CONSTRUCTION AND DEMOLITION RECYCLED WOOD WASTE ASSESSMENT IN THE NORTHWEST UNITED STATES

By

GERALD ANDREW SCHNEIDER

A thesis submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE IN CIVIL ENGINEERING

WASHINGTON STATE UNIVERSITY
Department of Civil & Environmental Engineering

JULY 2013

To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of GERALD ANDREW SCHNEIDER find it satisfactory and recommend that it be accepted.

Karl Englund, Ph.D., Chair

Liv Haselbach, Ph.D.

Michael Wolcott, Ph.D.

ACKNOWLEDGEMENTS

I would like to thank the Northwest Advanced Renewables Alliance (NARA) for funding this research. NARA is led by Washington State University and supported by the Agricultural and Food Research Initiative Competition Grant no. 2011-68005-30416 from the USDA National Institute of Food Agriculture.

I would also like to thank all of the professors that have assisted and supported me throughout my graduate research and undergraduate education.

CONSTRUCTION AND DEMOLITION RECYCLED WOOD WASTE ASSESSMENT IN THE NORTHWEST UNITED STATES

Abstract

by Gerald Andrew Schneider, M.S.
Washington State University
July 2013

Chair: Dr. Karl Englund

The research discussed in this thesis examines construction and demolition (C&D) sourced recycled wood waste (RWW) within the northwest United States, which includes the states of Washington, Oregon, Idaho, and Montana. The three primary objectives of this assessment include a literature review of the RWW supply chain, an inventory assessment of RWW within the northwest United States, and an evaluation of potential factors that may influence RWW. A literature review was performed to assess supply chain characteristics, which includes sources of wood waste, operational factors of recycling wood, transportation and hauling, markets for recycled wood, and federal government policies. Notable federal policies include recent revisions to the Clean Air Act and Resource Conservation and Recovery Act, such as the Boiler MACT rule revision and the Non-Hazardous Secondary Material (NHSM) rule revision. The inventory assessment of RWW in the northwest United States included an examination of state websites and solid waste and recycling reports pertaining to government policies, methods of data collection, and annual quantities. A RWW supply chain assessment was performed to explore RWW characteristics for counties, landfills, and Material Recovery Facilities (MRFs).

A questionnaire was used to collect RWW data and understand aspects pertaining to MRFs, and the results were mapped and spatially analyzed using ESRI ArcGIS mapping software. The evaluation of factors compared RWW quantities with population and Residential Building Permits (RBPs) over time to determine potential correlations. A regression and multi-regression analysis was performed to determined models for estimating RWW quantities per population and RBPs.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Dedication

This thesis is dedicated to my wife Sherry for her support throughout my undergraduate and graduate education.

CHAPTER ONE

INTRODUCTION

1.1 Issue and Objectives

Wood is a valuable commodity and is widely utilized in energy and structural applications. Engineered wood products and smart forestry practices have developed over time, enabling wood industries to create more with less. Despite these practical and technological breakthroughs in wood science, there is still a lot of wood that is wasted. Rather than allowing wood waste to accrue in a landfill and squander its full potential, it can be recycled and used as a resource to create products such as compost, engineered wood, paper pulp, and biomass.

Three primary objectives of this recycled wood waste assessment include: 1) to conduct a literature review of general supply chain characteristics pertaining to recycled wood waste (RWW), 2) to create an inventory assessment of RWW in the northwest United States, and 3) to evaluate potential factors that may influence wood recycling. The literature review of the RWW supply chain examines sources of wood waste, operational factors, transportation and handling, markets of recycled wood, and federal policies that influence wood recycling. An inventory assessment indicates how much wood waste is currently disposed or recycled, and how it is recycled. An evaluation of potential factors that influence wood recycling, such as construction activity, may provide prospective modeling procedures for determining RWW quantities.

1.2 Literature Review of the Recycled Wood Waste Supply Chain

Five aspects of the wood waste recycling include wood waste sources, operational factors, transportation and handling, markets of recycled wood, and federal policies that influence wood waste recycling. Sourcing describes the origin of raw materials or desired products. Sources of wood waste derive from municipal solid waste (MSW), industrial waste, and construction and demolition (C&D) debris. Operations describe the process of transforming raw or recycled materials into new desired products, which may include transfer stations, material recovery facilities (MRFs), and disposal sites. Transportation and handling describe vehicle types, such as residential cars and trucks, commercial trucks, drop boxes, trailers, and freight containers, as well as safety measures involved during the RWW process. Markets that utilize recycled wood may include lumber reuse, engineered wood products, mulch, compost, or biomass. Federal policies impact the recycling of wood waste by creating and regulating solid waste disposal and recycling laws. Two federal policies that impact RWW include the Clean Air Act of 1970 (CAA), the Resource Conservation and Recovery Act of 1976 (RCRA), and revisions contained within each. The Clean Air Act affected RWW by implementing measures for boilers and incinerators that burn MSW and woody biomass, sometimes for energy recovery. The RCRA influenced wood recycling by regulating solid waste management and promoting the recycling and the conservation of natural materials. Recent revisions within each policy have updated incinerator and boiler emission standards as well as altered the definition of solid waste and non-hazardous secondary material, which will affect the practice of burning RWW for energy recovery.

1.3 Inventory Assessment of Recycled Wood Waste in the Northwest United States

An inventory assessment of RWW includes a preliminary MSW and RWW assessment and a RWW supply chain assessment within the northwest United States, which includes the states of Washington, Oregon, Idaho, and Montana. The preliminary MSW and RWW assessment utilizes a compilation of annual solid waste and recycling reports and websites provided by state governments in order to examine state policies, methods of data collection, and annual quantities.

Solid waste and recycling policies are important because government incentives and regulations may promote recycling rather than disposal. Data collection methods describe who and how the MSW and RWW information is disposed, recycled, and recorded. Annual quantities provide actual volumes and tonnages rather than estimates that may be inaccurate.

The RWW supply chain assessment collected MSW and RWW data for counties, non-hazardous landfills, and MRFs within the northwest United States. County MSW and RWW data was acquired from state, county, and local governments. MRF information was gathered via telephone and utilized a questionnaire designed to collect data regarding wood waste types, quantities, tipping fees, and the range of supply and distribution. Pertinent information was mapped and spatially analyzed using ESRI ArcGIS software.

1.4 Understanding the Factors that Influence Recycled Wood Waste

Potential factors that influence RWW were assessed over time using selected model communities within the northwest United States. A compilation of information was conducted to understand prospective aspects of wood recycling, such as C&D activity, local government policy, and economic and market conditions. Potential factors of RWW, such as population and residential building permits, were graphically compared with RWW for a time period of 2000 through 2011 in Washington, Oregon, and selected model communities. Model communities were selected based on population density and the availability of RWW data. Population density was used in order to include communities with low, moderate, and high population densities. Methods for recording RWW were important for ensuring similar data characteristics. The model communities included the Seattle-Tacoma-Bellevue (STB) metropolitan area, the Spokane-Spokane Valley (SSV) metropolitan area, the Portland-Vancouver-Hillsboro (PVH) metropolitan area, the Coeur D’Alene (CDA) metropolitan area, and the Southern Idaho Solid

Waste District (SISW). High population densities were represented by STB and PVH metropolitan areas, moderate population densities were represented by the SSV and CDA metropolitan areas, and low population densities were represented by the SISW. Other remaining counties in Washington and Oregon were also assessed using the same methods. RWW data regression analysis was conducted to determine single and multivariable models for quantify potential RWW quantities.

Figure 1.1: Picture taken at wood recycling facility of C&D wood waste.

CHAPTER TWO

THE RECYCLED WOOD WASTE SUPPLY CHAIN

2.1 Introduction

A literature review was conducted to examine five aspects of the recycled wood waste (RWW) supply chain, which include sources of wood waste, operational factors of recycling wood waste, transportation and handling of RWW, markets of recycled wood, and federal policies that influence the recycling of wood waste. Sourcing is the acquisition process of raw materials or products into the supply chain for the purpose of manufacturing, refining, or retail distribution of products [1]. Sources of wood waste may include municipal solid waste (MSW), industrial waste, and construction and demolition (C&D) debris. Operations are input-to-output transformation processes within the supply chain [1]. Operational factors of wood waste may include transfer stations, disposal sites, and material recovery facilities (MRFs). Transportation methods may include residential self haul, commercial/industrial self haul, packer truck, roll-off truck, and long distance haul. Handling of RWW is important for ensuring personal safety and quality of material. Marketing is the relationship between the producers and the consumers within the supply chain [1]. General markets of recycled wood waste may include lumber reuse, engineered wood products, mulch or compost, biomass fuel, or other miscellaneous uses. Government policies that influence the recycling of materials such as wood waste are done so with the initiative to conserve energy and natural resources. Examples of federal policies that have influenced the recycling of wood waste are the Clean Air Act of 1970, The Clean Water Act of 1972, the Resource Conservation and Recovery Act of 1976, and associated current revisions.

2.2 Sources of Wood Waste

In previous research conducted by G. Wiltsee in 1998 [2], Wiltsee analyzes urban wood waste characteristics within 30 urban areas throughout the United States; the findings were then reported to the National Renewable Energy Laboratory (NREL) in Golden, Colorado. Wiltsee discusses three general sources of urban wood waste: MSW, industrial waste, and C&D debris [2]. General sources of MSW include residential, commercial, and institutional wastes. [3]. Industrial wood waste includes residue from various industries such as pallet and woodworking companies [2]. C&D debris derives from construction and demolition processes, and can occasionally include land-clearing debris [2]. Wiltsee produced regression plots from MSW, industrial, and C&D data in an effort to produce a model for determining urban wood waste quantities, which is represented in Figure 2.1. A map utilizing Wiltsee's model and representing urban wood waste estimates per county was created by NREL and is represented in Figure 2.2.

MSW Wood (tons/year) = 0.20 x Population, $R^2 = 0.95$

Industrial Wood (tons/year) = 0.04 x Population, $R^2 = 0.83$

C&D Wood (tons/year) = 0.09 x Population, $R^2 = 0.56$

Total Urban Wood Waste (tons/year) = 0.33 x Population, $R^2 = 0.91$

Figure 2.1: Wiltsee's Model, in Tons/Year/Person, for determining urban wood waste quantities [2]

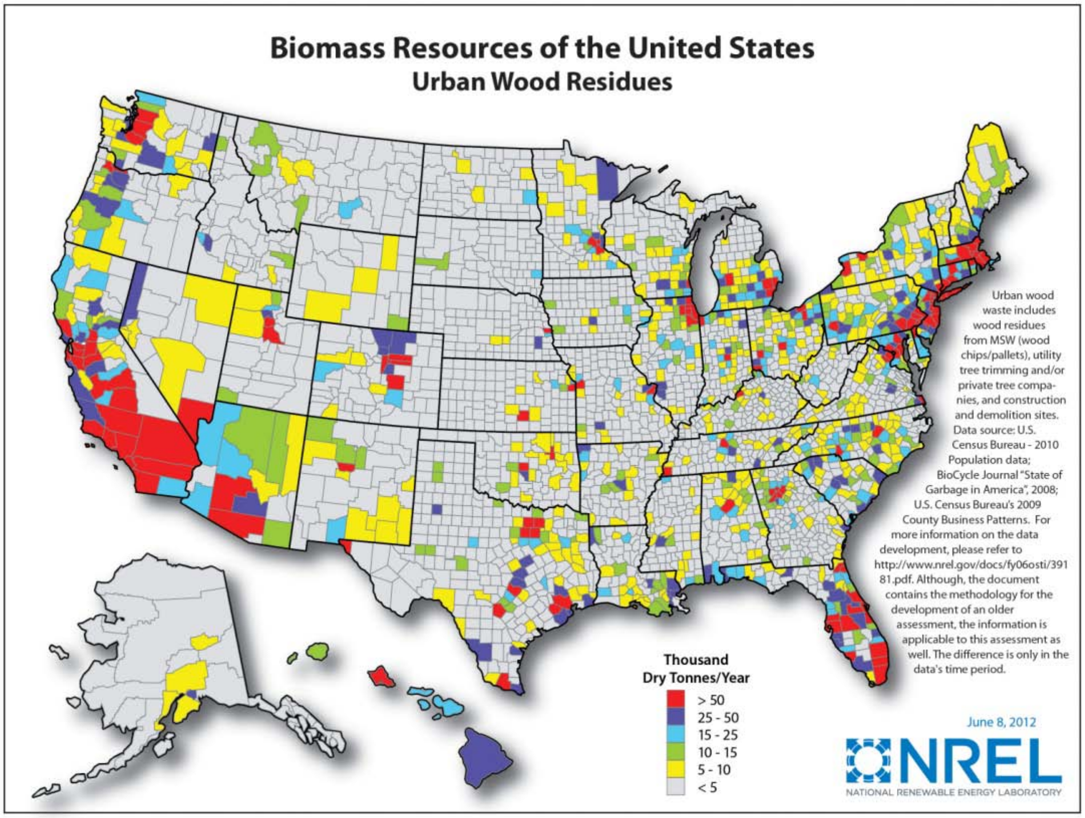


Figure 2.2: United States map illustrating urban wood waste quantities per county within each state [4].

Municipal Solid Waste

General sources of MSW, according to the United States Environmental Protection Agency (EPA), include residential, commercial, institutional, and industrial wastes, but does not include industrial process wastes and C&D debris [3]. Materials within MSW may include product packaging, newspapers, office papers, classroom papers, bottles, cans, boxes, wood pallets, consumer electronics, food scraps, grass clippings, clothing, furniture, appliances, tires, and batteries [3]. In 2010, the EPA recorded 250 million tons of generated MSW for the United States [5]. The estimated materials within the waste stream were as follows: 28.5% paper, 4.6%

glass, 9% metals, 12.4% plastics, 8.4% rubber, leather, and textiles, 6.4 % wood, 13.4% yard trimmings, and 3.4% other [5]. Figure 2.3 represents the aforementioned material.

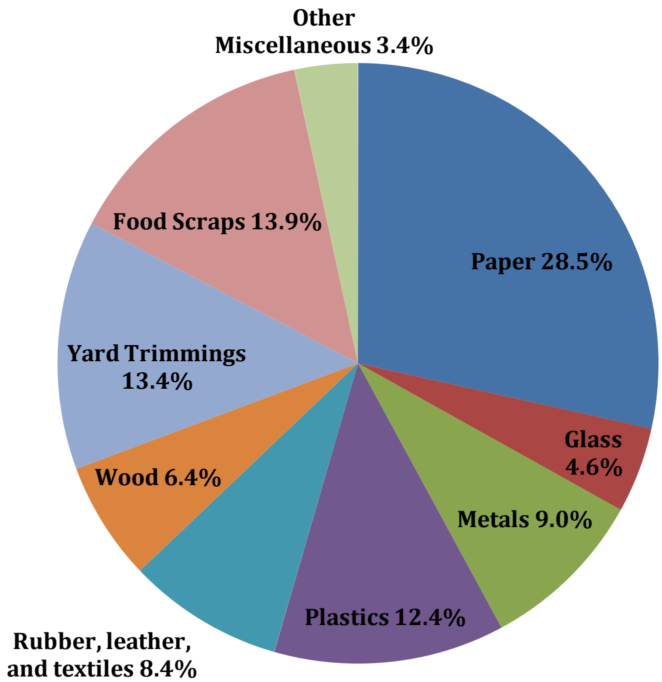


Figure 2.3: EPA estimated percentages of materials included in municipal solid waste in 2010. [5].

Industrial Waste

Institutional wood waste, as described by Wiltsee [2], includes wastes such as wood scraps and saw dust from pallet companies, truss companies, wholesale lumber companies, retail companies, and woodworking companies. According to Wiltsee, large pallet companies and wholesale lumber companies tend to recycle their own wood waste, while wood waste from other industries may be recycled by material recovery facilities (MRFs); MRFs also recycle material from municipal and C&D sources [2]. In the report, Wiltsee implied that the two primary sources of industrially sourced wood waste are pallet and lumber companies.

Construction and Demolition Debris

Previous research conducted by the EPA estimated materials used during construction and targeted materials for reduction, reuse, and recovery as part of its Resource Conservation Challenge [6]. The EPA investigated three phases of construction, which were new construction, demolition, and renovation. The EPA found that demolition typical produces more wastes than new construction [6]. Renovation utilizes both demolition and new construction, and therefore falls in between in regards to waste volumes [6]. The EPA also divides the construction industry into two sectors: residential and nonresidential. The residential sector refers to single home and multi-family home construction, demolition, and renovation, while nonresidential refers to commercial, institutional, or industrial construction, demolition, and renovation [6]. Figure 2.4 represents the percentages of C&D material sources among the six categories of construction, demolition, and renovation. The largest contributor to C&D materials is nonresidential demolition at 39% of total C&D, while the smallest contributor is nonresidential construction at 3% [6]. The largest residential contributor to C&D materials is renovation at 22% [6]. The other percentages are: nonresidential renovation at 19%, residential construction at 6%, and residential demolition at 11% [6].

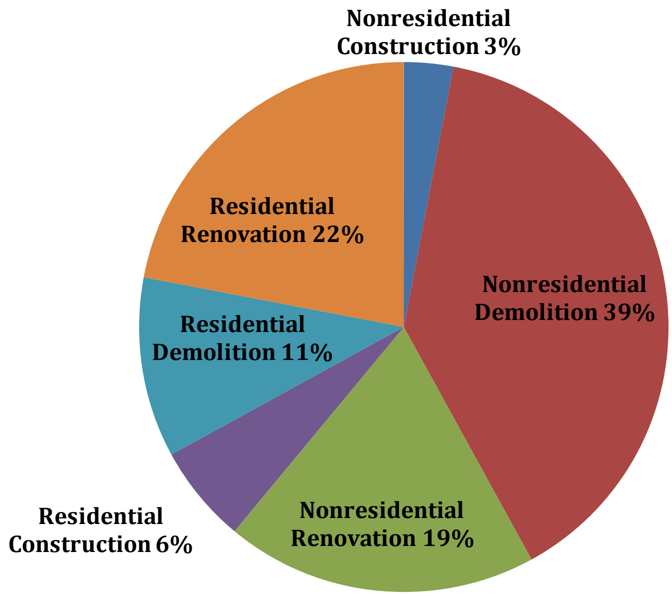


Figure 2.4: EPA estimate of wastes produced from construction, demolition, and renovation per residential and non-residential sectors [6].

Previous research [7] compared C&D waste generation rates among 11 government entities, including but not limited to King County, Washington, the state of California, and the EPA. By comparing government entities with similar waste recording methods and calculating average C&D material waste, the their research concluded: 31% of C&D material waste by weight is wood, while 11% is roofing, 6% is clean drywall, 4% is dirty drywall, 9% is concrete rubble, 5% is metal, and 2% is plastics [7]. Figure 2.5 represents this information. Figure 2.6 represents wood waste composition percentages: 27% is untreated or unpainted wood, 7% is pallets and crates, 24% is engineered wood, 19% is painted or stained wood, 5% is pressure treated, 1% is wood furniture, and 18% is other wood. In summary, the research stated that high grade wood waste, which consists of pallets, crates, and unpainted wood, represents 34% of wood waste and11.5% of total C&D waste [7].

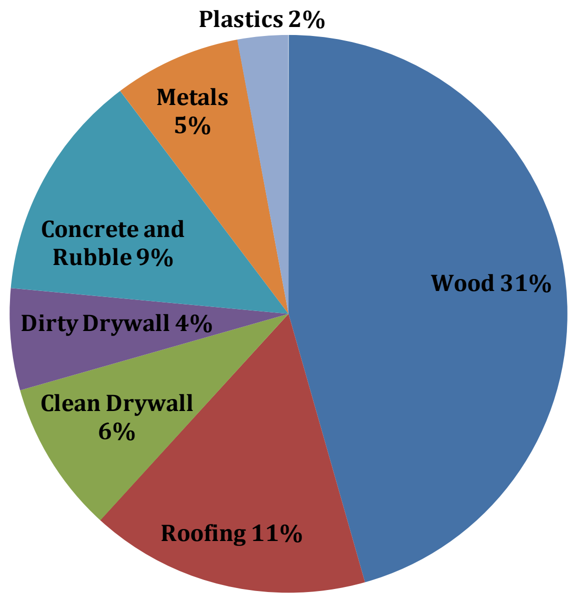


Figure 2.5: Estimate of percentages of materials within construction and demolition waste as indicated through a C&D waste characterizations study [7]

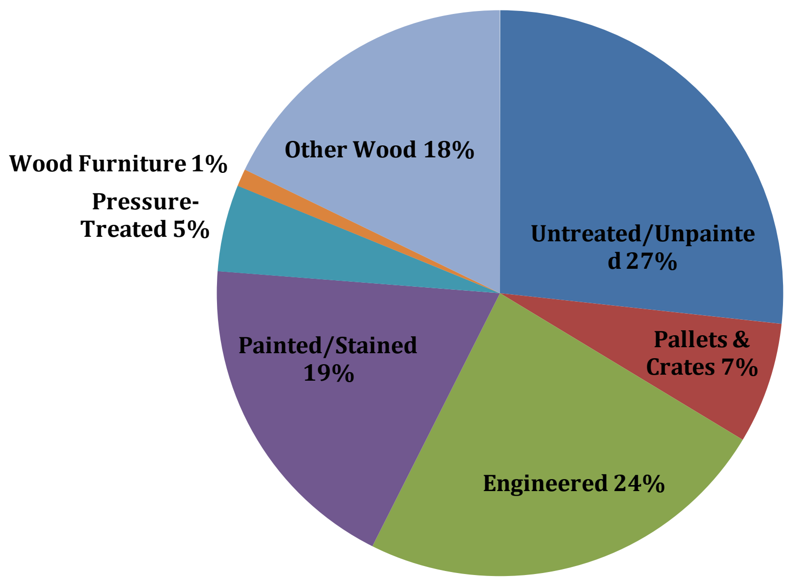


Figure 2.6: Estimate of percentages of types of wood waste as indicated through a C&D waste characterization study [7]

2.3 Operational Factors of Recycled Wood Waste

The three primary operational factors of generated solid waste are transfer stations, MRFs, and disposal sites. Transfer stations are used as small hubs for MSW collection, and may be responsible for diverting waste types for the purpose of recycling. MRFs provide recycling services to public and private entities with the purpose of selling wood chips or products to various markets. Disposal sites include landfills and waste-to-energy plants. Landfills are sites where waste is permanently buried, while waste-to-energy plants combust waste to produce heat, electricity, or fuel.

Transfer Stations

The EPA defines a transfer station as a facility where MSW is unloaded from collection vehicles and briefly held while it is reloaded onto larger long-distance transport vehicles for shipment to landfills or other treatment or disposal facilities [8]. According to the EPA, transfer stations provide three benefits: they create an opportunity to screen waste prior to disposal, they provide flexible waste disposal options, and they may serve as convenience centers for communities [9]. Transfer stations may be designed to divert recyclable material from the waste stream; they may implement diversion bays for material separation or utilize mechanical diversion equipment, such as conveyor belts [9]. Transfer stations provide communities flexibility by providing more options of where to transport their waste to, potentially saving money due to landfill competition. Last, transfer stations may serve as convenience sites by providing members of a community a location to drop off solid waste and recyclables without the dependency of a publically operated solid waste hauling system [9]. Rural transfer stations may include partial enclosures that contain multiple drop boxes for material diversion; drop boxes are large containers used to transport solid waste [9].

Material Recovery Facilities

The EPA defines an MRF as a facility that separates, processes, and consolidates recyclable materials for shipment to one or more recovery facilities rather than to a landfill or other disposal site [9]. MRFs may include transfer station convenience sites or privately owned companies that provide service to commercial and residential customers. Materials typically recycled in an MRF include paper, plastic, glass, metal, wood, and other miscellaneous materials found in municipal or C&D waste streams. MRFs that recycle wood waste may grind wood into small chips called hogged fuel and sell it to various markets or resell the wood as reused or reclaimed.

Disposal Sites

Two forms of disposal sites are waste-to-energy plants and landfills. According to the EPA, energy recovery from waste is defined as the conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion, and landfill gas recovery [10]. A landfill, as defined by ASTM International, is a place, location, tract of land, area, or premises used for the disposal of solid wastes as defined by state solid waste regulations [11]. Although specific classifications of landfills vary from state to state, the two primary classifications of landfills are hazardous and non-hazardous. General types of non-hazardous landfills include MSW, inert, and C&D landfills. MSW landfills accept non-hazardous residential and commercial waste. Inert landfills collect inert waste, which consists entirely of non-water soluble solids that do not contain significant amounts of decomposable waste [12]. Inert wastes may include C&D and industrial wastes, such as soil, rocks, clay, concrete rubble, asphalt, and tires [12]. C&D landfills collect construction and demolition materials, such as wood, sheetrock, concrete, and steel.

2.4 Transportation and Handling

Five modes of solid waste transportation include residential self haul, commercial/industrial self haul, packer truck, roll-off truck, and long distance haul [9]. Residential self haul refers to cars and pickups that are used by members of the public. Commercial/industrial self haul refers to vehicles used by commercial and industrial companies, such as construction site dump trucks that transport construction and demolition debris. Packer trucks visit multiple residential and commercial sites and compact solid waste as it is collected. Roll-off trucks utilize drop boxes that collect large volumes of solid waste and usually visit one site at a time. Long distance haulers are typically used to transport solid waste from the transfer station to the disposal site. Long distance haulers include transfer trailers, trains, barges, and intermodal systems [9]. Transfer trailers, like the one represented in Figure 2.7, are similar to highway tractor trailers and are capable of transporting 15-25 tons per trip [9]. Trains and barges transport solid waste by rail and water, and are capable of transporting thousands of tons of solid waste per trip. Intermodal systems combine short distance trucks with long distance trains or barges [9].

Once wood waste has been dropped off at a transfer station or MRF, construction wood debris and land clearing debris is separated into different pile in order to avoid fire. If mixed, the heat from the land clearing debris and the dry moisture content of the construction wood debris may cause a fire. Green wood waste, such as land clearing debris, will produce large amounts of heat and may be subject to deterioration and fire if not handled correctly [13]. Construction wood, such as dimensional lumber, is kiln dried to lower moisture content with the intent of avoiding potential warping, cracking, or dimensional changes that may occur once utilized in construction [14].

RWW industries may gain transportation and handling benefits when woody biomass is processed into pellets. Previous research [15] has been conducted to determine the benefits of pelletizing agriculturally based biofuels in Sweden. The research discusses four advantages to pelletizing biofuel when compared to traditional methods: higher energy density, more even quality, higher mass fluidity, and smaller fuel particles [15]. Higher energy density lowers transportation and storage costs, because increased density reduces bulk, therefore maximizing handling capabilities [15]. Pellets with an even quality maintain constant moisture content, which improves processing efficiency for downstream consumers [15]. Higher mass fluidity allows for the use of automatic feeding equipment [15]. Smaller fuel particles produce evenly distributed boiler feeding [15]. In summary, pelletizing biomass allows for more efficient transportation, storage, and handling of biofuel.

Figure 2.7: Picture taken at MRF site of commercial haul tractor-trailer dumping wood waste

2.5 Markets for Recycled Wood Waste

Previous research has indicated five primary markets for recycled wood waste: lumber-reuse, engineered wood products, mulch or compost, biomass fuel, and other miscellaneous uses [16]. Lumber-reuse may be used for architectural applications, such as casing, molding, and banisters; structurally speaking, reused lumber may be re-certified by a lumber grading inspector and used as a structural element [16]. Engineered wood such as particle board and fiber board may be created from re-milled and chipped wood waste[16]. Mulch and compost are created from chipped wood waste. Biomass fuel is created when wood waste is chipped into hogged fuel and burned or converted into a liquid or gaseous fuel [16]. Miscellaneous uses of RWW include landfill cover, animal bedding, wood flour filler for plastics, soil amendments, and chemicals [16].

Increased market competition for wood waste material may develop as biorefineries become more prevalent. Previous research discusses the results of a questionnaire given to southern sawmills, fiber mills, and wood-energy facilities [17]. According to the survey results, urban wood waste on average account for 1% of fiber mill supply, and up to 6% of wood-energy industry supply [17]. Over the next ten years, 32% of fiber mills expect wood-to-energy facilities to be their greatest competitor, and 5% of fiber mills expect biomass pelletizing industries to be their greatest competition [17]. This is because downstream industries that produce compost, paper pulp, and biomass usually procure lower quality wood, creating direct competition with each other. Furthermore, the research suggests that increased competition over wood supplies will create an increase in material costs over the next decade [17]. In conclusion, if MRFs in the northwest U.S. become more efficient at diverting wood from the waste stream, then urban wood waste may presumably see an increase in demand as fiber mills and wood-energy industries compete for wood resources.

2.6 Federal Policies that Influence Wood Waste Recycling

Federal policies that influence recycled urban wood waste include the Clean Air Act of 1970, the Clean Water Act of 1972, and the Resource Conservation and Recovery Act (RCRA) of 1976, and applicable revisions made within each. The Clean Air Act has defined the responsibilities of the EPA in establishing, regulating, and enforcing emissions and air quality standards [18]. The Clean Water Act regulates the amount of pollutants discharged into water sources. The RCRA prompted the regulation of hazardous and non-hazardous solid waste management with the goal of protecting human health and the environment [19]. The revision of the Boiler Maximum Achievable Control Technology (MACT) rule, officially revised in 2011, updated emission level limits produced by incinerators and boilers regulated under the Clean Air Act. The Non-Hazardous Secondary Material (NHSM) rule, officially revised in 2011, altered the definitions of solid waste and non-waste fuels defined within the RCRA. The results of these revisions are important for RWW applications because boilers using C&D sourced wood waste for energy recovery do not have to comply with the new Boiler MACT rules.

The Clean Air Act

The Clean Air Act regulates the amount of pollutants and toxic emissions that are released from Commercial and Industrial Solid Waste Incinerator Units (CISWI) and Industrial, Commercial, and Institutional Boilers and Process Heaters (ICIB). As defined by the EPA, a CISWI unit is any device used to burn solid waste at a commercial or industrial facility [20]. Likewise, the EPA provides a definition for ICIBs: boilers that burn natural gas, coal, wood, and other fuels to produce steam, while process heaters heat raw or intermediate materials during industrial processes [21].

The Clean Water Act

The Clean Water Act regulates the amount of pollutants discharged into water sources from point sources, such as solid waste landfills [22]. Landfills that discharge wastewater directly into receiving waters are regulated under this policy, while landfills that discharge wastewater into publically owned water treatment facilities are not [23]. This regulation does not apply to landfills regulated at industrial sites, such as manufacturing plants or pulp and paper mills, because these facilities are regulated by their associated industry standards and guidelines [23].

The Resource Conservation and Recovery Act

The RCRA defines and regulates hazardous and non-hazardous solid waste. According to the EPA website, the five principle purposes of the RCRA are 1) to protect human health and the environment, 2) to conserve energy and natural resources, 3) to reduce generated waste, 4) to ensure proper disposal of wastes, and 5) to regulate the management of hazardous and non-hazardous solid waste [19]. Hazardous waste, managed under Subtitle C of the RCRA, refers to solid waste that poses a risk to human health or the environment [24]. Non-hazardous waste, regulated under Subtitle D of the RCRA, primarily refers to MSW and non-hazardous industrial solid waste.

Recent EPA Revisions to the Boiler MACT Rule and NHSM Rule

On December 20th of 2012, the EPA finalized revisions to Clean Air Act emission standards for ICIBs and CISWI units [25], otherwise known as the Boiler MACT rule [26].[1] According to the EPA, the five primary aspects of the revised emission standards are 1) to maintain extensive public health by reducing toxic air pollution, such as mercury and particle pollution, 2) to

[1] The original date of the Clean Air Act emission standard regarding ICIBs and CISWI units was March of 2011.

increase the rules' flexibility and address concerns raised by stakeholders, 3) to address new data regarding real-world performance and conditions under which boilers and incinerators operate, 4) to ensure dramatic cuts in the cost of implementation, and 5) to give major source boilers three years to comply [27]. The purpose of the emission standards is to reduce the amount of pollutants such as mercury, particle pollutions, sulfur dioxide, dioxin, lead, and nitrogen dioxide [27].

The emission standards will affect area source and major source ICIBs and CISWI units. Area source ICIBs are considered small sources of air toxic emissions and are generally used in institutional and commercial applications, such as educational buildings or medical establishments [28]. Major source ICIBs are considered major sources of air toxic emissions and are utilized during industrial applications such as manufacturing, mining, and refining [29]. According to the EPA, 86% of boilers would not be covered by the new emission standards, 13% would need to follow work practice standards to minimize toxins, and less than 1% need to meet the new emission standards [27]. Small area source ICIBs, such as those utilized in hospitals, schools, and churches, are not required to comply to the new standards [27].

On February 7th of 2013, the USEPA finalized a revision of the Non-Hazardous Secondary Material (NHSM) rule within the RCRA [30], which in turn affects the revision of the Boiler MACT rule.[2] As defined by the EPA, NHSM refers to a non-primary material—such as scrap—that is considered non-hazardous when disposed [31]. Under the revision, resinated wood is now considered a categorical non-waste fuel, which means that it is not governed by the same regulations as MSW when combusted for energy recovery [30]. As defined by the EPA, resinated wood refers to wood products containing resin adhesive derived from primary or secondary wood products manufacturing [31]. Resinated wood refers to engineered wood

[2] The original date of the NHSM Final Rule was March 21, 2011.

products used during construction applications, including but not limited to plywood, particle board, oriented strand board, and glue-laminated beams.

According to previous research [32], the revision of the NHSM rule indicates that ICIBs burning wood derived from C&D debris are exempt from the revised Boiler MACT rule. A partnership between the Construction Materials Recycling Association (CMRA) and Education Fund and the Biomass Power Association provided the EPA with chemical testing data that indicated that contaminant levels in C&D wood materials were acceptable to the EPA [32]. Although environmental groups have voiced concerns for the levels of lead, urban toxics, arsenic, and chromium within C&D sourced wood waste, the EPA has stated that testing may be periodically conducted to compare contaminant levels among various NHSMs, and also maintains its position that chromate copper arsenate-treated wood contaminant levels are not comparable to those of traditional fuels [32].

2.7 Conclusion

A literature review was conducted to examine general aspects of the RWW supply chain, which discussed wood waste sources, operational factors, transportation and handling, associated markets, and federal policies. Sources of RWW include MSW, industrial waste, and C&D debris. Operational factors include transfer stations, disposal sites, and MRFs. Transportation methods include residential, commercial, industrial, and long distance haulers. Markets of recycled wood include lumber-reuse, engineered wood products, mulch, compost, biomass fuel, and other miscellaneous uses. Federal policies, such as the Clean Air Act, the Clean Water Act, the RCRA, and applicable revisions within them, affect the burning of RWW in ICIBs for energy recovery.

CHAPTER THREE

RECYCLED WOOD WASTE INVENTORY ASSESSMENT WITHIN NORTHWEST UNITED STATES

3.1 Introduction

An inventory assessment of recycled wood waste (RWW) within the northwest United States includes a preliminary assessment of MSW and RWW information for the states of Washington, Oregon, Idaho, and Montana, as well as a RWW supply chain assessment within the region. The compilation of MSW and RWW information per state utilized annual solid waste and recycling reports and pertinent websites provided by applicable state departments in order to examine state policy, methods of data collection, and annual quantities of MSW and RWW. The RWW supply chain assessment collected MSW and RWW data associated with counties, solid waste districts, non-hazardous landfills, and material recovery facilities (MRFs) within the northwest United States. The results of the supply chain assessment were mapped and spatially analyzed using ESRI ArcGIS software.

3.2 Preliminary Municipal Solid Waste and Recycled Wood Waste Assessment within Northwest United States

MSW and RWW information was collected from annual solid waste and recycled reports and websites from the states of Washington, Oregon, Idaho, and Montana regarding three solid waste topics: management policy, data collection methods, and quantities for MSW and RWW. Understanding solid waste management policy is important because government regulations and incentives may influence the disposal and recycling trends of various materials, such as wood or steel. Data collection methods describe who and how the MSW and RWW information is disposed, recycled, and recorded. Actual tonnage quantities of MSW and RWW provide real data for analysis, rather than relying on per capita solid waste models that may not account for regional priorities.

Method

Solid waste disposal and recycling policies, data collection methods, and quantities were collected for the states of Washington, Oregon, Idaho, and Montana through corresponding websites and annual reports. MSW and RWW data for the state of Washington were compiled through the Washington Department of Ecology (Washington DOE) website, most notably within the website section titled "Waste 2 Resources" [33]. Oregon data was compiled through the Oregon Department of Environmental Quality (Oregon DEQ) website section titled "Land Quality Solid Waste" [34]. Montana data was collected from the Montana Department of Environmental Quality (Montana DEQ) website section titled "Solid Waste Management" [35]. Idaho data was collected from the Idaho Department of Environmental Quality (Idaho DEQ) website section titled "Municipal Solid Waste Landfills in Idaho" [36]. Pertinent solid waste reports will be described within the following sections.

Solid waste data collection methods and quantities are represented in Tables 3.1 and 3.2 and will be discussed at length within the following sections. Table 3.1 represents the solid waste calculation methods per state. Table 3.2 represents MSW and wood waste quantities per state. Unfortunately, Idaho does not provide MSW and wood waste data at the state level and therefore is not sufficiently represented in Tables 3.1 and 3.2. MSW and wood waste data per county was collected for some counties in Idaho and is discussed in a later section, but the data is not represented in Table 3.2 because it does not represent data from all counties in Idaho.

Table 3.1: Solid Waste Calculation Method per State within Northwest U.S.

State	Mass Balance Approach
Idaho	*No Data Available*
Montana	Generated Waste = Recycled + Recycled/Diverted + Disposed
Oregon	Generated Waste = Recovered + Disposed
Washington	Generated Waste = Recovered + Recycled + Disposed

Table 3.2: MSW and Wood Waste Quantities per State within the Northwest U.S.

STATE	MSW (tons)			WOOD WASTE (tons)		
	Diverted or Recycled	Generated	Diversion Rate	Diverted or Recycled	Generated	Diversion Rate
Idaho	*No Data Available*			*No Data Available*		
Montana 2011 [37]	327,859	1,697,085	19.3%	*No Data Available*		
Oregon 2011 [38]	2,302,794	4,740,561	52.3%	368,393	376,798	97.8%
Washington 2010 [39]	4,312,581	8,860,856	48.7%	1,194,252	1,203,074	99.3%

Washington

There were two reports used to determine solid waste disposal and recycling policies within the state of Washington: "Solid Waste in Washington State: First Annual Status Report", published in January of 1993 [40], and "Beyond Waste Plan 2009 Update", published in October of 2009 [41]. According to these reports, three state policies that influence the recycling of wood waste within the state of Washington, which are the Solid Waste Management Act of 1969, the Waste Not Washington Act of 1989, and the 2004 Beyond Waste Plan. The Solid Waste Management Act of 1969 closed open dumps and prompted local governments to regulate sanitary landfills [40]. The Solid Waste Management Act was amended in 1984 with the purpose of defining four priorities of solid waste management: waste reduction, recycling, energy recovery or incineration, and landfill disposal [40]. The Waste Not Washington Act of 1989 prompted a goal of reducing and recycling generated solid waste by 50% by 1995 [40]. The Beyond Waste Plan issued in 2004 is a comprehensive plan that covers years from 2005 until 2035 [41]. As stated by the Beyond Waste Plan, the five initiatives of the plan are: 1) to significantly reduce most wastes and the use of toxic substances in Washington's industry, 2) to significantly reduce small-volume hazardous wastes from businesses and households, 3) to expand the recycling system in Washington for organic wastes such as food wastes, yard wastes, and crop residues, 4) to reduce negative impacts from design, construction, and operation of buildings, and 5) to develop a system to measure the progress in these goals [41]. Current recommendations the plan suggests to promote these goals include but are not limited to: encouraging new businesses to adopt sustainability measures, encourage waste handlers to become materials brokers, promote sustainability in product development, to reduce high risk wastes, and to provide Beyond Waste incentives [41]. The plan is intended to be updated every five years to account for current issues and progress.

Washington Solid Waste Management Method

In their 20th annual solid waste report, the Washington DOE states six types of waste management methods, which include 1) disposal in landfills, 2) combustion of mixed MSW in regulated incinerators, 3) combustion of source separated material in regulated industrial incinerators for energy recovery, 4) composting in regulated facilities, 5) recycling in regulated facilities, and 6) other diversions in regulated and non-regulated facilities [39]. Washington uses a mass balance approach to recording solid waste: generated waste is equal to the sum of recovered, recycled, and disposed solid waste. Wood waste in Washington is recorded as diverted, recovered for energy, and disposed. Diverted wood waste is that which is not buried in a landfill, and may be reused or recycled into new products. Wood waste recovered for energy is ground into hogged fuel, occasionally compressed into pellets, and combusted in a boiler to produce heat and electricity. Disposed wood waste is buried in landfills. Two classifications of landfills in the state of Washington that divert and dispose of wood waste include MSW landfills and Limited Purpose Landfills, otherwise known as C&D landfills. MSW landfills, as mentioned previously, bury MSW associated with residential and commercial waste. Limited Purpose Landfills, as defined by the Washington State Legislation, receives solid wastes limited by type and source, which may include segregated industrial solid waste, construction, demolition, and land-clearing debris, wood waste, ash, and dredged material [42].

Washington MSW and RWW Quantities

According to their 20th annual solid waste report, Washington DOE recorded roughly 16.6 million tons of total generated solid waste in 2010, in which 54.3% was recycled [39]. Of that total, 8,860,856 tons were recorded as generated MSW, in which 4,548,275 tons were disposed [39]. Recycled MSW accounted for 4,312,581 tons, creating a MSW recycling rate of 48.7% [39]. Also according to the report, the state of Washington recorded a total of 1,203,074 tons of generated wood waste in 2010. Of that total, 8,822 tons were disposed, 347,137 tons were diverted, and 847,115 tons were recovered for energy [39]. In conclusion, 99.3% of wood waste was diverted or recycled, and 70.9% of diverted/recycled wood waste was used for energy recovery in the state of Washington in 2010.

Oregon

According to the Oregon Department of Environmental Quality website, three government policies that have influenced Oregon's solid waste management practices include: the Opportunity to Recycle Act of 1983, the Oregon Recycling Act of 1991, and House Bill 3744 of 1997. The Opportunity to Recycle Act of 1983 was passed due to a perceived shortage of landfill space as well as recognized environmental benefits from waste prevention [43]. The 1991 Oregon Recycling Act, otherwise known as Senate Bill 66, set a statewide goal of recycling 50% of generated waste from disposal by the year 2000 [43]. The 1997 House Bill 3744 made changes to Senate Bill 66 with further provisions to ensure the 50% waste recycling rate, which had not yet been achieved [43].

In 1983, the state of Oregon recognized the environmental benefits of solid waste reduction, reuse, and recycling and therefore passed the Opportunity to Recycle Act. The act established a hierarchy of solid waste management: 1) to reduce the amount of generated waste, 2) to reuse materials for their original purpose, 3) to recycle what cannot be reused, 4) to compost what cannot be reused or recycled, 5) to recover energy from what cannot be reused, recycled, or composted, and 6) to dispose of residual materials safely [43]. The act further required communities to provide recycling depots and monthly curbside recycling services.

The Oregon Recycling Act, also known as Senate Bill 66, was passed in 1991 and set a statewide goal of recycling 50% of generated waste by the year 2000. In order to ensure this goal, the act required Oregon DEQ to develop a solid waste management plan, to annually record material recovery rates, and to conduct waste characterization studies every two years [43]. The act funded grants to local governments that was paid for through landfill tipping fees [43].

House Bill 3744 provided changes to Senate Bill 66 as a way of ensuring the 50% recycling rate was achieved by 2000. In order to achieve the goal, communities were required to choose from a list of elements listed within the bill. Recycling service elements included weekly residential curbside recycling, residential yard debris collection, recycling collection for multi-family housing units, and onsite collection of source-separated recyclable materials from commercial and industrial sectors [43]. Other elements include adjusting garbage collection rates to promote waste reduction, as well as an expanded network of recycling depots for eased convenience [43]. Oregon met its goal of a 50% recovery rate in 2010 [43].

Oregon Solid Waste Management Method

Oregon uses a mass balance approach to recording solid waste. Waste in Oregon is primarily recorded as recovered, disposed, and generated; generated is equal to the sum of recovered and disposed waste. Recovered and disposed MSW quantities are provided to Oregon DEQ by regulated landfills, transfer stations, and other recycling producers per wasteshed within the state of Oregon. Oregon DEQ defines a wasteshed as being "an area of the state that shares a common solid waste disposal system, or an appropriate area in which to develop a common recycling system [34]." Oregon wastesheds primarily represent counties within the state, with exception to the city of Milton-Freewater, which represents its own wasteshed, and the greater Portland tri-county area Metro wasteshed, which includes the counties of Clackamas, Multnomah, and Washington [34].

Oregon defines wood waste as chemically untreated wood pieces or particles generated from processes commonly used in the timber products industry; which may include sawdust, chips, shavings, stumps, bark, hog-fuel, and log sort yard waste [44]. Wood waste does not include wood pieces or particles containing or treated with chemical additives, glue resin, or chemical preservatives [44]. According to a telephone interview with the Oregon DEQ Solid Waste Analyst, land-clearing sourced wood waste, such as tree branches, is often recorded separately from construction, demolition, and transportation sourced wood waste, although occasional mixing of land-clearing debris may be intermittently recorded as well [45]. Recovered wood waste quantities are obtained from wood recycling processors, which may include landfill-affiliated transfer stations and MRFs [1]. Wood waste disposal is recorded by non-hazardous solid waste landfills.

Oregon MSW and RWW Quantities

According to the 2011 annual recycling report, the state of Oregon Generated a total of 4,740,561 tons of MSW, in which 2,302,794 tons was recovered, producing a recovery rate of 52.3% [38]. Wood waste recorded a total of 376,798 tons of generated wood waste, in which 368,393 tons of wood waste was recovered, indicating a wood waste recovery rate of 97.8% [38]. Recovered wood waste accounts for 16% of the total recovered material waste stream in the state of Oregon.

Idaho

According to the Idaho Department of Environmental Quality website, two government policies regarding MSW and wood waste recycling include: the Idaho Environmental Protection and Health Act of 1972 and the Wood and Mill Yard Debris Act of 1996 [46]. The Idaho Environmental Protection and Health Act prompted the creation of the Idaho DEQ, which monitors and enforces federal environmental regulations such as the Clean Air Act and the Resource Conservation and Recovery Act [46]. The Idaho DEQ is responsible for: 1) assessing environmental problems and overseeing facilities that generate air, water, and hazardous waste pollution, 2)monitoring air and water quality, 3)cleanup of contaminated sites, and 4) provide education, outreach, and assistance to businesses and local governments throughout the state [46]. The Idaho DEQ does not provide annual MSW or RWW quantities for the state [47]. According to the Idaho DEQ website, the state does not have a mandated waste diversion goal; however, it encourages recycling and waste reduction due to natural resource conservation and environmental concerns [46]. The Wood and Mill Yard Debris Act provided a manual that provides best management practices for the disposal and recycling of wood waste and mill yard debris [48]. It provides technical standards and suggests alternative uses for wood waste residue, which includes firewood, hogged fuel, landfill cover, erosion control, landscape materials, road fill, soil amendments, stockyard bedding, and visual and sound barriers [48].

Montana

According to the report titled "2006 Integrated Waste Management Plan", two policies that have impacted MSW and wood waste recycling: the Solid Waste Management Act and the Integrated Waste Management Plan. The Solid Waste Management Act, revised in 1977, devised a system that allowed the state to provide technical and financial assistance to local governments to establish solid waste management plans [49]. The Integrated Waste Management Act of 1991 established a hierarchy of solid waste management principles, which included solid waste source reduction, material reuse, recycling, composting, and landfill or incineration [49]. The "Integrated Waste Management Plan", revised in 2006, set a goal to recycle 22% of solid waste by the year 2015 [49].

The "Integrated Waste Management Plan" also made recommendations for the disposal and recycling of various materials. As the plan states, recommendations for C&D debris are 1) to educate consumers to request that materials from homes and businesses be recycled, 2) educate builders about incentives for recycling or for purchasing recycled, 3) to look for local solutions for the reuse of building materials and support centers that recycle building material reuse and recycling, and 4) to reduce the amount of material that needs to be reused or recycled by carefully purchasing supplies and materials [49]. Reduction and recycling incentives include a recycling tax credit, a recycling tax deduction, and an air permit fee reduction incentive for glass[49].

Montana Solid Waste Management Method

Montana uses a mass balance approach to recording solid waste at the state of level. Diverted materials are classified as “recycled commodities” and “other recycled/diverted” [37]. Generated solid waste is equal to the sum of recycled, recycled/diverted, and landfill disposed solid waste. Recycled commodities include paper, cardboard, plastic, glass, and metal [37]. Other recycled/diverted materials include organic waste, textiles, fly ash, aggregate, C&D debris, electronic wastes, and automotive fluids [37]. Data from landfills, transfer stations, composters, and recyclers is obtained through annual licensing renewals [37]. Small non-licensed recyclers and processors are not mandated to report annual recycled volumes, and therefore are not completely represented in the recycling data [15]. Montana landfill classifications associated with MSW and wood waste are Class II, Class III, and Class IV landfills, as well as burn sites. According to the Montana DEQ, Class II landfills may collect non-hazardous wastes associated with MSW, inert waste, and C&D waste [50]. Class III landfills collect non-hazardous wood and inert wastes [50]. Class IV landfills collect non-hazardous C&D and asphalt debris [50].

Montana MSW Quantities

According to the annual solid waste report, Montana generated 1,697,085 tons of solid waste in 2011 [37]. Of that total, 212,436 tons were recycled, 115,423 tons were diverted, and 1,366,226 tons were disposed of in landfills, creating a recycling/diversion rate of 19.3% [37]. The Montana DEQ does not provide annual recycled wood waste quantities at the state level [51]. Furthermore, although wood waste may be compiled within Class III and Class IV landfills, it is not known how much is actually wood. It also does not specify if or how wood was recycled, and therefore the quantities within those landfills are not being used to quantify RWW volumes within the state of Montana.

3.3 Recycled Wood Waste Supply Chain Assessment within Northwest United States

This section discusses the survey and questionnaire process conducted during this research, in which state and local governments, landfills, and MRFs within the northwest U.S. were contacted with an effort to collect MSW and RWW supply chain information. Collecting MSW and RWW information from local governments, such as counties, wastesheds, and collaborative solid waste districts, is fundamental for understanding where the majority of the RWW is accumulating. Knowing which landfills collect wood waste is important for analyzing potential wood recycling rates. MRFs are the primary processors of RWW and give us valuable insight regarding wood recycling methods, quantities, and potential markets for utilization. Once pertinent data was collected, information was mapped and spatially analyzed using ESRI ArcGIS mapping software. The following sections describe the methods and results for data collection of non-hazardous landfills, counties, and wastesheds within the northwest U.S., the MRF questionnaire process, and the spatial analysis.

Method for Data Collection per Landfill, County, Wasteshed, and Solid Waste District

MSW and RWW data pertaining to landfills, counties, wastesheds, and solid waste districts within the northwest United States were collected from state, county, and local governments. Landfill information for the states of Washington, Oregon, and Montana were collected via excel spreadsheets provided by their respective departments, as mentioned in the previous sections. Idaho landfill information was collected by searching through county websites and phone surveys. Counties often feature their own solid waste department and therefore provide solid waste management information for its residents within their website. Telephone contact was achieved in order to confirm the information that was provided on the website. County and wasteshed information within Washington and Oregon were collected from the Washington

DOE and the Oregon DEQ upon request. Montana used one excel spreadsheet for collecting both county and landfill MSW data. Idaho county information was collected via telephone interview with prospective county departments.

MSW and RWW information per landfill, county, and wasteshed were mapped using ESRI ArcGIS software. It is assumed that the reader has working knowledge of ESRI ArcGIS geoprocessing tools in order to understand the method discussed in this process. State, county, and interstate highway GIS shapefiles were accessed through a database provide by Washington State University [52]. A GIS shapefile for Montana Type II landfills was accessed from the Montana Natural Resource Information System website [53]. All other landfill locations were determined by using the Location Finder tool, in which their address was used to determine the longitude and latitude of their geographic location. The geographic coordinate system used for the landfill shape file was WGS 1984. In order to account for wastesheds, in which multiple counties record MSW as one entity, a wasteshed shapefile was created by using the geoprocessing tool Dissolve. The Dissolve tool is used combine attributes with similar characteristics into one shapefile. In this circumstance, an attribute field was added to the attribute table which was then used to define which counties belonged to associated wastesheds. Once the new wasteshed shapefile was created, the Joins and Relates tool was used to combine shapefile with the Microsoft Excel spreadsheet, which was used to compile MSW and RWW data.

Non-Hazardous Landfills Results

A list of non-hazardous landfills was developed using state-provided data bases, local government inquiries, and various internet searches in order to determine where the disposal of wood waste occurs, and then mapped using ESRI ArcGIS software. Data regarding landfill location, materials disposed, and quantities in Washington, Oregon, and Montana were provided by personnel within the Washington Department of Ecology (DOE), Oregon Department of Environmental Quality (DEQ), and Montana Department of Environmental Quality (DEQ). Contact information is typically provided on corresponding state websites. Personnel from the state of Idaho Department of Environmental Quality (DEQ) provided a database of landfills within the state, but it did not include MSW and wood waste quantities, and further internet web searches and contact with local governments was required for necessary updates. 160 non-hazardous landfills were located in the northwest U.S. that dispose or potentially divert wood waste, as represented in Figure 3.1. Of those landfills, 93 collect general MSW, 22 collect C&D debris, 30 are Montana class III landfills that collect wood and inert material, 7 are landfills in Oregon that collect wood, 6 are burn sites located in Montana, and one is a municipal waste-to-energy incinerator, located in eastern Washington.

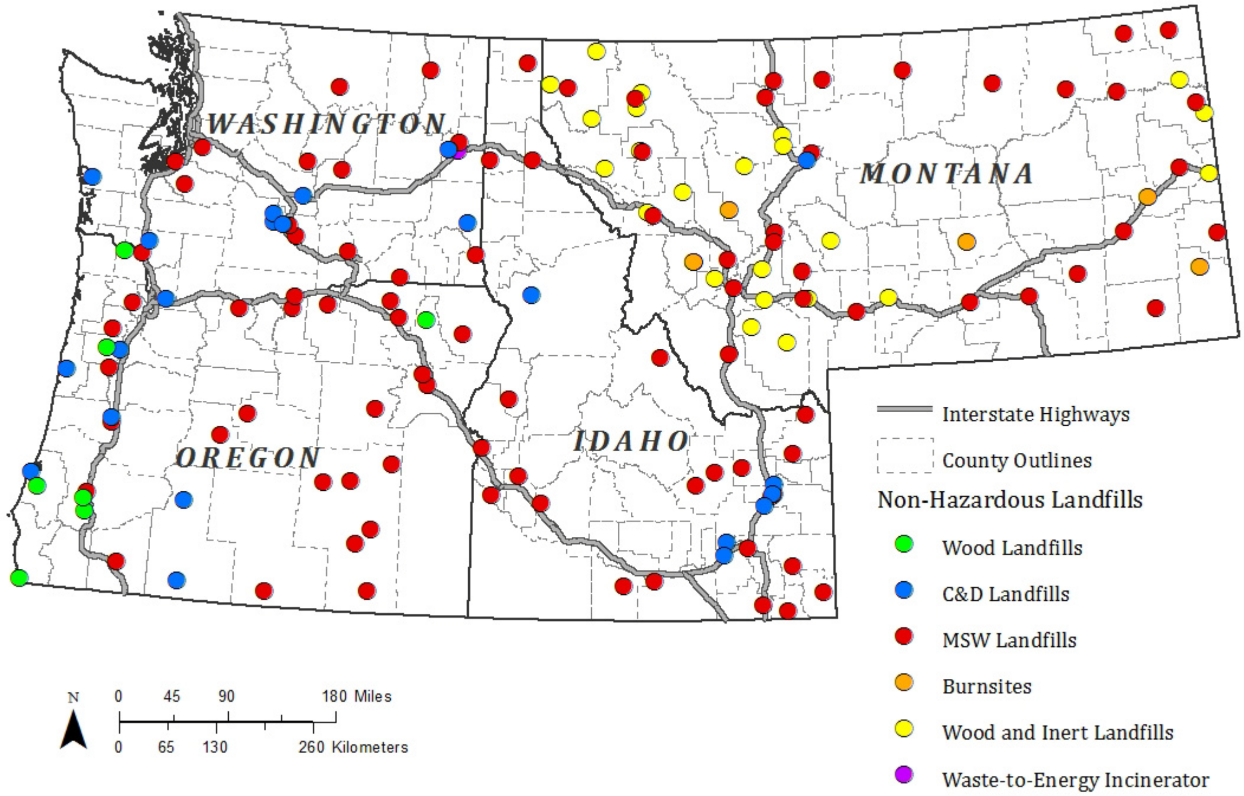


Figure 3.1: Map of northwest U.S. representing non-hazardous landfills that dispose of wood waste

Counties, Wastesheds, and Solid Waste Districts Results

MSW and RWW quantities per county, wasteshed, and solid waste district were provided by state and local government departments and then mapped using ESRI ArcGIS mapping software. For the purpose of simplicity, the term "wasteshed", as defined by the state of Oregon, has been adopted in this research as a blanket term for all counties, wastesheds, and solid waste districts within the northwest United States. MSW and RWW per wasteshed within the states of Washington and Oregon were collected from the Washington DOE and the Oregon DEQ from personnel within the corresponding departments upon telephone and email request [45], [54]. MSW quantities per wasteshed within the state of Montana were provided by personnel within the Montana DEQ upon email request, although RWW quantities were not provided. Idaho DEQ did not provide MSW or wood waste quantities per county. Since the states of Idaho and Montana do not provide recycled wood waste quantities, contact with individual city, county, or landfill personnel was necessary to collect pertinent data. Contact information is typically found within corresponding websites. Unfortunately, contact was not achieved with all of them due to communication and time constraints. A list of wastesheds in Idaho and Montana that were successfully contacted is represented in Appendix A. Figure 3.2 is a map of the northwest U.S. that represents MSW quantities per wasteshed, and Figure 3.3 is a map of the northwest U.S. that represents RWW per wasteshed.

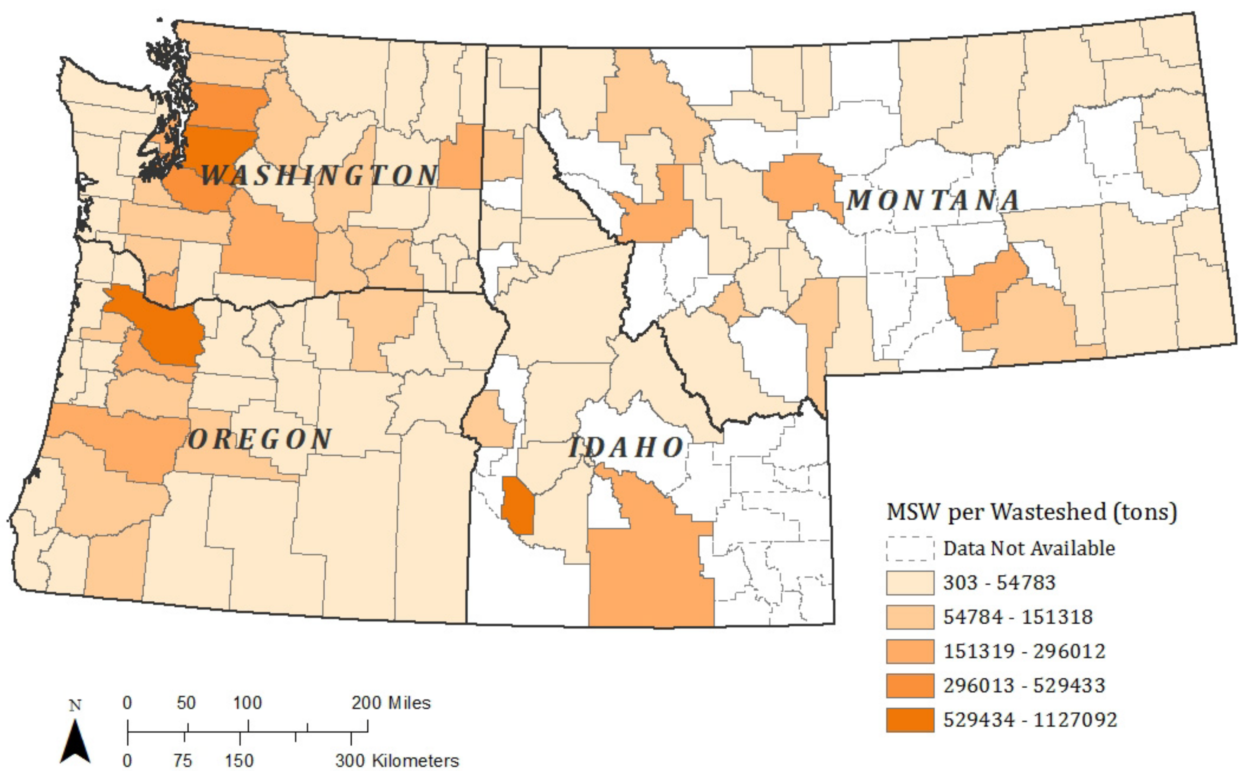


Figure 3.2: Map of northwest U.S. representing disposed MSW per wasteshed

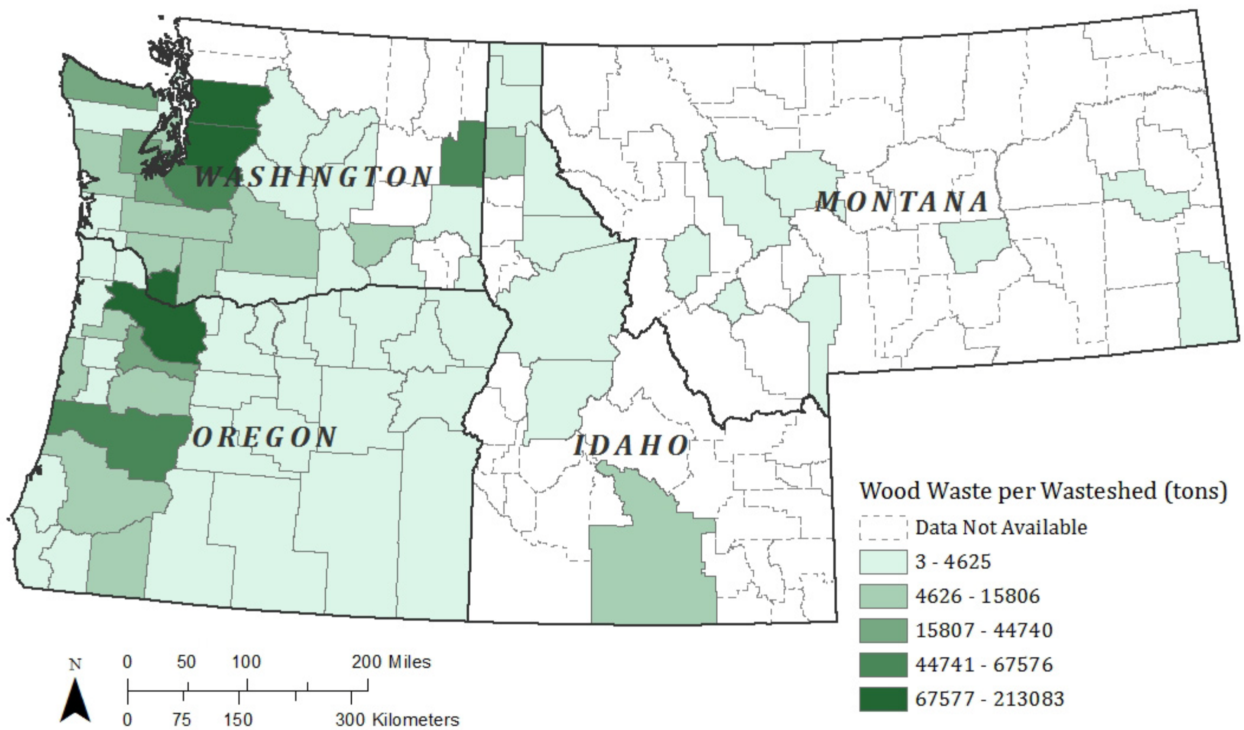


Figure 3.3: Map of northwest U.S. representing RWW per wasteshed

Material Recovery Facilities

A preliminary list of MRFs that recycle wood waste was compiled using state provided databases and various internet searches; MRFs that recycle only land-clearing debris were not included. The types of MRFs targeted during the list-making procedure varied due to regional trends and priorities. Once the list was created, a questionnaire was developed with the intent of asking questions regarding types of wood waste collected, annual quantities, separation techniques, markets for recycled wood, tipping fees, and the range of supply and distribution.[3] MRFs on the list were contacted via telephone or email in order to collect data pertaining to the prescribed details of the questionnaire. The method and results of the questionnaire process are described in the following sections.

[3] The MRF Questionnaire is represented in Appendix A.

MRF Survey and Mapping Methods

A preliminary list of MRFs within Washington and Oregon was collected from the Washington DOE and Oregon DEQ. Other MRFs not listed within the states' databases were determined using internet searches. Once a preliminary list of MRFs was compiled, another internet search was performed for every MRF to determine whether or not they recycled C&D wood waste. If C&D wood waste was not recycled, then the MRF was removed from the list. MRFs that recycled both land-clearing and C&D wood were left on the list, although only C&D information was targeted. Contact information, which included telephone number, street address, and email address, were collected for the MRFs on the list.

A questionnaire was designed to ask questions regarding types of wood waste, volumes and tonnages of wood waste, whether or not the wood is separated, markets for recovered wood waste, what form the recovered wood was sold as, maximum capacity, supplier and distribution reach, tipping fees, transportation, and associated wastes. An example of the questionnaire is provided in Appendix A. Telephone conversation was the most successful form of contact with the MRFS. Not all MRFs were able to answer all of the questions as they were designed. The questions most consistently answered were those regarding wood waste types, quantities, reach, tipping fees, and market.

MRF data, which includes RWW quantities and geographic coordinate location, were compiled into a Microsoft Excel spreadsheet and uploaded into ESRI ArcGIS mapping software. The geographic locations of the MRFs were determined by using the Location Finder tool in ArcGIS, in which their addresses were used to determine their corresponding longitude and latitude. The geographic coordinate system used for the MRF shape file was WGS 1984. The

MRF symbology in the map used graduated symbols in order to depict RWW quantities per MRF. All other shapefiles, including state boundaries, county boundaries, and interstate highways, were collected from a GIS database provided by Washington State University [52].

MRF Questionnaire Results

The survey set a goal to contact a total of 53 MRFs within the northwest U.S., in which 47 were contacted. Of those contacted, 31 were cooperative with the questionnaire and 16 didn't provide annual quantities. Six MRFs were never contacted due to failed attempts at communication. Table 3.3 represents an overview of the data collected by each MRF, and Figure 3.4 represents the locations and known quantities of MRFs within the northwest United States. Appendix A represents an example of the questionnaire and a table of the MRFs contacted, which includes pertinent data such as location, volume, reach, tipping fees, and associated market information collected by the MRFs during the questionnaire process.

Table 3.3: Overview of MRF Data Collection.

State	Total Known MRFs	Total MRFS with Data Unknown	Total MRFs with Volume Data Unknown	Estimated MRF Wood Quantities (tons/year)	Recycled Wood Majority Market
Idaho	4	0	0	45,000	Reclaim Timber
Montana	7	1	2	6,800	Reclaim Timber
Oregon	18	3	6	100,000	Hogged Fuel
Washington	24	2	8	495,000	Hogged Fuel
Total	**53**	**6**	**16**	**646,800**	-------------

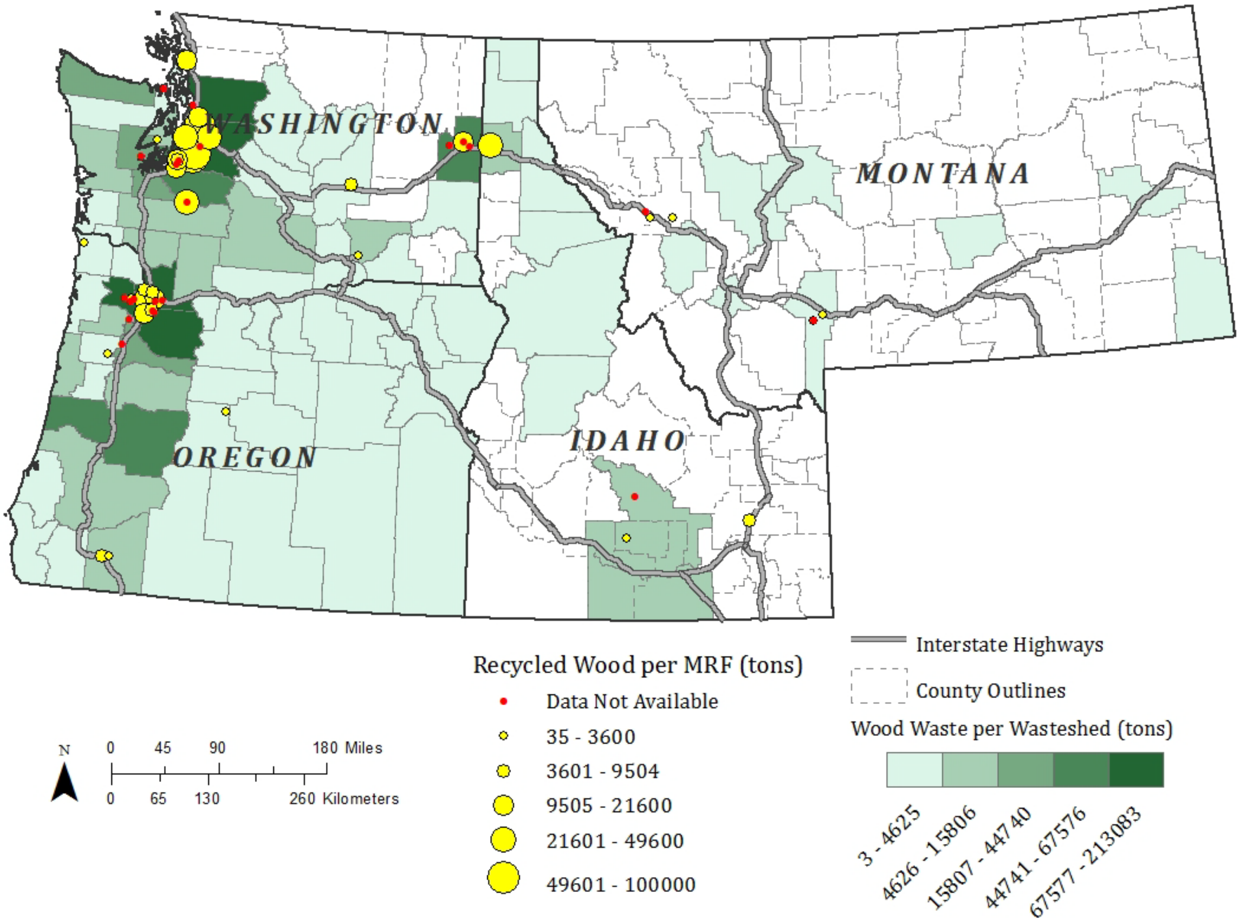


Figure 3.4: Map of northwest U.S. representing material recovery facilities that recycle wood waste.

Observations made during research indicated various types of MRFs that recycle urban wood waste, which include reclaimed timber mills, building salvage stores, wood grinding service companies (WGSC), and landfill-affiliated transfer stations. Reclaimed timber mills recycle timber from old and unused wood structures by re-milling the wood into new and more usable products. Building salvage stores recycle or restore materials that are associated with building construction; wood in this case is often sold for reuse. WGSCs may be mobile, stationary, or a combination of both. WGSCs in rural areas are often equipped with mobile grinders that allow them to travel to various customers, such as construction sites or landfill-affiliated transfer stations. WGSCs located in urban settings act as stationary hubs for residential and commercial customers and recycle various types of construction and demolition materials. WGSCs located in smaller city areas act as both stationary hubs and mobile grinders. WGSCs are also hired by landfills to maximize usable space by grinding solid wastes and decreasing their volume. Landfill-affiliated transfer stations occasionally act as recycling facilities, especially in small cities and rural areas. However, many landfill-affiliated transfer stations subcontract recycling duties to mobile WGSCs as a way of reducing operational costs. Landfill-affiliated transfer stations were not contacted during the MRF survey process.

The majority of C&D RWW collected by MRFS was grinded and utilized for new products or sold for energy recovery. Out of 45 MRFs contacted that do not process reclaimed timber, 33 of them stated that their C&D RWW was utilized or sold for energy recovery, resulting in 73.3%. This is similar to the 70.9% of diverted wood waste that was burned for energy recovery in the state of Washington in 2010. According to MRF managers, a common explanation for this outcome is because of the inhomogeneous nature of C&D wood waste. Wood recyclers that produce mulch, compost, paper, or composites tend to request clean wood waste, while large portions of C&D wood waste is often a mixture of clean wood, painted wood (non-lead), and resinated wood, such as plywood, particle board, and other miscellaneous engineered wood. In many cases, wood that is coated with lead paint or treated with chemicals such as creosote or chromate copper arsenate was not accepted or recycled at all.

MRF quantities varied from actual tons to estimates of weekly, monthly, or annual volumes. Quantities were often reported in units of cubic yards or tons, although there were a few that responded with other units, such as trucks per week, month, or year; the cubic yardage per truck was given in these circumstances. All quantities that were received were converted to tons; a table of wood volume conversion factors is provided in Appendix A. In total, 646,800 tons of wood were recycled from MRFs that provided quantities, in which 6,800 tons were recorded from Montana MRFs, 45,000 tons were recorded from Idaho MRFs, 100,000 tons were recorded from Oregon MRFs, and 495,000 tons were recorded from Washington MRFs. It is important to note that RWW quantities recorded from MRFs during the questionnaire process do not represent all of the RWW within the region. A reason for this may be that industries such as pulp and paper mills and wood products manufactures that often recycle their own wood wastes were not considered as MRFs during the questionnaire process and therefore were not contacted, even though they may be required by the state to report RWW quantities.

MRF tipping fees were lower than those of MSW landfills. Tipping fees were usually charged in dollars per ton or cubic yard. Tipping fees for clean wood varied from $15/ton to $63/ton, producing an averaged tipping fee of $39/ton. According to the Washington DOE, tipping fees during the fiscal year of 2010-2011 at MSW landfills in Washington varied from $32/ton to $150/ton, producing a calculated average tipping fee of $67/ton [55].

The supply and distribution reach provided by MRFs was often estimated and varied due to what type of material they recycled. MRFs that recycle reclaimed timber usually exhibit a vast network of suppliers that span 2,500 miles, occasionally reaching into Canada. An assumed reason for their vast supply and distribution reach may be due to the fact that they are producing high-end finished products that result in high demand. MRFs that grind RWW for hogged fuel, mulch, or compost observably maintain a regional supply and distribution reach that varies from 10-200 miles and averages at 98 miles.

Wood-to-Energy Facilities

A list of Wood-to-Energy Facilities (WEFs) was compiled in response to the notion that 73.3% of RWW is burned for energy, as discussed in the previous section. The list of WEFs in the northwest United States was compiled using internet searches and a database provide by [56], [57]. The results were mapped using ESRI ArcGIS software and utilized the same ArcGIS methods as discussed in the MRF Survey Method section. Figure 3.5 represents the WEFs in the northwest United States, which depicts them according their energy capacity. There are thirty-five WEFs represented in Figure 3.5, in which twelve are located in Washington, sixteen in Oregon, four in Idaho, three in Montana. Further analysis regarding WEFs was not performed.

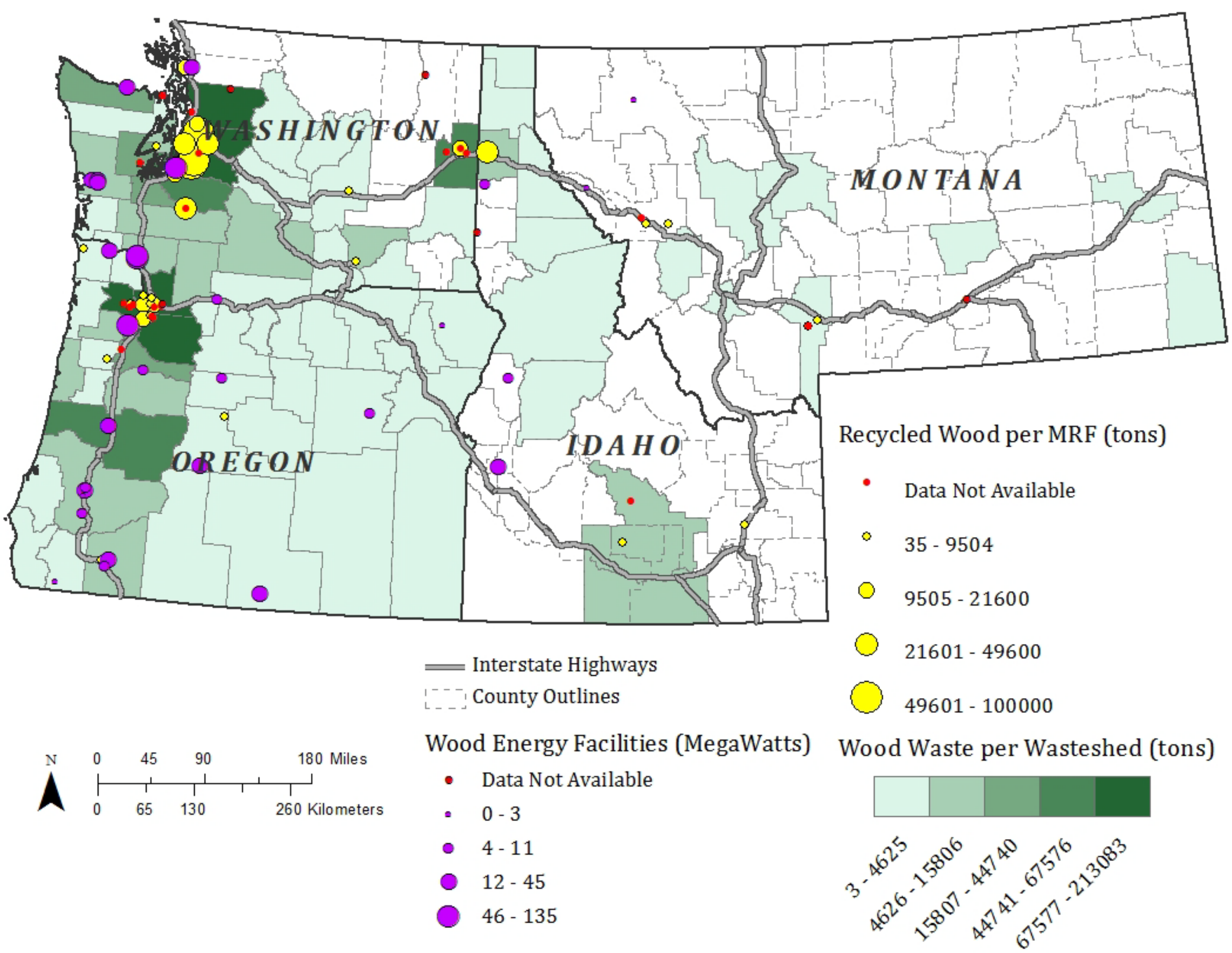


Figure 3.5: Map of northwest U.S. representing wood-to-energy biomass facilities.

Spatial Analysis of RWW in Western Washington and Oregon

Spatial analysis of RWW within western Washington and Oregon was performed using ESRI ArcGIS mapping software with the intent of determining the geographical mean center of RWW point sources, which include wastesheds and MRFs. The purpose of this spatial analysis was to determine a hypothetical location for a RWW production facility, such as a wood pellet mill, that falls within the average supply and distribution reach of the MRFs contacted during the questionnaire process. In order to determine a suitable location, it is assumed that the production facility be located in a region with an abundance of RWW quantities. As observed in Figure 3.4 in the previous section, the largest quantities of RWW within the northwest United States appear to be located in western Washington and Oregon. A map of the western region, represented in Figure 3.6, depicts the concentration of RWW near the cities of Seattle, Tacoma, Vancouver, and Portland. The spatial analysis during this procedure used geoprocessing tools such as Buffer, ModelBuilder, Feature-to-Point, Merge, and Mean Center in order to determine the geographical mean center of the RWW point sources located within the western Washington and Oregon. The method and results of the spatial analysis are discussed in the following sections.

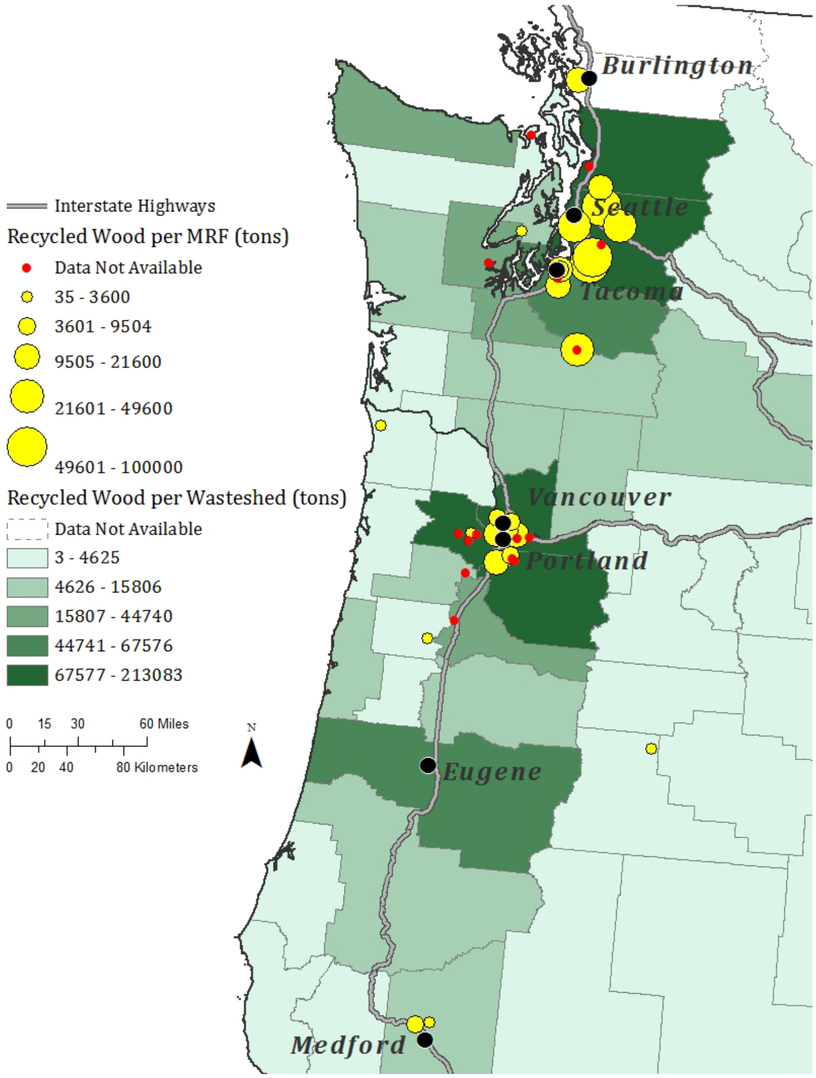


Figure 3.6: Map of western Washington and Oregon representing RWW quantities per MRF and wasteshed

Spatial Analysis Method

In order to determine the geographical mean of RWW point sources, the spatial analysis procedure utilized the following ArcGIS geoprocessing tools: Buffer, ModelBuilder, Feature-to-Point, Merge, and Mean Center. It is assumed that the reader has working knowledge of ESRI ArcGIS geoprocessing tools in order to understand the spatial analysis discussed in this method. In order to fall within the average supply and distribution reach of the MRFs contacted during the survey process, an arbitrary distance of 50 miles was chosen as a supply and distribution reach for the spatial analysis process; 50 miles also happens to be the rounded-up quotient of half the average reach of 98 miles. The Buffer tool was used to create the 50 mile radius around all of the MRFs within the region, as depicted in Figure 3.7. A hypothetical region of study, as represented in Figure 3.8, was selected from the wastesheds that fell within contact of the 50 mile buffers. The wastesheds and MRFs that fell within the hypothetical region were selected and created into new layers.

ModelBuilder was used to spatially analyze the selected wasteshed and MRF feature layers and determine a geographic and weighted mean center. ModelBuilder is an application within the ArcGIS program that uses a diagram that allows the user to utilize multiple geoprocessing tools at once [58]. The tools used within the ModelBuilder include the Feature-to-Point, Merge, and Mean Center. Figure 3.9 represents the described ModelBuilder diagram. Since wastesheds are represented as polygons and MRFs are represented as points, the Feature-to-Point tool was used to determine the centroids of the wasteshed polygon layers in order to transform them into point sources; the result is represented in Figure 3.10. Once transformed into point sources, the wasteshed layer was merged with the MRF layer using the Merge tool. In order to merge attributes from two separate layers during the merge process, it is important that the attribute field headings be identical, otherwise the data will not be able to combine into one attribute field. The result of the Merge tool is represented in Figure 3.11.

The Mean Center tool determines the geographical mean of point sources within a specified layer [58]. The Mean Center tool was used to determine two outcomes: the geographic mean center and weighted mean center of the RWW point sources represented by the merged MRF and wasteshed layers. The geographical mean center uses only geographic locations to determine the center of the RWW point sources. The weighted mean center was uses the geographic location and an attribute field value in order to find a geographic center that favors the specified field. The attribute field used during the weighted mean center analysis in this method was RWW quantities. The result of the mean center and the weighted mean center is represented in Figure 3.12, and will be discussed further in the following section.

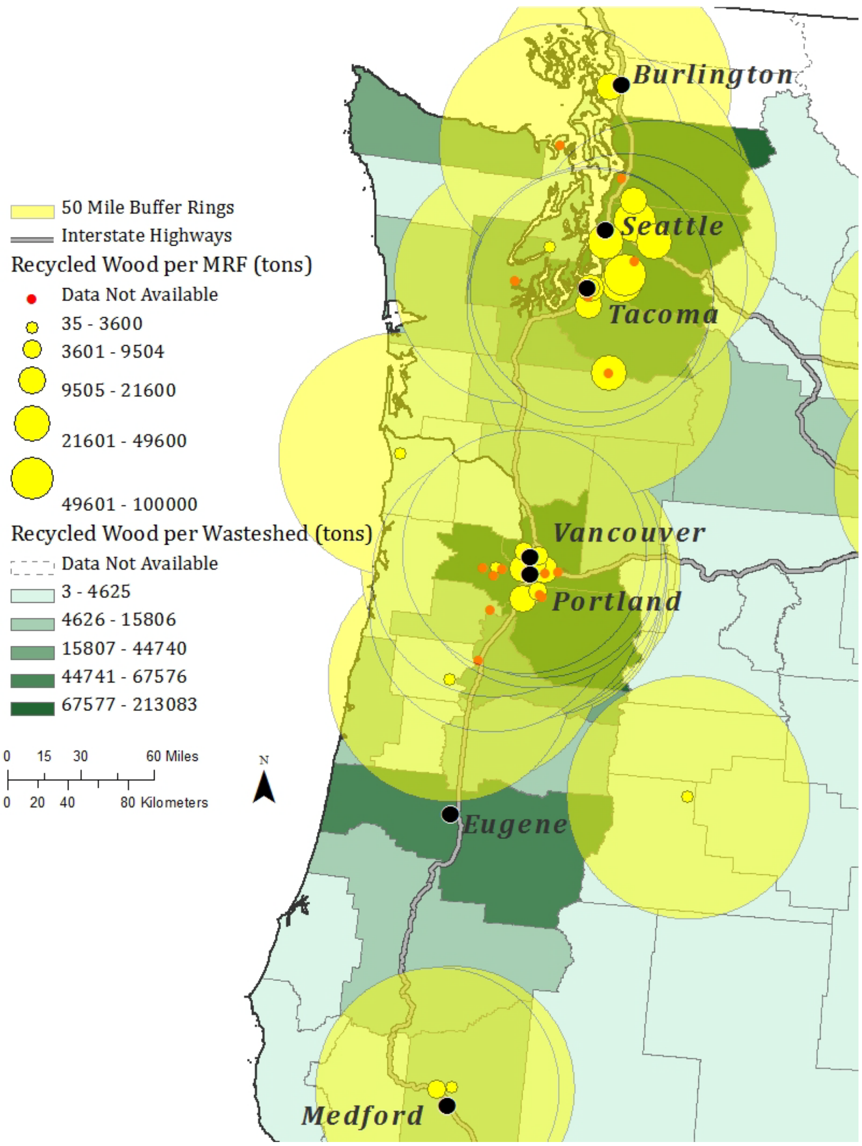


Figure 3.7: Map of western Washington and Oregon representing the Buffer tool used during the spatial analysis process.

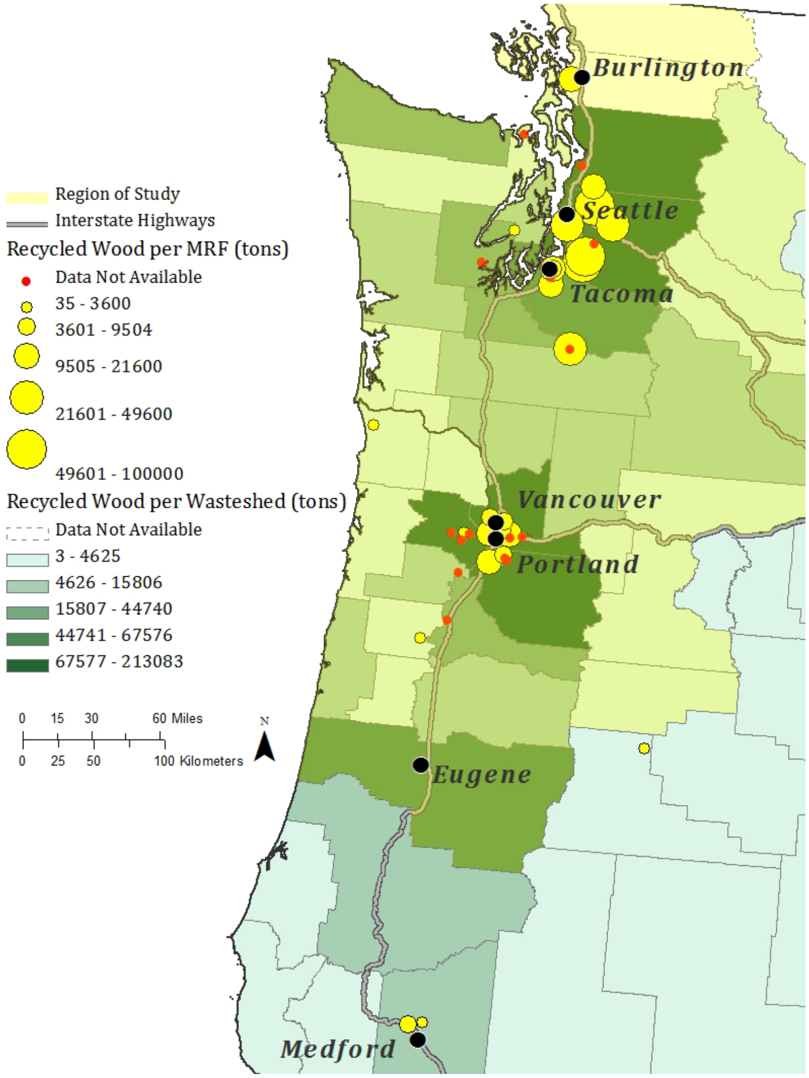


Figure 3.8: Map of western Washington and Oregon representing the region of study, as determined by wastesheds that come into contact with the 50 radius rings produced during the Buffer tool process

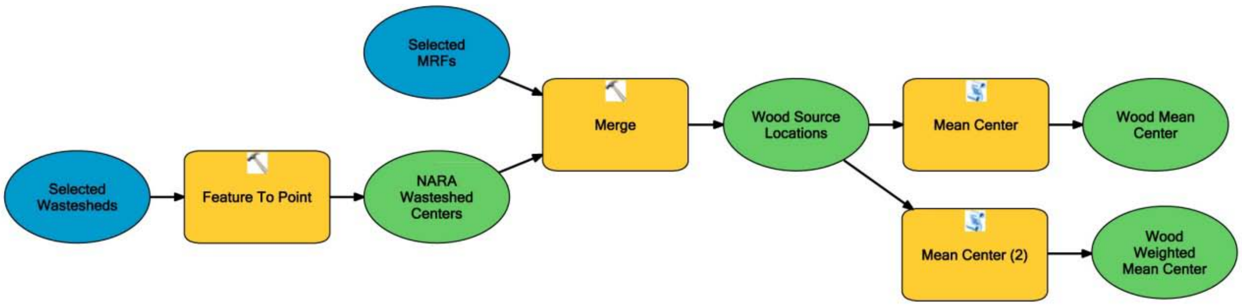


Figure 3.9: Diagram of ESRI ArcGIS ModelBuilder used during spatial analysis of RWW in western Washington and Oregon

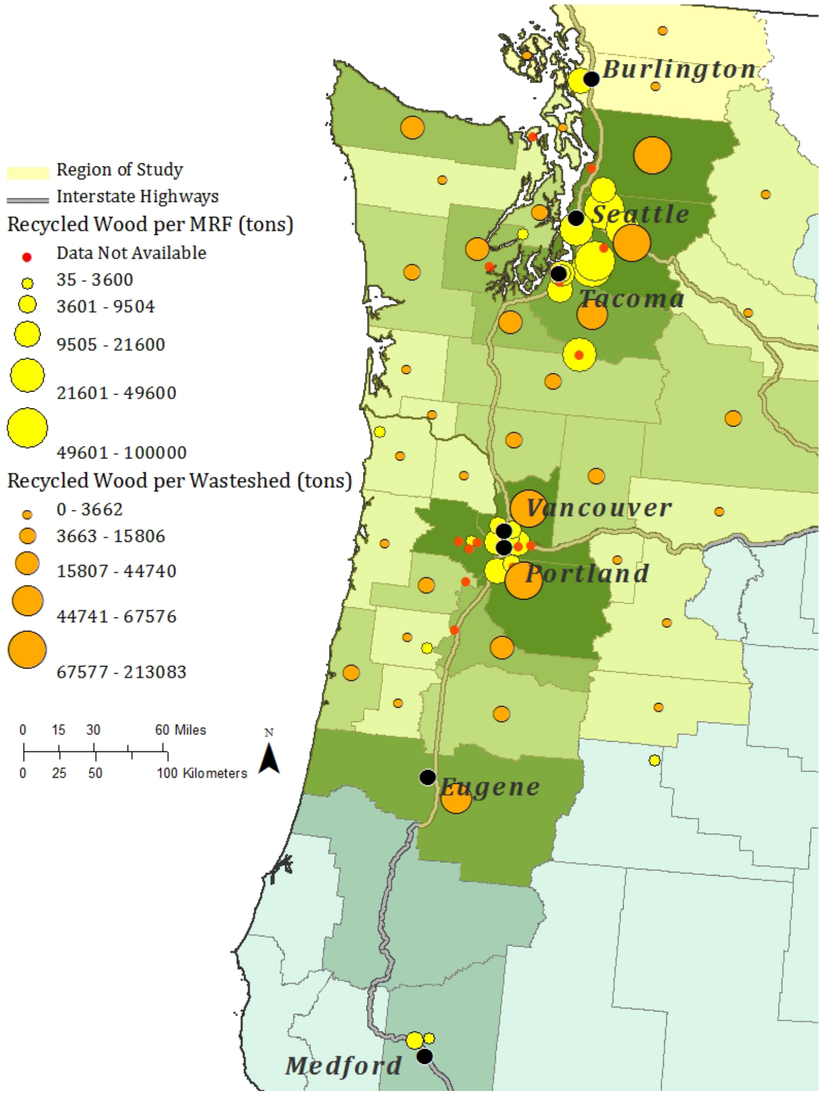


Figure 3.10: Map of western Washington and Oregon representing MRFs and the wasteshed point sources as determined by using the Feature-to-Point tool

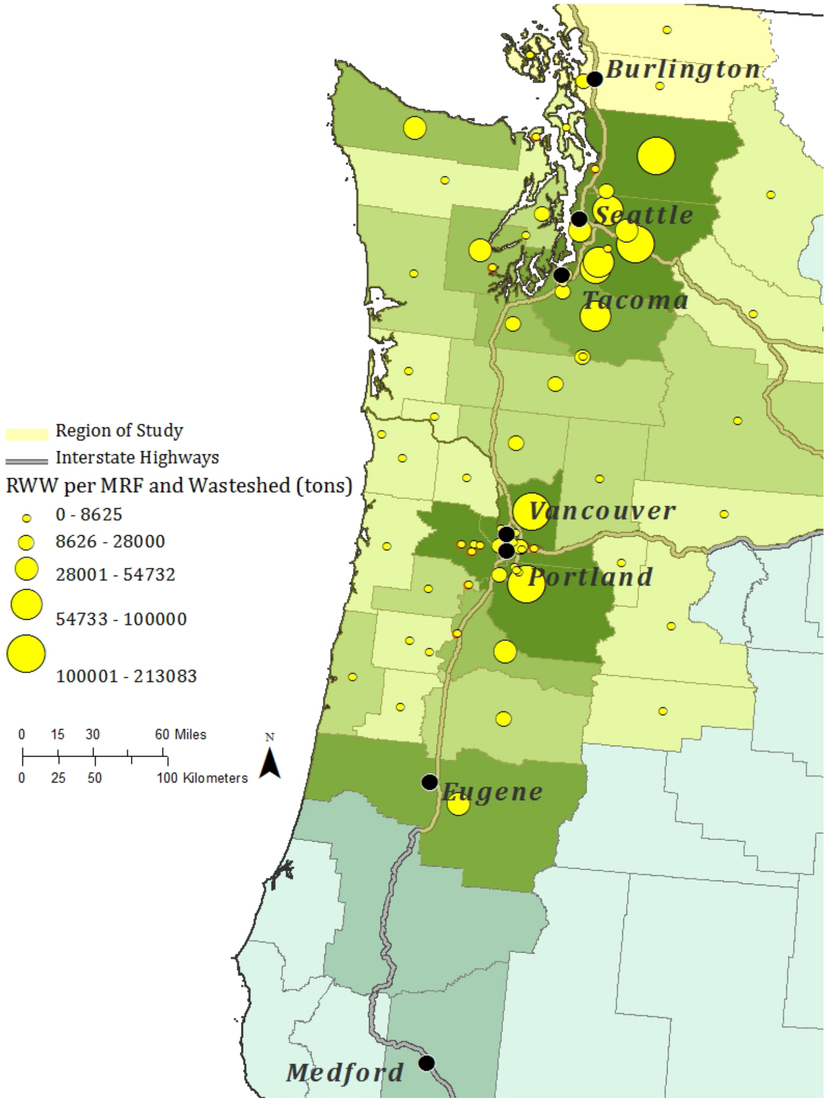


Figure 3.11: Map of western Washington and Oregon representing the merged MRF and wasteshed point sources as determined by the Merge tool

Spatial Analysis Results

The geographical mean and weighted mean centers of RWW from MRF and wasteshed point sources may potentially indicate an ideal location for facilities that utilize woody biomass, such as a wood pellet production facility. Figure 3.12 represents a map of the geographical mean and weighted mean centers of RWW point sources established during the spatial analysis. The city of Centralia, which happens to be located on the nearest interstate highway within proximity to the weighted mean center, is represented on the map. The Buffer Tool was used within the map in order to determine a 100 mile radius around the city of Centralia; this represents the rounded-up average distance of supply and distribution reach of MRFs discussed during the questionnaire process. Hypothetically speaking, if a woody biomass pellet plant were located in or near Centralia, Washington, then it could theoretically be within a distance suitable for both the supply of raw RWW, as well as the distribution of woody biomass pellets to WEFs within the region. However, further analysis would need to be performed to examine state or local codes and ordinances that may influence the development of such a facility.

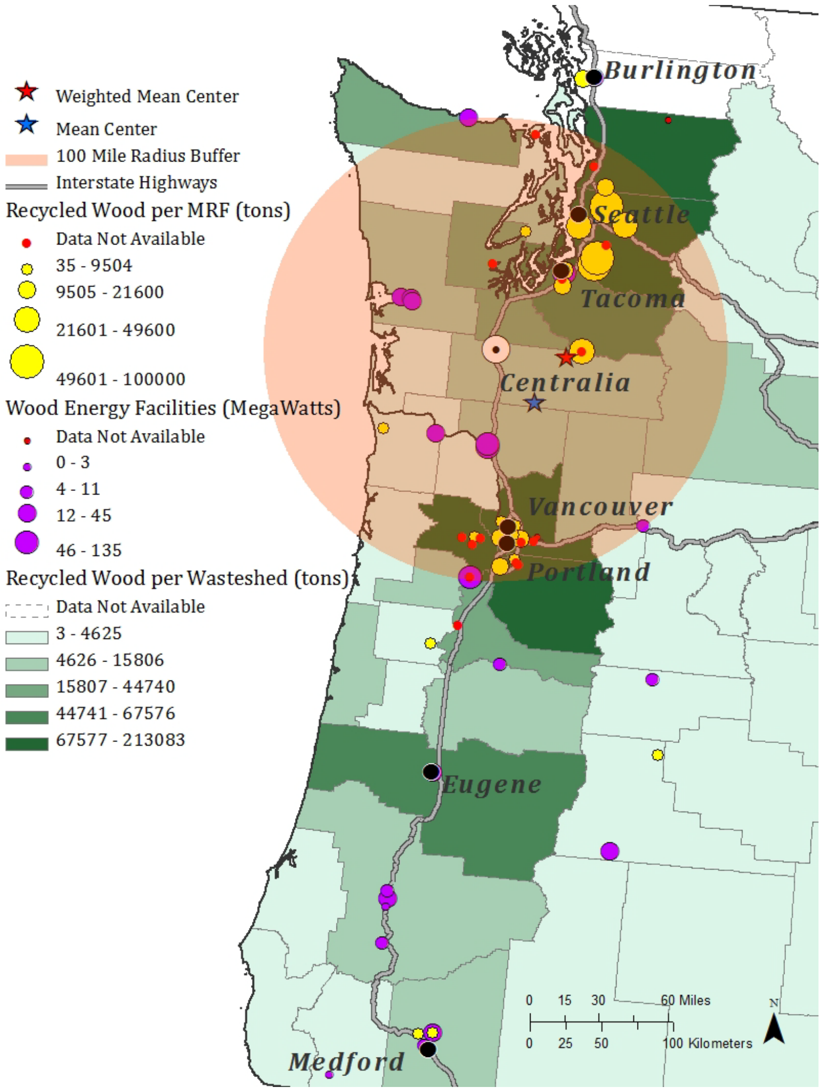


Figure 3.12: Map of western Washington and Oregon representing the geographical mean center and weighted mean center of MRF and wasteshed RWW sources, as determined by the Mean Center tool; the map indicates an ideal location for a woody biomass processing facility

3.4 Conclusion

The RWW inventory assessment within the northwest U.S. included a compilation of MSW and RWW information for the states of Washington, Oregon, Idaho, and Montana, as well as a supply chain assessment within the region. The compilation utilized annual solid waste and recycling reports as well as information provided by websites in order to explore solid waste policies, data collection methods, and annual quantities of MSW and RWW for the states within the region. The RWW supply chain assessment collected MSW and RWW data per county, wasteshed, landfill, and MRF within the region. Landfill and wasteshed information was provided by state and county personnel within their respective solid waste departments. MRF data was provided during a survey process in which a questionnaire was used to collect RWW information regarding wood waste types, quantities, reach, tipping fees, and markets of recycled wood. The results were mapped and spatially analyzed using ESRI ArcGIS software, which then determined an ideal location for a hypothetical woody biomass pellet production facility.

CHAPTER FOUR

UNDERSTANDING THE FACTORS THAT INFLUENCE RECYCLED WOOD WASTE

4.1 Introduction

Factors that potentially influence recycled wood waste (RWW) were assessed over time and modeled using data collected from Washington, Oregon and model communities selected within the northwest United States. Research began with a compilation of information in order to examine aspects regarding RWW, such as regional factors, industry activity, local government policy, economy, and RWW market conditions. An evaluation of potential factors of RWW was performed by selecting aspects such as population and residential building permits (RBP) and graphing them over time with annual RWW quantities for the states of Washington and Oregon and selected model communities within the northwest United States. Model communities were selected based on population density and methods of recording RWW. The model communities include the Seattle-Tacoma-Bellevue metropolitan area, the Spokane-Spokane Valley metropolitan area, the Portland-Vancouver-Hillsboro metropolitan area, the Coeur D'Alene metropolitan area, and the Southern Idaho Solid Waste District. Remaining counties in Washington and Oregon were also assessed using the same technique. Single variable and multivariable models were produced with the intent of determining RWW per population, RBPs, or a combination of both.

4.2 Compilation of Information Regarding Aspects that Influence Wood Waste Recycling

A compilation of information was collected in order to examine potential factors that influence RWW. Information was compiled from news articles and government reports with the purpose of obtaining information regarding RWW aspects such as regional solid waste recording methods, industry activity, local government policy, and market trends. Examining regional solid waste recording methods should provide accurate data that will aid in future MSW and recycling assessments, rather than relying on broad estimates. Industries are primary sources of wood waste and influence RWW through their economic activity. Local government policy directly influences the regulation and activity of MSW and RWW. Market trends influence RWW by providing end-user products or services.

Utilizing actual tonnage recorded by local or regional recycling and disposal facilities may provide a more accurate means of determining and forecasting MSW and RWW quantities. According to the measurements of research previously conducted [59], the EPA's estimate of annually disposed MSW waste is inaccurate. The research group examines actual recorded MSW tonnage collected from individual states and publishes the results on a biennial basis [59]. According to the research, the EPA estimate of solid waste disposed in landfills is 98.5 million tons less then what is actually disposed of in MSW landfills [59]. This is due to the estimation method used by the EPA. In order to estimate landfill-disposed MSW, the EPA subtracts its estimate of composted, recycled, and incinerated solid waste from an estimate of total generated solid waste [59]. Furthermore, the report states that the EPA estimate is based on a compilation of sources, which includes materials and products generated and their life spans, key industry associations and businesses, waste characterization studies, and surveys conducted by governments, industry, and the media [59].

Industrial and C&D activity may influence the amount of RWW. EPA research indicates that the amount of C&D waste generated is the product of the level of construction, renovation, and demolition activity, most notably weight per floor area [6]. The EPA provided a model that was based on variables such as total residential construction put-in-place value, average cost per square foot, and average waste generated per area for residential construction; however, the same report also states that C&D costs do not have a direct relationship with materials consumption due to inflation, profit, and other general costs [6]. Likewise, Wiltsee's research indicates that there seems to be a correlation between urban wood waste and population, although Wiltsee suggests that the results of the research would have been more accurate if other variables, such as local industry inputs or C&D building permits, were used to assess urban wood waste [2].

Local government policies may directly influence RWW. For example, the city of Seattle adopted a city ordinance with the plan of recycling 70% of C&D wastes by the year 2020 [60]. The three objectives of the ordinance are 1) to ban the disposal of recyclable materials in landfills, 2) to certify recycling levels at MRFs which receive and process C&D materials from Seattle jobs, and 3) to require permit holders for new construction, renovation, and demolition to file waste diversion reports in order to prove compliance of the disposal bans [60]. By the year 2016, C&D materials such as asphalt paving, metal, cardboard, bricks, concrete, plastic film wrap, tear-off asphalt shingles, new construction gypsum scrap, and clean wood will be banned from landfills, with exceptions that include painted, hazardous, and other miscellaneous materials [60].

The amount of annual RWW derived from C&D materials may be influenced by economic and market conditions. A report [61] discusses how the recent economic recession and changing trends in timber demand have dramatically impacted wood production, paper manufacturing, and biomass industries. According to the report, the new housing construction market dropped 74% from 2005 through 2009, and has not recovered despite economic recoveries in other sectors [61]. Figure 4.1 represents the number of single unit housing construction permits issued in the United States from 2000 through 2010 and indicates the collapse of the housing market starting in 2005 [61], [62]. Recycled wood waste is also influenced by trends in the market place. According to the report, a projected expansion of U.S. wood fuel feedstock is expected to nearly double by the year 2060, due to factors such as increases in conventional wood fuel, supplies of mill residue, pulpwood for energy, and logging residue recovery [61].

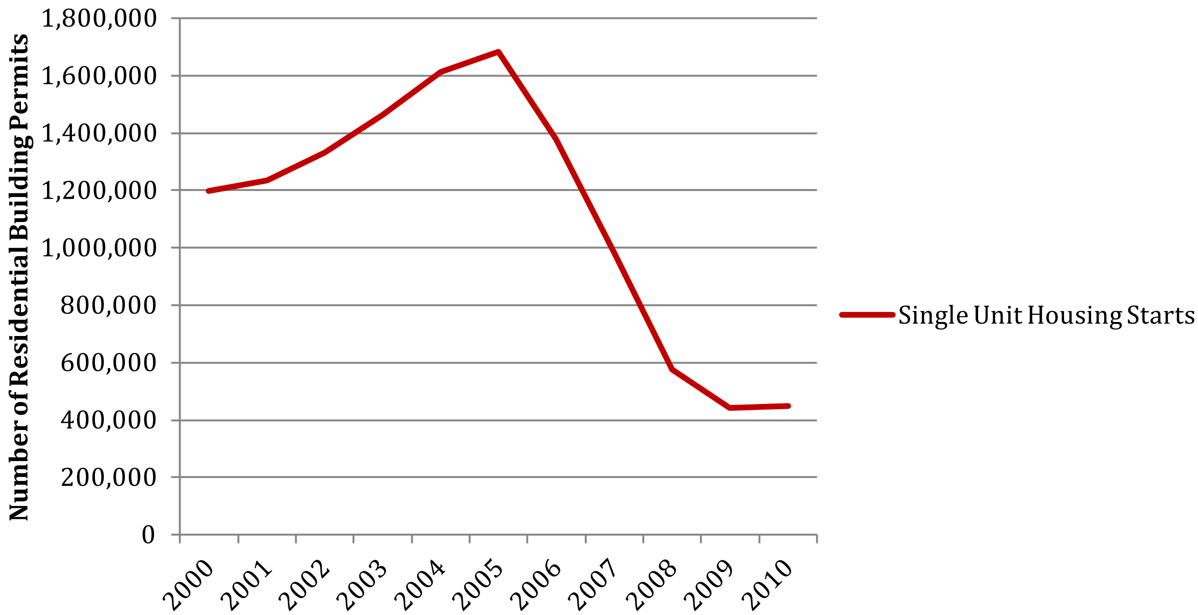


Figure 4.1: Single unit residential building permits in the United States from 2000 through 2010 [62]

4.3 Preliminary Evaluation of Potential Factors of Recycled Wood Waste

A preliminary evaluation of potential factors that influence RWW was performed for the states of Washington and Oregon, as well as selected model communities within the northwest United States. As inferred through the compiled information previously discussed, ideal factors of wood waste should be based on population and C&D activity. Furthermore, *it was decided during the research process that ideal factors be based on data that is easily available to the* *general public, preferably through internet searches of federal, state, or local government databases.* The factors under assessment during the preliminary process include population and residential building permits (RBP). Population is a widely accepted factor of normalization. RBPs were selected in reaction to Wiltsee's research as discussed in the previous section [2]. The following sections explains the methods used for data collection and selecting model communities, and discusses the results of the factor evaluation for Washington, Oregon, and the selected model communities.

Method of Data Collection

RWW quantities per state for the years 2000 through 2011 were collected for Washington, Oregon, and selected model communities and compared over time with population and residential building permits (RBP). The method of selecting model communities is described in a later section. Microsoft Excel was used to plot the line graphs that compare RWW to Population and RBPs over time. RWW quantities for Washington and its counties were provided by the Washington Department of Ecology [54]. RWW quantities for Oregon and its wastesheds were provided by the Oregon Department of Environmental Quality [45]. Population and RBP data was obtained per state and county from the U.S. Census Bureau website [63], [64]. RBP data is based on new privately-owned residential building permits and is recorded in buildings, units, and construction cost [64]. RBP units were collected per state and county during this research process. Population and RBP data was compiled for every county within the selected communities and summed in order to produce a total per model community.

Results for Washington and Oregon

A preliminary evaluation was performed for Washington and Oregon to determine if population and RBPs correlate with RWW over time. Figures 4.2 and 4.3 represent a comparison of RWW and population from the years 2000 through 2011 in Washington and

Oregon. In Washington, RWW appears to correlate with population over time with the exception of RWW peaks in 2001, 2002, 2006, and 2010. In Oregon, RWW appears to correlate with population until the years 2006 through 2009, when there appears to be a dramatic drop in RWW quantities. Figures 4.4 and 4.5 represent a comparison of RWW and RBPs from the years 2000 through 2011 in Washington and Oregon. In Washington, RWW minimally correlates with RBPs, and there appears to be a three year lag between the dramatic decrease in the quantities, which started in 2007 for RBP. In Oregon, RWW appears to correlate with RBPs with a time lag of only one year before the dramatic drop off in quantities. It is assumed that the dramatic drop in RWW from the years 2006 through 2009 was the result of a drop in residential building permits in 2005.

Further analysis was performed in order to understand the spikes and dips of RWW quantities over time in Washington. RWW was compared to the number of MRFs and facilities that burn RWW for energy in the state of Washington from the years 2000 through 2011. A database containing a list of MRF wood recyclers and facilities that burn wood for energy recovery was provided by the Washington Department of Ecology [54]. The database provided by the Washington DOE represented similar WEFs as those represented in Figure 3.5, but also included additional smaller facilities that burn RWW for energy, such as MRFs that burn wood for energy. Figure 4.6 represents a comparison of RWW and the number of MRFs from the year 2000 through 2011, and Figure 4.7 represents a comparison of RWW and the number of facilities that burn RWW for energy recovery from 2000 through 2011. The number of MRFs that process RWW appears to have a minimal impact on the number of annual RWW. However, the number of facilities that burn RWW for energy recovery appears to significantly correlate with RWW over time. An explanation for this may be that the majority of RWW in the state of

Washington is used for energy recovery—70.9% in 2010.[4] In summary, this indicates that facilities that burn RWW for energy recovery appear to drive the market demand for RWW in the state of Washington.

[4] 70.9% was provide in Chapter 3

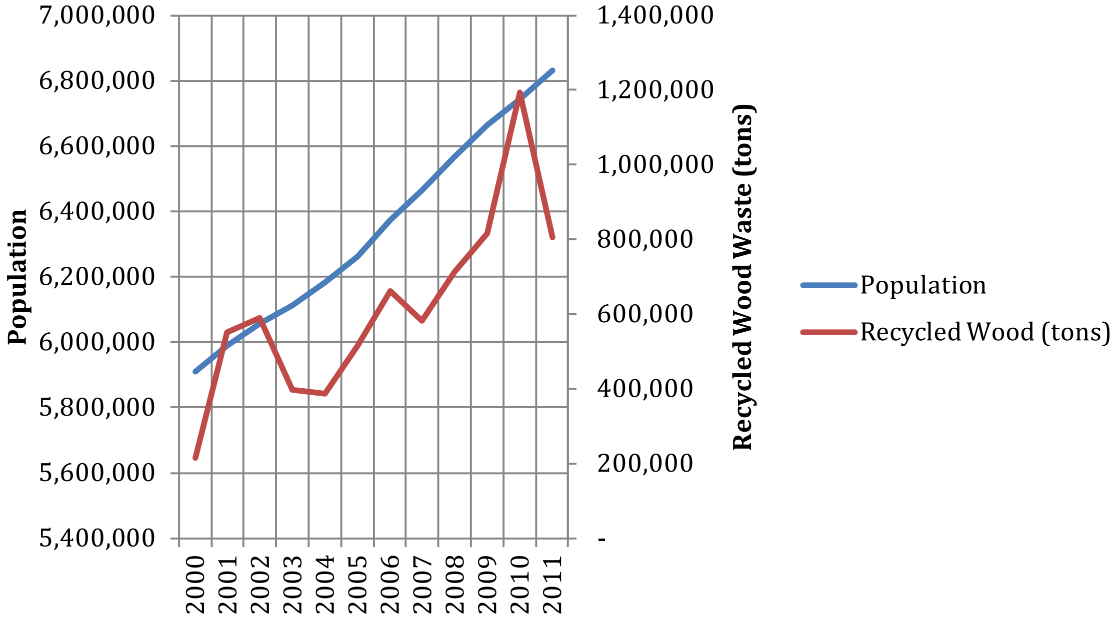


Figure 4.2: Population and RWW compared over time in Washington for years 2000-2011

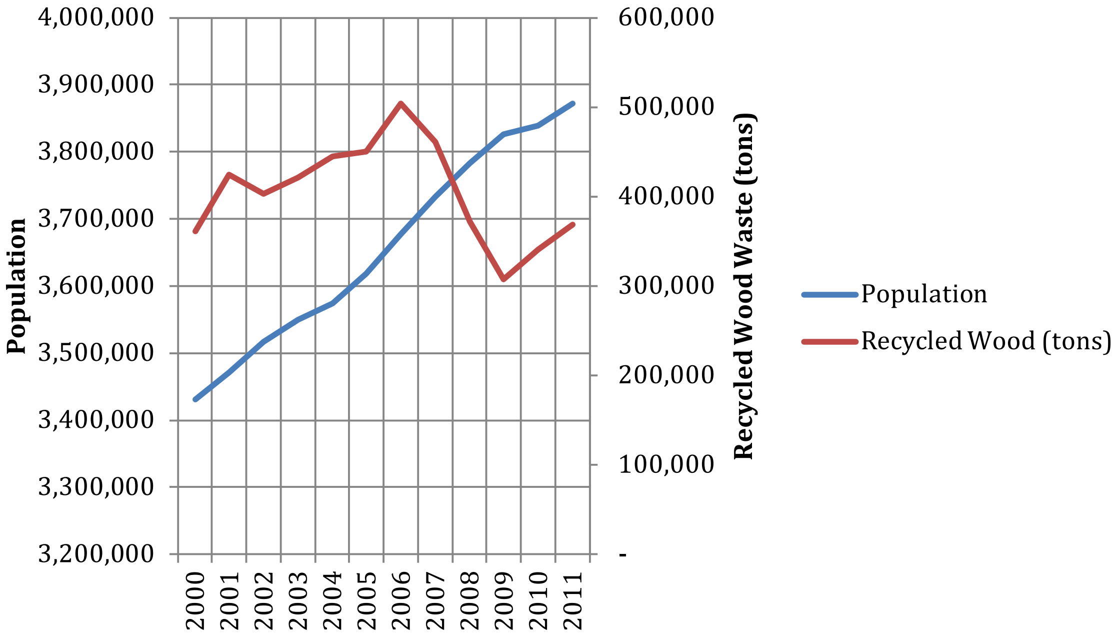


Figure 4.3: Population and RWW compared over time in Oregon for years 2000-2011

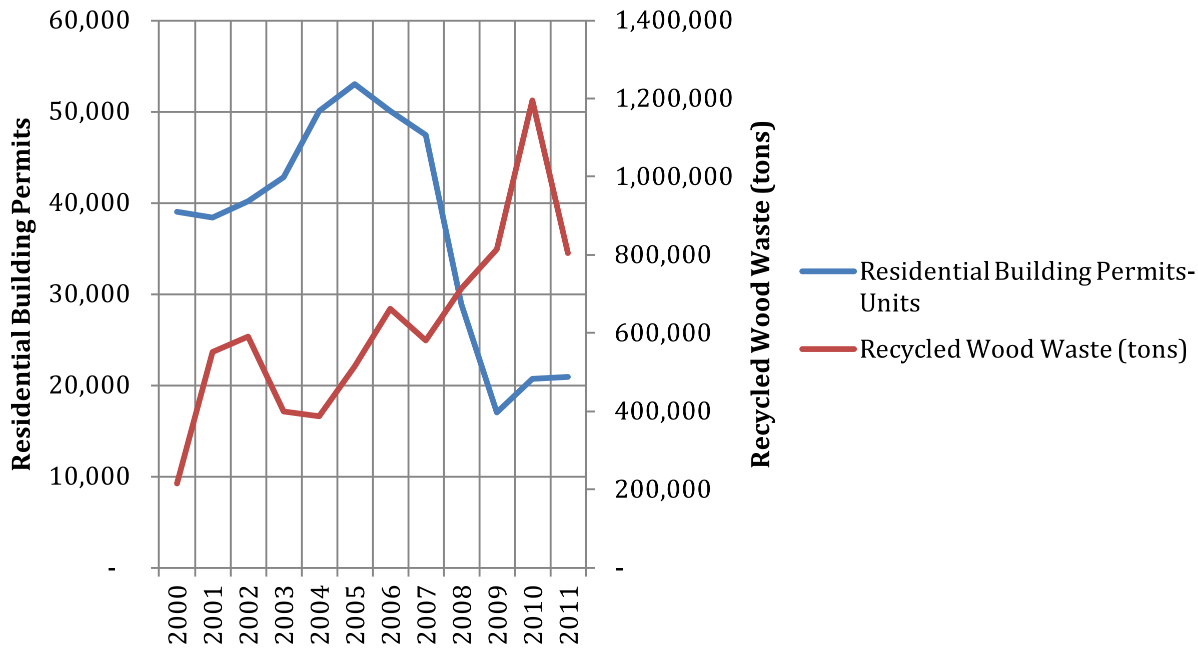


Figure 4.4: RBPs and RWW compared over time in Washington for years 2000-2011

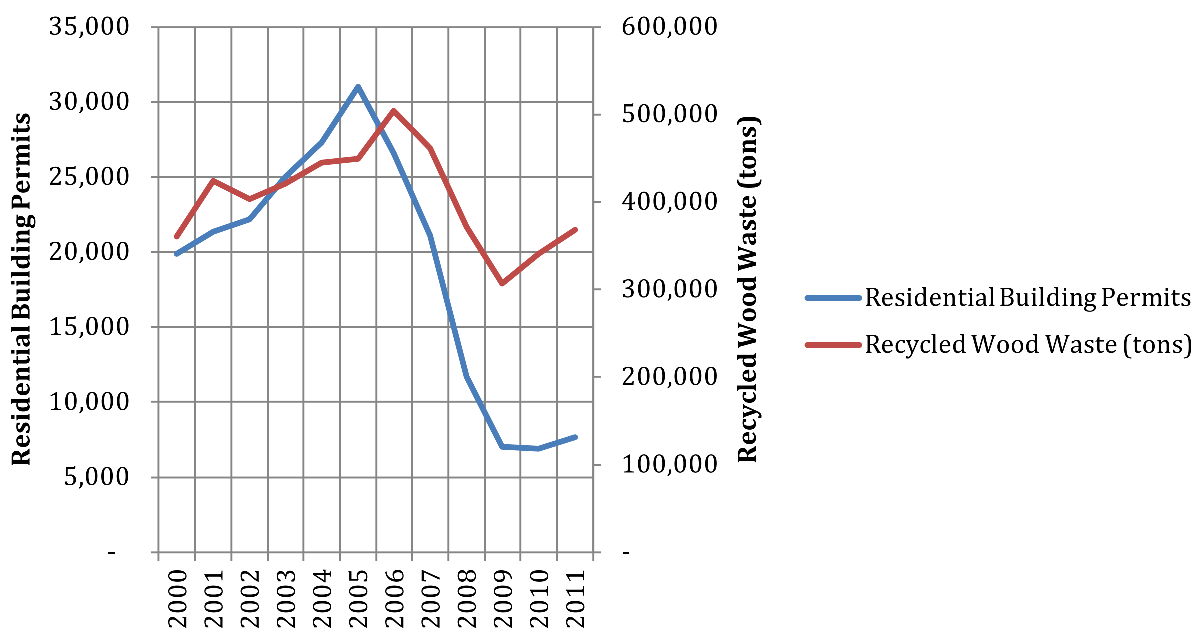


Figure 4.5: RBPs and RWW compared over time in Oregon for years 2000-2011

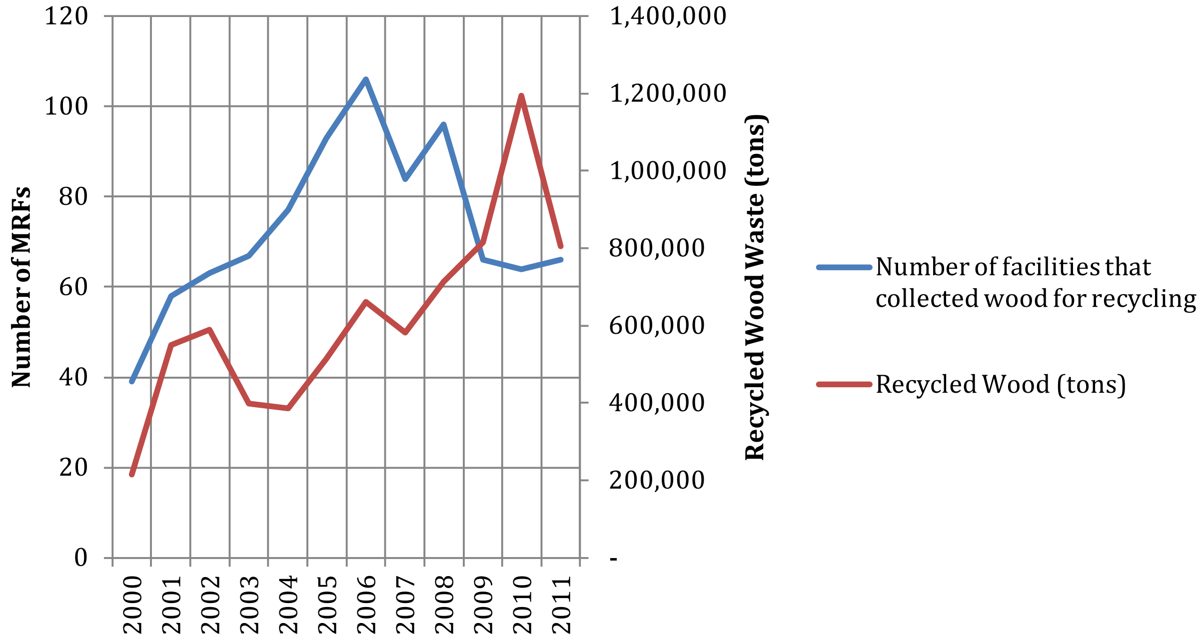


Figure 4.6: MRFS and RWW compared over time in Washington for years 2000-2011

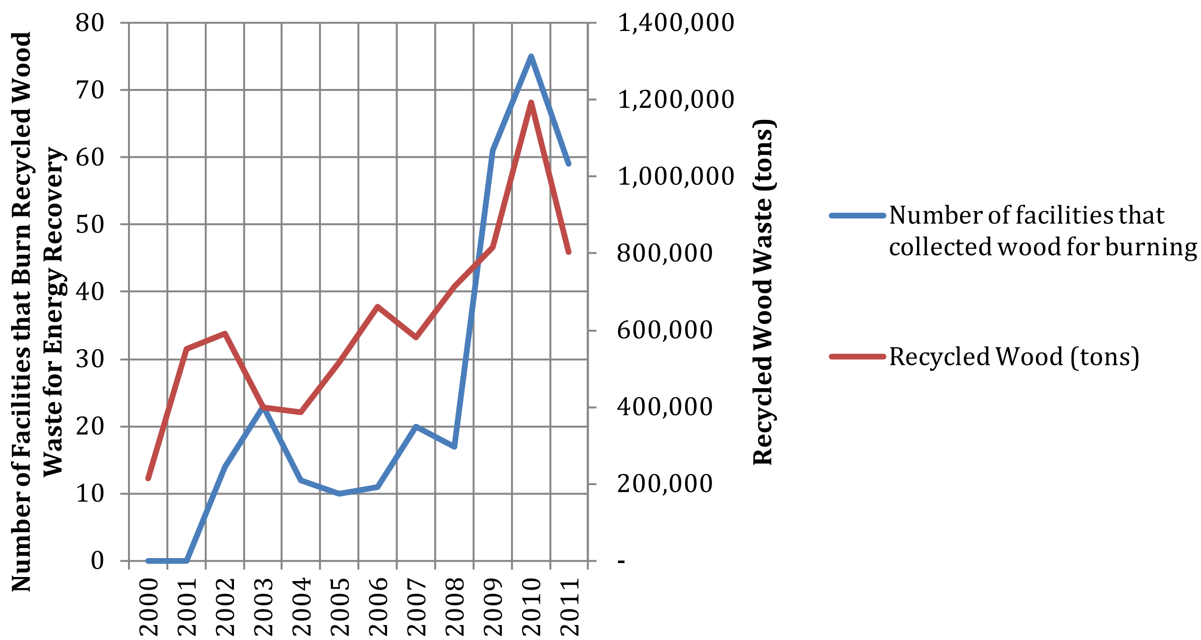


Figure 4.7: Facilities that burn RWW for energy recovery and RWW compared over time in Washington for years 2000-2011

Method of Selecting Model Communities

Model communities in the northwest United States were selected based on the availability of RWW data and population density. Only counties with recorded RWW data over a specified time period were selected as model communities. For the purpose of this research, it was decided that the specified time period be at least eight or more years to account for time before the economic recession of 2008. The counties with available recorded RWW for the specified time period include nearly every county and wasteshed in Washington and Oregon, and several counties in Idaho. Model communities were not chosen from Montana because adequate RWW quantities over the specified time period for counties in Montana were not determined. Montana does not provide RWW per county and not all counties were contacted during the preliminary RWW assessment as discussed in Chapter 3.

Population density was chosen to represent urban and rural communities. ESRI ArcGIS mapping software was used to determine the population densities of the counties within the northwest United States. Attribute fields containing population per square mile were provided within the county shapefiles acquired from WSU [52]. Figure 4.8 represents the population densities of counties within the northwest United States.

Qualitative observation was used to select five model communities—four urban and one rural—which are represented in Figure 4.9. Four urban model communities were based on their metropolitan statistical areas, because research has shown that a core urban community shares a high degree of economic and social integration with its adjacent communities [65]. Counties per metropolitan area were acquired from the U.S. Census Bureau website [66]. The metropolitan areas chosen as model communities include the Seattle-Tacoma-Bellevue (STB), Portland-Vancouver-Hillsboro (PVH), Spokane-Spokane Valley (SSV), and Coeur d'Alene (CDA) metropolitan areas. The STB and PVH metropolitan areas represent urban communities with high population densities, while the SSV and CDA metropolitan areas represent urban communities with moderate population densities. The Southern Idaho Solid Waste District (SISW) represents a rural community with low population density. The SISW is compilation of rural counties in southern Idaho that formed a coalition in order to minimize solid waste management costs. The remaining counties in Washington and the remaining wastesheds in Oregon were also evaluated by taking statewide totals of the RWW, Population, and RBP data and subtracting the data from counties included within the model communities.

RWW quantities per county for the years 2000 through 2011 were collected for the selected model communities and evaluated over time with population and residential building permits (RBP). RWW quantities for counties in Washington and Oregon were collected from the Washington Department of Ecology and the Oregon Department of Environmental Quality [45], [54]. RWW quantities for the years 2000 through 2011 for the Coeur d'Alene metropolitan area were collected from annual solid waste and recycling reports provided by the Kootenai County Department of Solid Waste Department [67], [68], [69]. RWW for the years 2003 through 2011 for the SISW were provided by telephone from the SISW executive director [70]. RWW over time for the selected model communities are represented in Figures 4.10 and 4.11.

Description of Model Communities

The STB metropolitan area is represented by the Washington counties of King, Pierce, and Snohomish. The SSV metropolitan area is represented by the Washington counties of Spokane, Stevens, and Pend Oreille. RWW quantities in the state of Washington are collected through annual surveys filled out by regulated and non-regulated companies that process or utilize RWW. Companies that respond to annual surveys are required to report which county the wood waste is coming from, but the Washington DOE mentioned that there may be uncertainty to the accuracy of that data [54]. However, it is assumed that this uncertainty should be decreased when compiling RWW quantities per metropolitan area rather than by county, since the majority of the MRFs in Washington are located within the STB and SSV metropolitan areas, as observed in Figure 3.4. The PVH metropolitan area includes the Oregon wastesheds of Columbia, Metro, and Yamhill, as well as the Washington counties of Clark and Skamania, and represents an area with high population density. RWW quantities in the state of Oregon are provided through annual surveys turned in by facilities that recycle wood waste, and respondents are required to report the wasteshed source of wood waste [45].

The CDA metropolitan area is represented by Kootenai County, Idaho [66]. Wood waste in Kootenai County is recorded by the MSW landfill and affiliated transfer stations, and wood recycling is subcontracted to wood grinding service companies [67]. The SISW is a solid waste collaboration that includes the seven Idaho counties of Blaine, Cassia, Gooding, Jerome, Lincoln, Minidoka, and Twin Falls [71]. Wood waste in the SISW is recycled and recorded by the MSW landfill-affiliated transfer stations within the district [70]. RWW in the SISW includes both land-clearing wood debris and C&D source wood debris [70]. Annual RWW quantities were provided by telephone from the SISW executive director [70].

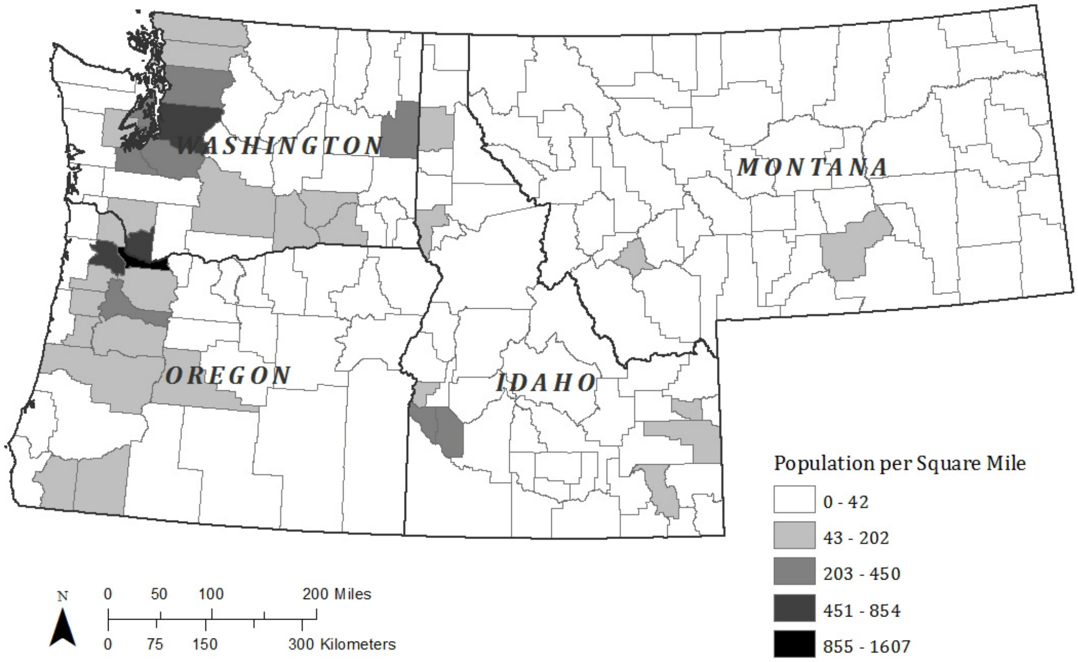


Figure 4.8: Map of northwest U.S. representing population densities per county

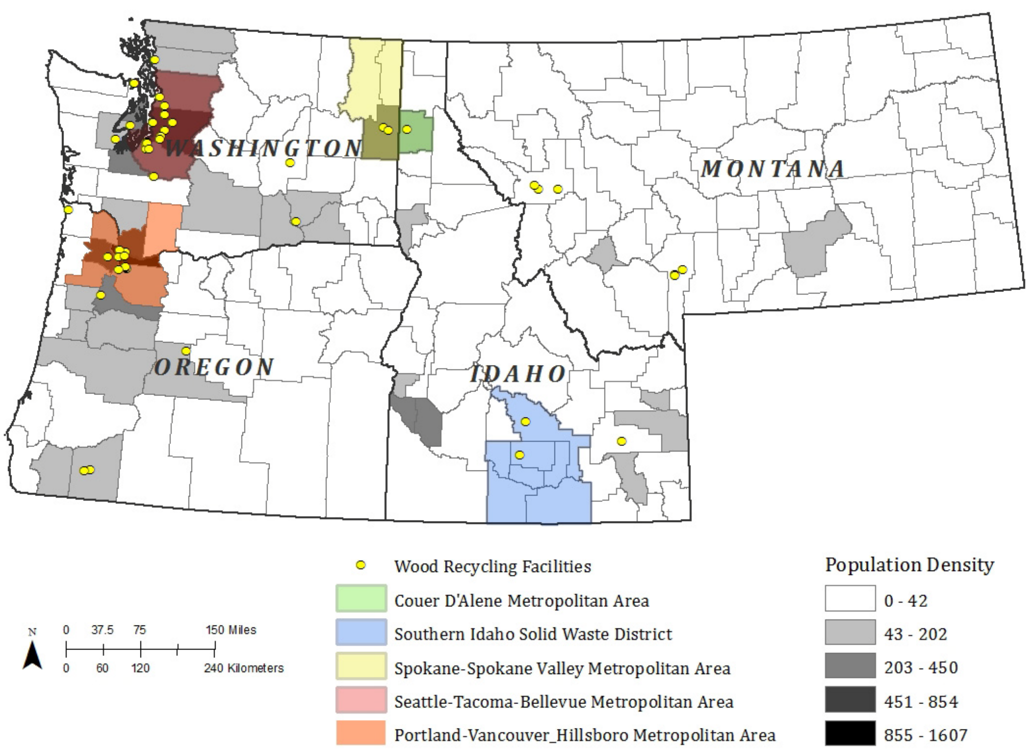


Figure 4.9: Map of northwest U.S. representing selected model communities

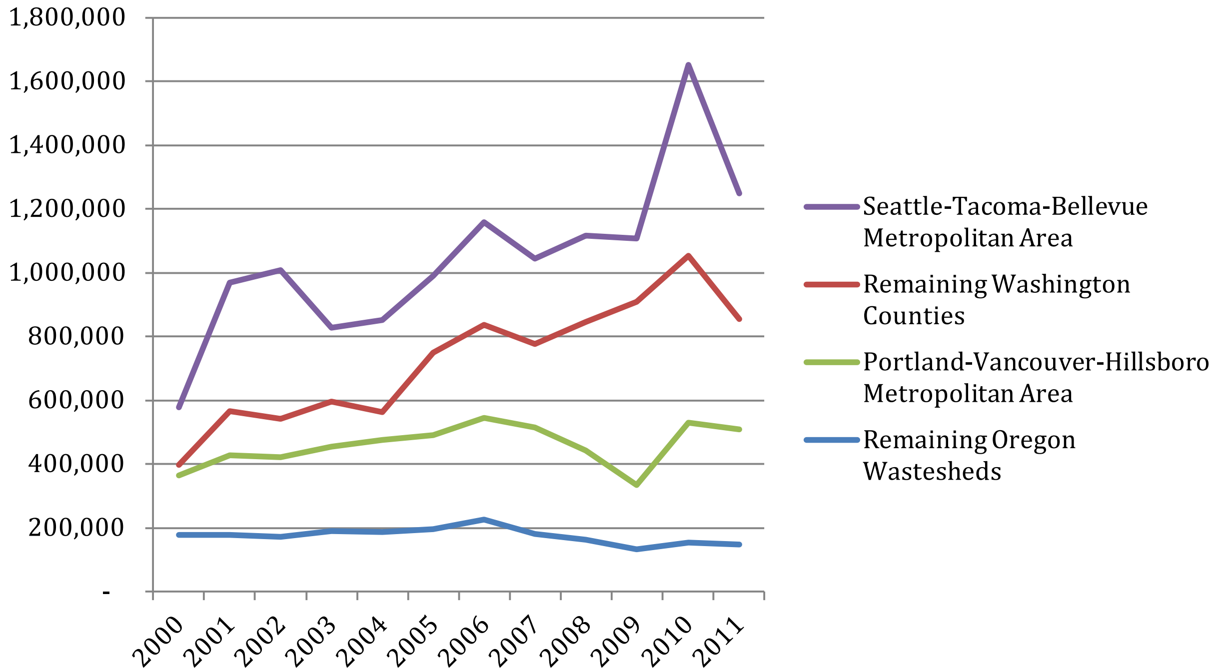


Figure 4.10: Trends of RWW quantities within STB and PVH metropolitan areas, remaining Washington counties, and remaining Oregon wastesheds for years 2000-2011.
Note: the lines in this graph intentionally do not overlap and therefore the may not be exactly represented by the tons labeled on the left.

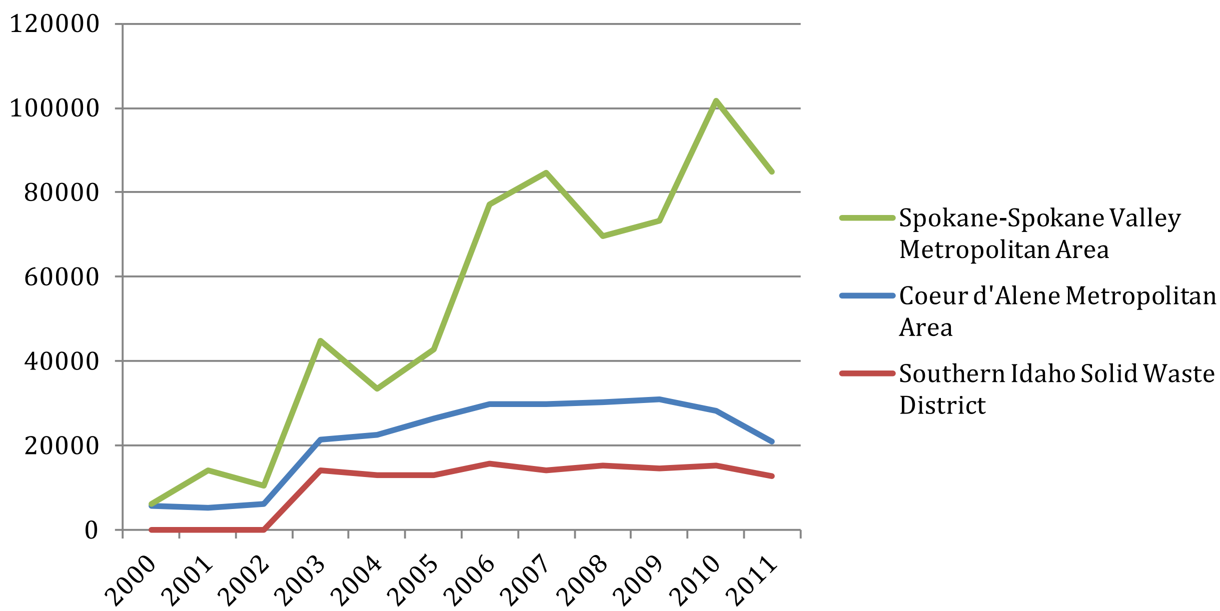


Figure 4.11: Trends of RWW quantities within SSV and CDA metropolitan areas and SISW for years 2000-2011. *Note: the lines in this graph intentionally do not overlap and therefore the may not be exactly represented by the tons labeled on the left.*

Results of Selected Model Communities

A preliminary evaluation was performed for the selected model communities to determine if RWW correlates with population over time. Figures 4.12 through 4.18 represent comparisons of RWW and population for the years 2000 through 2011 for the model communities, with an exception of the SISW, which represents the years 2003 through 2011. Figure 4.12 depicts a comparison of RWW and population for the STB metropolitan area, but there appears to be minimal correlation. Figure 4.13 represents a correlation between RWW and population in the PVH metropolitan area until the years 2007 through 2010, where there appears to be a substantial dip in the amount of RWW. Figure 4.14 represents RWW and population in the SSV metropolitan area, which depicts a correlation with an exception for dips and spikes in the RWW quantities over time. Figure 4.15 depicts a correlation between RWW and population in the CDA metropolitan area with an exception for the years 2003 through 2005, where there appears to be a dramatic increase in RWW quantities, and 2009 through 2011, where there appears to be a decrease. Figure 4.16 represents minimal correlation between RWW and population in the SISW. Figure 4.17 represents a correlation between RWW and population in the remaining Washington counties, but there appears to be spikes and dips in the RWW quantities in the years 2001, 2004, 2007, and 2009. Figure 4.18 depicts a correlation between RWW and population in the remaining Oregon wastesheds, but there appears to be a major dip in RWW from the years 2006 through 2009.

A preliminary evaluation was also performed for selected model communities to determine if RWW correlates with RBPs over time. Figures 4.19 through 4.25 represent comparisons of RWW and RBPs for the years 2000 through 2011, with the same exception for the SISW. Figure

4.19 represents an observed lack of correlation between RWW and RBPs in the STB metropolitan area. Figure 4.20 represents a correlation between RWW and RBPs in the PVH metropolitan area, which also indicates a lag time of two years of RWW behind RBPs. Figure 4.21 represents an observably minimal correlation between RWW and RBPs in the SSV metropolitan area. Figure 4.22 represents an apparent correlation between RBPs in the CDA metropolitan area, in which RWW appears to lag in time for one-to-two years behind RBPs. Figure 4.23 represents RWW and RBPs over time in the SISW, which depicts minimal correlation. Figure 4.24 represents an apparent correlation between RWW and RBPs in the remaining Washington counties, with an exception for spikes and dips in the RWW quantities during the years 2001, 2004, and 2007; it also appears as if RWW has a two year lag time behind RBP. Figure 4.25 represents an observed correlation between RWW and RBP in the remaining Oregon wastesheds, in which RWW observably lags behind RBP by one year.

RWW appears to correlate with population and RBP in several of the preliminary studies. RWW observably correlates with population in four of the model communities, but there appears to be a consistent drop in RWW from the years 2005 through 2010. This drop in RWW appears to be explained by a similar drop in RBPs during the same time frame, in which RWW consistently lags by one to two years behind the number of RBPs on an annual basis. The lag in time is assumedly due to the fact that building permits are usually acquired before construction begins, which means that wood waste would typically come later in time. The dramatic drop in RWW during the timeline is most likely explained by the recent recession as discussed in a previous section, where housing starts dramatically dropped nationwide starting in 2005.

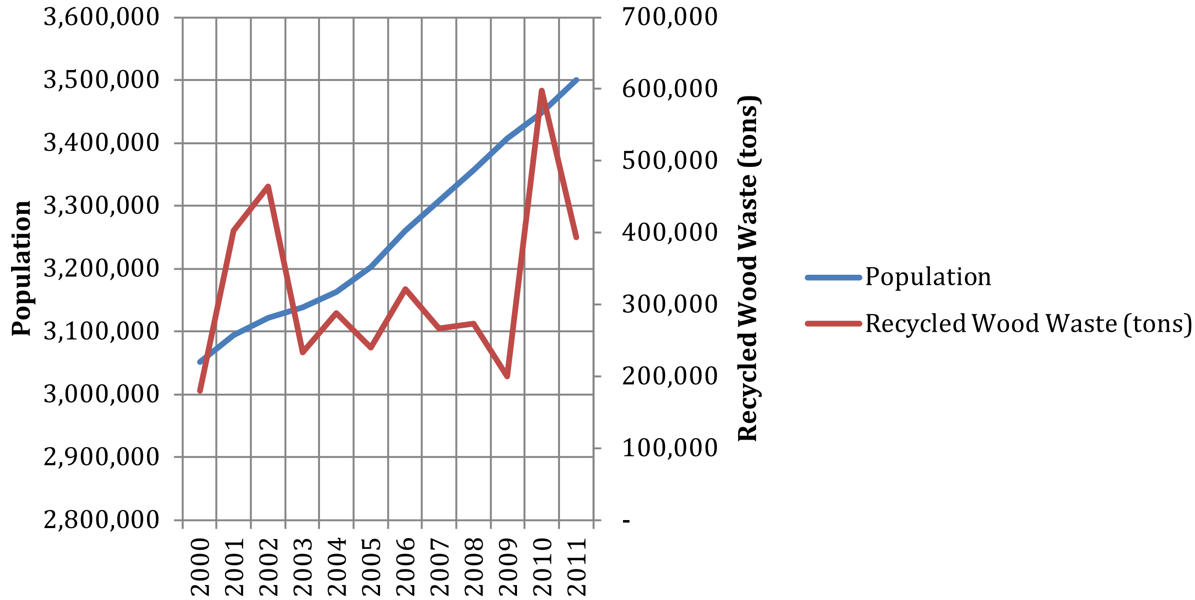


Figure 4.12: Population and RWW compared over time in the Seattle-Tacoma-Bellevue metropolitan area for years 2000-2011

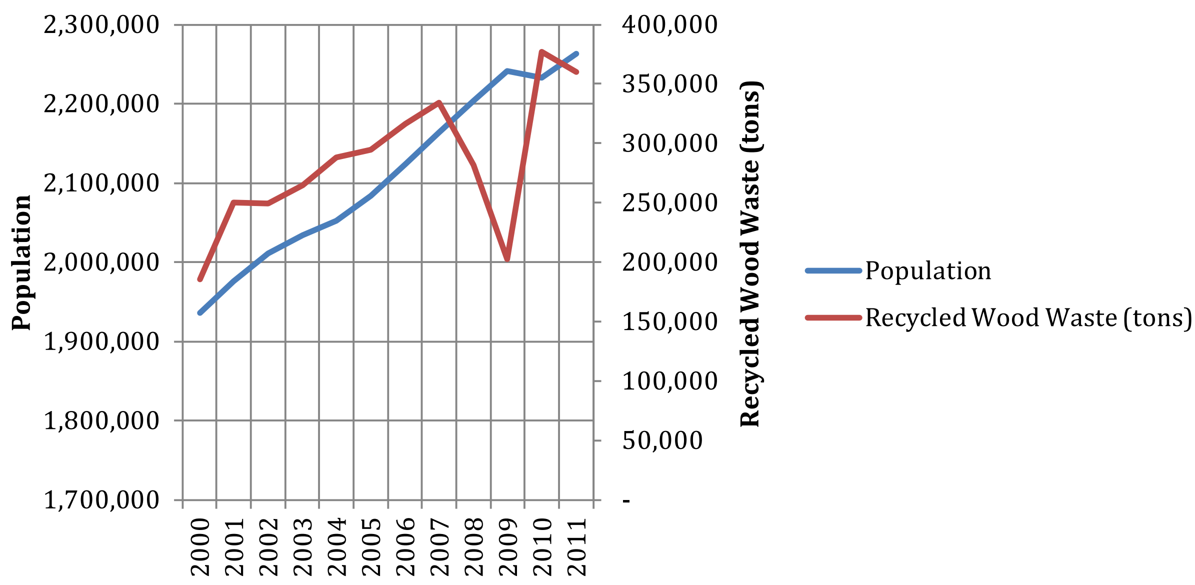


Figure 4.13: Population and RWW compared over time in the Portland-Vancouver-Hillsboro metropolitan area for years 2000-2011

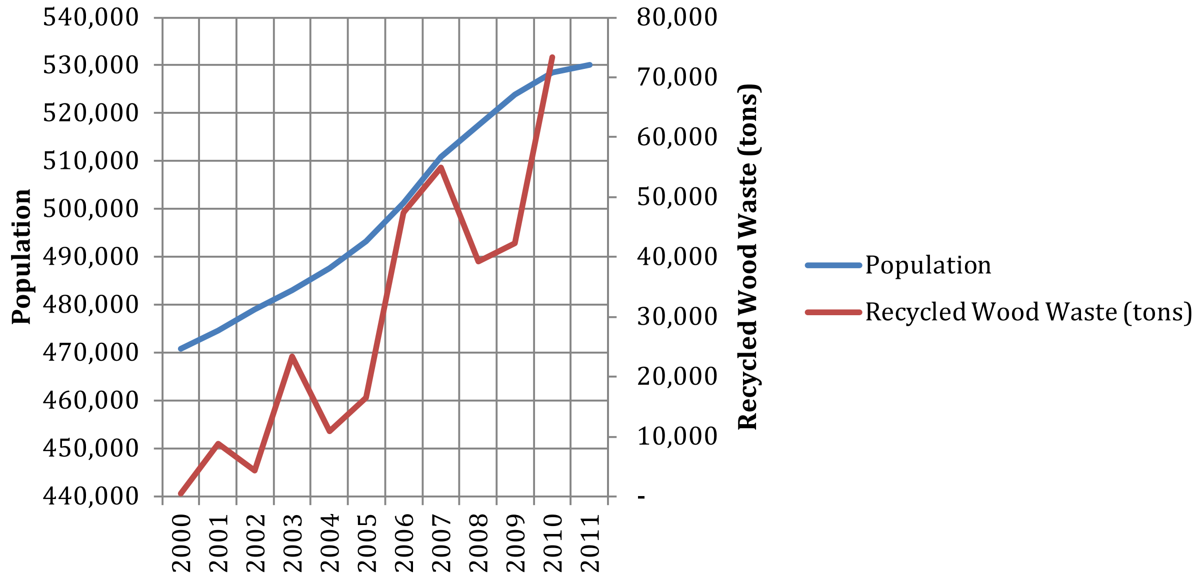


Figure 4.14: Population and RWW compared over time in the Spokane-Spokane Valley metropolitan area for years 2000-2011

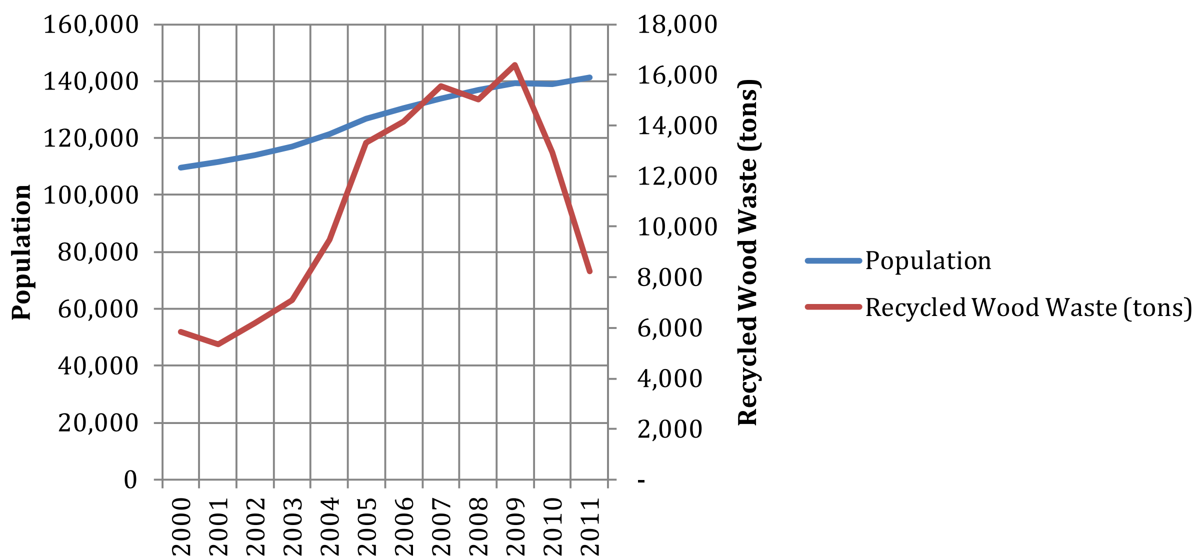


Figure 4.15: Population and RWW compared over time in the Coeur d'Alene metropolitan area for years 2000-2011

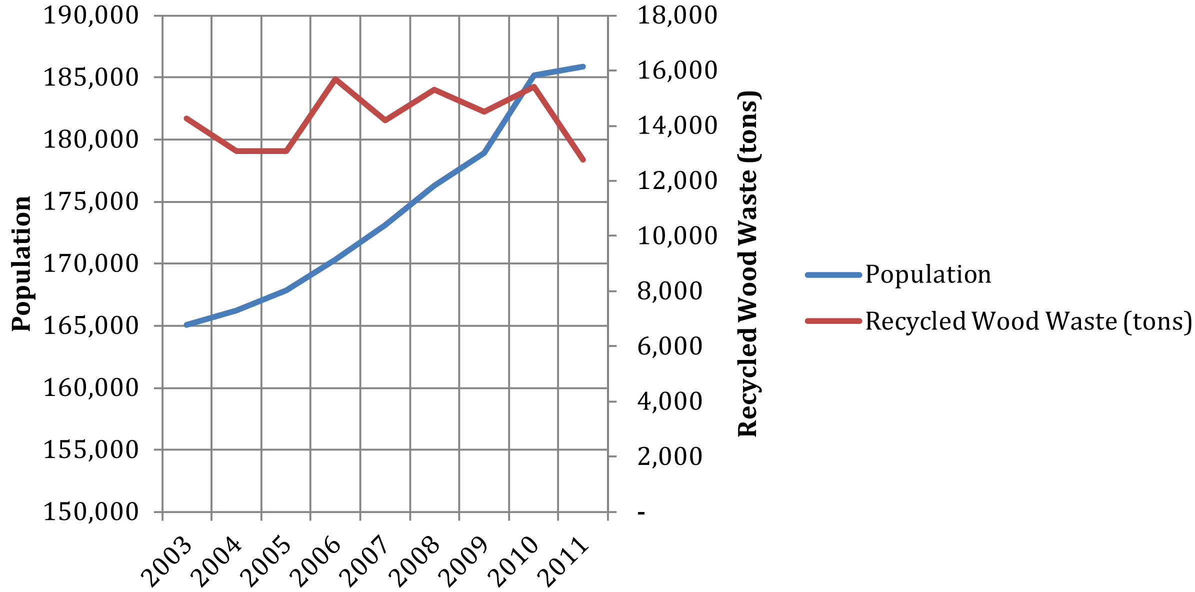


Figure 4.16: Population and RWW compared over time in the Southern Idaho Solid Waste District for years 2003-2011

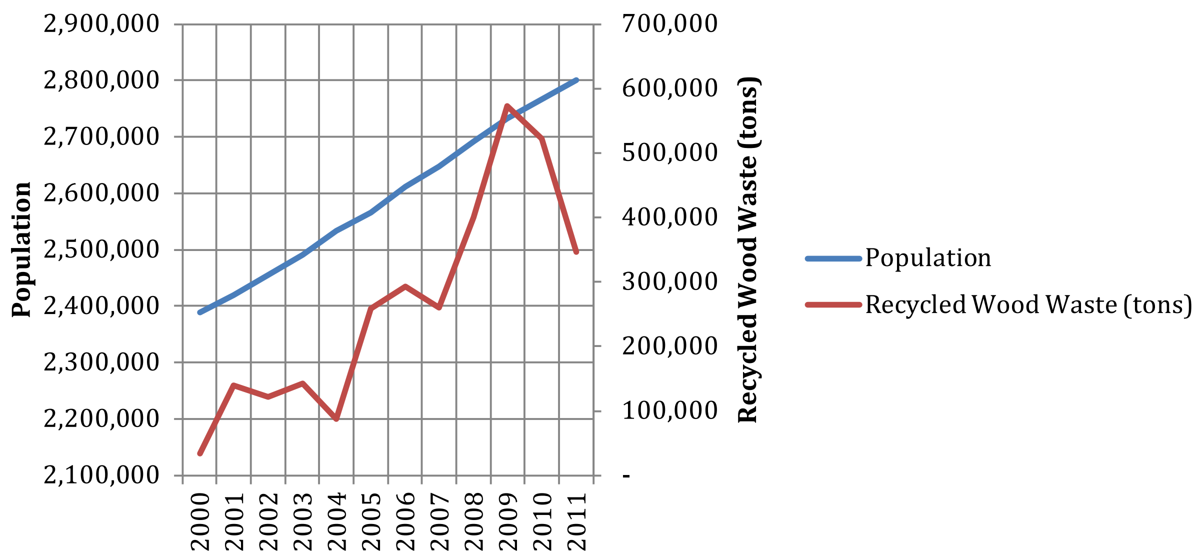


Figure 4.17: Population and RWW compared over time in the Remaining Washington Counties for years 2000-2011

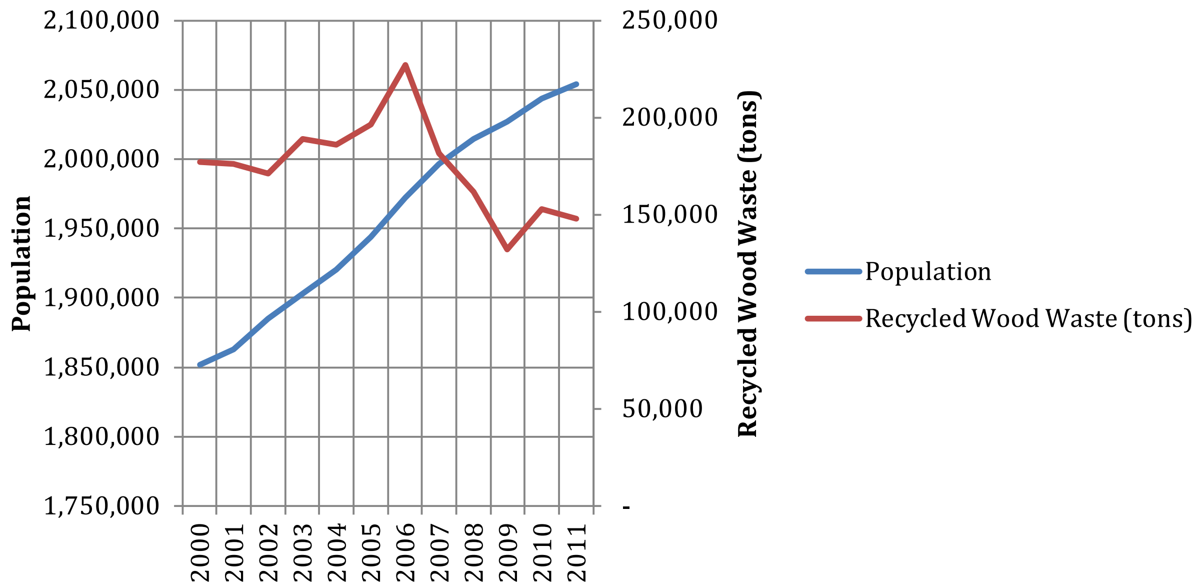


Figure 4.18: Population and RWW compared over time in the Remaining Oregon Wastesheds for years 2000-2011

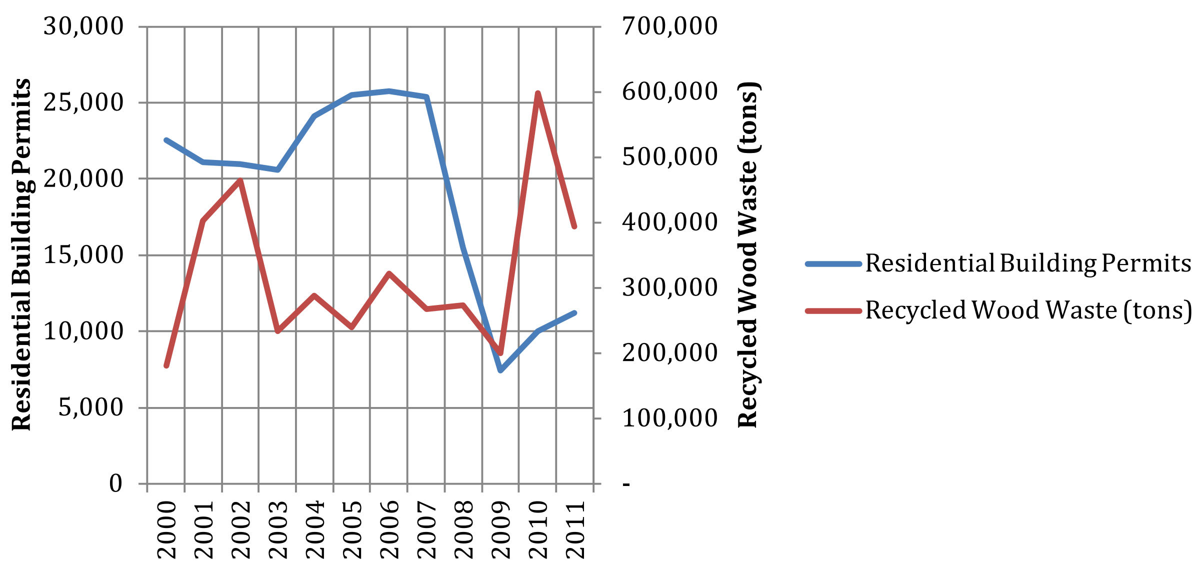


Figure 4.19: RBPs and RWW compared over time in the Seattle-Tacoma-Bellevue metropolitan area for years 2000-2011

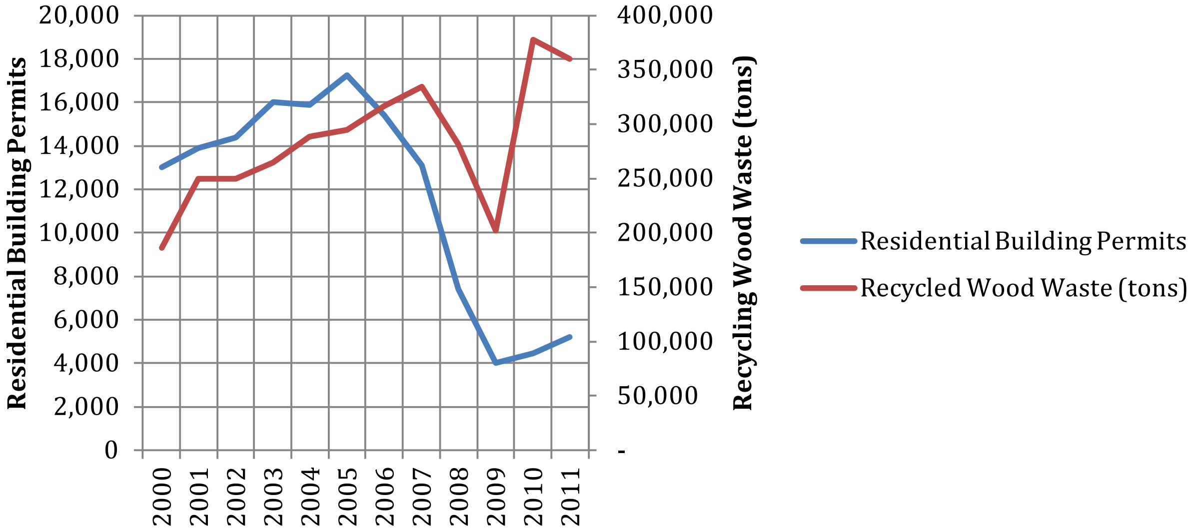


Figure 4.20: RBPs and RWW compared over time in the Portland-Vancouver-Hillsboro metropolitan area for years 2000-2011

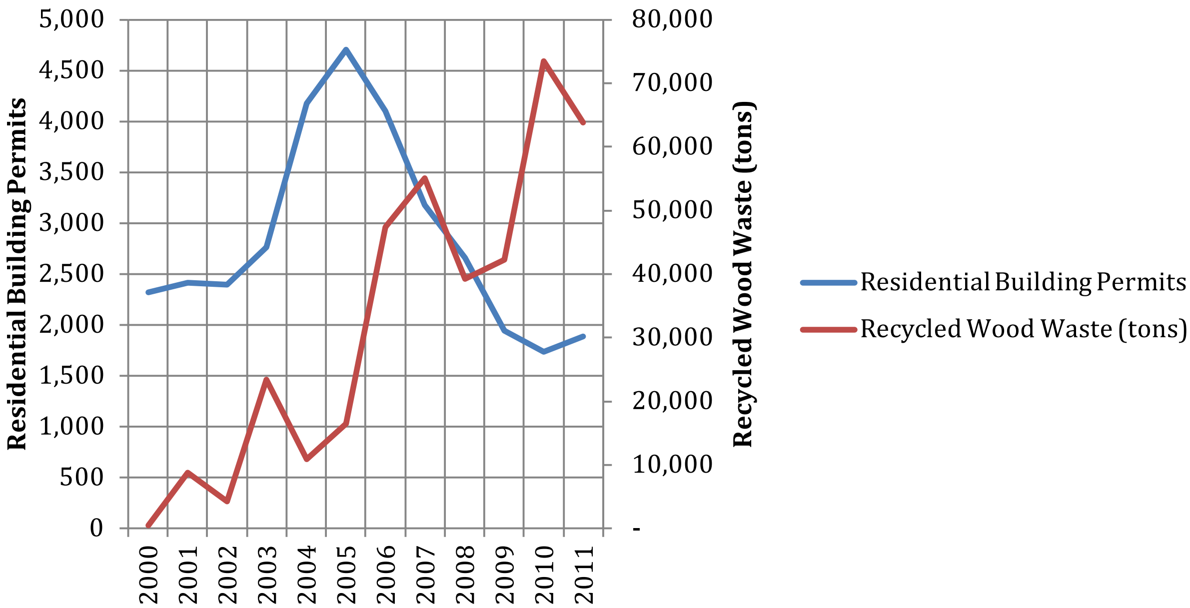


Figure 4.21: RBPs and RWW compared over time in the Spokane-Spokane Valley metropolitan area for years 2000-2011

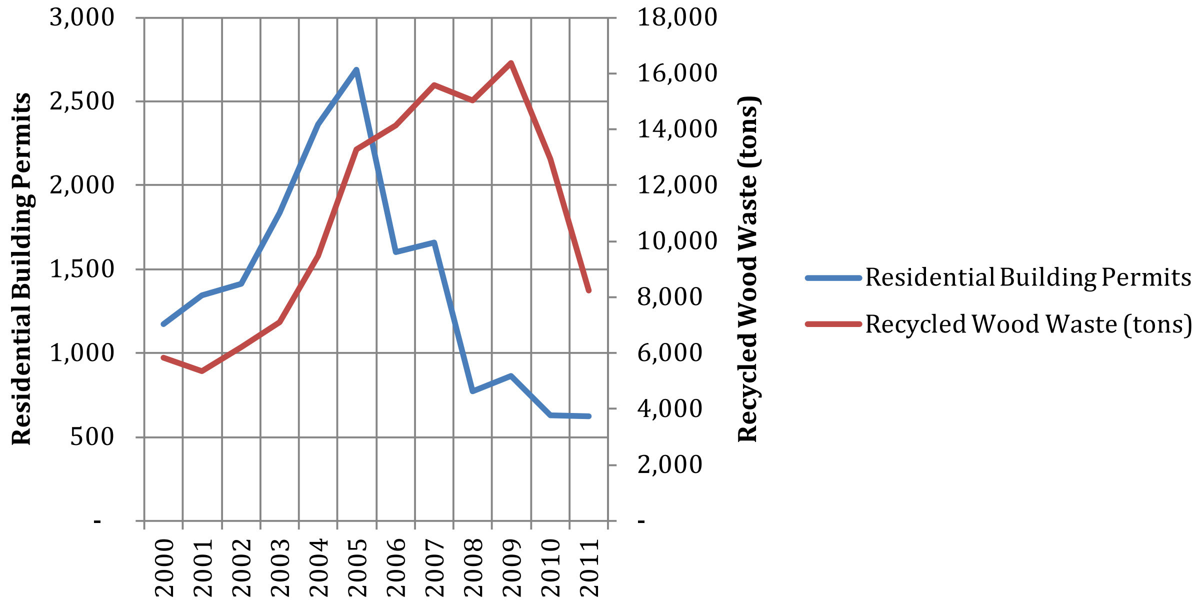


Figure 4.22: RBPs and RWW compared over time in the Coeur d'Alene metropolitan area for years 2000-2011

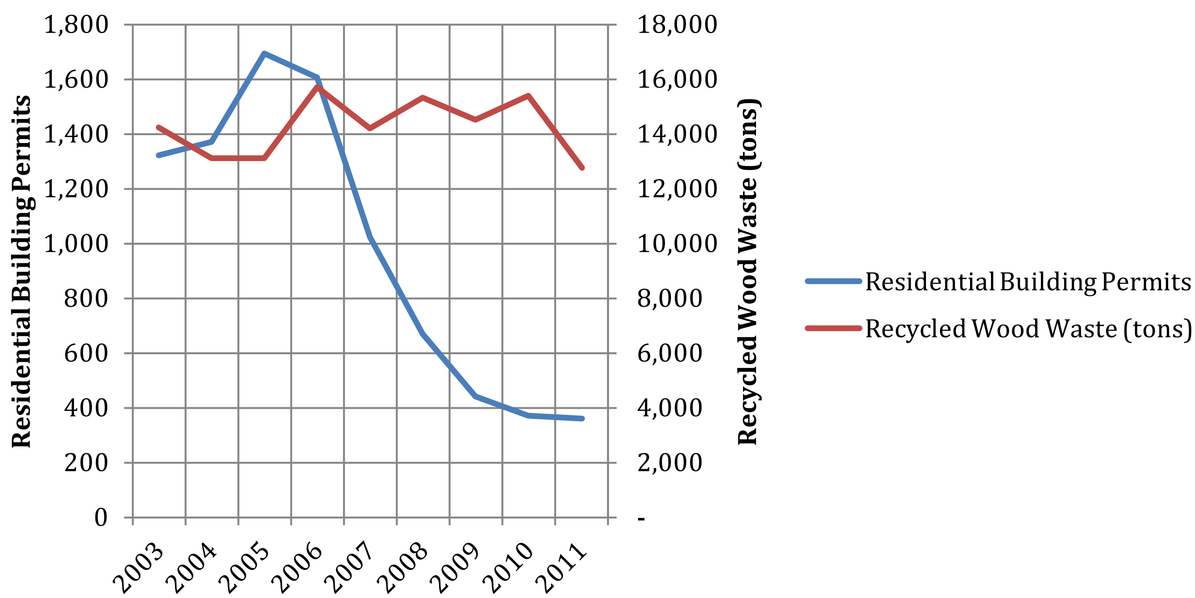


Figure 4.23: RBPs and RWW compared over time in the Southern Idaho Solid Waste District for years 2003-2011

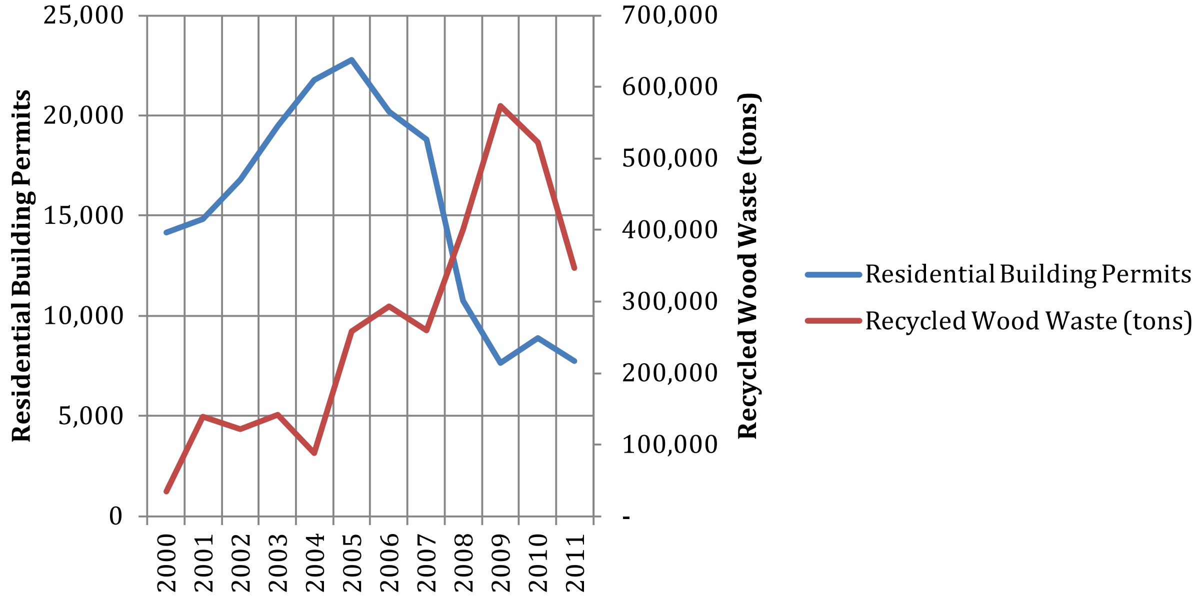


Figure 4.24: RBPs and RWW compared over time in the Remaining Washington Counties for years 2000-2011

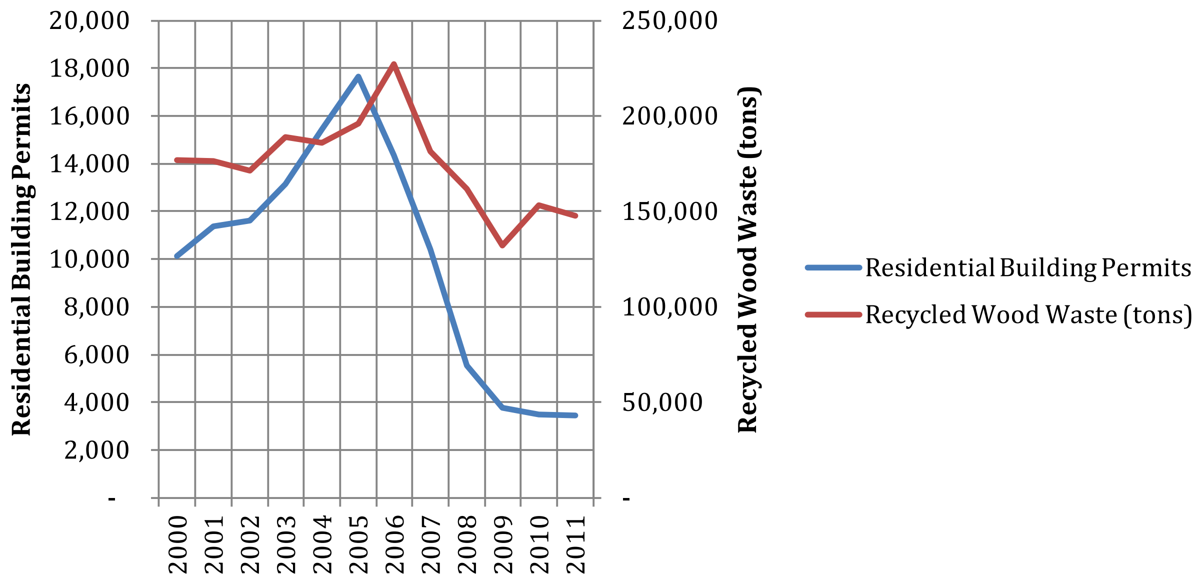


Figure 4.25: RBPs and RWW compared over time in the Remaining Oregon Wastesheds for years 2000-2011

4.4 Modeling Potential Factors that Influence Recycled Wood Waste

A single variable and multivariable regression analysis was conducted to statistically determine the correlation of RWW with population, residential building permits (RBP), and wood-to-energy facilities (WEF). The regression analyses were conducted using RWW as the independent variable and population, RBP, and WEF as the dependent variables. RWW supply models per population and per RBP were determined for Washington, Oregon, each model community, and for the sum of data for the model communities. A RWW per WEF demand model was determined for the state of Washington. A multivariable model for Washington, Oregon, and the compiled model community data was determined using population and RBP. Another multivariable model in Washington was determined using population and WEFs. The following sections describe the method and results of the modeling procedure.

Method

A regression analysis was conducted for determining RWW per population and RBP models using data compiled during the preliminary assessment. The regression analysis was performed using the regression data analysis tool in Microsoft Excel 2007. RWW data was entered into column one as the dependent Y variable. Population and RBP data were entered into columns two and three as independent variables X1 and X2. The regression analysis was performed independently for population and RBP. During the regression procedure set up, the Y column RWW data was selected for the Input Y Range, and the X1 or X2 columns representing population and RBP data were selected one at a time for the Input X Range. The constant was set at zero with the assumption that there wouldn't be RWW without population or RBP. The confidence interval was set to the default setting of 95%. The line fit plot was selected to represent a scatter plot of the XY data, as well as the predicted Y. The resulting scatter plot diagram and summary of outputs were compiled together per state and model community. The summary of outputs include the coefficient of correlation (Multiple R), the coefficient of determination (R Square), the analysis of variance (ANOVA), and the corresponding data regarding the X-data variable, which includes the coefficient, standard error, t stat, P-Value, and upper and lower 95% statistics. The model for solving Y is determined by multiplying the X variable to the coefficient. The described regression analyses were conducted for Washington, Oregon, the individual model communities, and for the combined data from the model communities. A regression analysis using the same methods was conducted to determine a model for RWW per facility that burns RWW for energy in the state of Washington.

A multi-regression analysis was conducted to determine a multivariable model for quantifying RWW for Washington, Oregon, and the combined model communities. RWW was considered the dependant variable, and population and RBP were considered the independent variables. The multi-regression analysis was conducted using the regression data analysis tool in Microsoft Excel 2007. RWW was entered into column one as the dependent Y variable during the set-up procedure. Population and RWW were entered into columns two and three as the independent variables X1 and X2. The Y column representing RWW data was selected for the Input Y Range, and columns X1 *and* X2 were selected for the Input X Range. Similar to the method previously described, the constant was set at zero, the confidence interval was set at 95%, and the line fit plot was selected during the regression set up procedure. The resulting scatter plot diagram and summary of outputs were compiled together per state and model community. The multivariable model was determined by adding the products of the X variable and X variable coefficients. A separate multi-regression analysis using the same methods was conducted to determine a multivariable model for determining RWW based on population and the number of facilities that burn wood for energy.

Results

The results of the regression analyses for determining RWW per population in Washington, Oregon, and the selected model communities are represented in Table 4.1. Communities with a coefficient of determination (R^2) of greater than 0.9 include the state of Oregon, the PVH metropolitan area, the remaining wastesheds in Oregon, and the CDA metropolitan area. The communities with an R^2 between 0.7 and 0.9 include Washington, the STB metropolitan area, the SISW, and the remaining counties in Washington. The SSV metropolitan area was the only community with an R^2 of less than 0.7. The combined data for the selected model communities provided a model of 0.105 tons of RWW per person a year with an R^2 of 0.863.

The results of the regression analysis for determining RWW per RBP for Washington, Oregon, and the selected model communities are represented in Table 4.2. The only community with an R^2 of more than 0.9 was the state of Oregon. Communities with an R^2 between 0.7 and 0.9 include the STB metropolitan area, the PVH metropolitan area, the CDA metropolitan area, the SISW, and the remaining Oregon wastesheds. Communities with an R^2 of less than 0.7 include Washington, the SSV metropolitan area, and the remaining counties in Washington. The combined data for the selected model communities provided a model of 15.237 tons of RWW per person a year with an R^2 of 0.675. It is assumed that the apparent lag time between RBP and RWW, as depicted in Figures 4.19 through 4.25, may describe the lower R^2 values of the RWW per RBP models.

The results of the multi-regression analysis for determining RWW per population and RBP are represented in Table 4.3. A multivariable RWW supply model was created for Washington, Oregon, and the selected model communities, and a multivariable RWW demand model was developed for Washington based on WEF information provided by the Washington DOE, which includes smaller MRFs that burn RWW for energy. The RWW supply model for Oregon appears to be the most accurate with a R^2 of 0.996. The demand RWW model for Washington, with an R^2 of 0.970, appears to be more accurate than RWW supply model for Washington, which has an R^2 of 0.947. The RWW supply model for the selected model communities resulted in an R^2 of 0.874.

4.5 Discussion

Future models for determining RWW based on demand, such as RWW per WEF, may produce more accurate results as information becomes more accessible and available. Starting in 2012, the U.S. Census Bureau started independently tracking a NAICS code category titled "Biomass Electric Power Generation", which tracks establishments engaged in operating biomass electric power generation [72]; this category was previously grouped with other energy sectors in a classification called "Other Electric Power Generation" [73]. As this information becomes more readily available through the U.S Census Bureau website, it is assumed that multivariable models utilizing WEFs as an dependent variable may produce more accurate RWW models.

Table 4.1: RWW per Population Regression Analysis for Washington, Oregon, and Selected Model Communities

State or Model Community	RWW/Population (tons/person/year)	Coefficient of Correlation (R)	Coefficient of Determination (R^2)
Washington	0.099	0.912	0.893
Oregon	0.110	0.988	0.977
Seattle-Tacoma-Bellevue Metro	0.099	0.943	0.890
Portland-Vancouver-Hillsboro Metro	0.135	0.986	0.972
Spokane-Spokane Valley Metro	0.066	0.827	0.684
Coeur d'Alene Metro	0.087	0.958	0.918
Southern Idaho Solid Waste District	11.396	0.882	0.778
Remaining Washington Counties	0.105	0.873	0.762
Remaining Oregon Wastesheds	0.089	0.988	0.977
Combined Data—Model Communities	*0.105*	*0.929*	*0.863*

Table 4.2: RWW per Residential Building Permit Regression Analysis for Washington, Oregon, and Selected Model Communities

State or Model Community	RWW/RBP (tons/RBP/year)	Coefficient of Correlation (R)	Coefficient of Determination (R^2)
Washington	13.716	0.811	0.657
Oregon	18.860	0.954	0.911
Seattle-Tacoma-Bellevue Metro	14.636	0.861	0.742
Portland-Vancouver-Hillsboro Metro	20.566	0.895	0.801
Spokane-Spokane Valley Metro	9.436	0.711	0.506
Coeur d'Alene Metro	6.297	0.848	0.719
Southern Idaho Solid Waste District	11.396	0.882	0.778
Remaining Washington Counties	13.329	0.693	0.480
Remaining Oregon Wastesheds	15.068	0.946	0.894
Combined Data—Model Communities	*15.237*	*0.821*	*0.675*

Table 4.3: Multi-Regression Analysis of RWW per Population and Residential Building Permits in Washington, Oregon, and Selected Model Communities

State or Model Community	RWW Model (Tons/Year)	Coefficient of Correlation (R)	Coefficient of Determination (R^2)
Washington (supply)	RWW = 0.167(Population) - 11.685(RBP)	0.973	0.947
Washington (demand)	RWW = 0.069(Population) + 7321.48(WEF)	0.985	0.970
Oregon (supply)	RWW = 0.077(Population) - 6.454(RBP)	0.998	0.996
Combined Data—Model Communities (supply)	RWW = 0.134(Population) – 5.213(RBP)	0.935	0.874

4.6 Conclusion

Potential factors that influence RWW were assessed over time and then modeled in order to determine future quantities of RWW. Research began with a compilation of information regarding aspects of RWW, including regional factors, construction activity, local government policy, economy, and RWW markets. A preliminary assessment and data regression analysis was conducted on RWW data of Washington, Oregon, and selected model communities within the northwest United States. Model communities were selected based on population density in order to represent urban and rural communities. A preliminary assessment was conducted in order to graphically compare RWW with population and RBPs over time. A RWW data regression analysis followed with the intent of determining single variable and multivariable models for determining RWW per population, RBPs, and in the case of Washington, WEFs.

CHAPTER FIVE

CONCLUSION AND RESULTS

5.1 Conclusion

The three primary objectives of the recycled wood waste assessment include a RWW supply chain assessment, an inventory assessment of RWW in the northwest United States, and an evaluation of potential factors that may influence wood recycling. The RWW supply chain assessment examines sources, operational factors, transportation and hauling, markets of recycled wood, and federal policies that influence wood recycling. An inventory assessment indicates if and how much wood waste is currently disposed or recycled. An evaluation of potential factors that may influence wood recycling could lead to prospective modeling procedures for determining RWW quantities.

5.2 Results of the Recycled Wood Waste Supply Chain Literature Review

A literature review was performed to assess supply chain characteristics, which include sources of wood waste, operational factors of recycling wood waste, transportation and hauling, markets for recycled wood, and federal government policies. Sources of RWW include MSW, industrial waste, and C&D waste. Operational factors include transfer stations, MRFs, and disposal sites such as waste-to-energy incinerators and landfills. Transportation methods include residential and commercial self haul, as well as industrial self haul, packer truck, roll-off truck, and long distance haul. Markets of recycled wood include lumber reuse, engineered wood products, mulch or compost, biomass fuel, and other miscellaneous products. Federal policies that influence RWW include the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act. Recent revisions within these policies, such as the revised

Boiler MACT rule and the revised Non-Hazardous Secondary Material (NHSM) rule, may impact RWW quantities in the future.

5.3 Results of Inventory Assessment of RWW within Northwest United States

The inventory assessment of RWW in the northwest United States included a preliminary MSW and RWW assessment and a RWW supply chain assessment within the region. The preliminary MSW and RWW assessment featured a compilation of information that investigated state policies, solid waste data collection methods, and annual MSW and recycling quantities. Washington, Oregon, and Montana have all set individual solid waste recycling goals; only Washington and Oregon record recycled wood waste quantities. Idaho encourages communities within the state to recycle but hasn't currently set statewide recycling goals nor do they record generated solid waste at the state level. In 2010, Washington generated 1,203,074 tons of wood waste, in which 847,115 tons were recycled for energy recovery, 347,137 tons were diverted, and 8,822 tons were disposed—70.9% of recycled wood in Washington was burned for energy recovery. In 2011, Oregon generated 376,798 tons of wood waste, in which 368,393 tons were recycled, establishing a wood recycling rate of 97.8%.

MSW and RWW information regarding non-hazardous landfills and MRFs were also collected. In total, 160 non-hazardous landfills were located in the northwest United States, in which 92 were MSW landfills, 22 were C&D landfills, 7 were wood landfills in Oregon, 30 were Montana Class III landfills that collect wood and inert waste, and 6 were burn-sites located in Montana. Average tipping fees of Washington landfills are $67 per ton. MRFs within the northwest United States were contacted and asked a questionnaire in order to receive data such as wood waste types, markets for RWW, separation techniques, annual quantities, tipping fees, and the range of supply and distribution. A total of 646,800 tons of RWW was assessed during the questionnaire process, in which 495,000 tons were from Washington MRFs, 100,000 tons were from Oregon MRFs, 45,000 tons were from Idaho MRFs, and 6,800 tons were from Montana MRFs. Average tipping fees of MRFs were $39 per ton, and average range of supply and distribution 98 miles.

5.4 Results of Evaluation of Factors that Influence Recycled Wood Waste

The evaluation of factors that may influence RWW included a compilation of information regarding RWW, a preliminary evaluation of potential factors that influence RWW within model communities, and RWW data regression analysis for determining single and multi-variable models for determining RWW quantities. The compilation of information inferred that RWW may be influenced by factors such as C&D activity, local government policy, economy, and RWW market conditions. The preliminary evaluation of RWW factors compared to RWW quantities with population and RBPs over time from the years 2000 through 2011 within Washington, Oregon, and selected model communities in the northwest United States. RWW models per population and RBPs were determined for Washington, Oregon, and the selected model communities. In terms of population, an estimate of 0.099 tons/person/year with an R^2 of 0.893 was determined for Washington, an estimate of 0.110 tons/person/year with an R^2 of 0.977 was determined for Oregon, and an estimate of 0.105 tons/person/year with an R^2 of 0.863 was determined for the model communities. In terms of RBPs, an estimate of 13.716 tons/RBP/year with an R^2 of 0.657 was determined for Washington, an estimate of 18.860 tons/RBP/year was determined for Oregon, and an estimate of 15.237 tons/RBP/year with an R^2 of 0.675 was determined for the model communities. Other results of the single and multi-regression analyses are provided in Tables 4.1, 4.2, and 4.3.

REFERENCES

[1] N. R. Sanders, *Supply Chain Management: A Global Perspective*. Hoboken, NJ: John Wiley & Sons, Inc., 2012.

[2] G. Wiltsee, “Urban Wood Waste Resource Assessment,” National Renewable Energy Laboratory, Golden, Colorado, NREL/SR-570-25918, Nov. 1998.

[3] “MSW Characterization Methodology.” United States Environmental Protection Agency.

[4] “Biomass Resources of the United States: Urban Wood Residues,” National Renewable Energy Laboratory, 08-Jun-2012.

[5] “Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2010,” United States Environmental Protection Agency, EPA-530-F-11-005, Nov. 2011.

[6] “Estimating 2003 Building Related Construction and Demolition Amounts,” United States Environmental Protection Agency.

[7] “2007 Massachusetts Construction Debris Industry Study Final Report,” DSM Environmental, Windsor, VT, May 2008.

[8] United States Environmental Protection Agency, “Transfer Stations.” [Online]. Available: http://www.epa.gov/osw/nonhaz/municipal/transfer.htm. [Accessed: 22-May-2013].

[9] “Waste Transfer Stations: A Manual for Decision Making,” United States Environmental Protection Agency, EPA530-R-02-002, Jun. 2002.

[10] United States Environmental Protection Agency, “Energy Recovery from Waste.” [Online]. Available: http://www.epa.gov/osw/nonhaz/municipal/wte/index.htm. [Accessed: 24-May-2013].

[11] “Standard Terminology for Waste and Waste Management,” ASTM International, West Conshohooken, PA, D5681-13.

[12] Jon B. Marshack, D. Env, “California Classification System,” California Environmental Protection Agency.

[13] W. S. Fuller, “Chip pile storage--a review of practices to avoid deterioration and economic losses.,” *Tappi J. J. Tech. Assoc. Pulp Pap. Ind.*, vol. 68, no. 8, Aug. 1985.

[14] R. Bergman, “Wood Handbook, Chapter 13: Drying and Control of Moisture and Dimensional Changes,” U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI, General Technical Report FPL-GTR-190, 2010.

[15] D. Nilsson, S. Bernesson, and P.-A. Hansson, “Pellet production from agricultural raw materials: A systems study.,” *Biomass Bioenergy*, vol. 35, pp. 679–689, 2011.

[16] Solid Waste Association of North America: Applied Research Program, “Successful Approaches to Recycling Urban Wood Waste,” U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Silver Spring, Maryland, General Technical Report FPL-GTR-133.

[17] J. L. Conrad, C. M. Bolding, R. L. Smith, and W. M. Aust, “Wood-energy market impact on competition, procurement practices, and profitablility of landowners and forest products industries in the U.S. south.,” *Biomass Bioenergy*, vol. 35, pp. 280–287, 2011.

[18] United States Environmental Protection Agency, “Clean Air Act.” [Online]. Available: http://www.epa.gov/air/caa/. [Accessed: 10-Jun-2013].

[19] United States Environmental Protection Agency, “Resource Conservation and Recovery Act.” [Online]. Available: http://www.epa.gov/agriculture/lrca.html. [Accessed: 10-Jun-2013].

[20] United States Environmental Protection Agency, “Commercial and Industrial Solid Waste Incinerator Units (CISWI).” [Online]. Available: http://www.epa.gov/air/ej/ejciswi.html. [Accessed: 10-Jun-2013].

[21] United States Environmental Protection Agency, “Industrial, Commercial, and Institutional Boilers and Process Heaters (ICIB).” [Online]. Available: http://www.epa.gov/air/ej/ejicib.html. [Accessed: 10-Jun-2013].

[22] United States Environmental Protection Agency, “Clean Water Act.” [Online]. Available: http://cfpub.epa.gov/npdes/cwa.cfm?program_id=45. [Accessed: 10-Jun-2013].

[23] United States Environmental Protection Agency, “Effluent Guidelines: Landfills Point Source Category,” Dec-1999. [Online]. Available: http://water.epa.gov/scitech/wastetech/guide/landfills/landfact.cfm. [Accessed: 06-Jul-2013].

[24] United States Environmental Protection Agency, “Solid Waste; RCRA Subtitle D.” [Online]. Available: http://www.epa.gov/region02/waste/dsummary.htm. [Accessed: 10-Jun-2013].

[25] “Emissions Standards for Boilers and Process Heaters and Commercial/Industrial Solid Waste Incinerators: Regulatory Actions.” [Online]. Available: http://www.epa.gov/airquality/combustion/actions.html. [Accessed: 11-Jun-2013].

[26] United States Department of Energy, “Boiler MACT Technical Assistance.” National Renewable Energy Laboratory.

[27] “Fact Sheet: Adjustments for Major and Area Source Boilers and Certain Incinerators: Summary Overview.” United States Environmental Protection Agency.

[28] United States Environmental Protection Agency, “Fact Sheet: Final Adjustments to the Air Toxics Standards for Industrial, Commercial, and Institutional Boilers at Area Source Facilities.” .

[29] United States Environmental Protection Agency, “Fact Sheet: Final Adjustments to the Air Toxics Standards for Industrial, Commercial, and Institutional Boilers and Process Heaters at Major Source Facilities.” .

[30] United States Environmental Protection Agency, “Identification of Non-Hazardous Secondary Materials That Are Solid Waste.” [Online]. Available: http://www.epa.gov/epawaste/nonhaz/define/index.htm. [Accessed: 10-Jun-2013].

[31] United States Environmental Protection Agency, “Title 40-Protetcion of Environment: Section 241.1 Definitions.” [Online]. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title40-vol26/xml/CFR-2012-title40-vol26-sec241-2.xml. [Accessed: 10-Jun-2010].

[32] “EPA’s Revised NHSM Rule Favors C&D Biomass,” *C&D World*, 02-Jan-2013. [Online]. Available: http://www.cdworldmag.com/index.php/news/industry-news/575-epas-revised-nhsm-rule-favors-cad-biomass). [Accessed: 26-Jun-2013].

[33] Washington Department of Ecology, “Waste 2 Resources.” [Online]. Available: http://www.ecy.wa.gov/programs/swfa/index.html. [Accessed: 07-Jun-2013].

[34] Oregon Department of Environmental Quality, “Land Quality Solid Waste.” [Online]. Available: http://www.deq.state.or.us/lq/sw/disposal/index.htm#WasteComp. [Accessed: 07-Jun-2013].

[35] Montana Department of Environmental Quality, “Solid Waste Management.” [Online]. Available: http://deq.mt.gov/solidwaste/default.mcpx. [Accessed: 12-Jun-2013].

[36] Idaho Department of Environmental Quality, “Municipal Solid Waste Landfills in Idaho.” [Online]. Available: http://www.deq.idaho.gov/waste-mgmt-remediation/solid-waste/landfills/mswlf.aspx. [Accessed: 06-Jul-2013].

[37] “State of Montana 2011 Recycling and Waste Diversion Summary,” Montana Department of Environmental Quality.

[38] “2011 Oregon Material Recovery and Waste Generation Rates Report,” Oregon Department of Environmental Quality Solid Waste Policy and Program Development Land Quality Division, 12-LQ-035, Oct. 2012.

[39] “Solid Waste in Washington 20th Annual Status Report,” State of Washington Department of Ecology, Waste 2 Resources Program, Publication #: 11-07-039, Dec. 2011.

[40] “Solid Waste in Washington State: First Annual Status Report,” State of Washington Department of Ecology Solid and, Hazardous Waste Program, Solid Waste Section, Publication #: 92-103.

[41] “Beyond Waste Plan 2009 Update: Summary of the Washington State Hazardous Waste and Solid Waste Management Plan,” State of Washington Department of Ecology, Waste 2 Resources Program, Olympia, WA, Publication #: 09-07-026, Oct. 2009.

[42] Washington State Legislation, “WAC 173-350-100 Definitions.” [Online]. Available: http://apps.leg.wa.gov/wac/default.aspx?cite=173-350-100. [Accessed: 10-Jun-2013].

[43] Oregon Department of Environmental Quality, “Land Quality, Solid Waste: Oregon Recycling Laws.” [Online]. Available: http://www.deq.state.or.us/lq/sw/recyclinglaws.htm. [Accessed: 07-Jun-2013].

[44] "Conversion Technology Rulemaking Associated Definitions." State of Oregon Department of Environmental Quality, 14-Mar-2012.

[45] Peter Spendelow, Oregon DEQ Solid Waste Analyst, "Telephone conversation and Email communication regarding wood waste in Oregon."

[46] Idaho Department of Environmental Quality, "Solid Waste in Idaho." [Online]. Available: http://www.deq.idaho.gov/. [Accessed: 10-Jun-2013].

[47] Dean Ehlert, Idaho DEQ Solid Waste & Emergency Response Program Coordinator, "Telephone conversation and Email communication regarding wood waste in Idaho."

[48] "Wood and Mill Yard Debris Technical Guidance Manual," Feb. 1998.

[49] "Integrated Waste Management Plan 2006," Montana Department of Environmental Quality: Air, Energy and Pollution Prevention Bureau, Sep. 2005.

[50] Montana Department of Environmental Quality, "Solid Waste Management System License Renewal Application Definitions for July 1, 2003 - June 30, 2004." .

[51] Mary Henderson, Montana DEQ Environmental Science Specialist, "Email communication regarding municipal solid waste in Montana."

[52] *GIS Shapefiles*. Washington State University Department of Crop and Soil Sciences.

[53] Montana Natural Resource Information System, "Montana Geographic Information Clearinghouse." [Online]. Available: http://nris.mt.gov/default.asp. [Accessed: 07-Aug-2012].

[54] Gretchen Newman, Washington DOE Performance Measures Personel, "Telephone conversation and Email communication regarding wood waste in Washington."

[55] Washington Department of Ecology, "Tipping Fees for MSW Landfills in Washington State." .

[56] Northwest Clean Energy Application Center, "Database of Wood to Energy Facilities in Pacific Northwest." .

[57] D. Sjoding, "Wood to Energy Facilities."

[58] ESRI, "ArcGIS Resources." [Online]. Available: http://resources.arcgis.com/en/home/. [Accessed: 21-Jun-2013].

[59] R. van Haaren, N. Themelis, and N. Goldstein, "The State of Garbage in America: 17th Nationwide Survey of MSW Management in the U.S.," Joint study by BioCycle and the Earth Engineering Center of Columbia University.

[60] Seattle Public Utilities, "Recycling Required for Construction and Demolition Projects." [Online]. Available: http://www.seattle.gov/util/ForBusinesses/Construction/CDWasteManagement/RecyclingRequirements/index.htm. [Accessed: 17-Jun-2013].

[61] P. J. Ince and P. Nepal, “Effects on U.S. Timber Outlook of Recent Economic Recessoin, Collapse in Housing Construction, and Wood Energy Trends,” United States Department of Agriculture, General Technical Report FPL-GTR-219, Dec. 2012.

[62] United States Census Bureau, “Building Permits Survey.” [Online]. Available: http://www.census.gov/construction/bps/stateannual.html. [Accessed: 13-Jun-2013].

[63] “Population Estimates.” [Online]. Available: http://www.census.gov/popest/data/historical/index.html. [Accessed: 08-Jul-2013].

[64] United States Census Bureau, “Building Permits.” [Online]. Available: http://censtats.census.gov/bldg/bldgprmt.shtml. [Accessed: 08-Jul-2013].

[65] United States Census Bureau, “Metropolitan and Micropolitan Statistical Areas Main.” [Online]. Available: http://www.census.gov/population/metro/. [Accessed: 10-Jul-2010].

[66] United States Census Bureau, “Metropolitan and Micropolitan Delineation Files.” [Online]. Available: http://www.census.gov/population/metro/data/def.html. [Accessed: 09-May-2013].

[67] L. Chaffin, “Telephone conversation and Email communication regarding wood waste in Kootenai County, ID.”

[68] “2009 Solid Waste Analysis,” Kootenai County Solid Waste Department, Coeur D’Alene, ID.

[69] “2011 Solid Waste Analysis,” Kootenai County Solid Waste Department, Coeur D’Alene, ID.

[70] J. Bartlome, “Telephone conversation regarding wood waste in the Southern Idaho Solid Waste District.”

[71] “Southern Idaho Solid Waste District Website.” .

[72] NAICS Association, “NAICS Code Description: 221117 Biomass Electric Power Generation.” [Online]. Available: http://www.naics.com/free-code-search/naicsdescription.php?code=221117. [Accessed: 21-Jun-2013].

[73] United States Census Bureau, “County Business Patterns (NAICS).” [Online]. Available: http://censtats.census.gov/cgi-bin/cbpnaic/cbpsect.pl. [Accessed: 14-Jun-2013].

APPENDICES

APPENDIX A: RECYCLED WOOD WASTE INVENTORY DATA COLLECTION

WASHINGTON 2011				
County	**Population**	**MSW (tons)**	**Diverted C&D (tons)**	**Diverted Wood (tons)**
Adams	19,027	16,747	0	0
Asotin	21,933	19,405	0	856
Benton	180,678	145,665	46	2,851
Chelan	73,477	70,210	203	3,662
Clallam	71,838	42,657	209	44,740
Clark	433,418	228,004	750	131,713
Columbia	4,050	2,522	0	0
Cowlitz	102,478	89,536	0	12,316
Douglas	38,971	27,895	0	9
Ferry	7,689	2,738	0	0
Franklin	83,455	97,098	0	8,955
Garfield	2,262	1,272	0	0
Grant	91,265	89,473	19	1,380
Grays Harbor	72,546	50,672	69	5,723
Island	78,971	42,506	803	2,833
Jefferson	29,924	16,857	0	325
King	1,969,722	1,127,092	154,133	133,453
Kitsap	254,633	177,804	2,885	10,182
Kittitas	41,629	28,570	114	110
Klickitat	20,697	17,874	0	6
Lewis	75,901	62,804	627	15,806
Lincoln	10,476	2,408	37	0
Mason	61,019	27,875	651	37,172
Okanogan	41,411	23,300	0	0
Pacific	20,930	13,986	12	1,300
Pend Oreille	12,936	7,066	0	0
Pierce	807,904	529,433	51,510	67,576
San Juan	15,844	7,038	0	0
Skagit	118,109	86,933	0	0
Skamania	11,137	2,430	0	7,800
Snohomish	722,400	411,128	39,488	192,815
Spokane	473,761	296,012	100	63,780
Stevens	43,496	20,381	240	0
Thurston	256,591	151,318	12,521	24,328
Wahkiakum	3,991	1,591	0	685
Walla Walla	59,588	61,889	1	1,737
Whatcom	203,663	130,171	0	0
Whitman	45,077	24,009	0	4,625
Yakima	247,141	223,431	444	8,625
TOTAL	**6,830,038**	**4,377,800**	**264,862**	**785,363**

APPENDIX A: RECYCLED WOOD WASTE INVENTORY DATA COLLECTION

OREGON 2011				
Wasteshed	**Population**	**MSW (tons)**	**Diverted C&D (tons)**	**Diverted Wood (tons)**
Baker	15,984	11,926	*No Data*	56
Benton	85,928	54,525		1,355
Clatsop	37,153	29,266		3,482
Columbia	49,402	24,614		1,814
Coos	62,791	39,987		992
Crook	20,839	16,415		2,776
Curry	22,426	16,660		39
Deschutes	160,338	112,751		4,186
Douglas	107,490	73,716		7,756
Gilliam	1,937	2,108		3
Grant	7,410	4,010		67
Harney	7,373	3,043		40
Hood River	22,493	18,221		106
Jackson	204,822	139,973		9,509
Jefferson	21,771	9,714		147
Josephine	82,987	49,130		3,102
Klamath	66,299	53,361		2,535
Lake	7,908	6,773		14
Lane	353,416	215,728		54,732
Lincoln	45,933	38,810		5,939
Linn	118,122	78,919		13,085
Malheur	31,068	20,176		183
Marion	318,872	195,332		30,392
Metro*	1,668,648	977,769		213,083
Milton-Freewater	NA	4035		39
Morrow	11,169	10,885		182
Polk	75,993	37,817		1,493
Sherman	1,718	1,203		3
Tillamook	25,403	20,560		1,352
Umatilla	76,725	67,354		2,651
Union	25,791	17,785		1,068
Wallowa	6,990	3,250		12
Wasco	25,234	17,005		442
Wheeler	1,426	417		3
Yamhill	100,000	64513		5757
TOTAL	**2,304,637**	**2,437,767**		**368,395**

APPENDIX A: RECYCLED WOOD WASTE INVENTORY DATA COLLECTION

IDAHO 2011				
County	**Population**	**MSW (tons)**	**Diverted C&D (tons)**	**Diverted Wood (tons)**
Ada	400,842	1,042,786*	*No Data*	*No Data*
Adams	3,977	*No Data*	*No Data*	*No Data*
Bannock	83,691	*No Data*	*No Data*	*No Data*
Bear Lake	6,001	*No Data*	*No Data*	*No Data*
Benewah	9,209	*No Data*	*No Data*	*No Data*
Bingham	45,952	*No Data*	*No Data*	*No Data*
Blaine	21,199	*Southern Idaho Solid Waste District (SISW)*		
Boise	7,025	3,000	*No Data*	*No Data*
Bonner	40,808	33,330	*No Data*	*No Data*
Bonneville	105,772	*No Data*	*No Data*	*No Data*
Boundary	10,804	4500	*No Data*	318
Butte	2,822	*No Data*	*No Data*	*No Data*
Camas	1,124	*No Data*	*No Data*	*No Data*
Canyon	191,694	*No Data*	*No Data*	*No Data*
Caribou	6,850	*No Data*	*No Data*	*No Data*
Cassia	23,186	*Southern Idaho Solid Waste District (SISW)*		
Clark	949	*No Data*	*No Data*	*No Data*
Clearwater	8,702	4,793	1,860	120
Custer	4,333	*No Data*	*No Data*	*No Data*
Elmore	26,346	31,792	37,881	*No Data*
Franklin	12,850	*No Data*	*No Data*	*No Data*
Fremont	13,128	*No Data*	*No Data*	*No Data*
Gem	16,665	*No Data*	*No Data*	*No Data*
Gooding	15,475	*Southern Idaho Solid Waste District (SISW)*		
Idaho	16,446	3,343	*No Data*	502
Jefferson	26,301	*No Data*	*No Data*	*No Data*
Jerome	22,682	*Southern Idaho Solid Waste District (SISW)*		
Kootenai	141,132	121,171	7,899	10,899
Latah	37,704	17,874	9,663	*No Data*
Lemhi	7,967	9,048	644	*No Data*
Lewis	3,822	54,783	516	*No Data*
Lincoln	5,186	*Southern Idaho Solid Waste District (SISW)*		
Madison	37,864	*No Data*	*No Data*	*No Data*
Minidoka	20,155	*Southern Idaho Solid Waste District (SISW)*		
Nez Perce	39,543	*No Data*	*No Data*	*No Data*
Oneida	4,215	*No Data*	*No Data*	*No Data*
Owyhee	11,438	*No Data*	*No Data*	*No Data*
Payette	22,624	*No Data*	*No Data*	*No Data*
Power	7,766	*No Data*	*No Data*	*No Data*
Shoshone	12,672	5,691	*No Data*	2,110
SISW	185,888	171,000	**13,651**	12,755
Teton	10,166	*No Data*	*No Data*	*No Data*
Twin Falls	78,005	*Southern Idaho Solid Waste District (SISW)*		
Valley	9,638	10,000	*No Data*	650
Washington	10,255	135,720	*No Data*	*No Data*
TOTAL	**1,584,985**	**1,648,831**	**72,114**	**27,354**
	*Data from previous year due to lack of available data for 2011.			

APPENDIX A: RECYCLED WOOD WASTE INVENTORY DATA COLLECTION

MONTANA 2011				
County	**Population**	**MSW (tons)**	**C&D/Inert (tons)**	**Wood/Burn Site (tons)**
Beaverhead	9,198	10,450	*No Data*	*No Data*
Big Horn	13,093	94,931	*No Data*	*No Data*
Blaine	6,565	22,198	*No Data*	*No Data*
Broadwater	5,752	712	*No Data*	*No Data*
Carbon	10,028	*No Data*	*No Data*	*No Data*
Carter	1,152	303	*No Data*	303
Cascade	81,837	206,083	*No Data*	*No Data*
Chouteau	5,793	*No Data*	*No Data*	*No Data*
Custer	11,752	11,617	*No Data*	*No Data*
Daniels	1,763	996	*No Data*	*No Data*
Dawson	8,989	13,993	*No Data*	*No Data*
Deer Lodge	9,299	*No Data*	3,110	*No Data*
Fallon	2,956	29,127	*No Data*	*No Data*
Fergus	11,506	*No Data*	*No Data*	*No Data*
Flathead	91,301	94,223	2,709	*No Data*
Gallatin	91,377	108,647	7,114	375
Garfield	1,251	*No Data*	*No Data*	*No Data*
Glacier	13,624	*No Data*	929	*No Data*
Golden Valley	865	*No Data*	*No Data*	*No Data*
Granite	3,068	*No Data*	*No Data*	165
Hill	16,397	*No Data*	*No Data*	*No Data*
Jefferson	11,381	35,489	1,140	*No Data*
Judith Basin	2,004	*No Data*	*No Data*	*No Data*
Lake	28,947	4,827	4,036	*No Data*
Lewis & Clark	64,318	41,577	29	70
Liberty	2,402	1,240	*No Data*	*No Data*
Lincoln	19,566	17,500	63	*No Data*
McCone	1,711	*No Data*	*No Data*	*No Data*
Madison	7,660	*No Data*	477	*No Data*
Meagher	1,911	*No Data*	25	*No Data*
Mineral	4,208	*No Data*	*No Data*	*No Data*
Missoula	110,138	225,200	19	*No Data*
Musselshell	4,701	*No Data*	*No Data*	44
Park	15,469	2,838	*No Data*	*No Data*
Petroleum	491	*No Data*	*No Data*	*No Data*
Phillips	4,250	2,741	*No Data*	*No Data*
Pondera	6,257	23,223	50	*No Data*
Powder River	1,738	1200	*No Data*	*No Data*
Powell	7,063	5100	*No Data*	*No Data*
Prairie	1,159	*No Data*	*No Data*	10
Ravalli	40,450	*No Data*	*No Data*	*No Data*
Richland	10,128	20,774	5,329	*No Data*
Roosevelt	10,527	9,206	53	53
Rosebud	9,379	10,931	*No Data*	*No Data*
Sanders	11,440	*No Data*	2,225	*No Data*
Sheridan	3,460	4,338	*No Data*	*No Data*
Silver Bow	34,383	75,679	13,060	*No Data*
Stillwater	9,131	*No Data*	*No Data*	*No Data*
Sweet Grass	3,623	*No Data*	230	*No Data*
Teton	6,091	*No Data*	3,668	*No Data*
Toole	5,239	7,078	*No Data*	*No Data*
Treasure	727	*No Data*	*No Data*	*No Data*
Valley	7,487	13,234	*No Data*	*No Data*
Wheatland	2,140	*No Data*	*No Data*	*No Data*
Wibaux	985	*No Data*	26	26
Yellowstone	150,069	227,888	*No Data*	*No Data*
TOTAL	**998,199**	**1,323,343**	**44,292**	**1,046**

APPENDIX A: RECYCLED WOOD WASTE INVENTORY DATA COLLECTION

County	Associated Landfills	Does the Associated Landfill Separate Wood or C&D Waste?
Ada	Ada County Landfill Simco Road Landfill	Yes No
Adams	Goodrich Landfill	NA
Bannock	Bannock County Landfill	No
Bear Lake	Bear Lake County Landfill	No
Benewah	Aberdeen C&D Site	C&D Only
Bingham	Aberdeen C&D Site Bannock County Landfill Rattlesnake Landfill	C&D Only No C&D Only
Blaine	Milner Butte Landfill (SISW)	Yes
Boise	Simco Road Landfill	No
Bonner	Columbia Ridge Landfill, OR	
Bonneville	Peterson Hill Landfill Hatch Pit	Yes C&D Only
Boundary	Boundary County Landfill	Yes
Butte	Arco Landfill (small exempt) Howe Landfill (small exempt)	Yes Yes
Camas	Milner Butte Landfill	Yes
Canyon	Pickles Butte Sanitary Landfill	Yes
Caribou	Caribou County Landfill	Yes
Cassia	Milner Butte Landfill (SISW)	Yes
Clark	Circular Butte Landfill	No
Clearwater	Asotin County Regional Landfill, WA	Yes
Custer	Lemhi County Landfill	No
Elmore	Simco Road Regional Landfill	No
Franklin	Franklin County Landfill	No
Fremont	St. Anthony Landfill Island Park Landfill	Yes Yes
Gem	Clay Peak Landfill	Yes
Gooding	Milner Butte Landfill (SISW)	Yes
Idaho	Clay Peak Landfill (Walco Inc.) Walco C&D Site	Yes C&D Only
Jefferson	County Line C&D Site Circular Butte Landfill	C&D Only No
Jerome	Milner Butte Landfill (SISW)	Yes
Kootenai	Fighting Creek Landfill	Yes
Latah	Finley Butte Landfill, OR (Latah Sanitation, Inc)	Yes
Lemhi	Lemhi County Landfill	Yes
Lewis	Roosevelt Landfill, WA	Yes
Lincoln	Milner Butte Landfill (SISW)	Yes
Madison	Circular Butte Landfill	No
Minidoka	Milner Butte Landfill (SISW)	Yes
Nez Perce	Finley Butte Landfill, OR (Latah Sanitation, Inc)	Yes
Oneida	Oneida County Landfill	Yes
Owyhee	Pickles Butte Landfill Simco Road Landfill	No No
Payette	Clay Peak Landfill	Yes
Power	Milner Butte Landfill Power County Demo Pit	Yes C&D Only
Shoshone	Allied Waste Landfill, MT Bunker Hill Superfund Site (wood)	No Wood Only
Teton	Circular Butte Landfill	No
Twin Falls	Milner Butte Landfill (SISW) Hub Butte Landfill (Twin Falls Landfill)	Yes
Valley	Simco Road Regional Landfill	No
Washington	Clay Peak Landfill, OR	Yes

APPENDIX A: RECYCLED WOOD WASTE INVENTORY DATA COLLECTION

WOOD VOLUME CONVERSTION FACTORS		
Volume Type	**Conversion**	**Source**
Board Feet [BF]	BF * [0.008 Ton/1 BF]	[60]
Clean Wood within C/D Waste	C/D Tons * [0.115 Clean Wood/CD ton]	[8]
Cubic Yard [CY]: Shredded Wood Chips	CY * [500 lbs/1 CY] * [1 ton/2000 lbs]	[61]
Cubic Yard [CY]: Wood Scrap, Loose	CY * [329.5 lbs/1 CY] * [1 ton/2000 lbs]	[61]

APPENDIX A: RECYCLED WOOD WASTE INVENTORY DATA COLLECTION

Company Name *Address* *City, State, Zip Code*	**Date:**
Phone: *Email:* *Person/Position:*	*Notes:*

STATEMENT: Hello, my name is Jerry Schneider and I am a graduate student at Washington State University. We are conducting biomass research regarding biofuels developed from wood residue. My responsibility is to conduct an inventory assessment of Material Recycling Facilities that recycle wood waste derived from construction and demolition within the four states of Washington, Oregon, Idaho, and Montana. If you have time, I have a few questions regarding this subject that I would like to ask you…

INCOMING
What types of wood materials do you currently accept? Answer

What are your current volumes of incoming/outgoing wood materials? Answer

Is your wood separated between clean and resonated/coated? Answer

OUTGOING
What are your current markets for recovered wood? Answer

What form (chips or particles, timber, dimensional lumber) is your recovered wood sold as? Answer

CAPACITY
What would be your wood volume at maximum capacity?
Area: Answer
Wood Grinded/Time: Answer
Transport: Answer

REACH
How far does your supplier base reach (miles)? Answer

How far does your distribution base reach? Answer

COSTS
What are your tipping fees? Compared to local landfills? Answer

Are there transportation costs? Answer

WASTE (for reclaimed timber mills)
How much wood waste do you generate (milling, fall-off, 'useless' etc.)? Answer

Where does it go? Answer

APPENDIX A: RECYCLED WOOD WASTE INVENTORY DATA COLLECTION

IDAHO					
MRF	**Location**	**Volume**	**Reach**	**Tipping Fees**	**Market**
Building Material Thrift Store	Hailey, ID	25,000 tons Building Materials per year	No Data	No Data	Timber/Lumber Reuse
Cannon Hill Industries	Post Falls, ID Spokane, WA	ID: 32,000 green tons WA: 15,000 green tons	100 miles	No Data	Hog Fuel sent to Clearwater Paper Corporation
Ross Lumber	Shoshone, ID	600 tons/year	Supply: Through U.S. Distribution: Pacific Northwest	No Data	Timber/Lumber Reuse
Trestlewood	Blackfoot, ID	9504 tons/year	Supply: Western U.S. Distribution: Throughout U.S.	Bid Based	Reclaim Timber
MONTANA					
MRF	**Location**	**Volume**	**Reach**	**Tipping Fees**	**Market**
Big Timberworks	Gallatin Way, MT	35 tons/year of wood waste residue	Throughout U.S.	Bid Based	Reclaim Timber
Eko Compost	Missoula, MT	No Data	Supply: Bonner, ID No Distribution	$1/bag $7/pickup or small trailer $15/ large trailer $50/semi load No charge for pre-chipped	Compost Firewood
Heritage Timber	Bonner, MT	2800 tons stored	Supply: 250 miles Distribution: Pacific Northwest	No Data	Reclaim Timber
Home ReSource	Missoula, MT	1977 tons/year through	Eastern Montana and Idaho	All is donated Tax Class 501C3	Mostly Reuse Small Pieces sent to Eko Compost
Johnson Brothers Recycle	Missoula, MT	No Data	No Data	No Data	No Data
Montana Reclaimed Lumber Company	Gallatin Gateway, MT	16,000 tons stored	No Data	Bid Based	Reclaim Timber
Resource Site Services	Bozeman, MT	2000 tons/year	100 miles service reach, no distribution	Bid based	Mobile Wood and Construction Material Grinding
OREGON					
MRF	**Location**	**Volume**	**Reach**	**Tipping Fees**	**Market**
Allwood Recyclers	Fairview, OR	No Data	No Data	$7/yard $12 minimum	Hog Fuel
Bar 7 Trucking Wood Recycling	Redmond, OR	1,685.62 BDT/year	50 mile service reach, no distribution	$2/cubic yard	Hog Fuel
Best Buy in Town	Hillsboro, OR	No Data	No Data	No Data	No Data
Biomass One	White City, OR	252,000 BDT/year Total 2,500 BDT/year clean C/D	Supply: 30 miles Distribution: Oregon	No Fees	Hog Fuel Energy
Clackamas Compost Products	Clackamas, OR	No Data	10-20 miles	$10/cubic yard	Urban Wood: Hog Fuel Land Clearing: Compost
Clayton Ward	Salem, OR	No Data	Supply: 50 miles	3 cents/pound	Hog Fuel
Environmentally Conscious Recycling	Portland, OR	No Data	No Data	No Data	No Data
Greenway Recycling	Portland, OR	16,200 tons/year	15 miles most of time, but will reach to 75 miles	$81/ton commingled $35/ton clean wood	Hog Fuel
Hilton Landscape Supply	Central Point, OR	Average 8,000-10,000 tons/year	Supply: 40 miles	No charge for dumping.	Hog Fuel Compost

APPENDIX A: RECYCLED WOOD WASTE INVENTORY DATA COLLECTION

				Drop Boxes are bid based.	
JB Wood Recyclers	Monmouth, OR	300 ton/year	Supply: 35 miles	$6/yard	Hog Fuel
KB Recycling	Clackamas, OR	No Data	Supply: 5 miles	$25/ton	Hog Fuel
McFarlane's Bark	Milwaukie, OR Vancouver, WA	5,120 tons 2012	30 miles	$10/yard retail $9/yard commercial	Hog Fuel
Northwest Wood and Fiber Recovery	Portland, OR	19,500 tons/year	Supply: 5 miles Distribution: 40-50 miles	$5/cubic yard non-commercial $1/cubic yard commercial	Hog Fuel to paper company for energy co-generation
Northwest Environmental and Recycling	Cornelius, OR	No Data	No Data	No Data	No Data
Recology	Portland, OR West Linn, OR	40,000 ton/year everything 20,000 tons/year urban wood waste	Supply: 15 miles	$45/ton	Hog Fuel
SH Landscape Supplies and Recycling	Tualatin, OR Hillsboro, OR	Tualatin: 12,750 tons/year Hillsboro: 2,250 tons/year	Supply: 20 miles Distribution: Oregon	$7/cubic yard for clean urban wood waste	Hog Fuel
Trails End Recovery	Warrenton, OR	3,600 tons urban wood waste 2012	Supply: 25-30 miles	$82.50/ton mixed $45.90/ton clean wood	Hog Fuel
Wood Waste Management	Portland, OR	7373.75 tons 2012	Supply: 50 miles	$26/yard first two yards $13/yard after that	Hog Fuel
WASHINGTON					
MRF	**Location**	**Volume**	**Reach**	**Tipping Fees**	**Market**
All Wood Recycling	Redmond, WA	"Hundreds of thousands of mixed—clean wood and inert wood" NOTE: Recorded as 100,000 tons/year	Supply: 50 miles	$30/ton clean wood	Hog Fuel
Allen Shearer Trucking & Landscape Supply	Belfair, WA	"A couple hundred tons per year"	Supply: 200 miles	$30/ton	Hog Fuel
Bobby Wolford Trucking and Demolition	Woodinville, WA	14,879 tons 2012	Supply: 50 miles	Bid Based	Hog Fuel
Busy Bee Wood Recycling	Spokane, WA	No Data	Spokane County Distribute: Plummer, Idaho.	$8/cubic yard	Hog Fuel
CDL Recycle	Seattle, WA	32,760 tons/year average	Supply: Pierce and King Counties Distribution: 110 miles	$20/ton clean $55/ton mixed wood $95/ton commingled C/D	Hog Fuel, Mulch, "a little of everything"
Cedar Grove Composting	Maple Valley, WA	No Data	Supply: 75 mile	$10/ton urban wood waste	Compost
City Bark LLC	Vancouver, WA	4708.75 tons 2012	Supply: 50 miles	$11/yard	Hog Fuel
Diversified Wood Recycling	Spokane, WA	260 tons/year	No Data	$6/cubic yard	Lumber Reuse Hog Fuel
Eastside Wood Recycling	Moses Lake, WA	8,000 tons urban wood waste per year	Supply: 150 miles	Bid Based	Hog Fuel
Gillardi Logging and Construction	Elbe, WA	No Data	Supply 75 miles	$8/cubic yard drop off Pick-up fees vary	Hog Fuel
Glacier Recycle [Waste	Auburn, WA	88,440 tons/year NOTE: Volume given	No Data	No Data	No Data

APPENDIX A: RECYCLED WOOD WASTE INVENTORY DATA COLLECTION

Management]		by Veneer Chip Transport			
H&H Wood Recyclers	Vancouver, WA	28,000 tons/ year	Supply: 50-75 miles	$7/cubic yard clean lumber $3.5/cubic yard pallets	Hog Fuel Compost
Lautenbach Industries	Mount Vernon, WA	19,500 tons/year	Supply: 30 miles	$55/ton	Hog Fuel for Port Townsend Paper Mill
Mason County Wood Recyclers	Shelton, WA	No Data	Supply: 150 miles	$10/pick-up load	Hog Fuel
Pacific Northwest Timbers	Port Townsend	No Data	No Data	No Data	Reclaim Timber
Pacific Topsoils	Everett, WA	No Data	Assuming 100 miles	$22-44/cubic yard depending on location	Hog Fuel for various purposes
Pallet Services	Mount Vernon, WA Pasco, WA Tacoma, WA	Wood Waste Residue: Pasco: 2,600 tons/year Tacoma: 15,600 tons/year	Supply: 355 miles	No data	Good Wood: Pallet construction Residue: Hog Fuel sent to Port Townsend Paper
Sunshine Recycling	Spokane Valley, WA	No Data	Spokane County	$45/ton C/D Bid Based	Hog Fuel Compost
Rainier Wood Recycling	Fall City, WA Covington, WA	Fall City: 49,600 tons Covington: 74,400 tons	Supply: 200 miles	$7.50/cubic yard, although may vary	Hog Fuel Mulch Composites Pulp Bedding
Recovery 1	Tacoma, WA	2012 Report: 27,968.22 tons commingled const. 3,214 tons commingled demo. 7033.63 tons bright mixed (lumber, ply, particle board, etc.) 2,065.64 tons land-clearing	125 miles	$65/ton commingled C/D $15/ton Bright-Mixed $20/ton Land-clearing	Hog Fuel Mulch Composites
Resource Woodworks	Tacoma, WA	No Data	No Data	No Data	No Data
RW Rhine	Tacoma, WA	21,600 tons stored	Supply: 2500 miles	C/D Bid Based	Reclaim Timber
Veneer Chip Transport	Tacoma, WA	Under Pallet Services and Glacier Recycle	No Data	No Data	Transport
West Van Material Recovery Center	Vancouver, WA	5800 tons	30 miles	$62.57-60.66/ton clean urban wood waste	Hog Fuel

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

WASHINGTON				
Year	Wood Waste [62], [63], [30]			
	Disposed (tons)	Diverted (tons)	Recovered for Energy (tons)	Generated (tons)
2000	197,929	215,211	121	413,261
2001	246,754	538,242	12,460	797,456
2002	91,697	394,261	196,100	682,058
2003	90,303	208,920	189,584	488,807
2004	89,905	257,495	129,927	477,327
2005	61,918	351,855	163,408	577,181
2006	52,833	289,612	372,678	715,123
2007	40,579	228,146	353,683	622,408
2008	39,926	381,866	331,528	753,320
2009	29,449	200,980	613,888	844,317
2010	8,822	347,137	847,115	1,203,074

OREGON	
Year	Recovered Wood Waste (tons) [36]
2000	360,819
2001	424,569
2002	402,799
2003	420,889
2004	444,017
2005	449,791
2006	503,967
2007	460,896
2008	371,531
2009	307,005
2010	340,794
2011	368,393

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

RECYCLED WOOD WASTE PER MODEL COMMUNITY IN WASHINGTON [44]				
Year	**Washington Total**	**Seattle-Tacoma-Bellevue Metro**	**Spokane-Spokane Valley Metro**	**Other Remaining Counties**
2000	215,332	180,597	465	34,270
2001	550,702	402,887	8,727	139,088
2002	590,361	464,914	4,256	121,191
2003	398,504	233,023	23,453	142,028
2004	387,422	288,576	10,939	87,907
2005	515,263	240,135	16,487	258,641
2006	662,290	321,903	47,361	293,026
2007	581,829	267,161	54,992	259,676
2008	713,394	273,455	39,277	400,662
2009	814,868	199,646	42,312	572,910
2010	1,194,252	598,489	73,402	522,361
2011	804,728	393,844	63,780	347,104

RECYCLED WOOD WASTE PER MODEL COMMUNITY IN OREGON (tons)			
Year	**Oregon Total**	**Portland-Vancouver-Hillsboro Metro**	**Other Remaining Wastesheds** [1]
2000	360,819	183,958	176,861
2001	424,569	248,285	176,284
2002	402,799	231,421	171,378
2003	420,889	232,067	188,822
2004	444,017	257,915	186,102
2005	449,791	253,564	196,227
2006	503,967	277,052	226,915
2007	460,896	279,254	181,642
2008	371,531	209,782	161,749
2009	307,005	174,980	132,025
2010	340,794	187,735	153,059
2011	368,393	220,654	147,739

[1] Recycled wood waste totals from the Clark and Skamania counties in Washington were omitted from the Portland-Vancouver-Hillsboro metropolitan area before this calculation was made.

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

SEATTLE-TACOMA-BELLEVUE METROPOLITAN AREA							
Year	Wood Waste per County [44]						
	King		Pierce		Snohomish		TOTAL (tons)
	Diverted (tons)	Recovered for Energy (tons)	Diverted (tons)	Recovered for Energy (tons)	Diverted (tons)	Recovered for Energy (tons)	
2011	32,171	101,282	26,762	40,814	31,687	161,128	**393,844**
2010	57,585	28,240	26,393	16,378	92,182	377,711	**598,489**
2009	16,063	25,575	28,382	18,362	74,496	36,768	**199,646**
2008	62,075	26,375	53,390	24,502	96,183	10,930	**273,455**
2007	22,962	76,680	23,292	25,777	93,060	25,390	**267,161**
2006	43,650	103,832	52,350	35,681	51,192	35,198	**321,903**
2005	94,736	21,533	63,660	13,490	30,950	15,766	**240,135**
2004	89,794	36,188	50,463	35,997	53,147	22,987	**288,576**
2003	59,103	34,039	45,076	49,333	31,338	14,134	**233,023**
2002	132,440	26,923	104,908	15,813	69,491	115,339	**464,914**
2001*	186,705		109,536		106,646		**402,887**
2000*	94,981		34463		51,153		**180,597**

PORTLAND-VANCOUVER-HILLSBORO METROPOLITAN AREA								
Year	Diverted Wood Waste per Wasteshed (Oregon) or County (Washington) [35], [44]							
	Columbia, OR	Metro, OR	Yamhill, OR	Clark, WA		Skamania, WA		TOTAL (tons)
	Diverted (tons)	Diverted (tons)	Diverted (tons)	Diverted (tons)	Recovered for Energy (tons)	Diverted (tons)	Recovered for Energy (tons)	
2011	1,814	213,083	5,757	12,307	119,406	0	7,800	**360,167**
2010	1,056	180,954	5,725	209	180,310	2,091	7,042	**377,387**
2009	214	170,798	3,968	12,045	12,016	3,453	0	**202,494**
2008	287	205,498	3,997	19,756	52,062	0	0	**281,600**
2007	158	274,598	4,498	19,707	35,269	0	0	**334,230**
2006	564	271,465	5,023	9,973	29,714	0	0	**316,739**
2005	378	245,706	7,480	11,798	28,939	0	0	**294,301**
2004	438	238,688	18,789	8,200	22,079	0	0	**288,194**
2003	379	224,584	7,104	208	32,235	0	0	**264,510**
2002	668	210,763	19,990	18,325	0	0	0	**249,746**
2001*	1,805	232,923	13,557	1,675		10		**249,970**
2000*	1,749	170,362	11,847	1,912		0		**185,870**

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

SPOKANE-SPOKANE VALLEY METROPOLITAN AREA							
Year	Diverted Wood Waste per County [44]						
	Pend Orielle		Spokane		Stevens		TOTAL (tons)
	Diverted (tons)	Recovered for Energy (tons)	Diverted (tons)	Recovered for Energy (tons)	Diverted (tons)	Recovered for Energy (tons)	
2011	0	0	5,528	58,252	0	0	**63,780**
2010	0	1,936	15,880	55,586	0	0	**73,402**
2009	0	5,554	10,630	25,154	0	974	**42,312**
2008	0	10,126	3,564	25,054	0	533	**39,277**
2007	0	0	2,468	52,406	0	118	**54,992**
2006	0	0	23,818	23,538	5	0	**47,361**
2005	0	0	16,487	0	0	0	**16,487**
2004	1	0	10,937	0	1	0	**10,939**
2003	0	0	2,732	20,721	0	0	**23,453**
2002	10	0	2,567	1669	10	0	**4,256**
2001*	75		8,575		77		**8,727**
2000*	0		465		0		**465**

RWW STATISTICS FOR WASHINGTON				
Year	Dependent Variable	Independent Variables		
	RWW (tons)	Population	RBP	Wood to Energy
2000	215,332	5,911,122	39,021	N/A
2001	550,702	5,987,785	38,345	N/A
2002	590,361	6,056,187	40,200	14
2003	398,504	6,113,262	42,825	23
2004	387,422	6,184,289	50,089	12
2005	515,263	6,261,282	52,988	10
2006	662,290	6,372,243	50,033	11
2007	581,829	6,464,979	47,397	20
2008	713,394	6,566,073	28,919	17
2009	814,868	6,664,195	17,011	61
2010	1,194,252	6,742,950	20,691	75
2011	804,728	6,830,038	20,864	59

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

RWW STATISTICS FOR OREGON			
Year	Dependent Variable	Independent Variables	
	RWW (tons)	Population	RBP
2000	360,819	3,430,891	19,877
2001	424,569	3,470,382	21,322
2002	402,799	3,517,111	22,186
2003	420,889	3,550,180	25,015
2004	444,791	3,573,505	27,309
2005	449,791	3,617,869	31,024
2006	503,967	3,677,545	26,623
2007	460,896	3,732,957	21,101
2008	371,531	3,782,991	11,676
2009	307,005	3,825,657	7,039
2010	340,794	3,838,332	6,868
2011	368,393	3,871,859	7,663

RWW STATISTICS FOR THE SEATTLE-TACOMA-BELLEVUE METROPOLITAN AREA			
Year	Dependent Variable	Independent Variables	
	RWW (tons)	Population	RBP
2000	180,597	3,052,379	22,525
2001	402,887	3,094,380	21,097
2002	464,914	3,121,895	20,991
2003	233,023	3,138,938	20,601
2004	288,576	3,163,703	24,135
2005	240,135	3,202,388	25,519
2006	321,903	3,259,945	25,743
2007	267,161	3,307,360	25,403
2008	273,455	3,356,637	15,512
2009	199,646	3,407,848	7,419
2010	598,489	3,447,886	10,040
2011	393,844	3,500,026	11,230

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

RWW STATISTICS FOR THE PORTAND-VANCOUVER-HILLSBORO METROPOLITAN AREA			
Year	Dependent Variable	Independent Variables	
	RWW (tons)	Population	RBP
2000	185,870	1,936,108	12,998
2001	249,970	1,975,589	13,874
2002	249,746	2,010,666	14,378
2003	264,510	2,034,000	16,003
2004	288,194	2,052,776	15,859
2005	294,301	2,084,053	17,251
2006	316,739	2,123,960	15,376
2007	334,230	2,163,577	13,115
2008	281,600	2,203,745	7,408
2009	202,494	2,241,841	4,020
2010	377,387	2,232,896	4,476
2011	360,167	2,262,605	5,213

RWW STATISTICS FOR SPOKANE-SPOKANE-VALLEY METROPOLITAN AREA			
Year	Dependent Variable	Independent Variables	
	RWW (tons)	Population	RBP
2000	465	470,743	2,316
2001	8,727	474,702	2,414
2002	4,256	479,037	2,396
2003	23,453	483,021	2,760
2004	10,939	487,640	4,176
2005	16,487	493,289	4,707
2006	47,361	501,255	4,101
2007	54,992	510,932	3,176
2008	39,277	517,539	2,660
2009	42,312	523,964	1,946
2010	73,402	528,552	1,733
2011	63,780	530,193	1,887

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

RWW STATISTICS OF COEUR D'ALENE METROPOLITAN AREA			
Year	Dependent Variable	Independent Variables	
	RWW (tons)	Population	RBP
2000	5,844	109,541	1,174
2001	5,353	111,707	1,344
2002	6,195	114,000	1,414
2003	7,096	116,910	1,837
2004	9,471	121,553	2,365
2005	13,299	126,641	2,688
2006	14,137	130,353	1,599
2007	15,569	133,922	1,661
2008	15,019	136,998	774
2009	16,374	139,390	861
2010	12,931	138,913	627
2011	8,248	141,132	623

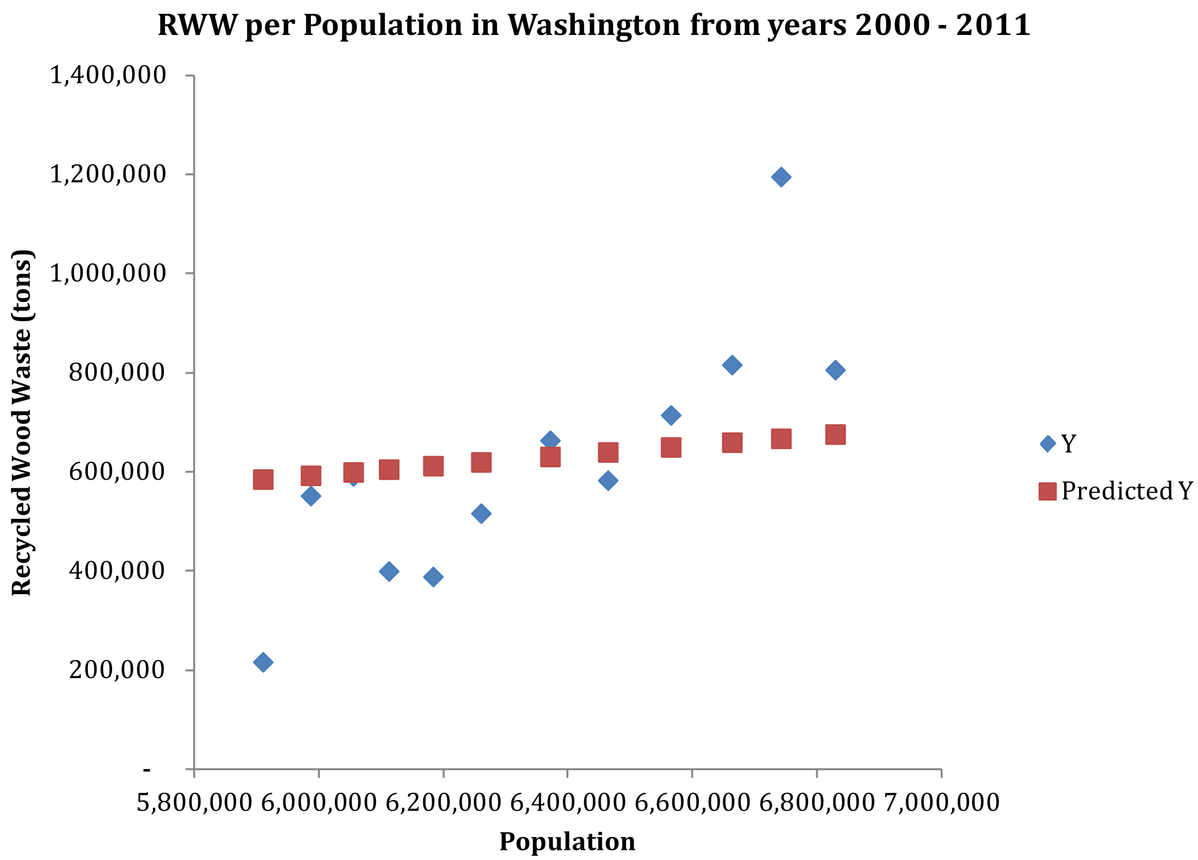
RWW STATISTICS FOR SOUTHERN IDAHO SOLID WASTE DISTRICT			
Year	Dependent Variable	Independent Variables	
	RWW (tons)	Population	RBP
2003	14,244	165,040	1,320
2004	13,092	166,245	1,371
2005	13,092	167,878	1,692
2006	15,696	170,351	1,606
2007	14,196	173,118	1,022
2008	15,320	176,271	670
2009	14,517	178,885	441
2010	15,401	185,172	369
2011	12,755	185,888	359

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

RWW STATISTICS FOR REMAINING WASHINGTON COUNTIES			
Year	Dependent Variable	Independent Variables	
	RWW (tons)	Population	RBP
2000	34,270	2,388,000	14,180
2001	139,088	2,418,703	14,834
2002	121,191	2,455,255	16,813
2003	142,028	2,491,303	19,464
2004	87,907	2,532,946	21,778
2005	258,641	2,565,605	22,762
2006	293,026	2,611,043	20,189
2007	259,676	2,646,687	18,818
2008	400,662	2,691,897	10,747
2009	572,910	2,732,383	7,646
2010	522,361	2,766,512	8,918
2011	347,104	2,799,819	7,747

RWW STATISTICS FOR REMAINING OREGON WASTESHEDS			
Year	Dependent Variable	Independent Variables	
	RWW (tons)	Population	RBP
2000	176,861	1,852,201	10,120
2001	176,284	1,863,139	11,357
2002	171,378	1,885,014	11,619
2003	188,822	1,903,441	13,149
2004	186,102	1,920,093	15,421
2005	196,227	1,943,641	17,664
2006	226,915	1,972,274	14,349
2007	181,642	1,996,791	10,418
2008	161,749	2,014,776	5,552
2009	132,025	2,026,712	3,760
2010	153,059	2,043,547	3,487
2011	147,739	2,053,809	3,445

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



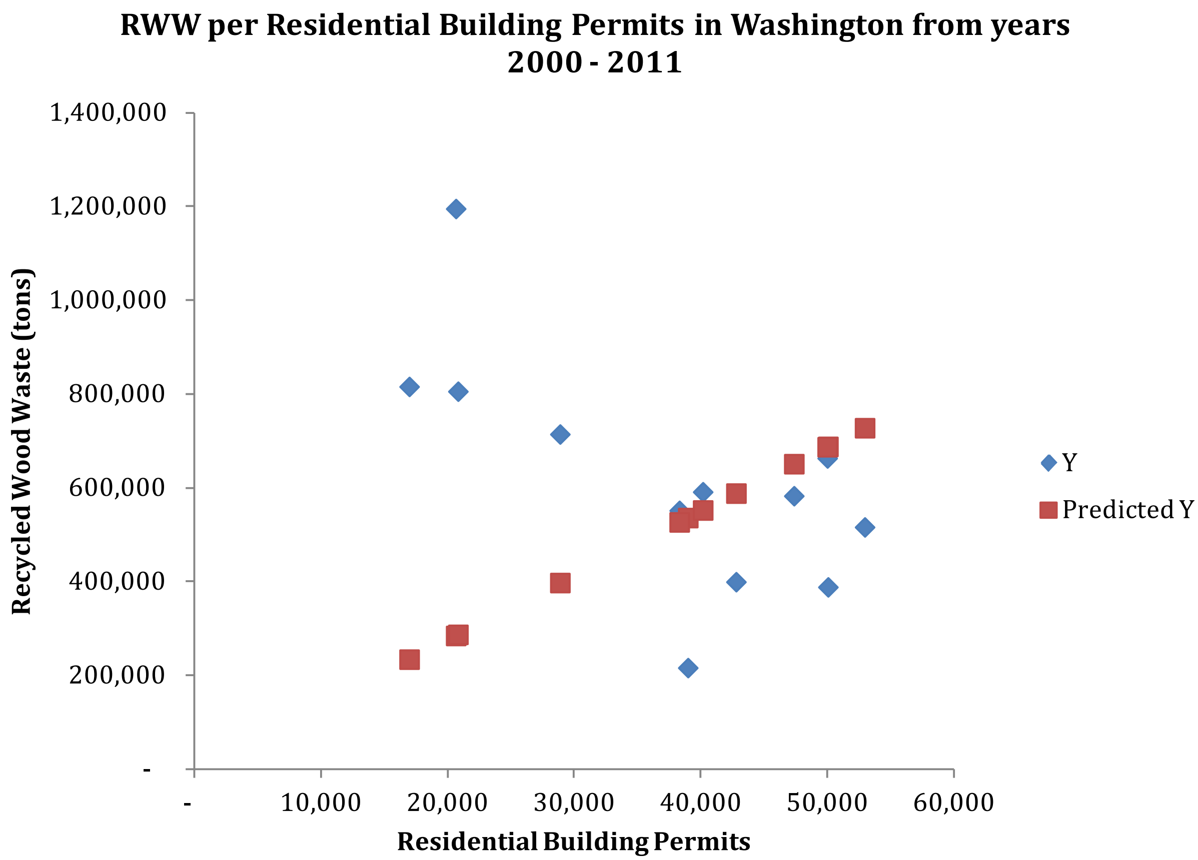
Regression Statistics	
Multiple R	0.945
R Square	0.893
Adjusted R Square	0.802
Standard Error	227484.876
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4.72724E+12	4.72724E+12	91.348741	2.40258E-06
Residual	11	5.69243E+11	51749368896		
Total	12	5.29648E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.099	0.010	9.558	0.000	0.076	0.122	0.076	0.122

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



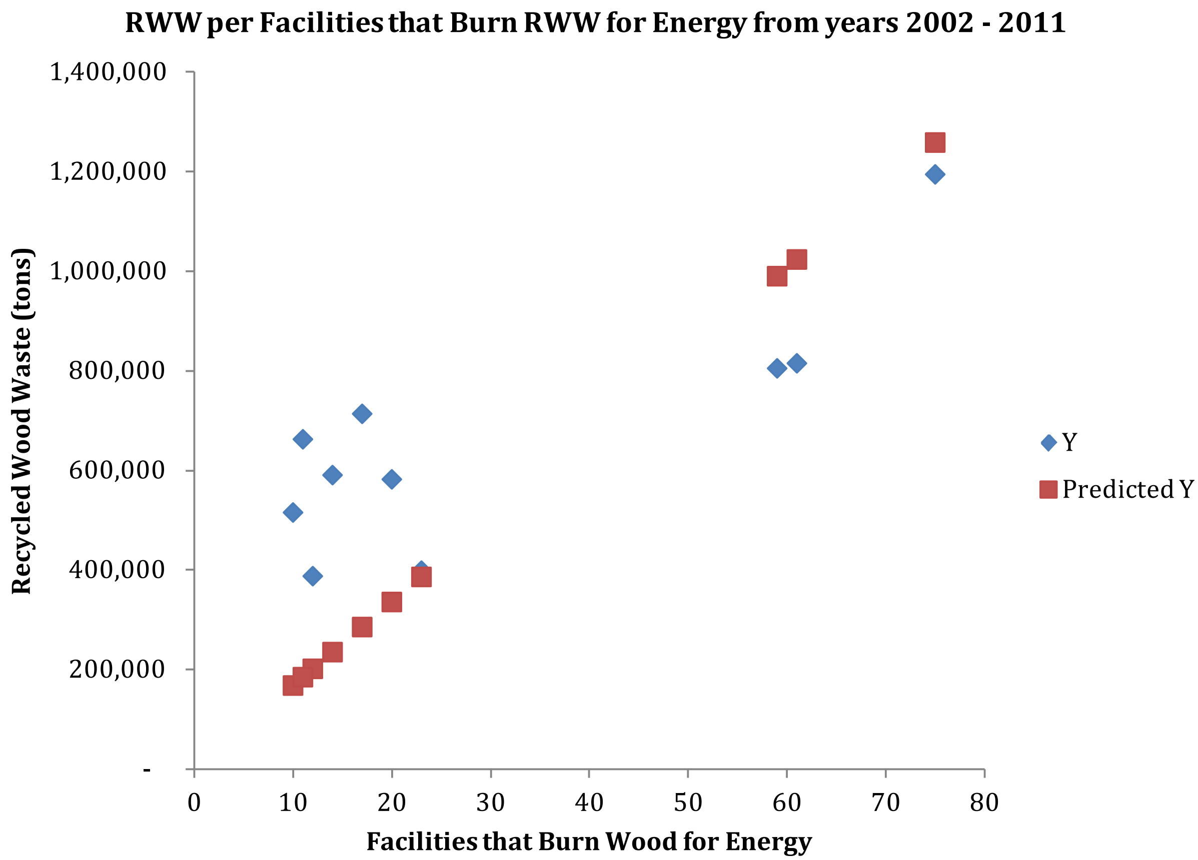
Regression Statistics	
Multiple R	0.811
R Square	0.657
Adjusted R Square	0.566
Standard Error	406337.972
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.48027E+12	3.4803E+12	21.078403	0.00099354
Residual	11	1.81622E+12	1.6511E+11		
Total	12	5.29648E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
RBP	13.716	2.988	4.591	0.001	7.141	20.292	7.141	20.292

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



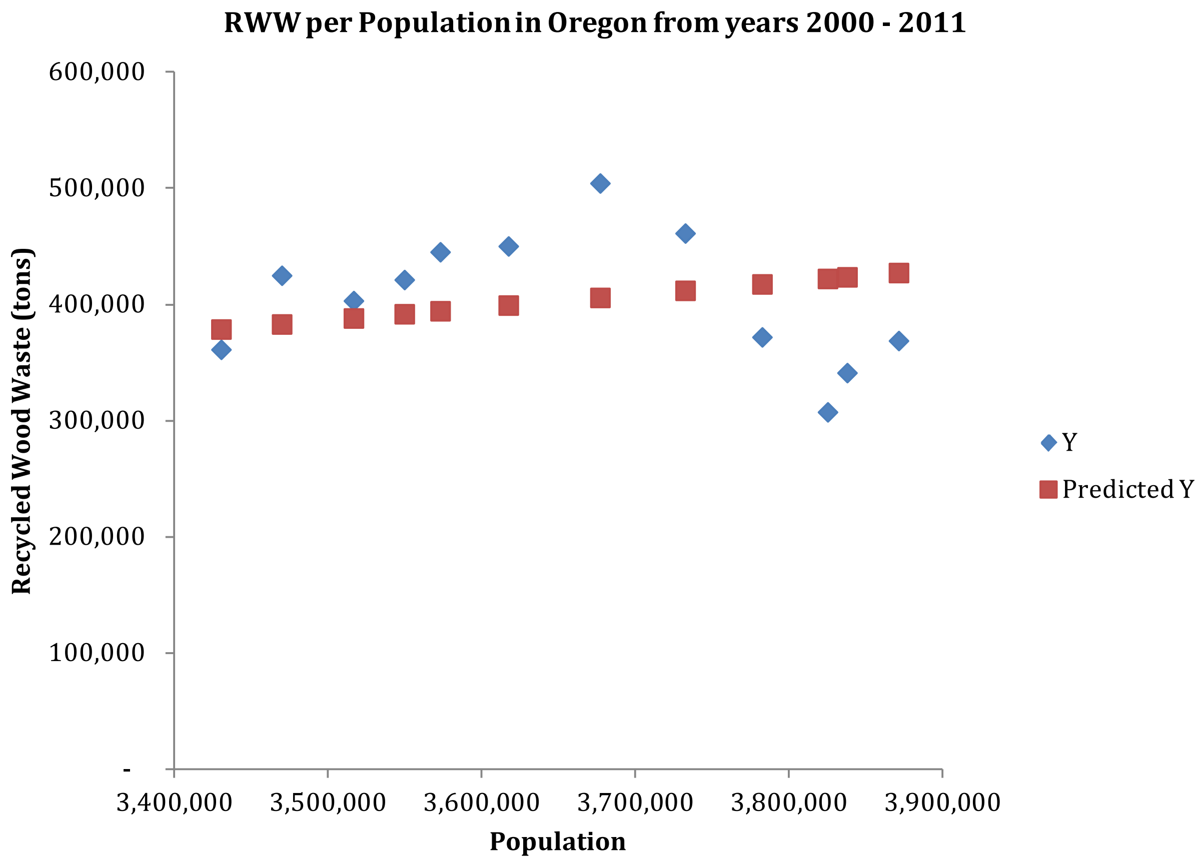
Regression Statistics	
Multiple R	0.912
R Square	0.831
Adjusted R Square	0.720
Standard Error	304777.058
Observations	10.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4.11084E+12	4.111E+12	44.255383	0.000160396
Residual	9	8.36001E+11	9.289E+10		
Total	10	4.94684E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Wood to Energy	16776.435	2521.835	6.652	0.000	11071.648	22481.221	11071.648	22481.221

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



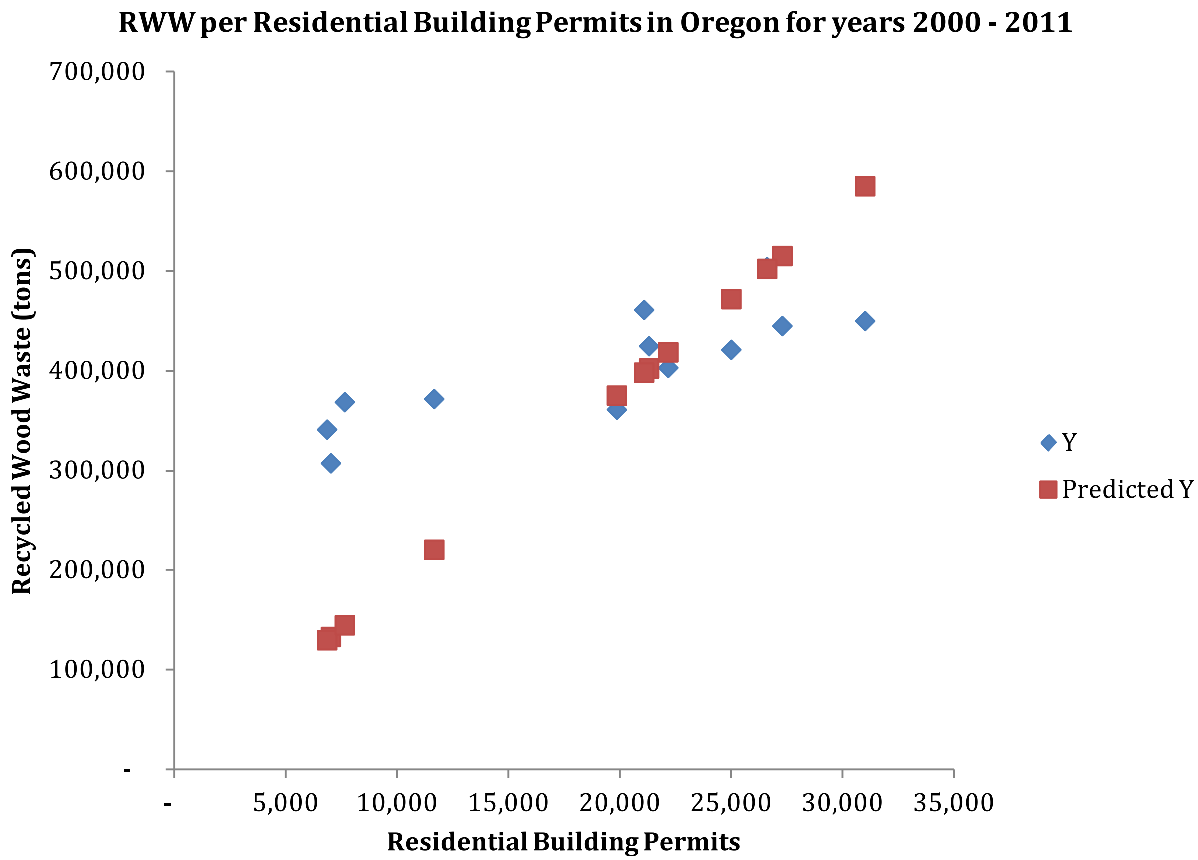
Regression Statistics	
Multiple R	0.988
R Square	0.977
Adjusted R Square	0.886
Standard Error	64616.720
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.95462E+12	1.9546E+12	468.135415	9.93495E-10
Residual	11	45928525427	4175320493		
Total	12	2.00054E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.110	0.005	21.636	0.000	0.099	0.121	0.099	0.121

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



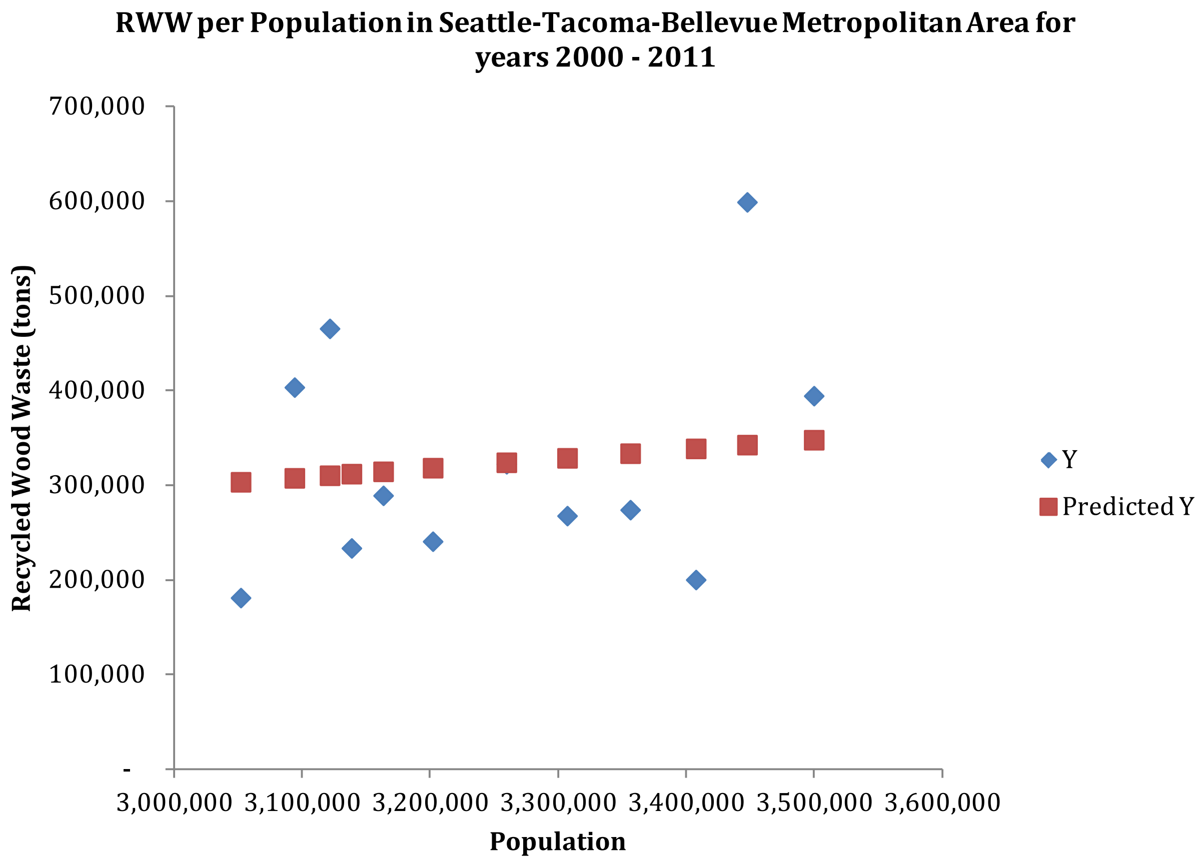
Regression Statistics	
Multiple R	0.954
R Square	0.911
Adjusted R Square	0.820
Standard Error	127478.311
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.82179E+12	1.822E+12	112.10494	9.3931E-07
Residual	11	1.78758E+11	1.625E+10		
Total	12	2.00054E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
RBP	18.860	1.781	10.588	0.000	14.939	22.780	14.939	22.780

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



Regression Statistics	
Multiple R	0.943
R Square	0.890
Adjusted R Square	0.799
Standard Error	118851.010
Observations	12.000

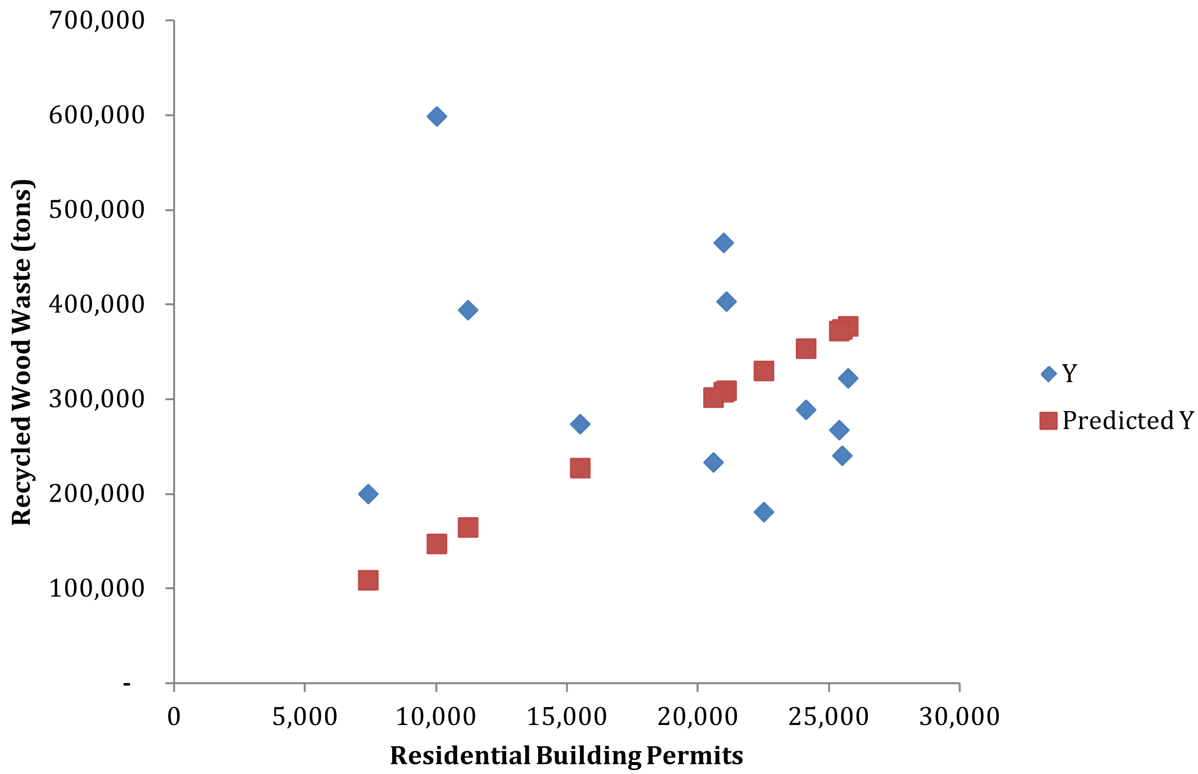
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.25387E+12	1.2539E+12	88.76620505	2.73677E-06
Residual	11	1.55381E+11	1.4126E+10		
Total	12	1.40925E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.099	0.011	9.422	0.000	0.076	0.122	0.076	0.122

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

RWW per Residential Building Permit in Seattle-Tacoma-Bellevue Metropolitan Area for years 2000 - 2011



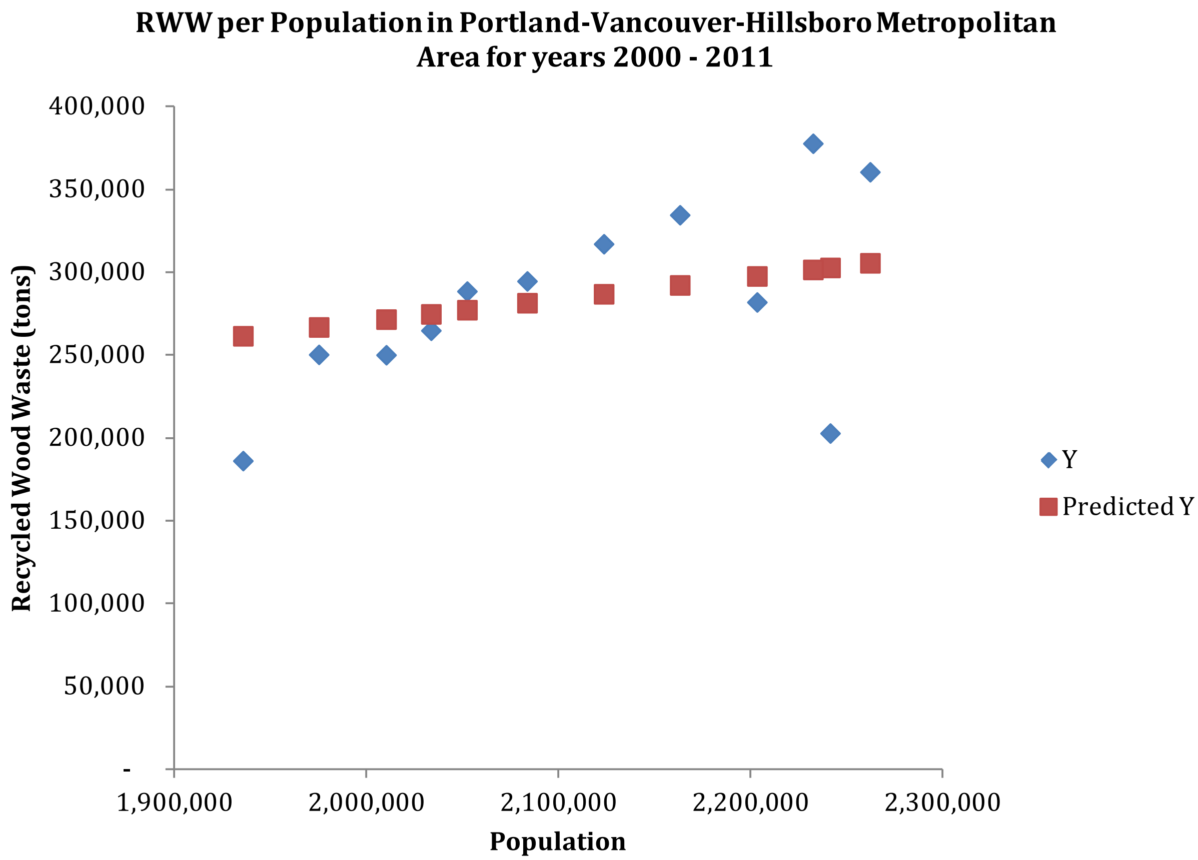
Regression Statistics	
Multiple R	0.861
R Square	0.742
Adjusted R Square	0.651
Standard Error	181800.556
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.04569E+12	1.046E+12	31.638193	0.000219996
Residual	11	3.63566E+11	3.305E+10		
Total	12	1.40925E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
RBP	14.636	2.602	5.625	0.000	8.909	20.363	8.909	20.363

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



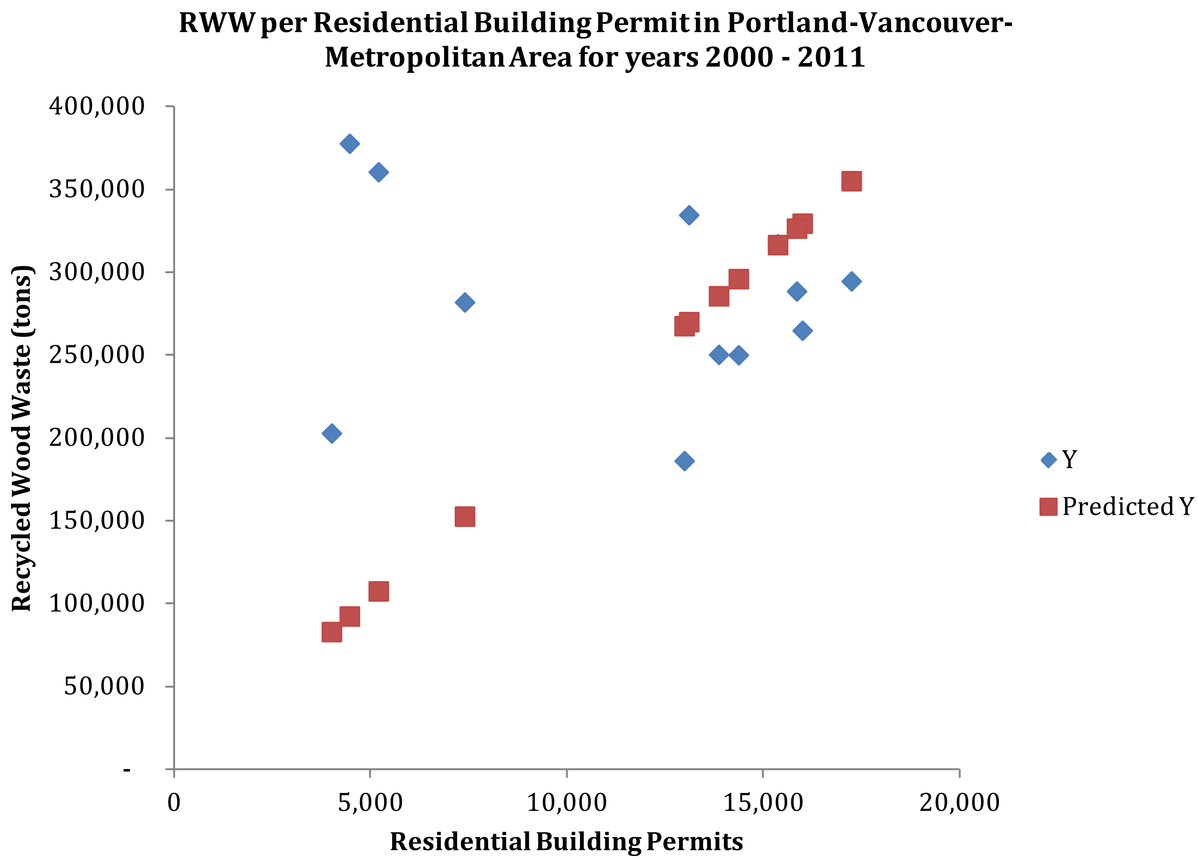
Regression Statistics	
Multiple R	0.986
R Square	0.972
Adjusted R Square	0.881
Standard Error	50959.183
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9.74952E+11	9.74952E+11	375.438	2.92467E-09
Residual	11	28565221673	2596838334		
Total	12	1.00352E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.135	0.007	19.376	0.000	0.120	0.150	0.120	0.150

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



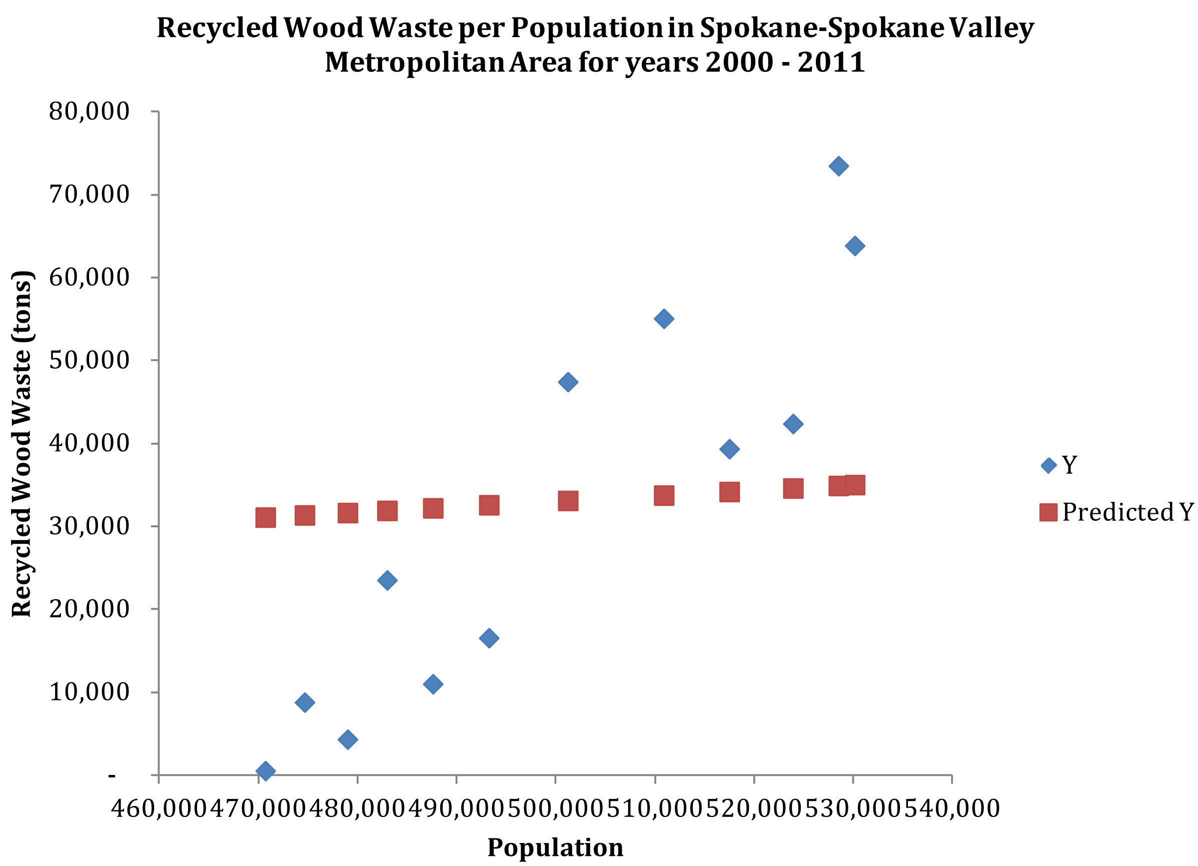
Regression Statistics	
Multiple R	0.895
R Square	0.801
Adjusted R Square	0.710
Standard Error	134804.276
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	8.03623E+11	8.036E+11	44.222669	5.70926E-05
Residual	11	1.99894E+11	1.817E+10		
Total	12	1.00352E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
RBP	20.566	3.093	6.650	0.000	13.759	27.373	13.759	27.373

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



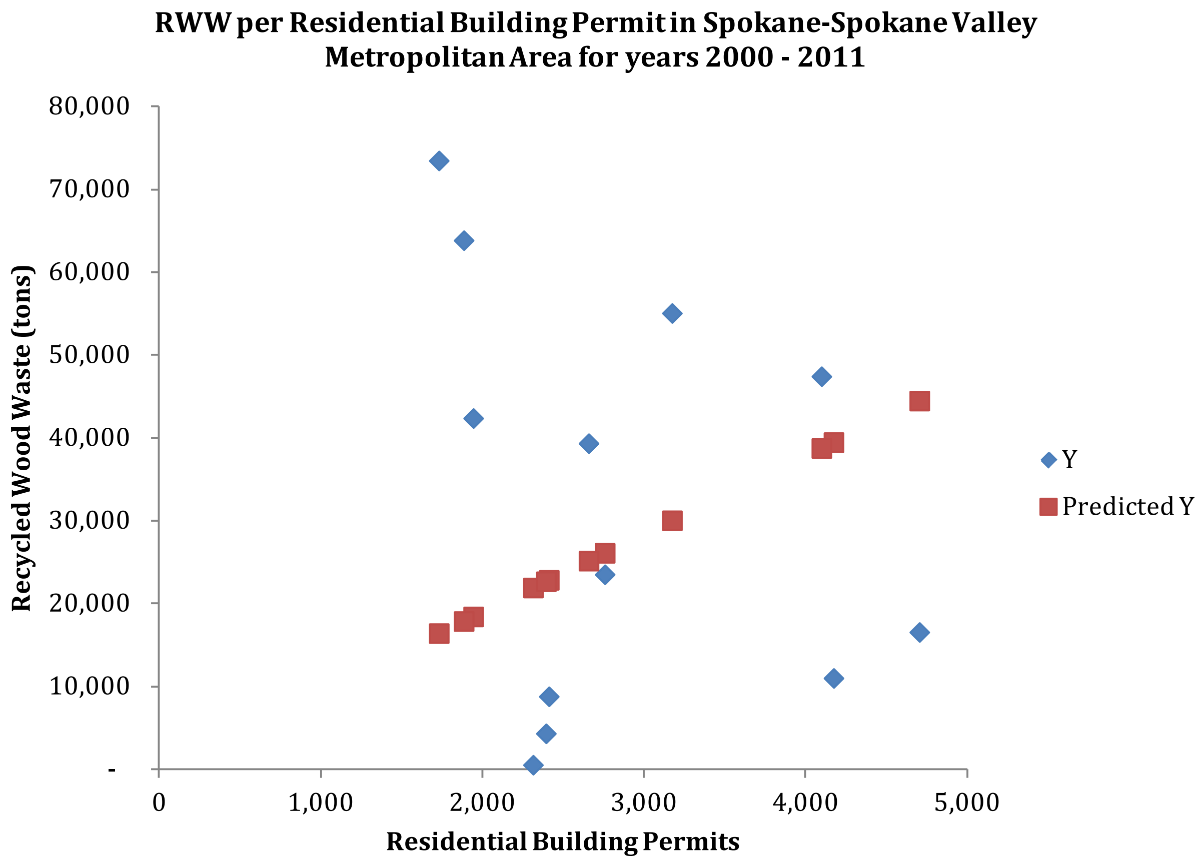
Regression Statistics	
Multiple R	0.827
R Square	0.684
Adjusted R Square	0.593
Standard Error	23415.764
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	13060652826	13060652826	23.8203546	0.00064137 7
Residual	11	6031278025	548298002.3		
Total	12	19091930851			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.066	0.014	4.881	0.000	0.036	0.096	0.036	0.096

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



Regression Statistics	
Multiple R	0.711
R Square	0.506
Adjusted R Square	0.415
Standard Error	29283.584
Observations	12.000

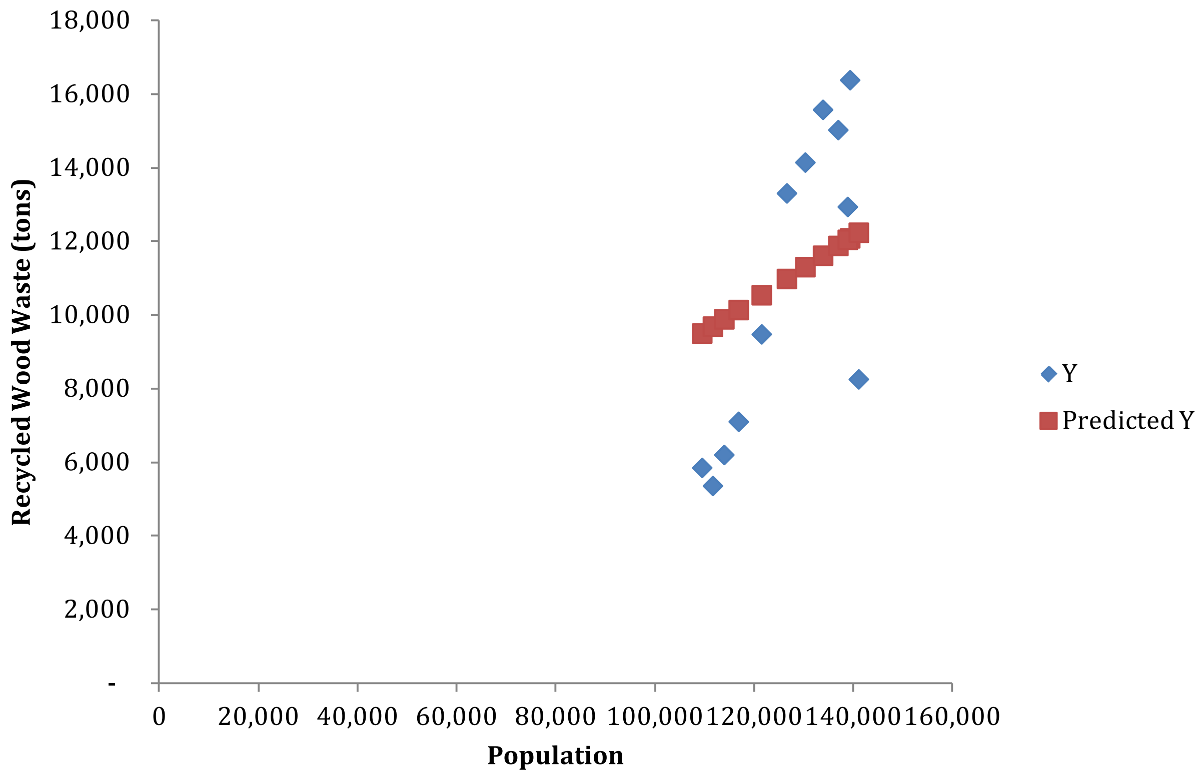
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9659119491	9659119491	11.2639075	0.007289129
Residual	11	9432811360	857528305		
Total	12	19091930851			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
RBP	9.436	2.812	3.356	0.006	3.248	15.625	3.248	15.625

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

RWW per Population in Coeur d'Alene Metropolitan Area for years 2000 - 2011



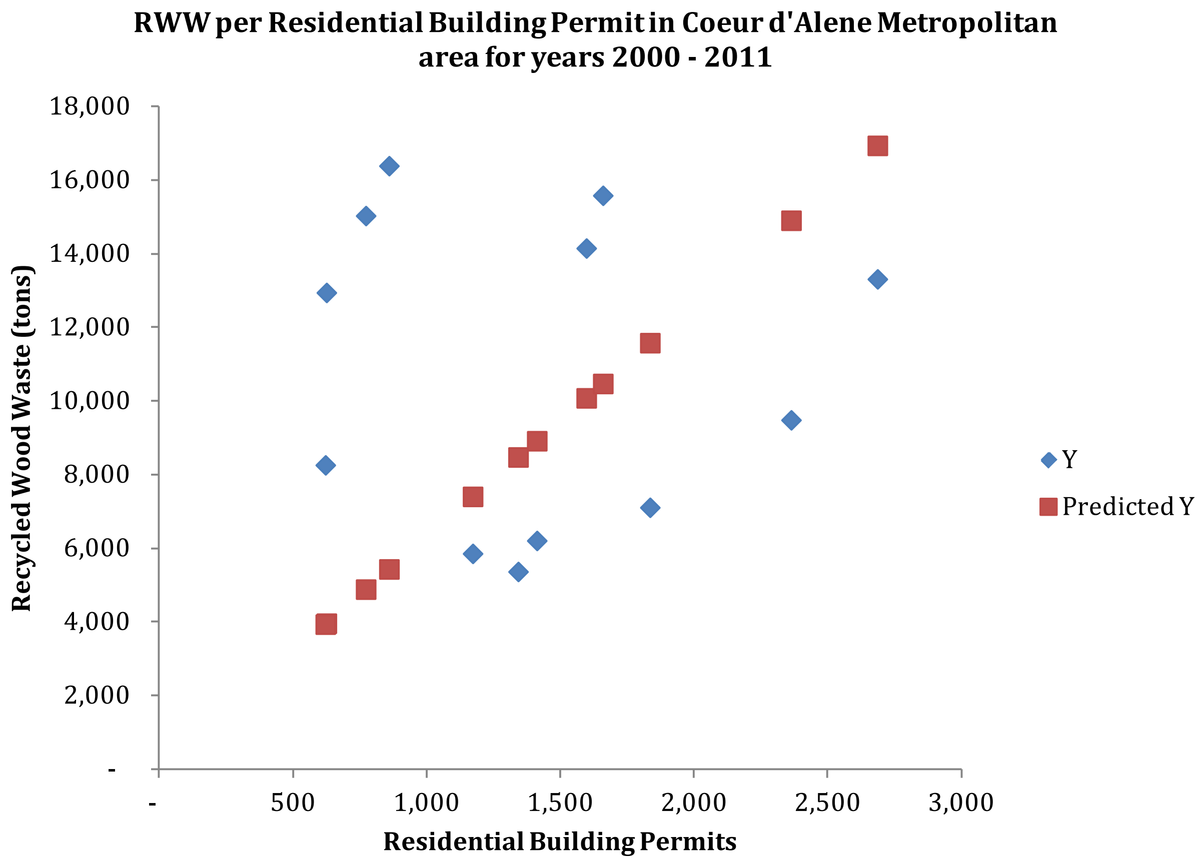
Regression Statistics	
Multiple R	0.958
R Square	0.918
Adjusted R Square	0.827
Standard Error	3439.602
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1459128991	1.459E+09	123.33245	6.03193E-07
Residual	11	130139468.7	11830861		
Total	12	1589268460			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.087	0.008	11.106	0.000	0.069	0.104	0.069	0.104

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



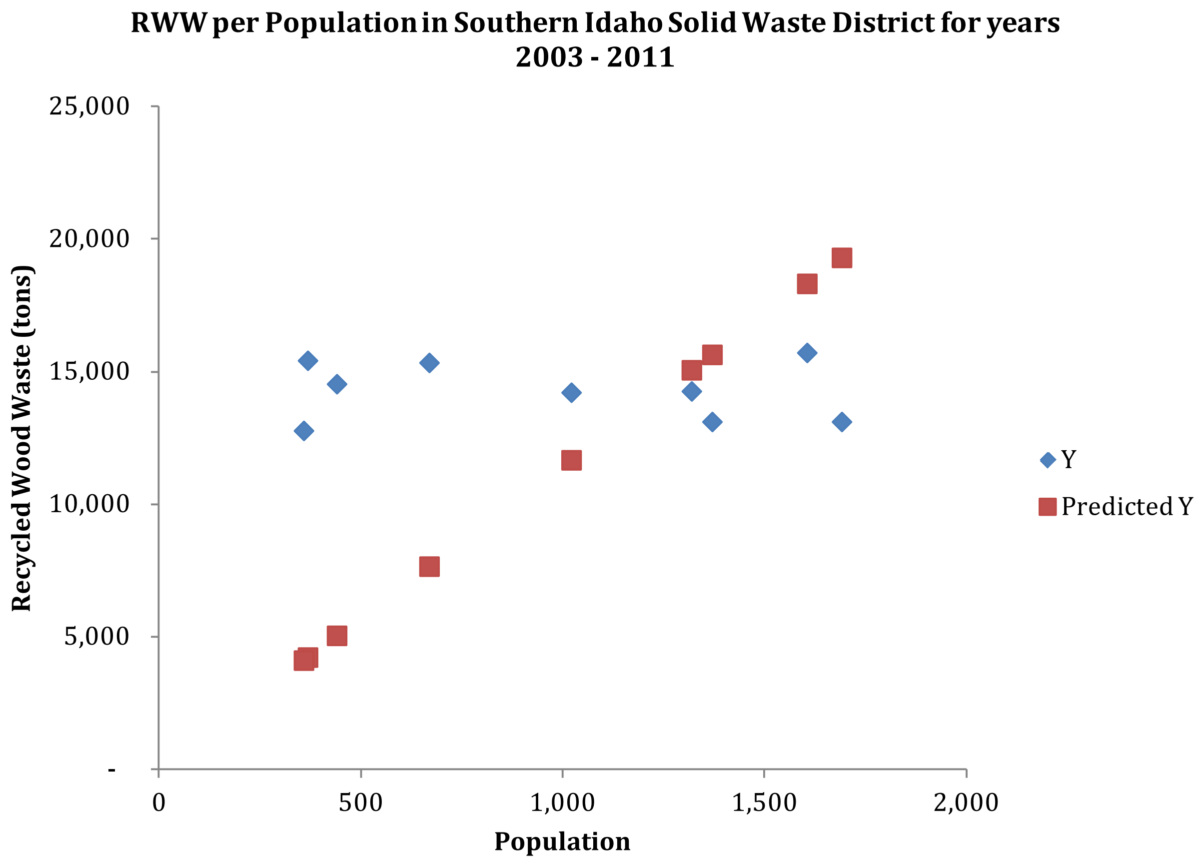
Regression Statistics	
Multiple R	0.848
R Square	0.719
Adjusted R Square	0.628
Standard Error	6373.841
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.142E+09	1.142E+09	28.119641	0.000346156
Residual	11	446884290	40625845		
Total	12	1.589E+09			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
RBP	6.297	1.187	5.303	0.000	3.683	8.910	3.683	8.910

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



Regression Statistics	
Multiple R	0.882
R Square	0.778
Adjusted R Square	0.653
Standard Error	7143.222
Observations	9.000

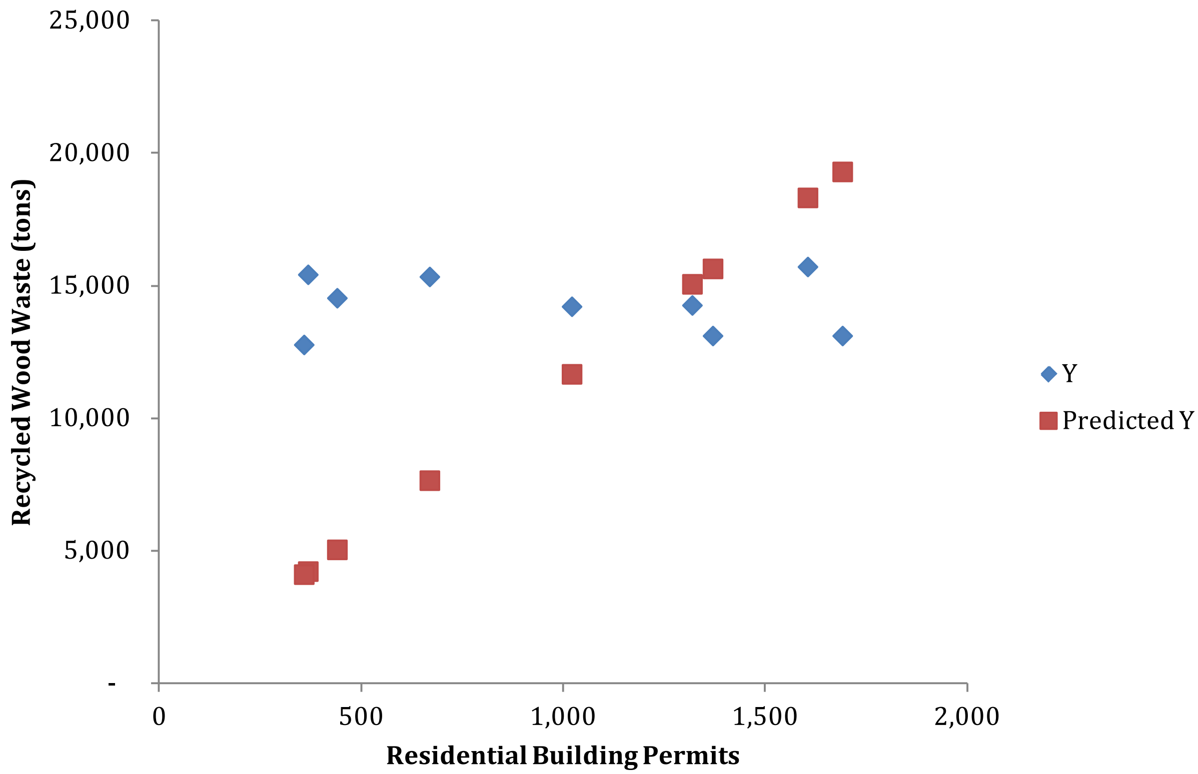
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1430704792	1430704792	28.03894565	0.001129261
Residual	8	408205018.8	51025627.35		
Total	9	1838909811			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	11.396	2.152	5.295	0.001	6.433	16.358	6.433	16.358

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

RWW per Residential Building Permits in Southern Idaho Solid Waste District for years 2003 - 2011



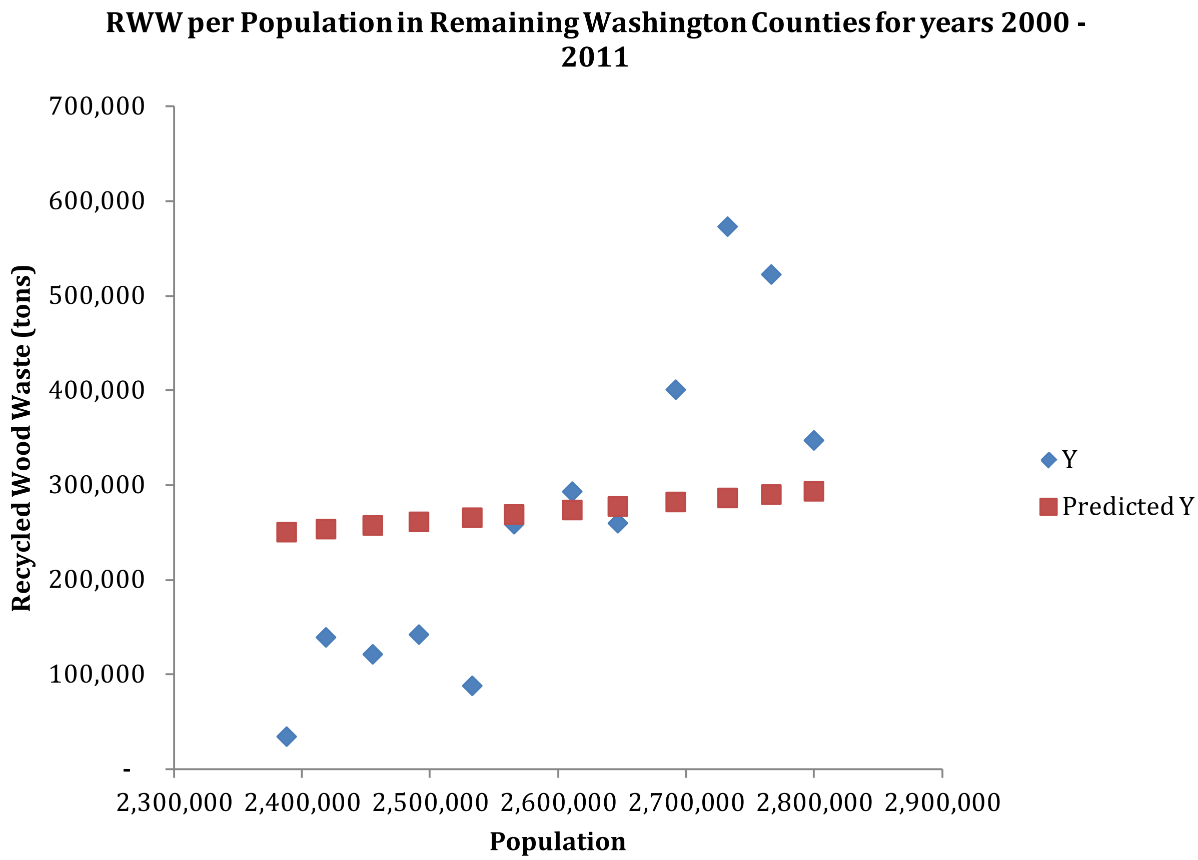
Regression Statistics	
Multiple R	0.882
R Square	0.778
Adjusted R Square	0.653
Standard Error	7143.222
Observations	9.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1430704792	1.431E+09	28.038946	0.0011293
Residual	8	408205018.8	51025627		
Total	9	1838909811			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
RBP	11.396	2.152	5.295	0.001	6.433	16.358	6.433	16.358

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



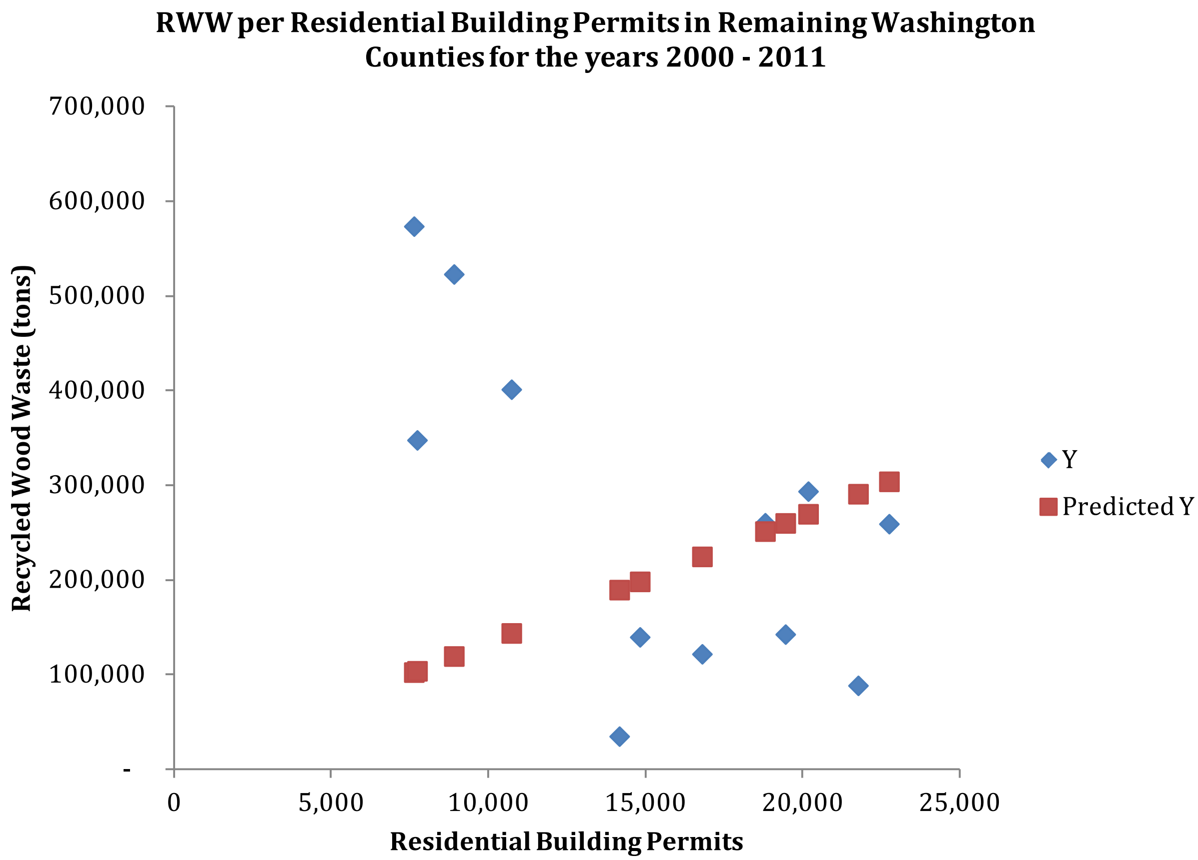
Regression Statistics	
Multiple R	0.873
R Square	0.762
Adjusted R Square	0.671
Standard Error	158926.308
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	8.876E+11	8.876E+11	35.140457	0.0001455
Residual	11	2.778E+11	2.526E+10		
Total	12	1.165E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.105	0.018	5.928	0.000	0.066	0.144	0.066	0.144

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



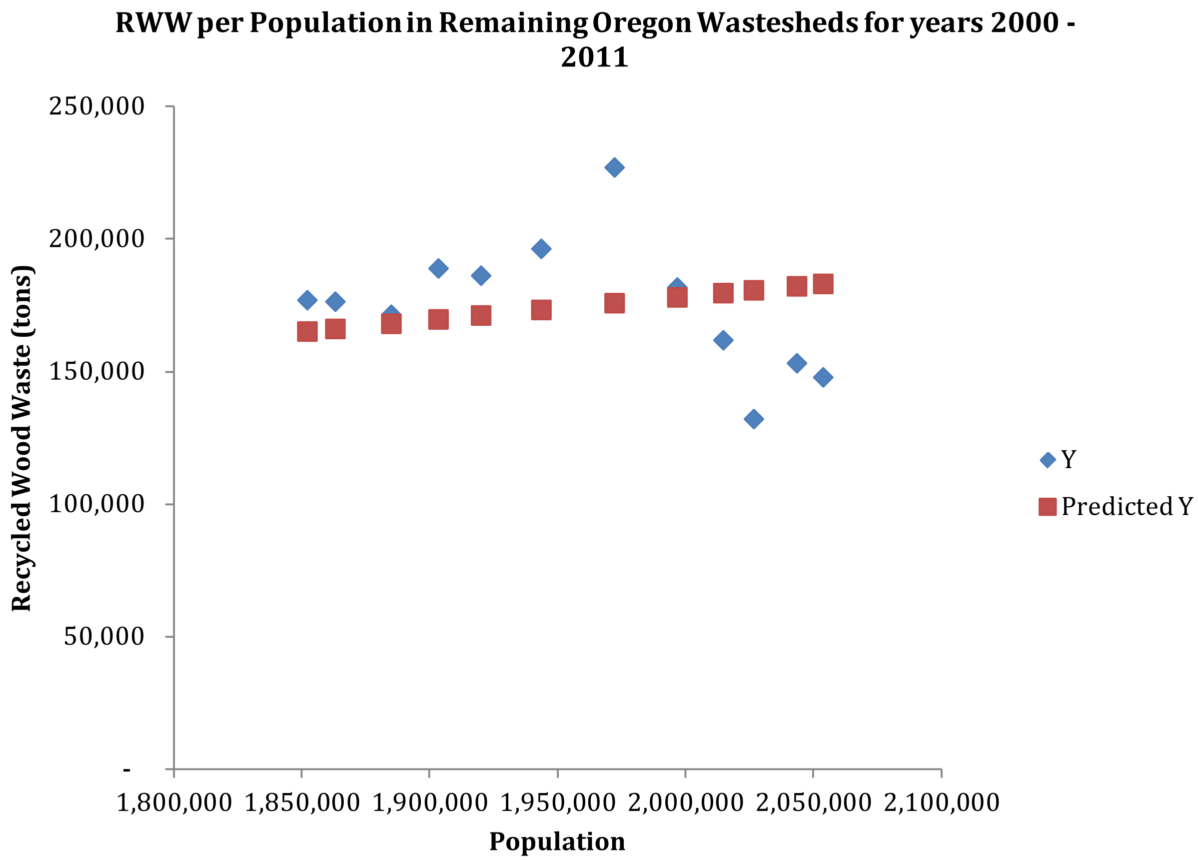
Regression Statistics	
Multiple R	0.693
R Square	0.480
Adjusted R Square	0.389
Standard Error	234662.408
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	5.597E+11	5.59665E+11	10.163449	0.009686709
Residual	11	6.057E+11	55066445745		
Total	12	1.165E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
RBP	13.329	4.181	3.188	0.009	4.127	22.531	4.127	22.531

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



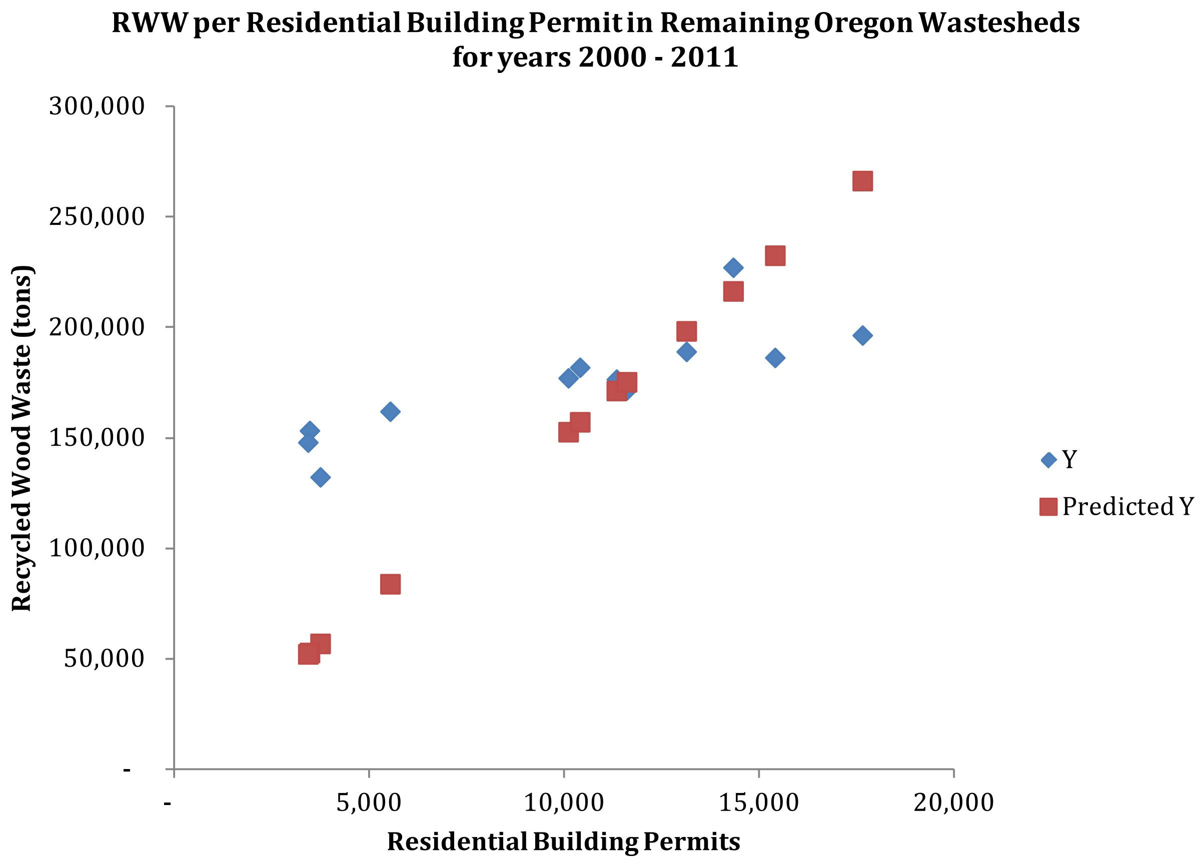
Regression Statistics	
Multiple R	0.988
R Square	0.977
Adjusted R Square	0.886
Standard Error	28245.827
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.65074E+11	3.65074E+11	457.5860179	1.11096E-09
Residual	11	8776094281	797826752.8		
Total	12	3.7385E+11			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.089	0.004	21.391	0.000	0.080	0.098	0.080	0.098

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



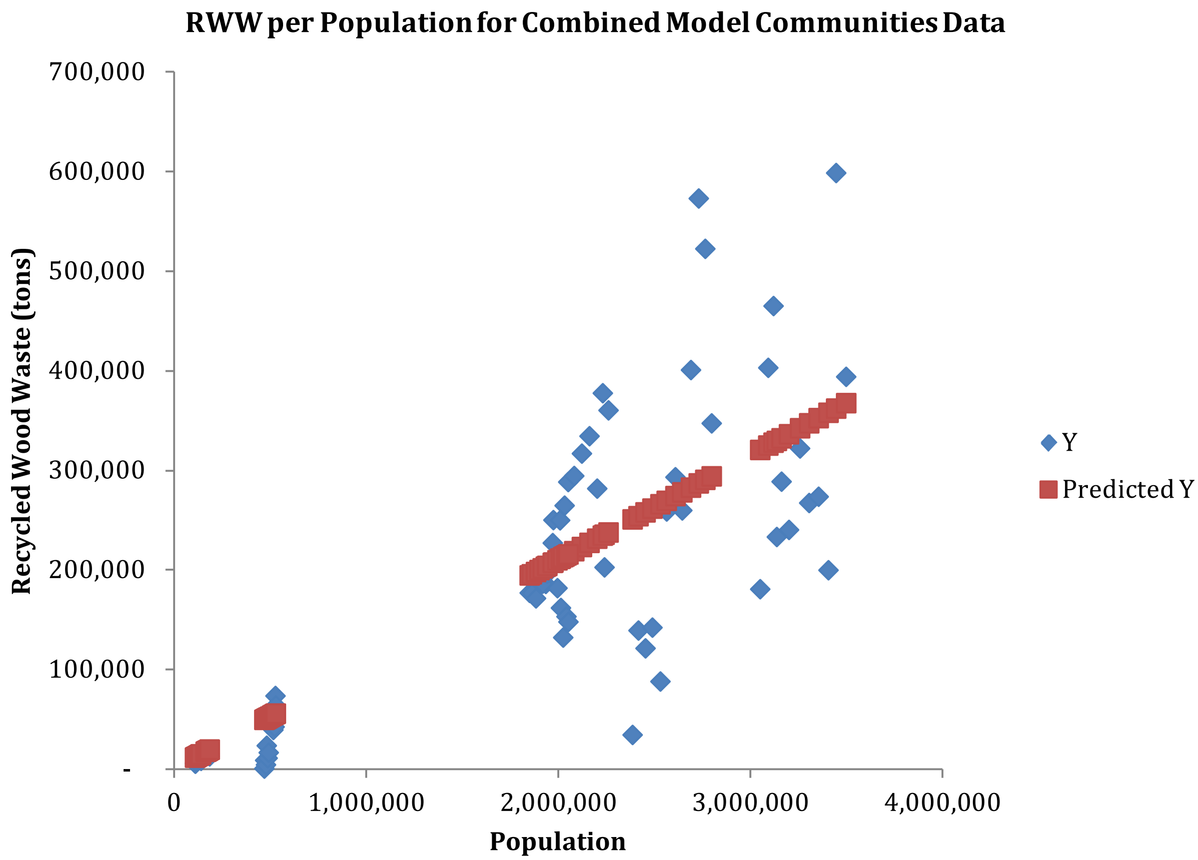
Regression Statistics	
Multiple R	0.946
R Square	0.894
Adjusted R Square	0.803
Standard Error	59954.914
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.3431E+11	3.3431E+11	93.00359378	2.21408E-06
Residual	11	39540509349	3594591759		
Total	12	3.7385E+11			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
RBP	15.068	1.562	9.644	0.000	11.629	18.506	11.629	18.506

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW



Regression Statistics	
Multiple R	0.929
R Square	0.863
Adjusted R Square	0.850
Standard Error	82561.352
Observations	81.000

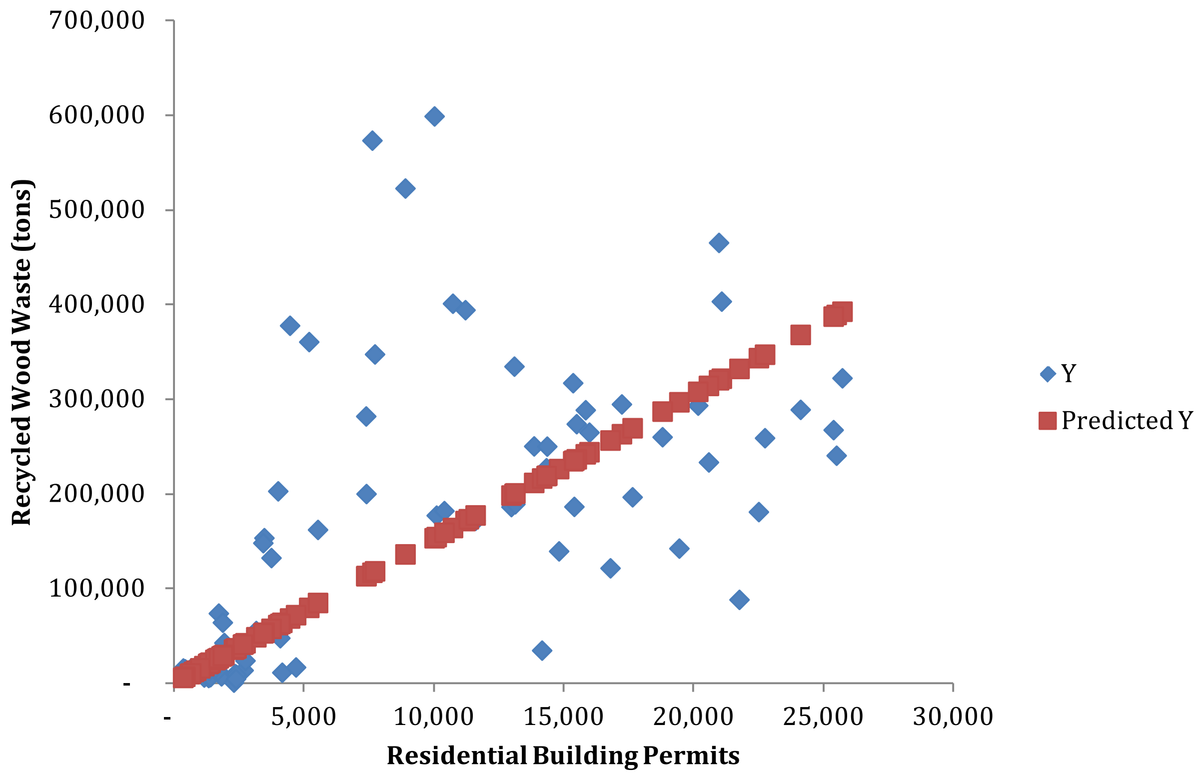
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.4292E+12	3.4292E+12	503.086495	5.27047E-36
Residual	80	5.4531E+11	6816376765		
Total	81	3.9745E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.105	0.005	22.430	0.000	0.096	0.114	0.096	0.114

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

RWW per Residential Building Permits for Combined Model Communities Data



Regression Statistics	
Multiple R	0.821
R Square	0.675
Adjusted R Square	0.662
Standard Error	127100.686
Observations	81.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.68217E+12	2.68217E+12	166.0315388	4.12813E-21
Residual	80	1.29237E+12	16154584304		
Total	81	3.97454E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
RBP	15.237	1.183	12.885	0.000	12.884	17.590	12.884	17.590

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

Multi-Regression of RWW per POP and RBP in Washington

Regression Statistics	
Multiple R	0.973
R Square	0.947
Adjusted R Square	0.842
Standard Error	167776.142
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	5.015E+12	2.507E+12	89.079967	1.17256E-06
Residual	10	2.815E+11	2.815E+10		
Total	12	5.296E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.167	0.023	7.384	0.000	0.116	0.217	0.116	0.217
RBP	-11.685	3.655	-3.197	0.010	-19.827	-3.542	-19.827	-3.542

Multi-Regression of RWW per POP and WEF in Washington

Regression Statistics	
Multiple R	0.985
R Square	0.970
Adjusted R Square	0.842
Standard Error	135571.308
Observations	10.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	4.79981E+12	2.3999E+12	130.574412	2.87427E-06
Residual	8	1.47037E+11	1.838E+10		
Total	10	4.94684E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.069	0.011	6.123	0.000	0.043	0.096	0.043	0.096
WEF	7321.480	1908.714	3.836	0.005	2919.978	11722.982	2919.978	11722.982

APPENDIX B: POTENTIAL FACTORS THAT MAY INFLUENCE RWW

Multi-Regression of RWW per POP and RBP in Oregon

Regression Statistics	
Multiple R	0.998
R Square	0.996
Adjusted R Square	0.896
Standard Error	28144.242
Observations	12.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.9926E+12	9.9631E+11	1257.8128	9.64284E-12
Residual	10	7920983666	792098367		
Total	12	2.0005E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.077	0.005	14.686	0.000	0.066	0.089	0.066	0.089
RBP	6.454	0.932	6.927	0.000	4.378	8.531	4.378	8.531

Multi-Regression of RWW per POP and RBP in Combined Model Communities

Regression Statistics	
Multiple R	0.935
R Square	0.874
Adjusted R Square	0.860
Standard Error	79645.987
Observations	81.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.4734E+12	1.7367E+12	273.7771934	5.462E-36
Residual	79	5.01135E+11	6343483212		
Total	81	3.97454E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Population	0.134	0.012	11.168	0.000	0.110	0.158	0.110	0.158
RBP	-5.213	1.975	-2.639	0.010	-9.144	-1.281	-9.144	-1.281