

**The College of Forest Resources
University of Washington**

Report to the Washington State Legislature

**Wood to Energy in Washington:
Imperatives, Opportunities, and
Obstacles to Progress**

Executive Summary/Full

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http://www.ruraltech.org/pubs/reports/2009/wood_to_energy/index.asp

“The fuel of the future is going to come from apples, weeds, sawdust—almost anything. There is fuel in every bit of vegetable matter that can be fermented.”

Henry Ford,

"Ford Predicts Fuel from Vegetation," New York Times, Sept. 20, 1925, p. 24.

"With all due deference for the dream chemists, armchair farmers and platform orators who have touted alcohol-gasoline as the greatest of all fuels, oil industry technologists know and automotive engineers know that it is not as satisfactory a fuel as straight gasoline of normal quality."

Conger Reynolds,

"The Alcohol Gasoline Proposal," American Petroleum Institute Proceedings, 20th Annual Meeting, Nov. 9, 1939.

Executive Summary

At the request of the Washington State Legislature, a thorough investigation of the potential for utilization of wood for renewable energy in Washington has been conducted by University of Washington scientists. Summary findings and recommendations are presented below.

Key Study Findings:

- **Three fundamental imperatives compel changes in energy policy: Climate Change Mitigation, Energy Independence, and Sustainability.**
 - ✓ *Washington is 100 percent reliant upon oil imported from other states or abroad. Petroleum consumption for transportation accounts for half of all Washington greenhouse gas (GHG) emissions. Washingtonians spent \$9 billion on fuel imports in 2006.*
 - ✓ *Washington, with substantial hydro-electric and nuclear generation capacity, is a net power exporter, has low electricity rates, and generates the cleanest electricity in the Nation. Unlike the transportation sector, changes in electricity generation have comparatively limited potential to reduce greenhouse emissions.*
- **Where possible, development of renewable in-state sources of transportation fuel should be the State's highest energy priority.**
 - ✓ *Plant biomass is the only Washington renewable resource that can be converted to biofuels for transportation, such as ethanol.*
 - ✓ *Wood is the dominant biomass resource in Washington; accounting for two-thirds of all potentially available biomass.*
- **Production of renewable biofuels in Washington will necessarily require wood as a primary feedstock and efforts to reduce State greenhouse gas emissions must fully consider forests and forest resources.**
 - ✓ *Forests play a unique role in climate change mitigation by absorbing CO₂ through photosynthesis, storing carbon in tree biomass and building products, offsetting use of polluting building product alternatives, and by providing biomass for energy.*
 - ✓ *Thinning forests to avoid CO₂ emissions from catastrophic wildfires while providing wood resources for green building materials and renewable biofuels will deliver double greenhouse gas emission reduction benefits while sustaining forest ecosystems. As example, in 2006, greenhouse gas emissions from wildfires in Washington were greater than total emissions from electricity generation.*
 - ✓ *The forest industry represents the State's largest biomass collection system, is the largest industrial provider of renewable energy, and has potential to significantly improve wood-to-energy recoveries and outputs.*
- **Energy recovery of liquid fuels from wood biomass will require large integrated biorefinery installations that must be able to secure resources for operations and markets for bioenergy outputs.**
 - ✓ *Significant production of biofuels in Washington will be dependent upon regular collection of millions of tons of wood biomass augmented, where possible, with recovered biomass from cities and fields.*
 - ✓ *Federal policies, such as the Energy Independence and Security Act of 2007, restrict use of wood biomass from National Forests for energy conversions undermining both biofuels development and reduction of CO₂ emissions from forest fires.*
 - ✓ *Where possible, co-location of biorefineries with pulp and paper mills represents the greatest potential State opportunity to maximize energy recovery of liquid fuels, electricity, and process steam from woody biomass resources. Co-location will bring reduced capital costs, access to*

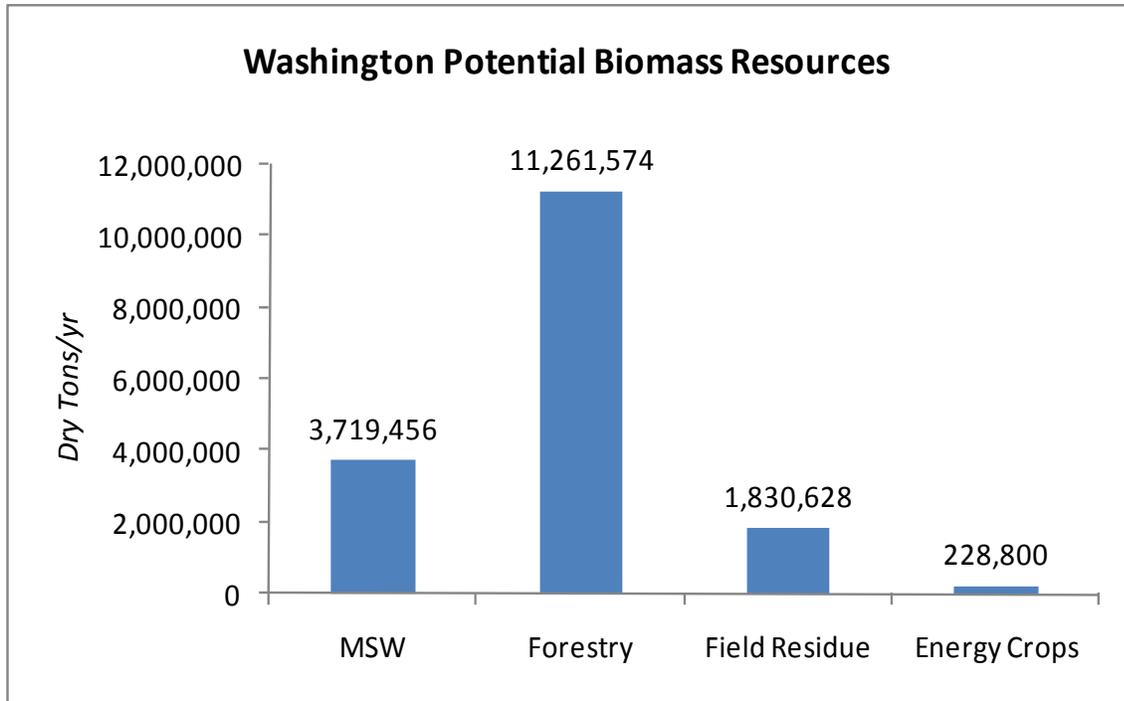
needed infrastructure, synergies for integrated raw materials and product streams, and an engaged corps of highly-skilled chemical engineers and union workers.

- **Sustainable development of renewable energy alternatives to fossil fuels will require careful planning, resource conservation, and committed policy supports.**
 - ✓ *Where biorefinery development is feasible, State policies must be designed to accommodate considerable biomass deliveries.*
 - ✓ *Where biorefinery development is not feasible, secondary wood-to-energy priorities could include co-fired generation, wood pellet manufacture, or institutional heating.*
- **Washington State must have a cohesive strategy for renewable energy development to meet its renewable energy and green house emission goals.**
 - ✓ *Washington does not have a Department of Energy or other organizational framework for effective scientific participation in policy consideration of the interrelated topics of energy, climate, and forest resources.*
 - ✓ *Criteria for comparisons of potential alternative energy and resource applications have not been developed to inform energy policy priorities. As example, the implications of wood biomass combustion for electricity verses chemical conversion to transportation fuels appear, as of yet, to have not been considered in State energy policy.*
 - ✓ *The many public benefits of energy alternatives to fossil fuels are not readily captured by consumer markets and, in lieu of integrated planning, are not adequately characterized in State energy policy.*
 - ✓ *Current State energy policies, such as I-937, inadvertently favor small-scale and inefficient conversions of biomass to electricity which fail to address energy independence, have poor raw material-to-energy yields, and compromise biofuels development.*
- **In absence of integrated planning and enduring commitment to change, opportunities for wood to energy are compromised while combustion of imported fossil fuels and associated green house gas emissions continue to increase.**

Recommendations:

- **A lead State agency is needed to coordinate policy development for the interrelated topic areas of climate change mitigation, energy independence, and sustainable management of State natural resources.**
 - ✓ *An inter-disciplinary team of scientists from Washington's universities should be assembled to develop recommendations for realistic, effective, and implementable strategies for renewable energy development and climate change mitigation.*
 - ✓ *Robust methodologies such as Life Cycle Assessments (LCA) and Net Energy Balance (NEB) must be employed for energy alternative evaluations if comparative benefits are to be understood.*
- **Energy priorities need to be identified to inform development of a cohesive State energy plan.**
 - ✓ *Policy mechanisms should be designed to capture the non-market values and avoided costs of reduced reliance upon fossil energy.*
 - ✓ *An effectiveness comparison for Washington of a cap and trade program verses a carbon tax or other climate policy option should be conducted once energy priorities are identified.*
 - ✓ *Policy supports must be developed to encourage investment in renewable energy and assure viable markets for energy products.*

- **Washington should pursue policies that support large-scale biofuels projects rather than inefficient small-scale power projects.**
 - ✓ *A pilot project for an integrated biorefinery, located at a pulp and paper mill, should be developed and implemented in Washington.*
 - ✓ *Washington policy makers should pursue regulatory changes that broaden rather than constrain access to forest biomass resources.*
 - ✓ *Investments in thinning for forest health offer unique opportunities to combine ecosystem protections with bioenergy development.*



Washington's Potential Biomass Resources (Frear 2008).

Summary Narrative:

This analysis began as an investigation of barriers to woody biomass utilization for energy in Washington but expanded quickly to become more comprehensive as our analysis revealed that perhaps a significant barrier is a lack of integrated understanding of complex issues that need serious consideration if progress is to be achieved. Issues include technical, economic, environmental, social, and moral questions that require continued scholarly research but ultimately can only be resolved by an informed political process. The choices ahead are difficult, expensive and long-lasting with implications for future generations and forest ecosystems in Washington and around the world. While obstacles appear formidable and numerous, none are insurmountable if Washington citizens *choose* to focus sufficient resolve.

The conversion of solar radiation into chemical energy via photosynthesis results in the growth of vegetative biomass made up of organic compounds which have intrinsic energy content. Biomass is effectively stored solar energy. Most of the world's biomass is found in forests. Forests play a specific and important role in global carbon cycling by absorbing carbon dioxide during photosynthesis, storing carbon above and below ground, and producing oxygen as a by-product of photosynthesis. In the presence of increased greenhouse gases in the atmosphere, healthy forests help to mitigate the effects of climate change on the environment by removing carbon dioxide (CO₂) from the atmosphere. Forests in the United States absorb and store about 171 million metric tons of carbon each year, an amount

equivalent to 11 percent of the country's CO₂ emissions. The highest sustained carbon accumulation rates for American forests are reported to occur with new forest growth on high productivity sites in the western Pacific Northwest. Sustainably-managed forests that are periodically harvested, planted, and re-grown to produce a continuing series of short- and long-lived products and energy feedstocks, sequester and offset more cumulative carbon than forests that are left unharvested. When forest health declines or when forest fires occur, releases of stored forest carbon transform forests so that they become a carbon source rather than a sink.

Wood residues from forests can be referred to as woody biomass or as lignocellulosic or cellulosic energy feedstocks. All wood fiber that does not have higher value product potential for non-energy applications can be considered as woody biomass. Woody biomass can include forest residues such as tops, limbs, foliage, bark, rotten logs, and stumps (otherwise commonly known as logging slash) that historically have been left on site or burned following timber harvest. Woody biomass may also include such materials as may be salvaged from pre-commercial thinning activities, designed to reduce stocking densities in young forests such that remaining tree growth is optimized. Forest fuels reductions (generally in fire-prone dry forests) can produce woody biomass as small diameter understory stems and ladder fuels are removed to create conditions such that, when an ignition occurs, a comparatively benign ground fire is the result rather than a destructive crown fire. Woody biomass also refers to primary and secondary wood product manufacturing residuals including bark, saw dust, planer shavings, and ground wood pieces known as hog fuel. Wood chips that are manufactured from round logs not suitable for lumber manufacture or sawmill slabs and pieces may also be used for energy feedstocks but are generally considered to have higher value for paper manufacture. A by-product of pulp and paper manufacture is black liquor; which is another wood process residual that is used for energy. Dedicated tree plantation crops such as fast-growing poplar and willow may also be used for energy generation. The yield from such crops is considered woody biomass although the cultivation practices more closely resemble those of agriculture.

There are many contemporary wood-to-energy conversion alternatives that can be and are employed to produce heat and electricity as well as solid, liquid, or gaseous fuels. Energy conversions can be as simple as combustion for heat or as sophisticated as biochemical and thermochemical processes to produce transportation fuels such as ethanol. We find that, while conversion technologies are improving through continued research, many wood-to-energy applications have been used for decades, are technically feasible, and could be immediately implemented; albeit at costs that are not readily competitive with fossil fuel alternatives given current energy market dynamics.

Examination of energy markets reveals that significant environmental and economic costs resulting from fossil fuel combustion and reliance upon imported oil have not been incorporated into consumer prices. For example, societal costs of climate change and health impacts from gasoline combustion have been estimated at more than \$1.00 per gallon while reliance upon imported oil from politically volatile areas of the world has been shown to reduce US gross domestic product by upwards of one percent. These real public costs add up to hundreds of billions of dollars annually but are not included in the consumer price of fossil energy.

There are also substantial public costs associated with failure to manage forests to reduce overstocked densities. Especially compelling are the considerable potentially avoided environmental and economic costs of catastrophic wildfires. US wildfire suppression costs alone are in the billions of dollars annually and the Climate Impacts Group at the University of Washington forecasts that, without action, global warming will increase incidence and intensities of forest fires in the inland west. Wood biomass is the dominant State non-hydro source of renewable energy; representing fully two-thirds of Washington's potentially available biomass inventory. Unlike agriculture, forests don't require large amounts of polluting fertilizers, volumes of water for irrigation, or transformations of ecosystems to non-native vegetation. The Washington forest industry represents the largest biomass collection infrastructure in the state. Given Washington commitments to renewable energy development and greenhouse gas emissions reductions, utilization of wood wastes for energy should be a high priority.

However, if progress is to occur then the economics and other benefits of wood biomass for energy must be better understood. Given that fossil fuels are energy-rich and inexpensive, policy supports for

renewable energy alternatives, based upon explicit cost/benefit analyses, will be needed. It should be recognized that the existing forest industry infrastructure is a significant contributor of renewable energy and that, with policy support for investment, could increase energy outputs from the existing captured resources such as hog fuel and black liquor. Manufacturing wastes are a byproduct of higher value solid wood and paper manufacture and are the lowest cost source of biomass. The pulp and paper industry has potential for biorefinery development to efficiently produce a mixture of products outputs that could be expanded to include heat, electricity, and liquid fuels, such as ethanol, at lower cost than new stand-alone energy plants. Low cost hog fuel, when mixed with higher cost forest residues, can result in a raw material cost index to support broad utilization of wood biomass resources.

We identify three imperatives for guiding progress that have been well-documented in the literature, but have not been adequately integrated into policy. ***Energy policies should seek to maximize integrated achievement of three important goals: climate change mitigation, energy independence, and sustainability.*** When viewed from this perspective, it is readily apparent that the state energy priority should be liquid transportation fuels and that, for Washington, wood is the primary raw material available for biofuels conversions. Combustion of fossil fuels for transportation accounts for fully one-half of the annual greenhouse emissions in Washington; more than twice that released from any other source. Other than minor in-state production of biodiesel, all transportation fuels consumed in Washington are imported from other states or abroad whereas Washington, with abundant hydro-power, generates the cleanest electricity in the nation and is a net electricity exporter. Wind power installations are adding new clean electricity capacity but cannot provide for liquid fuel needs. The decline in Alaska oil production, on which Washington is dependent, should further focus State attention towards securing new liquid fuel resources.

Washington's potentially available wood biomass resource has been estimated to be more than 11 million bone dry tons per year. For relative perspective on the magnitude of this resource, we offer the following theoretical conversions. Total potential ethanol produced from all Washington wood biomass resources could be 900 million gallons per year; enough to replace one-third of 2008 gasoline consumption. WSU colleagues have estimated that the potential electricity from Washington's wood biomass would be equal to 11.5 million MWh or about 13 percent of total Washington electricity use.

We find, however, that a lack of strategic energy priorities in Washington, compounded by political disagreements, has resulted in a peculiar assortment of counterproductive policies (discussed below) that inadvertently reward underutilization of energy resources by focusing on small-scale, capital-intensive, and inefficient conversion projects to produce low-priority electricity. Further, although State policy makers have clearly identified greenhouse gas emissions reductions and renewable energy development as very important public objectives, policies appear to have overlooked the need to integrate resource stewardship and energy generation towards best fit with existing industrial infrastructure.

While obstacles appear formidable and numerous, we hypothesize that none are insurmountable if Washington citizens *choose* to focus enlightened resolve. We refer the reader to the history of ethanol development in Brazil as example. On the other hand, the challenges to substantive reductions in fossil fuel consumption must not be discounted. Fossil fuels are energy-rich, are supported by a vast infrastructure, and, without consideration of factors such as greenhouse gas emissions and energy independence, appear as least-cost energy options for consumers.

Important to any discussion of renewable energy substitution for fossil fuels is a recognition that progress will occur at the margin. Review of domestic and international analyses indicates that total energy independence from fossil fuels is not potentially achievable within any foreseeable planning window. This does not imply, however, that incremental improvements cannot be important or should not be pursued. Development of all potential domestic renewable resources, with careful planning towards an integrated energy portfolio, will ensure optimized levels of success.

Evolving public perceptions regarding forests, biomass exploitation, and non-market amenities will play a major role in how much of the wood resource base may be used for energy. The public must be credibly assured that woody biomass produced from Washington State forests is an environmentally sound and

safe source of renewable energy. However, given the mounting problems of global warming and forest health declines, concerned stakeholders must be challenged to revisit out-dated notions that forests unmanaged are protected. It will be important that the consequences of failing to act be fully appreciated. As demonstrated in many of the discussions presented throughout this report, failure to mitigate climate change, reduce fossil fuel pollution, increase energy independence, and implement practices to ensure forest sustainability is already resulting in significant environmental, social, and economic costs. Numerous international, national, and state political leaders have characterized the need for effective response to current climate and energy challenges as the paramount concerns of the twenty-first century.

The Intergovernmental Panel on Climate Change (IPCC) is a globally-convened body of hundreds of scientists that are generally recognized as the pre-eminent international authority on climate change. IPCC investigation into potential climate change mitigation options resulted in the following conclusion.

“In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fiber, or energy from the forest, will generate the largest sustained mitigation benefit.” (IPCC. 2007. *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the IPCC.*).

The four most important findings that emerge from this study:

- 1) Energy policy must be examined in the context of three over-arching imperatives that compel immediate attention: Climate Change Mitigation, Energy Independence, and Sustainability.
- 2) Wood is second only to water as a source of renewable energy for Washington, and, conversions to liquid transportation fuels emerge as the highest priority for maximizing integrated achievement of the imperative objectives.
- 3) Liquid fuels conversions from wood biomass will require large biorefinery capacity designed to utilize dispersed biomass resources for maximized bioenergy outputs. Co-location with State pulp and paper mills represents the greatest opportunity for success.
- 4) While a paradigm shift from fossil fuels to renewable energy will be difficult and expensive, the environmental and economic costs of inaction outweigh needed investment for change.

Expanded Discussion and Recommendations Linked to Report Text

The following text presents key recommendations and support discussions from the Wood to Energy in Washington study with reference to pertinent sections of main body of the report for ease of navigation to greater detail.

Climate change

- **Discussion:** Significant research contributions regarding climate change are being achieved by the Climate Impacts Group at the University of Washington. However, alarming findings, in the absence of suggested strategies for mitigation and adaptation, can serve to confuse policy discussions resulting in uninformed and counterproductive political responses as discussed in [Section IV: 4.4. Obstacle 4 – Policy and regulations](#). The Climate Leadership Initiative, in a study conducted for the Washington Department of Ecology, estimated that by 2020 the cumulative costs of climate change in Washington will be equal to \$3.8 billion per year, about 1.2 percent of total State 2007 GDP. Part of this cost is attributed to increases in incidence and intensity of wildfires. As mentioned above, such public cost liabilities are not currently incorporated into commercial energy markets. See [Section II: 2.1. Greenhouse Gases and Climate Change; *In Washington State and The costs of inaction*](#) and [Section III: 3.3. Biomass from forests – opportunities and benefits; *Forest health*](#).
- **Recommendation: Policy mechanisms to include non-market values and avoided costs in energy accounting are needed.**

Energy independence

- **Discussion:** The value of energy independence appears to be significant but under-appreciated in policy frameworks. US expenditures on oil imports were \$330 billion in 2007 and accounted for 40 percent of the national trade deficit. In 2005, Alan Greenspan estimated that oil imports reduced US GDP by \$100 billion. Washington citizens spent \$9 billion on fuel imports in 2006. When policy makers combine strategies for energy independence with climate change mitigation, the economic benefits of energy independence should serve to underwrite the costs of biofuels development and greenhouse gas emissions reductions. See Section II: 2.2. Energy independence; *Price is not cost.*
- **Recommendation:** *An assessment of costs and benefits that could derive from reduced reliance upon imported fossil fuels in Washington resulting from development of wood biomass for ethanol should be conducted.*

Forest health

- **Discussion:** Deforestation refers to a loss of forestland to another land-use. For example, deforestation could result from clearing forests for agriculture or could occur as a result of fires or floods. Most global deforestation occurs in developing countries with tropical forests; however, deforestation is occurring in Washington with net losses of forestlands to wildfires, insects and disease and from land-use conversion for development. When deforestation occurs the loss is two-fold. The carbon that has been stored (sequestered) in the forest is released and the opportunity for future sequestration of atmospheric carbon is also lost. Increases in forest mortality and wildfire frequency and intensity have reached crisis levels. Reports from climate scientists indicate that, as the planet warms, the destructive impacts of forest health declines will escalate resulting in releases of stored forest carbon transforming forests so that they become a carbon source rather than a sink. In 2006, 33 million metric tons of CO₂ were released into the atmosphere by wildfires in Washington accounting for 42 percent of the state annual total CO₂ releases; close to three times the emissions released by electric power generators. We suggest that forest biomass removals that address climate change mitigation and energy independence through production of biofuels warrant public investment to avoid much larger long-term costs. Critical to the dual goals of forest health and biomass energy development will be a change towards proactive stewardship on National Forests. See Section III: 3.3. Biomass from forests – opportunities and benefits; *Forest health* and Section IV: 4.1. Obstacle 1- Access to the resource; *Supply assurance* and Section IV: 4.2. Obstacle 2 – Public perception; *What is deforestation?*
- **Recommendation:** *Washington needs a plan to integrate biomass removals for forest health with climate change mitigation and energy development. Policy makers should urge revision of current restrictions that exclude biomass from National Forests for renewable energy conversions.*

Wood biomass resources

- **Discussion:** All types of wood-derived biomass resources including black liquor, and recoverable wood and paper from municipal solid waste should be recognized as renewable energy resources. Ambiguous terminologies such as “old growth” are unnecessary, redundant, and counterproductive when used to limit potentially available wood biomass. There are abundant limitations in statute that restrict removals of forest biomass from reserved forests. Forests that aren’t reserved and may have potential for sustainable biomass removals should be managed to do so. Maximizing the procurable wood resource for energy within identified tributary areas is of paramount importance to supply assurance, energy investment, and biofuels production. As this investigation has shown, woody biomass contribution from all forest ownerships will be required in most regions of the state if sufficient resources are to be made available for the large-scale conversion facilities needed to efficiently produce biofuels. See Section I: 1.3. Biomass and energy – Terminology and Section IV: 4.1. Obstacle 1 – access to the resource; *Supply assurance* and Section IV: 4.2. Obstacle 2 – public perception; *Social license and Forests; neither factory nor wilderness* and *How we think about forests* and Section IV: 4.4. Obstacle 4 – Policy and regulations; *I-937 – Washington’s defacto energy priority* and *Energy Independence and Security Act of 2007 (EISA).*

- **Recommendation: Arbitrary constraints that limit biomass availability for renewable energy, such as appear in I-937, should be revised. If a cohesive strategy for biomass supply assurance and utilization is not developed quickly, Washington resources may be exported into other markets, like Oregon, where biofuels development is further advanced.**

Guidelines for slash removals

- **Discussion:** Existing state forest practice rules did not anticipate increased interest in removals of harvest residues. Limiting factors for consideration include soil productivity, water quality, biodiversity, wildlife habitats, cultural values, forest health, and forest sustainability. In anticipation of an increased demand for woody biomass, a number of states are developing guidelines for removals of harvest residues. See Section III: 3.3. Biomass from forests – opportunities and benefits; *Slash recovery* and Section IV: 4.1. Obstacle 1 – access to the resource; *Guidelines for slash removals.*
- **Recommendation: As evidenced by successes in other states, forest biomass collection guidelines should be developed and incorporated into Washington forest practice rules.**

Integrated infrastructure and product hierarchies

- **Discussion:** The value of existing forest industry investment in renewable energy production and the cost-effective utilization of the wood resource must not be underestimated. Higher use wood products such as solid building materials underwrite the costs of biomass collection and provide environmentally preferable product alternatives to steel and concrete. The present policy paradigm (I-937) inadvertently prioritizes development of small-scale inefficient distributed wood power generators that will waste the resource, create undesirable competition for the least-expensive process residuals, effectively undermine recovery of more costly forest residues, and ultimately jeopardize the industrial infrastructure and employment base upon which significant development of biofuels must depend. See Section III: 3.2. Woody biomass – material and process opportunities and Section IV: 4.1. Obstacle 1 – access to the resource and Section IV: 4.4. Obstacle 4 – Policy and regulations; *I-937 – Washington’s defacto energy priority.*
- **Recommendation: Biomass energy priorities should favor liquid fuels conversions at integrated biorefineries that can optimize energy yields through recovery of heat, electricity, and chemical byproducts. As possible, biorefineries will be best sited with pulp and paper mills. State investment in support of biorefinery development would be the most effective biomass-to-energy approach for response to the three imperatives of climate change mitigation, energy independence, and sustainability.**

Conversion technology advancement

- **Discussion:** The technologies for wood heating and combined heat and power systems are mature and implementable, however, while conversion technologies for wood-to-liquid fuels, such as ethanol, are technically feasible, no commercial-scale operations are yet deployed. An important finding of this investigation has been that biomass resources are finite and, when renewable energy alternatives from potentially available resources are compared in the context of the three imperatives (climate change mitigation, energy independence, and sustainability), liquid fuels conversions emerge as the over-arching priority. It will be imperative that the biomass resource is used prudently to maximize energy yields. Since liquid fuels conversions will require large scale facilities, mixed feedstocks from forests, fields, and cities may be needed to ensure that adequate biomass volumes can be sustained. Additional biomass may become available from dedicated energy crops once biorefineries become established. Conversion strategies will need customization to accommodate local resource availability. For example, at sites close to urban areas, mixtures of forest-derived materials and recovered wood and paper from municipal solid waste may be attractive while in rural areas of eastern Washington mixed feedstocks comprised of forest and agricultural residues may make the most sense. Where inexpensive rail and water freight are available, biomass tributary areas can be expanded to facilitate transport of diverse feedstocks to assure access to adequate volumes of biomass. An ancillary benefit may also be increased and diversified raw material availability for pulp and paper production as research at the University of Washington into the

potential use of grasses and other vegetative material for paper products shows promise. The strategic economic benefits of captured process residues as an inexpensive anchor feedstock with potential for bioenergy recovery augmented by addition of more expensive recovered field residuals are discussed in this report and will be important factors for consideration of conversion technology development options. See Section I: 1.4. Wood-to-energy – conversion options and Section III: 3.2. Woody Biomass – material and process opportunities and Section IV: 4.1. Obstacle 1 – access to the resource; *Raw materials*.

- ***Recommendation: Continued research investment to develop superior conversion technologies for liquid fuel production from Washington biomass resources will help to identify advancements that provide maximum energy yields at least costs. Investment in a pilot project towards development of a commercial integrated biorefinery is highly recommended as an important next step. Research towards further development of mixed biomass applications for liquid fuels conversions customized for effective exploitation of locally available resources will be essential to assure sufficient raw material availability and maximized energy yields.***

Social license

- ***Discussion:*** As demonstrated by our review of the scientific literature, failure to mitigate climate change, reduce fossil fuel pollution, increase energy independence, and implement practices to ensure forest sustainability will result in significant environmental, social, and economic costs. The public must be credibly assured that woody biomass produced from Washington State forests is an environmentally sound and safe source of renewable energy. Educational outreach and consensus building activities such as those undertaken by the University of Washington through the Northwest Environmental Forum and the Olympic Natural Resource Center have been successful at building stakeholder consensus in support of sustainable forestry and wood biomass to energy. Communication alliances also provide fertile opportunity for cooperative interaction between stakeholders, scientists, and State agency personnel. See Section IV: 4.2. Obstacle 2 – public perception and Section IV: 4.5. Obstacle 5 – Research; *Science and education*.
- ***Recommendation: These and other programs that facilitate public education and dialogue towards consensus solutions to contemporary resource and energy challenges are worthy of State support.***

Green jobs

- ***Discussion:*** There is a growing shortage of skilled forestry professionals in Washington. Workforce challenges are an obstacle to wood-for-energy development but remarkably, forestry is excluded from the State “green jobs” program. Management of forest ecosystems with resultant production of “green” building products and renewable energy feedstocks represents the single greatest State opportunity to reduce both GHG emissions and imported fossil fuel reliance. See Section IV: 4.1. Obstacle 1 – access to the resource; *The foresters, the loggers, and the truckers* and Section IV: 4.4 Obstacle 4 – Policy and regulations; *Green jobs*.
- ***Recommendation: We recommend that State leaders acknowledge forest biomass-to-energy as a cornerstone element of a clean future economy. State agencies should work with universities and community colleges to establish training programs for forestry workers that cover the spectrum from collection through conversion.***

Green building products

- ***Discussion:*** State programs for green building have potential for beneficial change but only if rigorous assessment methodologies for product comparisons such as life cycle assessment (LCA) and net energy balance (NEB) are used to develop uniform performance standards. Current programs rely upon arbitrary product standards that are not scientifically supported. Unintended consequences include under-appreciation of the environmental benefits of locally-grown renewable wood building products as compared to alternative construction materials like steel or concrete. Failure to value wood as a green building product undermines both the green building program and

the viability of the Washington wood industry and while jeopardizing the product value hierarchy needed to support utilization of woody biomass for bioenergy. See Section III: 3.4 Forests, products, energy, and carbon; Life cycle assessment and Section IV: 4.4 Obstacle 4 – Policy and regulations; Green building standards.

- **Recommendation: Green building standards should be revised to include product comparisons based upon rigorous scientifically-supported performance standards such as LCA and NEB.**

Policy Guidance

- **Discussion:** We suggest that, without a cohesive strategy for progress based upon targeted renewable energy priorities, substantive improvements in climate change mitigation, energy independence, and sustainability are unlikely to occur. In lieu of a consistent science-based policy framework, various regulatory mechanisms evolve in isolation with narrow focus. We find a number of counterproductive contradictions in current policy framework that limit potential for biofuels development. As example, consider I-937, the Western Climate Initiative (WCI), and the Energy Independence and Security Act of 2007 (EISA). I-937 is a State initiative that, in function, excludes portions of the wood resource from use and directs the eligible biomass subset to small-scale inefficient electric generators (rather than biorefineries) that could undermine the viability of existing infrastructure and result in considerable portions of the wood biomass resource left too isolated for recovery. The WCI, a regional climate change mitigation consortium of which Washington is a member, has evolved an elaborately complicated cap and trade scheme that, given its priority to address the electric sector in its first phase of implementation, is partially redundant to the renewable portfolio standard established by I-937 and fails to address the State's largest emissions problem: transportation. Based upon the experience of the European cap and trade program, we conclude that WCI may also result in increased energy price volatility which has been shown to discourage renewable energy investment. EISA, on the other hand, was passed by the US Congress to create a national renewable fuel standard based upon ambitious additions of cellulosic ethanol capacity to be added by 2022. WA has one-twentieth of the Nation's forest biomass inventory but current State prioritization of biomass-to-electricity (I-937 and WCI) acts to undermine the EISA cellulosic ethanol target as well as to compromise the State's need to reduce greenhouse gas emissions and fuel imports. EISA, in apparent direct conflict with its ambitious schedule for cellulosic ethanol expansion, excludes wood from National Forests as eligible for conversion to renewable energy. Yet two-thirds of the nation's forest health crisis is occurring on National Forests and in many areas of the west, including Washington, wood biomass contribution from federal forests will be necessary if cellulosic ethanol is to be produced. We find that current State and national energy policies represent significant obstacles to wood-to-energy in Washington. See Section IV: 4.4. Obstacle 4 – Policy and regulations.
- **Recommendation: Liquid transportation fuels, such as ethanol, should be the State energy priority. Formal scientific review of existing policies and potential policy alternatives to examine barriers to wood for biofuels conversion is recommended. Special attention should be given to I-937, WCI, and EISA.**

Interdisciplinary science support for energy policy development

- **Discussion:** Washington's universities are home to many prestigious scientists, yet it is rare that scientists of differing disciplines and from different research organizations are asked to work together to develop integrated analysis of resource policy alternatives. See Section IV: 4.4. Obstacle 4 – Policy and regulations.
- **Recommendation: Sorely needed is programmatic investment in sustained in-state interdisciplinary research to assist policy makers and stakeholders in the development of realistic and effective strategies to address the difficult and complex challenges of renewable energy development and climate change mitigation.**

Research

- **Discussion:** The Government Accountability Office reports that, in contrast to increasingly urgent national calls for climate change mitigation and energy independence, US investments in research have generally declined over the last thirty years. In Washington, there is no programmatic investment in sustained in-state interdisciplinary research to accelerate development of renewable energy from wood biomass or to investigate the role of sustainable forest management and wood products in climate change mitigation. There is also no continuing state program to enlist forest scientists in support of policy development or educational outreach to stakeholder groups. By contrast, the Oregon Legislature created the Oregon Forest Resources Institute (OFRI) in 1991 to improve public understanding of the state's forest resources and to encourage environmentally sound forest management. OFRI is funded by a dedicated harvest tax on forest products producers. Issues include technical, economic, environmental, social, and moral questions that require continued scholarly research but ultimately can only be resolved by an informed political process. The choices ahead are difficult, expensive and long-lasting with implications for future generations and forest ecosystems in Washington and around the world. See Section IIV: 4.5. Obstacle 5 – Research.
- **Recommendation:** *Our analysis has revealed that a significant obstacle to wood utilization for renewable energy in Washington is a lack of integrated understanding of many complex issues that need serious consideration if progress towards climate change mitigation, energy independence, and sustainability is to proceed. We recommend that Washington establish a permanent interdisciplinary program of research and outreach to address emerging topics concerning biomass energy development with implications for the environment and the economy as discussed in greater detail throughout this report.*

We have prepared an information-rich examination of many factors found to be related to development of energy from wood biomass in Washington. To the best of our knowledge, such a broad investigation has not previously been conducted. We find that, to be most effective, wood energy policies must be examined in the context of three over-arching imperatives that compel immediate attention: *Climate Change Mitigation, Energy Independence, and Sustainability.* We conclude that, given these imperatives for action and a national commitment to cellulosic ethanol, utilization of wood for renewable transportation fuels should be the paramount priority. Biorefineries co-located at pulp and paper mills, offer the greatest opportunities for success. While utilization of the wood resource for biofuels presents logistical and technical challenges, we find that, when compared to other states that are already moving forward with biofuels development, Washington's abundant and productive forests should provide superior opportunity. However, a lack of public focus hinders progress. A State commitment to development of a cohesive energy strategy supported by interdisciplinary research to target priority objectives for achievement will be needed to spur investment for Wood to Energy in Washington. The most costly future outcome will result from failure to proceed.



Sandia National Laboratories and General Motors have found that ethanol from plant and forestry biomass could sustainably replace a third of gasoline use by the year 2030 (Wong).