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A GREEN NEW DEAL FOR WASHINGTON STATE

Climate Stabilization, Good Jobs, and Just Transition

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Highlights of Main Findings

This study examines the prospects for a transformative Green New Deal for Washington State. The centerpiece of this Green New Deal project is clean energy investments—i.e. investments in renewable energy and energy efficiency—throughout the state. These clean energy investments can advance two fundamental goals:

- Promoting global climate stabilization by reducing carbon dioxide (CO_2) emissions in Washington State without increasing emissions outside of the state.
- Protecting existing employment levels and expanding good job opportunities throughout the state.

Reducing CO_2 Emissions

- The first aim of the Green New Deal will be to achieve, by 2035, a 40 percent reduction in CO_2 emissions in Washington State relative to the 2014 level of emissions.
- Current emissions are at 73.4 million tons. The emissions level in 2035 will need to be no more than 44 million tons.

Major Areas of Clean Energy Investments

- **Energy Efficiency.** Dramatically improving energy efficiency standards in Washington State's stock of buildings, automobiles and public transportation systems, and industrial production processes.
- **Clean Renewable Energy.** Dramatically expanding the supply of clean renewable energy sources—primarily wind, solar, and geothermal power—available at competitive prices to all sectors of Washington State's economy.
- **Total Investment Expenditures.** The required level of investment will be roughly $6.6 billion per year between 2021 – 2035.
    - This estimate assumes that Washington State's economic growth proceeds at an average rate of 2.0 percent per year.
    - Clean energy investments will need to equal about 1.2 percent of Washington State's annual GDP.
    - The average annual clean energy investment level of 1.2 percent of GDP means that nearly 99 percent of Washington State's economic activity will still be directly engaged in activities other than clean energy investments.

Employment Stability and New Job Creation through the Green New Deal

- Investing $6.6 billion per year in clean energy projects in Washington State will generate between about 36,000 and 41,000 jobs per year in the state.
- New job opportunities will be created in a wide range of areas, including construction, sales, management, production, engineering, and office support.
- Current average total compensation in these occupations ranges between $52,000 - $90,000.
- Employment growth in these areas should create increased opportunities both for women and minority workers to be employed and to raise unionization rates.
- Higher unionization rates should promote gains in compensation and better working conditions in the affected industries.
- Because the state's clean energy investment program will support healthy overall economic growth in the state, existing employment levels in the state will be protected as the Green New Deal transition proceeds.

Just Transition for Fossil Fuel Industry Dependent Workers and Communities

- Fossil fuel consumption in Washington State consists almost entirely of petroleum and natural gas. Consumption of these fuels will need to fall by about 40 percent as of 2035 to bring the state's total CO_2 emissions down to 44 million tons.
- About 5,400 workers in Washington State are presently employed in nine industries that will be heavily affected by this 40 percent fossil fuel consumption cut.
- Assuming that the fossil fuel related industries' contraction proceeds smoothly between 2021 -2035, total job losses will average about 140 per year.
- All of these job losses can be handled through attrition by retirement when workers reach age 65.
    - Regulations are needed to ensure that workers moving into retirement will have their full pensions available to them.
- When the fossil fuel industries' contraction is more episodic—for example, if 700 workers lose their jobs in one year rather than only 140—there will be workers who become displaced.
- We advance Just Transition policies to support displaced workers. These include:
    - "Glide paths" to retirement for older workers.
    - Substantial levels of income, retraining, and relocation support for younger displaced workers.
    - The costs for these policies will vary greatly depending on the specific conditions and features of the program. A rough average cost range would be around $30 - $40 million per year.
    - The costs will fall dramatically if displaced workers can be guaranteed reemployment. Jobs could be made available either from the growing clean energy investment projects or within the Washington State public sector.

- Just Transition for heavily impacted communities can be provided through channeling a relatively high proportion of new clean energy investments into these communities.

A Clean Energy and Sustainable Communities Investment Policy Agenda

- Our policy framework builds from the set of measures already in operation in Washington State.
- The main recommended policy measures include:
  - A carbon tax.
    - We estimate revenues from a carbon tax at varying tax rates.
    - A flat carbon tax rate of $15 per ton of CO_2 will generate about $900 million per year in tax revenues.
  - Strengthening existing energy efficiency and renewable energy portfolio standards.
  - Strengthening existing procurement programs to support an expanding market for electric vehicles.
  - Expanding subsidized financing policies currently available through the state's Clean Energy Fund.
  - Channeling new investment funds into communities that are, at present, significantly dependent on the state's fossil fuel related industries, primarily in petroleum refining.
  - Washington State can achieve a 40 percent reduction in statewide CO_2 emissions even if the state's Energy Intensive and Trade Exposed facilities do not reduce their emissions at all through 2035.

Summary of Study

This study examines the prospects for a transformative Green New Deal project for Washington State. This project should be understood as a major initiative within the state to advance the fundamental goal of global climate stabilization. The centerpiece of the Green New Deal will be clean energy investments—i.e. investments in the areas of renewable energy and energy efficiency. These clean energy investments should be undertaken by both the public and private sectors in Washington State, supported by a combination of public funding and incentives for private investors. Most of the new clean energy investments in the state should be privately owned and managed.

To be more specific, the first aim of this Green New Deal project is to achieve a 40 percent reduction in all human-caused carbon dioxide (CO_2) emissions in Washington State relative to the state's 2014 emissions level (the most recent figures). The second, equally important, goal is to achieve this 2035 CO_2 emission reduction standard while also supporting existing employment levels, expanding job opportunities and raising average living standards throughout Washington State. The expansion of clean energy investments will need to focus on 1) dramatically improving energy efficiency standards in Washington State's stock of buildings, automobiles and public transportation systems, and industrial production processes; and 2) equally dramatically expanding the supply of clean renewable energy sources available at competitive prices to all sectors of Washington State's economy. This means greatly increasing the state's supply of wind, solar, and geothermal power, to operate alongside the state's already abundant supply of hydro energy resources.

Such efforts to drive down CO_2 emissions in Washington State are representative of the types of climate stabilization initiatives that need to be advanced throughout the world without further delay. The December 2015 UN-sponsored Paris Climate Agreement was a major milestone on behalf of the global project of climate stabilization. Coming out of the conference, all 196 countries formally recognized the grave dangers posed by climate change and committed to take action to substantially cut emissions generated by their respective economies.

On June 1, 2017, U.S. President Donald Trump announced that the United States would pull out of the Paris agreement. This decision dealt a severe blow to the prospects for putting the global economy onto a sustainable path toward climate stabilization. At the same time, the pledges made by all countries combined at the Paris conference are not close to being adequate to stabilize the climate at a global mean temperature at between 1.5 – 2^0C above pre-industrial levels no later than 2100—the goal that the Paris Agreement itself recognizes as necessary to achieve climate stabilization. Rather, according to the credible estimate by the environmental research NGO Climate Action Tracker, if all countries were to keep to the pledges they made at Paris, the global mean temperature would rise by between 2.4 – 2.7^0C by 2100.[1] In addition, even these inadequate pledges were not made legally binding in Paris.

This study examines measures to reduce that portion of total greenhouse gas emissions produced by burning fossil fuels—oil, coal and natural gas—to generate energy. Climate change cannot be entirely blamed on we humans consuming oil, coal, and natural gas to gen-

1 http://climateactiontracker.org/global.html.

Footnotes are included in this summary section; endnotes are used for the main text.

erate energy. But people consuming fossil fuels for energy can be blamed for about 74 percent of the problem. CO_2 emissions from burning coal, oil and natural gas alone produce about 63 percent of all greenhouse gas emissions, while another 11 percent is caused mainly by methane leakages during extraction. Agricultural production is the other major source of greenhouse gas emissions, accounting for about 13 percent in total, in about equal shares of methane and nitrous oxide. Controlling methane and nitrous oxide emissions from agricultural as well as other, smaller sources of emissions will of course be necessary to advance a successful global climate stabilization project. But this study will focus on the roughly 75 percent of the problem that we can solve by burning less oil, coal and natural gas, as well as, to a lesser extent, high-emissions renewables, such as corn ethanol.[2]

Within this context, Washington State can assume a leadership role in advancing a climate stabilization project that will be adequate to the challenges we face—specifically to cut CO_2 emissions in the state by 2035 without increasing emissions outside the state. Washington State can also demonstrate that such a project will create major opportunities to expand job opportunities and launch new industrial development initiatives throughout the state, while also supporting a healthy overall level of economic growth that supports existing employment levels. As we will see, clean energy investments in Washington State that would be sufficient to put the state on a true climate stabilization trajectory will generate about 40,000 jobs per year within the state.

This growth in jobs generated by clean energy investments, in both the areas of energy efficiency and clean renewable energy sources, should also increase opportunities for women and minority workers seeking employment in these sectors. This is especially significant given that, at present, women and minority workers are underrepresented in the workforce of the relevant industries. The expansion of job opportunities should therefore be accompanied by affirmative efforts to support women and minorities moving into these positions. The growth of jobs in these sectors will also create new opportunities to increase union coverage for workers employed in these sectors. The rise in unionization rates should, in turn, promote improved compensation levels and working conditions in these sectors.

At the same time, the state's fossil fuel related industries will need to contract by 40 percent as of 2035, in correspondence with the 40 percent decline in fossil fuel consumption in the state needed to bring the state's CO_2 emissions down to 44 million tons by 2035. This means that the state's fossil fuel related industries will need to contract at an average rate of 3.5 percent per year between 2021 and 2035. The fossil fuel related industries operating in Washington State include: petroleum refining; natural gas distribution; oil and gas pipeline construction and transportation; petroleum bulk stations and terminals; fossil fuel based electric power generation; and support activities for oil and gas. These are in addition to coal mining and oil and gas extraction themselves, though, with both of these basic extractive sectors, the level of activity in Washington State is negligible. Other than in these fossil fuel related industries, this clean energy investment project will not create pressures for job losses in any sector of the Washington State economy. To the contrary, the Green New Deal program will help undergird a healthy economic growth path for the state. This will, in turn, protect current employment levels and support overall employment growth in the state.

2 We rely on three main sources for data on global CO_2 and overall greenhouse gas emissions: the U.S. Energy Information Agency's (EIA) International Energy Statistics, the International Energy Agency's (IEA) World Energy Outlook, and the World Bank's World Development Indicators. There are small differences in details among these three sources. To reconcile these differences, we try to use the source that provides the most recent set of figures for the global economy. We use less recent data, as needed, when they provide an improved level of detail.

A major focus of this study is to develop Just Transition policies for the workers in Washington State who are presently dependent on these fossil fuel industries for their livelihoods. We also consider initiatives to assist fossil fuel dependent communities in revitalizing their local economies as fossil fuel based activities decline. A first step in advancing effective Just Transition policies is to establish how many workers and communities are likely to be significantly affected by the 40 percent decline in fossil fuel related production throughout the state.

Toward that end, we show that a 3.5 percent average annual rate of decline in Washington State's fossil fuel related industries should entail an average of only about 140 job losses per year throughout the state. As a critical finding, we also show that this level of job losses is less than the average number of fossil fuel related industry workers who will be moving into retirement voluntarily at age 65 by 2035. That is, based on the available demographic evidence, we find that an average of about 170 workers currently employed in all of the fossil fuel related industries combined in Washington State should be turning 65 every year between 2021- 2035. In terms of designing effective Just Transition policies, the first priority should therefore be to ensure that the pension plans for all workers in the affected fossil fuel related industries—i.e. all 170 workers each year moving into voluntary retirement—are secure.

We do also recognize that the contraction in fossil fuel industry related jobs is not likely to proceed smoothly every year through 2035. When the industries' contraction is episodic—for example, if 700 jobs are lost in one year rather than the average of 140 job losses per year—there will be workers who become displaced. We advance a series of Just Transition policies to support all of these workers. These include "glide paths" to retirement for older workers, as well as substantial levels of income, retraining and relocation support for the younger displaced workers.

In addition to developing Just Transition policies to support workers and communities that are presently dependent on the state's fossil fuel related industries, we also consider a series of policies to support clean energy investments in the state. These include a carbon tax, which we estimate can raise an average of about $900 million per year even with a low-end tax rate of $15 per ton of carbon. The tax revenues will of course rise proportionally at higher tax rates—for example, to an average of $1.5 billion per year at a rate of $25 per ton.

We also consider a series of regulatory policies, direct public spending measures, and private investment incentives. These policies will be aimed at generating an overall level of clean energy investments in Washington State—including primarily private sector investments—of about $6.6 billion per year on average. We calculate that this will be the investment level necessary to achieve the target of a 40 percent reduction in statewide CO_2 emissions as of 2035. This level of investment would amount to a roughly three-to-fourfold increase in clean energy investments in Washington State relative to current levels, which are between about $1.5 - $2 billion per year. At the same time, an average of about $6.6 billion per year in clean energy investments would still amount to only about 1.2 percent of Washington State's overall GDP between 2021 – 2035. In other words, our estimate of Washington State's annual clean energy investment needs for bringing CO_2 emissions down in the state by 40 percent as of 2035 implies that nearly 99 percent of all economic activity in Washington State can still be directly engaged in activities other than clean energy investments. Correspondingly, virtually all jobs in the state will be unaffected by the state's clean energy transition program.

The study is divided into nine sections. These are:

1. Introduction
2. Sources of Energy and CO_2 Emissions for Washington State
3. Determinants of Washington State's Emissions Levels
4. Prospects for Energy Efficiency Gains
5. Prospects for Clean Renewables
6. Clean Energy Investment Levels and Emissions Reductions
7. Job Creation through Clean Energy Investments
8. Just Transition for Fossil Fuel Industry Dependent Workers
9. A Clean Energy Investment Policy Agenda

The main findings and conclusions of the study are as follows:

Current CO_2 Emissions Levels in Washington State

As of the most recent 2014 data, CO_2 emissions in Washington State were at 73.4 million tons. This emissions level is only about 4 percent above the state's 1990 level of 70.9 million tons, even while the State's GDP has more than doubled between 1990 – 2014 and its population has grown by nearly 50 percent. Thus, Washington State has already made progress toward "decoupling"—i.e. reducing CO_2 emissions while the economy and population have been growing.

In fact, Washington State is presently the seventh "cleanest" of the 50 U.S. states, as measured by CO_2 emissions per capita. As of 2014, CO_2 emissions in Washington State were 10.3 tons per capita. By contrast, the figure for the U.S. as a whole was 17.0—70 percent higher than that for Washington State. Washington State has reached this relatively low level of per capita emissions because it operates at a relatively high level of energy efficiency and relies on a relatively clean mix of energy sources. The most important factor with respect to energy sources is the fact that the state relies on hydro power to provide about one-third of its total energy supply. In addition, Washington State relies on coal—the most heavily CO_2 emitting energy source—for only 3.3 percent of its total energy supply.

Despite this relatively positive performance to date, it will still be necessary for Washington State to make major further improvements in order for the state to contribute meaningfully toward global climate stabilization. As one metric, Washington State's current emissions level of 10.3 tons per capita is more than four times higher than the 2.4 tons per capita figure that is needed just to reduce global emissions by 40 percent as of 2035.

Energy Consumption and CO_2 Emissions Sources

As of 2014, the primary sources of Washington State's energy supply are petroleum (35.1 percent), hydro (32.8 percent) and natural gas (15.2 percent). These three sources account for 83.1 percent of all Washington State's energy consumption, with total statewide energy consumption at 2.0 quadrillion British Thermal Units (Q-BTUs). In addition, biomass provides 4.9 percent of total supply, nuclear provides 4.3 percent and, again, coal provides 3.3 percent. In combination, at present, wind, geothermal and solar account for 3.1 percent, with almost all of that provided by wind. These figures make clear that transforming these clean renewable sources into a major provider of energy in Washington State will be a formidable challenge. CO_2 emissions in Washington State are generated almost entirely from combusting petroleum and natural gas, with about 67 percent due to petroleum and 23 percent from natural gas.

Prospects for Energy Efficiency

Washington State operates at an energy efficiency level that is about 20 percent below the national average. The state made major gains in efficiency between 1990 – 2014 due almost entirely to gains in efficiency achieved in the state's commercial building operations and in industrial energy consumption. The gains with commercial buildings resulted from implementing strong statewide building codes. With respect to industrial efficiency, the gains resulted primarily from the contraction of energy-intensive industries such as aluminum and the corresponding relative growth of high value-added and less energy-intensive industries, in particular information technology and biotech. Further gains in efficiency will need to result through further improvements in buildings, as well as with private automobiles and the equipment powering industrial activities. From a review of the relevant literature, in particular from the U.S. National Academy of Sciences, we conclude that major efficiency improvements—in the range of 30 – 40 percent—are possible at relatively low upfront capital expenditures. We assume, specifically, that the average costs throughout the full range of energy efficiency investments will be $35 billion per Q-BTU in efficiency gains.

Prospects for Clean Renewable Energy Sources

We focus on expanding Washington State's share of energy supply that will be provided through three clean renewable sources—wind, solar and geothermal energy. We distinguish between the costs to consumers of expanding the supply from these three sources, as opposed to the upfront capital expenditures of building more clean renewable energy productive capacity. In terms of costs to consumers, we review evidence from the U.S. Energy Information Agency (EIA) showing that, as of 2021, the average costs of delivering a given supply of electricity from clean renewable sources will be roughly equal to, if not cheaper than, virtually all fossil fuel based technologies. Consumers should therefore experience no price increases when they purchase energy from clean renewable sources. We also review evidence from the EIA on the one-time costs of expanding productive capacity in clean renewable sources. We conclude, roughly, this average cost will be about $200 billion per Q-BTU of new capacity.

Clean Energy Investments to Achieve Emissions Reduction Goal

To explore the prospects of bringing Washington State's CO_2 emissions down by 40 percent, to 44 million tons by 2035, we work with a few basic assumptions as to the state's economic trajectory between now and 2035. In particular, we assume that the state's average rate of GDP growth through 2035 will be 2.0 percent, the same growth rate that prevailed between 1990 and 2014. Within this growth framework, we then consider two alternative scenarios with respect to the state's energy infrastructure. The first is that the energy infrastructure remains basically intact through 2035. The second is that Washington State undertakes a major expansion in clean energy investments between 2021 – 2035. Following from these investments, the Washington State economy both raises energy efficiency and expands its reliance on clean renewable energy sources to the extent necessary to bring statewide CO_2 emissions down to 44 million tons or below. We show that, over 2021 – 2035, if investments throughout Washington State average about $2.8 billion per year in energy efficiency and $3.8 billion per year in clean renewable energy—for a total level of clean energy investments at about $6.6 billion per year—the state can bring CO_2 emissions down to about 44 million tons by 2035. Total investment spending at this level would average about 1.2 percent of the state's projected GDP between 2021 – 2035, assuming the state's GDP did grow at 2.0 percent per year over this period.

Job Creation through Clean Energy Investments

We estimate the employment effects in Washington State of advancing clean energy investments at the level of about $6.6 billion per year over 2021 – 2035. After estimating the number of jobs that this overall investment level will generate, we then consider indicators of job quality, the profile of the workers engaged in these activities at present, and the prevalent types of specific jobs associated with the major areas of both energy efficiency and clean renewable energy investments. Overall, we find that, for 2021, the first year of the large-scale investment expansion, the total extent of direct plus indirect employment created will be about 41,000 jobs, equal to about 1.2 percent of the state's total workforce. Assuming that labor productivity in these activities improves at an average rate of 1 percent per year, total job creation through $6.6 billion in clean energy investments will be about 36,000 in 2035.

In terms of job quality, we find that average total compensation for the newly created areas of employment will range between $52,000 and $90,000. We show the proportions of workers in these jobs who have private pensions, are covered by private health insurance and are union members. We also report on the educational credentials of workers currently employed in these areas, as well as the racial and gender composition of workers in these jobs.

Among other results, we find that these jobs are held disproportionately by white male workers and that unionization rates range mostly between 10 - 20 percent of the respective workforces. The growth in employment in these industries that will be generated by large-scale new investments should create increased opportunities both for women and minority workers to be employed in these industries as well as to raise unionization rates. The rise in unionization, in turn, should help improve compensation levels in these industries as well as the diversity of the workforce.

Just Transition for Fossil Fuel Industry Dependent Workers and Communities

In order for Washington State to bring total CO_2 emissions down to 44 million tons by 2035, consumption of fossil fuels in the state will need to fall by approximately 40 percent relative to its 2014 level. It follows that production activity and employment in fossil fuel dependent industries throughout Washington State will also decline by approximately 40 percent as of 2030. As discussed above, we consider the impact on employment in nine industries and also propose a set of measures—a "Just Transition" program—to compensate both workers and communities that are, at present, dependent on the fossil fuel industry for their livelihoods. This section of the study focuses on Just Transition policies for workers. We discuss community transition measures in the next section.

As we discussed above, the single most important finding of our work on this question is that, with a 3.5 percent average annual rate of decline in Washington State's fossil fuel related industries, there will be an average of only about 140 job losses per year throughout the state. This level of job losses is less than the average number of fossil fuel related industry workers who will be moving into retirement voluntarily at age 65 by 2035. This is why, again, the first priority of a Just Transition program should be to ensure that the pension plans for all workers in the affected fossil fuel related industries are secure.

But we then also need to create effective Just Transition protections for displaced workers when the fossil fuel related industries contract in more episodic patterns. In recognizing those situations, we have developed policies along three dimensions:

1) Providing an adequate "glide path" to retirement for workers who are laid off near the age at which they would have normally retired.
2) Providing adequate levels of income, retraining, and relocation support for younger workers facing displacement—i.e. those workers who are not at or near retirement age. Among this group of younger workers, we must give consideration both to those who are able to move into new employment opportunities and to those who do not obtain new jobs. These measures would assume that there are no job guarantees incorporated into the Just Transition program.
3) Considering these same programs of support for younger workers within a framework in which workers are also guaranteed reemployment.

We generate estimates of the costs of an overall Just Transition program that includes these elements along with pension guarantees for workers moving into retirement. The range of our estimates is extremely wide—between about $5 million and nearly $300 million per year, depending on a series of assumptions, including: 1) whether the fossil fuel industry contraction is smooth or episodic; 2) whether the pattern of layoffs starts with the youngest or the oldest workers; and 3) what specific amount of financial support is provided within each of the Just Transition programs.

In the case of the U.S. oil refining sector, most shutdowns over the past 35 years have occurred over a short period of time. But these shutdowns have almost always involved small refining operations. With larger-scale refineries such as those currently operating in Washington State, more protracted rates of decline could occur. Probably the most reasonable assumption is that the actual path of contraction will entail periods of steady annual job losses which are then punctuated by sporadic periods of larger job losses. This kind of pattern—alternating periods of steady contraction with occasional episodes of large-scale losses—would suggest that the actual average costs range for the Just Transition program is probably around $30 – $40 million per year.

Most of the other components of the Just Transition program can be handled through regulatory and industrial policy initiatives that need not entail major new costs. For example, the private fossil fuel dependent firms that are maintaining the pension funds for their workers should be prevented from allowing the funds to become significantly underfunded. One way this could be achieved is by prohibiting the companies from paying dividends or financing share buybacks until their pension funds have been brought to full funding and maintained at that level. In addition, displaced workers could be provided with guarantees of reemployment. These workers could be placed into new jobs within the pool of roughly 40,000 jobs generated annually at the $6.6 billion level of spending for clean energy investment projects, or through the pool of nearly 130,000 jobs that constitute the payroll of the State of Washington itself. Workers transitioning into these job areas should then also be provided with wage insurance that enables them to maintain the income levels they had through their fossil fuel industry jobs.

A Clean Energy Investment Policy Agenda

In this section, we consider what would constitute an effective package of policies for reaching this overall clean energy investment level averaging $6.6 billion per year between 2021 – 2035. Our proposed policy framework builds from the set of measures that are already in operation in Washington State. We consider the prospects for building on these already existing policies, as well as new proposals, within four broad categories:

Market-shaping taxes and regulations that take account of the social costs of burning fossil fuels as an energy source and help build demand for energy efficiency and clean renewable energy sources. These include the proposal for a carbon tax, along with energy efficiency and renewable energy portfolio standards for the state's utilities. With a carbon tax set even at a low-end figure of $15 per ton fixed through 2021 – 2035, we estimate that the tax would still generate an average of about $900 million per year in revenue.

Direct public spending that includes investments in infrastructure, procurement and research and development (R&D). This would include expanding the state's existing procurement program for purchasing electric vehicles.

Private investment incentives that lower the costs and risks for private investors for investments in energy efficiency and clean renewable energy sources. A primary focus here is to expand the state's existing Clean Energy Fund.

Transitional support for communities that will be disproportionately hurt through the contraction of the state's fossil fuel related industries. The largest relative impacts are likely to be in the communities in which the state's oil refineries are located. The four largest refineries in the state are located in the areas around Ferndale and Anacortes respectively. The most direct way to support these communities in transition will be to channel a relatively high proportion of new clean energy investments into these communities. These communities will also need general state-level support to maintain adequate public sector spending and employment levels during the transition period. We also consider in this category the special conditions faced by Washington State's "Energy Intensive and Trade Exposed" (EITE) facilities, especially the conditions for the seven largest facilities which are responsible for virtually all of the CO_2 emissions generated by all EITE enterprises in the state. Six of these firms are in the pulp and paper industry. We show how Washington State can reach its emission reduction goals for 2035 even if these facilities do not lower their emissions at all by 2035.

A GREEN NEW DEAL FOR WASHINGTON STATE

Climate Stabilization, Good Jobs, and Just Transition

1. INTRODUCTION

This study examines the prospects for a transformative Green New Deal project for Washington State. The centerpiece of this project is investments throughout the state in renewable energy and energy efficiency. Taken as a whole, these clean energy investments should be understood as a major initiative within the state to advance the fundamental goal of global climate stabilization. These investments should be undertaken by both the public and private sectors in Washington State, supported by a combination of public investments and incentives for private investors. Most of the new clean energy investments in the state should be privately owned and managed.

The first specific aim of the Green New Deal for Washington State is to achieve, by 2035, a 40 percent reduction below the 2014 level (the most recent figures) in all human-caused carbon dioxide (CO_2) emissions in Washington State. The second, equally important, goal is to achieve this 2035 CO_2 emission reduction standard while also promoting a healthy economic growth rate, expanding job opportunities and rising average living standards throughout Washington State. This program will support existing jobs while also creating new opportunities through large-scale clean energy investments. The program will also provide a Just Transition for workers and communities that are currently dependent on any sector of the state's fossil fuel industry.

The expansion of clean energy investments will need to focus on 1) dramatically improving energy efficiency standards in Washington State's stock of buildings, automobiles and public transportation systems, and industrial production processes; and 2) equally dramatically expanding the supply of clean renewable energy sources available at competitive prices to all sectors of Washington State's economy. This specifically means greatly expanding the state's supply of wind, solar, and geothermal power, to operate alongside the already abundant supply of hydro energy resources in the state.

Such efforts to rapidly and dramatically drive down CO_2 emissions in Washington State are representative of the types of climate stabilization initiatives that need to be advanced throughout the world without further delay. The December 2015 UN-sponsored Paris Climate Agreement was a major milestone on behalf of the global project of climate stabilization. Coming out of the conference, all 196 countries formally recognized the grave dangers posed by climate change and committed to take action to substantially cut emissions generated by their respective economies.

On June 1, 2017, U.S. President Donald Trump announced that the United States would pull out of the Paris agreement. This decision dealt a severe blow to the prospects for putting the global economy onto a sustainable path toward climate stabilization. At the same time, the pledges made by all countries combined at the Paris conference are not close to being adequate to stabilize the climate at a global mean temperature of between 1.5 – 2^0C above pre-industrial levels no later than 2100—the goal that the Paris Agreement itself recognizes as necessary to achieve climate stabilization. Rather, according to the credible estimate by the environmental research NGO Climate Action Tracker, if all countries were to keep to the pledges they made at Paris, the global mean temperature would rise by between 2.4 – 2.7^0C by 2100.[1] In addition, even these inadequate pledges were not made legally binding in Paris.

Within this context, Washington State can assume a significant leadership role in advancing a climate stabilization project that will be adequate to the challenges we face. Washington State can also demonstrate that such a project will support economic growth and existing employment levels as well as create major opportunities to expand job opportunities and launch new industrial development initiatives throughout the state. As we will see, clean energy investments in Washington State that would be sufficient to put the state on a true climate stabilization trajectory will generate about 40,000 jobs per year within the state. At the same time, the state's fossil fuel related industries will need to contract by 40 percent between 2021 - 2035—a rate of decline that would average about 3.4 percent per year. But as we show, this rate of decline in Washington State's fossil fuel related industries can be accomplished with only a modest number of workers being displaced each year, after we take account of the workers who will move into retirement voluntarily at age 65 by 2035. Moreover, all displaced workers will need to be supported through a generous set of Just Transition policies, including income replacement and efforts to provide new employment opportunities, including in the state's clean energy sectors.

The growth in jobs generated by clean energy investments, in both the areas of energy efficiency and clean renewable energy sources, should also increase opportunities for women and minority workers seeking employment in these sectors. This is especially significant given that, at present, women and minority workers are underrepresented in the workforce of the relevant industries. The growth of jobs in these sectors will also create new opportunities to increase union coverage for workers employed in these sectors. The rise in unionization rates should, in turn, promote improved compensation levels and working conditions in these sectors.

Overall, advancing large-scale clean energy investments in Washington State—a Green New Deal—offers the prospect of a transformational project in support of both global climate stabilization and the expansion of good job opportunities throughout the state. At the same time, this investment project will need to be managed with tremendous care in order to take full advantage of the opportunities ahead. We propose a series of specific policy measures, drawing mainly on the state's existing set of clean energy programs. Our policy proposals include: a carbon tax; enhanced renewable energy and energy efficiency portfolio standards for the state's utilities; increased support for the state's Clean Energy Fund; maintaining the state's high automobile fuel efficiency standards; transitional support for the state's fossil fuel industry dependent communities, in particular in the areas around Ferndale and Anacortes, where the state's large oil refineries are located; and careful management of the state's Energy Intensive and Trade Exposed (EITE) establishments, especially in the pulp and paper sector.

Without careful management—both in the areas of new investment initiatives as well as the Just Transition measures in support of workers and communities currently dependent on the state's fossil fuel related industries—the major overarching opportunities ahead could get lost.

Washington State's Emissions Levels and Emissions Reduction Targets

In 2008, the Washington State legislature established greenhouse gas emissions reduction targets for the state through 2050. These targets required the state to reduce greenhouse gas emissions to the 1990 level by 2020; 25 percent below the 1990 level by 2035; and 50 percent below the 1990 level by 2050.

In this study, we focused on the share of total greenhouse gas emissions contributed by CO_2 emissions that are generated by burning oil, coal and natural gas to produce energy. Considering the U.S. overall, CO_2 emissions are responsible for about 80 percent of overall greenhouse gas emissions.[2]

In 1990, total CO_2 emissions in Washington State were at 70.9 million metric tons.[3] Following from this baseline, the state's official emissions reduction goals with respect to CO_2 would be:

- 2020 goal—70.9 million tons (= to 1990 level)
- 2035 goal—53.2 million tons (= 25 percent below 1990 level)
- 2050 goal—35.4 million tons (= 50 percent below 1990 level)

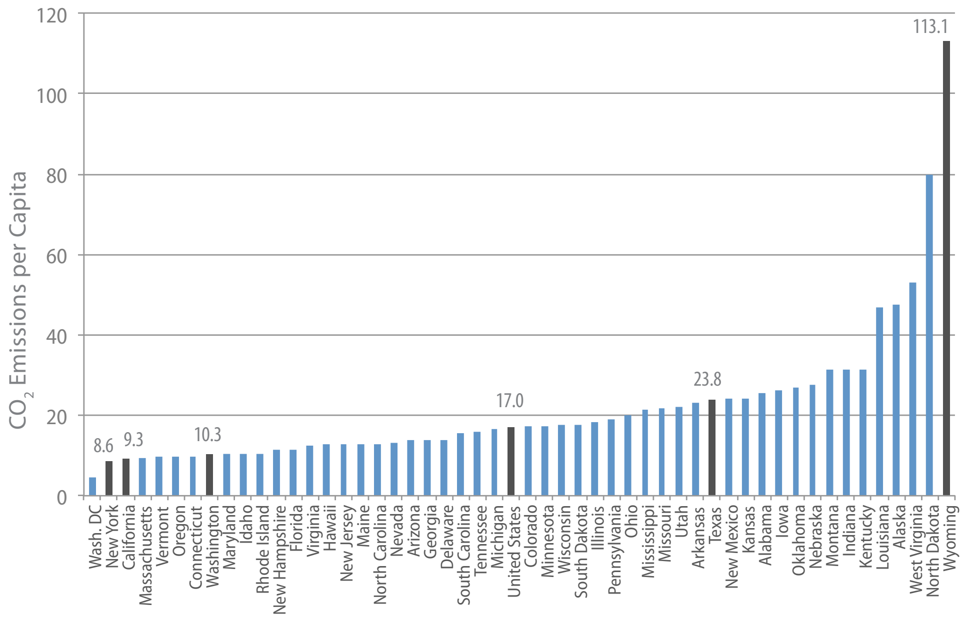
However, working from the wide range of studies on climate change and prospects for stabilization surveyed and synthesized by the Intergovernmental Panel on Climate Change (IPCC), the world's most authoritative body focused on this issue, the emissions reduction goals set out in 2008 in Washington State are not sufficiently ambitious. More specifically, the IPCC provides conservative benchmarks as to what is required to stabilize the average global temperature at no more than 2^0 Celsius (3.6^0 Fahrenheit) above the pre-industrial average. The IPCC presents these benchmarks in terms of ranges and probabilities, but a fair summary of their two most recent assessments—i.e. their *Fourth* and *Fifth Assessment Reports*, published in 2007 and 2014 respectively—is that global CO_2 emissions need to fall by about 40 percent within 20 years, to 20 billion tons per year, and by 80 percent as of 2050, to 7 billion tons.

Given these IPCC standards, we have set as the target for this study that Washington State should reduce its CO_2 emissions by 40 percent as of 2035 relative to its current level. We do not examine in this study prospects for further emissions reductions as of 2050. However, a viable plan to achieve the IPCC's standard of an 80 percent reduction in emissions by 2050 would follow naturally from the intermediate program of emissions reduction that we develop here for 2035.

As of the most recent 2014 data, CO_2 emissions in Washington State were at 73.4 million tons. This is about 4 percent higher than the 1990 figure of 70.9 million tons. Working from this current figure of 73.4 million tons, to achieve a 40 percent reduction in CO_2 emissions would mean that, as of 2035, CO_2 emissions in Washington State would be no more than 44 million tons—i.e. at a level about 20 percent below the goal that the legislature had set in 2008.

In setting out this more ambitious goal for Washington State, it is, at the outset, important to recognize that, at present, Washington is among the "cleanest" of the 50 U.S. states, as measured by CO_2 emissions per capita. We can see this in Figure 1, which shows CO_2 emissions per capita for all 50 states and Washington, DC as of 2014. As we see, CO_2 emissions in Washington State as of 2014 were at 10.3 tons per person. Only six states and Washington, DC have lower per capita emissions levels. The figure for the United States overall is 17.0 tons per person. That is, emissions for Washington State are about 40 percent lower than the U.S. average. The emissions levels for other large states includes New York at 8.6 tons per person, California at 9.3, and Texas at 23.8—i.e. over twice the level for Washington State. Wyoming has the highest state-level emissions, at 113.1 tons per person—11 times higher than Washington State.

FIGURE 1: Carbon Dioxide Emissions Per Capita, All States, 2014



Source: U. S. Energy Information Administration, U.S. Census.

In comparison with other countries, per capita emissions generated in Washington State are roughly 25 percent below the 13.5 figure for Canada. Washington State's per capita emissions are only about 11 percent above the 9.2 figure for Germany, even while Germany is a global leader among rich countries in bringing down its emissions. Emissions are much lower in a country like India, where the figure is 1.6 tons of CO_2 per capita, only 20 percent as high as the Washington State figure. But this is only because India's per capita income is approximately 1/45th the average per capita income in Washington State. We return to this issue below.

Even while recognizing Washington State's relatively positive record to date on CO_2 emissions, it is even more important to understand that the state cannot be satisfied with this status quo. As one metric, Washington's current emission level of 10.3 tons per capita is over four times higher than the 2.4 tons per capita figure that is needed just to reduce global emissions by 40 percent as of 2035. Moreover, as we will discuss, building a clean energy economy in Washington State represents a tremendous opportunity to both support global climate stabilization and expand good job opportunities throughout the state.

2. Sources of Energy and CO_2 Emissions

In this section, we review the sources of energy supply and demand in Washington State, as well as the factors generating CO_2 emissions in the state. This discussion will provide necessary background both for analyzing the achievements in Washington State in effectively stabilizing CO_2 emissions over the past 25 years, as well as for advancing a viable framework to lower emissions much further, to 44 million tons, by 2035.

Table 1 shows Washington State's energy consumption profile both in terms of sources and uses of energy. In this table and throughout the study, we measure all energy sources uniformly in terms of British Thermal Units (BTUs). A BTU represents the amount of thermal energy necessary to raise the temperature of one pound of pure liquid water by one degree Fahrenheit at the temperature at which water has its greatest density (39 degrees Fahrenheit). Burning a wood match to its end generates about 1 BTU of energy. We will present figures on energy production and consumption, as appropriate, in terms of both trillion and quadrillion BTUs, referring to the acronyms T-BTUs and Q-BTUs respectively.

TABLE 1
Washington State Energy Consumption by Sector and Energy Source, 2014
Figures are T-BTUs

	Buildings						
	Residential	Commercial	All Buildings	Industrial	Transportation	TOTAL	% of TOTAL
1. Total	**481.80**	**376.60**	**858.40**	**566.80**	**586.90**	**2,037.80**	**98.7%**
2. % of Total	**23.64%**	**18.48%**	**42.12%**	**27.81%**	**28.80%**	**100.00%**	
3. Petroleum	10.27	11.86	22.12	116.75	577.10	715.98	35.1%
4. Hydro	254.18	210.39	464.57	202.93	-	667.50	32.8%
5. Natural Gas	111.77	81.36	193.12	106.58	9.80	309.51	15.2%
6. Biomass	22.82	4.77	27.60	72.79	-	100.39	4.9%
7. Nuclear	33.40	27.65	61.04	26.67	-	87.71	4.3%
8. Coal	24.82	20.55	45.37	22.52	-	67.89	3.3%
9. Wind	23.24	19.24	42.48	18.56	-	61.03	3.0%
10. Geothermal	0.40	0.80	1.20	-	-	1.20	0.1%
11. Solar	0.90	-	0.90	-	-	0.90	0.0%
12. Net Interstate Flow of Electricity			-			(25.70)	-1.3%
13. Total	**481.80**	**376.60**	**858.40**	**566.80**	**586.90**	**2,037.80**	98.7%
14. % of Total	**23.64%**	**18.48%**	**42.12%**	**27.81%**	**28.80%**	**100.00%**	

Source: U.S. Energy Information Agency (EIA) https://www.eia.gov/state/data.cfm?sid=WA#ConsumptionExpenditures

Note: Electricity use is distributed within each energy source and sector. Electricity figures include losses, distributed by source and sector..

As one metric of how much energy is provided by 1 Q-BTU of energy, as we see in Table 1, total energy consumption in Washington State in 2014 was 2,037.8 trillion BTUs, or, approximately 2.0 Q-BTUs. This means that, roughly, 1 Q-BTU provided all the energy consumed for all purposes in Washington State over a six-month period in 2014.

Moving into the specifics of Table 1, we see in rows 1 and 2 how total energy consumption is divided between the sectors of Washington State's economy. As we see, about 42 percent of all consumption is used to operate buildings, both residential and commercial structures. The remaining 58 percent is mainly distributed in roughly equal shares between transportation and industrial uses. There is also a small amount of electricity generated in other states that is imported into Washington State.

In rows 3 – 12 of Table 1, we see how the state's energy is supplied broken down by energy sources. As we see in row 3, petroleum is the most heavily utilized energy source in Washington State, providing 35 percent of all the state's energy supply. Most of the state's petroleum consumption, not surprisingly, is used for transportation—i.e. 80 percent of total petroleum consumption goes to power cars, buses, trucks, and airplanes in Washington State. Meeting the state's transportation needs in turn accounts for nearly 30 percent of the state's total energy consumption.

The next largest source of energy supply in Washington State is hydro power, which provides nearly 33 percent of the state's total energy supply and nearly 70 percent of its electricity. Of course, all hydro power is produced in the form of electricity, which is then distributed to both the building and industrial sectors in the state. Washington State is unique in relying on hydro power to such a large degree. Other states which rely heavily on hydro for electricity generation are Oregon, with 55 percent of electricity generated by hydro, Maine with 29 percent, Vermont with 20 percent, New York with 19 percent, Tennessee with 14 percent and California with 12 percent.

After hydro, natural gas provides the next largest share of total energy supply to Washington State, at 15.2 percent of total supply. About two-thirds of the natural gas supply in Washington State is used to operate buildings, with the remaining one-third used for industrial purposes.

In combination, petroleum, hydro, and natural gas provide 83 percent of all energy in Washington State. Beyond this, we see in Table 1 that biomass is the state's next largest energy source, at 4.9 percent of total supply. Nuclear energy supply is at roughly the same level as biomass, at 4.3 percent. Significantly, as of 2014, coal has become a negligible source of the state's overall energy supply, at 3.3 percent of total supply.[4] This figure is nearly matched by the 3.0 percent of total supply provided in Washington State by wind energy. This percentage for wind power is also high relative to other U.S. states.

Finally, we see in Table 1 that, as of 2014, geothermal and solar power barely register as energy sources for Washington State, with both sources providing no more than one-tenth of a percent of total supply. Assuming that Washington State's supply of hydro power will remain fixed moving forward, this means that expanding overall energy supply in the state from clean renewable sources will be a formidable challenge. Significant initial progress has already been achieved with respect to wind energy. This progress with expanding wind energy supply should therefore serve as a framework for also advancing clean renewable sources across-the-board in Washington State between now and 2035.

Electricity Supply and Demand

To further clarify the profile of energy consumption in Washington State, we show data in Tables 2 and 3 on the uses and sources of electricity in the state.

Electricity, of course, is unique in that it is an intermediate energy source, relying on several primary sources—primarily hydro and natural gas in Washington State, but also nuclear, biomass, coal and wind—for its generation. It is also unique in that, as Table 2

TABLE 2
Washington State Total Electricity Consumption and Energy Losses in Electricity Generation, 2014

Total Energy Consumed in Generating Electricity	966 T-BTUs 47.4% of state energy consumption
Electricity Consumption as Share of Overall Energy Consumption	314 T-BTUs 15.6% of state energy consumption
Energy Losses as Share of Energy Consumed in Generating Electricity	67.5%

Source: EIA State Energy Data System, "Energy Consumption by Source, 2014," and Table C9, "Electric Power Consumption by Source, 2014"

TABLE 3
Washington Electricity Consumption, 2014
Figures are T-BTUs

	Building	Industrial	Transport	Total
Hydro	151.13	66.03	-	217.16 69.1% of total
Nuclear	19.86	8.68	-	28.53 9.1% of total
Natural Gas	17.64	7.71	-	25.35 8.1% of total
Coal	14.76	6.45	-	21.21 6.7% of total
Wind	13.82	6.04	-	19.86 6.3% of total
Bioenergy	1.56	0.68	-	2.24 0.7% of total
Petroleum	0.04	0.02	-	0.06 0% of total
Solar	-	-	-	-
Geothermal	-	-	-	-
Total	218.80	95.60	-	314.40
% of Total	**69.6%**	**30.4%**	**0.00%**	**100.00%**

Source: See Table 2.

shows, approximately two-thirds of all energy consumed is lost in the conversion process from the primary energy sources to electricity supply, while only one-third is channeled into energy that is consumed. That is why, as we see in Table 2, electricity production requires 966 T-BTUs of Washington's total energy consumption, amounting to fully 47 percent of all energy consumed in the state, while, as an energy source to final consumers in the state's building, transportation and industrial sectors, electricity provides only about 15 percent of the total energy supplied. One evident way to raise energy efficiency, in Washington State and elsewhere, would therefore entail reducing the percentage of energy losses through electricity use.[5]

In terms of electricity demand, we see in Table 3 that the most prevalent use is for the operation of buildings, accounting for about 70 percent of all electricity demand. Industrial processes utilize the remaining 30 percent of all electricity. At present, electricity is not used to a measurable extent at all in transportation. But the share of electricity demand for transportation would rise sharply if the use of electricity-powered cars were to grow through 2035.

Table 3 also shows the primary energy sources used in Washington State to generate electricity. As we see, hydro power is the dominant source of electricity generation in the state, providing, as noted above, nearly 70 percent of total supply. The fact that Washington State is able to rely so heavily on hydro power is a major factor enabling the state's CO_2 emissions levels to be relatively low. Nuclear energy is the next largest source of electric power, at 9.1 percent of total supply. Thus, nearly 80 percent of total electricity generation in Washington comes from emissions-free sources. But as we discuss below, Washington State cannot assume that it will be able to expand its hydro infrastructure significantly beyond its current level. It will also not be desirable to expand nuclear capacity, due to issues of public safety.[6] Further reductions in emissions will therefore have to be achieved primarily through gains in energy efficiency as well as expanded production of other clean renewable energy sources, especially wind, solar, and geothermal power.

Another major factor in keeping CO_2 emissions in Washington State relatively low is that coal is only a modest source for electricity generation in the state, at 6.7 percent of supply. This stands in sharp contrast with the U.S. overall, in which coal still provides about 33 percent of the primary energy for electricity generation.

CO_2 Emissions Sources for 2014 and 2035

Table 4 shows how Washington State generated 73.4 million tons of CO_2 as of 2014 (with energy consumption figures now expressed in this table in terms of Q-BTUs). In column 1, we see again that petroleum is the largest source of fossil fuel energy supply in the state, at 0.71 Q-BTUs. Column 2 shows that burning petroleum in Washington State generated 49.2 million tons of CO_2 emissions, which amounts to a rate of 69.3 million tons of CO_2 per Q-BTU of energy, as shown in column 3. Natural gas use in Washington State is lower than petroleum, at 0.32 Q-BTUs. Natural gas is also a modestly cleaner energy source than petroleum, generating 53.2 million tons of CO_2 per Q-BTU of energy. Thus, overall emissions from natural gas in Washington State in 2014 was 17 million tons. Finally, as we see, coal is the dirtiest fossil fuel energy source, generating in Washington State 90.0 million tons of CO_2 per Q-BTU of energy. But because coal is used so sparingly in Washington, the level of emissions generated by combusting coal is correspondingly modest, at around 7 million tons.

TABLE 4
Sources of CO_2 Emissions for Washington State: *2014 Actuals and 2035 Projections*

	2014 Actuals			2035 Projections	
	1) 2014 Energy Consumption *(in Q-BTUs)*	**2) 2014 CO_2 emissions** *(in millions of tons)*	**3) CO_2 emissions per Q-BTU** *(= column 2/ column 1)*	**4) 2035 Energy Consumption** *(in Q-BTUs)*	**5) 2035 CO_2 emissions** *(in millions of tons; = column 3 x column 4)*
Petroleum	0.71	49.2	69.3	0.45	31.2
Natural Gas	0.32	17.0	53.2	0.22	11.7
Coal	0.08	7.2	90.0	0	0
Totals	**1.11 Q-BTUs of energy from fossil fuels**	**73.4**	**66.0 weighted average of emissions per Q-BTU**	**0.67**	**42.9**

Sources: EIA: http://www.eia.gov/environment/emissions/state/; https://www.eia.gov/state/?sid=WA#tabs-1
Note: EIA sources do not assign emissions levels for the 0.100 Q-BTU level of Washington energy consumption for biomass.

We can extrapolate from these figures that driving down overall emissions in Washington State from 73 to 44 million tons by 2035 will require cuts in both natural gas and petroleum consumption in the range of 40 percent, while coal consumption is phased out entirely. Indeed, we can be specific here as to the maximum levels at which Washington State can combust petroleum and natural gas if it is going to succeed in bringing down annual CO_2 emissions to 44 million tons by 2035.

As a realistic first approximation, let us assume that petroleum and natural gas will continue to be consumed in Washington State at roughly their current proportions as of 2035. Petroleum will continue to be needed primarily as a liquid fuel for transportation while natural gas will be used primarily to generate electricity. Under this assumption, total petroleum consumption will need to fall from 0.71 to 0.45 Q-BTUs by 2035, and natural gas will need to decline from 0.32 to 0.22. As we see in Table 4, at this level of natural gas and petroleum consumption, total CO_2 emissions in Washington State as of 2035 would amount to about 43 million tons. Columns 4 and 5 of Table 4 present the calculations through which we derive this result.

3. DETERMINANTS OF EMISSIONS LEVELS

What explains the favorable performance to date of Washington State, relative to most other U.S. states and the country overall, in terms of its current level of CO_2 emissions per capita? To obtain a clearer understanding of the factors at play, it will be useful to decompose the emissions per capita ratio into three component parts. This yields three ratios, each of which provides a simple measure of one major aspect of the climate change challenge, for Washington State, the rest of the U.S. states and elsewhere. That is, CO_2 emissions per capita can be expressed as follows:

Emissions/population = (GDP/population) x (Q-BTUs/GDP) x (emissions/Q-BTU).

These three ratios provide measures of the following in each state, regional, or country setting:

1. *Level of development*: Measured by GDP per capita (i.e. GDP/population);
2. *Energy intensity*: Measured by Q-BTUs/GDP;
3. *Emissions intensity*: Measured by emissions/Q-BTU.

In Table 5, we show these ratios for Washington State, as well as, for comparison purposes, some other U.S. states. Some significant observations emerge through considering these ratios. The first, most generally, is that there are three distinct ways in which any country, state or region can achieve a low figure for per capita emissions. The first is for the relevant economic area—the state, country or region—to operate at a low level of economic

TABLE 5
Determinants of per capita CO_2 emissions levels in various states, 2014:
Level of development, energy intensity and emissions intensity

CO_2 Emissions/population = (GDP/population) x (Q-BTUs/GDP trillions) x (Emissions/Q-BTU)

	CO_2 emissions/ population	GDP/population (2015$)	Energy intensity ratio: Q-BTUs/trillion dollars GDP	Emissions intensity ratio: CO_2 emissions/Q-BTU
Washington	10.3 tons	$61,625	4.7 Q-BTUs	36.3 million tons
U.S.	17.0 tons	$54,181	5.7 Q-BTUs	55.0 million tons
New York	8.6 tons	$69,341	2.7 Q-BTUs	45.4 million tons
California	9.3 tons	$60,945	3.2 Q-BTUs	47.0 million tons
Texas	23.8 tons	$58,798	8.1 Q-BTUs	49.8 million tons
West Virginia	53.0 tons	$39,870	10.2 Q-BTUs	130.2 million tons
Wyoming	113.1 tons	$67,850	13.5 Q-BTUs	123.2 million tons

Source: EIA, U.S. Census, BEA.
Note: Most recent data on CO_2 emissions is for 2014.

activity—i.e. at a low GDP level. Thus, as mentioned above, the Indian economy operates with a very low figure for emissions per capita of 1.6. This is entirely due to the fact that per capita income in India is also still extremely low, at about $1,600.

By contrast, per capita income in Washington State as of 2014 was nearly $62,000. This sets Washington as having the 12th highest figure for per capita income among the 50 U.S. states. It is therefore clear from these figures that Washington is achieving its low per capita emissions figure not because the state's economy operates at a low level of GDP, but rather, *despite the fact that it operates at a relatively high GDP level.*

With respect to this relatively high average income level, Washington State could, hypothetically, reduce its per capita GDP figure by 40 percent, to around $37,000, while maintaining its existing energy infrastructure fully intact. But this is obviously not a program for expanding well-being while also reducing emissions. To the contrary, the aim of a statewide clean energy project, again, is to achieve the 2035 emissions reduction level of 44 million tons of CO_2 while the state's economy grows at a healthy rate and job opportunities expand.

In fact, the two factors that are responsible for Washington State's relatively low level of per capita emissions at present are:

1. *Energy efficiency*: The state operates at an energy efficiency level that is about 20 percent below the national average, with an energy intensity ratio of 4.7 Q-BTUs per $1 trillion in GDP versus the U.S. national average of 5.7. But Washington also utilizes energy far less efficiently than either New York, whose energy intensity ratio is 2.7 or California, with a 3.2 energy intensity ratio. New York's high efficiency level is due primarily to the intensive use in the state of both rail transit and apartment-based residential dwellings, which would be difficult for Washington to replicate. But California has achieved its high efficiency level largely through high automobile efficiency standards. One of the main policy initiatives in Washington State is to replicate the California high auto efficiency standard.
2. *Clean-burning energy*: The state's emissions intensity ratio of 36.3 million tons per Q-BTU of energy is 34 percent below the U.S. average of 55.0. The two factors here are the heavy reliance in Washington State on hydro power, which generates electricity emissions-free; and the low reliance on coal, which generates the most emissions among all energy sources. But there are virtually no further improvements available with this low-emissions energy source. Thus, further gains here will need to be achieved through expanding other clean renewable energy sources, i.e. wind, solar, and geothermal.

In addition to these factors explaining Washington State's level of per capita emissions at present, it is also important to recognize that Washington State has achieved gains over time in what is termed "decoupling"—i.e. in reducing emissions per capita from 1990 to the present even while both average incomes and population in the state grew. We can see the factors driving the gains in emissions reduction in Table 6. As the table shows, the gains were achieved entirely as a result of the state's energy intensity ratio falling from 10.5 to 4.7 Q-BTUs per trillion dollars of GDP. That is a nearly 60 percent improvement in energy efficiency in Washington State over a 24-year period.

This gain in energy efficiency, in turn, was almost entirely due to cutting energy intensity ratios in both the state's commercial building operations and in industrial energy consumption. The gains with commercial buildings resulted from the implementation of strong

TABLE 6
Determinants of Washington State per capita CO_2 emissions, 1990 and 2014:
Level of development, energy intensity and energy mix

Washington	CO_2 emissions/ population	GDP/population (2015$)	Energy intensity ratio: Q-BTUs/trillion dollars GDP	Emissions intensity ratio: CO_2 emissions/Q-BTU
1990	14.5 tons	$39,861	10.47 Q-BTUs	34.6 million tons
2014	10.3 tons	$61,625	4.7 Q-BTUs	36.3 million tons

Source: EIA, U.S. Census, BEA.

statewide building codes, requiring high efficiency standards in this sector. With respect to industrial efficiency, the gains resulted primarily from a statewide shift away from energy-intensive industries such as aluminum and the corresponding relative growth of high value-added and less energy-intensive industries, in particular information technology and biotech.[7]

4. PROSPECTS FOR ENERGY EFFICIENCY GAINS

As we saw in Table 1, buildings account for a bit more than 40 percent of all energy consumption in Washington State, while industry and transportation, respectively, account for slightly less than 30 percent each. Achieving large-scale gains in efficiency will therefore need to address all three areas of statewide energy consumption. One careful recent study of the potential gains available in the U.S. economy through energy efficiency investments is the 2010 survey study by the National Academy of Sciences (NAS), called *Real Prospects for Energy Efficiency in the United States*. This study provides detailed descriptions of the main research findings in all major areas of energy consumption in the U.S. economy. For our purposes here, we will want to draw on the main conclusions of the study as well as more recent relevant work regarding the gains that can be achieved with buildings and automobiles.[8] We briefly consider these in turn.

Buildings

The NAS study provides extensive evidence showing that energy consumption in both commercial and residential buildings could fall by approximately 30 percent or more below a reference case for 2030 set by the U.S. Department of Energy. These gains in the range of 30 percent are available through a wide range of "low cost" investments in energy efficiency. By "low cost" investments, we refer to the NAS measure of the "cost of conserved energy." Low-cost investments are those in which the costs of conservation are below the market price of energy from the relevant energy source. For buildings, the relevant energy threshold is the price of delivered electricity or natural gas. Thus, in considering the use of electricity in commercial buildings, the NAS finds that in all the main areas of consumption—including lighting, space cooling, office equipment, ventilation, refrigeration, space heating and other uses of the buildings' thermal shells—savings are available relative to the reference case in the range of 35 percent. The NAS estimated the costs of these savings as being 2.8 cents per kilowatt hour as of the study's 2010 publication date.

Because of its abundant hydro power, Washington State provides the lowest average retail price for electricity in the U.S., at 7.4 cents per kilowatt hour as of 2015.[9] This compares with the average costs of purchasing electricity throughout the U.S. of 10.6 cents in 2015.[10] But even this low average electricity price is nearly three times higher than the costs of achieving energy savings through energy efficiency investments in buildings. The NAS estimates the gross costs of achieving these energy savings—i.e. costs prior to factoring in the energy savings available—at about $28 billion per Q-BTU of savings.

The NAS does also analyze the additional potential savings through the use of newer technologies. The study notes that:

> The conservation supply curves …do not take into account a number of newer technologies and whole-building design approaches. These technologies and approaches add to the energy-savings potential identified in the conservation supply curves. Thus, the panel judges that these supply curves represent the lower estimate of energy-saving potential (2010, p. 80).

The NAS study highlights seven areas in which advanced technologies are "the most promising for further improving the energy efficiency of buildings." These include solid state lighting, advanced cooling systems, lower energy consumption in home electronics, reduced consumption in servers and data centers, advanced window technology, and better construction methods for both home and commercial-buildings.

In advancing beyond the lowest cost opportunities for efficiency gains, we therefore have to ask whether we can achieve these further gains at the same average cost of $28 billion per Q-BTU level. In fact, there are valid reasons to assume that costs could actually come down as energy efficiency investments are advanced at a large scale in Washington State. These include the following considerations:

- **The average cost of gaining a given amount of efficiency in Washington State buildings remains well within the market price of electricity**. Even if we allow that the average costs of achieving efficiency gains in Washington State's buildings are, at present, significantly higher than the 2010 average figure cited by the NAS study of 2.8 cents per kilowatt hour, the current average costs are still certainly well below the current average price of electricity in the state of 7.4 cents.
- **The returns on investment in building efficiency are high, but the market has been thwarted because of underdeveloped market and financing infrastructures**. The systems of financing and risk-sharing that enable businesses and homeowners to capture the benefits of high returns without having to carry the full burden of initial financial risk remains immature. Developments in these areas should come rapidly once the initial set of business models, market structures, and financial innovations take hold.
- **The absolute level of efficiency gains attainable in buildings is very high, as evidenced by the growing number of recently constructed carbon neutral buildings**. Of course, the costs of getting buildings to the point of carbon neutrality are also high at this point, meaning that before reaching carbon neutrality, we begin to approach a point of diminishing returns on investments—i.e. rising costs needed to achieve a given gain in efficiency. At the same time, as the market for efficiency investments expands, the costs of the best upcoming technologies begin to fall. As the NAS study notes, this has certainly been true with LED lighting. Similar opportunities are emerging in the other six areas mentioned above—cooling, home electronics, servers and data centers, windows, and construction of both homes and commercial buildings.

Despite all of these factors suggesting falling costs as the level of investment expands, there have also been many instances of over-optimism in assessing the prospects for raising efficiency standards in buildings. Thus, while the engineering evidence consistently finds, for example, that investments in building efficiencies will have rapid payoffs, it is still necessary to obtain financing for projects to proceed. Another issue is the hassle factor involved in undertaking such projects. Considering home-weatherization efficiency programs specifically, Allcott and Greenstone write that "Weatherization takes time, and for most people it is not highly enjoyable: the process requires one or sometimes two home energy audits, a contractor appointment to carry out the work and sometimes additional follow-up visits and paperwork," (2012, p. 16). Such matters can create serious difficulties for individual homeowners in particular.

The implication that follows is not that the engineering level of analysis is wrong, but rather that both public policy and private initiatives are needed to tackle the financial issues and the hassle factors that are involved in building efficiency projects. Given these considerations, and the fact that we are assuming that the gains in efficiency will need to occur rapidly between 2021 – 2035, it will be prudent to assume that costs will be higher than the average estimated by the NAS. For our purposes, we therefore assume the costs of achieving gains in building efficiency to be in the range of $35 billion per Q-BTU, i.e. 25 percent higher than the NAS estimate.

Transportation

For the purposes of our discussion, we focus here on the case for achieving gains in automobile efficiency as of 2035, since it is the state's dominant transportation mode. For example, about 90 percent of all workers in the state commute to their jobs with cars, trucks, or vans.[11]

The starting point for considering efficiency gains in auto transit is the agreement reached in 2011 between the Obama Administration and 13 major auto manufacturers to raise the miles per gallon (mpg) standard for new U.S. cars to 54.5 mpg as of 2025. Pollin et al. analyzed the impact of this measure in detail in the 2014 study *Green Growth*. The analysis in Green Growth also drew largely on the 2010 NAS study on efficiency prospects for the overall U.S. economy. The main finding on this issue in *Green Growth* was that achieving a 30 percent reduction in emissions from the U.S. auto fleet by 2030 is attainable and at a cost that will be comparable to the costs for achieving efficiency gains in buildings.

More specifically, Pollin et al. found that raising the 2025 mandated efficiency level of new cars from its previous level of 35.9 mpg to 54.5 mpg will mean that the average car on the road as of 2030 will operate at an efficiency level of 42.4 mpg. This efficiency level is roughly 15 percent lower than the average gasoline-powered Toyota Prius sold in U.S. markets in 2016, which are at approximately a 50 mpg level of efficiency.[12]

This average figure for 2030 will, of course, include not only cars produced in 2025 and thereafter—all of which will be at least at the 54.5 mpg level by mandate—but earlier model cars as well that were not subject to this mandate and thereby operate much less efficiently. We also estimated that, had the U.S. continued to maintain the earlier mandate for 2025 of 35.9 mpg, the overall fleet as of 2030 would be at an average efficiency level of 28.7 mpg. The average efficiency gain from 28.7 to 42.4 mpg is an improvement of roughly 48 percent. The NAS estimated the average cost increase for achieving this higher level of efficiency at about 25 percent above the retail price of standard gasoline engine cars. The average car owner will then also save about $1,000 per year in gasoline purchases.

In March 2017, the Trump Administration announced that it was reviewing the Obama fuel efficiency standards. The expectation is that Trump will attempt to implement a significant relaxation of these standards at the federal level, though the review process itself is likely to take a year or longer.[13] In any case, some states are already operating with high fuel efficiency standards. This includes Washington State, which under the 2005 Clean Car Law, requires new vehicles that are used or sold in the state must follow the standard set in California. The California standard, in turn, is consistent with those set by the Obama administration. It is possible that the Trump Administration would attempt to challenge the authority of states to maintain standards above those set by the federal government. But any such efforts are likely to entail a protracted legal process. Washington State can therefore proceed, along with California, Oregon and other states, in maintaining and defending its efficiency standard against any forthcoming Trump Administration efforts to weaken them.[14]

Washington State should also commit to expanding the availability of public transportation throughout the state. This will also help support transportation efficiency standards and to make low-cost transportation options widely accessible. As we discuss further below, we assume that state-level investments to expand public transportation will be comparable to the financial incentives provided to raise the state's auto efficiency standards. We also conclude that the costs of achieving efficiency gains throughout the state's various transportation sectors are likely to be in the same range as those for building efficiency investments, i.e. at about $35 billion per Q-BTU of energy savings.

Industry

As discussed above, Washington State has advanced substantial efficiency gains in its industrial sector between 1990 – 2014 through the structural shift in the state's composition of industrial activities, away from energy-intensive activities, such as aluminum production to high value-added activities with relatively low energy requirements, especially information technology and biotechnology. However, it is not likely that further efficiency gains are attainable through comparable structural gains in the state's industrial activity, nor do we assume that further such structural changes are desirable. As discussed below, we rather assume that the state's existing level of production in energy-intensive activities remains intact through 2035.

Achieving further efficiency gains in the state's industrial sector will therefore primarily entail changes in production methods, as opposed to relying on further shifts in industrial composition toward low-energy intensity industries. The major additional energy-efficiency gains in industrial production should therefore result from two types of changes in production methods:

1. **Crosscutting investments.** These are investments that are applicable in a wide range of industrial settings. The most important example is combined heat and power, or CHP, systems. CHP systems in industry are capable of dramatically improving energy efficiency through using waste process heat to generate a productive low-cost energy source.
2. **Industry-specific investments.** This includes a wide range of specific energy-saving measures and process improvements, especially in the high-energy intensity activities. In Washington State, these would include the pulp and paper industry as well as aluminum production. For the pulp and paper industry, the National Academy of Sciences study describes a range of areas in which major efficiency gains are available utilizing only proven technologies and processes. These include the papermaking process, steam efficiencies, fiber substitution, and pulping. Overall, the NAS study found that, utilizing only existing technologies, efficiency gains in industry in the range of 25 percent are attainable at relatively low costs.[15]

Overall, the NAS finds that the upfront costs for achieving efficiency gains in industry should be comparable to those in buildings and transportation, i.e. within the range of $30 billion per Q-BTU of energy savings. For the purposes of our discussion, we will assume here as well a higher average cost figure of $35 billion per Q-BTU of energy savings.

5. PROSPECTS FOR CLEAN RENEWABLES

Assuming that, through aggressive energy efficiency investments, Washington State is able to bring down overall statewide energy consumption dramatically, it will still be necessary to greatly expand the state's reliance on clean renewable energy sources in order for total CO_2 emissions to fall to 44 million tons by 2035. We saw in Table 4 that, to bring total CO_2 emissions to no more than 44 million tons, the overall consumption of natural gas and petroleum can be no more than 0.67 Q-BTUs by 2035. This also assumes that coal consumption in Washington State has ended altogether and that nuclear energy supply remains at its current level.

At present, virtually all of the state's clean renewable supply comes from hydro power. But we are not assuming any significant increase in hydro energy production through 2035. We also are assuming that clean bioenergy sources—primarily cellulosic biofuels—will remain negligible in Washington State.[16] This therefore means that the full expansion of clean renewable energy as of 2035 will need to be provided through expanding the production of wind, solar, and geothermal power.

What would be the costs associated with this expansion of clean renewable energy supply? We need to consider any such costs from two distinct perspectives. The first is what the cost increases would likely be for energy consumers, as they substitute wind, solar, or geothermal energy for the existing fossil fuel energy sources. The second is the costs of building the new generating capacity for wind, solar, and geothermal power.

Costs to Consumers

To consider costs to consumers, we refer to the U.S. Energy Department's calculations as the "levelized costs" of supplying electricity through alternative energy sources. The Energy Information Agency (EIA), an office within the Energy Department, describes levelized cost as representing:

> The per-kilowatt hour cost (in real dollars) of building and operating a generating plant over the assumed financial life and duty cycle. Key inputs to calculating levelized costs include overnight capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs and an assumed utilization rate for each plant type.[17]

In short, levelized costs takes account of *all costs* of producing and delivering a kilowatt of electricity to a final consumer. The cost calculations begin with the upfront capital expenditures needed to build the generating capacity, continues through to the transmission and delivery of electricity, and includes the costs of energy that is lost during the electricity-generation process.

In Table 7, we present details on average levelized cost figures for four major clean renewable energy sources—hydro, onshore wind, geothermal and photovoltaic solar energy. The figures come directly from the EIA. In panel 7A, we present these average cost figures in the United States, measured in dollars per megawatt hours of electricity. In panel 7B, we present the same data, but expressed now in terms of billions of dollars per Q-BTU of electricity supplied. We show figures on total average levelized costs for these four clean renewable energy sources, as well as the six components comprising these overall average costs—i.e. capital costs, fixed operations and maintenance, variable operations and maintenance, transmission, capacity utilization rates, and tax credits, as they apply. Focusing now on overall costs in dollars per megawatt hour, we see that, for operations entering service in 2022, the average costs per megawatt hour are $41.90 for geothermal, $56.90 for onshore wind, $66.30 for solar, and $67.80 for hydro.

TABLE 7A
Estimated Average Levelized Costs of Electricity from Clean Renewable Energy Sources
Plants Entering Service in 2022, simple averages for regional values

In dollars per megawatt hour

	Hydro	Onshore Wind	Geothermal	Solar photovoltaic
Levelized Capital costs	$57.5	$48.5	$30.9	$70.7
Fixed Operations and Maintenance	$3.6	$13.2	$12.6	$9.9
Variable Operations and Maintenance	$4.9	0	0	0
Transmission investment	$1.9	$2.8	$1.4	$4.1
Capacity factor	60%	41%	90%	25%
Total System LCOE	$67.8	$64.5	$45.0	$84.7
Levelized Tax Credit	---	-$7.6	-$3.1	-$18.4
Total LCOE, including Tax Credit	$67.8	$56.9	$41.9	$66.3

Source: U.S. Energy Information Agency, "Levelized Cost and Levelized Avoided Cost of New Generation Resources," in the Annual Energy Outlook 2016, http://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

TABLE 7B
Estimated Average Levelized Costs of Electricity from Clean Renewable Energy Sources
Plants Entering Service in 2022, simple averages for regional values

In billions of dollars per Q-BTU

	Hydro	Onshore Wind	Geothermal	Solar photovoltaic
Levelized Capital costs	$196.2 billion	$165.5 billion	$105.4 billion	$241.2 billion
Fixed Operations and Maintenance	$12.3 billion	$45.0 billion	$43.0 billion	$33.8 billion
Variable Operations and maintenance	$16.7 billion	0	0	0
Transmission investment	$6.5 billion	$9.6 million	$4.8 billion	$14.0 billion
Capacity factor	60%	41%	90%	25%
Total System LCOE	$231.3 billion	$220.1 billion	$153.5 billion	$289.0 billion
Levelized Tax Credit	---	-$25.9 billion	-$10.6 billion	-$62.8 billion
Total LCOE, including Tax Credit	$231.3 billion	$194.2 billion	$143.2 billion	$226.2 billion

Source: U.S. Energy Information Agency, "Levelized Cost and Levelized Avoided Cost of New Generation Resources," in the Annual Energy Outlook 2016, http://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

Note: Cost Conversion factor is $1 per mwh = $3.412 billion per Q-BTU.

In Table 8, we now show, for comparison purposes, total levelized cost figures for non-renewable sources of electricity, including: 1) coal, with carbon capture and sequestration (CCS) technology; 2) natural gas utilizing conventional technology 3) natural gas with CCS; and 4) nuclear energy. CCS encompasses a number of specific technologies that capture CO_2 from point sources, such as power plants and other industrial facilities. The captured CO_2 is then transported, usually through pipelines, and stored indefinitely in subsurface geological formations.[18]

Column 1 of Table 8 reports the overall average levelized cost figures for these non-renewable sources. These figures range between $58.10 using conventional natural gas, $84.80 with natural gas and CCS technology, $102.80 with nuclear energy, and $139.50 with coal produced with CCS technology.

In columns 3 – 5 of Table 8, we then show the cost figures for these four non-renewable energy sources relative to onshore wind, solar PV and geothermal energy. As we see, advanced coal with CCS technology ranges between roughly 110 – 233 percent more than the three clean renewable sources. Natural gas produced conventionally is about 12 percent less than solar PV, but 2 percent more than onshore wind and 39 percent more than geothermal. When natural gas is produced using CCS technology, it becomes 28 percent more expensive than solar PV, 49 percent more than wind, and 102 percent more than geothermal. Finally, nuclear energy ranges between 55 percent more than solar PV, 81 percent more than onshore wind, and 145 percent more than geothermal energy.

We emphasize that these cost figures from the EIA are simple averages. They do not show differences in costs due to regional or seasonally-specific factors. In particular, solar energy costs will vary significantly by region and season. Moreover, both wind and solar energy are intermittent sources—i.e. they only generate energy, respectively, when the sun is shining or the wind is blowing. Of course, these factors will need to be fully accounted for when clean renewable energy systems are designed to provide a major share of an economy's overall energy load.

TABLE 8
Average Levelized Costs of Electricity Generated with Clean Renewables versus Fossil Fuels and Nuclear Energy

	Average Total System Levelized Costs				
	1) In dollars per megawatt hour	2) In billions of dollars per Q-BTU	3) Average costs relative to onshore wind	4) Average costs relative to solar PV	5) Average costs relative to geothermal
Coal: *Advanced with carbon capture and sequestration*	$139.5	$40.9 billion	+145.2%	+110.4%	+232.9%
Natural Gas:					
Conventional	$58.1	$17.0 billion	+2.1%	-12.4%	+38.7%
with carbon capture and sequestration	$84.8	$24.5 billion	+49.0%	+27.9%	+102.4%
Nuclear	$102.8	$30.1 billion	+80.7%	+55.0%	+145.3%

Source: U.S. Energy Information Agency, "Levelized Cost and Levelized Avoided Cost of New Generation Resources," in the Annual Energy Outlook 2016, http://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

Note: Cost Conversion factor is $1 per mwh = $3.412 billion per Q-BTU.

Keeping all such considerations in mind, we can still roughly conclude from these figures that, for the most part, clean renewable energy sources are rapidly emerging into a position at which they can produce electricity at comparable or lower costs than non-renewable sources. As such, assuming that wind, solar and geothermal energy production can be scaled up to meet demand in Washington State by 2035, then the costs to the state's consumers of purchasing this energy should not be significantly different from what these consumers would have paid for non-renewable energy. Indeed, overall, the costs to consumers of purchasing electricity from clean renewable sources, including hydro as well as wind, solar, and geothermal power, are likely to be lower than what they would be from either coal or natural gas with CCS technology or nuclear power.

Costs of Expanding Renewable Capacity

As we can see in Table 7, by far the largest share of overall costs in generating electricity from renewable sources are capital costs—i.e. the costs of producing new productive equipment, as opposed to the costs of operating that productive equipment once it has been built and is generating energy. The figures in Table 7 show that, once we account for the federal tax credit for renewable energy investments, the levelized capital costs amount to 85 percent of overall costs for onshore wind, 74 percent for geothermal, and 106 percent for solar PV.

Still, these figures are average levelized costs of producing a megawatt or Q-BTU of electricity once the necessary capital equipment is installed and operating. But it is also important to estimate these capital costs as a lump sum—i.e. how much investors need to spend *upfront* to put this capital equipment into place and in running order.

We produce estimates of these lump sum capital costs in Table 9. Specifically, these figures represent the present values of total lump-sum capital expenditures needed to produce one Q-BTU of electricity from onshore wind, solar PV, and geothermal energy.[19] As we see, the average lump-sum costs range from $146 billion per Q-BTU for geothermal, $188 billion for onshore wind, and $215 billion for solar.

If we assume that, roughly speaking, new clean renewable productive capacity will consist of 45 percent respectively from wind and solar PV technologies, and 10 percent from geothermal energy, this would place the average costs of producing one Q-BTU of overall renewable energy equipment at about $200 billion. As we will see below, this average investment figure will be useful in calculating the overall costs of achieving the goal of bringing Washington State's CO_2 emissions down to 44 million tons by 2035, and what the impact will be of these investments on employment creation.

TABLE 9

Capital Expenditure Costs for Building Renewable Electricity Productive Equipment

Present Values of Total Lump-Sum Capital Costs per Q-BTU of Electricity

Wind	$188 billion
Solar PV	$215 billion
Geothermal	$146 billion
Average costs *assuming investments are 45% wind; 45% solar; and 10% geothermal*	$198 billion

Sources: Table 7 for levelized capital costs per Q-BTU for alternative energy sources. See Pollin et al. (2014) pp. 136 – 37 for methodology in converting levelized costs per Q-BTU into lump-sum capital costs.

6. CLEAN ENERGY INVESTMENT LEVELS AND EMISSIONS REDUCTIONS

The clean energy investment initiative being proposed in this study is designed to achieve, again, two interrelated fundamental goals. The first is to bring total CO_2 emissions in Washington State down to 44 million tons by 2035, from its 2014 level of 73.4 million tons. The second is to advance this climate stabilization program while the Washington State economy grows at an adequate rate between now and 2035, so that existing jobs are protected, job opportunities expand, and average well-being rises throughout the state. In this section of the study, we describe the clean energy investment levels that will be needed to bring together these two goals.

To explore the prospects for achieving the 2035 emissions reduction goal within the context of a growing Washington State economy, we must, unavoidably, work with some assumptions as to the state's real economic growth trajectory from now until 2035. Thus, we assume that the Washington State economy will grow in real (i.e. inflation-adjusted) terms between now and 2035 at an average rate of 2.0 percent per year. This is the average annual growth rate that Washington State has experienced between 1990 – 2014. We do not have any basis for assuming that this growth trajectory should change significantly through 2035.

In Table 10, we first report on Washington State's real GDP as of 2014 and the projected level in 2035, assuming the economy's average real growth rate is maintained at 2.0 percent through 2035. We see that, under this growth assumption, Washington State's real GDP will be approximately $643 billion, as opposed to the 2014 figure of $424 billion. Over the period 2014 – 2035, the midpoint GDP would be $534 billion, assuming, again, that average GDP growth is sustained at 2.0 percent per year between 2014 – 2035.

Within this framework, we can then project an energy and CO_2 emissions profile for Washington State for 2035. We consider two distinct scenarios. For the first 2035 scenario, we assume that the state's energy infrastructure as of 2014 remains basically intact through 2035. We see the results of this scenario in Table 11. Specifically, in column 1 of Table 11, we show the actual breakdown of energy consumption and emissions as of 2014. In column 2, we then present projected figures, assuming Washington State's economy grows at an average annual rate of 2.0 percent through 2035 and the state's energy infrastructure remains basically intact. We term this the "steady state" energy infrastructure trajectory for Washington State.

TABLE 10
Washington State GDP Levels, 2014 Actual and 2035 Projected

2014 GDP	$424 billion
Projected average GDP growth rate through 2035	2.0 percent
Projected 2035 GDP	$643 billion
Projected midpoint GDP between 2014 – 2035	$534 billion

Source: BEA and authors' projections.

TABLE 11
Washington State Energy Consumption and Emissions: 2014 Actuals and Alternative 2035 Projections

	1) 2014 Actuals	2) 2035 *With Approximate Steady State Energy Infrastructure*	3) 2035 *Through Clean Energy Investment Program*
1) Real GDP	$424 billion	$643 billion *(with 2.0% average growth)*	$643 billion *(with 2.0% average growth)*
2) Total Energy Consumption	2.0 Q-BTUs	3.0 Q-BTUs	1.8 Q-BTUs
3) Energy Intensity Ratio (Q-BTUs/$1 trillion GDP)	4.7	4.7	2.8
Energy Mix			
Non-Renewables and Bioenergy			
4) Petroleum	0.716	1.160	0.480
5) Natural Gas	0.310	0.667	0.200
6) Nuclear	0.088	0.088	0.088
7) Coal	0.068	0.068	0
8) Biomass	0.100	0.155	0
Clean Renewables			
9) Hydro	0.667	0.667	0.667
10) Wind, Solar, Geothermal	0.063	0.188	0.350
Emissions			
11) Total CO2 emissions	73.4 million tons	122 million tons	44 million tons
12) Emissions Intensity Ratio (CO2 emissions/Q-BTUs)	36.3	40.7	24.4
13) CO2 emissions per capita (with 2035 population = 8.8 million)	10.3	13.9	5.0

Sources: See Tables 1, 6 and 10, and authors' projections.

Thus, we see in row 3, columns 1 and 2, that Washington State's energy intensity ratio remains constant between 2014 and 2035, at 4.7 Q-BTUs per $1 trillion in GDP. The state's emissions intensity ratio does rise, as shown in row 12, columns 1 and 2, from 36.3 to 40.7 million tons in CO_2 emissions per Q-BTU of energy. This occurs because we assume that the state's supply of both hydro and nuclear energy remains fixed through 2035, with the increased demand for electricity-generating capacity being met by an expansion in natural gas. As such, natural gas consumption more than doubles in this steady state scenario, from 0.31 to 0.67 Q-BTUs. Petroleum consumption also rises, from 0.716 to 1.160 Q-BTUs, to meet the rising demand for liquid fuels in transportation. We see the impact of this economic growth pattern on statewide CO_2 emissions in row 11 of Table 11. That is, total CO_2 emissions increases from 73.4 to 122 million tons, an increase of 66 percent.

In column 3 of Table 11, we then show the impact on the energy mix and emissions levels of a clean energy program focused on bringing down CO_2 emissions to 44 million tons by 2035. The first component of this program is energy efficiency investments. As noted in section 4, we assume energy efficiency investments will span across the building, transportation and industrial sectors of the Washington State economy.

As we show in row 2 of Table 11, the efficiency investments result in reducing the state's overall energy consumption from 3.0 Q-BTUs under the approximate steady state energy infrastructure to 1.8 Q-BTUs under the clean energy investment program scenario. This is a reduction of 1.2 Q-BTUs. Following our discussion in section 4, we assume that the costs of achieving 1 Q-BTU of efficiency gains will be $35 billion. As such, the level of investment needed to reduce consumption by 1.2 Q-BTUs will be $42 billion. Spread out over 15 years, this level of efficiency investments will average $2.8 billion per year.

We then need to consider the energy mix that will be necessary to allow for 1.8 Q-BTUs of consumption while still maintaining emissions below 44 million tons. As we have seen in Table 4, in order to bring overall CO_2 emissions in Washington State down to 44 million tons by 2035, petroleum consumption will need to be in the range of 0.45 Q-BTUs as of 2035 and natural gas will need to be no more than 0.22 Q-BTUs. In column 3 of Table 11, we show petroleum consumption at 0.48 Q-BTUs and natural gas at 0.20, totaling to 0.68 Q-BTUs. We assume coal consumption has been eliminated.

This then entails that 1.12 Q-BTUs of energy will need to be provided by alternative sources in order for Washington State's overall energy consumption in 2035 to reach 1.8 Q-BTUs. As noted above, we assume that both hydro power and nuclear energy supply remain constant through 2035, at 0.667 Q-BTUs for hydro and 0.088 Q-BTUs for nuclear. We are also assuming that biomass energy falls to zero, given that it generates emissions at roughly the level of coal.[20]

The remaining 0.35 Q-BTUs of energy supply therefore must be provided by wind, solar, and geothermal energy, as we see in row 10, column 3 of Table 11. As of 2014, wind, solar, and geothermal energy combined to supply 0.0635 Q-BTUs to Washington State. Effectively then, what we are showing is that roughly 0.285 Q-BTUs of *new supply* needs to be provided by wind, solar, and geothermal in order for Washington State to bring overall CO_2 emissions down to 44 million tons by 2035.

As discussed in section 5, we assume that the average lump-sum capital expenditures needed to expand the clean renewable energy supply by 1 Q-BTU will be roughly $200 billion. This then means that, to expand the clean renewable energy supply for Washington State by 0.28 Q-BTUs will require about $57 billion in new capital expenditures. Working, again, with the assumption that this is effectively a 15-year investment program, this implies that the average level of expenditures per year to increase the supply of clean renewable energy by 0.28 Q-BTUs in 2035 will be $3.8 billion per year.

In Table 12, we summarize the main features of the 2035 clean energy investment program. These include the following:

- **Efficiency**. $2.8 billion per year in energy efficiency investments between 2021 – 2035, amounting to about 0.5 percent of Washington State's projected midpoint GDP between 2014 – 2035. These efficiency investments will generate 1.2 Q-BTUs of energy savings relative to the state economy's steady state growth path through 2035.
- **Clean renewables**. $3.8 billion per year for investments in wind, solar, and geothermal energy production. This will amount to about 0.7 percent of Washington State's projected midpoint GDP between 2014 – 2035. It will generate an increase of 0.28 Q-BTUs of clean renewable energy by 2035.

TABLE 12
Washington State Clean Energy Investment Program for 2021- 2035

Energy Efficiency Investments	
Total Investments	$42 billion
Average Annual Investments	$2.8 billion
Average Annual Investments as share of Midpoint GDP	0.5 percent
Total Energy Savings through Investments	1.2 Q-BTUs
Clean Renewable Energy Investments	
Total Investments	$57 billion
Average Annual Investments	$3.8 billion
Average Annual Investments as Share of Midpoint GDP	0.7 percent
Total Capacity Expansion through Investments	0.3 Q-BTUs
Overall Clean Energy Investments—Efficiency + Clean Renewables	
Total Investments	$99 billion
Average Annual Investments	$6.6 billion
Average Annual Investments as Share of Midpoint GDP	1.2 percent
Total Energy Savings or Clean Renewable Capacity Expansion	1.5 Q-BTUs

Source: See Table 11.

- **Overall program and emissions reduction**. Combining the efficiency and clean renewable investments, the program will therefore cost about $6.6 billion per year, or 1.2 percent of Washington State's projected midpoint GDP between 2014 – 2035. Overall, this program will generate 1.5 Q-BTUs in either energy savings relative to the steady state scenario or expanding the clean renewable energy supply. The end result of this program will be that overall CO_2 emissions in Washington State in 2035 will be 44 million tons, 40 percent less than its level for 2014. Washington State will have achieved this 40 percent emissions reduction while the state's economy also will have grown at an average rate of 2.0 percent per year through 2035.

Is $6.6 Billion per Year in Clean Energy Investments Realistic?

The short answer is "yes." To understand why, it is important to consider our estimate of Washington State's annual clean energy investment needs within the broader context of the state's overall economic trajectory. As we have already noted above, this $6.6 billion annual investment figure represents about 1.2 percent of Washington State's average GDP over 2021 – 2035, assuming that the state continues to grow at about 2.0 percent per year over that 15-year period. In other words, our estimate of Washington State's annual clean energy investment needs for bringing CO_2 emissions down in the state by 40 percent as of 2035 implies that nearly 99 percent of all economic activity in Washington State can continue to be directly engaged in activities *other than* clean energy investments.

As an additional valuable metric, we roughly estimate that, at present, the level of annual clean energy investments in Washington State is already in the range of $1.5 - $2 billion per year.[21] From this figure, we conclude that clean energy investments in Washington State between 2021 – 2035 will need to increase three- to fourfold relative to current investment levels. This will certainly be a substantial challenge. But, as we discuss in Section 9 below, Washington State does already have a strong policy infrastructure in place to support clean energy investments, mainly through incentivizing private investors. Increasing the level of clean energy investments will therefore primarily entail strengthening this policy framework on the basis of its existing foundation.

7. JOB CREATION THROUGH CLEAN ENERGY INVESTMENTS

In this section, we estimate the employment effects in Washington State of advancing a clean energy investment program in the state at the level we developed in the previous section—i.e. at about $2.8 billion per year in energy efficiency investments over a 15-year investment cycle between 2021 – 2035 and $3.8 billion per year in clean renewable investments over this same 15-year cycle. Total annual clean energy investments will therefore amount to $6.6 billion per year, about 1.2 percent of Washington State's average GDP over 2021 – 2035, assuming the state's economy grows at an average annual rate of 2.0 percent.

After estimating the number of jobs that this investment project will generate, we then consider indicators of the quality of these jobs. These quality indicators include average compensation levels, health care coverage, retirement plans, and union membership. We also provide data profiling the types of workers who are employed at present in the job areas that will be created by clean energy investments, including evidence on both educational credentials of these workers as well as their racial and gender composition. We then report on the prevalent types of jobs that will be generated by the energy efficiency and clean renewable energy investments.

Before proceeding with describing our estimates, we will first provide a brief overview of the methodology we used to generate our results. We provide a fuller discussion of our methodology in Appendix 1.

Methodological Issues in Estimating Employment Creation

Our employment estimates are figures generated directly with data from national surveys of public and private economic enterprises within Washington State and organized systematically within the official state-level input-output (I-O) model. The "inputs" within this model are all the employees, materials, land, energy and other products that are utilized in public and private enterprises within Washington State to create goods and services. The "outputs" are the goods and services themselves that result from these activities that are then made available to households, private businesses and governments as consumers within both domestic and global markets. Within the given structure of the Washington State economy, these figures from the input-output model provide the most accurate evidence available as to what happens within private and public enterprises when they produce the economy's goods and services. In particular, these data enable researchers to observe how many workers were hired to produce a given set of products or services, and what kinds of materials were purchased in the process.

Here is one specific example of how our methodology works. If we invest an additional $1 million on energy efficiency retrofits of an existing building, how will the business undertaking this retrofit project utilize that million dollars to actually complete the project? How much of the $1 million will they spend on hiring workers, how much will they spend on non-labor inputs, including materials, energy costs, and renting office space, and how much will be left over for business profits? Moreover, when businesses spend on non-labor inputs, what are the employment effects through giving orders to suppliers, such as lumber and glass producers or trucking companies?

We also ask this same set of questions for investment projects in renewable energy as well as spending on operations within the non-renewable energy sectors. For example, to produce $1 million worth of wind energy productive capacity, how many workers will need to be employed, and how much money will need to be spent on non-labor inputs? Through this approach, we are able to make observations as to the potential job effects of alternative energy investment and spending strategies at a level of detail that is not available through any alternative approach.

Direct, Indirect and Induced Job Creation

Spending money in any area of any economy, including Washington State, will create jobs, since people are needed to produce any good or service that the economy supplies. This is true regardless of whether the spending is done by private businesses, households, or government entities. At the same time, for a given amount of spending within the economy, for example, $1 million, there are differences in the relative levels of job creation through spending that $1 million in different ways. Again, this is true regardless of whether the spending is done by households, private businesses or public sector enterprises.

There are three sources of job creation associated with any expansion of spending—direct, indirect, and induced effects. For purposes of illustration, consider these categories in terms of investments in home retrofitting or building wind turbines:

1. *Direct effects*—the jobs created, for example, by retrofitting buildings to make them more energy efficient or building wind turbines;
2. *Indirect effects*—the jobs associated with industries that supply intermediate goods for the building retrofits or wind turbines, such as lumber, steel, and transportation;
3. *Induced effects*—the expansion of employment that results when people who are paid in the construction or steel industries spend the money they have earned on other products in the economy. These are the multiplier effects within a standard macroeconomic model.

In this study, we focus on direct and indirect effects. Estimating induced effects—i.e. multiplier effects—within I-O models is much less reliable than the direct and indirect effects. In addition, induced effects derived from alternative areas of spending within a national economy are likely to be comparable to one another. Nevertheless, we will report the induced effect figures that are generated through the Washington State I-O model, even while we give them less emphasis in our analysis.

Within the categories of direct plus indirect job creation, how is it that spending a given amount of money in one set of activities in the economy could generate more employment than other activities? As a matter of simple arithmetic, there are only three possibilities. These are:

1. *Labor Intensity*. When proportionally more money of a given overall amount of funds is spent on hiring people, as opposed to spending on machinery, buildings, energy, land,

and other inputs, then spending this given amount of overall funds will create relatively more jobs.

2. *State-level content.* When a given amount of money is spent on Washington State's clean energy investment program, some of the spending will occur outside of the Washington State economy. The I-O model enables us to estimate Washington State specific spending proportions as opposed to outside-the-state spending. In fact, as we describe below, we will make low-end assumptions in our estimates as to the share of spending that will be internal to Washington.

3. *Compensation per worker.* If $1 million in total is spent on employing workers in a given year on a project, and one employee earns $1 million per year working on that project, then only one job is created through spending this $1 million. However, if, at another enterprise, the average pay is $50,000 per year, then the same $1 million devoted to employing workers will generate 20 jobs.

Time Dimension in Measuring Job Creation

Jobs-per-year vs. job years. Any type of spending activity creates employment over a given amount of time. To understand the impact on jobs of a given spending activity, one must therefore incorporate a time dimension into the measurement of employment creation. For example, a program that creates 100 jobs that last for only one year needs to be distinguished from another program that creates 100 jobs that continue for 10 years each. It is important to keep this time dimension in mind in any assessment of the impact on job creation of any clean energy investment activity.

There are two straightforward ways in which one can express such distinctions. One is through measuring *job years*. This measures cumulative job creation over the total number of years that jobs have been created. Thus, an activity that generates 100 jobs for 1 year would create 100 job years. By contrast, the activity that produces 100 jobs for 10 years would generate 1,000 job years.

The other way to report the same figures would be in terms of *jobs-per-year*. Through this measure, we are able to provide detail on the year-to-year breakdown of the overall level of job creation. Thus, with the 10-year program we are using in our example, we could express its effects as creating 100 jobs per year for 10 years.

This jobs-per-year measure is most appropriate for the purposes of this study, in which our focus is on measuring the impact on employment opportunities of clean energy investments. The reason that jobs-per-year is a better metric than job years is because the impact of any new investment, whether on clean energy or anything else, will be felt within a given set of labor market conditions at a point in time. Reporting cumulative job creation figures over multiple years prevents us from scaling the impact of investments on job markets at a given point in time. For example, if clean energy investments create 50,000 jobs in a given year, we are able to scale that to the size of the Washington State labor market in that year. At present, 3.4 million people are employed in Washington State. Adding 50,000 jobs would therefore amount to an increase in employment of about 1.5 percentage points.

If we then assume that the clean energy investments continue for 10 years at the same scale, that would mean 50,000 jobs per year would be created through these investments. That would continue to expand employment opportunities in Washington State by around

1.5 percent per year (allowing also for the natural growth of the state's labor market). However, if we measure this employment impact in terms of cumulative job creation, the 10 years worth of investment would, by this measure, amount to 500,000 jobs. It is misleading to compare that cumulative job creation figure to the total of 3.4 million jobs in Washington State at a specific point in time (e.g. 2017). If we did want to scale the cumulative job creation figure of 500,000, the appropriate comparison would be with the cumulative job figures for the whole state over 10 years, i.e. a cumulative level of employment over 10 years of 34 million jobs (i.e. 3.4 million jobs x 10 years). But this 34 million cumulative jobs figure is not a particularly clear or useful way to understand labor market conditions at any given point in time.

The case of construction jobs. One specific area where it is important to proceed clearly on this issue is in consideration of construction industry job creation. Construction industry jobs created by clean energy investments are frequently regarded as being short-term, while manufacturing jobs are seen as inherently longer term. However, especially in evaluating the impact of alternative areas of spending within a broad clean energy investment agenda, the distinctions are not so straightforward. Of course, any single construction project is limited by the amount of time required to complete that project, while manufacturing activity in a single plant can continue indefinitely, as long as the manufacturer is able to sell the goods being produced at a profit. But if we consider any large-scale clean energy construction project, total job creation over time can vary widely, depending precisely on the annual level of expenditure that is laid out to complete the project.

Consider, for example, a project to retrofit the entire publicly-owned building stock in Washington State, in which we assume the entire budget devoted to labor in the project is $5 billion, and each worker on the project receives $50,000 per year in total compensation. This means that, in total, the project will generate 100,000 job years, no matter how these job years are divided up over time. If the annual labor-cost budget for the project is $500 million over 10 years, that means the project will generate 10,000 jobs per year over 10 years, making it a long-term source of job creation. However, if the annual budget rose to $5 billion, that means the project would generate 100,000 jobs, but over just one year.

Incorporating Labor Productivity Growth over the 15-Year Investment Cycle

The figures we use for the input-output tables are based on the technologies that are prevalent at present for undertaking these clean energy investments. Yet we are estimating job creation through clean energy investments that will occur over a 15-year cycle. The relevant production technologies will certainly change over this 15-year period, so that a different mixture of inputs may be used to produce a given output.

For example, new technologies are likely to emerge, making other technologies obsolete. Certain inputs could also become more scarce, and, as a result, firms may substitute other less expensive goods and services to save on costs. The production process overall could also become more efficient, so that fewer inputs are needed to produce a given amount of output. Energy efficiency investments do themselves produce a change in production processes—i.e. a reduction in the use of energy inputs to generate a given level of output. In short, the input-output relationships in any given economy—including its employment effects of clean energy investments—are likely to look different in 2035 relative to the present.

We have addressed this issue in depth in previous research (e.g. Pollin et al. 2015, pp. 133 - 44). For the purposes of this study, we will work with two simple assumptions: 1) current input-output relationships will prevail as of 2021, the year in which the clean energy investment program commences in full; and 2) between 2021- 2035, average labor productivity in clean energy investments rises by 1 percent per year.

Job Creation Estimates

In Tables 13 and 14, we present our estimates as to the job creation effects of investing in energy efficiency in Washington State. Tables 15 and 16 then present comparable estimates for investments in clean renewable energy in the state. In both cases, we report two sets of figures—first job creation per $1 million in expenditure, then job creation given the annual level of investment spending we have proposed, i.e. $2.8 billion per year in energy efficiency and $3.8 billion per year in renewable energy. We first report figures for direct and indirect jobs, along with the totals for these main job categories. We then include the figures on induced jobs, and show total job creation when induced jobs are added to that total.

Beginning with the energy efficiency investment figures in Table 13, we show the job creation figures per $1 million in spending for our five categories of efficiency investments: building retrofits; industrial efficiency; electrical grid upgrades; public transportation expansion and upgrades; and high-efficiency private auto purchases. As Table 13 shows, direct plus indirect job creation per $1 million in spending ranges between 6.1 jobs for electrical grid upgrades to 10.0 jobs for public transportation expansion and upgrades.

Spending to bring high efficiency automobiles into operation rapidly will be an important component of the overall efficiency investment initiative. However, our assumption, as shown in Table 13, is that this will not be a source of new job creation. This is because producing high efficiency automobiles will basically substitute for producing lower-efficiency models. Roughly the same level of employment will be needed either way.[22]

In Table 14, we show the level of job creation through spending $2.8 billion per year on these efficiency projects in Washington State. We have assumed that 60 percent of the $2.8 billion total is channeled into building retrofits, and the remaining 40 percent supports the

TABLE 13
Job Creation in Washington State through Energy Efficiency Investments:
Job Creation per $1 million in Efficiency Investments

	Direct Jobs	Indirect Jobs	Direct + Indirect Jobs Total	Induced Jobs	Direct, Indirect + Induced Jobs Total
Building retrofits	5.3	3.1	8.4	2.4	10.8
Industrial efficiency	5.9	2.2	8.1	2.6	10.7
Electrical grid upgrades	4.3	1.8	6.1	2.2	8.3
Public transportation expansion/upgrades	7.9	2.1	10.0	2.3	12.3
Expanding high efficiency automobile fleet	0	0	0	0	0

Sources: See Appendix 1.

TABLE 14
Job Creation in Washington State through Energy Efficiency Investments:
Job Creation through Spending $2.8 billion per year in Efficiency Investments

ASSUMPTIONS FOR ENERGY EFFICIENCY INVESTMENTS

- 60% on building retrofits
- 10% on industrial efficiency measures
- 10% on electrical grid upgrades
- 10% on public transportation expansion/upgrades
- 10% on expanding high-efficiency auto fleet
  - No job creation through auto purchase subsidies

	Spending Amounts	Direct Jobs	Indirect Jobs	Direct + Indirect Jobs Total	Induced Jobs	Direct, Indirect + Induced Jobs Total
Building retrofits	$1.68 billion	8,904	5,208	14,112	4,032	18,144
Industrial efficiency	$280 million	1,652	616	2,268	728	2,996
Electrical grid upgrades	$280 million	1,204	504	1,708	616	2,324
Public transportation expansion/upgrades	$280 million	2,212	588	2,800	644	3,444
Expanding high efficiency automobile fleet	$280 million	0	0	0	0	0
TOTALS	**$2.8 billion**	**13,972**	**6,916**	**20,888**	**6,020**	**26,908**

Sources: See Appendix 1.

other efficiency investment areas equally, at 10 percent of the total each. The result of efficiency investment spending at this level, as we see, will be the creation of about 14,000 direct jobs and 7,000 indirect jobs, for a total of about 21,000 direct plus indirect jobs through this energy efficiency investment program. Including induced jobs adds another roughly 6,000 jobs to the total figure. This brings the total job creation figure for efficiency investments, including induced jobs to roughly 27,000 jobs.

In Table 15, we show the job creation figures for our three clean renewable energy categories—wind, solar, and geothermal power. As we see, the extent of direct plus indirect jobs ranges from 4.4 – 6.8 per $1 million in spending. Adding induced jobs brings the range to between 6.4 – 9.1 jobs per $1 million in spending.

Based on these proportions, we see in Table 16 the levels of job creation in Washington State associated with $3.8 billion in annual spending on clean renewable energy. We divide

TABLE 15
Annual Job Creation in Washington State through Clean Renewable Energy Investments:
Job Creation per $1 million in Clean Renewable Investments

ASSUMPTION FOR RENEWABLE INVESTMENTS

- 10% of new manufacturing activity retained in Washington State

	Direct Jobs	Indirect Jobs	Direct + Indirect Jobs Total	Induced Jobs	Direct, Indirect + Induced Jobs
Wind	2.8	1.6	4.4	2.0	6.4
Solar	4.5	1.6	6.1	2.3	8.4
Geothermal	4.5	2.3	6.8	2.3	9.1

Sources: See Appendix 1.

the overall level of annual spending to include $1.71 billion per year respectively for wind and solar power and $380 million for geothermal. We also assume, as a low-end estimate, that of this total level of new investments in clean renewables needed to deliver about 0.3 Q-BTUs of energy in Washington State by 2035, only 10 percent of the total *manufacturing activity* will take place within Washington State. In other words, we assume that 90 percent of the manufacturing goods needed to produce 0.3 Q-BTUs of clean renewable energy in Washington State as of 2035 will be imported from outside the state.

Following from these assumptions, we see in Table 16 that total direct plus indirect job creation generated in Washington State by this large-scale expansion in the state's clean renewable energy supply will be about 21,000 jobs. If we include induced jobs, then the total rises to about 29,000 jobs.

Table 17 brings together our job estimates for both energy efficiency and clean renewable energy through spending about $6.6 billion per year on this project in Washington State. We show total figures for direct plus indirect jobs only, then we also show the total when induced jobs are included. We also provide estimates for 2021, the first year of the full-scale investment program, and for 2035, the last year of the investment cycle. The employment levels fall in 2035 relative to 2021 because of our assumption that average labor productivity rises at an average rate of one percent per year in the relevant sectors of Washington State's economy.

We see in row 10 of Table 17 that total direct and indirect job creation as of 2021 is 41,427 jobs and 55,674 jobs when we add induced jobs to the total. As we see in row 11, this level of job creation amounts to between 1.2 and 1.7 percent of total employment in Washington State as of 2015, the range depending on whether we include induced jobs in the total. In row 12, we show our job estimates for 2035, assuming productivity gains at an average annual rate of 1 percent. These job figures are 35,713 for direct plus indirect employment and 47,995 when we include induced job creation.

TABLE 16
Annual Job Creation in Washington State through Clean Renewable Energy Investments:
Job Creation through spending $3.8 billion per year in Clean Renewable Investments

ASSUMPTIONS FOR RENEWABLE ENERGY INVESTMENTS

- 45% on solar PV energy
- 45% on wind energy
- 10% on geothermal energy
- 10% of new manufacturing activity retained in Washington State

	Spending Amounts	Direct Jobs	Indirect Jobs	Direct + Indirect Jobs Total	Induced Jobs	Direct, Indirect + Induced Jobs Total
Wind	$1.71 billion	4,788	2,736	7,524	3,420	10,944
Solar	$1.71 billion	7,695	2,736	10,431	3,933	14,364
Geothermal	$380 million	1,710	874	2,584	874	3,458
TOTAL JOB CREATION	**$3.8 billion**	**14,193**	**6,346**	**20,539**	**8,227**	**28,766**

Sources: See Appendix 1.

TABLE 17
Annual Job Creation in Washington State through Combined Clean Energy Investment Program

Initial Year of Job Estimate Is 2021

Industry	Number of Direct and Indirect Jobs Created	Number of Direct, Indirect and Induced Jobs Created
$2.8 billion in Energy Efficiency		
1) Building Retrofits	14,112	18,144
2) Industrial efficiency	2,268	2,996
3) Electrical grid upgrades	1,708	2,324
4) Public transportation expansion/upgrades	2,800	3,444
5) Total Energy Efficiency Job Creation	20,888	26,908
$3.8 billion in Clean Renewables		
6) Wind	7,524	10,944
7) Solar	10,431	14,364
8) Geothermal	2,584	3,458
9) Total Clean Renewable Job Creation	20,539	28,766
10) TOTAL	**41,427**	**55,674**
11) TOTAL AS SHARE OF 2015 WASHINGTON STATE EMPLOYMENT	**1.2 percent**	**1.7 percent**
12) 2035 JOB ESTIMATE, with 1 percent annual productivity growth	**35,713**	**47,995**

Sources: See Tables 13 – 16.

Indicators of Job Quality

In Table 18, we provide some basic measures of job quality for the jobs that will be generated through clean energy investments in Washington State. These basic indicators include: 1) average total compensation (including wages plus benefits); 2) the percentage of workers receiving health insurance coverage; 3) the percentage having retirement plans through their employers; and 4) the percentage that are union members.

Starting with compensation figures, we see that the averages range widely, between about $53,000 for workers in the mass transit sector to nearly $90,000 for workers employed in either the industrial efficiency or geothermal energy sectors.

The range is much narrower in terms of health insurance coverage. At the low end, about 55 percent of workers in the building retrofit and mass transit sectors have private health insurance, while nearly 70 percent of workers in industrial efficiency are covered. The figures in all the clean renewable areas—wind, solar, and geothermal—are between 60 - 67 percent.

The range of coverage with respect to private retirement plans is similar to health insurance. The low-end figure is in building retrofits, in which about 44 percent have private

TABLE 18
Indicators of Job Quality in Washington State Clean Energy Industries: Direct and Indirect Jobs Only

	Energy Efficiency Investments				Clean Renewable Energy Investments		
	1. Building Retrofits *(14,112 workers)*	**2. Industrial Efficiency** *(2,268 workers)*	**3. Grid Upgrades** *(1,708 workers)*	**4. Mass Transit** *(2,800 workers)*	**5. Wind** *(7,524 workers)*	**6. Solar** *(10,431 workers)*	**7. Geothermal** *(2,584 workers)*
Average total compensation	$67,400	$89,100	$77,500	$52,700	$71,900	$69,200	$89,500
Health insurance coverage, percentage	55.1%	69.2%	66.9%	55.3%	66.6%	60.4%	59.8%
Retirement plans, percentage	43.9%	53.6%	63.3%	53.3%	55.4%	50.2%	51.7%
Union membership, percentage	19.8%	8.7%	11.9%	32.6%	12.3%	10.1%	13.7%

Sources: See Appendix 2.

pension coverage, while 63 percent of workers in grid upgrades have such pensions. The figures on union coverage also are generally low, with the one exception of mass transit, in which about one-third of workers are union members. Otherwise, coverage ranges between a low of about 9 percent in industrial efficiency to 20 percent in building retrofits.

These indicators of job quality will be valuable for purposes of comparison when we consider the jobs that will be lost in Washington State as a result of the contraction of fossil fuel production and consumption in the state through 2035. What is especially important to highlight now—in anticipating our discussion in section 8 on workers in Washington State's fossil fuel related industries—is that the compensation figures in clean energy industries are low in comparison with those for fossil fuel industry based workers. As such, one of the aims of a clean energy investment agenda for Washington State will be to raise wages, benefits and working conditions in the newly-created clean energy investment industries. Raising unionization rates in these industries will provide an important foundation in support of these goals.

Educational Credentials and Race/Gender Composition for Clean Energy Jobs

In Table 19, we present data on both the educational credentials for workers in jobs tied to clean energy investment activities in Washington State and the race and gender composition of these workers.

Educational Credentials

With respect to educational credentials, we categorize all workers who would be employed directly or indirectly by clean energy investments in Washington State according to three educational credential groupings: 1) shares with high school degrees or less; 2) shares with some college or Associate degrees; and 3) shares with Bachelor's degree or higher.

TABLE 19
Educational Credentials and Race/Gender Composition of Workers in Washington State Clean Energy Industries: Direct and Indirect Jobs Only

	Energy Efficiency Investments				Clean Renewable Energy Investments		
	1. Building Retrofits *(14,112 workers)*	**2. Industrial Efficiency** *(2,268 workers)*	**3. Grid Upgrades** *(1,708 workers)*	**4. Mass Transit** *(2,800 workers)*	**5. Wind** *(7,524 workers)*	**6. Solar** *(10,431 workers)*	**7. Geothermal** *(2,584 workers)*
Share with high school degree or less	46.2%	23.6%	36.0%	48.2%	38.5%	29.3%	40.3%
Share with some college or Associate degree	31.6%	28.8%	33.1%	31.0%	32.0%	35.0%	24.2%
Share with Bachelor's degree or higher	22.2%	47.6%	31.0%	20.8%	29.5%	35.8%	35.4%
Racial and Gender Composition of Workforce							
Pct. non-white	24.2%	20.3%	27.9%	32.2%	21.5%	25.1%	21.2%
Pct. female	23.1%	36.5%	22.7%	25.2%	23.9%	33.1%	26.8%

Sources: See Appendix 2.

As Table 19 shows, the distribution of educational credentials varies widely depending on the specific clean energy industry. In the areas of building retrofits and mass transit, about half of the workers have high school degrees or less. In the three renewable energy areas, wind, solar, and geothermal, only about 30 – 40 percent of the workers have high school degrees or less. With industrial efficiency, only about 24 percent of workers are at this lower educational credential level.

At the other end of the credential range, nearly half of all workers in industrial efficiency have Bachelor's degrees or higher. This is more than twice the proportion prevailing with building retrofit and mass transit workers. With grid upgrades and the renewable energy areas, between 30 – 36 percent hold Bachelor's degrees or more.

If we consider this range of clean energy investment areas as a whole, it is clear that there will be new jobs generated at roughly comparable proportions for workers at all educational credential levels. Here again, it will be useful to be able to compare these patterns in educational levels for jobs in clean energy with those that will be displaced through the contraction in Washington's fossil fuel industries. We consider this in section 8.

Race and Gender Composition

It is clear from the figures in Table 19 that, at present, the jobs created by clean energy investments are held predominantly by white male workers. Thus, the share of jobs held by non-white workers is between 20 – 32 percent in the seven sectors we are considering. With respect to gender composition, the share of female employment is between 23 and 36 percent.

Despite these large disparities in the current composition of the workforce associated with clean energy investments in Washington State, the large-scale expansion of these investments will provide a major opportunity to increase opportunities for non-white and female workers. An initiative focused on equal opportunity in the growing clean energy investment areas could be readily integrated into the broader investment project.

Prevalent Job Types with Clean Energy Investments

To provide a more concrete picture of the jobs that will be created in Washington State through investments in energy efficiency and clean renewable energy, in Tables 20 - 22 we report on the prevalent job types associated with the various efficiency and renewable energy activities. Table 20 provides data for investments in building retrofits, our largest category of energy efficiency investments. Table 21 combines data for the other efficiency investment areas, i.e. industrial efficiency, electric grid upgrades, and public transportation expansion and upgrades. Table 22 then reports these same figures combined for our three areas of clean renewable energy investments, i.e. wind, solar, and geothermal power. In all cases, we report on the job categories in which we estimate that 5 percent or more of the new jobs will be created through clean energy investments.

It is difficult to summarize the detailed data on job categories presented in these tables. But it will be useful to underscore a few key patterns. First, a high proportion of jobs will be created in the construction industry through all of the clean energy investment activities. Of course, this is true with the 39 percent of jobs created through building retrofit investments. But we also find that 13 percent of investments in the other areas of energy efficiency investments and 18 percent in the clean renewable sectors will be in construction. The specific types of construction industry jobs will vary widely, given the different types of construction projects that will be pursued. Thus, investments in building retrofits as well as the other areas of efficiency investments will create large numbers of jobs for laborers, carpenters, and electricians. This pattern of job creation holds as well with renewable-energy based construction work.

Management as well as office and administrative support also constitute a large share of overall job creation across all categories. Management ranges between 14 – 15 percent in all the tables, while office and administrative support consistently accounts for about 8 percent of all jobs.

TABLE 20
Building Retrofits: Prevalent Job Types in Washington Industry
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Construction	39.1%	Carpenters, laborers, electricians
Management	15.2%	Construction managers, chief executives, marketing and sales managers
Sales	12.0%	Retail salespersons, first-line sales supervisors, cashiers
Office and Administrative Support	7.8%	Secretaries, stock clerks, bookkeeping clerks
Transportation and Material Moving	5.1%	Truck drivers, material movers, industrial tractor operators

Sources: See Appendix 2.

TABLE 21
Industrial Efficiency, Electric Grid Upgrades, Public Transportation Expansion/ Upgrades: Prevalent Job Types in Washington Industry
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Transportation and Material Moving	18.9%	Bus drivers, truck drivers, freight and stock laborers
Management	13.6%	Construction managers, marketing managers, chief executives
Construction	12.6%	Carpenters, laborers, electricians
Production	11.5%	First-line production supervisors, metalworkers, inspectors
Business and Financial Operations	9.0%	Management analysts, accountants, wholesale buyers
Office and Administrative Support	8.0%	Secretaries, customer service representatives, administrative support workers
Sales	5.9%	Wholesale sales representatives, first-line sales supervisors, retail salespersons
Installation and Maintenance	5.5%	Bus and truck mechanics, mobile equipment service technician

Sources: See Appendix 2.

TABLE 22
Wind/Solar/Geothermal: Prevalent Job Types in Washington Industry
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Construction	18.3%	Carpenters, laborers, electricians
Arts, Design, Entertain-ment, Sports, and Media	15.2%	Photographers, designers, communication workers
Management	13.7%	Construction managers, marketing managers, chief executives
Production	13.1%	First-line production supervisors, welders, inspectors
Office and Administrative Support	8.4%	Secretaries, bookkeeping clerks, customer service representatives
Computer and Mathematical Science	6.1%	Software developers, network administrators, computer systems analysts
Sales	5.6%	Wholesale sales representatives, first-line sales supervisors, retail salespersons

Sources: See Appendix 2.

What emerges generally from these tables is that clean energy investments will generate a wide range of new employment opportunities. This broad range of new opportunities will be available for workers in Washington State that have been displaced by the contraction of the state's fossil fuel industry activities, as well as more broadly throughout the state's labor force.

Relative Job Creation through Alternative Spending Targets

What would be the impact on job creation of channeling a given amount of funds into other areas of Washington State's economy, as opposed to pursuing the investments on which we have focused in energy efficiency and clean renewable energy? To consider this question, in Table 23, we report figures as to the job creation impacts of spending in three alternative areas: the fossil fuel industry itself, traditional infrastructure—i.e. roads, bridges, tunnels, airports and related areas—and tax cuts. The impact of any tax cuts on jobs results through Washington State's residents having more money to spend on their standard baskets of goods and services. As with our previous discussions in this section, we are focusing on the direct and indirect categories of job creation.

As we see in Table 23, the largest impact on job creation among the alternative spending areas is energy efficiency, which generates 7.5 direct and indirect jobs per $1 million in spending in Washington State. This is a combined figure for energy efficiency investments, based on the relative weights we have assigned earlier (i.e. from Table 14—60 percent on building retrofits, and 10 percent respectively on industrial efficiency, electrical grid upgrades, public transportation, and high-efficiency autos). The figure for renewable energy is lower, at 5.4 direct plus indirect jobs per $1 million. In this case, we are generating this overall renewable energy figure through following the proportional spending levels we report in Table 16, i.e. solar PV and wind both receiving 45 percent of total spending and geothermal energy obtaining the remaining 10 percent.

Considering now the three alternative spending areas, we see that traditional infrastructure investments in Washington State will generate 7.0 direct plus indirect jobs per $1 million

TABLE 23
Job Creation in Washington State Generated through Alternative Spending Targets
Direct plus indirect job creation per $1 million in spending

	Direct Jobs	Indirect Jobs	Direct + Indirect Jobs
Clean Energy Investments			
-- Energy Efficiency	5.0	2.5	7.5
-- Clean Renewables	3.7	1.7	5.4
Alternative Washington State spending targets			
-- Infrastructure	5.0	2.0	7.0
-- Household Tax Cuts	3.6	1.1	4.7
-- Oil and Gas	2.1	1.0	3.1

Source: See Appendix 1.

in spending. This is followed by tax cuts, at 4.7 jobs per $1 million, and then oil and gas, at 3.1 jobs.

Overall then, we see that, comparatively speaking, clean energy investments are a robust source of job creation, especially so in the area of energy efficiency. Combining energy efficiency and clean renewable investments will generate more jobs per dollar of expenditure than any combination between traditional infrastructure, tax cuts and expanding the fossil fuel industry. It is especially notable that the job creating opportunities for energy efficiency investments, in particular, are twice as large as what would result through a project focusing only on expanding Washington State's fossil fuel infrastructure.

8. JUST TRANSITION FOR FOSSIL FUEL INDUSTRY DEPENDENT WORKERS

As we have shown above, in order for Washington State to bring total CO_2 emissions down from its 2014 level of 73 million tons to 44 million tons by 2035, consumption of fossil fuels in the state will need to fall by approximately 40 percent relative to its 2014 level of 1.11 Q-BTUs to about 0.67 Q-BTUs. As we have seen, petroleum consumption in Washington State in 2014 was at 0.72 Q-BTUs or 35.1 percent of total statewide energy consumption and natural gas was 0.31 Q-BTUs, or 15.2 percent of total consumption. Coal consumption is already negligible in Washington State, at 0.07 Q-BTUs, or about 3 percent of total consumption.

The issue on which we focus in this section is what the impact will be on workers in industries in Washington State that are dependent on statewide consumers continuing to purchase fossil fuel energy. We assume that production activity and employment in these industries will also decline by approximately 40 percent as of 2035.[23] In particular, we develop here a Just Transition program for the workers in these fossil fuel dependent sectors who will face displacement as a result of the statewide contraction in fossil fuel consumption.

In principle, there are nine industries that would likely be heavily affected by a significant cut in fossil fuel consumption and production. Of course, the first two would be oil and gas extraction and coal mining. There are also seven ancillary industries that would be impacted. The first two would be support activities for both oil/gas extraction and coal mining. Five additional industries that would be impacted are: petroleum refining; natural gas distribution; oil and gas pipeline construction and transportation; petroleum bulk stations and terminals; and electric power generation, in which the electricity is generated by fossil fuel energy sources.[24]

In Table 24, we show employment levels for these nine industries as of 2014. The first thing that stands out in Table 24 is that the employment levels for both oil and gas extraction and coal mining are both negligible—a total of 7 workers employed in oil and gas extraction and 60 in coal mining. Moreover, only 87 workers are employed in support activities for oil and gas. There is no employment at all in Washington State for support activities in coal.

Beyond this, we see that total employment in all fossil fuel and ancillary industries in Washington State was 5,411 in 2014. This amounts to about 0.18 percent of the total 2014 Washington State workforce of 3.0 million. We further see that this total of 5,411 jobs is concentrated in four industries. These are petroleum refining, which, as of 2014, employed 1,918 workers, or 35 percent of all workers employed in any fossil fuel dependent sector in Washington State; natural gas distribution, which employed 1,164 workers in 2014, or 22 percent of all fossil fuel related workers in the state; oil and gas pipeline construction and transportation, with 1,137 workers, equaling 21 percent of the total; and petroleum bulk stations and terminals, with 738 workers, equaling 14 percent of the total. In other words, roughly 92 percent of all fossil fuel industry dependent workers in Washington State are employed in petroleum refining, natural gas distribution, pipeline construction and transportation, and petroleum bulk stations.

TABLE 24
Number of Workers in Washington State Employed in Fossil Fuel Production Activities and Ancillary Industries, 2014

Industry	Number of Employed Workers
Oil and Gas Extraction	*7 (0.1% of total)*
Coal Mining	60 (1.1% of total)
Ancillary Industries	
Support Activities for Oil/Gas	*87 (1.6% of total)*
Support Activities for Coal	0
Natural Gas Distribution	*1,164 (21.5% of total)*
Fossil Fuel Electric Power Generation	300 (5.5% of total)
Petroleum Refining	*1,918 (35.4% of total)*
Petroleum Bulk Stations and Terminals	*738 (13.6% of total)*
Oil and Gas Pipeline Construction and Transportation	*1,137 (21.0% of total)*
TOTAL	**5,411**
TOTAL AS SHARE OF WASHINGTON STATE EMPLOYMENT	**0.18%**

Source: See Appendix 2. "Support Activities for Oil/Gas" includes "Drilling of oil and gas wells."
Note: Total 2014 employment = 3.0 million.

Of the remaining 8 percent of fossil fuel dependent jobs in Washington, as Table 24 shows, 300, or 5.5 percent, are employed in electric power generation; 87, or 1.6 percent, in support activities for oil and gas; 60, or 1.1 percent, work in coal mining, and 7, or 0.1 percent, work in oil and gas extraction.

Characteristics of Fossil Fuel and Ancillary Industry Jobs

Table 25 provides basic figures on the characteristics of the jobs in Washington State for workers in fossil fuel dependent sectors. We focus first on the nearly 92 percent of the jobs—roughly 5,000 jobs in total—that are in petroleum refining, natural gas distribution, oil and gas pipeline construction and transportation, and petroleum bulk stations and terminals (shown in columns 1 - 4 of Table 25). As the table shows, on average, these are relatively high-quality jobs. The average overall compensation is very high in petroleum refining, at $226,000. It is also high, if not at the level of petroleum refining, in natural gas distribution, at $123,000 and oil and gas pipeline construction, at $111,000. The average compensation figure for petroleum bulk station workers is substantially lower, at $79,000, and the range for the less well-represented industries—oil/gas extraction, coal mining and support activities for these industries, is also relatively low, between $53,000 and $85,000. Overall, most of the existing pool of jobs in the fossil fuel related industries in Washington State offer better compensation levels than in the industries that would be growing through large-scale investments in energy efficiency and clean renewable energy.

In terms of private health insurance coverage, the workers in both petroleum refining and natural gas distribution are well covered, with between 92 – 96 percent of workers having insurance in these two industries that account by themselves for 57 percent of employment in fossil fuel and ancillary industries in Washington State. Otherwise, private health insurance coverage ranges fairly widely, between about 65 – 90 percent among the other fossil fuel based industries. Overall here as well, health insurance coverage is higher than is generally true with the industries that would expand as a result of clean energy investments.

Union membership ranges more widely still. About 25 percent of the 1,918 petroleum refining workers in Washington State are union members. Nearly 50 percent of natural gas distribution workers are unionized, and 38 percent are unionized among pipeline construction and transportation workers. However, only 5.3 percent of workers in petroleum bulk stations are unionized. Among the smaller fossil fuel based industries in the state, union membership ranges between 9 – 47 percent.

Table 25 also reports figures on educational credential levels for workers in each of the nine industries, as well the percentages of non-white and female workers in these nine indus-

TABLE 25
Characteristics of Workers in Washington State Fossil Fuel and Ancillary Industries

	1. Petroleum Refining (1,918 workers)	2. Natural Gas Distribution (1,164 workers)	3. Oil and Gas Pipeline Construction and Transportation (1,137 workers)	4. Petroleum Bulk Stations and Terminals (738 workers)	5. Fossil Fuel Electric Power Generation (300 workers)	6. Support Activities for Oil and Gas (87 workers)	7. Coal Mining (60 workers)	8. Oil and Gas Extraction (7 workers)
Average total compensation	$226,000	$123,000	$111,000	$79,000	$119,000	$82,000	$85,000	$53,000*
% Health Insurance coverage	92.2%	95.6%	67.8%	86.9%	93.2%	64.5%	87.7%	90.1%
% Union membership	25.2%	48.7%	38.3%	5.3%	37.6%	9.1%	47.5%	12.4%
Educational Credentials								
% High school degree or less	27.6%	25.2%	45.0%	40.9%	18.4%	25.5%	26.7%	28.2%
% Some college or Associate degree	47.6%	50.5%	40.3%	40.0%	44.1%	36.8%	59.7%	30.1%
% Bachelor's degree or higher	24.8%	24.3%	14.7%	19.0%	37.6%	37.6%	13.6%	41.7%
Racial and Gender Composition of Workforce								
% Non-white	16.7%	20.9%	18.9%	18.9%	16.9%	4.5%	2.0%	12.1%
% Female	16.1%	19.7%	10.8%	10.9%	26.6%	7.5%	5.3%	17.1%

Source: See Appendix 2.
Note: Data on unionization among coal miners is taken from the "Other western region" in the Annual Coal Report 2014 instead of the CPS. This is because the CPS has a limited number of workers in its sample.
* The compensation figure for oil and gas extraction is an average for 2013-20015, due to the small sample size for 2014 alone. This average figure likely reflects a high proportion of part-time and/or part-year workers among the overall small number of total employees.

tries. With respect to educational credentials, the range is fairly modest in the four largest industries—i.e. petroleum refining, natural gas distribution, pipeline construction and transportation, and petroleum bulk stations. Thus, the share of workers with bachelor's degrees or higher ranges between 15 – 25 percent among these four industries, while the share with some college ranges between 40 – 51 percent.

The shares of either minority or female workers is low in each of these four large industries. In terms of racial and gender composition of the existing workforce employed in fossil fuel production and ancillary industries in Washington State, we again see, as with the clean energy investment areas, that most jobs are presently held by white males. Non-white workers constitute between 17 – 21 percent of all workers in the petroleum refining, natural gas distribution, pipeline construction and transportation, and bulk station industries, while employment for women ranges between about 11 – 20 percent. These percentages for minority and female employment are consistently lower than those tied to energy efficiency and clean renewable energy investments, though not dramatically so.

We can gain further detailed information on workforce and employment conditions for workers in these fossil fuel dependent industries in Washington State through the data in Tables 26 - 31. In these six tables, we report on the various job categories associated with each of the employers in the fossil fuel related industries. For each industry, we show the most prevalent job categories and the representative occupations in each job category. In Tables 26 – 30, we report separately on individual industries, presented according to their respective levels of employment, from largest to smallest—i.e. petroleum refining, natural gas distribution, pipeline construction and transportation, bulk stations and terminals, and electric power generation. In Table 31, we then show combined figures on the remaining three fossil fuel based industries that are active in Washington State.

The key finding that emerges from these tables is that the fossil fuel related industries in Washington State provide a wide range of employment opportunities for the 5,411 workers

TABLE 26
PETROLEUM REFINING: Prevalent Job Types in Washington Industry, 1,918 Workers
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Production	37.5%	First-line production supervisors, plant and systems operators, mixing and blending machine setters
Transportation, and Material Moving	12.4%	Truck drivers, material movers, transportation inspectors
Installation, Maintenance, and Repair	11.0%	Millwrights, industrial machinery mechanics, precision instrument repairers
Management	8.1%	Operations managers, computer systems managers, industrial production managers
Business Operations Specialists	7.8%	Purchasing agents, compliance officers, human resource workers
Construction	6.7%	Construction equipment operators, electricians, pipelayers and pipefitters
Architecture and Engineering	5.9%	Chemical engineers, industrial engineers, engineering technicians

Source: See Appendix 2.

TABLE 27

NATURAL GAS DISTRIBUTION: Prevalent Job Types in Washington Industry, 1,164 Workers

(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Production	27.2%	First-line production supervisors, inspectors, welders
Construction	15.8%	First-line construction supervisors, pipelayers, laborers
Office and Administrative Support	13.1%	Meter readers, customer service representatives, secretaries
Installation, Maintenance, and Repair	11.8%	Heating, air conditioning, and refrigeration mechanics; control and valve installers; small engine mechanics
Management	10.0%	Chief executives, computer systems managers, purchasing managers
Business Operation Specialists	8.3%	Market research analysts, purchasing agents, cost estimators
Architecture and Engineering	6.2%	Computer hardware engineers, engineering technicians, industrial engineers

Source: See Appendix 2.

TABLE 28

OIL AND GAS PIPELINE CONSTRUCTION AND TRANSPORTATION: Prevalent Job Types in Washington Industry, 1,137 Workers

(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Construction	51.5%	Construction equipment operators, construction laborers, pipelayers
Management	14.3%	Chief executives, construction managers, operations managers
Transportation, and Material Moving	10.6%	Truck drivers, crane operators, excavating and loading machine operators, laborers
Office and Administrative Support	6.7%	Production, planning, and expediting clerks, bookkeeping clerks, secretaries
Installation, Maintenance, and Repair	5.8%	Mobile equipment service technicians, millwrights, truck mechanics

Source: See Appendix 2.

TABLE 29
PETROLEUM BULK STATIONS: Prevalent Job Types in Washington Industry, 738 Workers
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Transportation, and Material Moving	41.8%	Truck drivers, laborers, cleaners of vehicles and equipment
Sales	18.0%	First-line sales supervisors, wholesale sales representatives, cashiers
Office and Administrative Support	15.6%	Customer service representatives, secretaries, shipping and receiving clerks
Installation, Maintenance, and Repair	7.7%	Truck mechanics, machinery maintenance mechanics, general maintenance and repair workers

Source: See Appendix 2.

TABLE 30
FOSSIL FUEL-BASED ELECTRIC POWER GENERATION: Prevalent Job Types in Washington Industry, 300 Workers
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Installation, Maintenance, and Repair	19.6%	Electrical and electronic repairers, electrical power line installers, industrial machine mechanics
Office and Administrative Support	16.5%	Customer service representatives, secretaries, accounting clerks
Architecture and Engineering	12.6%	Electrical engineers, civil engineers, engineering technicians
Management	12.3%	Computer system managers, purchasing managers, human resource managers
Production	11.7%	First-line production supervisors, power plant operators, inspectors
Computer and Mathematical Occupations	6.3%	Computer systems analysts, software developers, network administrators
Construction	5.3%	Construction laborers, electricians, construction equipment operators
Business Operation Specialists	5.3%	Purchasing agents, training and development specialists, and compliance officers

Source: See Appendix 2.

TABLE 31
OIL AND GAS EXTRACTION, COAL MINING AND SUPPORT ACTIVITIES:
Prevalent Job Types in Washington Industry, 153 Workers
(Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Extraction	34.1%	Derrick operators, rotary drill operators, mining machine operators
Installation, Maintenance, and Repair	18.0%	Truck mechanic, mobile equipment service technician, industrial machinery mechanics
Managers	11.0%	Chief executives, construction managers, sales managers
Architecture and Engineering	9.9%	Petroleum engineers, geological engineers, engineering technicians
Construction	8.4%	Construction supervisors, construction equipment operators, electricians

Source: See Appendix 2.

currently employed in these industries. Thus, with the two largest statewide employers in the fossil fuel industries, petroleum refining and natural gas distribution, the largest proportion of jobs is in production. In petroleum refining, 37 percent of all industry jobs—about 700 jobs in total—are in production, including first-line supervisors, plant and systems operators, as well as mixing and blending machine setters. With natural gas distribution, production workers account for 27 percent of all employment, amounting to about 315 jobs. With oil and gas pipeline construction and transportation, over 50 percent of the jobs—totaling about 650 jobs—are in construction alone, with management jobs being the second largest category, with 14 percent of all jobs.

Overall, from the data presented in Tables 26 – 31, we see that there are a large number of jobs that match up well with new types of employment that will be generated through clean energy investments in Washington State. But that obviously will not be the case with *all occupations* in which workers are now employed in Washington State's fossil fuel related industries. As such, any Just Transition program to support displaced workers in Washington's fossil fuel related industries will need to be focused on the specific background and skills of each of the impacted workers. We now turn to considering the specific dimensions and features of such a Just Transition program.

Features of a Just Transition Program

The issue on which we now focus is creating a Just Transition—i.e., how best to protect the well-being of the workers and communities that will be affected by the contraction of Washington State's fossil fuel related industries. There will be four factors to consider. These are:

1. Guaranteeing the pensions for the workers in affected industries who will retire up until the year 2035;
2. Providing an adequate "glide path" to retirement for workers who are laid off near the age at which they would have normally retired;

3. Providing adequate levels of income, retraining, and relocation support for younger workers facing displacement—i.e. those workers who are not at or near retirement age. Among this group of younger workers, we must give consideration both to those who are able to move into new employment opportunities and to those who do not obtain new jobs. These measures would assume that there are no job guarantees incorporated into the Just Transition program.
4. Considering these same programs of support for younger workers within a framework in which workers are also guaranteed reemployment.

We consider the distinct issues with respect to providing support for heavily impacted communities in Section 9 below.

To translate these general principles of a Just Transition for fossil fuel industry related workers into specific policies, and to estimate costs of providing these policies, we now examine two alternative sets of policy packages. Each of the "policy packages" includes detailed policy measures, at varying levels of support. We present these alternative policy measures in Table 32.

As we see in Table 32, both policy packages include five components. These are:

1. Pension guarantees for retired workers, starting at age 65;
2. A glide path to retirement for workers ages 60 – 64;
3. Retraining to assist younger workers to obtain the skills needed for a new job and wage insurance for these workers after they obtain a new job. With wage insurance, workers are guaranteed that their total compensation in their new job will be supplemented to reduce any losses relative to the compensation they received working in the fossil fuel based industry[25];

TABLE 32
Alternative Policy Packages for Laid Off Workers
Differences between packages in italics

	Policy Package 1	Policy Package 2
Pension guarantees for retired Workers	Legal pension guarantees	Legal pension guarantees
Glide path to retirement for Workers 60 – 64 years old	100% wage replacement for five years	100% wage replacement for five years
Retraining and wage insurance after reemployment for workers < 59 years old	- 2 years training cost at $4,100/year - 100% wage replacement while training ($150,000/year) *- 4 years wage insurance for reemployed capped at $10,000/year*	- 2 years training cost at $4,100/year - 100% wage replacement while training ($150,000/year) *- 5 years full wage insurance ($71,000/year)*
Immediate reemployment with wage insurance	*4 years wage insurance capped at $10,000/year*	*5 years of full wage insurance ($71,000/year)*
Wage replacement with no reemployment	*Up to 20 years of wage replacement with schedule:* *- Years 1 – 4: 100% replacement* *- Years 5 – 8: 90% replacement* *- Years 9 – 12: 80% replacement* *- Years 13 – 16: 70% replacement* *- Years 17 – 20: 60% replacement*	*Up to 10 years of wage replacement with schedule:* *- Years 1 – 2: 75% replacement* *- Years 3 – 6: 66.7% replacement* *- Years 7 – 10: 50% replacement*

4. Wage insurance for workers who are immediately reemployed; and
5. Wage replacement for workers who do not become reemployed.

Pension guarantees and glide paths to retirement. Table 32 shows the detailed levels of support that we examine within each of the policy packages. As we see, under both policy packages, we include both pension guarantees for retired workers and a glide path to retirement for workers between ages 60 – 64. The level of glide path support is identical for workers in both packages—i.e. 100 percent compensation replacement for five years.

Retraining, wage replacement and wage insurance for younger workers. We then consider somewhat different measures in the areas of compensation insurance for workers who are laid off. In both policy packages, we allow for workers receiving two years of training support, at $4,100 per year. This figure is the average level of tuition for community colleges in Washington State. We also allow that workers will receive 100 percent compensation replacement over their two years of retraining. We assume this figure to be $150,000, which is the average compensation figure for all 5,411 workers now employed in all the Washington State fossil fuel related industries. The difference between the two packages in this category of support is that, in Policy Package 1, workers receive compensation insurance in their new jobs that continues for four years and is capped at $10,000 per year. Under Policy Package 2, there is no cap to the compensation insurance, and the workers receive this insurance for 5 years. When there is no cap to the compensation insurance, we assume that the average worker will receive $71,000 per year for five years. This figure is the difference between the average pay in Washington State's fossil fuel industries versus the average pay in the state's public sector jobs.

Wage insurance for workers who are immediately reemployed. The two policy packages again differ here according to the level of support provided for younger workers who are immediately reemployed—i.e. workers who do not spend two years in training for new jobs. Again, in Policy Package 1, the workers receive four years of support, capped at $10,000 per year; and in Policy Package 2, they receive five years of full compensation insurance.

Wage Replacement for workers who are not reemployed. As we see in Table 32, there are significant differences in the details being proposed in the two policy packages. In particular, in Policy Package 1, workers are provided with up to 20 years of wage replacement, while in Policy Package 2, they receive up to 10 years only. The level at which wages are replaced also differs between the two packages.

Employment guarantees. Of course, if younger workers are guaranteed a new job after having experienced displacement, the only policy measures that would be relevant to them would be either the retraining and wage replacement options, assuming they pursued retraining; or the immediate reemployment with wage insurance option. We will therefore consider possible ways to provide employment guarantees as part of either policy package as a concluding issue within this discussion.

We will provide cost estimates for each of these measures within both policy packages. But before moving into the discussion of these cost estimates, it is first necessary to understand how any such policy measures will be affected by the conditions under which the fossil fuel industry contraction occurs in Washington State. Specifically, the scope and cost of any set of Just Transition policies will depend heavily on two sets of considerations. These are:

Steady versus episodic industry contraction through 2035. Under a pattern of steady contraction, there will be uniform annual employment losses between 2021 – 2035 in the affected industries. That is, given that a total of 2,164 jobs will need to be cut from the affected industries between 2021 – 2035, this means that a total of 144 jobs will need to be cut every year (i.e. 2,164 jobs lost/15 years = 144 jobs lost per year). Under such a steady pattern of industry contraction, the focus of the Just Transition program will need to be on addressing the concerns of the 144 workers per year whose jobs will have been cut.

But it is not realistic to assume that the pattern of industry contraction will always proceed at a steady rate. An alternative pattern would entail relatively large episodes of employment contraction, followed by periods in which no further employment losses are experienced. This type of pattern would occur if, for example, one or more relatively large firms were to undergo large-scale cutbacks at one point in time as the industry overall contracts, or even for such firms to shut down altogether. To capture this sort of episodic industry contraction, we assume that, of the 2,164 total jobs that will be lost between 2021 – 2035, one-third of the jobs, or 721 jobs, will be lost, respectively, in the years 2021, 2026 and 2031. There would then be no additional job losses occurring in any of the remaining years between 2021 – 2035.

In reality, the rate at which Washington State's fossil fuel industries decline between 2021- 2035 is likely to proceed somewhere in between being either reliably steady or strictly episodic. But providing cost estimates of both the steady and episodic patterns of contraction will provide a clear range for the costs that will emerge over the actual transition process.[26]

Job losses are distributed to either older or younger workers first. Typically, when a significant employment contraction occurs with either an individual firm or an industry, the jobs of the workers with the most seniority are protected, with job losses mostly absorbed by younger workers. We do consider this typical pattern in what follows. But we also consider an alternative scenario, in which job losses are borne first by the older workers. This becomes a viable Just Transition strategy as long as: 1) All workers' pensions are fully guaranteed for them when they reach age 65; and 2) workers who are between ages 60 – 64 have the option, once they are laid off due to the industry contraction, of continuing to receive their full compensation through the glide-path to retirement policy.

In what follows, we show how these factors will play out in calculating the costs of a viable Just Transition program.

Just Transition Policies under Steady Employment Contraction

In Table 33, we show figures on annual employment reductions in fossil fuel production and ancillary industries that would result from a 40 percent contraction in fossil fuel production activities in Washington State, *assuming that contraction proceeds steadily over the 15-year period 2021 – 2035*. That is, starting with the present level of overall employment in the relevant industries of 5,411, we show how the distribution of 2,164 job losses will proceed between 2021 – 2035, assuming that the job contractions occur on a steady basis every year between 2021 – 2035—i.e. that, across all the relevant industries, a total of 144 jobs are lost every year.

The columns in Table 33 list all eight industries in Washington State that will be affected by the 40 percent contraction in fossil fuel consumption and production in the state. The industries are listed according to their current level of employment. Thus, petroleum refining is listed first in the columns, since its current employment level of 1,918 workers represents, by itself, 35 percent of all fossil fuel related employment in the state.

In the rows of Table 33, we show the calculations through which we estimate employment losses in each of the affected industries. We also then show the proportion of workers who will move into retirement at age 65 by 2035.

Once we know the share of workers who will move into voluntary retirement at age 65, we can then estimate the number of workers who will be displaced through the industry-

TABLE 33
Attrition by Retirement and Job Displacement for Younger Workers through 40 Percent Contraction of Fossil Fuel Sector Activity in Washington State

	1. Petroleum Refining	2. Natural Gas Distribution	3. Oil and Gas Pipeline Construction and Transportation	4. Petroleum Bulk Stations and Terminals	5. Fossil Fuel Electric Power Generation	6. Support Activities for Oil and Gas	7. Coal Mining	8. Oil and Gas Extraction	TOTALS
1) Current employment, total	1,918	1,164	1,137	738	300	87	60	7	5,411
2) Job losses over 15-year transition *(= row 1 x 0.4)*	767	466	455	295	120	35	24	3	2,164
3) Average annual job losses over 15-year production decline *(= row 2/15)*	51	31	30	20	8	2	2	0	144
4) Number of workers between 50 – 65 over 2021 – 2035	864	638	468	363	172	35	33	4	2,577
(= row 1 x % of workers 45 and over between 2015 – 2035)	(45% of all workers)	(55% of all workers)	(41% of all workers)	(49% of all workers)	(57% of all workers)	(40% of all workers)	56% of all workers)	(52% of all workers)	(48% of all workers)
5) Number of workers per year reaching 65 during 15-year transition period *(= row 4/15)*	58	43	31	24	11	2	2	0	171
6) Number of workers requiring reemployment *(= row 3 – row 5)*	0	0	0	0	0	0	0	0	0

Source: See Appendix 3.

wide contraction. As described above, the Just Transition program will provide support for all displaced workers through wage replacement, retraining, and relocation support, and perhaps a reemployment guarantee as an additional option.

Our approach to estimating the number of workers both moving into retirement and facing displacement is clear through considering the figures in Table 33 on the petroleum refining industry in column 1. As we see again, at present there are 1,918 workers in Washington State employed in petroleum refining. We assume that this industry will face a 40 percent contraction in 2035 relative to its 2014 production level. As we see in row 2 of the table, this means that total employment in the industry will fall by 40 percent, i.e. that 767 jobs will be lost. That means that 1,151 jobs will be retained in the state's petroleum industry as of 2035. If we then assume that the contraction in the industry proceeds at a steady rate between 2021 – 2035, this means that 51 jobs in the industry will be lost each year, as we see in row 3 (i.e. 767 job losses in total/15 years of industry contraction = 51 job losses per year).

We see in row 4 that, of the workers presently employed in petroleum refining in Washington State, 864, or 45 percent, will be between 50 – 65 years old between 2021 – 2035. If these workers retire at a steady rate over 2021 – 2035, this means that 58 workers will move into retirement every year over the 15-year period.

Given that total job losses each year will average 51 over the 2021 – 2035 period, that in turn means that there will be a larger number of workers (58 workers) moving into voluntary retirement each year than there will be job losses in petroleum refining each year (51 jobs). Thus, we show in row six of Table 33 that the number of workers in petroleum refining that will require reemployment will be *zero*.

This is a critical result. The point it conveys is that, under a steady pattern of job contraction in Washington State's petroleum refining industry to reach a 40 percent job cut as of 2035, the Just Transition program will only need to make certain that pensions are guaranteed for the 58 workers per year who move voluntarily into retirement at age 65. Beyond the 58 workers per year moving voluntarily into retirement, there will be no workers who will experience displacement, since only 51 jobs will be lost in the industry each year under the steady pattern of contraction between 2021 – 2035.

We show the equivalent patterns for the other seven fossil fuel production and ancillary industries in columns 2-8 of Table 33. As we see in row six of this table, the main result that we found for the petroleum refining industry holds equally for all the other fossil fuel related industries in Washington State. That is, for all of these industries, the number of workers who will move into voluntary retirement at age 65 between 2021 – 2035 will be greater than the average annual job losses in the respective industries over this same period. As such, we can reach the general conclusion that, to the extent that Washington State would experience a *steady* rate of job contraction in fossil fuel related industries between 2021 – 2035 as part of a clean energy transition project—that is, a pattern of contraction in which average annual job losses will be 144 jobs while an average of 171 workers per year will voluntarily move into retirement from these industries—the *only* Just Transition policy that will be needed to assist individual workers will be to guarantee the pensions for the workers moving into retirement.

Pension Guarantees for Retiring Workers

What becomes clear from the evidence on the steady rate of contraction for Washington State's fossil fuel related industries is that guaranteeing workers' pension funds must be a centerpiece of the state's overall Just Transition program. This is especially important, given that the fossil fuel dependent industries will be contracting over 2021 – 2035. They will likely face financial challenges as a result.

In Table 34, we review the status of the pension funds for the firms currently operating in Washington State in all of the major relevant industries—i.e. petroleum refining, natural gas distribution, pipeline construction and transportation, petroleum bulk stations and electric power generation. These industries employ 97 percent of all fossil fuel related workers in Washington State. The table shows the names of the 10 firms operating in Washington State as well as, in parentheses, these firms' parent companies, where applicable. The table shows the extent to which firms are carrying unfunded pension liabilities as of 2013. We also show their net income level, as well as their allocation of funds for stock buybacks and dividends between 2013 - 2015.

TABLE 34
Status of Pension Funds and Overall Financial Conditions for Fossil Fuel Related Firms Operating in Washington State, 2013 – 2015
(Parent Companies in Parentheses)

	Unfunded pension liabilities, 2013	Net income, 2013-2015	Dividends, 2013-2015	Share buybacks, 2013-2015
1. BP West Coast Products (BP PLC)	$366 million	$21.4 billion	$18.0 billion	$9.9 billion
2. Centralia Power Plant (TransAlta Corp.)	0 (overfunded by $1 million)	$259 million	$285 million	0
3. Chevron Corp.	$908 million	$45.6 billion	$23.4 billion	$9.1 billion
4. Enbridge Inc.	$6 million	$1.5 billion	$1.8 billion	0
5. Kinder Morgan Inc.	0 (overfunded by $29 million)	$5.3 billion	$7.6 billion	$8.4 billion
6. Northwest Pipeline Group (Williams Companies)	$130 million	$1.7 billion	$4.2 billion	0
7. Phillips 66	$176 million	$12.8 billion	$3.0 billion	$5.7 billion
8. Shell Oil Products (Royal Dutch Shell)	0 (overfunded by $318 million)	$33.5 billion	$26.0 billion	$8.7 billion
9. Tesoro West Coast (Tesoro Corporation)	0	$3.0 billion	$768 million	1.6 billion
10. Transcanada, Gas Transmission NW (Transcanada Corp.)	0 (overfunded by $9 million)	$2.1 billion	$3.1 billion	$221 million

Sources: See Appendix 4.

To begin with, all of the 10 firms have defined benefit pension programs for their workers. Of these 10 firms, 5 were operating with unfunded liabilities as of 2013. The other 5 firms either have no unfunded liabilities or are overfunded.

With the five firms carrying unfunded liabilities as of 2013, in all of the cases, the unfunded liabilities are quite modest relative to the firms' income levels, or the funds they are channeling into either dividends or stock buybacks.

For example, Chevron Corporation was operating with the largest unfunded liability among these firms, with a $908 million liability in 2013. But Chevron received $45.6 billion in net income over 2013-15, an amount exceeding the firms' 2013 liability roughly 50 times over. Even Chevron's stock buybacks over 2013-15 of $9.1 billion was 10 times greater than their 2013 unfunded pension liability. BP West Coast Products had the next largest unfunded pension liability in 2013, of $366 million. In this case, the parent company's net income over 2013-15 was $21.4 billion, nearly 60 times more than its 2013 unfunded liability. The company's share buybacks were $9.9 billion, 27 times the amount of their 2013 unfunded liability.

Overall, as of the most recent 2015 data, all of the 10 fossil fuel related firms operating at a large scale in Washington State are fully capable of honoring their pension fund commitments. At the same time, under Washington State's clean energy investment project, these firms will need to contract their operations in the state in the range of 40 percent as of 2035. Under these circumstances, we cannot expect these firms to replenish their pension funds between 2021 – 2035 as a matter of course. To the maximum legal extent, state government policy will therefore have to mandate full funding, in coordination with the federal Pension Benefit Guarantee Corporation (PBGC). One way to enforce this would be to prohibit the relevant companies from paying dividends or financing share buybacks unless their pension funds are maintained at full funding. As needed, the state government, again in coordination with the PBGC, will need to place liens on company assets when pension funds are underfunded. Through such measures, the pension funds for the affected workers in the state can be protected through regulatory intervention alone, without the government having to provide financial infusions to sustain the funds.

At the same time, it is possible that there could be individual cases in which one or more of the firms do experience serious financial crises in the future, especially given the fact that the market for their products will be contracting substantially through 2035 and beyond. As a roughly comparable case in point, some coal companies operating in other U.S. states do now already face critical conditions with their pension funds, due to cutbacks in U.S. coal demand. Under such conditions, the pension commitments to the affected workers, in coal nationally as well as all fossil fuel and ancillary industries in Washington State, will still need to be fully honored.

In addressing the crisis with coal industry pensions, in its 2016 budget proposal, the Obama administration advanced a measure to support these pensions, under its "Power Plus" program that aimed broadly to support coal communities and workers. This proposal was blocked in the U.S. Congress by the Republican majority. But the broader point is that such a measure must be understood as a centerpiece for any Just Transition program for Washington State. Given the absence of a funding crisis at present, we are not proposing here a level at which such a program may need to be financed in the future. But such an insurance-type policy should be a measure that deserves careful attention in ongoing work to develop the specifics of a Washington State Just Transition program.

Further Just Transition Policies with Episodic Employment Contractions

Of course, in the real world, we cannot assume that the rate of job contraction over the 15-year period 2021 – 2035 will necessarily be steady. This is why we now consider an alternative scenario, in which job losses in the eight affected fossil fuel and ancillary industries in Washington State will occur in three large episodes. With the total number of job losses that will need to occur by 2035 remaining at 2,164, we now assume that one-third will be lost in 2021, a second third will be lost in 2026 and the final set of losses will occur in 2031. In other words, there will be a combined total of 721 jobs lost in the eight fossil fuel related industries in Washington State in each of the years 2021, 2026 and 2031. We assume that no job losses will occur in any other year over this 15-year time span.

The issue we now explore is how the Just Transition policies—including pension guarantees, wage replacement, retraining and relocation support, along with perhaps a reemployment guarantee—would be affected by such an episodic rate of employment losses. In fact, the effect on Just Transition policies will depend on whether job losses are experienced first by older or younger workers. We show below the results that will follow from either pattern of age-related layoffs.

Cost Estimates of Just Transition Packages under Episodic Contraction

In Tables 35 and 36, we present figures on two specific scenarios under an episodic pattern of layoffs. That is, we are considering the pattern of layoffs when 721 workers in total would be laid off in 2021, and that the policies provided to support these 721 workers include:

- Pension guarantees for workers 65 and older;
- A glide path to retirement for workers between 60 – 64 years old;
- The package of retraining and wage replacement, then wage insurance after reemployment for workers who are 59 years old and younger.

We report on the costs of these three policy measures, assuming, first in Table 35, that oldest workers are laid off first; then in Table 36, that youngest workers are laid off first. We are also first estimating these costs under Policy Package 1. For this case—in which workers receive 2 years of retraining and wage replacement, followed by 4 years of wage insurance after obtaining a new job—what is distinct about Policy Package 1 relative to Package 2 is that younger workers will receive 4 years of wage insurance after being reemployed, with the wage insurance capped at $10,000 per year. This provision under Package 1 is much more modest than under Package 2, in which workers receive 5 years of wage insurance after obtaining a new job, with the amount of the wage insurance uncapped for the full five years.

As we see first in Table 35, in which we assume oldest workers are laid off first, of the total of 721 job losses that will occur in this episode, 108 workers will be 65 or older. These workers will begin receiving their guaranteed company-based defined benefit pensions after being laid off. As discussed earlier, these pensions will be guaranteed by law. There will be no public budgetary impact to guaranteeing these pensions for the 108 workers, other than any possible modest administrative costs of enforcing the pension guarantee regulations.

TABLE 35

Policy Package 1: Oldest Workers Laid Off First

Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Retraining and 100% Wage Replacement (2 years);
  - Wage Insurance after Reemployment, Capped at $10,000 (4 years)

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	433	Glide Path to Retirement	$450,000*
59 and less	180	Retraining, wage replacement and wage insurance package	$348,200

Sources: See Appendix 3.
Notes: *This figure is equal to $150,000 x 3 years, since we assume the average worker in this age range would be about 3 years away from reaching age 65.

As we further see in Table 35, an additional 433 workers between the ages of 60 – 64 will then also be laid off. Each of these 433 workers will receive the glide path to retirement support program. That is, each of these 433 workers will receive 100 percent of their wages until they reach the retirement age of 65, at which point they will begin receiving their pensions. As we see in Table 35, we estimate that the average cost per worker of this glide path support will be about $450,000 per worker. This assumes that the average compensation per worker is $150,000 per year, and that these workers will receive an average of three years of glide-path support.

As we see in Table 35, when the 108 workers who are 65 or older and the 433 workers who are between 60 – 64 years old are laid off, that totals to 541 workers. This means that an additional 180 workers will still need to be laid off to bring total layoffs to 721. These additional 180 layoffs will have to come from workers who are 59 years old or younger. We calculate that the costs of providing each of these workers with 2 years training; 100 percent wage replacement during these 2 years of training; plus 4 years of wage insurance subsequently; will cost an average of $348,000 per worker.

In Table 36, we proceed through the same set of calculations as in Table 35, with the one difference being that, in Table 36, youngest workers are laid off first, not the oldest workers. Thus, as we see in Table 36, 721 workers are laid off in 2021. In addition, of that total, the first group of layoffs are again the 108 workers who are 65 and older. But, in this case, the workers who are 60 – 64 experience no layoffs. That means to get 721 layoffs in total, 613 of the youngest workers will have to be laid off. Each of these workers will then receive the Policy Package 1 set of benefits. Again, these include: 2 years of retraining; 100 percent wage replacement during the retraining period; and 4 years of wage insurance thereafter, capped at $10,000 per year. Again, this package of benefits averages $348,000 per laid off worker.

TABLE 36
Policy Package 1: Youngest Workers Laid Off First
Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Retraining and 100% Wage Replacement (2 years);
  - Wage Insurance after Reemployment, Capped at $10,000 (4 years)

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	0	Glide Path to Retirement	$0
59 and less	613	Retraining, wage replacement and wage insurance package	$348,200

Sources: See Appendix 3.

In Table 37, we show estimates of the full costs of providing this set of Just Transition benefits each year between 2021 – 2036. We show these figures under both the assumption that oldest workers are laid off first and, alternatively, that youngest workers are laid off first.

As Table 37 shows, the total level of spending will vary considerably every year, depending on whether there was a layoff episode in that year, in which 721 workers faced layoffs. For example, in 2021, the total cost of supporting all laid off workers under the Just Transition program will be $93 million when oldest workers are laid off first, and $95 million when youngest workers are laid off first. But by 2024, the total costs will be only $1.8 million when oldest workers are laid off first, and $6.1 million when youngest workers are laid off first.

We also show the average costs per year over a 15-year period in the last row of Table 37, including the three years of episodic layoffs, 2021, 2026, and 2031; as well as the years in between in which no layoffs occur. As we see, the average annual costs will be about $58 million per year when oldest workers are laid off first, and $43 million when youngest workers are laid off first.

In Table 38, we present our estimates for each of the alternative set of Just Transition scenarios under Policy Package 1—in which older workers are laid off first (column 1) and then in which younger workers are laid off first (column 2). We then add one more possible variation in the scenarios that also impacts costs: in rows 1-3, we show cost estimates that result from the different combination of benefits that workers would receive depending on the pace at which displaced workers find new jobs—after retraining (row 1), immediately with no retraining (row 3), or in the case where displaced workers do not find new jobs and remain unemployed (row 2). In row 4 of Table 38, we present the cost estimates assuming now that 1/3 of displaced workers retrain and find new jobs, another 1/3 find new jobs right away with no retraining, and the final 1/3 remain unemployed.

In Table 39, we provide the same set of estimates, based on the assumptions of Policy Package 2. In Appendix 3, we provide the full set of calculations through which we derive all the figures reported in Tables 38 and 39.

TABLE 37
Policy Package 1: Annual Costs of Providing Just Transition Support, 2021 - 2036

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Retraining and 100% Wage Replacement (2 years);
  - Wage Insurance after Reemployment, Capped at $10,000 (4 years)

	Oldest Workers Laid Off First (millions, 2015 dollars)	Youngest Workers Laid Off First (millions, 2015 dollars)
2021	$92.7	$94.5
2022	$92.7	$94.5
2023	$66.8	$6.1
2024	$1.8	$6.1
2025	$1.8	$6.1
2026	$111.0	$103.8
2027	$109.2	$97.7
2028	$72.9	$6.3
2029	$2.5	$6.3
2030	$2.5	$6.3
2031	$111.1	$97.4
2032	$108.6	$91.1
2033	$93.2	$5.9
2034	$1.1	$5.9
2035	$1.1	$5.9
2036*	$1.1	$5.9
TOTAL	$869.9	$640.0
Average Costs per Year (= Total costs/15 years)	$58.0	$42.7

Source: See Appendix 3.
Note: Workers laid off in 2031 and will receive benefits for a total of 6 years, i.e., through 2036.

As we can see in Table 38, the average annual total cost figures range widely. Under Policy Package 1, the costs range between $4.9 million and $294 million per year. The reason for this large difference in average annual costs under Policy Package 1 is due to the difference generated through assuming workers are reemployed immediately after being laid off (the $4.9 million cost figure); or, alternatively, the workers do not find a new job at any point after being laid off (the $294 million cost figure).

In Table 39, we report on the average annual costs of the full Just Transition program under the alternative set of assumptions with Policy Package 2. As we see, under Policy Package 2, the full range of average annual costs is much narrower than with Policy Package

TABLE 38
Total Average Annual Costs under Policy Package 1 With Alternative Benefit Packages

Benefit Packages	Oldest Workers Laid Off First	Youngest Workers Laid Off First
- Pensions - Glide Path for age 60+ workers - Retraining with wage replacement for 2 years - Wage insurance after reemployment	$58.0 million	$42.7 million
- Pensions - Glide Path for age 60+ workers - Support for unemployed workers assuming no reemployment	$81.6 million	$294.1 million
- Pensions - Glide Path for 60+ workers - Workers receive wage insurance with immediate reemployment	$46.9 million	$4.9 million
Costs of Combining Alternative Policy Packages—1/3 of workers receive one form of policy support: - Retraining, wage replacement, wage insurance with reemployment - Unemployment benefits with no reemployment - Wage insurance after moving to new job = (rows 1+2+3)/3	$62.2 million	$113.9 million

Source: See Appendix 3.

TABLE 39
Total Average Annual Costs under Policy Package 2 With Alternative Benefit Packages

Benefit Packages	Oldest Workers Laid Off First	Youngest Workers Laid Off First
- Pensions - Glide Path for age 60+ workers - Retraining with wage replacement for 2 years - Wage insurance after reemployment	$69.3 million	$81.3 million
- Pensions - Glide Path for age 60+ workers - Support for unemployed workers assuming no reemployment	$70.6 million	$113.4 million
- Pensions - Glide Path for 60+ workers - Workers receive wage insurance with immediate reemployment	$58.2 million	$43.5 million
Costs of Combining Alternative Policy Packages—1/3 of workers receive one form of policy support: - Retraining, wage replacement, wage insurance with reemployment - Unemployment benefits with no reemployment - Wage insurance after moving to new job = (rows 1+2+3)/3	$66.0 million	$79.4 million

Source: See Appendix 3.

1. The lowest average annual costs under Package 2 are $44 million and the highest average annual costs are $113 million. There are two reasons for the narrower range of costs under Policy Package 2. The first is that, under Package 2, workers who are reemployed receive much more generous wage insurance benefits than under Package 1—i.e. uncapped benefits for five years, which we estimate will amount to, on average, about $71,000 per year, as opposed to the capped $10,000 per year of wage insurance under Package 1. But alternatively, under Package 2, workers who do not obtain a new job will receive a more modest set of benefits than under Package 1—i.e. 10 years of wage replacement, as opposed to 20 years under Package 1; and the amount of the wage replacement is also lower than under Package 1 (the details of the differences, again, are shown in Table 32).

Full Cost Range: Steady and Episodic Contractions Combined

It is important to emphasize that these average Just Transition cost estimates presented in Tables 38 and 39 are based on the specific assumptions we have made as to the path of employment contraction for Washington State's fossil fuel related industries. That is, these cost estimates assume that the pattern of contraction will be strictly episodic. Specifically, we assume that over the full period 2021 – 2035, there will be three years—2021, 2026, and 2031—in which 721 workers will be laid off. As such, total layoffs will reach 2,164 by 2035—that is, the 40 percent employment contraction in all fossil fuel related industries in Washington State relative to the 2014 employment level in these industries of 5,411. As of 2035, as noted earlier, these fossil fuel related industries in Washington State will therefore still employ 3,247 workers.

To keep these cost estimates based on an episodic rate of contraction in full perspective, it is equally important to also recall that, if the employment contraction from 5,411 down to 3,247 workers proceeds *at a steady rate* between 2021 – 2035, the public-sector costs of the Just Transition program will be *zero,* other than administrative expenses of regulating private pension funds. As we saw in Table 33, this is because the average annual rate of employment contraction between 2021 – 2035 will need to be 144 jobs per year in order to shed a total of 2,164 jobs over the full 15-year period. Over that same 15-year period, we estimate that there will be 171 voluntary retirements per year at age 65 among the fossil fuel related industry workers in Washington State.

There is obviously a huge difference between a Just Transition program which entails only modest administrative costs to regulate private pension funds versus spending $60 - $100 million per year, or perhaps even more, depending on which policy package is in place, and how many workers are eligible for each of the features of the various policy packages.

It is simply not possible to know in advance what the actual pattern of employment contraction is most likely to be over 2021 – 2035, as Washington State reduces its CO_2 emissions by 40 percent. Probably the most reasonable assumption is that the actual path of contraction will entail periods of steady annual job losses which are then punctuated by sporadic periods of larger annual losses. This kind of pattern—alternating periods of steady contraction with occasional episodes of large-scale losses—would suggest that the actual average cost range for the Just Transition program is probably around $30 - $40 million per year. This $30 - $40 million range would be about half of the amount that we estimate for the episodic pattern of job losses, in which we combined the alternative features of both Policy Packages 1 and 2—that is, the figures that we report in row 4 of Tables 38 and 39.

Prospects for a Reemployment Guarantee

As we have seen, the costs of providing Just Transition support to all Washington State fossil fuel related industry workers during the 2021 – 2035 period of employment contraction will vary widely. This wide variation depends on whether, and how quickly, displaced workers become reemployed. For example, as we saw in Table 38, the average annual total costs of Just Transition policies under Policy Package 1 ranges between $4.9 million and $294 million. The total costs average $4.9 million when displaced younger workers are immediately reemployed, with no older workers experiencing layoffs. In this situation, the only Just Transition program costs will be for wage insurance for younger workers in their new jobs. By contrast, the total Just Transition costs balloon to $294 million under the assumption that younger workers who face displacement do not find a new job over a 20-year period. Under Policy Package 1, each of these younger workers therefore would be eligible to receive 20 years of wage replacement, starting at 100 percent replacement in years 1-4 after losing their fossil fuel industry job, then falling to 60 percent replacement in years 17 – 20 after losing their job.

Both for controlling the costs of the Just Transition program and for supporting the well-being of the displaced workers, it is clearly a more desirable option that displaced workers get reemployed as quickly as possible. One way to ensure that this would happen would be to include a *reemployment guarantee* for all workers who are displaced through the state's clean energy transition.

This reemployment guarantee could be provided in coordination with two employment pools within Washington State. The first would be with the new jobs created through investments in energy efficiency and clean renewable energy in Washington State. As we saw in Table 17 above, if the public and private sectors in Washington State do in fact combine to generate roughly $6.6 billion per year in clean energy investments—i.e. the level of annual investments needed for the state to reach a 40 percent emissions reduction by 2035—that should create between about 35,000 – 40,000 jobs per year in the state. With the investments that are either public projects or private projects subsidized by public funds, the state could require that the recipients of the public funds commit to giving preference in hiring to the workers displaced by fossil fuel industry layoffs. Such a commitment should not be burdensome for the clean energy investment projects, since the number of displaced workers in any given year between 2021- 2035 will almost certainly be well below 1,000, and probably well below 100 in most years—perhaps even zero in many years, depending on whether the industry contraction is relatively steady or episodic.

A second pool of job opportunities would be within Washington State's overall public sector. As of 2014, Washington State employed 59,000 people. With an ongoing employment pool of this size, it should not be difficult to find new opportunities for displaced fossil fuel industry workers. This would be, again, assuming that the number of displaced workers in any given year will almost certainly be well below 1,000, and probably closer to 100 or less in most years.

In Tables 20 – 22 and 26 – 31 above, we presented the profiles of prevalent job types that would be created through clean energy investments and within the existing fossil fuel related industries. From these data, we can conclude that there should be reasonably close job matches for displaced workers in a wide range of areas. This is certainly true for most administrative and office-type jobs, as well as many of the construction and manufacturing industry jobs. But it is also the case that a significant share of displaced workers will require retraining, which will be provided through the Just Transition program. In addition, the Just Transition program will also need to provide active job placement support for all displaced workers, regardless of their previous work experience.

9. A CLEAN ENERGY INVESTMENT POLICY AGENDA

We have seen in Section 6 that, for Washington State to achieve a 40 percent reduction in CO_2 emissions by 2035 relative to 2014—i.e. from an overall level of emissions of 73.4 to 44 million tons—the state's economy will need to invest an average of $6.6 billion per year to both dramatically raise the state's energy efficiency standards and to equally dramatically expand the available supply of clean renewable energy. This figure amounts to about 1.2 percent of Washington State's average GDP between 2021 – 2035, assuming that the state's GDP grows by an average of 2 percent per year over that 15 year period.

In this section, we consider what would constitute an effective package of policies for reaching this overall investment level averaging $6.6 billion per year. As we have discussed above, we estimate that, at present, annual private investment in clean energy in Washington State amounts to roughly $1.5 - $2 billion per year. We are therefore proposing that overall clean energy investments will need to increase, on average, by three- to fourfold to achieve a 40 percent emissions reduction as of 2035.

We can divide the policy agenda according to four broad categories. These are:

Market-shaping taxes and regulations that take account of the social costs of burning fossil fuels as an energy source and help build demand for energy efficiency and clean renewable energy sources.

Direct public spending that includes investments in infrastructure, procurement and research and development (R&D).

Private investment incentives that lower the costs and risks for private investors for investments in energy efficiency and clean renewable energy sources.

Transitional support for regions, communities and workers facing cutbacks and job losses through the contraction of the fossil fuel industry.

In Section 8, we have already examined at length the issue of a Just Transition for workers facing displacement through the contraction of Washington State's fossil fuel industries. In this section, we therefore focus on the areas of regulation, public spending, private investment incentives, and transitional support for communities.

We emphasize at the outset that the majority of new investment spending will need to come from private investors. Carefully targeted public investments can serve both to complement and to help incentivize private investments. We also emphasize at the outset that Washington State already operates with a range of measures in most of the policy areas listed. These policy initiatives are presented regularly in the state's biennial *Energy Report and State Energy Strategy Update* documents. The most recent 2017 version of this report was published in December 2016 (Bonlender 2016). We are proposing that the state build on the existing foundation of policies described in this report and related studies in order to bring overall clean energy investments up three- to fourfold—from about $1.5 - $2 billion per year to about $6.6 billion per year. We will highlight here some of the primary policy measures that have been discussed or are already in place as the basis for achieving this clean energy investment goal.

Carbon Pricing

The best-known regulatory approach for reducing CO_2 and other greenhouse gas emissions is to establish a price on carbon that reflects the environmental costs of emissions. This can be done in two distinct ways—either through setting a firm limit on emissions—a carbon cap—or through establishing a carbon tax.

Depending on the specific design features of the policy, the cap or tax can be an effective tool supporting a large-scale transition out of fossil fuels and into energy efficiency and clean renewable energy investments. This policy can also generate large amounts of tax revenue. The revenue, in turn, can be used in part to help finance a clean energy investment project. Part of the funds will also be needed to support Just Transition policies as well as to return a share of the revenues back to taxpayers so that their living standards are not reduced through having to pay higher fossil fuel prices.

In October 2014, Governor Inslee created a Carbon Emissions Reduction Task Force that provided analysis and recommendations with respect to implementing a carbon tax in the state as well as other measures (Bonlender 2016, p. 30). The report was non-committal on the idea of a carbon tax or carbon cap.[27]

As with most policy interventions, both carbon taxes and carbon caps have strengths and weaknesses. There is a longstanding debate as to their relative merits. We do not delve into the debate here, but focus on the revenue prospects with a carbon tax, as opposed to a cap.[28]

Our specific aim is to provide estimates of the revenue that would be generated by a carbon tax, allowing for the tax rate to vary. Our estimates incorporate the key assumption of this study, which is that the level of CO_2 emissions in Washington State will decline by 40 percent, from its 2014 level of 73.4 million tons to 44 million tons as of 2035. Moreover, we assume that the clean energy program for the state is implemented in full only over the 15-year period, 2021 – 2035. We therefore assume that the carbon tax is implemented in 2021 and continues through 2035.

We provide revenue estimates for the carbon tax under four separate scenarios. In all cases, we are estimating the tax revenues over a 15-year cycle. We also assume under all scenarios that statewide CO_2 emissions fall by 40 percent, to 44 million tons, relative to their 2014 level of 73 million tons.

1. In Year 1, the tax rate begins at $15 per ton and remains at $15 per ton over the full 15-year period.
2. In Year 1, the tax rate begins at $15 per ton and rises steadily over the 15-year period to $75 per ton.
3. In Year 1, the tax rate begins at $25 per ton and remains at $25 per ton over the full 15-year period.
4. In Year 1, the tax rate begins at $25 per ton and rises to $75 per ton over the full 15-year period.

We see the full results of the calculations through these four scenarios in Tables 40A – 40D. The summary Table 41 provides a summary of the most pertinent information.

TABLES 40A – 40D: Revenue Generation through a Carbon Tax for Washington State

A) Tax Rate Flat at $15 per Ton over 15-Year Cycle

Year	Annual Emissions (millions of tons: assume emissions fall by 40% by year 15)	Carbon Tax Rate: Dollars per ton of CO_2 emissions	Annual Tax Revenue
Year 1	73.00	$15	$1.1 billion
2	70.93	$15	$1.1 billion
3	68.86	$15	$1.0 billion
4	66.79	$15	$1.0 billion
5	64.71	$15	$971 million
6	62.64	$15	$940 million
7	60.57	$15	$909 million
8	58.50	$15	$878 million
9	56.43	$15	$846 million
10	54.36	$15	$815 million
11	52.29	$15	$784 million
12	50.21	$15	$753 million
13	48.14	$15	$722 million
14	46.07	$15	$691 million
Year 15	44.00	$15	$660 million
ANNUAL AVERAGES	**58.5**	**$15**	**$878 million**

Sources: Figures based on table's assumptions.

B) Tax Rate Rises from $15 – $75 per Ton over 15-Year Cycle

Year	Annual Emissions (millions of tons: assume emissions fall by 40% by year 15)	Carbon Tax Rate: Dollars per ton of CO_2 emissions	Annual Tax Revenue
Year 1	73.00	$15.00	$1.1 billion
2	70.93	$19.29	$1.4 billion
3	68.86	$23.57	$1.6 billion
4	66.79	$27.86	$1.9 billion
5	64.71	$32.14	$2.0 billion
6	62.64	$36.43	$2.3 billion
7	60.57	$40.71	$2.5 billion
8	58.50	$45.00	$2.6 billion
9	56.43	$49.29	$2.8 billion
10	54.36	$53.57	$2.9 billion
11	52.29	$57.86	$3.0 billion
12	50.21	$62.14	$3.1 billion
13	48.14	$66.43	$3.2 billion
14	46.07	$70.71	$3.3 billion
Year 15	44.00	$75.00	$3.3 billion
ANNUAL AVERAGES	**58.5**	**$45.00**	**$2.5 billion**

Sources: Figures based on table's assumptions.

C) Tax Rate Flat at $25 per Ton over 15-Year Cycle

Year	Annual Emissions (millions of tons: assume emissions fall by 40% by year 15)	Carbon Tax Rate: Dollars per ton of CO_2 emissions	Annual Tax Revenue
Year 1	73.00	$25	$1.8 billion
2	70.93	$25	$1.8 billion
3	68.86	$25	$1.8 billion
4	66.79	$25	$1.7 billion
5	64.71	$25	$1.6 billion
6	62.64	$25	$1.5 billion
7	60.57	$25	$1.5 billion
8	58.50	$25	$1.5 billion
9	56.43	$25	$1.4 billion
10	54.36	$25	$1.4 billion
11	52.29	$25	$1.3 billion
12	50.21	$25	$1.3 billon
13	48.14	$25	$1.2 billion
14	46.07	$25	$1.2 billion
Year 15	44.00	$25	$1.1 billion
ANNUAL AVERAGES	**58.5**	**$25**	**$1.5 billion**

Sources: Figures based on table's assumptions.

D) Tax Rate Rises from $25 – $75 per Ton over 15-Year Cycle

Year	Annual Emissions (millions of tons: assume emissions fall by 40% by year 15)	Carbon Tax Rate: Dollars per ton of CO_2 emissions	Annual Tax Revenue
Year 1	73.00	$25.00	$1.8 billion
2	70.93	$28.57	$2.0 billion
3	68.86	$32.14	$2.2 billion
4	66.79	$35.71	$2.4 billion
5	64.71	$39.29	$2.5 billion
6	62.64	$42.86	$2.7 billion
7	60.57	$46.43	$2.8 billion
8	58.50	$50.00	$2.9 billion
9	56.43	$53.57	$3.0 billion
10	54.36	$57.14	$3.1 billion
11	52.29	$60.71	$3.2 billion
12	50.21	$64.29	$3.2 billion
13	48.14	$67.86	$3.3 billion
14	46.07	$71.43	$3.3 billion
Year 15	44.00	$75.00	$3.3 billion
ANNUAL AVERAGES	**58.5**	**$50.00**	**$2.8 billion**

Sources: Figures based on table's assumptions.

TABLE 41
Summary Results on Revenues for Alternative Washington State Carbon Tax Scenarios

	Year 1 Revenue	Total Revenue over 15-Year Cycle	Average Annual Revenue over 15-Year Cycle
Flat $15 per ton tax	$1.1 billion	$13.2 billion	$878 million
Flat $25 per ton tax	$1.8 billion	$21.9 billion	$1.5 billion
Tax escalates from $15 to $75 per ton over 15-year cycle	$1.1 billion	$37.0 billion	$2.5 billion
Tax escalates from $25 to $75 per ton over 15-year cycle	$1.8 billion	$41.8 billion	$2.8 billion

Source: Estimates from Tables 40A – D.

As Table 40A shows, if we begin with the lowest tax rate of a flat $15 per ton, the revenue generated by the tax will be approximately $1.1 billion in Year 1. By year 15, with emissions having fallen by 40 percent to 44 million tons, the flat $15 per ton tax will generate approximately $660 million. Average revenue over the full 15-year cycle under this scenario will be about $878 million.

As we see in the summary Table 41, revenues from the tax of course rise when we assume higher tax rates. Thus, when we assume that the tax escalates from $15 to $75 per ton over the 15-year cycle, the average annual tax revenue is $2.5 billion. With a flat $25 per ton tax rate for the 15-year cycle, the average annual revenue is $1.5 billion. Finally, when the tax begins at $25 per ton and rises to $75 per ton by the end of the 15-year cycle, the average annual tax revenue is $2.8 billion.[29]

Energy Efficiency and Renewable Energy Portfolio Standards

Washington State currently operates with both energy efficiency and renewable energy standards for the utilities operating in the state, as established by the Energy Independence Act. These standards have been broadly effective in both achieving efficiency gains and expanding the utilities' reliance on renewable energy sources.

With respect to efficiency gains, the *2017 Biennial Energy Report* states as follows, "Assuming the utilities meet their 2016-2017 targets as expected, the cumulative amount of energy saved will exceed 10 percent of the electricity delivered to customers in 2009, which is the last year before the law took effect," (p. 6). This 10 percent gain in efficiency over roughly 8 years (from 2009 to 2016-2017) is a notable accomplishment. However, to bring the state's overall emissions down by 40 percent as of 2035 will entail achieving a roughly 30 percent additional gain in overall efficiency relative to current levels of consumption—amounting to an annual rate of efficiency improvements of about 2.3 percent per year. This can be accomplished through efficiency investments in buildings, industrial processes, as well as electricity generation and transmission itself.

The aim of policy will therefore be to establish a higher efficiency standard as a regulation. The utilities will then be required to make the necessary investments on their own, as well as support investments from the electricity-consuming sectors. These investments could be financed in part through subsidized loans. But beyond that, the state government will not bear any costs to reach these major efficiency gains. Over time, again, all energy consumers will benefit from being able to purchase a given level of energy services at lower costs. These cost savings can then, in turn, be the basic financing source for the efficiency investments.

With respect to renewable energy, the *2017 Biennial Energy Report* states as follows:

> The renewable portfolio standard started in 2012 at 3 percent of retail electricity sales, and it increased in 2016 to 9 percent of sales. The third and final standard of 15 percent takes effect in 2020 (p. 9).

This standard does not apply to existing hydro energy resources, focusing rather on solar and wind power. Here again, to achieve an overall reduction in emissions of 40 percent between 2014 and 2035, it will be necessary to raise this standard. Given that, as we saw earlier, the average total costs of producing electricity from wind and solar power will be at rough cost parity with fossil fuel sources and nuclear energy as of 2022, there should not be significant cost barriers to increasing the renewable portfolio standard to substantially above 15 percent. Indeed, the U.S. military has set as a goal to meet 25 percent of its total energy needs with renewable energy by 2025, including both liquid fuels and electricity generation. Washington State should be able to achieve at least this 25 percent standard in the electricity sector by 2025, and a 40 percent standard by 2035. Here again, the costs of achieving this goal through expanding renewable energy investments will be borne almost entirely by private investors.

Net Metering

The *2017 Biennial Energy Report* describes Washington's net metering policy as follows:

> Net metering is the compensation arrangement between a utility and a customer with an on-site generation system, typically a solar photovoltaic system. Net metering gives the customer credit for power generation at the utility's retail rate and allows a customer to bank generation during hours or months when it exceeds the customer's consumption (p. 27).

Net metering is an important policy tool for encouraging private building owners, including private homeowners, to invest in solar photovoltaic systems on their property. Washington State does currently have a net metering law in place. However, this law requires utilities to offer net metering to its customers only up to the point at which the cumulative capacity of all net metered systems reach 0.5 percent of a utility's cumulative capacity. To encourage further expansion of private investments in solar photovoltaic systems, the limit on utility's net metering obligations needs to increase well beyond the current 0.5 percent threshold. The *2017 Biennial Energy Report* notes that the 2012 Washington State Energy Strategy does itself identify three potential improvements for the state's net metering program. These would 1) expand the maximum size of individual systems; 2) expand the cumulative capacity of systems that must be offered net metering; and 3) expand the energy banking provision to allow carry over from year to year (p. 28). Acting on all of these proposals will greatly encourage private investments in solar photovoltaic systems throughout Washington State.

Financing

Washington State currently supports clean energy investments through multiple financing programs. The most prominent is the Clean Energy Fund. For 2015-2017, the Clean Energy Fund provides financial support to clean energy investments totaling $40 million. The allocation breakdown for that $40 million total is as follows:

- **Energy Revolving Loan Fund Grants ($10 million).** These are matching grants for loan loss reserves or interest rate buy-downs for proven building energy efficiency and renewable energy technologies that currently lack access to capital. These financing opportunities are available within residential and commercial sectors.
- **Grid Modernization Grants to Utilities ($13 million).** Matching grants to advance integration of renewables through energy storage and information technology, improved reliability, and reduced costs of intermittent renewable or distributed energy.
- **Research Matching Fund Grants ($10 million).** Matching grants to support clean energy research and development awarded from competitive solicitations.
- **Credit Enhancement Grants ($6.6 million).** Matching grants for loan loss reserves, interest rate buy-downs and other credit support for the development of new, or expansion of existing, in-state renewable energy manufacturing.

The basic idea behind each of the programs is that they provide matching grants, to serve as supplements to private financing sources. In other words, *none of these investment projects receive support from the Clean Energy Fund until private investors make commitments to providing the bulk of the financing for the projects.*

To obtain a sense of the extent to which this type of financing arrangement can leverage private investments, it will be useful to briefly review the experience with the federal Department of Energy Loan Guarantee Program, which was one part of the 2009 American Recovery and Reinvestment Act—i.e. the Obama stimulus program. This program helped underwrite about $14 billion in new clean energy investments between 2009 – 2013. Even after taking full account of the large-scale and widely publicized failure of the Northern California solar company Solyndra, the default rate and corresponding financial obligations stemming from this program were modest. According to estimates discussed in Pollin et al. (2014), total losses covered by the government's loan guarantees amounted to about $300 million, i.e. equal to about 2.1 percent of the $14 billion in new loans for clean energy investments that the government guaranteed. This means that the leverage rate for the loan guarantee program was about $47 in additional clean energy investments underwritten by $1 of federal support.

It would be difficult to accurately estimate how much the Clean Energy Fund would need to expand in order to adequately support a fourfold increase in clean energy investments within Washington State, to a level of about $6.6 billion per year. But if we allow that the current level of financial support has helped underwrite approximately $1.5 billion in investments, this would imply that a fourfold increase in public financial support, to a level of about $160 million, should provide a strong foundation for reaching the $6.6 billion annual investment level.

Other financing tools can also be utilized at zero to minimum public costs to strengthen the clean energy investment market. One important example is Property Assessed Clean Energy (PACE) financing. PACE financing applies a long-established principle in infrastructure finance—the special assessment district, which uses local taxing authorities to collect payments on debt that finances publically beneficial infrastructure investments. PACE financing harnesses public tax collection authorities to establish a strong form of repayment security and offers long-term fixed-rate loans to finance clean energy projects and building retrofits. PACE does not need to rely on general obligation funds from local governments nor any form of public subsidy, and can be administered purely through the private sector. The security created by placing repayment on the tax bill makes clean energy projects more affordable for borrowers, and more attractive for participating financial institutions.

Under typical PACE financing arrangements, property owners borrow from a local government or bank to finance clean energy investments. The amount borrowed is then repaid via a special assessment on property taxes, or another locally-collected tax or bill. The security of the tax collection mechanism reduces the risk to the private lender or bond investor, and the note on the property offers collateral to secure the loan.

Under PACE financing, when a property owner participating in the program sells the property, then the repayment obligation legally transfers with the property. This feature creates an important incentive for building owners who might otherwise be disinclined to tie up their personal credit. Also, because, formally speaking, PACE financing is a tax bill, it can be accounted for as an operating expense and not a form of traditional debt. Because tax bills can generally be passed through in commercial lease arrangements, PACE financing also offers an important tool for overcoming the so-called "split incentive" with energy efficiency investments. This occurs when building owners are reluctant to take on capital expenses that reduce utility bills for their tenants, but that provide them with no direct financial benefit. By allowing the pass-through of costs of raising the efficiency standards of buildings, PACE financing closely aligns the interests of the owner and tenant in lowering energy costs in the building. These features of PACE financing mean that the risks of lending for energy efficiency projects are reduced and the costs of borrowing can correspondingly decline. Further, PACE potentially offers a deduction of the repayment obligation from federal taxable income, as part of the local property tax deduction.[30]

As of 2014, PACE programs were operating successfully in at least eleven states. These include California, Connecticut, Florida, Georgia, Maine, Michigan, Minnesota, Missouri, Ohio, New York, and Wisconsin, along with Washington, DC. Washington State has not yet developed a PACE financing program. This therefore offers a new opportunity for supporting private sector investments in clean energy throughout Washington State without the state having to incur large costs.

A variation on PACE is "on-bill financing." With on-bill financing, a loan that pays for an energy efficiency or renewable energy investment is repaid through a utility bill and secured by a strong contract with the utility. Additional collateral must be obtained by the lender since non-payment can lead to borrowers having their electricity delivery suspended. The 2012 Washington State Energy Strategy did identify on-bill financing, also known as meter-based financing, as what the *2017 Biennial Energy Report* described as a "promising alternative to traditional ways of paying for energy efficiency and renewable energy projects." According to the *Report*, this is because "it allows for repayment from the reduction in energy cost savings," (p. 25).

According to the *Report*, there are at present no publicly supported on-bill financing programs in Washington State. Rather, Craft3, a nonprofit lender, has developed and implemented a program available to residential customers of Seattle City Light. But the Craft3 initiative remains modest—574 loans for a total of $6.7 million.

With the lack of well-developed PACE and on-bill financing programs in Washington State, the opportunity exists for greatly expanding low-cost financing of clean energy investments, through which public policy levers are used to encourage private investment, without having to incur major public costs.

Auto Fuel Efficiency Standards and Electric Vehicle Deployment

As discussed in Section 4, Washington State has maintained its commitment to uphold the California fuel efficiency standards as one component of its Clean Car Law, first enacted in 2009.[31] The California standard requires that new cars operate at a 54.5 miles per gallon standard, a roughly 50 percent increase over the currently prevailing California standard of 36 miles per gallon. Washington will be able to maintain this standard for its fleet despite the efforts of the Trump Administration to repeal these standards at the federal level. Achieving this level of improvement in auto efficiency in Washington State will clearly make a major contribution toward reducing overall CO_2 emissions in the state. Emissions from transportation sources account for about 30 percent of total statewide emissions, with the largest share of transportation consumption coming from automobiles (i.e. "light duty vehicles").

In addition to this, the *2017 Biennial Energy Report* notes as follows:

> Washington State has emerged as one of the leading states for deployment of electric vehicles. New state actions have included reauthorization of the state sales tax incentive for electric vehicles (EV), commitment for purchase of 20 percent EVs in the state fleet annually, and funding for a state EV infrastructure pilot program (p. 19).

Washington State can build from these existing financing and procurement programs to foster accelerated auto efficiency advances in support of the overall goal of a 40 percent reduction in CO_2 emissions as of 2035. Here again, the extent of the additional public funding to finance these initiatives would be only modest. The public-sector costs of maintaining the California fuel efficiency standards should not extend beyond the administration of the program. The state's EV procurement requirements will entail public expenditures. But these are public expenditures that will need to be undertaken in any case, whether the state is purchasing conventional gasoline-powered vehicles or electric vehicles.

Support from Federal Government Policies

In considering the full range of policies to expand clean energy investments roughly fourfold in Washington State by 2035, we should also recognize that these state-level policies have been supported by policies established at the federal government level. The most important of these programs are the investment and production tax credits that are provided for renewable energy projects.[32] It is true that the Trump administration is likely to seek repeal of many, if not all, of these programs. But it is not a foregone conclusion that it will succeed in such efforts. To date, no programs have been repealed. Moreover, the investment and production tax credits have not been mentioned as targets for repeal.

Overall State-level Costs for a Clean Energy Investment Program

Considering these programs as an overall package, the conclusion that emerges is that the combination of regulations, public investments, and private investment incentives should not entail costs that are unmanageable in order to bring overall clean energy investments in Washington State to a level of about $6.6 billion per year, i.e. at around 1.2 percent of average state GDP between 2021 – 2035. The only state-level programs that we have discussed that include anything other than purely administrative costs are the four loan and grant matching fund programs. We suggested these four financing programs should be expanded to a total of about $160 million per year.

In general, estimating conservatively, the public sector costs of investing $6.6 billion in clean energy investments should be in the range of a 30/1 leveraging ratio—i.e. $1 of public funds should be able to effectively incentivize $30 in private investments. This would suggest that the total level of state spending would need to be in the range of $220 million per year. Achieving success with this leveraging ratio will of course be contingent on whether the full range of complementary tax and regulatory policies are also operating effectively.

Transition Programs for Fossil Fuel Industry Dependent Communities

As we have seen, the total amount of employment in the fossil fuel and ancillary industries in Washington State is relatively low, at 5,411. This amounts to about 0.18 percent of total statewide employment. As such, there will not be more than a handful of communities in the state that will experience job losses that will significantly affect the overall level of economic activity in that community. Nevertheless, there are some communities which will experience the effects of the contraction of the fossil fuel industry to a disproportionate extent.

The largest relative impacts are likely to be in the communities in which the state's oil refineries are located. This is first of all because the largest share of overall employment in the fossil fuel and ancillary industries in Washington State are in the petroleum refining sector—with 1,918 workers employed, i.e. 35 percent of all fossil fuel related employment in the state. The three other sectors with relatively large fossil fuel related employment are, again, natural gas distribution, pipeline construction and transportation, and petroleum bulk stations and terminals. But in each of these three cases, we would not expect that the workers would necessarily be living within a few geographically concentrated communities.

Focusing then on the oil refineries, there are a total of five refineries in Washington State. These five refineries are listed in Table 42, in order of their respective production levels, with the locations shown for each of the refineries. As we see in Table 42, two of the large refineries are located outside Ferndale and two are outside Anacortes. The fifth, and smallest refinery, is on the Deepwater Port of Takoma.

Based on this geographic distribution of the refineries, it is clear that the two communities that would be most negatively impacted through a 40 percent contraction in fossil fuel related production activity in Washington State will be Ferndale and Anacortes.

The most direct way to support these communities in transition will be to channel a relatively high proportion of new clean energy investments into these communities. Given that the overall level of required clean energy investment will be in the range of $6 billion

TABLE 42
Location of Oil Refineries in Washington State

Owner	Production Level (in barrels/day)	Location
BP	225,000	Outside Ferndale
Royal Dutch Shell	145,000	Outside Anacortes
Tesoro	120,000	Outside Anacortes
Phillips 66	101,000	Outside Ferndale
U.S. Oil	40,700	Deepwater Port of Takoma

Source: http://www.energytrans.org/uploads/4/7/9/7/47971323/2015-08-20_jones_refineries.pdf

per year, channeling something on the order of 10 percent into these communities will provide substantial compensation for the contraction of fossil fuel industry related jobs and tax revenues. These communities will also need general state-level support to maintain adequate public sector spending and employment levels during the transition period.

One model for developing such investment and financial support programs in these communities would be the Worker and Community Transition program that operated through the U.S. Department of Energy from 1994 – 2004. This initiative was targeted at 13 communities which had been heavily dependent on federal government operated nuclear power and weapons facilities but subsequently faced retrenchment due to nuclear decommissioning. One study of the program, by Lynch and Kirshenberg (2000), published in the *Bulletin of the Energy Communities Alliance*, concluded as follows:

> Surprisingly, the 13 communities, as a general rule have performed a remarkable role in attracting new replacement jobs and in cushioning the impact of the cutbacks at the Energy-weapons complex across the country … The community and worker adjustments to the 1992 – 2000 DOE site cutbacks have been strong and responsive, especially when compared with any other industrial adjustment programs during the same decade.

The experience in Piketon, Ohio provides a good case study of how this program has operated in one community. Piketon had been the home of a plant producing weapons-grade uranium that closed in 2001. The workers in the plant were represented by the Oil Chemical and Atomic Workers union (OCAW—which merged in 1999 with the Paper, Allied-Industrial, Chemical, and Energy Workers International Union (PACE), which in turn merged with the United Steel Workers in 2005). The union leadership was active in planning the plant's repurposing project. The closure could have been economically devastating for the region, but the federal government provided funding to clean up the 3,000 acre complex. The clean-up operation began in 2002, and is scheduled to take 40 years to complete.[33] Currently 1,900 workers are employed decontaminating the site at a cost of $300-$400 million a year. The contractor hired to clean up the site employs union workers and the president of the USW local union is enthusiastic about the long-term prospects for the project and the site (Hendren 2015).

Another large-scale restoration project was at the former plutonium production plant in Hanford, Washington. The plutonium plant began operating in 1943. The Worker and

Community Transition program began in 1993, continuing at full scale through 2000. According to the U.S. government's own assessment in 2000, the program was largely successful both in preventing involuntary job losses for workers at the former plant and in supporting new community investments.[34]

Despite the positive achievements with projects such as Piketon and Hanford, Lynch and Kirshenberg also note more generally that "The most serious problem facing the energy-impacted communities…was the lack of a basic regional economic development and industrial diversification capacity for most of the regions affected by the cutbacks…" A separate study by Lowrie et al. (1999) reaches the same conclusion. They write:

> The community transition efforts thus far are inadequate, and the cleanup funds being distributed to the sites have become a substitute for adjustment to a post-Department of Energy world. Continued dependence on cleanup jobs at the sites rather than transitioning to a non-DOE economy will exact a toll on long-term economic sustainability (1999, p. 121).

To address this problem directly, community assistance initiatives could encourage the formation of new clean energy businesses in the affected areas. One example of a successful diversification program was the repurposing of a nuclear test site in Nevada to what is now a solar proving ground. More than 25 square miles of the former nuclear site are now used to demonstrate concentrated solar power technologies and help bring them to commercialization.[35]

There are also important cases of successful repurposing projects in other countries. Most prominent has been the experience in Germany's Ruhr Valley, which has been the traditional home for its coal, steel and chemical industries. Since the 1990s, the region has advanced industrial policies to develop new clean energy industries.[36] For example, RAG AG, a German coal mining firm, has been developing plans to convert coal mines that are scheduled to close in 2018 into hydroelectric power storage facilities to stabilize energy production when solar or wind power fluctuates. In periods of slack solar and wind energy production, water that was earlier pumped into a surface pool during excess supply periods is dropped through 1,000 meters of pipes to drive the underground turbines. In addition to hydroelectric power storage, the company is also erecting wind turbines on the top of tall waste heaps and installing solar panels on the slopes. Other firms in the region have branched into producing wind and water turbines. This regional transition project has succeeded through mobilizing the support of the large coal, steel and chemical companies and their suppliers, along with universities, trade unions and government support at all levels.

Washington State's Energy Intensive and Trade Exposed Facilities

Within Washington State's existing full portfolio of policies to reduce CO_2 emissions within the state, a major emphasis is placed on bringing down the emissions produced by the state's "Energy Intensive and Trade Exposed" (EITE) facilities.

The legislative background, briefly, is as follows. As noted earlier, in 2008, the Washington Legislature enacted emission reduction targets, but did not specify the measures that would be responsible for achieving the targets. One critical initiative—termed the Clean Air Rule—was promulgated in 2015 by the state's Department of Ecology, following from a directive from Governor Jay Inslee. According to the Rule, as of 2017, any facility in the state emitting more than 100,000 tons of greenhouse gas emissions per year would need to reduce emissions by 1.7 percent per year relative to their baseline level between 2012 – 2016.[37]

The issue on which we want to focus here is how significant are the emissions reductions from these EITE facilities in terms of the state reducing its overall emissions from 73.4 to 44 million tons between 2014 and 2035.

Table 43 lists the 20 facilities that have been identified as EITE entities as of the most recent 2013 data. The firms are listed according to their emissions levels. As the table shows, total emissions from these 20 facilities are at 7.7 million tons. This amounts to about 10 percent of all emissions generated in the state.[38]

What Table 43 also shows is that of the 7.7 million tons in total from these EITE facilities, 7.4 million tons, or 96 percent of the total, are produced by seven facilities alone, the first seven entities listed in Table 43. Further, of these seven major polluters in Washington State, six are in the state's pulp and paper industry, while one, Alcoa, produces aluminum.

The pulp and paper industry is a major contributor to Washington State's economy. Overall employment totals 4,778 as of 2014, nearly as high as the 5,411 jobs in all fossil fuel and related industries in the state. A large percentage of these jobs offer good compensation. The average level of compensation, at $103,000, is 56 percent above the state's average level of compensation for all workers, which is $66,000. As such, environmental measures in the state will need to be designed to achieve the state's overall emissions targets without creating an excessive burden on the paper industry or, to a lesser extent, the aluminum industry.

Toward that end, the following simple exercise is illustrative. Let us assume that emissions from these 7 major polluters in the state remain flat through 2035 at 7.6 million tons per year. For the state to still achieve the 2035 emissions reduction target of 44 million tons overall—falling by 40 percent from 73.4 million tons as of 2014—would then entail that all other emissions from all sectors would need to fall by 45 percent, as opposed to 40 percent. This additional five percentage point decline in emissions for the state's economy outside these EITE firms is certainly achievable within the context of the overall clean energy investment program that we have described above.

This is not to suggest that the state's EITE facilities should be exempt from having to reduce their emissions. It is rather to illustrate that it is feasible to develop an overall plan for achieving dramatic emissions reductions in the state overall without having to place a disproportionate burden on the EITE facilities, such that the pulp and paper manufacturers, in particular, would be unable to continue operating profitably in Washington State.

TABLE 43
Greenhouse Gas Emissions from Energy Intensive and Trade Exposed Facilities in Washington State, 2013

Firm	Industry	Emissions (millions of tons)
Longview Fibre Paper and Packaging, Inc/ KapStone Kraft - Longview	Paperboard mills	1.73 (22.5% of total)
Weyerhaeuser NR Company - Longview	Pulp and paper	1.47 (19.0% of total)
Alcoa Intalco Works - Ferndale	Primary aluminum production	1.09 (14.1% of total)
RockTenn Tacoma Mill - Tacoma (Simpson Tacoma Kraft Co)	Paperboard mills	1.02 (13.2% of total)
Boise Paper - Wallula	Paper (except Newsprint) Mills	0.83 (10.7% of total)
Georgia-Pacific Consumer Products LLC - Camas	Paper (except Newsprint) Mills	0.70 (9.0% of total)
Port Townsend Paper Corporation - Port Townsend	Paper (except Newsprint) Mills	0.56 (7.2% of total)
Ash Grove Cement Company - Seattle	Cement Manufacturing	0.35 (4.5% of total)
Alcoa Wenatchee Works - Malaga	Primary aluminum production	0.31 (4.0% of total)
Agrium Kennewick Fertilizer Operations (KFO) - Kennewick	Nitrogenous Fertilizer Manufacturing	0.16 (2.1% of total)
REC Silicon - Moses Lake	Primary Smelting and Refining of Nonferrous Metal (except Copper and Aluminum)	0.14 (1.8% of total)
Nucor Steel Seattle, Inc. - Seattle	Iron and steel mills	0.13 (1.7% of total)
WaferTech LLC	Semiconductor and Related Device Manufacturing	0.12 (1.6% of total)
Kaiser Aluminum Washington, LLC (Trentwood Works) - Spokane Valley	Aluminum Sheet, Plate, and Foil Manufacturing	0.11 (1.4% of total)
Cardinal FG Company - Winlock	Flat Glass Manufacturing	0.10 (1.3% of total)
McCain Foods - Othello	Frozen Fruit, Juice, and Vegetable Manufacturing	0.08 (1.0% of total)
Ardagh Glass Inc. - Seattle (dba Saint Gobain Containers)	Glass Container Manufacturing	0.08 (1.0% of total)
JR Simplot - Othello	Frozen Fruit, Juice, and Vegetable Manufacturing	0.08 (1.0% of total)
Boeing Commercial Airplanes - Everett	Aircraft manufacturing	0.07 (0.9% of total)
Tyson Fresh Meats, Inc. - Wallula	Animal (except Poultry) Slaughtering	0.06 (0.7% of total)
TOTAL		7.74 Million Tons

Source: http://www.energytrans.org/uploads/4/7/9/7/47971323/2015-08-20_jones_refineries.pdf

Appendix 1
Employment Estimating Methodology

The employment estimates for Washington State were developed using an input-output model. Here we used IMPLAN v3, an input-output model which uses data from the U.S. Department of Commerce as well as other public sources. The data set used for the estimates in this report is the 2014 Washington State data. An input-output model traces linkages between all industries in the economy as well as institutional sources of final demand (such as households and government). A full discussion of the strengths and weaknesses of input-output (I-O) models and their application to estimating employment in the energy sector can be found in Appendix 4 of Pollin et al. (2014).

One important point to note here is that I-O models to date do not identify renewable energy industries such as wind, solar, or geothermal, or energy efficiency industries such as building retrofits, industrial efficiency, or grid upgrades. However, all of the components that make up each of these industries are contained in existing industries within the models. For example, the hardware, glass production, and installation industries that are all activities within "solar" are each an existing industry in the I-O model. By identifying the relevant industries and assigning weights to each, we can create "synthetic" industries that represent each of the renewable energy and energy efficiency industries within the model. Below we show the industries and weights used in this study. A full discussion of the methodology for creating synthetic industries can be found in Garrett-Peltier (2017).

The energy industries and weight of each component industry are shown in Table A1.1, below.

Scaling Manufacturing Activity

The employment estimates produced in the IMPLAN model are disaggregated into over 400 sectors. After modeling the energy industries above, we aggregated the estimates into the following sectors:

- Agriculture
- Extraction and Utilities
- Construction
- Manufacturing
- Trade and Transportation
- Services

The expansion of clean energy that we propose in this report is significant, and occurs rather rapidly, over a 15-year period. While it may be possible for construction and service activities to keep pace with the rapid scaling up of clean energy consumption in Washington State, we assume that manufacturing facilities will take longer to develop, and that while manufacturing activity will indeed expand within the state, in the first 15 years of clean energy expansion some of the clean energy manufacturing will develop out of state. Here we make the conservative assumption that manufacturing will only increase 10% relative to the overall increase in clean energy activity. Thus the employment multipliers will be lower in this constrained case than if we were to assume that all sectors, including manufacturing, scaled up at the same pace as shown in Table A1.2.

For the purposes of this study, and to err on the side of underestimating rather than overestimating employment, we use the constrained multipliers in the right-most column in our estimates.

TABLE A1.1
Composition and weights for modelling energy industries within the I-O model

Energy Industries	Composition and weights of industries within I-O model
Building Retrofits	50% residential repair construction, 50% non-residential repair construction
Industrial Efficiency	30% environmental and technical consulting services, 20% repair construction of non-residential structures, 10% air and ventilation equipment, 10% heating equipment, 10% A/C, refrigeration, and warm air heating equipment, 10% all other industrial machinery manufacturing
Grid Upgrades	25% infrastructure construction, 25% mechanical power transmission equipment manufacturing, 25% miscellaneous electrical equipment manufacturing, 25% other electronic component manufacturing
Public Transport/Rail	30% construction of other new non-residential structures, 21% motor vehicle body and parts manufacturing, incl. electrical equipment, 6% railroad rolling stock manufacturing, 43% transit and ground passenger transportation
Wind	26% construction of new power and communication structures, 12% plastic and resin manufacturing, 12% fabricated structural metal manufacturing, 37% other industrial machinery manufacturing, 3% mechanical power transmission equipment manufacturing, 3% electronic connector manufacturing, 7% miscellaneous professional, scientific, and engineering services
Solar PV	30% construction of new power and communication structures, 17.5% hardware manufacturing, 17.5% mechanical power transmission equipment manufacturing, 17.5% capacitor, resistor, coil, transformer, and other inductor manufacturing, 17.5% miscellaneous professional, scientific, and engineering services
Geothermal	15% drilling wells, 45% construction of new non-residential structures, 10% pump and pumping equipment manufacturing, 30% R&D
Nuclear	100% nuclear electric power generation
Oil and Gas	23% extraction of natural gas and crude petroleum, 5% drilling oil and gas wells, 4% support activities for oil and gas, 9% natural gas distribution, 55% petroleum refineries, 1.5% industrial gas manufacturing, 2.5% pipeline transportation
Coal	21% coal mining, 4% support activities for mining, 40% electric power generation, 35% rail transportation

TABLE A1.2
Employment multipliers per $1 million in unconstrained and constrained cases

	If all sectors expanded 100%	Constrained: Manufacturing expands 10% only
	Direct, indirect, and induced jobs per $1 million	
Wind	8.34	6.35
Solar PV	10.32	8.32
Geothermal	9.46	9.08

Appendix 2
Estimating Job Characteristics

Characteristics of Jobs Created by Clean Energy Investments

Our strategy for identifying the types of jobs that would be added to the economy due to an investment in one of the seven energy efficiency and clean energy sectors involves two steps.

The first step is to calculate each of the 526 industry shares of total employment created through a specific investment program. We calculated the percentage of new employment generated in each of these 526 sectors through our input-output model as explained in Appendix 1.

Next, we apply this information on the industry composition of the new employment created by an investment to data on workers currently employed in the same industrial mix of jobs. We use the characteristics of these workers to create a profile of the types of jobs and the types of workers that will likely hold the jobs created with each investment. These characteristics include types of occupations, gender, race/ethnicity, union status, credential requirements, earnings and job-related benefits.

Our information about the workers currently employed in the industrial mix of jobs created by an investment comes from the Current Population Survey (CPS). The CPS is a household survey administered by the U.S. Census Bureau, on behalf of the Bureau of Labor Statistics of the U.S. Labor Department. The basic monthly survey of the CPS collects information from about 60,000 households every month on a wide range of topics including basic demographic characteristics, educational attainment, and employment status. Among a subset of its monthly sample—referred to as the outgoing rotation group (ORG)—respondents are asked more detailed employment-related questions, including about their wages and union status. The CPS' survey in March includes a supplement, referred to as the Annual Social and Economic survey (ASEC) that asks additional questions, particularly about income, poverty status, and job-related benefits. We pool five years of the most current CPS data available as of the writing of this report--2011-2015--for our analyses.[39]

To create a profile of the types of jobs and the types of workers that will likely hold the jobs created with each investment, we weight the CPS worker data with the industry shares generated by IMPLAN. This creates a sample of workers with an industry composition that matches that of the jobs that we estimate will be added by investing in a clean energy/energy efficiency sector.

Specifically, we use the IMPLAN industry shares to adjust the sampling weights provided by the CPS. The CPS-provided sampling weights weight the survey sample so that it is representative at various geographic levels, including national and state. We adjust the CPS-provided sampling weights by multiplying each individual worker's sampling weight with the following:

$$S \times \frac{\text{IMPLAN's estimate of the share of new jobs in worker i's industry j}}{\sum \text{CPS sampling weights of all workers in industry j}}$$

where *S* is a scalar equal to the number of direct and indirect jobs produced overall by the level of investment being considered. For example, say Washington's investment in mass transit of $1 billion would generate 10,000 direct and indirect jobs, then *S* is equal to 10,000.

Some of the 526 IMPLAN industries had to be aggregated to match the industry variable in the CPS, which has 242 categories, and vice versa. For example, among IMPLAN's 526 sectors, there are 13 construction sectors while the CPS has only one construction industry. In the end, 194 industry sectors are common to both IMPLAN and the CPS.

We use these adjusted sampling weights to estimate the job-related health insurance and retirement benefits, and union membership among workers in the specific industrial mix of jobs associated with each type of investment. We also estimate demographic characteristics, such as percent female and percent non-white, as well as workers' educational attainment. Finally, we determine what are the most prevalent occupations held by workers in the industrial mix of jobs associated with each type of investment.

The total compensation estimates for jobs in clean energy sectors are based on the 2014 Quarterly Census of Employment and Wages (QCEW). The QCEW tabulates employment levels monthly and wages quarterly through a joint effort by the Bureau of Labor Statistics of the U.S. Labor Department and the State Employment Security Agencies (SESAs). The QCEW provides a near-census of U.S. jobs (98 percent), and includes all unemployment insurance (UI) covered workers. A small group of workers are not covered by the QCEW. These workers include: members of the armed forces, the self-employed, proprietors, domestic workers, unpaid family workers, and railroad workers covered by the railroad unemployment insurance system.

As with estimating worker characteristics, we use the industry shares of employment generated by IMPLAN to estimate total compensation for jobs in clean energy sectors. Specifically, we used the IMPLAN industry shares, for the direct and indirect jobs, to estimate weighted average annual wages for each clean energy sector.

We then inflate this figure to add the value of the average level of benefits typically received by workers in the industrial mix of jobs associated with each type of investment. To determine how much we should inflate the average pay rate by, we calculate a ratio of total compensation to wages/salaries using 2014 data from the Bureau of Economic Analysis (BEA, Tables 6.2D and 6.3D). Specifically, for each clean energy or energy efficiency investment, we create a weighted average of the total compensation data using the IMPLAN industry shares aggregated up to the 2-digit level, and then again for the wage/salary data. We then apply the ratio of: (the weighted average of total compensation)/(weighted average of wages/salary) to our estimate of average pay.

All dollar figures are inflated to 2015 dollars using the CPI-U.

Characteristics of Jobs in Fossil Fuel Related Industries

The primary data sources that we use to estimate characteristics of jobs in the fossil fuels industries is the American Community Survey (ACS) and the Quarterly Census of Employment and Wages (QCEW) described above.

The ACS is an annual household survey administered by the U.S. Census Bureau and serves as the Census' primary method for collecting detailed information about the U.S. workforce and overall population in between decennial censuses. The ACS is specifically designed to provide estimates at the state and local levels, surveying roughly 3 million households. In order to get sufficient sample sizes to generate reasonable estimates on workers in each of Washington's fossil fuel sectors, we pool the most recent five years of ACS data available, 2010-2014.

We use the ACS to estimate the characteristics of workers and their jobs in the fossil fuel industries, including workers' health insurance coverage, educational attainment, age, race and gender. We also use the ACS to identify the most prevalent occupations among the jobs in fossil fuel industries. The ACS, however, does not collect data on union status of workers. For unionization rates, we use the CPS-ORG data files (described above). However, pooling five years of CPS data still produced insufficient sample sizes. To create larger samples, we pooled data across nearby states in the Northwest region with Washington, including California, and Oregon.

The ACS industry categories do not match up exactly with the fossil fuel sectors that we analyze in this report. As a result, in some cases, our ACS estimates are based on industry categories at a higher level of aggregation than the 6-digit NAICS code level that we are able to get employment and compensation figures for from the QCEW.

As noted above, the annual average 2014 employment and wage levels we report in the main text are estimates published directly by the QCEW. There are two exceptions. In both cases, we combine similar individual sectors into larger aggregated sectors. For the annual wage, we use an employment-weighted average. Specifically, we combine the figures for "Drilling oil/gas wells" and "Support activities for oil and gas." This is because all of our other job characteristics, based on the ACS data (discussed above) are only available for these sectors combined. We also combine the sectors "Pipeline transportation of natural gas," "Pipeline transportation of refined petroleum," and "Oil and gas pipeline and related structures construction," for a similar reason and for ease of exposition.

To estimate total compensation figures, we use, as in the case of the clean energy compensation estimates, BEA figures to inflate the QCEW annual wage figures. More specifically, for each fossil fuels sector, we use the BEA figures for the relevant 2-digit NAICS sector.

All dollar figures are inflated to 2015 dollars using the CPI-U.

Appendix 3
Estimating Costs of Just Transition Policy Packages

In order to produce cost estimates for the various Just Transition programs described in the main text, one of the key factors is how layoffs will likely occur for each episodic contraction: by seniority so that the youngest workers are laid off first, or the reverse so that those closest to retirement age are laid off first. As a result, we provide cost estimates based on both patterns of layoffs.

In the first two sections of this appendix, we document the two patterns of layoffs by age group that underlie our cost estimates for each episode of contraction. In the third section, we present details on our cost estimates of benefits under Policy Package 1. Specifically, we provide the same type of information as presented in Tables 35-37 in the main text for three different scenarios under Policy Package 1: (1) laid off workers either retire, retire early via the glide path option, or get training and become reemployed; (2) laid off workers either retire, retire early via the glide path option, or remain unemployed; and (3) laid off workers either retire, retire early via the glide path option, or immediately find new employment. In the fourth section, we present the analogous figures for Policy Package 2.

Layoffs: Oldest Workers Laid Off First

In Table A3.1, column 1, we show how workers in fossil fuel related industries are distributed across age groups based on our assumption that the fossil fuel industries' workforces will have the same age distribution in 2021 as in 2015. Column 2 shows how the first wave of layoffs in 2021 – for a total of 721 jobs lost – will be distributed across age groups.

TABLE A3.1
Workers and Layoffs by Age in 2021, Oldest Workers Laid Off First

	Year 2021		
Age in 2021	(1) # of Workers	(2) # of Layoffs	(3) # of Workers After Layoffs
15-29	812	0	812
30-34	703	0	703
35-39	595	0	595
40-44	703	0	703
45-49	541	0	541
50-54	866	0	866
55-59	649	180	469
60-64	433	433	0
65+	108	108	0
Total:	5,410	721	4,689

Source: ACS 2010 – 2014.

We assume that: (1) workers who are 65+ will retire, and (2) the remaining layoffs will be absorbed by the oldest workers first.

We can see from Table A3.1 that retiring workers age 65+ will absorb 108 layoffs in 2021. The remaining 613 layoffs will therefore be absorbed by other workers. There are 433 workers who are between 60 and 64 years old and who would be put on a "glide-path" to retirement. The final 180 layoffs will be absorbed by 55-59 year old workers. We can now see that after all the layoffs, the remaining workforce is between the ages 15 and 59 years old (see column 3).

We assume that employers will not need to hire any new workers between 2021 and 2026, with workers in 2021 staying with their employers through 2026. In particular, there are no further retirements between 2021 and 2026. Recall that those workers approaching retirement age in 2021 leave the workforce using the "glide-path" option.

In Table A3.2 we show the age distribution of the workforce in 2026 that results by simply allowing the workforce in 2021 (after layoffs) to age 5 years. For example, the number of workers between the ages 20 and 49 in 2026 is equal to the number of workers, after layoffs, who were between 15 and 44 years old in 2021.

The second wave of layoffs in 2026 affects another 721 workers which we show in Column 2 of Table A3.2. Of these 721 layoffs, 469 will be absorbed by workers between the ages of 60 and 64 years old. These workers will be put on a "glide-path" toward retirement. Workers between the ages of 55-59 years old will absorb the last 252 layoffs.

Table A3.3 shows the third wave of 721 layoffs in 2031. As before, the majority of the layoffs (614) will be absorbed by 60-64 year old workers. These workers will "glide" to retirement. The remaining 107 layoffs will be absorbed by 55-59 year old workers.

The final workforce will have 3,247 workers, after laying off 2,163 workers between 2021 and 2031. [40]

TABLE A3.2
Workers and Layoffs by Age in 2026, Oldest Workers Laid Off First

Age in 2026 (Age groups in Table A3.1 + 5 yrs.)	Year 2026 (1) # of Workers	(2) # of Layoffs	(3) # of Workers After Layoffs
20-34	812	0	812
35-39	703	0	703
40-44	595	0	595
45-49	703	0	703
50-54	541	0	541
55-59	866	252	614
60-64	469	469	0
65+	0	0	0
Total:	4,689	721	3,968

Source: Table A3.1.

TABLE A3.3
Workers and Layoffs by Age in 2031, Oldest Workers Laid Off First

Age in 2031 (Age groups in Table A3.2 + 5 yrs)	Year 2031 (1) # of Workers	(2) # of Layoffs	(3) # of Workers After Layoffs
25-39	812	0	812
40-44	703	0	703
45-49	595	0	595
50-54	703	0	703
55-59	541	107	434
60-64	614	614	0
65+	0	0	0
Total:	3,968	721	3,247

Source: Table A3.2.

Layoffs: Youngest Workers Laid Off First

As before, we start with the age distribution and workforce in 2021 for the fossil fuel sectors.

In addition, as before, the first wave of layoffs in 2021 affects 721 workers. We can see from the table that retiring workers age 65+ will absorb 108 layoffs in 2021. The remaining 613 layoffs go to the youngest workers.

Between 2021 and 2026, the majority of workers in the age range 60-64 years old in 2021 will reach retirement age *prior to* 2026. Specifically, we assume that 4 out 5 of such workers will retire prior to 2026, or 346 workers (i.e., 4/5 x 433). As a result, only 1 out of 5 of such workers will reach retirement age in 2026, or 87 workers (i.e., 1/5 x 433). We assume employers will want to hire workers to replace their retiring workers during the years between 2021 and 2026 to preserve the size of their workforces, and that these new workers will be younger. This means specifically that by 2026, employer will add 346 new workers to their workforce in the younger age group. We show this in Table A3.5. In Table A3.5, the youngest age group, 15-34 years old, now has 545 workers (199+346).

The second wave of layoffs in 2026 affects another 721 workers. 87 of these layoffs are absorbed by workers retiring in 2026. We then assume that the remaining layoffs will be absorbed by 545 workers between the ages of 15 and 34 years old and 89 workers between the ages of 35 and 39.

Table A3.6 shows the third wave of 721 layoffs in 2031. As before, we assume that between 2026 and 2031, the large majority of workers in the age range 60-64 years old in 2026 will reach retirement age *prior to* 2031. Specifically, we assume that 4 out 5 of such workers will retire prior to 2031, or 519 workers (i.e., 4/5 x 649). As a result, only 1 out of 5 of such workers will reach retirement age in 2031, or 130 workers (i.e., 1/5 x 649). We assume employers will want to hire workers to replace their retiring workers between 2021 and 2026,

TABLE A3.4
Workers and Layoffs by Age in 2021, Youngest Workers Laid Off First

Age in 2021	Year 2021 (1) # of Workers	 (2) # of Layoffs	 (3) # of Workers After Layoffs
15-29	812	613	199
30-34	703	0	703
35-39	595	0	595
40-44	703	0	703
45-49	541	0	541
50-54	866	0	866
55-59	649	0	649
60-64	433	0	433
65+	108	108	0
Total:	5,410	721	4,689

Source: ACS 2010 – 2014.

TABLE A3.5
Workers and Layoffs by Age in 2026, Youngest Workers Laid off First

Age in 2026 (Age groups in Table A3.4 + 5 yrs., except row 1 includes new hires)	Year 2026 (1) # of Workers	 (2) # of Layoffs	 (3) # of Workers After Layoffs
15-34	545	545	0
35-39	703	89	614
40-44	595	0	595
45-49	703	0	703
50-54	541	0	541
55-59	866	0	866
60-64	649	0	649
65+	87	87	0
Total:	4,689	721	3,968

Source: Table A3.4.

TABLE A3.6
Workers and Layoffs by Age in 2031, Youngest Workers Laid off First

Age in 2031 (Age groups in Table A3.5 + 5 yrs., except row 1 includes new hires)	Year 2031		
	(1) # of Workers	(2) # of Layoffs	(3) # of Workers After Layoffs
15-39	519	519	0
40-44	614	72	542
45-49	595	0	595
50-54	703	0	703
55-59	541	0	541
60-64	866	0	866
65	130	130	0
66+	0	0	0
Total:	3,967	721	3,246

Source: Table A3.5.

and that these new workers will be younger. This means specifically that by 2031, employers will add 519 new workers to their workforce in the younger age group, we show this in row 1 of Table A3.6. In Table A3.6, the youngest age group, 15-39 years old, now has 519 workers (0+519).

The third wave of layoffs in 2031 affects another 721 workers. 130 of these layoffs are absorbed by retiring workers. the remaining layoffs will be absorbed by 519 workers between the ages of 15 and 39 years old and 72 workers between the ages of 40 and 44.

The final workforce will have 3,246 workers, after laying off 2,163 workers between 2021 and 2031.[41]

Cost Estimates of Benefits Under Policy Package 1

In this section, we present a full set of tables presenting our cost estimates of benefits under Policy Package 1. Tables A3.7-A3.9 show the cost estimates for the situation where laid off workers receive retraining and subsequently become reemployed. Tables A3.10-A3.12 show the estimates for the situation where laid off workers remain unemployed. Lastly, Tables A3.13-A3.15 show estimates for the situation where laid off workers find jobs right away.

Cost Estimates of Benefits under Policy Package 2

In this section, we present a full set of tables that are analogous to Tables A3.7-A3.15, this time presenting our cost estimates of benefits under Policy Package 2.

TABLE A3.7
Policy Package 1: Oldest Workers Laid Off First
Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Retraining and 100% Wage Replacement (2 years);
  - Wage Insurance after Reemployment, Capped at $10,000 (4 years)

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	433	Glide Path to Retirement	$450,000*
59 and less	180	Retraining, wage replacement and wage insurance package	$348,200

Notes: *This figure is equal to $150,000 x 3 years, since we assume the average worker in this age range would be about 3 years away from reaching age 65.

TABLE A3.8
Policy Package 1: Youngest Workers Laid Off First
Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Retraining and 100% Wage Replacement (2 years);
  - Wage Insurance after Reemployment, Capped at $10,000 (4 years)

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	0	Glide Path to Retirement	$0
59 and less	613	Retraining, wage replacement and wage insurance package	$348,200

TABLE A3.9
Policy Package 1
Annual Costs of Providing Just Transition Support, 2021 - 2036

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Retraining and 100% Wage Replacement (2 years);
  - Wage Insurance after Reemployment, Capped at $10,000 (4 years)

	Oldest Workers Laid Off First (millions, 2015 dollars)	Youngest Workers Laid Off First (millions, 2015 dollars)
2021	$92.7	$94.5
2022	$92.7	$94.5
2023	$66.8	$6.1
2024	$1.8	$6.1
2025	$1.8	$6.1
2026	$111.0	$103.8
2027	$109.2	$97.7
2028	$72.9	$6.3
2029	$2.5	$6.3
2030	$2.5	$6.3
2031	$111.1	$97.4
2032	$108.6	$91.1
2033	$93.2	$5.9
2034	$1.1	$5.9
2035	$1.1	$5.9
2036*	$1.1	$5.9
TOTAL	$869.9	$640.0
Average Costs per Year (= Total costs/15 years)	$58.0	$42.7

Note: Workers laid off in 2031 and will receive benefits for a total of 6 years, i.e., through 2036.

TABLE A3.10
Policy Package 1: Oldest Workers Laid Off First
Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

• 65 and Older: Pension Guarantee
• 60 – 64: Glide Path to Retirement
• Under 60:
 - Workers are not reemployed
 - Workers receive between 100% – 60% wage replacement for 20 years

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	433	Glide Path to Retirement	$450,000*
55-59	180	Wage replacement	$1.0 million**
54 and less	0	Wage replacement	$0

Notes: *This figure is equal to $150,000 x 3 years, since we assume the average worker in this age range would be about 3 years away from reaching age 65. **This is the figure for 7 years since the average worker in this age range would be about 7 years away from reaching retirement age 65.

TABLE A3.11
Policy Package 1: Youngest Workers Laid Off First
Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

• 65 and Older: Pension Guarantee
• 60 – 64: Glide Path to Retirement
• Under 60:
 - Workers are not reemployed
 - Workers receive between 100% – 60% wage replacement for 20 years

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	0	Glide Path to Retirement	$0
45 – 59	0	Wage replacement	$0
44 and less	613	Wage replacement	$2.4 million*

Note: *This is the figure for the maximum of 20 years of wage replacement benefits since we assume that these workers will have 20 years (or more) before reaching retirement age 65.

TABLE A3.12
Policy Package 1
Annual Costs of Providing Just Transition Support, 2021 - 2050

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Workers are not reemployed
  - Workers receive between 100% – 60% wage replacement for 20 years

	Oldest Workers Laid Off First (millions, 2015 dollars)	Youngest Workers Laid Off First (millions, 2015 dollars)
2021	$92.0	$92.0
2022	$92.0	$92.0
2023	$92.0	$92.0
2024	$27.0	$92.0
2025	$24.3	$82.8
2026	$132.4	$177.9
2027	$132.4	$177.9
2028	$108.2	$177.9
2029	$37.8	$168.7
2030	$34.0	$159.2
2031	$142.2	$247.8
2032	$142.2	$247.8
2033	$108.2	$238.6
2034	$16.1	$229.1
2035	$14.4	$220.2
2036	$14.4	$220.2
2037	$14.4	$211.0
2038		$201.5
2039		$192.7
2040		$192.7
2041		$137.5
2042		$128.0
2043		$119.1
2044		$119.1
2045		$119.1
2046		$62.1
2047		$53.2
2048		$53.2
2049		$53.2
2050		$53.2
TOTAL	$1,223.9	$4,411.2
Average Costs per Year (= Total costs/15 years)	$81.6	$294.1

Note: Workers laid off in 2031 and will receive benefits for a total of 20 years, i.e., through 2050.

TABLE A3.13
Policy Package 1: Oldest Workers Laid Off First
Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

• 65 and Older: Pension Guarantee
• 60 – 64: Glide Path to Retirement
• Under 60:
 - Workers are immediately reemployed
 - Workers receive 4-years of wage insurance capped at $10,000

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	433	Glide Path to Retirement	$450,000*
59 and less	180	Wage Insurance	$40,000

Notes: *This figure is equal to $150,000 x 3 years, since we assume the average worker in this age range would be about 3 years away from reaching age 65.

TABLE A3.14
Policy Package 1: Youngest Workers Laid Off First
Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

• 65 and Older: Pension Guarantee
• 60 – 64: Glide Path to Retirement
• Under 60:
 - Workers are immediately reemployed
 - Workers receive 4-years of wage insurance capped at $10,000

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	0	Glide Path to Retirement	$0
59 and less	613	Wage Insurance	$40,000

TABLE A3.15
Policy Package 1
Annual Costs of Providing Just Transition Support, 2021 - 2035

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Workers are immediately reemployed
  - Workers receive 4-years of wage insurance capped at $10,000

	Oldest Workers Laid Off First (millions, 2015 dollars)	Youngest Workers Laid Off First (millions, 2015 dollars)
2021	$66.8	$6.1
2022	$66.8	$6.1
2023	$66.8	$6.1
2024	$1.8	$6.1
2025	$-	$-
2026	$72.9	$6.3
2027	$72.9	$6.3
2028	$72.9	$6.3
2029	$2.5	$6.3
2030	$-	$-
2031	$93.2	$5.9
2032	$93.2	$5.9
2033	$93.2	$5.9
2034	$1.1	$5.9
2035	$-	$-
TOTAL	$703.8	$73.5
Average Costs per Year (= Total costs/15 years)	$46.9	$4.9

TABLE A3.16

Policy Package 2: Oldest Workers Laid Off First

Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Retraining and 100% Wage Replacement (2 years);
  - Full Wage Insurance after Reemployment (5 years)

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	433	Glide Path to Retirement	$450,000*
59 and less	180	Retraining, wage replacement and wage insurance package	$663,200

Notes: *This figure is equal to $150,000 x 3 years, since we assume the average worker in this age range would be about 3 years away from reaching age 65.

TABLE A3.17

Policy Package 2: Youngest Workers Laid Off First

Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Retraining and 100% Wage Replacement (2 years);
  - Full Wage Insurance after Reemployment (5 years)

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	0	Glide Path to Retirement	$0
59 and less	613	Retraining, wage replacement and wage insurance package	$663,200

Notes: *This figure is equal to $150,000 x 3 years, since we assume the average worker in this age range would be about 3 years away from reaching age 65.

TABLE A3.18
Policy Package 2
Annual Costs of Providing Just Transition Support, 2021 - 2037

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Retraining and 100% Wage Replacement (2 years);
  - Full Wage Insurance after Reemployment (5 years)

	Oldest Workers Laid Off First (millions, 2015 dollars)	Youngest Workers Laid Off First (millions, 2015 dollars)
2021	$92.7	$94.5
2022	$92.7	$94.5
2023	$77.7	$43.5
2024	$12.8	$43.5
2025	$12.8	$43.5
2026	$122.0	$141.2
2027	$122.0	$141.2
2028	$88.2	$45.0
2029	$17.9	$45.0
2030	$17.9	$45.0
2031	$126.5	$136.1
2032	$126.5	$136.1
2033	$99.7	$42.0
2034	$7.6	$42.0
2035	$7.6	$42.0
2035	$7.6	$42.0
2037	$7.6	$42.0
TOTAL	$1,039.7	$1,219.0
Average Costs per Year (= Total costs/15 years)	$69.3	$81.3

Note: Workers laid off in 2031 and will receive benefits for a total of 7 years, i.e., through 2037.

TABLE A3.19

Policy Package 2: Oldest Workers Laid Off First

Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Workers are not reemployed
  - Workers receive between 75% – 50% wage replacement for 10 years

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	433	Glide Path to Retirement	$450,000*
55-59	180	Wage replacement	$700,200**
54 and less	0	Wage replacement	$0

Notes: *This figure is equal to $150,000 x 3 years, since we assume the average worker in this age range would be about 3 years away from reaching age 65. **This is the figure for 7 years since the average worker in this age range would be about 7 years away from reaching retirement age 65.

TABLE A3.20

Policy Package 2: Youngest Workers Laid Off First

Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Workers are not reemployed
  - Workers receive between 75% – 50% wage replacement for 10 years

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	0	Glide Path to Retirement	$0
55-59	0	Wage replacement	$0
54 and less	613	Wage replacement	$925,200*

Notes:*This is the figure for the maximum of 10 years of wage replacement benefits since we assume that these workers will have 10 years (or more) before reaching retirement age 65.

TABLE A3.21
Policy Package 2
Annual Costs of Providing Just Transition Support, 2021 - 2040

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Workers are not reemployed
  - Workers receive between 75% – 50% wage replacement for 10 years

	Oldest Workers Laid Off First (millions, 2015 dollars)	Youngest Workers Laid Off First (millions, 2015 dollars)
2021	$85.2	$69.0
2022	$85.2	$69.0
2023	$83.0	$61.3
2024	$18.0	$61.3
2025	$18.0	$61.3
2026	$116.7	$132.7
2027	$112.2	$117.3
2028	$95.6	$109.4
2029	$25.2	$109.4
2030	$25.2	$109.4
2031	$129.4	$129.9
2032	$123.0	$114.0
2033	$102.8	$106.7
2034	$10.7	$106.7
2035	$10.7	$106.7
2035	$10.7	$59.1
2037	$8.0	$44.3
2038	$-	$44.3
2039	$-	$44.3
2040	$-	$44.3
TOTAL	$1,059.6	$1,700.5
Average Costs per Year (= Total costs/15 years)	$70.6	$113.4

Note: Workers laid off in 2031 and will receive benefits for a total of 10 years, i.e., through 2040.

TABLE A3.22

Policy Package 2: Oldest Workers Laid Off First

Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Workers are immediately reemployed
  - Workers receive 5-years full wage insurance

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	433	Glide Path to Retirement	$450,000*
59 and less	180	Wage Insurance	$355,000

Notes: *This figure is equal to $150,000 x 3 years, since we assume the average worker in this age range would be about 3 years away from reaching age 65.

TABLE A3.23

Policy Package 2: Youngest Workers Laid Off First

Just Transition Policies Available for 721 Laid Off Workers in 2021

WORKERS RECEIVE:

- 65 and Older: Pension Guarantee
- 60 – 64: Glide Path to Retirement
- Under 60:
  - Workers are immediately reemployed
  - Workers receive 5-years full wage insurance

Age	Number of Workers	Types of Policy Support	Average Cost of Support per Worker
65+	108	Pension	$0
60 – 64	0	Glide Path to Retirement	$0
59 and less	613	Wage Insurance	$355,000

TABLE A3.24
Policy Package 2
Annual Costs of Providing Just Transition Support, 2021 - 2035

WORKERS RECEIVE:

• 65 and Older: Pension Guarantee
• 60 – 64: Glide Path to Retirement
• Under 60:
  - Workers are immediately reemployed
  - Workers receive 5-years of full wage insurance

	Oldest Workers Laid Off First (millions, 2015 dollars)	Youngest Workers Laid Off First (millions, 2015 dollars)
2021	$77.7	$43.5
2022	$77.7	$43.5
2023	$77.7	$43.5
2024	$12.8	$43.5
2025	$12.8	$43.5
2026	$88.2	$45.0
2027	$88.2	$45.0
2028	$88.2	$45.0
2029	$17.9	$45.0
2030	$17.9	$45.0
2031	$99.7	$42.0
2032	$99.7	$42.0
2033	$99.7	$42.0
2034	$7.6	$42.0
2035	$7.6	$42.0
TOTAL	$873.5	$652.5
Average Costs per Year (= Total costs/15 years)	$58.2	$43.5

Appendix 4
Status of Pension Funds

Pollin and Callaci (2016) document how among the fossil fuel and ancillary industries, only pension funds within the coal industry are truly distressed. The State of Washington, however, has no coal mines.

Among the other fossil fuel and ancillary industries, those workers covered by defined benefit pension plans pay into national pension plans pooled with all other participating workers in the country. There is no way to isolate the Washington portion of these pension plans' liabilities or assets. Nonetheless, we can provide a picture of the general health of these industries' pension funds by looking at national-level data.

To do this, we first identify each pension plan's sponsor. Table A4.1 presents each fossil fuel and ancillary industry firm employing workers in Washington, their industry, the location of their facility, the parent company, and the country where the parent company, if publicly traded, is listed.

Nine of these fifteen companies are U.S. companies, and eight of those nine are publicly traded. Due to these characteristics, we cannot use these companies' Form 10-Ks to get estimates of pension liabilities for all of the firms. This is because privately held companies do not report such information, and non-U.S. firms do not file Form 10-Ks but rather foreign annual reports using IFRS accounting standards, which are incompatible with the GAAP standards used in the U.S.

TABLE A4.1
Washington Firms Affected by Fossil Fuel Decline

Firm	Industry	Location	Parent Company	Listing country
BP West Coast Product	Petroleum refining	Ferndale	BP PLC	UK
Phillips 66	Petroleum refining, pipeline	Ferndale	Phillips 66	USA
Shell Oil Products	Petroleum refining	Anacortes	Royal Dutch Shell	UK
Tesoro West Coast	Petroleum refining	Anacortes	Tesoro Corporation	USA
US Oil and Refining	Petroleum refining	Tacoma	US Oil and Refinining	Private
Centralia Power Plant	Electric power generation	Centralia	TransAlta Corp.	Canada
Kinder Morgan	Crude oil distribution	Pipeline	Kinder Morgan Inc.	USA
Chevron	Refined petroleum pipeline	Pipeline	Chevron Corp.	USA
Enbridge	Refined petroleum pipeline	Pipeline	Enbridge Inc.	Canada
Northwest Pipeline Group	Natural gas pipeline	Pipeline	Williams Companies	USA
Transcanda	Natural gas pipeline	Pipeline	Transcanada Corp	Canada
Gas Transmission NW	Natural gas pipeline	Pipeline	Transcanada Corp	Canada

Source: http://www.eia.gov/state/print.cfm?sid=WA; subsidiary firm websites.

The other source of pension information is ERISA Form 5500s. Pension and benefit fund sponsors file these forms detailing financial and other information about the plans with the U.S. Department of Labor (DOL). The data contained in these forms are compiled and posted by the Employee Benefits Security Administration in a series of data files at https://www.dol.gov/ebsa/foia/foia-5500.html. It is important to note that these pension data are collected for different purposes, and are incommensurate with, the pension liabilities reported in Form 10-Ks. The DOL collects information from pension plans for the purposes of administering ERISA, while the Securities and Exchange Commission (SEC) requires publicly-traded companies to present information on benefit plan obligations as part of the required financial disclosures to investors. The crucial difference between the ERISA and the Form 10-K pension figures is that the Form 10-K figures contain estimates of future obligations not yet incurred, while the ERISA data do not make such projections. 2013 is the most recent year for which complete Form 5500 information is available.

We use the following 5500 data:

- Form 5500, the main form filed by employee benefit plans with at least 100 participants;
- Form 5500 SF, filed by plans with fewer than 100 participants;
- Schedule SB, which contains information on assets and liabilities for single-employer pension plans;
- Schedule MB, which contains similar information for multiemployer plans.

We identified Washington employers within the 5500 and 5500 SF files, and matched asset and liability data from the SB data set. The MB data set contained no Washington-based unions or industry names. Based on these data, we list in Table A4.2 the Washington employer with the plan sponsor of record and the pension funds. Some employers sponsor more than one plan.

We estimate unfunded liability figures for each pension plan by doing the following calculation using the 5500 data:

Unfunded liability = Funding Target – (Assets - (Carryover balance + Prefunding Balance))[42]

Our estimates of the national pension unfunded pension liabilities of Washington pension employers are presented in Table A4.3.

As these are unfunded liability figures, negative values represent *overfunded* pensions (values in parentheses). In total, the pensions are underfunded by $201 million using the market value method and $1.2 billion using the actuarial value method. While these figures look large, none of the plans are severely underfunded as a percentage of their funding target, and combining the assets and liabilities of all plans yields an "aggregate pension plan" that would be almost fully funded.

Company financials

We then also look at the finances of the above companies, to determine their ability to fully fund their employee pensions. We present data on net income, dividends paid, and share buybacks for the previous three years in Table A4.4 below.

TABLE A4.2
Affected Washington Companies and Corresponding Pension Plans

Firm	Plan Sponsor	Pension plan
BP West Coast Product	BP CORPORATION NORTH AMERICA INC.	BP RETIREMENT ACCUMULATION PLAN
Phillips 66	CONOCOPHILLIPS COMPANY	CONOCOPHILLIPS RETIREMENT PLAN
Phillips 66	PHILLIPS 66 COMPANY	PHILLIPS 66 RETIREMENT PLAN
Shell Oil Products	SHELL OIL COMPANY	SHELL PENSION PLAN
Tesoro West Coast	TESORO CORPORATION	TESORO CORPORATION RETIREMENT PLAN
Tesoro West Coast	TESORO, INC.	TESORO, INC. DEFINED BENEFIT PENSION PLAN
US Oil and Refining	U.S. OIL & REFINING CO.	THE RETIREMENT PLAN FOR UNION EMPLOYEES OF U.S. OIL & REFINING CO.
Centralia Power Plant	TRANSALTA USA, INC.	TRANSALTA RETIREMENT PENSION PLAN
Kinder Morgan	KINDER MORGAN, INC.	KINDER MORGAN RETIREMENT PLAN
Chevron	CHEVRON CORPORATION	CHEVRON RETIREMENT PLAN
Enbridge	ENBRIDGE EMPLOYEE SERVICES, INC.	ENBRIDGE EMPLOYEE SERVICES, INC. EMPLOYEES' PENSION PLAN
Northwest Pipeline Group	THE WILLIAMS COMPANIES, INC.	WILLIAMS PENSION PLAN
Northwest Pipeline Group	THE WILLIAMS COMPANIES, INC.	WILLIAMS INACTIVE EMPLOYEES PENSION PLAN
Transcanda	TRANSCANADA USA SERVICES INC.	TRANSCANADA USA SERVICES INC. RETIREMENT PLAN
Gas Transmission NW	TRANSCANADA USA SERVICES INC.	TRANSCANADA USA SERVICES INC. RETIREMENT PLAN

Source: ERISA 5500s, https://www.dol.gov/ebsa/foia/foia-5500.html

TABLE A4.3
Affected Companies and Corresponding Pension Plans, 2013

Plan	Unfunded liability, market value method	Unfunded liability, actuarial value method	Funded status (market value method)	Funded status (actuarial method)
BP RETIREMENT ACCUMULATION PLAN	(8,623,144)	366,498,822	1.001270743	0.945991195
CONOCOPHILLIPS RETIREMENT PLAN	45,346,057	151,748,309	0.984032511	0.946565598
PHILLIPS 66 RETIREMENT PLAN	(6,298,498)	24,562,859	1.003550191	0.986154977
SHELL PENSION PLAN	(641,445,374)	(317,812,171)	1.066691014	1.033042901
TESORO CORPORATION RETIREMENT PLAN	(10,647,107)	(2,078)	1.027949378	1.000005455
TESORO, INC. DEFINED BENEFIT PENSION PLAN	(10,221)	(10,221)	1.060909622	1.060909622
THE RETIREMENT PLAN FOR UNION EMPLOYEES OF U.S. OIL & REFINING CO.	513,439	513,439	0.942372838	0.942372838
TRANSALTA RETIREMENT PENSION PLAN	(947,734)	(947,734)	1.041885489	1.041885489
KINDER MORGAN RETIREMENT PLAN	(91,481,411)	(28,693,164)	1.044226824	1.013871753
CHEVRON RETIREMENT PLAN	807,581,382	907,691,035	0.898417679	0.8858253
ENBRIDGE EMPLOYEE SERVICES, INC. EMPLOYEES' PENSION PLAN	1,901,345	6,088,473	0.987695064	0.960597224
WILLIAMS PENSION PLAN	58,595,732	68,093,139	0.919154611	0.9060509
WILLIAMS INACTIVE EMPLOYEES PENSION PLAN	55,558,115	62,084,912	0.868427355	0.852970605
TRANSCANADA USA SERVICES INC. RETIREMENT PLAN	(8,896,947)	(8,896,947)	1.043878724	1.043878724
Total	201,145,634	1,230,918,673	0.993896088	0.962646869

Source: ERISA Form 5500s

TABLE A4.4

Net Income, Dividends, and Share Buybacks for Affected Firms (US$ millions)

Firm	Net income (millions)	Dividends	Share buybacks
BP PLC			
2015	-6400	6659	0
2014	4003	5850	4589
2013	23758	5441	5358
Phillips 66			
2015	4280	1172	1152
2014	4797	1062	2282
2013	3743	807	2246
Royal Dutch Shell			
2015	2200	9370	409
2014	14730	9444	3328
2013	16526	7198	5000
Tesoro Corporation			
2015	1690	228	644
2014	888	434	500
2013	454	106	440
US Oil and Refinining	NA	NA	NA
TransAlta Corp			
2015	87	93	0
2014	175	105	0
2013	-3	87	0
Kinder Morgan Inc.			
2015	208	4224	12
2014	2443	1760	192
2013	2692	1622	637
Chevron Corp.			
2015	4710	7992	211
2014	19310	7928	4412
2013	21597	7474	4494
Enbridge Inc.			
2015	-120	715	0
2014	1210	564	0
2013	372	507	0
Williams Companies			
2015	-1314	1836	0
2014	2339	1412	0
2013	668	982	0
Transcanada Corp			
2015	-858	1088	221
2014	1500	1012	0
2013	1438	967	0

Source: Company annual reports. All reports were in American dollars except Transalta, Enbridge, and Transcanada, which reported in Canadian dollars. Those companies results adjusted by the 2015 average annual exchange rate of 1.39

Endnotes

1 http://climateactiontracker.org/global.html

2 See World Development Indicators: http://data.worldbank.org/indicator/EN.ATM.CO2E.PC. The other primary sources of total greenhouse gas emissions, in the U.S. and globally, are methane and nitrous oxide.

3 Reference is: http://www.eia.gov/environment/emissions/state/, Summary Table. Hereafter, we will drop the reference to "metric" tons and refer, as shorthand, simply to "tons" of CO_2, with the "metric" measure being implicit in all such references.

4 As recently as 2000, coal provided nearly 8 percent of Washington State's total energy supply. For 1980, coal's share of total energy supply was 9.8 percent.

5 Various approaches to reduce energy losses in electricity generation are described in Prentiss (2015).

6 The public safety concerns with respect to nuclear energy are discussed briefly in Pollin (2015), with further references supplied there.

7 American Council for an Energy Efficient Economy, "State and Local Policy Database: Washington." http://database.aceee.org/state/washington. Accessed March 22, 2017. Morris, Jeff (2009) "Energy Efficiency in Washington State," National Conference of State Legislators. http://www.ncsl.org/documents/energy/Morris0709.pdf. Washington Department of Commerce State Energy Office (2014) "2015 Biennial Energy Report and State Energy Strategy Update: Issues, Analysis, and Updates." http://www.commerce.wa.gov/wp-content/uploads/2016/05/Energy-2015-Biennial-Energy-Report.pdf

8 We provide an extensive review of the NAS study in Pollin et al. (2014).

9 https://www.eia.gov/electricity/state/

10 https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a It is also important to recognize that this average cost figure of 10.6 cents per kilowatt hour includes a wide range of prices according to region and the sectors consuming electricity.

11 https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/state_transportation_statistics/washington/html/fast_facts.html

12 The estimates in *Green Growth* for average fuel efficiency levels for automobiles as of 2030 are lower than those derived by both the Energy Information Agency, whose estimate was at 44.0 mpg and the Environmental Protection Agency, whose estimate was 49.3 mpg. We are working with the lower estimate, so that we remain conservative in assessing the prospects for achieving efficiency gains within the auto transport sector. The references for the EIA figure are: Vehicle age from BLS CEX survey http://www.bls.gov/cex/pumd_data.htm#csv, file ovb15.csv, variable VEHICYR. Projected CAFÉ standards from EIA, http://www.eia.gov/outlooks/aeo/data/browser/#/?id=7-AEO2016&cases=ref2016~ref_no_cpp&sourcekey=0, Light Duty Vehicles. The reference for the EPA figures is: Vehicle age from BLS CEX survey http://www.bls.gov/cex/pumd_data.htm#csv, file ovb15.csv, variable VEHICYR.

13 http://www.reuters.com/article/us-usa-trump-autos-idUSKBN16M2C5

14 See, on the Washington State standard: http://www.ecy.wa.gov/programs/air/cleancars.htm#What_does_this_mean_to_me. For recent perspective on the status of the statewide standards relative to the Trump Administration initiatives, see https://www.washingtonpost.com/news/innovations/wp/2017/03/15/trump-to-pull-back-epas-fuel-efficiency-determination-opening-the-door-for-reduced-standards/?utm_term=.6b6a897f4272

15 Pollin et al. (2014) pp. 62 -70 discusses in detail the prospects for industrial efficiency gains, based on the NAS study.

16 Pollin et al. (2014) pp. 113-16 presents a discussion of the prospects in the United States overall for cellulosic bioenergy.

17 http://www.eia.gov/outlooks/aeo/electricity_generation.cfm

18 To date, there are no commercial scale CCS operations in place. Pollin (2015) pp. 25 – 27 provides a brief review of the feasibility and desirability of CCS technologies. The conclusion from this review is that there are several major problems associated with CCS technologies, which together render the approach unsuitable as a major clean-energy strategy.

19 The full methodology for generating these costs is presented in Pollin et al. (2014) pp. 136-37.

20 See Pollin et al. (2014), pp. 113 – 115 on emissions generated by conventional bioenergy sources, including biomass and corn ethanol.

21 To our knowledge, to date, there are no sources that directly report on the current level of clean energy investments in Washington State. Our estimate that the current level is between $1.5 - $2 billion per year is based on two indirect sources. First, Bloomberg New Energy Finance reports that for the U.S. as a whole, clean energy investments totaled $58.6 billion in 2016 (https://about.bnef.com/clean-energy-investment/ and https://www.greentechmedia.com/articles/read/global-clean-energy-investment-dropped-18-in-2016-with-slowdown-from-china). The GDP for Washington State in 2016 was about 2.6 percent of total U.S. GDP. Thus, if clean energy investments in Washington State were proportional to its share of U.S. GDP, that would imply that these investments would amount to about $1.5 billion in 2016. It is highly likely that Washington State is investing proportionally more in clean energy than at a level proportional to its state GDP. As we have seen, emissions per capita in Washington State are the 7th lowest among the 50 states. As we discuss further in Section 9 below, Washington State has a relatively strong set of clean energy investment incentive programs in place, certainly relative to the average among the other 49 states. As such, it is reasonable to assume that current annual levels of clean energy investments in Washington State are closer to $2 billion rather than $1.5 billion. In addition, the Renewable Northwest Project provides a report on the cumulative level of renewable energy projects in Washington State between 1998 – 2013 (http://www.rnp.org/sites/default/files/pdfs/WA_Factsheet_2013JUN28.pdf). They report this figure as $8.1 billion for this 15-year period. But their figure does not include energy efficiency investments at all. Moreover, the pace of renewable energy investments has certainly accelerated in more recent years, in Washington State and throughout the U.S., with investment incentives having expanded, technologies having improved, and costs having consequently fallen. It is therefore reasonable to assume that roughly 15 – 20 percent of this cumulative renewable energy investment figure of $8.1 billion between 1998 – 2013 will have occurred in 2013, the most recent year included in the report. It is also likely that the level of annual clean energy investments in Washington State will have increased over 2014 – 2016 relative to 2013, including both energy efficiency as well as renewable energy investments. Working from these indirect sources, it is therefore reasonable to conclude that Washington State's overall current level of clean energy investments is between $1.5 and $2 billion per year.

22 Nevertheless, it is still critical to support the purchase of high-efficiency autos by consumers, through, for example, subsidizing credit for such purchases. We return to this point later.

23 We emphasize that this assumption of a 40 percent decline in production and employment in Washington State's fossil fuel related industries by 2035, tied to a 40 percent decline in statewide consumption, also as of 2035, is only a *rough approximation*—though we believe it is the most reasonable such approximation. There are reasons to assume that production and employment in the affected industries will decline by less than the full fall in consumption. One factor could be that fossil fuel related business firms located in Washington State could still maintain higher levels of demand for their products with out-of-state customers, even while in-state demand declines by 40 percent. It is also possible that Washington State's fossil fuel related businesses will find it profitable to maintain a disproportionately large workforce even while overall demand declines because doing so maintains their operations at the most effective level. By contrast, it could also follow with some firms that the decline in demand for their products will encourage them to lay off workers by a more than proportional extent—i.e. to reorganize production with a higher level of capital intensity. (This pattern would be consistent with the increasing capital intensity of oil production work itself, as reported in the *New York Times*, 2/20/17, https://www.nytimes.com/2017/02/19/business/energy-environment/oil-jobs-technology.html). Some firms could also shut down altogether due to the steady decline in demand (Pollin and Callaci (2016) discuss this latter prospect more fully). Given this range of possibilities—some of which are counteracting—on balance, we conclude, again, that the most reasonable working assumption for our purposes is that the decline in production and employment in Washington State's fossil fuel related industries will be commensurate with the decline in statewide consumption. However, this assumption does not mean that the decline in production through 2035 will proceed smoothly. In what follows, we consider two sets of possibilities: that the rate of decline is smooth; and, alternatively, that the rate of decline is episodic.

24 These ancillary industries correspond roughly to some of the major industries in which indirect employment occurs resulting through fossil fuel sector production, as defined in the input-output tables. In estimating the number of workers who would require some form of support through a Just Transition program, it is more accurate to focus on the direct employment figures for these ancillary industries as opposed to utilizing the indirect employment data from the input-output tables. Among other factors, a high propor-

tion of the employment generated indirectly through fossil fuel industry activity will also have indirect links with clean energy investments. We would therefore not expect that a large share of the workers employed through indirect links will experience net job losses as the fossil fuel industries contract.

25 For convenience, we use the terms "wage insurance" and "wage replacement" for the policy tools described in this section. But as the passage in the main text notes, we are in fact referring to both insurance and replacement policies for the full level of compensation that the displaced fossil fuel related industry workers will have been receiving at the time of their displacement.

26 The patterns at which petroleum refineries have shut down in the U.S. over the past 35 years provide a useful reference point, since, as we have seen, fully 35 percent of Washington State's fossil fuel industry related employment is in petroleum refining. The picture here is mixed. For the most part, the time frame over which refineries have shut down in the U.S. since the early 1980s has been relatively short episodes. Thus, considering the two most recent examples, The Pelican Refining Company's refinery in Lake Charles, Louisiana stopped operating in December 2014 and then shut down fully one month later, in January 2015. The shutdown of the Antelope Refinery in Douglas, Wyoming was somewhat more drawn out, with operations stopping in February 2015 before fully shutting down 20 months later in December 2016 (see: https://www.eia.gov/petroleum/refinerycapacity/table13.pdf). More generally, between 1982 – 2017, the total number of operating refineries in the United States has contracted by more than half, from 301 to 141. But most of the refineries shutting down have been small operations, whose operating capacity has been replaced by larger refineries (https://www.forbes.com/sites/jamesconca/2015/03/02/forget-about-climate-change-americas-refineries-make-keystone-xl-a-bad-idea/#2fb4d7416d95) The pattern with which larger refineries would shut down over the next 15 – 20 years could be more gradual than with the small refineries that have shut down since the early 1980s, precisely because they are larger operations, for which a total episodic shut-down would entail more complicated logistics and larger costs. Refinery outages are distinct from shutdowns, as they result from the planned shutdown of units for maintenance and upgrades or from unplanned events such as mechanical failure, bad weather, power, power failures, fires and flooding. Outages can last for up to several months (https://www.eia.gov/petroleum/refinery/outage/archive/pdf/outage_nov2016.pdf). But the experience with outages are not comparable to the permanent phase-out and shut-down of a refinery resulting from the declining level of petroleum consumption.

27 According to the *2017 Biennial Energy Report*, the Task Force concluded that "thoughtful and informed policy design…will be required to achieve either an emissions-based or price-based policy approach that is workable for the State of Washington," (Bonlender 2016, p. 30).

28 See Pollin et al. (2014) for a brief discussion of the relative merits of the two approaches, along with further, more extensive, references to the relevant literature. One especially relevant recent study is Petersen and Elgie (2015), which describes the successful implementation of the carbon tax in neighboring British Columbia. The British Columbia carbon tax has been in operation since 2008, and is generating about $1.1 billion per year in revenues, while supporting the province's environmental goals.

29 We do not examine here the impact of the tax on retail prices for energy or energy-intensive products purchased in Washington State. A basic reference on this issue is Metcalf (2009). He finds, for example, that a $15 per ton carbon tax for the U.S. economy would raise prices as follows: 14.1 percent for electricity and natural gas; 10.9 percent for home heating; 8.8 percent for gasoline; 2.2 percent for air travel; and between 0.3 and 1 percent for other commodities.

30 This and other features of PACE financing are summarized at the DSIRE website here: http://www.dsireusa.org/solar/solarpolicyguide/?id=26

31 http://www.ecy.wa.gov/programs/air/cleancars.htm

32 See Pollin et al. (2014) for further discussions on these federally-based clean energy investment programs.

33 In May 2016 Congress legislated to maintain funding for the site: http://www.portman.senate.gov/public/index.cfm/press-releases?ID=84DB38D2-5B4C-434F-BC68-B14E60DFA440

34 The 2000 annual report of the U.S. Office of Worker and Community Transition describes in detail the program as it was implemented in Hanford, (http://www.lm.doe.gov/Office_of_the_Director/Work_Force_Restructuring/Work_Force_Annual_Reports/fy2000part2.aspx).

35 U.S. Department of Energy, "U.S. Departments of Energy and Interior Announce Site for Solar Energy Demonstration Projects in the Nevada Desert," Press release, 7/8/10, http://energy.gov/ articles/us-departments-energy-and-interior-announce-site-solar-energy-demonstration-projects-nevada.

36 The description in this paragraph is based on Galgoczi (2015) and Dohmen and Schmid (2011).

37 Beginning in 2017, the Rule covers organizations emitting more than 100,000 tons per year of greenhouse gases. Every three years, the threshold is then lowered, with more emitters brought into the program until 2035, when inclusion will be capped at 70,000 tons. Every three years, organizations covered under the rule will need to demonstrate they've made reductions equal to 1.7 percent each year from the baseline. For details, see: http://www.ecy.wa.gov/climatechange/CAROverview.html

38 The figures are presented as including all greenhouse gas emissions from these facilities, including methane and nitrous oxide as well as CO_2. However, with the pulp and paper industry, virtually 100 percent of emissions are CO_2. We therefore roughly approximate that the emissions reported are all CO_2. See https://www.epa.gov/ghgreporting/ghgrp-2013-pulp-and-paper for details on the composition of all GHG emissions generated by pulp and paper production.

39 We use the CPS data files provided by the Center for Economic and Policy Research (CEPR) which standardizes variables across years (www.ceprdata.org).

40 This is different from the final employment figure of 3,245 in the main text due to rounding.

41 This is different from the final employment figure of 3,245 in the main text due to rounding.

42 An actuary at EBSA confirmed over email that this is the correct calculation.

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