Hu. 2007. Life-cycle energy and greenhouse gas emission impacts of different corn ethanol plant types. *Enviromental Research Letters* 2(2): 1-13. http://dx.doi.org/10.1088/1748-9326/2/2/024001

Washington Climate Advisory Team. 2008. Leading the Way: A Comprehensive Approach to Reducing Greenhouse Gases in Washington State. Feb. 1. http://www.ecy.wa.gov/climatechange/CATdocs/020708_InterimCATreport_final.pdf

Washington State Biofuel Advisory Committee (WSBAC). 2007. Implementing the Minimum Renewable Fuel Content Requirements. AGR-PUB 110-197 (N/8/07). http://agr.wa.gov/bioenergy/docs/BiofuelsAdvisoryCommitteeReportAugust2007FINAL.pdf

Washington State Department of Agriculture (WSDA). 2008. Energy Freedom Loan Program. Update. November http://agr.wa.gov/bioenergy/docs/EnergyFreedomLoanFINAL-2008.pdf

Washington State Department of Ecology. 1999. GIS data for Washington State counties. http://www.ecy.wa.gov/services/gis/data/data.htm

Washington State Department of Revenue (WSDR). n.d. Business and occupation tax. http://dor.wa.gov/content/FindTaxesAndRates/BAndOTax/

___________________. 2008. Incentive Programs: Deferrals, Exemptions, and Credits. http://dor.wa.gov/content/FindTaxesAndRates/TaxIncentives/IncentivePrograms.aspx

Washington State University Biofuels Cropping Systems Research and Extension Project 2008. http://css.wsu.edu/biofuels/index.html

Weitzman, Martin L. 1974. Prices vs. quantities. *The Review of Economic Studies*

41(4): 477-491. http://www.jstor.org/pss/2296698

Western Climate Initiative (WCI). 2008. Design Recommendations for the WCI Regional Cap-and-Trade Program. March 13. http://www.westernclimateinitiative.org/WCI_Documents.cfm

Western Bioenergy Assessment Team (WBAT). 2008. Strategic Assessment of Bioenergy Development in the West: Analyses of Deployment Scenarios and Policy Interactions. Prepared for the Western Governors' Association. Final Report, September 1. http://www.westgov.org/wga/initiatives/transfuels/Task%204.pdf

Western States Petroleum Association (WSPA). 2008. LCFS Implementation Proposal. March 25. http://www.arb.ca.gov/fuels/lcfs/032508wspa_prop.pdf

Wilkins, Dave. 2008. Beet acreage down. *Capital Press*. July 4. http://archives.capitalpress.com/archive_detail.php?archiveFile=pubfiles/cps/archive/2008/July/04/News/cpa42725.xml&start=0&numPer=20&keyword=beet+acreage+down&sectionSearch=&begindate=1%2F1%2F2002&enddate=1%2F22%2F2009&authorSearch=&IncludeStories=1&pubsection=&page=&IncludePages=1&IncludeImages=1&mode=allwords&archive_pubname=%0A++++++

Wong, Jetta. 2008. Testimony before Congress about the Renewable Fuel Standard's definition of renewable biomass. Environmental and Energy Study Institute. http://www.eesi.org/0708_Wong_Testimony

Yacobucci, Brent D. 2008. Biofuels Incentives: A Summary of Federal Programs. Congressional Research Service report RL33572. July 29. http://www.nationalaglawcenter.org/assets/crs/RL33572.pdf

Yeh, Sonia. 2008. The U.S. Low-Carbon Fuel Policies as Global Warming Solutions. Presented at the 2nd International Palm Oil Trade Fair & Seminar, Kuala Lumpur, Malaysia, August 22-26. University of California, Davis, Institute of Transportation Studies. http://steps.ucdavis.edu/People/slyeh/syeh-resources/uc-lcfs/POTS_LCFS_SY_FINAL.pdf

Yoder, Jonathan K. 2004. Playing with fire: Endogenous risk in resource management. *American Journal of Agricultural Economics* 86(4): 933-948. http://www.ses.wsu.edu/PDFFiles/JournalArticle/Yoder/Yoder_AJAE_04.pdf

Yoder, Jonathan, Douglas Young, Kathleen Painter, Jie Chen, Joan Davenport, and Suzette Galinato. 2009. Ethanol Industry in Washington State. Report to the Washington State Department of Agriculture. Washington State University, School of Economic Sciences. http://agr.wa.gov/AboutWSDA/Docs/Ethanol%20from%20WA%20Sugar%20Beets%20WSU%20Study%20March2009.pdf

Young, F.L., L. Bewick, and W.L. Pan. 2008. Systems approach to crop rotation research: Guidelines and challenges. In *Crop Rotation*, pp. 41-70. Y.U. Berklian, ed. New York: Nova Science Publishers. http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=226961

Zaikin, A.A., D.L. Young, and W.F. Schillinger. 2008. Economics of an Irrigated No-till Crop Rotation with Alternative Stubble Management Systems Versus Continuous Irrigated Winter Wheat with Burning and Plowing of Stubble, Lind, WA, 2001-2006. Washington State University. Farm Business Management Report, EB2029E. February. http://cru.cahe.wsu.edu/CEPublications/eb2029e/eb2029e.pdf

Zheng, Q. and R. Shumway. 2008. Washington Biofuel Feedstock Crop Supply Analysis. Washington State University, School of Economic Sciences. Working Paper 2008-24, August. http://www.ses.wsu.edu/PDFFiles/WorkingPapers/Shumway/biofuels_supply_altern-082608_WP2008-24.pdf

Legislation

HB 1303. July 2007. Encouraging the use of cleaner energy. Washington State Legislature. http://apps.leg.wa.gov/billinfo/summary.aspx?year=2007&bill=1303

HB 2210. July 2007. Creation of a renewable fuel standard and tax incentives for consumers and producers of biofuels. Oregon State Legislature. http://www.leg.state.or.us/07reg/measpdf/hb2200.dir/hb2210.en.pdf

HB 2815. June 2008. Providing a framework for reducing greenhouse gas emissions in the Washington economy. Washington State Legislature. http://apps.leg.wa.gov/billinfo/summary.aspx?bill=2815&year=2007

HR 6. December 2007. Energy Independence and Security Act of 2007. United States Congress. http://www.ethanol.org/pdf/contentmgmt/Full_Text_of_HR6.pdf

HR 6124 (Farm Bill). June 2008. Food, Conservation, and Energy Act of 2008. United States Congress. http://www.usda.gov/documents/Bill_6124.pdf

SB 6001. July 2007. Mitigating the impacts of climate change. Washington State Legislature. http://apps.leg.wa.gov/billinfo/summary.aspx?bill=6001&year=2007

RCW 15.110. 2007. Energy freedom program. Washington State Legislature. http://apps.leg.wa.gov/RCW/dispo.aspx?cite=15.110

RCW 19.112.110. 2009. Special fuel licensees — Required sales of biodiesel fuel — Rules. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=19.112.110

RCW 19.112.120. 2007. Motor vehicle fuel licensees — Required sales of denatured ethanol — Rules — Limitation of section. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=19.112.120

RCW 19.112.170. 2006. Determination of the supply of certain fuels — Notification — Declaration concerning the applicability of RCW 19.112.110 or 19.112.120. Washington State Legislature. http://apps.leg.wa.gov/Rcw/default.aspx?cite=19.112.170

RCW 43.325.020. 2009. Energy freedom program — Established. Washington State Legislature. http://apps.leg.wa.gov/rcw/default.aspx?cite=43.325.020

RCW 43.325.040. 2009. Energy freedom account — Green energy incentive account — Energy recovery act account. http://apps.leg.wa.gov/rcw/default.aspx?cite=43.325.040

RCW 43.325.070. 2009. Applications — Criteria. Washington State Legislature. http://apps.leg.wa.gov/rcw/default.aspx?cite=43.325.070

RCW 70.94.151. 2008. Classification of air contaminant sources — Registration — Fee — Registration program defined — Adoption of rules requiring the reporting of emissions of greenhouse gases. Washington State Legislature. http://apps.leg.wa.gov/rcw/default.aspx?cite=70.94.151

RCW 82.04.260. 2009. Tax on manufacturers and processors of various foods and by-products… Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.04.260

RCW 82.04.4334. 2007. Deductions — Sale or distribution of biodiesel or E85 motor fuels. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.04.4334

RCW 82.04.4335. 2003. Deductions — Sale or distribution of wood biomass fuel. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.04.4335

RCW 82.08.955. 2007. Exemptions — Sales of machinery, equipment, vehicles, and services related to biodiesel blend or E85 motor fuel. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.08.955

RCW 82.08.960. 2003. Sales of machinery, equipment, vehicles, and services related to wood biomass fuel blend. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.08.960

RCW 82.12.955. 2007. Exemptions — Use of machinery, equipment, vehicles, and services related to biodiesel or E85 motor fuel. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.12.955

RCW 82.12.960. 2003. Exemptions — Use of machinery, equipment, vehicles, and services related to wood biomass fuel blend. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.12.960

RCW 82.23A. 2006. Petroleum products — underground storage tank program funding. Washington State Legislature. http://apps.leg.wa.gov/rcw/default.aspx?Cite=82.23A&full=true

RCW 82.29A.135. 2008. Exemptions — Property used to manufacture alcohol, biodiesel, or wood biomass fuel. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.29A.135

RCW 82.36. 2008. Motor vehicle fuel tax. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.36

RCW 82.36.020. 2007. Tax levied and imposed — Rate to be computed — Incidence — Distribution. Washington State Legislature. http://apps.leg.wa.gov/rcw/default.aspx?cite=82.36.020

RCW 82.36.025. 2007. Motor vehicle fuel tax rate — Expiration of subsection. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.36.025

RCW 82.36.026. 2007. Tax liability — General. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=82.36.026

RCW 84.36.635. 2008. Property used for the manufacture of alcohol fuel or biodiesel fuel. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=84.36.635

RCW 84.36.640. 2003. Property used for the manufacture of wood biomass fuel. Washington State Legislature. Washington State Legislature. http://apps.leg.wa.gov/RCW/default.aspx?cite=84.36.640

SB 6001. July 2007. Mitigating the impacts of climate change. Washington State Legislature. http://apps.leg.wa.gov/billinfo/summary.aspx?year=2007&bill=6001

SB 6508. July 2006. Developing minimum renewable fuel content requirements and fuel quality standards in an alternative fuels market. Washington State Legislature. http://apps.leg.wa.gov/billinfo/summary.aspx?year=2006&bill=6508

Appendices

Available electronically by request from Jonathan Yoder at yoder@wsu.edu or (509) 335-8596.