POLICY REPORT

The Potential for Sustainable Wood-Based Bioenergy in Maryland

Developing Safeguards for Woody Biomass Harvests and Evaluating Wood-Based Bioenergy Markets

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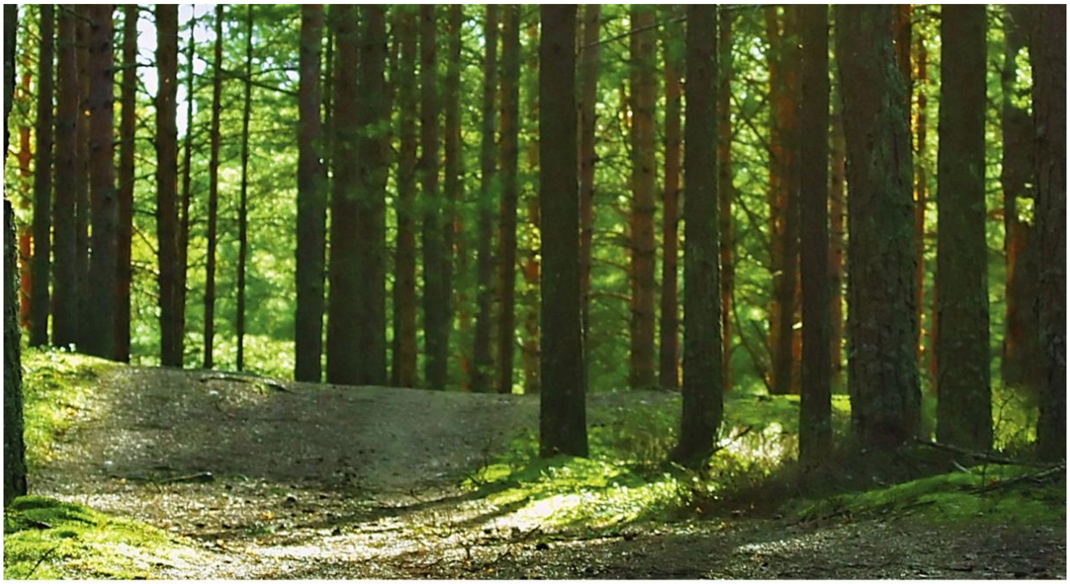

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EXECUTIVE SUMMARY 7
INTRODUCTION 11
CHAPTER 1 - POTENTIAL AVAILABILITY OF WOOD BIOMASS RESOURCES IN MARYLAND 13
1.1 INTRODUCTION 13
1.2 OVERVIEW OF MARYLAND'S FOREST RESOURCE 13
1.3 OVERVIEW OF MARYLAND'S FOREST INDUSTRY 15
1.3.1 Economic contribution of Maryland's forest sector 15
1.3.2 Classification of the wood products industry 16
1.3.3 Size and location of Maryland's wood products industry 17
1.3.4 Flow of the regional timber supply 18
1.3.5 Potential synergy and potential competition 20
1.4 MARYLAND'S WOODY BIOMASS RESOURCE 23
1.4.1 Review of studies of Maryland's biomass supply 27
1.4.2 Methods for assessing woody biomass availability from forests 30
1.4.3 Estimates of forest-derived biomass 33
1.4.4 USFS Forest Products Laboratory estimates 33
1.4.5 Results of analysis of FPL data 35
1.5 FACTORS AFFECTING AVAILABILITY OF FOREST-DERIVED BIOMASS 36
1.5.1 The impacts of parcel size 36
1.5.2 The impact of landowner attributes 40
1.5.3 Uncertainty in the supply chain 42
1.6 SUMMARY OF WOODY BIOMASS AVAILABILITY IN MARYLAND 45
1.6.1 Urban wood waste 45
1.6.2 Land clearing debris 46
1.6.3 Tree care debris 47
1.6.4 Summary of estimates of urban wood waste 48
1.6.5 Primary and secondary wood residues from manufacturing 49
1.6.6 Dedicated energy crops 50
1.6.7 Summary table of woody biomass supply 53
1.7 CONCLUSIONS AND RECOMMENDATIONS ON BIOMASS SUPPLY 55
CHAPTER 2 - DEFINING APPROPRIATE TECHNOLOGIES FOR BIOMASS UTILIZATION 59
2.1 INTRODUCTION 59
2.2 BIOPOWER POTENTIAL 63
2.3 CO-FIRING POTENTIAL 65
2.4 COMBINED HEAT AND POWER POTENTIAL 68
2.5 GASIFICATION / BIGCC 73
2.6 DENSIFIED BIOMASS POTENTIAL 74
2.7 THERMAL CONVERSION POTENTIAL 78
2.8 LIQUID BIOFUELS POTENTIAL 86
2.9 DEVELOPING TECHNOLOGIES 88
2.10 CONCLUSIONS AND RECOMMENDATIONS ON ENERGY TECHNOLOGIES 89
CHAPTER 3 - ENERGY POLICY AND BIOMASS MARKETS 91
3.1 INTRODUCTION 91
3.2 MARYLAND RULES, REGULATIONS, AND POLICIES 91
3.2.1 State regulations and standards 91
3.2.2 State non-regulatory policy goals 95
3.2.3 State financial incentives 98
3.3 FEDERAL RULES, REGULATIONS AND POLICIES 99
3.3.1 Federal regulations and standards 99
3.3.2 Federal financial incentives 100
3.4 CONCLUSIONS AND RECOMMENDATIONS ON ENERGY POLICY 102

CHAPTER 4 - ENVIRONMENTAL CONSIDERATIONS ASSOCIATED WITH FOREST BIOMASS HARVESTING 105

4.1 INTRODUCTION 105
4.2 THE ROLE OF DEADWOOD 106
4.2.1 Managing risks associated with the removal of DWM 107
4.3 PROTECTION OF FOREST SOILS 109
4.3.1 Potential impacts to soil nutrients 109
4.3.2 Managing the risks to soil resources 112
4.3.3 Forest fertilization 113
4.3.4 Maryland's soils in context 115
4.4 CONSERVATION OF WILDLIFE HABITAT AND BIOLOGICAL DIVERSITY 121
4.4.1 Wildlife habitat 121
4.4.2 Site level biodiversity and DWM 122
4.4.3 Restoration of early successional habitats 123
4.4.4 Plant and animal communities of special concern 124
4.5 PROTECTION OF WATER QUALITY AND AQUATIC RESOURCES 125
4.5.1 Water quality BMPs 125
4.5.2 The role of deadwood in the protection of water quality 126
4.6 SILVICULTURAL PRACTICES 127
4.6.1 Interest in biomass harvesting as a silvicultural tool 127
4.6.2 Forest management planning 128
4.6.3 Plantation forest management 128
4.7 MANAGEMENT OF SHORT ROTATION WOODY CROPS 129

CHAPTER 5 - REGULATORY AND NON-REGULATORY TOOLS THAT GOVERN FOREST MANAGEMENT IN MARYLAND 130

5.1 INTRODUCTION 131
5.2 APPROACHES TO FOREST MANAGEMENT 131
5.3 NON-REGULATORY PROGRAMS 133
5.3.1 Forest Stewardship Planning 134
5.3.2 Woodland Stewards Program 135
5.3.3 Forest Conservancy District Boards 135
5.3.4 Forestry for the Bay 135
5.3.5 Maryland Master Logger Program 136
5.3.6 Sustainable Forestry Act 136
5.3.7 Woodland Incentives Fund 137
5.3.8 Relevant State Tax Incentives 138
5.3.9 Forest Certification Systems 138
5.4 REGULATORY PROGRAMS 145
5.4.1 Forest Conservancy District Law 145
5.4.2 Pine Tree Reforestation Law 146
5.4.3 Erosion and Sediment Control Regulations 147
5.4.4 Chesapeake Bay Critical Areas Law 149
5.4.5 Forest Conservation Act 150
5.4.6 Forester Licensing Law 150
5.4.7 Forest Products Licensing Law 151
5.7.8 Road Side Tree Care Law 151
5.5 RELEVANT FEDERAL POLICIES 154
5.6 CONCLUSIONS AND RECOMMENDATIONS ON NATURAL RESOURCE POLICY 154

LITERATURE CITED 160

APPENDIX 174

GLOSSARY OF TERMS 174
RELEVANT CONVERSIONS 182

Figures

Figure 1. Consumption of Maryland's roundwood 19
Figure 2. Woody biomass supply categories 24
Figure 3. Estimated biomass in Maryland at various projected delivered costs 28
Figure 4. Potentially available quantities of biomass in nearby counties of adjacent states 30
Figure 5. Regions of potential biomass supply 32
Figure 6. Conceptual diagram of bioenergy systems 59
Figure 7. Relative efficiency of various bioenergy options. 61
Figure 8. Fuel use efficiency of an industrial CHP system as compared to generation of electricity and steam through separate processes 69

Tables

Table 1. Wood fiber flow in Maryland by product category (Green Tons) – 2001 20
Table 2. Counties from which biomass is assumed to be potentially economically available 31
Table 3. Description of Maryland forest Parcels in five subregions 38
Table 4. Potential for forest biomass based on parcel size 39
Table 5. Planned management activities of Maryland landowners 40
Table 6. Maryland's logging infrastructure 43
Table 7. Potentially recoverable wood from MSW and C&D (Green Tons) 48
Table 8. Potentially recoverable wood from urban areas in Maryland 49
Table 9. Availability of mill residues in subregions (dry tons) 50
Table 10. Summary of potential bioenergy feedstock energy yields for idle cropland and conservation lands and estimated production costs compared to coal 52
Table11. Biomass availability by subregion at varying price estimates 54
Table12. Mean percentage of total population and biomass availability by subregion 55
Table 13. Relative efficiencies of bioenergy options studied 60
Table 14. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential in Maryland 62
Table15. CHP technical potential in Maryland's commercial and institutional sector 72
Table16. Energy source quantity and price equivalent to one ton of wood pellets at $200/ton 76
Table 17. Residential wood combustion in Maryland 82
Table 18. Alternative energy source price equivalent to one ton of wood pellets at $200/ton, average residential price in Maryland, and potential fuel savings 85
Table 19. Maryland renewable energy credits generated by wood biomass in 2008 93
Table 20. Mass of DWM in Western, MD Appalachian Hardwoods 106
Table 21. Summary of non-regulatory policies and programs directly affecting forest management in Maryland 142
Table 22. Summary of regulatory policies and programs directly affecting forest management in Maryland 152

Tables in the Appendix

Table A-1. Estimated potential switchgrass yields and production costs on idle cropland and lands enrolled in conservation programs
Table A-2. Estimated potential hybrid poplar yields and production costs on idle cropland and lands enrolled in conservation programs
Table A-3. Estimated potential willow yields and production costs on idle cropland and lands enrolled in conservation programs
Table A-4. Biomass availability by subregion at varying price estimates adjusted for harvestable acreage
Table A-5. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential in western Maryland
Table A-6. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential in central Maryland
Table A-7. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy

potential in southern Maryland
Table A-8. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential on the upper eastern shore
Table A-9. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential on the lower eastern shore
Table A-10. Co-firing potential of Maryland's pulverized coal boilers
Table A-11. Comparison of wood biomass feedstock estimates for counties sourcing potential co-firing facilities
Table A-12. Difference between facility demands and estimated feedstock availability
Table A-13. Comparison of facility demands on estimated feedstock availability

Photo: Brian Kittler

Executive Summary

Emerging markets for woody biomass may contribute to the sustainable management and conservation of Maryland's forests by expanding the range of forest management opportunities available to landowners. However, these same markets raise concerns about the potential for negative impacts to the state's natural resources and existing industry. This study evaluates a number of social, economic, and environmental sustainability concerns regarding the development of wood-based bioenergy markets in Maryland. As such, this report explores biomass supply, utilization technologies, energy and natural resource policies, and the science behind biomass harvesting, in an integrated manner.

This report also serves as the foundation for *A Guide to Forest Biomass Harvesting and Retention in Maryland*, a set of voluntary guidelines developed to build upon the state's existing natural resource management policies and promote sustainable forest management should demand for woody biomass increase.

Sustainability and market expansion

Wood biomass markets have existed in Maryland for more than twenty years, yet this experience is largely limited to the wood products industry and one small facility with modest feedstock requirements. Landowners supplying this facility report expanded management options and incentive to reinvest in their forests. In recent years, energy policy has stimulated increased investment to expand bioenergy markets across the country. In Maryland, although significant speculation has occurred, such investments have yet to be made.

> <u>Key Finding</u> – **For bioenergy projects to be sustainable, site-level due diligence must consider: constraints on biomass supply including competition, social preferences, energy demand, and potential environmental impacts.**
>
> – State environmental review and forest product licensing processes, and supply analyses that are prerequisite for financial backing, may address much of this need for due diligence.
>
> – Individual energy facilities can adopt sustainable sourcing policies to help ensure sustainability.

Safeguards for biomass harvests

A number of existing programs governing forest management in Maryland address concerns related to soil health, water quality, wildlife habitat, biodiversity, and other ecosystem services. The integration of biomass harvesting guidelines with current outreach, education, and extension programs, such as the Maryland Master Logger Program, may offer assurances that sustainability is considered when such harvests are carried out in the field. Monitoring of the impacts of biomass harvests and the effectiveness of biomass harvesting guidelines is essential.

> **<u>Key Finding</u> – If biomass harvests are to contribute to sustainable management, biomass harvesting guidelines and forest management plans will need to be followed.**

Assessing regional biomass supply

Analyzing regional wood supply dynamics is a complex, but critical process when assessing potential for bioenergy development. There is tension between producing energy in facilities that are large enough to achieve economies of scale and supplying these facilities with a sustained fuel supply that is readily sourced from across the landscape.

> **<u>Key Finding</u> – When social, economic, ecological, technological, and other logistical constraints to biomass supply are considered, Maryland's available and sustainable supply is considerably reduced from estimates that consider physical inventory alone.**

- While Maryland's forests are extensive, their ability to support bioenergy development is significantly reduced (up to 80.5%) due to a number of social and economic constraints.
- If cultivated on Maryland's idle lands, more than 600,000 green tons of wood biomass could be available from dedicated wood energy crops each year. However, this supply is not economically feasible without subsidy, an increase in the price of energy alternatives (e.g. coal and natural gas), and/or valuing the ecological services provided by energy crops in ecosystem service markets.
- Over half of Maryland's total biomass supply comes from urban areas; however, just how much of this material is recoverable and usable as feedstock remains unclear.

Evaluating bioenergy options

Bioenergy projects are more likely to be sustainable if scaled appropriately to the economically, ecologically, and socially available supply of biomass. The optimal site, size, and type of bioenergy facility depends on the distribution of biomass resources, transportation costs, economies of scale, and energy demand.

> **<u>Key Finding</u> – Large-scale options with high fuel demands (e.g., electricity-only biopower plants, co-firing at coal-fired plants, and commercial-scale biorefineries) are likely to be less viable in Maryland.**

- Only central Maryland has enough feedstock to potentially supply a biopower facility capable of producing electricity at competitive prices. Relying greatly on urban wood waste, such a facility would only produce enough electricity to power 4% of Maryland's detached single-family homes.
- Co-firing biomass in existing power plants is one of the least capital-intensive and most easily implemented options to mitigate fossil fuel consumption. However, the relative inefficiency of co-firing, coupled with the fuel demands of utility-scale coal boilers, would likely prove taxing on biomass supplies in Maryland.
- Commercial-scale production of wood-based cellulosic ethanol is not presently feasible in Maryland when supply constraints are considered. Commercial-scale ethanol production is only economical in large facilities (at least 50 million gallons per year) that consume considerable volumes of biomass. If cellulosic ethanol could be produced at competitive prices in facilities producing 30 million gallons per year, it is technically possible for Maryland to support up to two cellulosic ethanol facilities of this scale with the state's current supply of woody biomass, but only if 100% of forest landowners participate, and 100% of the maximum potential supply of urban wood waste is used. These facilities would produce enough ethanol to equal just over 2% of Maryland's annual consumption of gasoline.

Key Finding – Small to moderate-scale bioenergy options (e.g., residential and institutional thermal energy projects, combined heat and power, and densification facilities) are more likely to be sustainable in Maryland.

- District thermal and "Fuels for Schools" type projects hold significant promise to use Maryland's limited biomass supply efficiently while keeping energy dollars local. A number of financial mechanisms that could support this type of venture are already in place within the state.
- Maryland has up to 3,000 opportunities to produce both usable heat and electricity in the most fuel-efficient manner available, and biomass may be an ideal fuel for a number of these combined heat and power (CHP) facilities. Maryland's net metering and interconnection policies may provide impetus for such projects, but additional support for CHP may be necessary.
- Converting to wood pellet appliances may offer homeowners substantial savings over the long-run as pellet fuels cost 20 – 70% less than traditional home heating fuels. Such a strategy also reduces the state's consumption of fossil fuels, as 33% and 16% of Maryland homes are heated by electricity and home heating oil respectively.

Implications for policy

Careful review of renewable energy policy proposals is needed given concerns related to the sustainability of biomass supplies and market competition with existing wood-users.

Key Finding – Existing bioenergy policies focus primarily on electricity and transportation fuels, but Maryland has limited potential to sustainably develop these market areas.

- Evaluate state policy goals for bioenergy to identify areas of synergy, incongruence, and infeasibility.
- Different policies will result in different outcomes for the energy and forest sectors. If carefully crafted, there is potential for energy policy to strengthen the forest sector, by capitalizing upon synergies between the energy and forest products sectors.
- Maryland's biomass resource has potential to support renewable energy goals for the 40% of Maryland's total energy demand that comes as thermal energy. Few existing renewable energy policies address this sector, yet thermal, CHP, and small-scale biomass densification offer the most potential for sustainable bioenergy development in Maryland.
- Renewable thermal energy from CHP and thermal technologies does not currently qualify for renewable energy credits (RECs) under Maryland's renewable portfolio standard. The state may wish to reevaluate this ruling, particularly if black liquor is excluded as a Tier 1 resource.
- Most policy focuses on generating demand for biomass energy, while doing little to guarantee feedstock supply. If Maryland's renewable energy future is to include biomass, policies supporting development of sustainable supply chains may be needed. It is imperative that any such policies be very carefully crafted to avoid unintended market distortions and unsustainable outcomes for forest resources.

Introduction

In recent years, interest in bioenergy has grown significantly within the forest and energy sectors, albeit for different reasons. The energy sector primarily views an expansion of bioenergy markets as a way to respond to public policy goals for renewable energy development. While many forest landowners and managers view an expansion of wood-based bioenergy markets as an opportunity to further goals for the sustainable management and conservation of Maryland's forests. This study explores the extent to which an expansion of bioenergy markets in Maryland would be consistent with these visions.

Markets for low-value **woody biomass** may offer managers an important opportunity to reduce the incidence of **high-grading** and other undesirable management practices. However, low-value woody biomass is currently unmerchantable in Maryland; the costs of harvesting, collecting, and transporting biomass from forests are simply greater than what existing markets will pay for the material. If bioenergy markets were to develop, it is conceivable that prices for woody biomass from forests could rise high enough to cover these costs, and even generate positive values for landowners in some instances. Under such a scenario, there are likely forest landowners who would be willing to reinvest in **timber stand improvement (TSI)** activities, such as pre-commercial thinning and **regeneration harvests**, to improve the health, resiliency, and overall productivity or their forests.

Defining terms

To help readers understand bioenergy markets, this report includes a glossary in the appendix that articulates the definitions of several bolded words and phrases within the text. **Forest-derived biomass** and woody biomass are referred to somewhat interchangeably throughout this report. In reality, *forest-derived biomass* is the entire vegetative biota within a forest and *woody biomass* describes all fibrous cellulose/lignin-based material (e.g., branches and stems) from woody plants, regardless of species, state, or market price. However, for the sake of discussion, both definitions will be narrowed to describe material that may be harvested for energy markets as **energy wood**.

Policy also defines such terms and thus shapes bioenergy markets. For instance, Maryland's Climate Action Plan states that, "*all biomass products will be sustainably harvested without depriving soils of important organic components for reducing erosion and maintaining soil nutrients and structure, nor depleting wildlife habitat or jeopardizing future feedstocks in quantity and quality*." Similarly, the Maryland Public Services Commission, which administers Maryland's Renewable Portfolio Standard, defines **qualifying biomass** (i.e., biomass resources that are allowed to contribute to the production of renewable electricity and generate renewable energy credits). While only one of these definitions, specifically *qualifying biomass*, has the weight of law behind it, they both heavily influence the development of bioenergy markets in Maryland.

Exploring questions of sustainability

The potential expansion of markets for energy wood in the Mid-Atlantic raises some important questions about the complexity and sustainability of bioenergy systems. How much wood fuel is currently harvested and consumed within this region? Do the region's forests and supply chain infrastructure have the capacity to support additional harvests? Can forest-derived biomass be harvested in a sustainable manner? How much low-value and non-commercial woody biomass is available over the long-term? Will there be competition for biomass, and if so, how will this affect the existing forest products industry? How do social and biophysical factors constrain biomass supply? Are **short rotation woody crops (SRWCs)** and other energy crops a realistic option? How extensive and reliable are supplies of **urban wood waste**? What types of bioenergy systems could best fit with Maryland's existing natural resource based industries?

These and other questions must be addressed if an expansion of the region's wood-based bioenergy capacity is to be sustainable. Indeed, finding a balance point that maximizes the opportunities of emerging bioenergy markets, while limiting the potential for unintended and negative consequences presents a significant challenge. While this report explores several questions related to the sustainability of bioenergy markets, others (e.g., lifecycle GHG balance) are touched upon only briefly, and warrant further discussion. Even among some issues addressed in detail, there remains considerable uncertainty that only long-term research could adequately tackle.

Report structure

In this report, the concept of sustainability is addressed in an integrative fashion. Thus, the first three chapters are intended to help clarify who the actors are likely to be in bioenergy markets, how these actors may respond to price signals, and how and why their actions may be constrained. Other issues explored in this report include the potential feedstock demands of various energy technologies, the energy outputs of these technologies, and the policies that influence their development. The last two chapters evaluate the ability of Maryland's system of voluntary and regulatory forest management programs to safeguard forest productivity, soil and water quality, wildlife habitat and biodiversity, and other natural resource values during biomass harvest regimes. The information from these last two chapters was instrumental in the development of *A Guide to Forest Biomass Harvesting and Retention in Maryland*, a voluntary set of practical biomass harvesting guidelines for loggers and foresters. While each chapter of this report ends with a number of conclusions and recommendations, the biomass harvesting guidelines functionally serve as the recommendations associated with chapter four. The conclusions and recommendations in this report are offered to further the public dialogue about the potential for sustainable wood-based energy as a component of Maryland's energy future.

Chapter 1

Potential Availability of Wood Biomass Resources in Maryland

1.1 Introduction

This chapter highlights many of the biomass supply chain factors influencing bioenergy market development in Maryland. To this end, chapter one provides: (1) A description of Maryland's forest resource; (2) A description of Maryland's existing wood-using industries and the flow of various types of materials through these industries; (3) An overview of biomass supply chains in Maryland; and (4) An analysis of biomass feedstock supply potential for Maryland.

1.2 Overview of Maryland's Forest Resource

Forests make up 41% (2.6 million acres) of Maryland's total land area, 90% of which is **timberland** (MD DNR, 2006a). The remaining 10% of forestland in the state is mostly held in reserve areas, where timber harvests are not undertaken. In Maryland, public forest land (3% federal, 17% state, and 4% local) comprises 609,000 acres in all, with 424,000 acres being owned and managed by the Maryland Department of Natural Resources (MD DNR) for "multiple uses." The remaining three-quarters of the state's forest land is privately owned and managed by more than 157,000 individual landowners (MD DNR, 2006a).

The USDA Forest Inventory and Analysis (FIA) data for Maryland suggests that net annual growth in **growing stock** was roughly 45 cubic feet per acre per year in 1999. However, based on the biophysical potential of Maryland's forests, productivity gains to over 65 cubic feet per acre per year may be realized through marginal increases in management intensity via pre-commercial thinning (Irland, 2004). In 2001, the rate of growth in Maryland's timberland exceeded the rate of removals by roughly 37%, a trend that has largely continued since that time (Irland, 2004).[1] However, the removal of commercially desirable species such as loblolly pine and oaks was roughly equal to growth, meaning that less commercially desirable species, like red maple and sweetgum, account for a significant amount of Maryland's net annual growth; providing evidence that the state's forests are commonly high-graded.

The number of commercially valuable oaks continues to decline in Maryland's forests (USDA, 2006a). A legacy of high-grading, insect infestation, disease, deer browsing, **acid deposition**,

[1] In 2001 net-growth (the ratio of growth to removals and mortality) of sawtimber was 181 board feet per acre per year as compared to a removal rate of 115 board feet per acre per year.

suppression of low-intensity ground fire, and climate change have all contributed to this decline. In addition to their value as timber, oaks also play important roles in forest ecosystems as a staple food source and habitat component for a variety of forest animals. While oaks and some other northern species (hard maple and hemlock in particular) struggle, southern hardwood and pine species appear to be increasing their presence in Maryland's forests. This raises challenging questions about potential shifts in species composition across Maryland's forests. Can forests be managed in a way that will encourage regeneration of productive stands capable of producing high-quality ecosystem services and high quality timber well into the future? Do high rates of mortality lead to new harvesting opportunities, and a potential woody biomass supply? If so, how long will this supply last?

In addition to these impacts to forest health and productivity, the most serious threat to Maryland's forests is urban and suburban development. From 1961 to 1999, the average annual loss of forest increased from 13,600 acres to more than 14,000 acres (Bones, 1980; MD DNR, 2006a). When last measured in 2006, Maryland was still losing an average of 7,200 acres of forest per year, despite advances in land use policy and planning. Into the future, central and southern Maryland are expected to see the highest rates of forest loss, while western Maryland and the lower eastern shore are expected to face comparatively low rates of forest loss. However, a significant unknown is the impact a large, oncoming inter-generational transfer of private land will have on rates of land conversion (Irland, 2004; Pinchot Institute, 2007; Butler *et al*., 2009). Markets for woody biomass may help increase the value of forest land, but the development of such markets depends greatly on forest landowner preferences, energy market demand for woody biomass, and the economics of removing biomass in a sustainable manner.

The likelihood for a significant transfer of land ownership foreshadows a potential increase in **parcelization** and **forest fragmentation** in the coming years. Fragmentation and parcelization present the challenge of coordinating management decisions and actions across multiple parcels and landowners, amplifying the difficulties of maintaining forest health (Sampson and DeCoster, 2000). In addition to losing the ecosystem services (clean water, clean air, carbon sequestration, wildlife habitat, etc.) that these forests provide, cleared, converted, and parcelized land also represents a reduction in the aggregate sustainable woody biomass supply. For example, the 190,000 acres of forestland that was lost to development in Maryland between 1973 and 1997 represents the loss of a sustainable wood supply of approximately 285,000 green tons per year,[2] just slightly more than the volume of wood residuals that is estimated to currently be consumed as fuel in Maryland on an annual basis. When looking at this situation in terms of the opportunity cost for renewable energy production, this volume of wood could supply up to six

[2] In this example, the sustainability of this biomass supply is defined as a source of biomass from managed forestland in which removals of biomass are equal to net annual growth, with an average net annual growth in Maryland's forests of 1.5 tons (45 cubic feet) per acre per year.

combined heat and power (CHP) facilities like the one that provides the majority of the heat and power to the Eastern Correctional Institution (ECI) in Somerset County, Maryland.

Photo: Brian Kittler

1.3 Overview of Maryland's Forest Industry

1.3.1 Economic contribution of Maryland's forest sector

In the years prior to the most recent economic recession, Maryland's forest industry produced an estimated $3 billion in direct, indirect, and induced economic output annually (Salisbury State University, 2004). An important part of Maryland's economy, the wood products industry provides 27,610 jobs (direct, indirect, and induced), many of which are high-wage manufacturing jobs in both rural and urban communities (F2M, 2009).[3] When considering all major industries within Maryland, the forest industry is the largest employer in Allegany and Garrett Counties, and the second-largest employer on the Eastern Shore. Approximately 2,500 – 5,000 of these jobs depend greatly on wood harvested in Maryland, while about 9,000 – 10,000 of these jobs depend on material that is imported from nearby states (Irland, 2004).

[3] Data from the Forest 2 Market report uses 2006 economic census data which occurred prior to the most recent economic recession. There may have been additional changes in Maryland's forest industry since the data underlying this report were gathered.

Maryland's standing timber resource is also of high-value. In fact, on an acre-per-acre basis Maryland's forests produced the highest value of timber per acre of any state in the nation in 2006 (F2M, 2009). This statement is of particular interest when considering the overall composition of the state's forests. As mentioned earlier, the majority of Maryland's forest acres show evidence of historic high-grading. It is therefore likely that high timber values have in part led to unsustainable forest management in Maryland in instances where markets for low-value timber were insufficient to balance demand for high-value timber. Should markets for woody biomass develop, land managers may be poised to capitalize on this sawtimber value, by balancing the demand for sawtimber with demand for biomass, and implementing carefully planned dual-market harvests.

In addition to revenue from the wood products industry, public and private forests provide other significant economic contributions. For example, Maryland's forests provide landowners with other sources of income through hunting leases and the sale of non-timber forest products. Maryland's forests provide myriad ecosystem services that are largely unvalued in traditional markets. These potentially marketable services include the sequestration of atmospheric carbon, the provision of clean drinking water and clean air, as well as wildlife habitat and biodiversity. In time, revenue may be generated for these services as science and policy have clearly moved towards valuing these ecosystem services in market transactions (P.L. 110-234 § 2709; E.O. 13508). While it may be possible to estimate the growth potential of ecosystem service markets; like biomass markets, only time will tell what form they will take in Maryland. Landowner participation in ecosystem markets may require that tradeoffs are made between potential opportunities in ecosystem service markets and biomass markets.

1.3.2 Classification of the wood products industry

The wood products industry can be classified in a number of ways, but a common scheme is to separate firms according to which portion of the industrial production of wood products they participate in. This includes *primary* firms (firms that buy **roundwood** for the production of dimensional lumber and other solid wood products) and *secondary* firms (firms that buy dimensional lumber and panel products to manufacture other high-value products). For the purposes of this report, pulp and paper is considered as a separate market segment from the primary and secondary wood products industries.

The above classification of wood-using firms (primary, secondary, and pulp and paper) helps describe the wood product value chain and the flow of residue materials (e.g., woodchips from processing sawtimber and poletimber), which may be used in the production of energy or sold in other markets. When exploring new market potential, it is of utmost importance to understand the type and flow of raw material used in existing industry (e.g., the flow of chips and shavings from wood products facilities to pulp and paper mills and livestock operations). Such analysis may reveal areas of synergy between the existing wood products industry and an emerging bioenergy industry; it may also reveal cases of direct competition.

In Maryland, the primary wood products industry uses roundwood in the form of **sawtimber** for the production of rough cut lumber (non-dimensional lumber), dimensional lumber, posts and poles, pilings, and other solid wood products.[4] In processing sawtimber into higher value products, sawmills also produce co-products in the form of "coarse" residuals (i.e., **slabs**, **edges**, and **trim ends**) and "fine" residual (i.e., planer shavings and sawdust). Coarse residuals are usually chipped and used in pulp and paper and composite wood products, while fine residuals are used for animal bedding, particle board, densified wood pellets,[5] or mixed with bark and combusted onsite for heat, and in a few instances electricity.

When low-grade wood, non-commercial species, and small-diameter trees, not usually suitable for higher value markets, are harvested, they are generally sold as pulpwood or **fuelwood**. Such low grade roundwood may also be stripped of bark and chipped to provide clean woodchips for pulp and paper, animal bedding, and feedstock for composite wood products. In these instances, bark is usually sold as mulch in local markets or used as **hog fuel**.[6]

1.3.3 Size and location of Maryland's wood products industry

When examining the potential market penetration for new users of low-grade wood it is also important to consider the physical location of Maryland's current wood processing infrastructure and existing consumers of wood residuals. This can help identify the potential areas of synergy and competition for these materials. This report addresses biomass supply by dividing the state into five sub-regions, which would naturally serve as supply areas for regional bioenergy and wood products facilities.

Maryland's primary wood processing infrastructure is located in the areas of the state where the most contiguous forestland exists, with larger sawmills located in western Maryland and the lower eastern shore, and smaller sawmills located throughout central and southern Maryland (MD DNR, 2004). With over two-thirds of the state's timberland being stocked with high-value sawtimber sized trees, Maryland's wood products industry is geared toward the production of wood products from sawtimber (Irland, 2004; MD DNR, 2004). According to the Maryland Forest Product Operator database, there are currently more than 80 mobile and stationary sawmills licensed to operate in the state, with roughly three-quarters of stationary mills

[4] The primary wood products sector also includes the production of high value **veneer quality timber**, which is typically exports cut-to-length and transported to out-of-state processing and utilization in higher value markets. This activity may produce some logging residuals during the harvest in the form of limbs and tops, but these are typically not collected for other markets.

[5] There are currently no densified pellet facilities in Maryland.

[6] Irland (2004) estimated that Maryland's wood products industry consumed as much as 120,000 green tons (60,000 dry tons) of residuals in boilers at wood product facilities in 2001.

specializing in hardwood (Irland, 2004). These hardwood mills consume 80% of the state's total roundwood supply in the production of approximately 175 million board feet of hardwood lumber annually (Irland, 2004). The remaining sawmills produce upwards of 110 million board feet of softwood lumber annually, and are mainly located in close proximity to highly productive loblolly pine forests of Maryland's coastal plain (MD DNR, 2003; Irland, 2004).

Over half of the sawmills surveyed in 2004 by the MD DNR Forest Service reported that they process more than a million board feet (1 MMBF) of lumber annually. These mills, which can be considered large by Maryland standards, reported sourcing as much as 75% of their timber within the state. It was estimated that over a quarter of this wood was procured as **gatewood**, the origins of which can be difficult to determine (MD DNR, 2004). Maryland's large sawmills (those processing more than 1 MMBF annually) reported procuring upwards of 72% of their timber as **stumpage** (MD DNR, 2004). In western Maryland, 69% of timber is reported as being bought as stumpage, usually from harvests on larger parcels (MD DNR, 2003; Irland, 2004). In other areas of the state gatewood arrives at the mill from multiple sources, with timber dealers playing a role in the supply chain. If demand for woody biomass from logging operations were to increase, a similar pattern of biomass procurement by stumpage and gatewood may follow, with biomass being purchased through stumpage contracts in western Maryland and the lower eastern shore, and **biomass aggregators** playing a more significant role in other parts of the state.

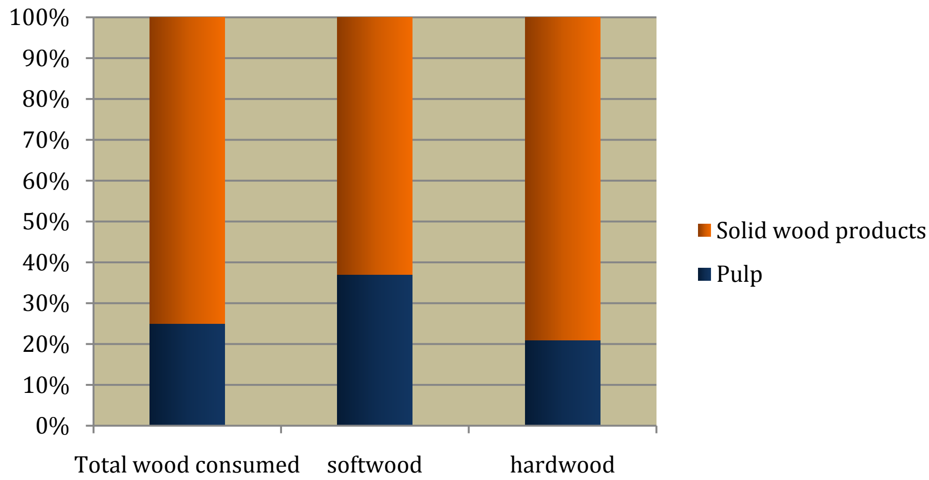
While some non-commercial and pulpwood-sized material is often removed during partial harvests, pulpwood harvests and pre-commercial thinnings of small-diameter trees currently play a relatively small role in forest management in Maryland. This is somewhat non-intuitive given that most forests managed for timber production seek to produce high-quality sawtimber, which can benefit greatly from pre-commercial thinning and other TSI activities. Where markets for pulpwood and non-commercial material do exist, low-value trees (e.g., **cull** and commercially undesirable tree species) may be removed through pre-commercial thinning and chipped at the landing. Opportunities to offset costs associated with pre-commercial thinning are limited due to market constraints for low-value wood, and the biomass generated by such activities is frequently left on the forest floor; that is, of course, if a landowner invests in pre-commercial thinning at all.

1.3.4 Flow of the regional timber supply

The forest products industry in Maryland and surrounding states process an estimated 2.2 – 2.5 million **green tons** of Maryland-grown roundwood on an annual basis (see Figure 1). Approximately 55% of this volume is used by sawmills to produce dimensional lumber, while most of the rest is used for pulp and solid wood products (Irland, 2004; MD DNR, 2003). A small amount of Maryland's wood is also used in the production of composite wood products in West Virginia. There currently are no composite wood panel plants operating in Maryland.

Such facilities may demand the same material as wood-based bioenergy facilities; however, the economic outputs of both types of facilities vary.

Figure 1. Consumption of Maryland's roundwood.



Source: Irland, 2004

A significant amount of Maryland's growing stock is also used for fuelwood (approximated at 200,000 green tons in 2001), but actual fuelwood harvest is difficult to determine, given that a significant number of small non-industrial private forest landowners harvest firewood, which is never tracked or reported (Lipfert and Dungan, 1983; Rider, 2010). In some states in the Northeast, firewood harvests can make up as much as a third of total wood harvested (Walker *et al.*, 2010). The Maryland Forest Product Operator database indicates that there are more than 265 contractors that process firewood, most of which is sold in local markets. Firewood may be yet another market that wood energy may compete with, yet most firewood harvests occur on small parcels for personal use, and are the only type of harvest that many landowners (especially small landowners) are likely to undertake.

While Maryland exports a large portion of its wood, it also imports a significant amount of material, which is used by more than 1,500 firms to process an estimated 3.6 million green tons of wood fiber on an annual basis. The Irland Group (2004) found that 35% of the in-state harvest is exported (49% to Pennsylvania and 45% to Virginia), and just over half (52%) of Maryland's fiber demand is met through imports (over 43% from West Virginia, 28% from Virginia, 17% from Pennsylvania, and 11% from Delaware). This import of material is largely due to the Luke, Maryland paper mill, which draws heavily upon imported chips and roundwood (Irland, 2004). The Luke mill's production capacity is estimated to be 520,000 tons per year of paper and approximately 411,000 tons per year of hardwood and softwood pulp (Irland, 2004; www.newpagecorp.com).

In addition to Maryland's only pulp and paper plant in Luke, Maryland, three other pulp mills draw supply from Maryland. These facilities are located in West Point, VA, Spring Grove, PA, and Roaring Spring, PA. In 2001, these four facilities sourced 811,000 green tons (32 – 37% of total annual harvest) of wood fiber from Maryland. Forty percent of this fiber is procured as roundwood, 30% is from chipped roundwood, and the remaining 30% is from sawmill residues (Irland, 2004).

A fifth pulp and paper plant in the region, International Paper Company's Franklin, Virginia paper mill, closed in 2009. This large paper mill periodically sourced wood from Maryland. Like many of the other pulp mills that have shut down operations recently, there are discussions about converting this plant's supply chain and infrastructure into a large-scale bioenergy facility. The Franklin mill was one of the largest paper mills in Virginia and is likely to be converted to a bioenergy facility (Pinchot Institute and Heinz Center, 2010).

Table 1. Wood fiber flow in Maryland by product category (Green Tons) – 2001.

Fiber Category	**Softwood**			**Hardwood**		
	Imported	Produced in state	Total	Total	Imported	Produced in state
Industrial Roundwood and Residuals	589,823	422,027	1,011,850	2,109,965	1,094,395	1,015,570
Fuelwood	44,000	28,660	72,660	512,600	305,000	207,600
Total wood fiber	633,823	450,687	1,084,510	2,622,565	1,399,395	1,223,170

Product Category	Total Softwood Product	Total Hardwood and Softwood Product	Total Hardwood Product
Pulp and other pulpwood products	468,660	1,665,260	1,196,600
Sawnwood	615,850	2,041,736	1,425,885
Lumber	277,155	918,821	641,666
Fuel	69,035	274,528	205,493
Mulch	70,765	601,369	530,604
Farm	118,244	227,407	109,163

Source: Irland, 2004

1.3.5 Potential synergy and potential competition

One indication of a potential increase in wood supply scarcity is the expansion of **procurement radii** for existing wood processing facilities. Procurement decisions for Maryland's sawmills are largely based on stumpage value and logging costs, both of which have implications for biomass supply chains. Certain sources of biomass (i.e., logging slash) are only economically available under certain harvesting scenarios (e.g., veneer log harvests), because these harvests may "subsidize" the removal and transportation of low-value woody biomass to an energy facility or sort-yard. Stumpage price and logging costs directly influence the economically viable procurement radii for a given facility. These market factors are related to parcel size, a critical factor that affects the long-term viability of Maryland's wood products industry. The MD DNR Forest Service concluded that, "large mills that have increased their procurement radius rank 'logging costs, competition, and tract size' much higher on the list [of factors that influence their procurement] than do the mills with stable procurement zones" (MD DNR, 2004).

The majority of Maryland's larger sawmills (those that process more than 1 MMBF of lumber annually) procure most of their wood as stumpage from larger parcels within an average radius of 59 miles. Nevertheless, some do source high-value material from as far as 100 miles away (MD DNR, 2004). The MD DNR Forest Service also found that many small mills procuring a high percentage of their material as gatewood, often source wood from more than 50 miles away, if need be. As much as a third of mills surveyed in 2004 reported that they had increased their procurement radius in recent years. The expansion of procurement radii suggests that the demand for timber by existing mills is fairly inelastic, a phenomenon that is largely associated with previously sunk investments in wood processing infrastructure. Such sourcing patterns have implications for what type and scale of woody biomass utilization infrastructure could be economically viable in Maryland.

Increased competition (from new wood consumers) for raw material and productive forest land can lead to localized wood scarcity. New large bioenergy facilities would likely compete with firms that are largely dependent on the existing wood residue market (e.g., the region's pulp and paper mills and local markets for mulch). A positive result (at least for forest landowners in the short-run) of such competition may be higher wood prices. As shown in Table 1, wood residues from Maryland's sawmills currently supply other markets in addition to supplying these sawmills with energy onsite.

Increases in wood price may have adverse effects for mills operating at slim margins; however, these same mills might be able to sell their residuals at a higher price. Some mills, facing a fragmented procurement land base, may strategically invest in new markets and technologies (e.g., small diameter mill capacity and biomass utilization) in order to remain economically viable. Others, for which these options are not economically attractive, might decide to forgo such investments and may decrease or cease production. As will be discussed later in this report, this can reverberate negatively through the biomass supply chain.

In 2001, the region's pulp and paper plants procured nearly 250,000 green tons of Maryland wood fiber as residuals from sawmills and other wood processing facilities, and close to another 250,000 green tons of woodchips sourced from Maryland's forests. To put this in terms of bioenergy, if all this material is used to fuel an electricity-only biopower plant, the maximum capacity of such a facility would be 21 megawatts (MW), enough to power 33,600 – 42,000 homes on an annual basis. Maryland also provided pulp and paper facilities 324,400 green tons of roundwood in 2001 (Irland, 2004). If this roundwood was diverted to the same bioenergy facility, the maximum capacity of the facility would increase to 48 MW.

Mulch is another market for low-grade wood that may face immediate competition with a bioenergy market. Mulch is currently the largest wood residue market in the state, consuming more than an estimated 600,000 green tons of residue on an annual basis. This quantity of biomass is equivalent to the volume needed to supply a 50 MW biopower plant; although biomass used to produce mulch may not be fuel grade for biopower. Most of this mulch is produced from the residues of small sawmills scattered across the state and from timber harvests. Residues used for mulch are often of the lowest value and unsuitable feedstock for most bioenergy technologies; however it is conceivable that bioenergy facilities may one day compete for at least some of the residuals currently used to produce mulch.

Some perceive that new competition in residual markets could have consequences for the agricultural sector. This perception is most readily apparent for the poultry industry, which uses wood shavings and sawdust from the wood products industry as animal bedding in poultry houses.[7] The industry has historically preferred pine shavings to hardwood shavings because of concerns over moisture content and related impacts to flock health and productivity. Following a 75% decrease in the softwood mill infrastructure on the Delmarva Peninsula in the early 2000s, the Delmarva poultry industry has experienced a scarcity of softwood shavings and sawdust for bedding material in poultry houses (Malone, 2008).

The eastern shore of Maryland produces approximately 350,000 tons of poultry litter on an annual basis (Lichtenberg *et al*., 2002). Assuming litter content to be approximately 50% wood shavings or sawdust,[8] the poultry industry on the eastern shore of Maryland uses approximately 168,000 green tons of wood (estimated to be over 70% of total wood residues used in agriculture in the state) on an annual basis. Should residuals market price increase due to competition, one indirect effect may be that poultry houses are cleaned out less often, which could have implications for nutrient management and water quality concerns (Shah *et al*., 2006). If the estimated 168,000 green tons of wood shavings and sawdust used in the eastern shore's poultry industry were completely diverted to fuel electricity production, this amount of biomass would only produce about 14 MW of power.

It is difficult to determine whether an expansion of even a moderately scaled wood-based bioenergy sector could have impacts on the poultry industry. One complicating factor is that the

[7] Wood shavings and sawdust do not currently qualify as biomass feedstock for electricity production under Maryland's Renewable Portfolio Standard.

[8] The wood fiber content of poultry litter varies widely and depends on the length of time between cleanings, the size of the flock and the size of the poultry house, and several other factors. This study assumed 50% fiber content, based on data from Mante (2008).

poultry industry typically prefers softwood shavings and sawdust over hardwood sawdust. Malone (2008) however, did find that poplar shavings (a key commercial tree species in Maryland) may be a suitable substitute for pine shavings as bedding for poultry houses. Another factor that is important to consider is the type of fiber going into these two markets.

Given that wood-based energy facilities may in some instances prefer hardwood over softwood,[9] an increase in wood-based energy infrastructure on the eastern shore geared towards utilization of non-commercial hardwoods (e.g., red maple and sweetgum) may not necessarily compete directly with the poultry industry for bedding. However, if wood-based energy infrastructure is not appropriately scaled, that is, to a scale that can be sustainably supplied given Maryland's available biomass resources, undesirable market competition could still result.

"Clean" woodchips at a regional wood processing facility. Photo: Brian Kittler

1.4 Maryland's Woody Biomass Resource

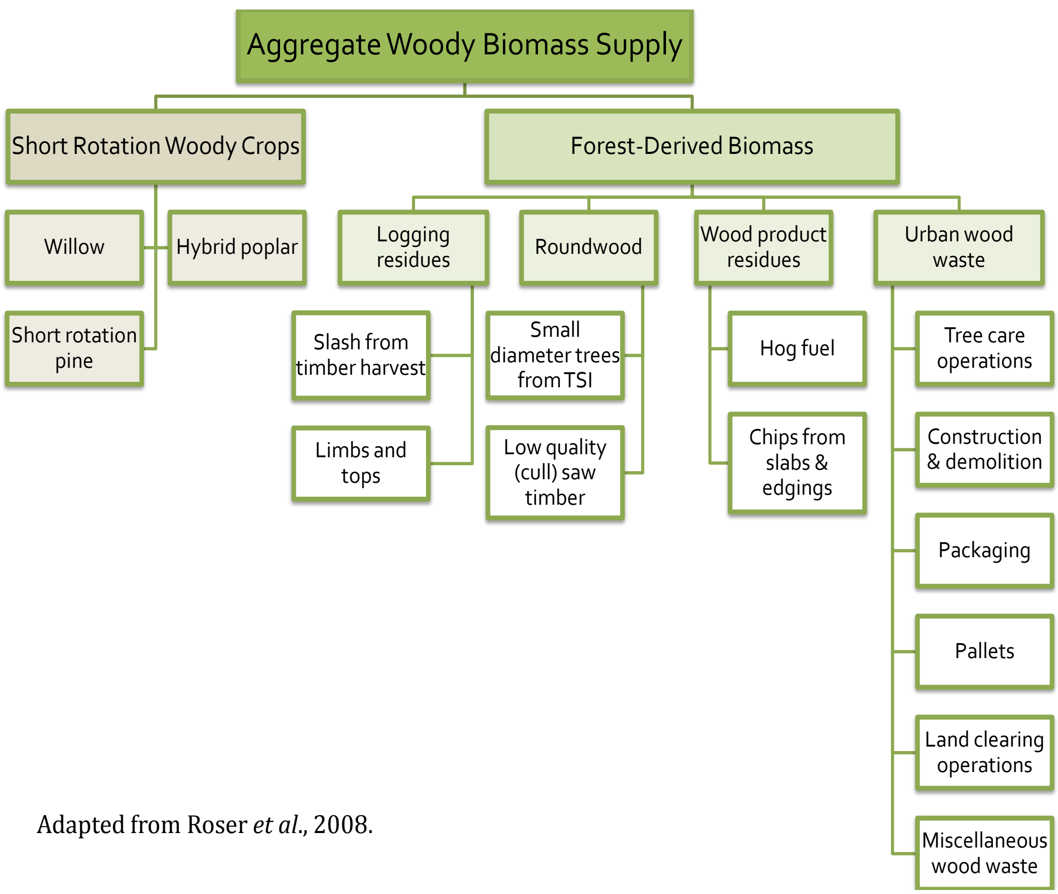
Determining the sustainable supply of biomass available for bioenergy is a complex, but essential, analytical process to assess the feasibility of proposed biomass projects. Supply analyses often occur at the regional and national levels, with this scale of analysis being most useful for policy makers and planners. However, because regional supply data lacks the specificity required to ensure sustainable development of individual bioenergy projects, project-level supply analysis is needed to ensure that projects are appropriately scaled to the available

[9] Hardwood typically has a higher energy density than softwood. Hardwood trees also produce more logging residue (i.e., limbs and tops) during harvest.

biomass resource. In order to account for future competition and supply disruptions during the 30 – 40 year service life of a given facility, project level due diligence calls for project developers to ensure that the available biomass supply is significantly larger than the planned facility demand.

While some bioenergy technologies are capable of utilizing multiple feedstocks from agricultural, forested, and developed landscapes in a single energy facility, this report focuses on the availability of woody biomass feedstocks (see Figure 2). Given that Maryland's landscape is a mixture of agricultural lands intermixed with blocks of forest and developed lands, evaluation of the potential for agricultural feedstocks such as agricultural residues, manures, and perennial grasses[10] are important considerations for project developers and state energy planners.

Figure 2. Woody biomass supply categories.



Adapted from Roser *et al.*, 2008.

[10] Maryland has early experience with grass-based energy systems through applied research at the Maryland Agro-ecology Center. Another useful resource that details the potential for densified grass energy is available at: www.biomasscenter.org/grass-energy.html

Some forms of woody biomass (specifically urban wood waste and wood product residues) may be concentrated at central wood processing facilities or in sort yards (e.g., recycling centers, mulch yards, and primary and secondary wood processing facilities), or spread out across the landscape in the form of roundwood and logging residues. In order to facilitate the efficient transfer of these various biomass categories, it is expected that mature biomass markets will include aggregators. If and when energy markets for biomass develop, Maryland's woody biomass supply chain will be somewhat different for each of the supply categories listed in Figure 2. For example, urban wood waste supply will likely be facilitated by tree care crews, arborists, land clearing companies, public works agencies, and municipal waste / recycling operations, whereas, forest-derived woody biomass will likely rely heavily on the approximately 265 licensed logging crews.[11]

Local markets for energy wood are shaped in part by what a particular energy technology can afford to pay for biomass feedstock. Similar to fossil-based energy systems, feedstock costs are a major component of the total cost of a given bioenergy system. However, unlike fossil-based energy, the price of biomass feedstock is not typically locked in through long-term fixed-price contracts (ESFPA, 2008). The selection of an appropriate biomass utilization technology is largely linked to the expected costs of feedstock, which includes production (i.e., cost of cultivation), harvest, and transportation costs. Transportation costs account for 20 – 40% of the delivered biomass fuel cost (Angus-Hankin *et al*., 1995), though this fluctuates greatly with the price of diesel fuel.

Not all bioenergy technologies can afford the same price for biomass, nor do they use the same type of biomass fuels. The economics (and thus the facility sourcing radii) of various bioenergy technologies can change dramatically with increases in the cost of feedstock procurement. Biomass-fired electric power (biopower) plants are usually unable to afford biomass procurement from beyond a 50 mile haul distance from the facility, although price supports may alter this dynamic. In theory, thermal energy and CHP facilities may be able to procure biomass from further distances because these technologies are able to pay significantly more for their feedstock than electricity-only facilities (Walker *et al.*, 2010). Most of the added cost for CHP and thermal facilities actually relates to the need for these technologies to source higher-quality fuels (e.g., bolewood chips) than electric power plants. Thus, while CHP facilities, in theory, are willing to "reach out farther," the marginal increase in fuel cost is usually associated with the need to source higher-quality fuels, rather than increased transportation costs associated with a larger supply area. Thus, while trade in energy wood is global, most bioenergy projects operating at scale with present-day technologies are economically constrained to procure the

[11] This estimate is based on data from the MD DNR Forest Service Forest Product Operator Database and other data from University of Maryland Extension. It is worth noting that based on these numbers; approximately 65% of logging crews licensed to operate in Maryland have completed Maryland's Master Logger Certification.

majority of their biomass through transportation networks that exist within 50 miles of the facility.

Maryland has well-developed transportation infrastructure capable of supporting the movement of biomass. Transportation costs may fluctuate as diesel costs also vary between rural areas where forest-derived biomass may be procured and the developed areas where urban biomass is located.

While this analysis is limited to trucking, which is presently the most common method of biomass transport in the U.S., pulp and paper facilities located in Virginia have previously sourced woodchips from Maryland's eastern shore by barge. This method of transport is often the most cost-effective way to transport large quantities of energy wood and pulp grade woodchips. As regional trade in energy wood reaches a certain threshold, additional efficiencies in transportation may be gained through existing barge and rail networks. Such a development could result in a significant change in Maryland's biomass supply chain, but it is difficult to imagine such investments in infrastructure being made based on the projected market price of biomass feedstock alone.[12] It remains to be seen whether regional biomass markets will yield a price point for biomass that could make this type of commodity driven market a reality, or if biomass markets will remain small and localized.

Biomass fuel price also varies significantly with changes in the cost of harvest and improvements in transport economics through the processing of biomass (e.g., chipping, bundling, or densification) prior to transportation. Since different biomass production systems have different cost structures,[13] the price that bioenergy facilities can feasibly pay for feedstock can influence the type of harvest systems selected, which in turn influences the type of forest-derived biomass that is ultimately removed. In Maryland, such a relationship can be observed in the case of ECI's CHP facility, which requires premium woodchips. This supply is procured through a long-term supply contract with an entity that sources biomass from harvest operations that utilize mechanized whole-tree harvests and whole-tree chipping.

[12] Individual state policies to promote biomass utilization, specifically subsidies to improve the economics of biomass procurement, have raised concerns in some circles about violations of the inter-state commerce clause of the U.S. Constitution.

[13] For a thorough review of forest-derived biomass harvest systems used in the Northeast see MA DOER and MA DCR (2007).

Short-line rail transport may reduce feedstock costs. Photo: Brian Kittler

1.4.1 Review of previous studies of Maryland's biomass supply

This section analyzes several studies which have estimated the availability of biomass in Maryland. This section is also intended to evaluate existing biomass supply data using some logical assumptions about landowner attributes and safeguards for forest sustainability. For this analysis, we use available data from several studies[14] to characterize the potentially available woody biomass supply.

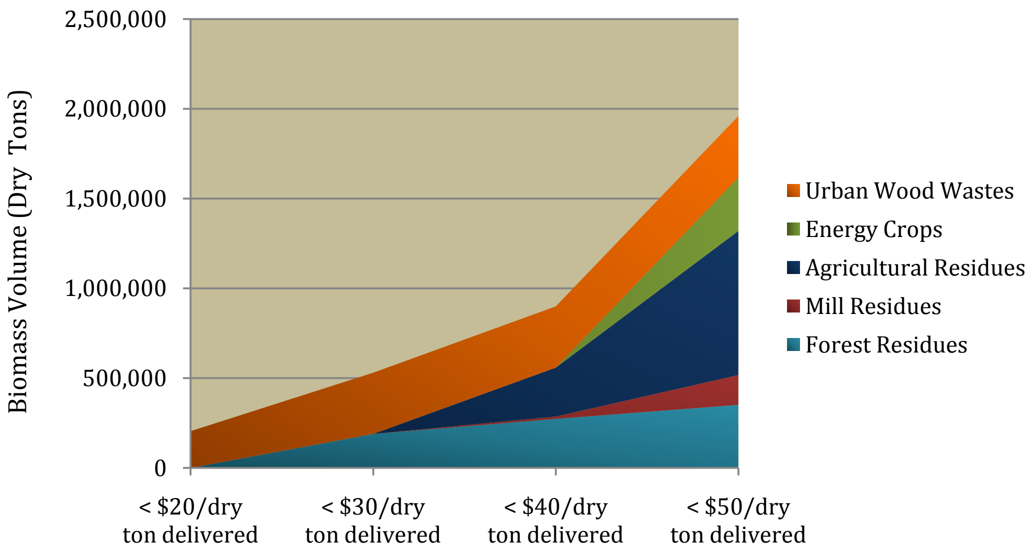
Given the significant uncertainties and sources of error inherent to each of these studies, biomass supply information presented in this report should be considered gross estimates that illustrate a general overview of the potential availability of biomass in this region. The specific form that biomass markets may take in the Mid-Atlantic region remains largely unknown since actual prices and quantities are negotiated in markets that have yet to develop to a point where robust economic analysis can be undertaken. The intent of this section is to merely present some potential futures based on several social and economic factors which will constrain the availability of biomass in Maryland. A more detailed and spatially explicit analysis will be necessary to determine actual biomass availability with any degree of certainty. This is most appropriately done at the scale of individual sites for proposed facilities, although optimization models are being developed at the regional scale that may aid in facility siting.

A widely utilized study (see Panich *et al*., 2007) by Oak Ridge National Laboratory (ORNL, 2000) estimates quantities and associated price points for various categories of biomass for each

[14] These studies include: Skog *et al*., 2009; ORNL, 2000; PPRP, 2006a; Butler *et al*., 2009; MD DNR, 2006b; CBC, 2010.

state in the U.S.[15] The ORNL study estimates that there is approximately 1.9 million dry tons of biomass in Maryland available annually at a delivered cost of $50 per dry ton ($25 per green ton) (see Figure 3). This price is within the range ($20 – $30 per green ton delivered cost) that most biopower facilities on the east coast pay (Burchfield, 2009; Walker *et al.*, 2010). This quantity of biomass would be enough to fuel approximately 244 MW of power on an annual basis.[16] At these price structures, ORNL determined 24% (351,000 dry tons) of the biomass procured would be residues from forest harvest operations.[17]

Figure 3. Estimated biomass in Maryland at various projected delivered costs.



Source: ORNL, 2000

The primary source of data on logging residuals that is most frequently used in biomass supply assessments (see ORNL, 2000; Panich *et al.*, 2007; PPRP, 2006a; Salisbury State University) is the Timber Products Output (TPO) data of the USDA Forest Service. This data source has been criticized for overstating the volume of recoverable forest residues. The ORNL forest residue estimates are based on the TPO data and assume a retrieval efficiency of 40%. Given that the ORNL study was national in scope, such a coefficient seems to be a fair method to account for

[15] This study estimated available quantities from < $20/dry ton to < $50/dry ton delivered to a given bioenergy facility.
[16] This assumes average moisture content (MC) of 10% for agricultural residues and energy crops (switchgrass) and a 50% MC for forest residues, urban wood waste, and mill residues. This also assumes that all biomass is transported to a central processing point, which is not feasible.
[17] ORNL (2000) assumes forest residues to include trees from "other removals" that are cut or killed by logging and left behind, rough trees that do not contain a sawlog (i.e., 50 percent or more of live cull volume) or non-merchantable species, trees that do not contain a sawlog because of rot (i.e., 50 percent or more of the live cull volume), salvageable dead wood that includes downed or standing trees that are considered currently or potentially merchantable, excess saplings are live trees of 5 inches or less diameter at breast height (dbh), poletimber with a dbh greater than 5 inches but less than 12 inch sawtimber, and the limbs and tops associated with all of these residue categories.

overall variability in the harvest methodology occurring from region to region, but this assumption does not necessarily account for Maryland's specific logging and forest management circumstances.

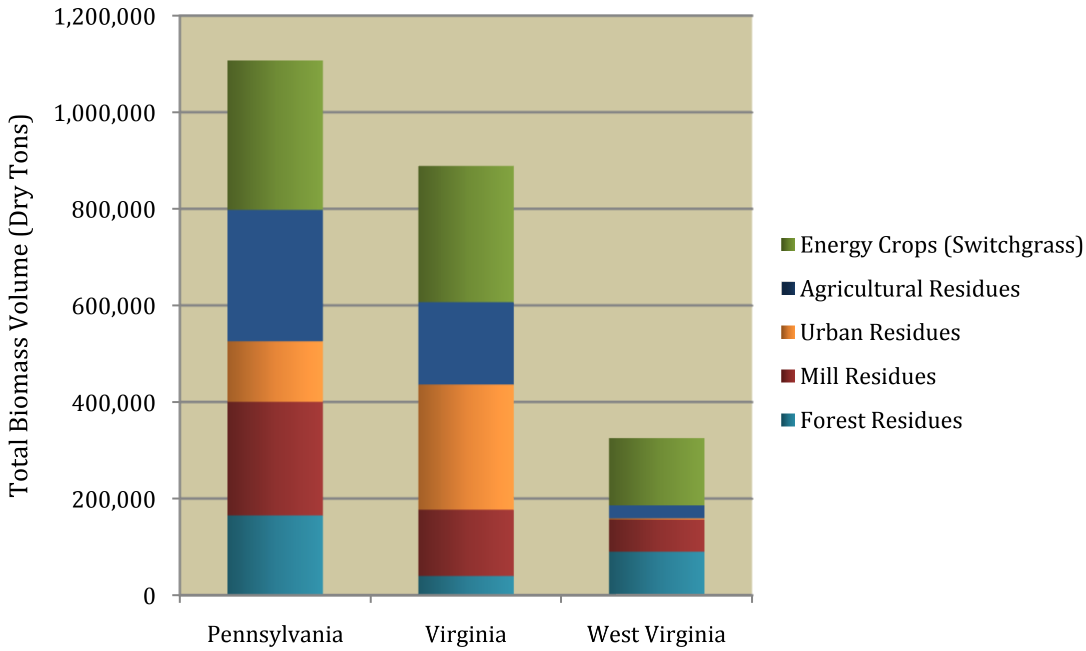
Moreover, the ORNL data assumes that the cost of transporting limbs and tops to the landing would be subsidized by the cost-value ratio of removing higher-value material in addition to biomass. This may certainly be the case for **whole-tree harvests**, where trees are felled and skidded as complete units to be delimbed, topped, and bucked at the landing. Yet, given current market conditions it should not necessarily be assumed that the collection and transport of limbs and tops is economically justified using other harvest systems (MA DOER and MA DCR, 2007; Irland, 2004; Rider, 2010).[18] While it may be feasible to recover limbs and tops in some instances when whole-tree harvesting is not used, the collection and delivery of logging residues is largely cost-prohibitive without the introduction of new equipment. Thus, estimates of biomass supply may be inflated when the economic efficiency of various harvest systems are not adequately accounted for.

In addition to estimates of forest harvest residues, the Maryland Power Plant Research Program (PPRP) estimates that there may be up to 2.3 million dry tons of additional biomass available from Pennsylvania, Virginia and West Virginia, in counties within 50 miles of Maryland's coal-fired power plants (see Figure 4) (PPRP, 2006a). Approximately 730,000 dry tons of the 2.3 million dry tons that PPRP estimates as potentially available from the three adjacent states would come in the form of switchgrass, which is not currently cultivated.

Based on the ORNL estimates, energy crops like switchgrass would presumably not "come on line" until demand grew large enough to increase biomass prices up to $40 per dry ton delivered cost (see figure 3). Energy crops are unlikely to be cultivated unless a conversion facility is willing to pay higher prices for biomass and/or subsidies are available to motivate landowners to cultivate energy crops.

[18] It is difficult to pin point harvest cost data due to the fact that every harvest is dramatically different than the last, with numerous hidden factors like road and trail construction costs, BMP installation costs, and other site specific costs. Harvesting is capital intensive and requires parcels be of a certain size, with a certain threshold volume of merchantable material being produced, in order for harvests to be economically feasible.

Figure 4. Potentially available quantities of biomass in nearby counties of adjacent states.



Source: PPRP, 2006a

While the urban wood waste category is the largest and lowest-cost source of biomass available, this source of biomass is very much dependent on urban development patterns. Urban/suburban development patterns in Maryland have changed since 1999, which suggests that the volume of urban wood waste currently available in Maryland may be different than that cited in the ORNL report, as construction and demolition (C&D) waste and land clearing debris constitute a considerable share of the urban wood waste supply.

Agricultural residues (e.g., corn stover) are often perceived as being a viable source of biomass for energy production. However, crop residues may be scarcer in Maryland than presented in the PPRP or ORNL reports. A Chesapeake Bay Commission study (CBC, 2010) concluded that it is not economically feasible or environmentally sound to remove crop residues from corn fields producing less than 200 bushels per acre. The Chesapeake Bay Commission study also concluded that given objectives for restoring water quality in Chesapeake Bay, and Maryland's average level of crop production, crop residues are not a viable source of biomass in Maryland (CBC, 2010). According to the CBC report, biomass derived from the region's forests is the largest potential source of feedstock available in the Chesapeake Bay watershed. This echoes the prevailing assumption that forests are a potentially significant untapped source of biomass.

1.4.2 Methods for assessing woody biomass availability from forests

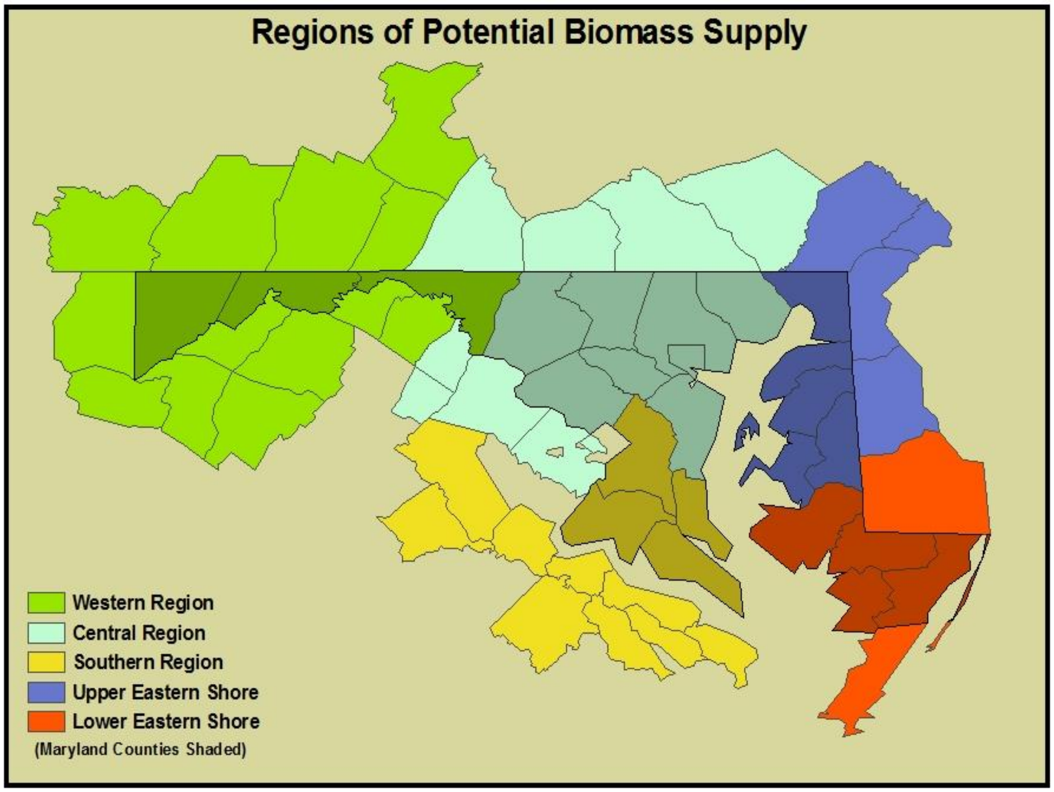
The ORNL and PPRP studies provide a valuable overview of the scale of the potential biomass resource in the region and the general costs of various feedstocks. However, to better understand how biomass markets may develop in Maryland, it is useful to think of how regional supply networks may develop in the near-term. In an attempt to delve deeper into the woody biomass portion of Maryland's aggregate biomass supply, this study modified the approach taken by PPRP (2006a) to define five subregions that may most readily become **biomass-sheds** (see Table 2).

These subregions segregate Maryland's 23 counties and relevant counties in adjacent states based on their connectivity to a central geographic location in each subregion through road networks, and their economic connectivity through the existing forest products industry. This last point is important because the existing forest products industry and its associated supply chain infrastructure are expected to provide a significant amount of the infrastructure for the woody biomass supply chain of energy facilities.

Table 2. Counties from which biomass is assumed to be potentially economically available.

Western region	Central region	Southern region	Upper Eastern	Lower Eastern Shore
Allegany, MD	Anne Arundel, MD	Prince George's, MD	Caroline, MD	Dorchester, MD
Garrett, MD	Baltimore, MD	St. Mary's, MD	Cecil, MD	Wicomico, MD
Washington, MD	Baltimore city, MD	Calvert, MD	Kent, MD	Somerset , MD
Fayette, PA	Harford, MD	Charles, MD	Queen Anne's, MD	Worcester, MD
Somerset, PA	Montgomery, MD	Caroline, VA	Talbot, MD	Sussex, DE
Bedford, PA	Howard, MD	Culpepper, VA	Delaware, PA	Accomack, VA
Huntingdon, PA	Carroll, MD	Essex, VA	Chester, PA	
Fulton, PA	Frederick, MD	Fauquier, VA	New Castle, DE	
Preston, WV	Franklin, PA	King George, VA	Kent, DE	
Tucker, WV	Adams, PA	North Umberland, VA		
Grant, WV	Lancaster, PA	Richmond, VA		
Mineral, WV	York, PA	Stafford, VA		
Hardy, WV	Jefferson, WV	Westmoreland, VA		
Hampshire, WV	Clarke, VA			
Morgan, WV	Loudon, VA			
Berkeley, WV	Fairfax, VA			
Frederick, VA	Arlington, VA			

Figure 5. Regions of potential biomass supply.



The National Renewable Energy Lab's Biopower Mapping application[19] was used to determine whether the counties in adjacent states were within a feasible transportation distance (50 miles via road networks) from a central point within each of the Maryland subregions. This was done in an effort to simulate how a centrally located bioenergy facility within each of these subregions would likely draw biomass supply from surrounding counties.

In reality, a biomass utilization facility could certainly be located on the edge of any of these subregions, or outside of the subregions altogether. Such a facility could draw at least a portion of its supply from within the subregions, which would limit the available supply for other facilities located in that particular subregion. Thus it is important to acknowledge that as bioenergy facility sourcing areas overlap, there may be increased potential for feedstock competition (Pinchot Institute and Heinz Center, 2010). Due to such unforeseen supply limitations, consultants performing biomass supply analysis for planned energy facilities often account for potential shortages by discounting the estimated total available supply of biomass by as much as 50% (Pinchot Institute, 2010).

[19] This tool is available at: http://rpm.nrel.gov/biopower/biopower/launch

1.4.3 Estimates of forest-derived biomass

One of the traditional methods of analyzing the availability of forest biomass is to use FIA inventory data to calculate the difference between timber growth and removal. Based on the latest (1999) USDA Forest Service inventory, net annual growth in Maryland is 23.7 million cubic feet for softwoods, and 83.4 million cubic feet for hardwood,[20] with growth-to-drain ratios for softwood timber and hardwood timber of 1.25 and 1.31 respectively. While such data may be useful as an indicator of increased sustainable harvest potential, this approach fails to account for how supply may be constrained by economic, social, and legal limitations.

A number of factors concerning **forest sustainability** are also important to consider when assessing the availability of forest-derived biomass. Such factors include the type and amount of woody material that needs to be retained in forests to maintain ecosystem service values, long-term economic effects, and a number of social considerations.[21]

1.4.4 USFS Forest Products Laboratory estimates

As an outgrowth of the federal government's "Billion Ton Study," (Perlack *et al*., 2005) the USDA Forest Products Laboratory (FPL) developed forest-derived biomass quantity and roadside cost estimates for each county in the U.S. These county level data assume that biomass will be harvested from **integrated harvest operations**. This is assumed because, in most instances, the cost of harvest preparation, site entrance, and the harvest itself, will not be offset by the market value of biomass on its own. Therefore, the FPL study assumes that integrated harvest operations will be performed with mechanized whole-tree harvests to move the entire tree from the stump to the landing where tops, branches, and low-value roundwood are chipped.

While the whole-tree harvest systems implicit in the FPL scenario are a very efficient means of removing larger volumes of biomass from a given site, these systems require significantly more open space for skidding, and are often judged inappropriate given parcel size and other site characteristics. In Maryland, whole-tree harvests are largely limited to southern Maryland and the eastern shore, where such harvests are typically associated with clearcutting and row thinning in plantation forests (MD DNR, 2008; Rider, 2010).

Whole-tree removal systems are also used for land clearing, especially in central Maryland. As development value traditionally outweighs timber market value, land clearing operations tend to

[20] A significant portion of removals was attributed to reclassification of forest out of timberland into reserved lands not subject to timber harvest.

[21] The role of personal decisions made by forest landowners is likely the most significant and the most difficult factor to account for when determining biomass supply. A number of studies focus on landowner participation in timber markets, while a few even address landowner willingness to participate in biomass markets. Relevant studies on private landowner behavior include: Irland, 2004; Butler *et al*., 2009; Butler *et al*., 2010; D'Amato *et al*., 2010; Sampson and DeCoster, 2000; Walker *et al*., 2010; MD DNR, 2008; Gan *et al*., 2009; Pinchot Institute, 2007. Of these studies, Gan *et al*. (2010), the Pinchot Institute (2007), and Walker *et al*. (2010) specifically address the role that biomass stumpage price plays in the decisions of private forest landowners.

focus more on speed than timber value when selecting harvest methods, with whole-tree harvest systems being the preferred option. Other mechanized systems may also be used to fell, delimb, and buck trees at the stump and grapple skid **bole wood** to the landing.[22] In these **tree-length harvest systems**, low quality roundwood may be chipped at the landing while slash is often left in the forest where trees are felled.

Besides economics, the primary difference between the two predominant harvesting systems used in Maryland is the general distribution of slash; in a tree-length system, slash is more evenly distributed across the entire site, while whole-tree systems tend to concentrate slash at the landing.

While the FPL study is limited in that it simulates biomass harvesting and production costs for a harvest system that is not completely representative of all harvest systems currently used across Maryland,[23] the FPL data are useful because they simulate what the upper bound of forest-derived biomass production could look like, given a level of biomass harvesting targeted towards silvicultural improvement. Specifically, the FPL model uses the inventory data from the study areas' FIA plots to simulate the use of uneven-aged whole-tree harvest systems over a 30-year period intended to reduce stand density in locations that exceed the maximum stand density index for the given forest type by at least 30%. The FPL methodology is also useful because they assume that 35% of logging residues would be retained within the harvest block due to breakage and the need to protect forest soils and other resource values.

Essentially, the FPL study uses inventory and age-class data to simulate silvicultural treatments across the study area that could occur over the next 30 years with the explicit purpose of reducing stand density to promote growth of larger diameter trees. This integrated harvest scenario assumes that trees with a diameter at breast height (dbh) of less than 5 inches will be harvested and chipped for biomass. In 2000, a full 73% (447 trees per acre) of the live trees growing on Maryland timberland were considered small diameter trees (< 5 inch dbh). This may seem like a large amount; however, this only represented approximately 11% of the standing inventory of trees (dead and alive) on Maryland timberland, with 87% being of larger diameter classes of **poletimber** (21%) and **sawtimber** (66%) (USDA, 1999).

The management scenario simulated by FPL conceives of biomass harvests from both public and private lands to include: (1) all wood from trees less than 5 inches dbh, (2) 80% of the tops and limbs from harvested trees larger than 5 inches dbh, and (3) 50% of the potentially available

[22] In western Maryland cut-to-length systems are frequently used, although mechanical felling with manual bucking, and other harvesting systems are also used.
[23] Given the current harvest systems and technologies used in Maryland, it is a safe bet that the systems employed in the FPL study will not be used more widely unless the stumpage value of biomass were to rise high enough.

"other forest removals," which includes the unutilized wood volume from cut or otherwise killed growing stock from silvicultural operations or from land clearing.

The FPL study includes "roadside cost" figures, which incorporate harvest, collection, and chipping costs.[24] The cost of chipping varies by location, but is assumed to average about $6.50 per green ton ($13 per dry ton). The study also estimates biomass stumpage based on multipliers associated with pulpwood stumpage costs for 2007 and the cost of logging residues produced during harvests in 2006. Stumpage price for small diameter biomass is assumed to range from $2 per green ton[25] ($4 per dry ton) to 90% of the pulpwood stumpage price. "Other forest removals" are assumed to cost $10 – $15 per green ton ($20 – $30 per dry ton) at roadside. For an expanded explanation of the methodology, assumptions, and potential sources of error in the FPL study see Skog *et al.*, 2009.[26]

For purposes of analyzing Maryland's potential biomass supply, county-level biomass price and quantity data were obtained from the FPL for each of the counties listed in Table 2. These data were analyzed to produce estimates of annual biomass supply (price and quantity) for Maryland's five biomass supply subregions.

1.4.5 Results of analysis of FPL data

Based on the county level data from the FPL study, assuming an average cost of transporting biomass from the landing to the bioenergy facility of $8 – $12 per green ton (Walker *et al.*, 2010), and that there are no other constraints (e.g., social, economic, or legal) on the forest-derived biomass supply, the total biomass supply from forests that would be available on an annual basis across the study area would be approximately 225,000 – 315,000 dry tons at delivered costs of $22 – $30 per ton. If facilities were willing to pay $50 or more per delivered dry ton of biomass, the available supply from forests increases to just over 675,000 tons.

The analysis of the FPL data also suggests that approximately 730,000 dry tons of economically recoverable non-forest woody biomass is available across this landscape. This included just less than 50,000 dry tons of unused mill residues and just over 680,000 dry tons of urban wood waste. Urban wood wastes were estimated by FPL using a methodology based on population density that was developed by McKeever (2004). For urban wood wastes, FPL assumed that only 10% of the amount available can be collected at a realistic cost of $17 per ton.[27] Inventories

[24] The FPL model assumes the lowest cost of three harvest and removal types: whole-tree harvesting with mechanized felling, whole tree harvesting with manual felling, or cable yarding of whole-trees that have been manually felled.
[25] $1−$2 per green ton is generally the stumpage price for biomass markets in the north east (SRI, 2007; Walker *et al*., 2010).
[26] http://www.pinchot.org/uploads/download?fileId=550
[27] Assumes a 15% average moisture content for urban biomass (PPRP, 2006a). Note that this does not include transportation costs from the collection point to the energy facility.

of unused mill residues were calculated by FPL using USDA Forest Service Forest inventory and analysis timber product output (TPO) database (USDA Forest Service, 2008). It was assumed that only unused mill residues would be available and that these would cost of up to $8.50 per green ton ($10 per dry ton) at the mill.[28] The FPL study did not assess the potential for energy crops.

1.5 Factors Affecting Availability of Forest-derived Biomass

While the FPL analysis determines the technical availability of biomass if it were to be harvested from forests using the most efficient harvesting systems available, there are a number of Maryland-specific social and economic factors which must also be considered. When forest sustainability is taken into consideration, harvestable land area shrinks slightly due to the fact that there are locations in Maryland where woody biomass harvesting is inappropriate (e.g., sites with steep slopes and sensitive soils). While the biophysical potential for increased wood harvesting in Maryland is significant, the actual potential is significantly constrained by social and economic factors.

1.5.1 The impacts of parcel size

Ownership of private forest land across Maryland is highly parcelized. This fragments both forest cover and the wood supply for wood-using industries. In 2003, 76% of Maryland's forest land was privately owned by over 130,600 family woodlot owners and other non-industrial private forest landowners. More than three quarters of these private forest tracts were less than 10 acres in size and the average private woodlot across the state was 17 acres (MD DNR, 2003). In 2006, the number of private forest landowners increased to 157,000, with almost 85% of woodlots being less than 10 acres in size. It is reasonable to assume that that the average parcel size has continued to decrease since this last survey in 2006.

In general, the smaller parcels become the less valuable they are in terms of habitat, ecosystem services, and production of commercial forest products. As these values drop, landowners become less inclined to make investments in forest planning and management, which increases the likelihood that both the quantity and quality of ecosystem services flowing from these lands—including a reliable wood supply—will be further reduced into the future (USDA, 2006b). When parcels fall below a certain size, the process of laying out harvest sites, complying with regulations, implementing **Best Management Practices (BMPs)**, operating harvesting equipment, and transporting both equipment and harvested material becomes increasingly difficult. There certainly is a threshold beyond which commercial timber harvests are no longer economically viable, but this is largely a "fluid" threshold (Butler *et al.*, 2009).

[28] Assumes an average 15% moisture content for mill residues (PPRP, 2006a). Note that this does not include transportation costs from the collection point to the energy facility.

While the feasibly-harvested parcel size threshold varies greatly from region-to-region, Butler *et al*. (2009) assumes a reasonable threshold for the northeast region to be approximately 20 acres. Since the average parcel size of forest land in Maryland is less than 17 acres—with over 85% of all parcels being smaller than 10 acres—parcels undertaking active forest management for the production of commercial forest products are operating at the margin. Despite this trend, there is still a core of larger parcels that may support sustainable forest management, with an estimated 774,000 acres (33% of the state's forestland, a land area that is approximately 20 times larger than Washington, DC) occurring in parcels larger than 50 acres each (Butler *et al.*, 2010).

Irland (2004) used parcel data from the MD DNR to discover that as of 2004, only 3% of parcels across the state were larger than 25 acres. Table 3 offers a variety of descriptive information about each of the five subregions used to analyze the biomass supply. Among other things, the data presented in Table 3 conveys just how fragmented Maryland's private forest landscape is, as parcels of 10 acres or less characterize close to 90% of all parcels in all subregions. While there has not been a conclusive study to define a minimum acreage threshold for biomass harvests that are not terminal harvests, 10 acres is likely at, or below, such a threshold.

Table 3. Description of Maryland Forest Parcels in Five Subregions.

Subregion	Description of Forests in Subregion	Percentage Contribution of Subregion to MD's Wood Using Industries /1	Number of Parcels and Parcel Size Category as a Percentage of Total Area /2					
			0 to 10	10 to 25	25 to 50	50 to 100	100 to 500	> 500
Western Maryland (Allegany, Garrett, Washington)	178,244 acres of forest. Larger contiguous blocks of forest land.	20.4% of Maryland's wood-based industry	160,367 (90%)	7,581 (4%)	4,052 (2%)	3,124 (2%)	3,006 (2%)	114 (>1%)
Central Maryland (Frederick, Carroll, Montgomery, Baltimore, Howard, Harford, Anne Arundel, Prince Georges)	751,434 acres of forest land (25% of total land area). Small fragmented forest parcels.	57% of Maryland's wood-based industry	730,310 (97%)	11,491 (2%)	4,479 (1%)	2,842 (>1%)	2,158 (>1%)	154 (>1%)
Southern Maryland (Calvert, Charles, St. Mary's)	111,011 acres of forest land (54 - 61% of total land area). Small blocks of forest.	3.4% of Maryland's wood-based industry	103,278 (93%)	3,721 (3%)	1,586 (1%)	1,208 (1%)	1,162 (1%)	56 (>1%)
Upper Eastern Shore (Cecil, Kent, Queen Anne's, Talbot)	Blocks of forest fragmented by agricultural land. 37 - 51% of land is forested	20% of Maryland's wood-based industry (includes Lower Eastern Shore)	53,529 (89%)	2,234 (4%)	1,251 (2%)	1,165 (2%)	1,752 (3%)	42 (>1%)
Lower Eastern Shore (Dorchester, Somerset, Wicomico, Worcester)	95,254 acres of forest land fragmented by agricultural land into both large and small blocks of forest.	20% of Maryland's wood-based industry (Includes Upper Eastern Shore)	82,831 (87%)	4,458 (5%)	2,895 (3%)	2,592 (3%)	2,297 (2%)	181 (>1%)

/1 Salisbury State University, 2004
/2 Maryland Property View (Irland, 2004)

Table 4 suggests that there exists a core amount of private land greater than 10 acres in size, which would thus have moderate to significant opportunity for timber management and harvest. Though it is reasonable to assume that biomass harvests from forests would be constrained to parcels 10 acres or larger, it remains unclear as to how the additional stumpage value associated with biomass harvests will impact the harvests on smaller parcels.

Table 4. Potential for forest biomass based on parcel size.

Parcel size	Number of landowners	Total acres	Potential as a source of renewable biomass
1 - 9 acres	134,000	329,000	Low
10 - 49 acres	22,000	1,091,000	Moderate
≥ 50 acres	6,000	774,000	Significant

Source: Butler *et al*., 2010

A number of factors suggest that the area of "low potential as a source of renewable biomass" will increase. Maryland is likely to see a continued loss of forestland to land clearing, and the biomass generated through such activities cannot be considered a renewable resource, as the forest that created it can be considered permanently lost to developed uses. Additionally, Irland (2004) cites the phenomenon of **shadow conversion**, to illustrate the impacts that a fragmented forest landscape can have on wood supply. Irland concluded that up to 700,000 forested acres in central and southern Maryland are essentially removed from active management due to their proximity to areas with high population density and/or development.

While lands lost to shadow conversion largely end the potential for these parcels to serve as a source of renewable biomass, they are expected to continue to generate episodic supplies of wood, largely from land clearing. That being said, even complete conversion to developed land does not preclude these areas from contributing to the aggregate supply of woody biomass; it merely changes the magnitude and type of supply. Urban wood wastes, particularly C&D material, wood from tree care operations, and other supplies will still be generated from these lands.

The major forested areas of the state—western Maryland and the lower eastern shore—are expected to experience some fragmentation and parcelization, but at a much lower rate than the central and southern regions. These are also the areas of the state where much of the primary wood processing infrastructure and larger parcels remain.

1.5.2 The impact of landowner attributes

Close to half (46%) of Maryland's forest landowners are 65 years of age or older (Butler *et al.*, 2010) and close to a quarter (463,000 acres) of Maryland's privately owned forestland is likely to be transferred to a new generation of landowners in the coming years. The motivations and decisions of their heirs will greatly impact forest management decisions and the availability of woody biomass (MD DNR, 2010; Pinchot Institute, 2007; Butler *et al.*, 2009). It is clear that whatever occurs during and after the intergenerational transfer of land will have a significant bearing on future trends in forest fragmentation, parcelization, and woody biomass availability.

A recent study of the intergenerational transfer of forestland in Pennsylvania revealed that the next generation of landowners view payment for forest-derived biomass harvested from their lands as the financial motive that they believe has the least potential to help them maintain their land as forest. In fact, the group that was surveyed reported being largely uninterested in timber harvests of any kind, and more interested in opportunities in ecosystem service markets (Pinchot Institute, 2007).

The situation is likely similar in parts of Maryland, but we cannot conclude that this same phenomenon carries throughout the state. When Maryland's current forest landowners ranked their top five reasons for owning their land in a recent survey, none of their reasons included active forest management.[29] As indicated in the 5-year management objectives of these landowners (see Table 5), there is a moderate-to-low willingness to actively manage their forest land. While the data from Table 4 suggest that forest-derived biomass availability is constrained by parcel size, the data from Table 5 suggest that social variables can occur somewhat independently of parcel size, further reducing the acres from which forest-derived biomass may be available.

Table 5. Planned management activities of Maryland landowners.

Planned management activity	Percentage of respondents
Minimal management	44%
No management	41%
Harvesting firewood	23%
Buying more land	22%
Collecting non-timber forest products	12%

Source: USDA, 2006b

For acres on which harvests are more likely, the degree of harvest intensity desired by landowners is also highly variable. Some landowners on the eastern shore report that they would

[29] The top five reasons landowners in Maryland say that they own their property are: (1) beauty/scenery, (2) part time home, (3) nature protection, (4) privacy, and (5) pass land on to heirs (USDA, 2006b).

gladly have someone "pay them for their slash," whereas, in the absence of markets for such material, landowners in western Maryland report quite the opposite. In a study of small woodlot harvests in western Maryland, landowner attitudes towards post harvest management of limbs and tops determined that 41% of landowners surveyed preferred piling slash to provide wildlife habitat, 23% preferred to have it chipped and scattered, 22% preferred leaving slash scattered on the forest floor, and only 9% preferred to have the limbs and tops chipped and hauled away (presumably at some cost to the landowner) (MD DNR, 2008).

Even among private landowners in southern states, who are more likely to intensively manage their land for timber production, mid-rotation management (e.g., thinning for stand density reduction) may not be incentivized by the presence of markets for biomass. A recent study by Gan *et al*. (2009) found that among a sample of private forest landowners across the south, less than 6% would be willing to thin overstocked stands for biomass when the average production cost was $45/dry ton. However, this study found that if landowners were presented with financial incentives and technical assistance, those willing to harvest biomass could increase to as much as 66%. The corresponding change in biomass volume from hazardous fuel reduction treatments would fluctuate from a low of 1 million dry tons at 6% of landowner participation to a high of 12 million dry tons with 66% participation (Gan *et al.*, 2009).

Factoring in landowner attributes into biomass estimates

Based on a number of social and economic constraints, Butler *et al*. (2009) determined that the accessibility of timber from Maryland's private family forests likely faces an overall reduction of 80.5% when various social and biophysical constraints are accounted for. Such a reduction factor ranks Maryland's wood supply the third most socially-constrained among the twenty northeastern states studied.

When social variables are considered, Maryland's annual 281,711 dry ton supply of woody biomass that may be available at delivered costs of $30 per green ton could be expected to change dramatically. If all other parameters from the FPL study are held equal, but an 80.5% reduction factor as determined by Butler *et al*. (2009) is factored in, the available biomass could shrink by as much as 226,000 dry tons, to approximately 55,000 dry tons available at $30 per dry ton delivered.[30] Assuming energy facilities were willing to pay $50 or more per dry ton delivered, just over 127,000 dry tons would be available from Maryland's forests annually.

It is worth emphasizing that the 80.5% reduction factor was applied to all parcels equally to get the net reduction figure. In reality, this may not be the case, as we would expect harvests

[30] This assumes the 80.5% reduction for all of the five subregions displayed in Table 2. This analysis applies the same 80.5% reduction to acres in other states; however, Butler *et al*. (2009) found varying reduction coefficient for other states with counties in these subregions (i.e., Delaware = 93.8%, Pennsylvania = 60.2%, West Virginia = 60.4%).

occurring on smaller parcels (<10 acres) to be less economically viable than larger parcels. As Table 4 shows, there may still be significant potential for biomass to become available, with approximately 85% of the state's public and private forests being larger than 10 acres. Table A-4 in the appendix offers an assessment of the available biomass in Maryland from parcels that are 10 acres or larger. This table reveals that considering parcel size alone, Maryland's biomass supply is still reduced considerably.

Some landowners may certainly respond to increased stumpage values, increasing the biomass supply, but given the number of social and economic constraints, it is impossible to determine exactly how the supply chain will respond. If markets for biomass do develop, the reduction coefficient may shift from the 19.5% response factor calculated by Butler *et al*. (2009) if more landowners are motivated to harvest biomass because of increased stumpage value and other factors. Under such a scenario, if the response factor were to increase from 19.5% to 50%, the forest-derived woody biomass supply for Maryland would be as much as 141,000 dry tons at delivered costs of $30 per dry ton, and would increase to over 326,000 dry tons when the delivered cost increased to $50 or more per dry ton.

1.5.3 Uncertainty in the supply chain

There are a number of uncertainties in the supply chain of forest-derived biomass. One key area explored below is that of uncertainty in the harvest system. Like other parts of "biomass production," there is a high degree of variability in terms of the feasible harvest type and additional costs incurred through site layout; with road construction/access, and installation of BMPs, being but a few variables that factor into the total cost of harvest. Without a more in-depth study, it is impossible to determine how representative the FPL harvesting scenario is for the study region. As previously stated, the FPL data are used in this report to merely illustrate one potential future and some of the dynamics of biomass supply.

In addition to the 265 loggers that are licensed to operate in Maryland, the woody biomass supply chain is also dependent on processors to chip and grind biomass feedstock, and truckers to transport the material. In addition to the small chippers and grinders operated by tree care companies, table 6 shows that 27 whole-tree chippers are licensed to operate in Maryland; 10 report that they operate occasionally on the lower eastern shore and 9 process residues from land clearing in central Maryland. After consultation with foresters and loggers on the eastern shore, it was determined that only a small number of whole-tree chippers actually operate on the lower eastern shore, and that those listed in the forest product operator list most likely include out-of-state firms that only occasionally operate in Maryland. This trend likely holds true for other categories from the forest products list, including the 265 registered loggers.

Table 6. Maryland's logging infrastructure.

Sawmills - Portable and Stationary	Firewood Contractors	Loggers	Pulpwood Contractors	Whole Tree Chippers
104	269	265	40	27

Source: Maryland Forest Product Operator List (Accessed in March, 2010)

Conceptually, the forest products industry supply chain is simple: trees are harvested and stacked at the landing; from the landing, logs are trucked, processed and delivered to a wood-using facility. In reality, however, the supply chain is much more complex. The logging and trucking industry of the region is comprised of a number of independent contractors, serving a range of landowners and wood-use facilities (Benjamin *et al.*, 2009). Much of the industry is based on informal agreements and is subject to relatively unpredictable supply and demand swings (Rider, 2010).

As mentioned earlier, Maryland's traditional forest products industry has faced considerable contraction in recent years. Landownership has shifted, industrial production has largely relocated, and supply chain infrastructure has shrunk. While one might assume that the potential increased demand from bioenergy markets would be embraced by most in the forestry sector, this may not prove to be entirely true.

Within the forestry sector, the primary stakeholders are public and private foresters, landowners, loggers, haulers, and processors. Given the unproven and emergent nature of bioenergy in Maryland, each one of these groups is likely to perceive the biomass market potential differently. Through informal conversations with a handful of loggers on the eastern shore, it was revealed that, at least among these loggers, opinions on biomass markets vary substantially. Some welcome the new market and state that they are willing to invest in new equipment, provided that they can obtain the requisite capital and have a market for biomass. Others are more cautious, and express anxiety over being one of the first to test the waters. These individuals express concern about possibly upsetting current relationships with sawmills that may view biomass as a threat to the timely production of sawtimber.

Uncertainty for supply chain participants

Biomass markets are currently highly speculative in the Mid-Atlantic region. While analyses like this strive to paint as clear a picture as possible, without real, on-the-ground data on supply chain infrastructure, it is difficult to predict what a stable market would look like in Maryland. The readiness of the region's logging infrastructure to accommodate biomass harvests in addition to traditional harvests is largely unknown.

Benjamin *et al*. (2009) note that "compared to handling roundwood, [logging residue] is simply more awkward and inefficient to work with," and may call for new investments in harvesting equipment. Timber harvesting equipment may constitute as much as 40 – 50% of the delivered cost of wood (Visser *et al*., 2006). Highly mechanized conventional timber harvesting systems capable of handling woody biomass commonly range from $600,000 to $2,000,000 (Visser *et al*., 2006). Added to these expenses are operation and maintenance costs of $120 to $650 per hour (Visser *et al*., 2006).

Many loggers will have to invest in new equipment in order to participate in biomass markets, given that existing logging equipment is designed for roundwood harvest only. With feller-bunchers, skidders, loaders, chippers, grinders, and processors costing approximately $195,000, $165,000, $130,000, $160,000, and $360,000, respectively, the capital outlay required to make the upgrades needed for a logging company to enter the biomass market is not insignificant (Baker *et al*., 2010). Because of these costs, some small contractors may elect to specialize in using this equipment once biomass markets are robust, but loggers suggest that "early joiner" firms are likely engaging in a risky endeavor.

In a survey of biomass suppliers in upstate New York, one logger reported spending as much as $3,000 a day to operate a whole-tree chipper to supply biomass to a large regional power plant (ESFPA, 2008). In-woods chipping is presently the most cost-effective harvesting system for recovering forest residue for biomass. Similarly, mechanized harvesters capable of the efficient removal of small diameter and cull trees also encumber loggers with significant fixed costs for depreciation, interest, and insurance, requiring consistently high ratios of product volume to cash flow. In landscapes where large clearcuts are fairly common, enough low-grade wood may be harvested to justify such investments in equipment and fuel.

For loggers to be willing to bear the logistical challenges and financial risk, the potential returns need to be high enough, or at least certain enough. With margins already quite thin, many loggers are likely to be wary of investing too deeply in biomass. Still, a number of studies have shown that even with the required initial capital outlay, biomass harvests can result in positive financial gains at reasonable market prices for roundwood and fuelwood, particularly when a chipper is integrated on site in a one-pass harvesting operation (Baker *et al*., 2010; Benjamin *et al*., 2009; Watson *et al.*, 1986; Puttock, 1995). Despite the evidence suggesting that participating in biomass markets can be profitable, there are no guarantees that loggers will readily take advantage of the opportunity. Biomass harvesting may be perceived as impinging on their ability to produce roundwood because of the extra time and effort required to remove the additional material.

Truckers may also have to invest in new equipment to haul biomass, requiring significant capital investment at the outset. There are also potentially significant opportunity costs for trucking firms to overcome before they enter the biomass supply chain, as every load of wood chips ties up a truck which could potentially haul higher-value categories of wood (e.g., sawtimber from another harvest). Chip vans, due to their relatively light weight and large capacity, are generally considered to be the most cost-efficient mode of transporting preprocessed woody biomass. However, chip vans can be quite expensive, particularly if they have an incorporated walking floor, and are sometimes limited by terrain and access road constraints. The economics of biomass hauling is somewhat unpredictable because of region-dependent factors (i.e., distance to facility, bulk density of harvested material, road conditions) and fluctuating fuel prices, but in general, biomass delivery yields financial gains at around $10/ton for trips 50 miles or less.

Uncertainty in supply contracts

Another area of the supply chain where the "chicken and the egg" phenomenon is acutely obvious is that of long-term contracts for wood supply. A 2008 report concerning biopower project developers in New York State found that feedstock procurement is the largest single cost (over 50%) of bioenergy projects and therefore has the greatest impact on the price of the energy produced (ESFPA, 2008). Any proposed energy facility will have to demonstrate that they have a secure supply of biomass prior to any commitments of capital by lenders. In some places, the recent credit crunch has resulted in financiers requiring that an even larger share of any newly proposed facility's biomass supply be secured in long-term contracts, preferably for as much of the facility's service life as possible. This is difficult to do in a fragmented and highly parcelized landscape, making in depth, site-specific, and spatially explicit analyses essential.

Any new large biomass consumer that would require significant amounts of feedstock may seek long-term contractual relationships with suppliers. Given the small profit margins associated with logging in Maryland, and the price uncertainty of biomass over the course of such contracts, most loggers are likely to be wary of entering into long-term biomass procurement contracts with energy facilities. This is especially true given that supply agreements between the region's existing mills and loggers have a long track record of informal and non-binding relationships. There is also a fear that written contracts between a facility and loggers may lead to in-field liability issues (e.g., OSHA compliance, insurance) for the facility. Given this incongruence, certain business models (e.g., biomass aggregators) may develop to facilitate biomass supply chain development in the region. Such firms could coordinate the flow of a number of different biomass streams and work directly with procurement staff for a facility. This is a similar model to traditional timber dealers, who have been forced to adapt to Maryland's shrinking forest landscape.

1.6 Summary of Woody Biomass Availability in Maryland

1.6.1 Urban wood waste flows

Urban wood waste appears to be an abundant and low-cost source of woody biomass in Maryland. Across the U.S., urban wood waste accounts for about 17% of the total waste received at municipal solid waste landfills (USDA, 2002). Urban wood waste has several subcategories, which include land clearing debris, tree care wood, street tree wood, C&D wood, and arboriculture waste. Panich *et al.* (2007) caution that a considerable amount of "clean" urban wood waste is currently recycled into higher value markets (e.g., reconstituted wood pallets), and would thus not be available unless the price of biomass increased. The recoverability of this wood varies, and an accurate estimate is impossible without a detailed study conducted on the scale of individual facilities or subregions.

With the region's population continuing to rise, landfill space will become increasingly valuable and thus alternative disposal methods for organic waste will become increasingly attractive as tipping fees rise. This trend has played out in Maryland in recent years with the establishment of a 40% voluntary municipal waste diversion goal in 2000, which has accelerated the establishment of natural wood waste recycling (NWWR) facilities. According to MDE (2006):

> A natural wood waste recycling (NWWR) facility manages and recycles NWW, (which is considered solid waste until it is recycled)... These facilities produce a variety of products including woodchips, mulch, compost, and firewood, which may be sold to consumers. These facilities are valued because they prevent NWW from entering the landfill and make useful products from such waste. Recycling NWW saves valuable space in landfills, thereby extending their useful lives. An individual or general NWWR Facility Permit is required for persons constructing and operating such a facility. A NWW recycling facility does not include a collection or processing facility operated by a nonprofit or governmental organization located in the State, or a single individual or business that provides recycling services solely for its employees or for its own recyclable materials generated on its own premises. During 2005, there were 37 permitted operations that reported processing approximately 210,328 tons of NWW.

Across the state there are many NWWR facilities, with the two highest volume facilities being Edrich Lumber Inc., and Comer Construction, Inc., which processed approximately 38,900 green tons and 27,400 green tons, respectively in 2005. Based on information available at www.mdrecycles.org, there are around 19 NWWRs and transfer stations in central Maryland, many of which process roundwood, yard waste, C&D waste and other sources of woody biomass. Likewise, this website suggests that there are at least two facilities on the lower eastern shore, five facilities on the upper eastern shore, and one facility in western Maryland. What constitutes the links of a biomass supply chain in the urban areas of the state (NWWR facilities, secondary wood processing facilities) certainly differs from rural areas (primary wood processing facilities and forest management operations).

1.6.2 Land clearing debris

When considering that as much as 7,200 acres of forest land are cleared in Maryland each year, as much as 936,000 green tons of wood (roundwood and biomass) are generated during these land clearing operations on an annual basis. Based on current stocking levels, an average of 159 green tons of wood are produced per forested acre in Maryland, 30 green tons of which is root and stump biomass. Assuming that roughly 40% (52 green tons) of all the merchantable timber is removed as higher-value roundwood and only 50% of the remaining material is available to be chipped as wood fuel,[31] roughly 38 green tons of biomass per acre (273,600 green tons total) are available to be utilized by bioenergy and other markets from land clearing operations annually. This amount is similar to the 276,000 green ton estimate put forth by the MD DNR during the preparation of the Maryland Climate Action Plan.

If we assume that 50 – 75% of this material would be available for energy utilization, 136,800 – 205,200 green tons of woody biomass fuels would be available annually from land clearing operations. Since wood from land clearing is a component of the urban wood waste supply, this 136,800 – 205,200 green ton estimate seems reasonable, given that MDE reported that 210,328 tons of woody material was processed at NWWR facilities in 2005. Such facilities are where the bulk of the state's land clearing debris is likely to end up.

Biomass supply from land clearing and conversion is episodic and non-renewable when the land is developed and/or the conversion of forest land is not offset through establishment of an equivalent area of forestland. If implemented to the full intent of the law, Maryland's Forest Conservation Act (see section 5.4.5) could provide some assurance that as lands are cleared, an equivalent area of forest is conserved or created. Still, implementing this policy to the letter of the law does not suggest that land clearing can be considered a source of renewable biomass.

1.6.3 Tree care debris

Landscaping and tree care in urban settings (including park maintenance) is sometimes included within estimates of municipal solid waste. Efforts are made to list this separately because the product is potentially close to 100% "clean" woody material. This is a poorly tracked category, but information obtained from at least one local government suggests that it may be a substantial source of woody biomass. From 2004 and 2008, the Baltimore County Department of Public Works removed 8,600 street trees. A sample of 463 of these trees removed between 2006 and 2008 revealed an average dbh of 26 inches. Almost all of this wood was chipped and disposed of in landfills or in NWWR facilities (Outen, 2009).

The MD DNR Forest Service administers licensing of "Tree Care Experts" and performed an informal survey of arborist's estimates of their daily production. It was assumed that 900 operations produced an average of 1.5 green tons of woodchips per crew on a daily basis, for 48 weeks per year, to yield an estimated 324,000 tons of woodchips annually (Rider, 2010). It was not estimated how much of this is currently sold into other markets such as mulch and compost, but it is likely substantial. Also, much of this waste may find its way into NWWR centers and

[31] This limit is imposed because of a number of factors including size and location of the parcel, breakage of residue material during saw timber harvests, and cleanliness of the biomass.

may thus be double-counted. A more statistically robust approach and/or more vigorous tracking would be needed to ascertain a dependable estimate of tree care waste wood supply that would be suitable for energy production.

1.6.4 Summary of estimates of urban wood waste

Several studies (MD DNR; PPRP, 2006a; Skog *et al*., 2009) have attempted to estimate urban wood waste supplies, which are summarized in Tables 7 and 8. There is the potential for significant error as some urban wood waste may be double-counted as land clearing debris in one instance and MSW in another instance. Nevertheless, while these numbers are not statistically reliable, they are likely to be of a correct order of magnitude and useful to offer a gross estimate of available wood from urban areas. It is important to note however that limited distinction is made between urban wood that is recoverable and wood that is usable as fuel for the energy technologies profiled in chapter two.[32]

The FPL study uses an approach based on estimates of wood waste associated with population and other demographic data, that assumes that 10% of the following wood waste categories are available and recoverable in urban wood waste streams: discarded furniture, pallets, containers, packaging materials, lumber scraps, yard and tree trimmings, and construction and demolition wood. The FPL methodology is applicable to all counties in all states of the study area, whereas the PPRP study only applies to 50 miles around Maryland's coal fired power plants and does not include some counties in adjacent states. Still the PPRP study uses data gathered by state waste management agencies collected between 2003 and 2005. Despite using different methods, these estimates of urban wood waste were generally similar in both studies.

Table 7. Potentially recoverable wood from MSW and C&D (Dry Tons)

Subregion	Total recoverable urban wood residues (MSW and C&D) FPL Study	Total recoverable urban wood residues (MSW and C&D) PPRP (2006a) Study	Difference (Tons)
Western	60,020	49,235	10,785
Central	417,800	470,196	52,396
Southern	89,110	91,538	2,428
Upper Eastern Shore	87,350	13,584	73,766
Lower Eastern Shore	28,670	19,308	9,362
TOTAL	**682,950**	**643,861**	**39,089**

Source: Skog *et al.*, 2009; PPRP, 2006a

[32] For example, PPRP (2006a) estimated that for every ton of MSW collected at a landfill, only approximately 46.6 pounds of urban waste wood may be recovered for co-firing with coal.

Table 8. Potentially recoverable wood from urban areas in Maryland (Dry Tons)/1

Type	MD DNR estimates/1	Estimate from this study
Land Clearing	138,000	102,600
Refuse (MSW)	178,500	NA
Tree care waste	162,000	NA
TOTAL	**478,500**	**NA**

Source: MD DNR estimates from Climate Action Plan; (Rider, 2010)
/1 Adjusted for a 15% average moisture content for MSW and 50% for land clearing debris and tree care waste (PPRP, 2006a; Skog *et al*., 2009).

1.6.5 Primary and secondary wood residues from manufacturing

The USDA Forest Service classifies primary mill residues into three categories: bark, coarse residues (chunks and slabs) and fine residues (shavings and sawdust). While the actual composition of coarse mill residue varies by tree species and mill type, a typical sawmill will produce 60 – 70% of useful timber as rough-cut lumber, 20 – 30% as woodchips, and 10% as fine residue.

The USDA Forest Service Timber Product Output (TPO) database tracks existing uses of these mill residues including woodchips for pulp and paper, fuel, composite timber products (e.g., oriented strand board (OSB), particle board, plywood, and composite lumber) and other uses (e.g., landscape mulch, animal bedding, and fuel). In 2007, only 1.5% of mill residues generated in the U.S. was not used for onsite energy production or other uses and was thus not available (Walsh, 2008). The majority of mill residues are already utilized, primarily for the production of heat and power for industrial processes in the wood products industry. However, as discussed previously, the allocation of these residues may shift from one use to another. Approximately 46,636 dry tons (93,272 green tons) are presently unused in the Maryland supply regions today (see Table 9) (Skog *et al*., 2009). If prices of energy wood were to rise, additional primary and secondary residues currently in other markets may find their way into the bioenergy market.[33]

The PPRP (2006a) biomass supply analysis suggests that there are 148,754 dry tons of mill residuals available in Maryland and 439,802 dry tons available in Pennsylvania, Virginia, and West Virginia. The PPRP analysis largely ignored that mill residuals are currently being utilized in other markets (including for onsite energy generation) and assumed that biomass for co-firing would readily compete for these residuals. Thus, the PPRP estimate of available mill residues is over 390,000 dry tons larger than the estimate of the FPL study.[34]

[33] For a description of the volume of these residues that presently satisfy other markets see Table 1 on page 20.
[34] For a graphical depiction of this discrepancy see Table A-11.

Table 9. Availability of mill residues in subregions (Dry Tons)

County	Total residue produced	Used for fiber byproducts	Used for fuel byproducts	Used for miscellaneous byproducts	Unused mill residues available for biomass
Western subregion					
Allegany, MD	222,507	40,074	12,334	153,031	17,067
Bedford, PA	61,313	20,034	7,353	28,322	5,604
Somerset, PA	34,286	7,392	11,966	12,718	2,210
Huntingdon, PA	53,667	22,839	9,015	21,154	658
Fulton, PA	15,257	632	2,857	5,784	5,983
Franklin, PA	68,747	14,274	15,481	36,203	2,789
Fayette, PA	53,298	22,935	7,300	17,518	5,545
Frederick, VA	16,421	7,122	5,414	3,786	99
					39,956
Central subregion					
Adams, PA	10,290	2,755	3,316	3,450	769
Lancaster, PA	26,032	2,300	5,093	17,189	1,450
Chester, PA	724	-	243	420	62
York, PA	18,491	804	4,741	11,419	1,527
Loudon, VA	16,033	5,243	24	10,560	206
					4,013
Southern subregion					
Caroline, VA	74,974	34,969	27,481	9,857	**2,666**
Total Unused Mill Residues					**46,636**

Source: Skog *et al*., 2009

1.6.6 Dedicated energy crops

Maryland's population more than doubled between 1950 and 2000, and during this time Maryland's actively cultivated farmland has decreased by more than half. Much of this land was developed over the last half-century, but some of it reverted to forest cover. Today, Maryland has approximately 1.2 million acres of actively cultivated land, 291,800 acres of **idle cropland** and 456,700 acres of pastureland (USDA NRCS Natural Resources Inventory, 2003). Neighboring states also have significant amounts of idle cropland (CBC, 2010). Economics and policy will dictate where and when energy crops may be grown on these lands.

Moreover, while plantation area accounts for a very small percentage of timberland in Maryland at the moment, the lines between plantation forests and agriculture may be blurred in the future if there is a significant increase in demand for biomass. Natural resource managers should consider the implications of an expansion of energy crop production, which may not be commonplace in the region at this point in time, but may increase in the future (i.e., planting of exotic and/or genetically modified species, whole-tree harvesting, increased application of fertilizers and/or herbicides, short-rotation woody crop plantations).

Short rotation woody crops (SRWCs) appear to have significant potential to serve as bioenergy feedstock by supplying more biomass on less land. The smaller footprint of these intensively managed plantations may reduce pressure on native forests to meet society's demands for forest products and energy while simultaneously improving degraded agricultural soils and protecting water quality (CBC, 2010). Energy crops appear to be an immediately adoptable solution to address biomass feedstock demands, but in field sustainability research on these systems in Maryland is nascent. Several policy, economic, social and environmental hurdles must be overcome before SRWC plantations are an economically attractive and socially acceptable option for Maryland landowners.

While a number of dedicated bioenergy crops exist, three species: switchgrass (*Panicum virgatum*), hybrid poplar (*Populus* spp.), and willow (*Salix* spp.), stand out in terms of yield, rotation length, and energy potential. Tables A-1, A-2, and A-3 in the appendix provide detailed county-by-county analysis of these three potential bioenergy crop yields for idle cropland and conservation lands (as defined by the USDA's 2007 Census of Agriculture) in Maryland.

It must be noted that the two land categories included in these tables overlap to some degree. "Conservation lands" include lands enrolled in USDA Farm Bill programs such as, the Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), Farmable Wetlands, or lands enrolled in the Wetlands Reserve Program. Some of these conservation acres may or may not be included in the "idle cropland" land use category. It should also be noted that not all of these lands are suitable for energy crop production, almost assuredly resulting in inflated yield and area-based cost estimates.

Aside from obvious land suitability limitations and landowner behavior uncertainties, some conservation programs (i.e., CRP and CREP) currently disallow the cultivation and harvest of energy crops. The acres covered by these programs represent significant investments in conservation values such as soil and water quality and wildlife habitat. Still, other acres have not seen such investments, and opportunities to improve environmental quality may go unrealized for landowners adverse to government incentive programs. Several studies are currently analyzing the effects of modification of restrictions and payment schemes of these programs to allow for the cultivation and harvest of dedicated energy crops, which may result in competitive bioenergy feedstock prices (Volk *et al*., 2006; Walsh *et al*., 2003; Tharakin *et al*., 2005; Updegraff *et al*., 2004; Keoleian and Volk, 2005; Turhollow, 2000).

By analyzing the estimated production costs per energy unit ($/GJ), a break-even point (BEP)[35] that must be recovered at the farmgate can be approximated to provide one measure of the economic feasibility of energy crop systems. Based on calculations summarized in Tables A-1,

[35] Farmgate BEP does not reflect a necessary reasonable internal rate of return (IRR) for landowners

A-2, and A-3 in the appendix, and adjusted for 2010 dollar value, a farmgate BEP of $1.50/GJ ($30.58/odt), $2.06/GJ ($44.99/odt), and $1.70/GJ ($36.16/odt) for switchgrass, hybrid poplar, and switchgrass, respectively (summarized in Table 10). These estimates differ from farmgate BEP values calculated in other reports; Tharakan *et al*. (2005) estimated current yield BEP for willow biomass in New York to be $1.90/GJ ($33.20/odt) and Walsh *et al*. (2003) estimated the national average BEP for switchgrass, hybrid poplar, and willow to be $30/odt, $32.90/odt, and $31.74/odt, respectively. The discrepancy in estimated farmgate BEPs is likely a result of uncertainty in attainable yields,[36] **high heating values (HHV)**, and production costs for each species. It is likely that the actual BEP for each feedstock differs from location to location.[37]

Table 10. Summary of potential bioenergy feedstock energy yields for idle cropland* and conservation lands* and estimated production costs compared to coal

Energy Crop	Potential Energy Yield (GJ/yr)		Estimated Production Costs** ($/GJ)	Estimated Production Costs** ($/dry ton)
	Idle Cropland*	Conservation Lands*		
Switchgrass	6,762,801	7,850,557	**$1.50**	**$30.58**
Hybrid Poplar	4,424,632	5,136,308	**$2.06**	**$44.99**
Willow	5,439,541	6,314,459	**$1.70**	**$36.16**
Coal			**< $1.10**	

* Idle Cropland and Conservation Lands as defined in USDA 2007 agriculture census, Maryland Table #8: Farms, Land in Farms, Value of Land and Buildings, and Land Use (http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Maryland/st24_2_008_008.pdf)
** Production costs converted from 1997 dollar value to 2010 dollar value. Coal production costs represent EIA open-market national average at minehead in 2008, HHV of 27.114 GJ/Mg, and conversion to 2010 dollar value.

In order to be considered viable fuel alternatives, biomass feedstocks must be price-competitive with existing energy fuels. In 2008, the minehead sales[38] price of coal was $1.10/GJ. With the lowest farmgate BEP of all three biomass energy crops being nearly 1.5 times greater than that of the average coal minehead sales price, a distinct competitive disadvantage begins to emerge. Despite the increased transportation distances required for coal fuel sourcing, the aggregate demand and challenging transportation supply logistics inherent to biomass utilization nullifies any potential savings from the transportation distance discrepancy, and may even widen the gap between feedstock prices. Moreover, the Mid-Atlantic's short-line rail infrastructure is a well developed and relatively efficient transportation network that allows coal to be transported over longer distances at relatively low costs. While it may be conceivable that regional biomass

[36] The yield values used for this analysis were 13.1, 8.0, and 10.1 (Mg/ha/yr) for switchgrass, hybrid poplar, and willow, respectively (Walsh *et al.*, 2003). These values were estimated for the Appalachia region, which includes DE, KY, MD, NC, TN, VA, and WV. Because these states have differing acreages and growth rate potentials for each species, these averages may overestimate or underestimate actual yields in Maryland.
[37] To facilitate such analysis SUNY-ESF has created a downloadable economic analysis tool, EcoWillow: http://www.esf.edu/willow/download.htm.
[38] Minehead sales price calculated from 2008 EIA national average, and reflects a rate of return to the supplier. The BEP of coal is less than $1.10/GJ ($2010).

supply chains may evolve to take advantage of the regional short-line rail transportation network, this potential remains largely undeveloped.

As pointed out by Keoleian and Volk (2005), the price differential between fossil fuels and biomass crops represents a significant market failure. If the negative externalities of fossil fuels are accounted for in market price, biomass feedstocks may become much more cost competitive; if markets for ecosystems services evolve to include the ecosystem services of energy crop establishment on idle lands (e.g., riparian buffers adjacent to agricultural land), these competitive effects will increase (Keoleian and Volk, 2005; Updegraff *et al*., 2004; Tharakan *et al*., 2005).

Similarly, more stringent rules related to agricultural nutrient management may contribute to a reduction in the cost of energy crop establishment as riparian buffers. When Turhollow (2000) modeled the cost of energy crop systems on the Delmarva Peninsula, it was found that if buffer strips were required as a condition of poultry litter application on row crops; the production costs borne by energy crops shifted to other facets of the agricultural operation and were not reflected in the delivered cost of biomass. This study concludes that based on the acres of buffer established on the Delmarva Peninsula in 1999 and a variety of economic variables, energy crops planted in riparian buffer strips could yield as much as 210,000 to 420,000 dry tons per year (Turhollow, 2000).[39]

1.6.7 Summary table of woody biomass supply

Table 11 lists biomass that is estimated to be available at certain prices in each of the five subregions of Maryland. Forest-derived biomass estimates were derived from the FPL data and adjusted to account for landowner preference and biophysical limitations. Since integrated harvest operations such as those implicit in the FPL biomass harvest simulation are less likely to occur on small parcels, Table A-4 was included in the appendix to show how available biomass supply changes if parcels of 10 acres or less are excluded from estimates of available biomass.

In addition to biomass from forests, the FPL estimates of available mill residues and urban wood waste are also given in Table 11. Energy crops are not included in these estimates because they do not represent a current source of available biomass. If favorable market conditions and government policies exist, energy crops have the potential to be a substantial source of biomass in Maryland. As previously discussed, if strong markets for biomass exist, the mill residue category may also increase, as energy wood competes with other markets for residuals. There is also potential for bioenergy facilities to compete with pulp and paper mills for feedstock in the future.

[39] Assumes yields of 7 to 8 dry tons/acre/year, and total delivered costs of \$2.35 to \$2.60/GJ.

Table11. Biomass availability by subregion at varying price estimates (Dry Tons)

Biomass (dry tons) available at $30 per ton delivered cost.

Subregion	Low (19.5%) landowner response	High (50%) landowner response	Landowner preference ignored	Urban Wood Waste	Mill Residues	Total Biomass: Low Landowner Response	Total Biomass: High Landowner Response	Total Biomass: Landowner Preference Ignored
Western	28,643	73,443	146,885	60,020	39,956	128,619	173,419	246,861
Central	9,439	24,202	48,403	417,800	4,013	431,252	446,015	470,216
Southern	12,424	31,856	63,711	89,110	2,666	104,200	123,632	155,487
Upper eastern shore	1,359	3,485	6,969	87,350	-	88,709	90,835	94,319
Lower eastern shore	3,070	7,872	15,743	28,670	-	31,740	36,542	44,413
Total for Maryland	**54,934**	**140,856**	**281,711**	**682,950**	**46,636**	**784,519**	**870,441**	**1,011,296**

Biomass (dry tons) available at $50 per ton delivered cost.

Subregion	Low (19.5%) landowner response	High (50%) landowner response	Landowner preference ignored	Urban Wood Waste	Mill Residues	Total Biomass: Low Landowner Response	Total Biomass: High Landowner Response	Total Biomass: Landowner Preference Ignored
Western	56,626	145,193	290,386	60,020	39,956	156,602	245,169	390,362
Central	23,313	59,777	119,554	417,800	4,013	445,126	481,590	541,367
Southern	27,284	69,958	139,916	89,110	2,666	119,060	161,734	231,692
Upper eastern shore	6,796	17,424	34,848	87,350	-	94,146	104,774	122,198
Lower eastern shore	13,044	33,445	66,889	28,670	-	41,714	62,115	95,559
Total for Maryland	**127,061**	**325,797**	**651,593**	**682,950**	**46,636**	**856,646**	**1,055,382**	**1,381,178**

Biomass (dry tons) available at $70 per ton delivered cost.

Subregion	Low (19.5%) landowner response	High (50%) landowner response	Landowner preference ignored	Urban Wood Waste	Mill Residues	Total Biomass: Low Landowner Response	Total Biomass: High Landowner Response	Total Biomass: Landowner Preference Ignored
Western	58,351	149,618	299,236	60,020	39,956	158,327	249,594	399,212
Central	23,647	60,633	121,266	417,800	4,013	445,460	482,446	543,079
Southern	28,061	71,951	143,901	89,110	2,666	119,837	163,727	235,677
Upper eastern shore	6,796	17,424	34,848	87,350	-	94,146	104,774	122,198
Lower eastern shore	13,409	34,382	68,763	28,670	-	42,079	63,052	97,433
Total for Maryland	**130,263**	**334,007**	**668,014**	**682,950**	**46,636**	**859,848**	**1,063,592**	**1,397,599**

Biomass (dry tons) available at $90 per ton delivered cost.

Subregion	Low (19.5%) landowner response	High (50%) landowner response	Landowner preference ignored	Urban Wood Waste	Mill Residues	Total Biomass: Low Landowner Response	Total Biomass: High Landowner Response	Total Biomass: Landowner Preference Ignored
Western	58,431	149,822	299,644	60,020	39,956	158,407	249,798	399,620
Central	23,668	60,686	121,372	417,800	4,013	445,481	482,499	543,185
Southern	28,961	74,258	148,515	89,110	2,666	120,737	166,034	240,291
Upper eastern shore	6,796	17,424	34,848	87,350	-	94,146	104,774	122,198
Lower eastern shore	13,923	35,699	71,397	28,670	-	42,593	64,369	100,067
Total for Maryland	**131,777**	**337,888**	**675,776**	**682,950**	**46,636**	**861,362**	**1,067,473**	**1,405,361**

1.7 Conclusions and Recommendations on Biomass Supply

In terms of geographic distribution, and ignoring landowner preference, the central subregion hosts the largest supply of biomass in Maryland, comprising approximately 34% of the state's total supply, a large portion of which is urban wood waste in and around Baltimore City. Western Maryland comes next with 33% of the total, and then southern Maryland with 18% and the lower and upper eastern shore with 15% (combined). When landowner preference is considered and only 19.5% of landowners participate, the statewide distribution of biomass shifts, with close to half (49%) being supplied from central Maryland, 21% coming from western Maryland, 15% from southern Maryland and the eastern shore, respectively.

Table 12. Mean percentage of total population and biomass availability by subregion.

Subregion	Percentage of Total Population	Mean Percentage of Total Biomass- Low Landowner Response (19.5%)	Mean Percentage of Total Biomass- High Landowner Response (50%)	Mean Percentage of Total Biomass- Landowner Preference Ignored
Western	4%	21%	27%	33%
Central	67%	49%	41%	34%
Southern	21%	15%	17%	18%
Upper eastern shore	4%	10%	9%	8%
Lower eastern shore	4%	5%	6%	7%

When considering the assumptions embedded in the FPL methodology and the PPRP estimate of urban wood waste, 784,519 dry tons of woody biomass is potentially available on an annual basis at $30 per ton delivered. This estimate includes reductions in the available volume of biomass due to social constraints. When such factors are ignored, this volume increases to just over 1 million dry tons of biomass being available at $30 per ton. When parcel size is used as the limiting factor such that biomass is only available from parcels greater than or equal to 10 acres, only approximately 23,000 dry tons of biomass from thinning operations is available for $30 per ton delivered or less each year. It is difficult to determine whether such a thinning scenario is realistic, or if the bulk of the forest-derived biomass supply will continue to come from regeneration harvests and land clearing operations, as it currently does. Significant amounts of biomass may be available in the state from parcels undergoing regeneration harvests, but it is difficult to determine how much may become available from such harvests over the long-term.

It is clear that Maryland's traditional forest product markets, and related silvicultural activities, are focused on the production of high-value sawtimber. In most places, the existing harvesting equipment is tailored to work with roundwood products, and is not currently conducive to harvesting forest-derived biomass, other than roundwood, in a highly efficient manner. Thus, the biomass likely to be harvested in the near-term may be more expensive and/or limited than those simulated by the analysis of the FPL data.

Conversely, while the FPL study generated county level estimates of how much wood may be available over the next 30 years by reducing stand density through thinnings, the study did not fully include the amount of biomass available from pulpwood sized roundwood or mill residues currently going into other end uses. Some whole-tree harvests in Maryland currently produce woodchips priced for energy around $40 per green ton delivered.[40] In these regeneration harvests, the amount of energy wood produced from roundwood chips can be significant, and the FPL data do not necessarily accurately account for such harvests.

The type and extent of biomass harvests that will take place on private forest lands in Maryland in the future remains uncertain. It is thus difficult to predict how much feedstock will be available in Maryland to furnish energy facilities. These volumes may grow to be substantial in the short-term, as a backlog of degraded stands comprised of poorly formed and undesirable trees is harvested and processed. However, after this backlog is worked through, the supply is expected to come from thinnings and final harvests. These are but some of the factors that make it difficult to predict the long-term sustainable supply and appropriate scale of any given facility.

Another significant unknown is the degree to which biomass may be imported from outside of the state at distances greater than 50 miles. Maryland's transportation infrastructure is advanced, and it is conceivable that this infrastructure could support the transport of densified and/or torrefied biomass to fuel bioenergy facilities in the future. However, in advance of more fluid commodity-driven supply chains, any bioenergy projects within the state should be appropriately scaled to the current supply of economically available and sustainable biomass to avoid risk of supply disruption.

While energy crops hold significant promise, and may actually help improve water quality, this supply is not economically competitive in current energy markets unless subsidized. Still, approximately 246,000 to 400,000 dry tons of biomass could potentially be cultivated on idle cropland in Maryland in the form of switchgrass, hybrid poplar, and willow, providing a significant source of additional feedstock and new economic opportunity.[41]

The economics of bioenergy technologies will also strongly influence the amount of biomass that comes to market. The various biomass supply studies discussed in this chapter have not fully analyzed the price elasticity of biomass demand inherent within each bioenergy technology in

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[40] This price point was estimated from discussions with logging crews.
[41] According to Tharakan *et al.* (2005), "Modeling estimates indicate that 75 direct and indirect jobs will be created for every 9,600 acres of willow biomass energy crops that are established."

relation to the potential supply. This is a difficult factor to incorporate, but is essential to establishing attainable bioenergy policy goals.

Traditionally, energy investment is risk-averse, and fuel supply security is a pre-requisite to project financing. Many transactions in forestry in Maryland are "handshake deals" based on trust, largely because the forestry community is small and tightly-knit (Rider, 2010). Considering the localized nature of the industry, it is not surprising that key actors are likely to have known each other for years and understand their mutual-dependence, making formalized agreements less necessary (Rider, 2010). This type of market structure does not translate well to the type of supply guarantees required in energy markets. Investors ultimately desire a guaranteed, steady supply of feedstock, which would normally be secured through contracts with fuel supply and transport companies. These types of fuel-sourcing contracts are extremely challenging to establish for biomass feedstocks because of the highly decentralized nature of the forestry sector and biomass resources themselves.

Support due diligence on supply

Given concerns about the availability of sustainable volumes of woody biomass feedstocks and the potential for market competition and displacement, the precautionary principle calls for all investments in bioenergy to carefully scrutinize the availability of biomass resources and to scale projects appropriately. While this process will likely require additional investments in upfront planning and analysis, it is the only way to ensure that any new bioenergy development will have an economically, socially, and environmentally sustainable future in Maryland. In some instances, such an analysis may reveal novel synergies between the existing wood products industry and the emerging bioenergy industry. In others, it may reveal direct competition.

Explore potential solutions to address supply-chain logistical challenges

For a variety of reasons, securing significant volumes of biomass will be difficult in Maryland. Emergent bioenergy markets may provide a new opportunity for entrepreneurs to capitalize on the disparity between traditional forestry and energy business models. These entrepreneurs would serve as aggregators who would own and operate biomass processing facilities specializing in securing biomass from multiple sources (i.e., logging operations, NWWR centers, and arborists), and thus would be able to enter into long-term biomass sourcing agreements with energy facilities. This type of facility may even incorporate a densification operation, mulch yard, or poultry bedding service in order to service multiple markets and guide different types and qualities of biomass into different production streams.

Another model could involve sawmills aggregating supply through the loggers they frequently source saw logs from, in an effort enhance these sawmills' capacity for cogeneration. Such a business model could also provide both mill residues and logging residues for densification from a large regional sawmill, or a conglomeration of several sawmills, to a single pelletization or biomass briquette manufacturer. Given the marginal economics that confront Maryland's existing forest products industry, such biomass utilization options may be explored to carve out an appropriate market niche to build upon their current operations.

Another approach to ensuring the sustainability of supply chains may be to simply keep the fuel requirements small by siting only small low-demand facilities throughout the region to minimize supply-drain potential. Similarly, the development of small regional pelletization facilities, possibly in conjunction with existing sawmills, may prove to be an appropriate way of producing a higher-value product with minimal biomass demand.

It is conceivable that landowner cooperatives could form to offer an increased amount of economically available sustainable biomass by minimizing acreage constraint issues. In these models, small landowners across a landscape could coordinate their planned management actions in a way that could supply a regional sawmill and/or energy facility with wood on a predictable basis. Previous experiments with woodland cooperatives have even attempted to apply harvest revenue from one or two parcels harvested on an annual basis, contributing to offsetting the tax burden for all individuals within the cooperative.

Support ongoing research, development, and demonstration

Several areas of state-level or regional collaborative research could help facilitate bioenergy market development. Some areas of further analysis include:

- Regional (multistate) economic analysis of the potential impacts of large-scale bioenergy development on wood markets and agricultural markets in the Mid-Atlantic. Such analysis could include the integrated economics of energy technologies (e.g., fermentation or combustion) and resource characteristics.
- Regional (multistate) and sub-regional (multicounty) research on supply chain infrastructure. This would answer questions such as: What are the major bottlenecks in the urban and rural supply chains? How can more quality waste wood be recovered? What are the equipment needs? How can parcel size limitations be overcome? Can energy crops be incentivized by environmental markets for water quality and through cost-share programs? What are the implications for policy?
- Fine scale optimization analysis of specific locations to better define which business models make the most sense in the different biomass-sheds of the state.

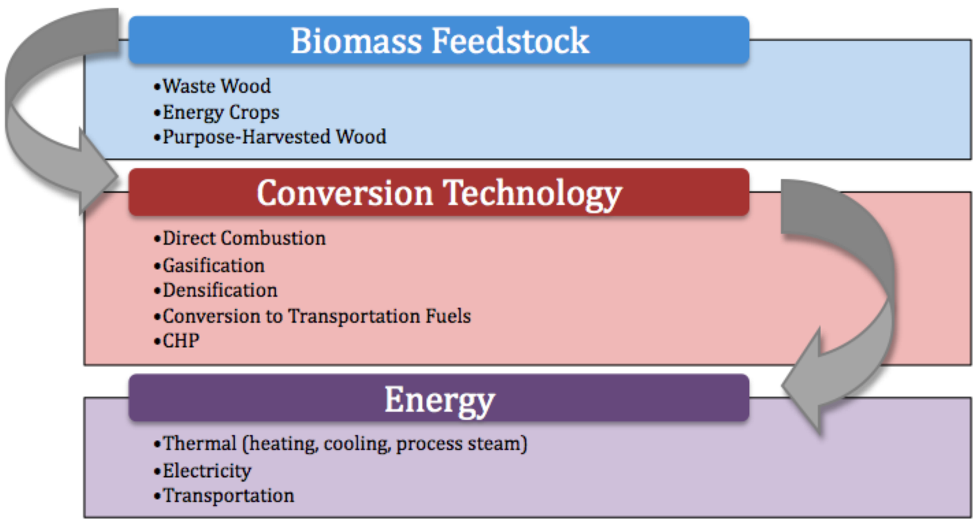
Chapter 2

Defining Appropriate Energy Technologies for Biomass Utilization

2.1 Introduction

Of all the renewable energy options, bioenergy is quite possibly the most flexible in that it is capable of contributing to all forms of energy demand. This unique attribute is shown in Figure 6, which offers a conceptual model outlining the basic components and pathways of bioenergy systems.

Figure 6. Conceptual diagram of bioenergy systems.



This chapter provides a brief overview of several biomass utilization technologies in an attempt to determine which options may offer the best fit given Maryland's unique attributes. The technological information presented here is based on relevant data from current research and does not necessarily address the future viability of these technologies. The technologies profiled are not an exhaustive list of options and the data used for analysis may not reflect the actual performance of these technologies under operational conditions.

Several key issues have remained unaddressed in this chapter, with additional considerations that should be addressed in the future including: net energy balance, net life cycle GHG balance, and the lifecycle economic feasibility of these various options. This analysis does not attempt to calculate the value of emission reductions for these options, or any of the various federal and state financial incentives (e.g., tax credits and renewable energy credits) that may affect project implementation decisions.

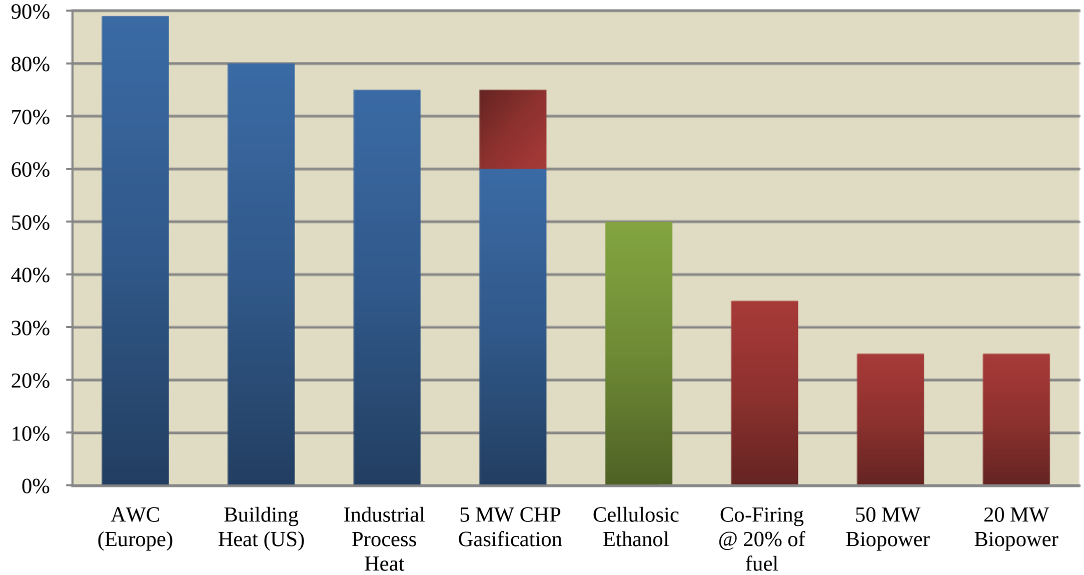
In the U.S., biomass is already widely utilized as an energy feedstock. In 2005, biomass became the largest source of domestic renewable energy, accounting for nearly 50% of the national renewable energy resources and 10% (9,848 MW) of domestic renewable electricity capacity (National Research Council, 2010). Maryland currently only has a few small-scale bioenergy facilities within the state, and the bulk of the renewable electricity purchased by regulated utilities for Renewable Portfolio Standard (RPS) compliance is derived from out of state biomass energy facilities (see discussion of Maryland RPS in chapter three) (MD PSC, 2010).

Energy conversion efficiencies of various bioenergy systems vary from 20% to over 90% (see Table 13 and Figure 7), which has significant effect on feedstock specifications, energy supplied, and the elasticity of demand for feedstock. The feasibility of these utilization options depends on a number of interrelated factors, including: capital outlay requirements, feedstock supply chain security, social constraints, investor recruitment, project implementation timeline, rate of return, alternative options, and the objectives of energy policy.

Table 13. Relative efficiencies of bioenergy options studied.

Conversion Technology		**Net Efficiency**	**Gross Efficiency**
	Biopower (Electricity Only)	25%	**25%**
Co-firing	**5% Biomass**	32%	**32%**
	10% Biomass	31.5%	**31.5%**
	20% Biomass	30.6%	**30.6%**
Direct Combustion CHP	Electricity	25%	**75%**
	Thermal	50%	
Gasification CHP	Electricity	29%	**75%**
	Thermal	46%	
	Cellulosic Ethanol	50%	**50%**
Thermal Energy Systems	**Wood-chip District Energy**	75%	**75%**
	Cordwood Stove (not EPA certified)	60%	**60%**
	Cordwood Stove (EPA certified)	68%	**68%**
	Pellet Stove	80%	**80%**
ORC Optimized Direct Combustion CHP	Electricity	18%	**98%**
	Thermal	80%	
Modular Stirling Engine CHP System	Electricity	16%	**91%**
	Thermal	75%	

Figure 7. Relative efficiency of various bioenergy options.



	AWC (Europe)	Building Heat (US)	Industrial Process Heat	5 MW CHP Gasification	Cellulosic Ethanol	Co-Firing @ 20% of fuel	50 MW Biopower	20 MW Biopower
Biofuel					50%			
Electricity				15%		35%	25%	25%
Thermal	89%	80%	75%	60%				

Source: Biomass Energy Resource Center; Richter *et al*., 2009

Woody biomass sources vary in terms of their quality as a fuel source, depending on tree species, density, moisture content (MC), bark content, particle size, and chemical composition. These qualities are closely linked with the type of forest management activities undertaken. In turn, prescribed forest management activities largely depend on the "market pull" for certain types of material.

Some biomass utilization technologies (e.g., combined heat and power and thermal systems) demand "cleaner" and more consistent forms of biomass, suggesting that roundwood chips will be demanded. Other technologies may be more flexible and able to utilize logging residues, such as chips from limbs and tops, chips with a bark component, non-forest-derived woody biomass, and agricultural biomass. The homeostatic market price of biomass feedstock demanded by each technology may influence forest management decisions. While procurement costs can vary from location to location and technology to technology, generalized feedstock procurement cost limitations are presented in Table 14, which offers a statewide summary of various biomass utilization technologies. Tables A-5 through A-9 in the appendix disaggregate this statewide assessment to outline the energy potential and procurement cost limitations of various energy technologies in the five subregions of Maryland. These tables offer a better description of the actual procurement limitations for various potential bioenergy options within five areas of the state where potential facilities may source biomass.

Table 14. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential in Maryland.

	Delivered Price (green tons)	$30		$50		$70		$90	
	Landowner Participation	Low Response (19.5%)	Preference Ignored (100%)	Low Response (19.5%)	Preference Ignored (100%)	Low Response (19.5%)	Preference Ignored (100%)	Low Response (19.5%)	Preference Ignored (100%)
	Biomass (green tons)	960,550	1,414,105	1,104,805	2,153,869	1,111,209	2,186,711	1,114,236	2,202,235
	Biopower Potential Electricity (MW)	**96**	**141**	110	215	111	219	111	220
Number of 300 MW Coal Plants that Could Cofire	5% Biomass	**7**	**10**	8	15	8	15	8	15
	10% Biomass	**3**	**5**	4	7	4	7	4	8
	20% Biomass	**2**	**2**	2	4	2	4	2	4
Number of 700 MW Coal Plants that Could Cofire	5% Biomass	**3**	**4**	3	7	3	7	3	7
	10% Biomass	**1**	**2**	2	3	2	3	2	3
	20% Biomass	**1**	**1**	1	2	1	2	1	2
CHP Potential (Direct Combustion)	Electricity (MW)	**43**	**63**	**49**	**96**	**49**	**97**	**50**	**98**
	Thermal (MMBtu)	**1,279,453**	**1,883,588**	**1,471,600**	**2,868,954**	**1,480,130**	**2,912,699**	**1,484,162**	**2,933,377**
CHP Potential (Gasification)	Electricity (MW)	**48**	**71**	**55**	**108**	**56**	**110**	**56**	**110**
	Thermal (MMBtu)	**1,251,328**	**1,842,183**	**1,439,252**	**2,805,888**	**1,447,594**	**2,848,672**	**1,451,538**	**2,868,896**
	Cellulosic Ethanol (Million Gallons)	**41**	**61**	**48**	**93**	**48**	**94**	48	95
	Wood Pellets (tons)	**480,275**	**707,053**	**552,403**	**1,076,935**	**555,605**	**1,093,356**	557,118	1,101,118
Thermal Energy (MMBtu)	Wood-chip District Energy	**5,763,300**	**8,484,630**	**6,628,830**	**12,923,214**	**6,667,254**	**13,120,266**	**6,685,416**	**13,213,410**
	Cordwood (not EPA certified)	**4,610,640**	**6,787,704**	**5,303,064**	**10,338,571**	**5,333,803**	**10,496,213**	5,348,333	10,570,728
	Cordwood (EPA certified)	**5,225,392**	**7,692,731**	**6,010,139**	**11,717,047**	**6,044,977**	**11,895,708**	6,061,444	11,980,158
	Pellet Stove	**6,147,520**	**9,050,272**	**7,070,752**	**13,784,762**	**7,111,738**	**13,994,950**	7,131,110	14,094,304
ORC Optimized Direct Combustion CHP	Electricity (MW)	**31**	**45**	**35**	**69**	**36**	**70**	**36**	**71**
	Thermal (MMBtu)	**2,047,124**	**3,013,741**	**2,354,560**	**4,590,326**	**2,368,209**	**4,660,318**	**2,374,660**	**4,693,403**
	Number of 2 kW Stirling Engine CHP Systems*	**25,685**	**37,812**	**29,542**	**57,593**	**29,713**	**58,471**	29,794	58,887

/1 Total Potential for Maryland given available biomass supply as defined in Table 11 and adjusted for moisture content. Area highlighted yellow with bolded numbers indicates that there is no estimated cost limitation for a given technology at a given biomass procurement cost (assumes current technology). Areas that are not highlighted indicate an estimated cost limitation for a given technology at a given biomass procurement cost. This also assumes that all technologies evaluated are able to use wood from all sources (i.e., urban wood waste, logging residues and material from thinnings, and mill residues), which may not reflect the operational fuel requirements of these technologies. That is certain technologies will only use "clean chips" or pellets, while others are more omnivorous, suggesting that the energy production potential listed here and in tables A-5 through A-9 may not be a completely accurate depiction of true energy production potential.

2.2 Biopower Potential

The direct combustion of biomass feedstocks is the most frequent form of energy conversion currently used in the U.S., accounting for approximately 80% of all electricity generated from biomass (National Research Council, 2010). Biopower is attractive from the perspective that it is a renewable source of **baseload electricity**, whereas other renewable energy technologies (e.g., wind and solar) supply intermittent amounts of renewable electricity. Similar to its coal-fired counterparts, biomass power plants operate on a lower-temperature steam-Rankine cycle in which the fuel is combusted, creating heat to produce high-pressure steam, which drives a turbine to produce electricity. Biopower plants of this nature currently comprise approximately 1,100 MW of installed capacity in the U.S., representing roughly a quarter of the electricity generated by biomass. The remaining three-quarters of biomass-derived electricity produced in the U.S. comes from CHP facilities, most of which are sited in traditional forest products manufacturing facilities.

Due to feedstock sourcing constraints and the relatively low energy content of wood as compared to fossil fuels, biomass-fired power plants rarely exceed 50 MW of generation capacity. However, large-scale facilities in regions with abundant biomass resources and/or highly developed supply chains may range as high as 100 – 350 MW[42] (National Research Council, 2010; Larson *et al*., 2009).

With biopower technologies, electricity is the desired energy product and the remaining "waste" heat unused and vented out cooling towers and water effluent. The sheer amount of waste heat created in the wood-to-electricity conversion process, and the low embedded energy content of wood, contribute to the fact that current biomass power facilities average approximately 25 – 30% gross efficiency (Hansson *et al.*, 2009; Walker *et al*., 2010). Biomass integrated gasification combined cycle (BIGCC) technology offers improvements in efficiency, with upwards of 50 – 65% being theoretically achievable; however, BIGCC is significantly more expensive (Hinnells, 2008; National Research Council, 2010). There is at least one 50 MW BIGCC plant being built by Xcel energy in Wisconsin[43] and DOE anticipates that others may be considered in the future (EIA, 2007).

The relatively low efficiency of today's biopower technologies, combined with the relatively high generation capacity of these facilities, results in a sizable demand for biomass feedstocks.

[42] At a proposed 350 MW, the Port Talbot biomass plant of Port Talbot, Wales will be the largest wood-fired facility in the world. Construction is scheduled to be completed by the end of 2010.

[43] This plant is being built at a capital cost of over $58 million in order to comply with Wisconsin's renewable portfolio standard, which requires Xcel energy to use a certain amount of biomass in their renewable mix (Donovan, 2009).

For example, a 50 MW biopower facility operating at 25 – 30% efficiency requires nearly 600,000 green tons of woody biomass feedstock annually (Walker *et al.*, 2010). When this demand is compared to the total biomass available within each of the five subregions as defined in this study (see Table 11 and Tables A-5 through A-9), only central Maryland could procure enough biomass at $30 per green ton delivered within the region to support a 50 MW power plant.[44]

Theoretically, if electricity prices rise, 100% of eligible landowners participate, and biopower facilities were willing to pay $70 – $90 per green ton delivered, the state could supply two large facilities over 70 MW, one in central Maryland and one in western Maryland. However, this scenario is only feasible if biopower is subsidized significantly or if the price of other electricity sources increases significantly. There has been anecdotal evidence of such a subsidization effect occurring in parts of the eastern U.S. during the roll out of the federal Biomass Crop Assistance Program (BCAP) in 2009 – 2010 (see discussion of BCAP in the summary of existing polices in Chapter 3). Given that most timber harvests are not economically justified on parcels smaller than 10 acres in size, and that as much as 90% (160,367 acres) and 97% (730,310 acres) of the parcels in western and central Maryland are 10 acres in size or less, respectively, such a regional harvesting scenario would be highly unlikely. If harvests could be economically justified on small tracts, other factors, such as supply chain and social constraints would likely still limit the available supply of biomass fuel from forestland in central and western Maryland, thereby limiting biopower potential.

Because consumers demand low-cost electricity, the market price of biomass fuel must be comparable to the market price of alternative fuels (i.e., coal and natural gas), which have historically been low-cost (Keoleian and Volk, 2005; Updegraff *et al.*, 2004; Tharakan *et al.*, 2005). Given the challenges of developing large, robust, and secure biomass supply chains in the region, biopower facilities (and ultimately ratepayers) would likely be more susceptible to market price swings, unless the comparative costs of fossil-based electricity and biopower changed dramatically. While policies like production tax credits (PTC), investment tax credits (ITC), and renewable portfolio standards (RPS) provide some financial incentives, the challenges of biomass supply logistics and financing suggest that large-scale biopower may not be feasible in Maryland.

[44] This potential relies on the participation of all eligible landowners, and would ultimately exhaust all of the estimated available biomass feedstock for the region. Central Maryland's woody biomass supply is overwhelmingly comprised of urban wood waste which presents its own logistical and technological hurdles. The theoretical 50 MW biopower facility may or may not be able to utilize all of the available urban wood waste. Also, the 18 MW Viking Energy biomass energy facility in Northumberland, Pennsylvania utilizes a significant amount of land clearing debris from central Maryland and any new capacity in central Maryland would compete with this facility (personal conversation with PA DCNR staff).

Biomass combustion in a 2 MW boiler. Photo: Brian Kittler

2.3 Co-firing Potential

As of 2007, approximately 150 coal-fired power plants worldwide have included biomass as a portion of their fuel mix. Of the plants in the U.S. that have pursued this option, most **co-fire** biomass at 1 – 8% of the total heat rate. However, there are facilities in Europe where biomass is successfully co-fired up at 20% of the total heat rate (Hansson *et al.*, 2009). Currently there are 62 biomass co-firing operations in the U.S., with a total installed capacity of approximately 5,080 MW, the majority of which are sited in forest products facilities (EIA, 2009a; Williams *et al.*, 2007).[45] The Luke Maryland Pulp and Paper plant currently mixes 10% biomass, 22% coal, 63% fuel oil and 5% natural gas in its 28 MW Generator 2. This facility is permitted to combust a higher percentage of biomass as part of its fuel mix for its twin boilers that have a combined 60 MW capacity, and the Maryland Department of the Environment (MDE) expects that this will be implemented in the future for the facility to comply with GHG reduction efforts as part of the Regional Greenhouse Gas Initiative (RGGI).

Maryland currently has a total of 7,543 MW of coal-fired generating capacity from 16 generators, representing 56% of the state's electrical generation (PPRP, 2006a). Maryland's Climate Action Plan has identified co-firing as a near-term strategy for offsetting a portion of the

[45] Some do not consider these boilers to be "co-firing facilities" as they are specifically designed to burn high percentages of different types of fuels.

state's coal consumption. In 2006, the Maryland Power Plant Research Program (PPRP, 2006a) evaluated Maryland's 16 coal-fired generators for co-firing potential. Given the economics and engineering of each plant in the state, PPRP only found the 573 MW Dickerson power plant in Montgomery County to be an immediately feasible option for co-firing. If **torrefaction** were used, there may be potential for co-firing torrefied wood in more of Maryland's power plants, however this option was not analyzed by PPRP.

Co-firing offers a unique set of advantages and disadvantages. First and foremost, it is one of the least expensive options to mitigate fossil fuel consumption and can be implemented in a relatively short time frame. The atmospheric benefits of substituting biomass for coal include: reduction of SO_2 emissions (100%),[46] reduction of NO_x (approximated average of 6% at 5% biomass and 10% at 10% biomass) and life cycle CO_2-equivalent emissions reductions (up to 22% of plant total at 15% biomass)[47] (PPRP, 2006a; Williams *et al*., 2007). Another potential benefit of co-firing is that plants are generally quite flexible with regards to biomass fuel price volatility in that these facilities can manipulate the fuel mix to optimize production costs with shifting fuel market prices (Hansson *et al*., 2009).

On the other hand, co-firing is one of the least efficient conversion technologies, with only about 33% of the biomass material's energy potential being realized (Williams *et al*., 2007). Biomass fuels also have higher alkali metal levels than coal, which may interfere with existing NO_x catalytic pollution control systems (PPRP, 2006a). Another potential drawback is that in order to co-fire with biomass accounting for greater than 2% of total heat input, coal-burning boilers must often be retrofitted to accommodate for the new fuel. The PPRP report (2006a) analyzed Maryland's existing infrastructure to estimate retrofit costs, with results ranging from \$150/kW to \$400/kW. While the cost of retrofit is not insignificant, it is much less expensive than new biopower plant construction (Williams *et al*., 2007).

In order for co-firing to be economically viable, biomass feedstock prices must be comparable to coal, a notoriously low-cost fuel. In Maryland, coal costs approximately \$1.41 per million Btu. Biomass feedstocks, including urban waste wood, mill residue, agricultural residue, forest residue, and purpose-grown energy crops, cost approximately \$1.70, \$1.93, \$4.95, \$3.65, and \$3.20 per million Btu, respectively (PPRP, 2006a). While current regulation and economic

[46] Reductions reflect a comparison of biomass to coal. Reductions are attributed to the biomass heat input only. Therefore, a facility co-firing at 10% biomass (by heat input) can expect an approximate 10% reduction of SO_2 emissions and 1% reduction of NO_x emissions. This is because biomass contains scant amount of sulfur, but a notable amount of nitrogen when compared to coal. NO_x emissions reductions are much more variable, as biomass nitrogen content is highly dependent on feedstock species and site characteristics, but the lower burning temperatures resultant of biomass feedstock inclusion facilitate more complete combustion of fuels over a longer period of time (PPRP, 2006a; Williams *et al*., 2007).

[47] The life cycle GHG gas emissions associated different bioenergy systems is currently an area of great debate in both science and policy (see Fargione *et al*., 2008; Searchinger *et al*., 2009; Walker *et al*., 2010) and the GHG reduction information presented here represents the findings of PPRP (2006a) and Williams *et al*., (2007).

incentive programs narrow this price discrepancy, it is probable that urban wood waste and mill residues will be the only economically viable feedstocks for co-firing projects in Maryland unless the price of electricity changes substantially (PPRP, 2006a).

Biomass supply is a significant constraint to co-firing. Coal has a **heating value** around 10,000 Btu/lb, while dry biomass offers around 8,600 Btu/lb and wet biomass falls between 4,700 and 7,100 Btu/lb. It takes approximately one ton of biomass to generate the same amount of energy as 0.61 tons of coal (Williams *et al.*, 2007). The relative inefficiency of co-firing, coupled with the fuel demands of utility-scale coal boilers, may prove taxing on biomass feedstock supply if co-firing were to become commonplace in Maryland. Indeed, even the idealized supply estimates of PPRP (2006a) provide evidence that co-firing related biomass demand may quickly exceed locally available supplies (see Tables A-11 and A-12 in the appendix).

The PPRP (2006a) study estimated the total supply of all available biomass types (urban wood waste, mill residue, agricultural residue, forest residue) within a 50-mile radius of each facility, without consideration of number of social constraints. Because the PPRP (2006a) study likely overestimates the available feedstock for co-firing facilities, these numbers were reworked with the estimates calculated for this report for comparative analysis. Tables A-10 through A-13 in the appendix summarize the key findings of the 2006 PPRP co-firing study and compares estimated available wood-feedstock values to elucidate some of the risks and benefits of coal-boilers in Maryland with the greatest potential for co-fire conversion.

The cornerstone finding of the PPRP study suggests that Dickerson would be the best-suited facility for co-firing in Maryland. However, when competing usage is accounted for in feedstock estimates,[48] the annual available woody biomass estimate is nearly cut in half (317,455 green tons per year vs. 562,396 green tons per year) (see Table A-13). Using the estimates of PPRP (2006a), the Dickerson facility would demand approximately 19% of the annual wood biomass supply when co-fired at 5% and 38% of total supply when cofired at 10% (Table A-13). However, the availability estimates of this study suggest that the Dickerson facility is more likely to demand 33% of total available supply at a 5% co-fire and 66% of the total available supply when co-firing at 10% biomass (Table A-13). It should also be noted that these estimated biomass values do not reflect landowner preference, and compare countywide supply values rather than 50-mile radius values, so even this analysis likely overestimates feedstock availability.

[48] This does not include the demand associated with the 18 MW Viking Energy facility in Northumberland, Pennsylvania, which sources land clearing debris from central Maryland.

2.4 Combined Heat and Power Potential

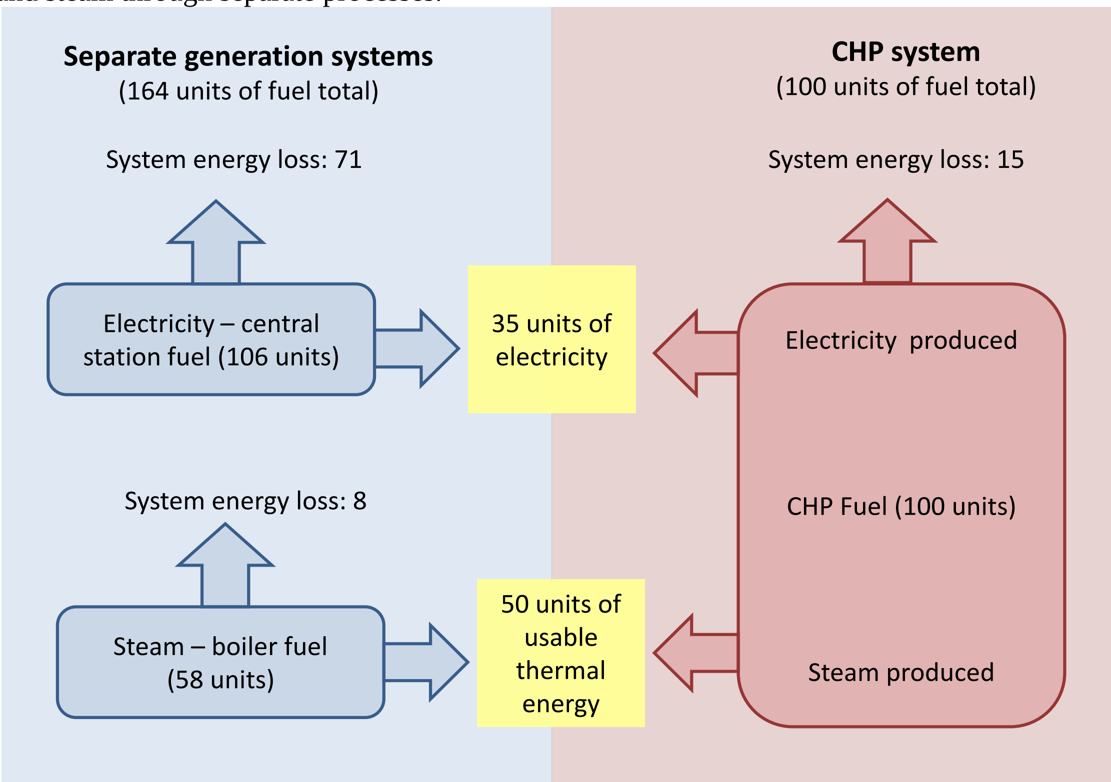
Combined heat and power (CHP) or cogeneration is the process of generating electricity while simultaneously harnessing useful thermal energy. Electricity production from combustion produces a significant amount of excess heat, most of which (usually upwards of 75%) is not utilized by traditional electricity-only power plants. Combined heat and power systems seek to harness "waste heat" by integrating thermal energy systems for heating, cooling, or process applications (U.S. EPA, 2007). By integrating CHP technology into biomass electricity production, gross energy efficiency can be improved significantly. While there are a number of different CHP technologies, average systems typically achieve efficiencies of 60 – 80%, with some technologies being theoretically capable of achieving efficiencies of over 90% (U.S. EPA, 2007). In general, CHP systems reach higher efficiencies when the system is designed primarily to meet the thermal energy needs of a given facility.

There are numerous benefits gained in producing electricity and useful thermal energy in a single process. Because CHP systems are more efficient and use less fuel than separate processes, the emissions profile (i.e., particulate matter, CO_2, SO_x, NO_x, etc.) is less than that of systems generating electricity and steam through separate processes (DOE, 2008). In fact, industrial-scale CHP units, typically emit 500 - 760 fewer tons of CO_2 per each MW of installed capacity (Hinnells, 2008). Other benefits include less energy loss in transmission since much of the electricity that is produced is used onsite, in a micro grid, or is exported to the regional electricity grid.

Woodchips outside the ECI CHP facility. Photo: Brian Kittler

Figure 8 is a conceptual depiction of the fuel use efficiency of CHP systems as compared to stand alone electricity-only power plants and on site production of steam through separate processes.

Figure 8. Fuel use efficiency of an industrial CHP system as compared to generation of electricity and steam through separate processes.



Source: Adapted from the Northwest Pulp and Paper Association

As attractive an option as CHP may be, it is limited to locations with a significant thermal energy demand. Communities in Europe have overcome this challenge in many places by connecting small biomass CHP facilities (1 – 10 MW) to district thermal energy grids, which provide heat to nearby residences and commercial areas. In Finland and Denmark, over half of the population receives their heat from such sources, with 96% of the city of Copenhagen being heated in this way (Hinnells, 2008). Biomass CHP, connected to district heating and cooling, also provides over 30% Russia's power (IEA, 2007). In the U.S., similar biomass district thermal systems currently exist or are being constructed on a number of college campuses, as well as downtown Seattle, St. Paul, and Boca Raton.[49] Mini-CHP technologies (<100 kW) can also be used in clusters of buildings in less dense suburban settings. Such models are worthy of consideration, given that over 40% of the electricity consumed and nearly 40% of the CO_2 emitted in the U.S. is

[49] The Boca Raton plant is actually a district cooling system fueled by biomass, and provides all the cooling needs for several office and commercial buildings through absorption chillers.

attributed to heating and cooling needs of commercial and residential buildings (Andrews and Jelley, 2007).

Most of the installed CHP capacity in the U.S. is natural gas or oil fired, although the domestic forest products industry generates approximately 65% of its own thermal energy and electricity through CHP (DOE, 2008). Since wood fuel can represent 80% or more of the operating cost of a biomass energy project, efficiency gains attained through CHP can make biomass feedstocks more cost-competitive to fossil fuel alternatives (U.S. EPA, 2007).

As evidenced in Table 14, CHP technologies are capable of paying more for biomass feedstock and may consequently promote desirable forest management activities not economically supported by other bioenergy options.

Although biomass supply can be difficult to source, Maryland's Eastern Correctional Institution (ECI) has managed to secure a long-term contract for the delivery of high quality wood fuel. This model may be easily replicated, albeit with more advanced and efficient energy conversion technologies, as the ECI boilers were originally designed to fire natural gas, but were retrofitted to use woody biomass. The 4 MW ECI Biomass CHP plant, located in Westover, MD, has operated since the mid-1980s to provide for 100% of the thermal needs and 80 – 85% of the electricity needs of the prison, which houses approximately 450 inmates. The facility is specifically designed to disconnect from the region's electricity grid during severe weather; during which, two 1 MW backup diesel generators supply the remaining electrical needs. At the time of installation, natural gas and liquid petroleum were cost-prohibitive on the Delmarva Peninsula, while biomass was relatively low-cost and abundant. The facility utilizes 50,000 – 65,000 green tons of bolewood chips annually, consuming approximately 180 tons per day. Treated wastewater is used to produce steam for space heat, hot water, laundry, and air conditioning.

CHP and district heating hold promise for Maryland at both the industrial and community scales. Presently, only about 6.5% of Maryland's total electricity generating capacity capitalizes on "waste heat" through CHP (Mid-Atlantic Clean Energy Application Center, 2010). A study by PPRP (2006b) profiled all existing CHP facilities in Maryland and identified the potential for additional CHP facilities. The study was intended to identify "geographical areas and the business and governmental sectors that could potentially benefit from the installation of CHP, provide potential cogenerators with information to help facilitate project implementation, and identify actions that can help facilitate the attractiveness and suitability of CHP projects in Maryland."

The PPRP study provides informational and technical resources for firms and organizations considering CHP. It also includes an in depth explanation of the various opportunities and barriers that projects are likely to face in Maryland, such as: service contracts, business structures, net metering policies, **interconnection** policies, utility **standby requirements**, utility pricing policies, operational and logistical issues, capital outlay requirements, fuel requirements, regulatory hurdles (e.g., permits for construction and operations), local government codes, and a lack of familiarity with CHP systems (especially biomass-fired CHP systems) among contractors and engineers. Additionally, the study identifies the Mid-Atlantic Clean Energy Application Center[50] as a clearinghouse of information and services available for potential CHP projects in Maryland.

As of 2006, there were 17 CHP facilities (820 MW of total capacity from 37 separate cogeneration technologies) operating in Maryland. Fourteen of these facilities are located in the Baltimore and Washington, D.C. metropolitan areas, two CHP units are located in Allegany County, and the ECI CHP unit is the only facility located on Maryland's portion of the Delmarva Peninsula. Approximately 90% (740 MW) of Maryland's installed CHP capacity operates in the industrial sector, with the remaining 10% (81 MW) in commercial or institutional settings. Eighty-six percent (703 MW) of this capacity is from just four industrial plants. Five companies operate CHP facilities (11 – 50 MW) in commercial and institutional settings through third-party system operations contracts. There are also 8 small-scale (<10MW) facilities that operate throughout the state (PPRP, 2006b).

Natural gas (47%), coal (29%), and blast furnace gas (15%) are the largest sources of fuel for Maryland's installed CHP capacity. Woody biomass, in the form of **black liquor** and wood waste, currently account for 8% and 0.35%, respectively. The PPRP (2006b) study also found that majority of the future CHP capacity is likely to be natural gas-fired. A proposed 30 MW CHP facility at the Ft. Detrick military base in Frederick, Maryland has completed a preliminary biomass fuel supply study, but additional analysis is needed for this site.

According to PPRP (2006b), there are approximately 3,700 sites (3,200 commercial or institutional and 500 industrial) in Maryland that could potentially install CHP systems. This is an upper-bound estimate, based on the presence of both electric and thermal demand.[51] The PPRP used U.S. Department of Energy[52] estimates to provide the "technical potential" of CHP systems, and did not perform additional analysis of economic feasibility. The study concludes that the bulk of new CHP systems will be very small, with approximately 2,300 sites (70%) having the technical potential for small (<500 kW) CHP systems in commercial or institutional settings. It also concludes that another 900 commercial or institutional sites could potentially host CHP systems larger than 500 kW.

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[50] http://www.maceac.psu.edu/stateinfo.htm
[51] Thermal energy loads in the form of steam or hot water, an electricity demand to thermal demand ratio of 0.5 – 2.5, and moderate to high operating hours (>166 days per year).
[52] Available at: http://www.eere.energy.gov/de/pdfs/bchp/eiacom.pdf

Table15. CHP technical potential in Maryland's commercial and institutional sector.

Size of CHP Facility	100 - 500 kW	500 - 1000 kW	1 - 5 MW	> 5 MW Total	Total
MW Potential	504	471.8	506.4	228.8	1,711 MW
Average Capacity per Site	220 kW	700 kW	2.5 MW	9.5 MW	540 kW
Number of Sites	2,291	674	203	24	3,192 Sites

Source: PPRP, 2006b

Table 15 shows potential sites and capacity for CHP plants in the commercial and institutional sectors of Maryland, as determined in the PPRP report. According to PPRP (2006b), the best opportunities for CHP in commercial and institutional settings are: office buildings, schools, hospitals, prisons, and nursing homes.

The 500 industrial sites that PPRP identified with greatest technical potential were:

- Food Products (336 sites):
  - central Maryland (247)
  - eastern Shore (62)
  - western Maryland (24)
  - southern Maryland (3)
- Chemicals (191 sites):
  - central Maryland (150)
  - eastern Shore (32)
  - western Maryland (7)
  - southern Maryland (2)
- Paper and Allied Products (51 sites):
  - central Maryland (41)
  - eastern Shore (4)
  - western Maryland (4)
  - southern Maryland (2)
- Primary Metals (49 sites):
  - central Maryland (39)
  - eastern Shore (6)
  - western Maryland (3)
  - southern Maryland (1)
- Petroleum and Coal Products (46 sites):
  - central Maryland (31)
  - eastern Shore (5)
  - western Maryland (6)
  - southern Maryland (4)

Biomass-fired CHP capacity for each subregion was determined across a number of feedstock prices and landowner participation scenarios (see Tables A-5 through A-9, in the appendix). Fuel quality and supply logistics are not accounted for in this analysis, and as most biomass-fired CHP systems require clean woodchips; these supply estimates are likely overstated. However, there still appears to be opportunity in each subregion for an expansion of biomass-fired CHP installations.

Woodchip conveyor at a biomass-fired CHP facility. Photo: Brian Kittler

2.5 Gasification / BIGCC

Biomass integrated gasification combined cycle systems are a new and promising biomass utilization technology. While it is not currently widely available in the U.S., it is quickly garnering attention as the technology develops. Instead of direct combustion to power a single steam engine, BIGCC uses a gasification process to power a gas turbine and a steam engine simultaneously.

Gasification is a thermo-chemical process in which biomass is heated to a level just below its combustion point. At this temperature, the wood fuel gasifies into a mixture of carbon monoxide and hydrogen, or “syngas.” The syngas is then pumped to a high-oxygen chamber, where it is combusted at extremely high temperatures. The exhaust gases of the syngas combustion are run through a Brayton cycle (gas turbine generator), and continue on to a boiler to power a Rankine cycle (steam engine) (National Research Council, 2010).

As with most energy conversion technologies, the efficiency of energy production from gasification is directly linked to technological development and economies of scale. Currently, the net energy conversion efficiency of small (<25 MW) gasifiers falls around 30%, while larger facilities (30 – 60 MW) have a net efficiency of 40 – 50% (National Research Council, 2010; McKendry, 2002). Theoretically, biomass conversion to energy using BIGCC has a maximum attainable net efficiency of 65%, due of the physics behind the system (National Research Council, 2010).

If gasification plants are appropriately sited to harness waste heat in a CHP system, gross efficiencies exceeding 75% are attainable for small systems (<25 MW), making biomass an attractive option for larger commercial and public facilities (i.e., hospitals, shopping malls, administrative buildings) (Walker *et al*., 2010). Future gross efficiencies of BIGCC CHP systems are expected to reach 85 – 90% (IEA, 2007)

Gasification CHP systems are frequently regarded as one of the most promising biomass utilization technologies in the medium-term (National Research Council, 2010; IEA, 2007; McKendry, 2002). However, gasification is a fledgling technology in the U.S. and capital investment costs are high. Capital cost for a biomass gasification power plant in the U.S. is about $2,000 – $3,000/kW, but this is expected to decrease, with a target set at $1000/kW, through increased establishment and technological improvements (IEA, 2007).

2.6 Densified Biomass Potential

Densifying biomass into **pellets**, **briquettes**, or **pyrolysis oils** has several advantages to non-densified biomass. First and foremost, **densified biomass** has higher energy content than raw woody material,[53] largely resultant from the lower moisture content and higher specific gravity of the material. Secondly, densified biomass is more convenient to burn, because it offers a more homogeneous structure, which passes through the conveyors and other conduits of energy facilities effectively and has a much more stable burn profile. Additionally, densified biomass has a lower transportation cost than non-densified biomass because of its inherent amplified energy content and homogenous shape and size. Densification also offers the potential to process multiple feedstocks together at one facility.

While the aforementioned characteristics make densified biomass attractive for certain applications, the densification process has its own set of challenges. As with all biomass conversion technologies, densification facilities require a steady and predictable supply of raw feedstock that must be collected and transported to the processing facility. After the biomass is

[53] Wood biomass pellets have an average HV of 16 MMBtu/ton vs. 7 MMBtu/ton for green wood and 12.8 MMBtu/ton for wood with a 20% moisture content

densified, it must again be transported to sales facilities or directly to an end-user. Because each one of these steps incurs incremental costs at the consumer level, a ton of densified biomass is much more expensive than a ton of undensified biomass (e.g., green wood chips). However, the increased energy value and enhanced fuel characteristics of densified biomass have potential to make up for at least a portion of this price differential.

Pelletization – Of all forms of densified biomass, pellets have had the most immediate and significant market penetration over the last two decades. Currently, there are 110 commercial scale manufacturers of wood pellets in Canada and the United States (Jackson *et al.*, 2010). While most of these facilities specialize in wood residues from the forest products industry, other biomass feedstocks (e.g., perennial grasses, like switchgrass) are being evaluated.[54] Most pelletization plants are relatively small, producing less than 50,000 tons of pellets/year, with the majority operating in the northeast, northwest, and Great Lakes regions. The U.S. wood pellet manufacturing industry has an estimated production capacity exceeding 2 million tons/year. U.S. production in 2008 was estimated at 1.63 million tons, 80% of which was used domestically (Jackson *et al.*, 2010). In the same year (2008), Canada produced approximately 1.8 million tons of pellets, of which, approximately 226,750 tons were used domestically, 408,000 tons were exported to the U.S., and 1.18 million tons were exported to Europe and other parts of the world (Jackson *et al.*, 2010). Based on these estimates, the U.S. consumed approximately 1,712,000 tons of pellets, accounting for an estimated 22 *trillion* Btus of energy[55] in 2008.

The wood pellet manufacturing process is quite similar to that used for agricultural feed pellets. Wood feedstock is dried in rotary drum dryers to a consistent moisture content of 10 – 12%, processed to uniform size using a hammermill, conditioned with chemical binding/lubricating agents and steam, pelletized by pressing the processed material through holes or a flat die, and cooled in a counter-flow cooler (Jackson *et al.*, 2010). Several considerations have dramatic effects on the overall performance of the final pellet product: if initial moisture content of the wood is too low, the pellets will overheat and char; if moisture content is too high, the pellets will not hold form and break apart; chemical binding agents can increase pellet durability dramatically; die hole diameter and taper have significant effect on durability and quality; pellets will not bind if the temperature of the woody material is too high or too low during the pelletization process; and if pellets are not appropriately cooled, they may not bind correctly,

[54] When combusted, straw, cereal, grass, and grain pellets contain high levels of N, Cl, S, and ash when compared to wood. This is of significant importance when considering emissions (particularly NO_x, HCl, SO_x, and particulate matter), corrosion, and equipment maintenance. (Obernberger and Thek, 2004; Dahl and Obernberger, 2004; Obernberger *et al*., 2006). Because of these characteristics, non-wood pellets are only currently suited for grate combustion with rigid emissions control systems in place (Obernberger and Thek, 2004; Obernberger *et al*., 2006).
[55] Assuming 100% consumption of domestically "used" pellets and imported pellets from Canada, pellet energy content of 16 MMBtu/ton, and that all domestic pellet appliances had a realized energy conversion efficiency of 80%.

resulting in a significant amount of loss (pellets crushed into fine powder) during handling (Jackson *et al.*, 2010).

Pellets are available in three grades, based on **ash content**, with premium grade having < 1%, standard grade at 1 – 2%, and industrial grade with ≥ 3%. According to BERC (2007), "Premium and standard grade pellets are suitable for any wood boiler with automatic ash removal, including most institutional or commercial-scale applications. Industrial grade pellets, or those with ash content greater than three percent, should be avoided due to the high volume of ash produced."

Table 16 provides some comparative estimates on the quantity and price of alternative forms of energy, as compared to 1 ton of wood pellets at $200/ton.

Table 16. Energy source quantity and price equivalent to one ton of wood pellets at $200/ton.

	Equivalent Quantity	Equivalent Price
No. 2 Heating Oil	120 gal.	$1.67/gal
Propane	170 gal.	$1.18/gal
Natural Gas	16,000 ft^3	$12.50/1,000 ft^3
Electricity	4,775 kWh	$0.04/kWh

Source: BERC (2007)

Recently, there has been growing interest in the establishment of "micro" pellet facilities. Such a conceptualized facility could have two 1.5 ton per hour pellet machines, producing around 11,250 tons of pellets per year.[56] Ideally, local demand would match 100% of the facility's production to minimize operating expense and bolster the local economy. A plant of this scale would theoretically cost roughly $3 million-plus,[57] and would provide enough pellets to heat 2,400 homes (Mueller, 2010). This type of facility may be a feasible regional economic development pilot project option through a coordinated "cradle to grave" incentive program.[58]

According to Walker *et al*. (2010), the maximum affordable price for a ton of pellets (used in thermal applications) is $261 per ton. When this threshold is worked backwards to the pelletization facility, the maximum affordable price for a ton of green wood chips is $85

[56] 1.5 t/hr, 15 hr/day, 5 days/wk, 50 wks/yr

[57] $300,000- Preprocessing Equipment, $500,000- Dryer and Controls, $200,000- Dry Grinder/Prep Equipment, $650,000- Pellet Mills (2), $300,000- Bagging System, $500,000- Buildings & Land, $200,000- Design Engineering, $200,000- Inventory, $250,000- Working Capital (Mueller, 2010).

[58] Capital investment will be required to strengthen the local wood supply chain, construct the pellet facility, and for household conversion to pellet stoves. Some degree of government backing in one, or all, of these sectors may have significant effect on overall success. In-depth economic analysis will be required to determine actual economic feasibility.

delivered (Walker *et al*., 2010).[59] Based on these numbers, the establishment of small densification facilities in each subregion of Maryland may be an economically desirable pursuit, provided that each facility is able to pelletize multiple types of feedstock (i.e., logging residues, roundwood, urban wood waste, mill residues, energy crops, etc.). Given that the current in-state demand for densified biomass is extremely low, without the simultaneous promulgation of densified biomass utilization technologies (e.g., pellet stoves and pellet furnaces) in Maryland, the processed material would likely be exported to other states or overseas.

According to the biomass supply estimates of this report, western Maryland can produce just over 100,000 tons of wood pellets annually when roundwood is utilized, while the central, southern, and eastern shore subregions could produce approximately 230,000, 270,000, and 80,000 tons per year, respectively if urban wood waste can be utilized.

If urban wood waste cannot be economically pelletized, the estimated wood biomass supply will shrink considerably, and pelletization may become a less viable option without the cultivation of energy crops. If energy crops and urban wood waste are excluded, western and southern Maryland would be the best candidates for regional wood pellet facilities, with potential annual production levels of nearly 80,000 tons and 30,000 tons respectively. If roundwood is not utilized and only mill residues are suitable, only Western Maryland could possibly support production of wood pellets at a limited production level of just shy of 30,000 tons per year of finished product, before competition for mill residuals would be realized.

Pyrolysis – As previously discussed, the energy density of wood fuel is an important constraint for its use in energy markets, and densifying biomass has been shown to improve the transportation economics significantly (Richard, 2010). One technology, **pyrolysis**, is rapidly advancing in terms of efficiency, applicability, and cost.

Pyrolysis is similar to gasification, but with several notable differences. Like with gasification, in the pyrolysis process, biomass is heated in a low-oxygen environment to capitalize on the chemical properties of the feedstock. However, the pyrolysis process heats the wood to temperatures around 500° C, while maintaining the low-oxygen environment, resulting in a mixture of usable liquids, gases, and solids (Jackson *et al*., 2010). The desired products of the pyrolysis process are fuel gas, liquid pyrolysis oils (bio-oils), and solid bio-chars.

Pyrolysis Oil / Bio-oil – The efficiency of the pyrolysis process is maximized (around 80%) when bio-oils are the primary end product through flash pyrolysis, where biomass is heated to around 500° C in a matter of a few seconds (Pendray, 2007). The energy density of pyrolysis oil

[59] However, this does not necessarily reflect the realized market price of pellets or raw feedstock. Most pelletization plant feasibility studies estimate the realized retail price of pellets to fall between $175 and $200 (BERC, 2007; Weitner *et al*., 2007; CBCL Limited, 2008).

is about six to seven times greater than the energy density of green woodchips (Dwivedi *et al*., 2009); however the heating value of bio-oil is still only half of that of No. 2 heating oil (Pendray, 2007). Pyrolysis oils are extremely complex, with a high water content (15 – 30%), high viscosity, and variable pH, depending on feedstock and conversion process (Jackson *et al*., 2010; Agbelvor *et al*., 2009). Bio-oils can be refined into liquid transportation fuels, converted to electricity and heat through gasification or combustion, or used in other bio-chemicals. However, the chemical complexity of bio-oils brings forth a number of challenges that must be addressed before these become economically viable options on a commercial scale (Jackson *et al*., 2010; Mante, 2008).

Bio-char **–** Bio-char production is maximized (35% efficiency) through the slow pyrolysis of biomass in low-oxygen conditions at temperatures less than 700° C, resulting in a highly porous, fine-grained and carbon-rich material. Research suggests that when used as a soil additive, bio-char may sequester carbon for thousands of years (Biochar for Environmental Management: Science and Technology, 2009). Proponents of bio-char also argue that the char enhances soil water and nutrient retention and increases crop yield.

Anthropogenic bio-char-enhanced soils date back to as much as 6,700 – 8,700 years ago, the most famous of which are the *terra preta* deposits of the Brazilian Amazon. These regions are generally characterized by soils with low fertility, but the char-enhanced soil deposits contain significantly higher levels of **soil organic matter (SOM)**, nitrogen, phosphorus, potassium and calcium. It is said that crops grown in *terra preta* soils grow three times faster than on surrounding soil (Sohi *et al.*, 2009). However, feedstock and production system have significant effects on the realized physical and chemical characteristics of bio-char, and because this is a relatively nascent technology, the majority of these claims are highly speculative.

Applied research in pyrolysis suggests that this technology may have potential to convert poultry litter to energy, as evidenced by an ongoing pilot project by Virginia Tech in Virginia's Shenandoah Valley (Agbelvor *et al*., 2009; Mante, 2008). Preliminary results from this project indicate that conversion of poultry litter into bio-oils and chars is possible, but the process tends to yield more char than oil. This research suggests that poultry litter char may be a viable slow release and carbon dense fertilizer. Considering concerns already expressed in Maryland about poultry litter combustion, and the need to address the Delmarva Peninsula's nutrient management issues, pyrolysis may prove to be a promising future technology for dealing with excess poultry litter.

2.7 Thermal Conversion Potential

Another option that appears to hold notable promise for biomass utilization in Maryland is small-scale thermal energy applications.

Small-Scale District Thermal – Small-scale district wood-fired thermal systems offer gross efficiencies around 75%, are scalable to site-specific requirements, and can frequently use existing infrastructure from outdated or unreliable coal, oil, and natural gas boiler systems. Unlike with other systems, these biomass boilers are not designed for the production of electricity. Rather, the sole purpose of these facilities is to provide the heating and cooling of space and water within a single building or small building complex. Since electricity is not being generated, gross efficiency is quite high, while feedstock demand is comparatively low.

This type of biomass boiler system can be quite capital-intensive upfront, but payback periods can be reached in 5 – 20 years (FFS&B, 2008). As with all direct-combustion options, wood chip-fired biomass boiler systems are susceptible to **slagging** and the fouling of heat transfer surfaces (U.S. EPA, 2007). Clean, uniform bolewood chips are preferred fuel, requiring a steady supply stream and the establishment of a processing facility if one does not already exist (U.S. EPA, 2007).

One of the best-known programs in the U.S. affiliated with small-scale thermal project implementation is the **Fuels for Schools and Beyond** program in the inter-mountain west. As of 2008, Fuels for Schools and Beyond has established biomass boiler systems in 14 primary schools, a university, a landfill, and a correctional facility (FFS&B, 2008). In addition to those participating in the Fuels for Schools and Beyond program in the inter-mountain west, at least four other states have Fuels for Schools programs in either a pilot or full implementation phase.

Across the U.S., most Fuels for Schools wood chip boiler projects are 1.5 – 5 MMBtu/hour, have installed capital costs of $800,000 – $1,000,000, and consume 150 – 250 green tons of wood chips per year (Maker, 2009). Buildings suited for wood chip thermal systems are typically 40,000 – 50,000 square feet and serve 200 – 300 students (Maker, 2009). The capital costs of automated wood chip boiler systems are significantly higher than the capital costs of oil and natural gas systems. This upfront capital investment in the biomass system is only viewed as affordable when fossil fuel savings, discounted over a relatively short timeframe, are enough to offset the cost of conversion.

Actualized data from several pilot projects have demonstrated the cost advantage of biomass-fired Fuels for Schools systems when compared to typical No. 2 heating oil systems. During 2007 – 2008 heating season, Maine schools using woodchip and pellet systems saved 63% and 10%, respectively, as compared to schools heated by No. 2 fuel oil (Maker, 2009). In Vermont, the 20-year operational track record of more than 45 schools heated by wood has demonstrated that the price of woodchips has stayed quite stable, while the price of heating oil has fluctuated dramatically (Maker, 2009). The Vermont history with these projects has shown the break-even point of investing in woodchip heating systems to be attained in eight to twelve years (Maker, 2009). Some public financing mechanisms, which cover as much as 30% of initial capital investment, have allowed these conversions to yield a positive cash flow within the first few years of installation (Maker, 2009).

Perhaps one of the most compelling Fuels for Schools projects is that of Darby Public Schools in Darby, Montana. The Darby project began in 2001, due to an increase in regional hazardous fuel reduction projects to minimize wildfire risk. The project connects three schools, comprising a total of 82,000 ft^2 of heated space, through a buried steam pipe campus heating system to a central woodchip boiler house. The total cost of the project, which includes the creation of the campus steam system and upgrades to existing mechanical equipment, but excludes professional fees for design and project management, was $885,000 (donation values included) (Bergman and Maker, 2007). Historically, these three schools paid an average of $115,000 per year for heating, cumulatively (Lee, 2008). Following the conversion, wood-fuel heating cost was just $24,805 for the 2005 – 2006 school year, representing a 78% cost-savings (Lee, 2008). Simplified NPV payback estimates show the payback period for the project to be 9.8 years at $1.85/gal for No. 2 fuel oil (Bergman and Maker, 2007).[60]

What makes the Darby project so compelling is the comparability of Darby's economic constraints with that of Maryland's. The 85,000 ft^2 project typically consumes between 600 – 700 green tons of wood chips per year, at a delivered cost of $29/green ton (Bergman and Maker, 2007). From 2005 – 2009, Bozeman, Montana averaged 8,229 HDD[61] and 782 CDD a year, while Baltimore, MD averaged 4,683 HDD and 1,485 CDD annually.[62] The Darby school project uses the system for heating only. If absorption chillers were combined with a similarly sized system in Maryland to supply cooling in the warm months (assuming year-round operation), the annual thermal demand of both facilities would be roughly equivalent, due to the fact that absorption chillers are approximately 60 – 70% efficient when converting steam heat to cool air, resulting in a net cooling efficiency between 45 and 55%. Because of the comparable thermal demands, biomass feedstock demand would likely prove comparable as well. As stated before, Darby Public Schools expects to attain the economic break-even point in 9.8 years due to cost savings from the avoided purchase of No. 2 heating oil at $1.83/gal. While similarly sized buildings in Maryland do not consume as much heating oil as those in Montana due to its lower

[60] The payback period is likely much shorter now, as fuel oil reached $2.30/gal in the region in 2005-2006 (Lee, 2008).
[61] Heating degree days (HDD) and cooling degree days (CDD) are simplified units of measure used for comparative analysis, depicting the number of degrees a building must be heated or cooled to reach a baseline temperature (65°F) over a number of days.
[62] Degree day estimates calculated by 5-year average HDD and CDD at baseline 65°F for KBZN and KBWI airports on www.degreedays.net

HDD value, Maryland consumers pay an average of $2.88/gal of No. 2 heating oil,[63] suggesting that fuel savings would likely be similar (EIA, 2010).[64]

Wood pellet boilers are best-suited for buildings with 10,000 to 50,000 ft^2 of heated space. Wood pellet boilers of this scale have lower upfront capital costs, typically ranging $150,000 – $700,000 (Maker, 2009). Pellet boilers are smaller than wood chip boilers and may not require the construction of a large dedicated boiler room if a silo of appropriate size is available. Pellet systems may offer advantages over wood chip systems based on the reduced footprint of the facility, the lack of need for onsite material processing, the automated fuel feed of pellet boilers, and where up-front capital costs are a concern. However, wood pellets cost more than woodchips, which may extend the payback period. Additionally, wood pellets are not currently available in bulk delivery in Maryland, making a system of this scale infeasible without a simultaneous buildup of infrastructure.

According to FFS&B (2010) there are a few key factors that can make a facility well suited for biomass energy:

(1) High heat demand and high fossil fuel costs. Generally, if a facility is not using at least 2,500 dekatherms/year of natural gas or spending at least $20,000 annually on heating fuel (natural gas, propane, fuel oil) they won't be likely candidates for conversion. However, there are exceptions if installing very small furnace systems.
(2) Proximity to a wood fuel source can be important in that generally, the closer the supply, the cheaper the fuel. A haul distance from a forest source of 50 – 80 road miles can generally keep costs of wood fuel reasonable at a rate of $35 – $40/ton. Other biomass fuel sources can include wood pellets, sawmill residues, and municipal wood waste such as clean demolition waste and urban trees, which may be nearby.
(3) Space available for the biomass burner, fuel storage, and access for delivery trucks.
(4) It's more cost-effective to install a biomass boiler system in the new construction of a facility compared to integrating it into an existing system.
(5) A simple payback on investment within 10 years is desirable.

Residential Wood Combustion (RWC) – Residential wood combustion is the burning of wood inside and outside of the home. Residential wood burning appliances span a number of applications, efficiencies, and emissions profiles. While this report seeks to be inclusive of these options, it is not exhaustive. Some of the technologies discussed in this section are not desirable

[63] The U.S. average price is $2.79/gal. Maryland currently ranks #5 in the nation in terms of heating oil cost. Heating oil price trend data is currently unavailable for Montana.
[64] For comparative purposes, commercial electricity in Maryland averages 11.56 cents/kWh (U.S. average is 9.97 cents/kWh, MT average is 8.08 cents/kWh) and the average city gate natural gas price is $6.71/thousand cu ft (U.S. average is $5.71/thousand cu ft, MT average is $4.88/thousand cu ft) (EIA, 2010).

for a number of social and environmental reasons. However, new modern RWC appliances are highly efficient, emit few pollutants, and offer an inexpensive option for the promotion of sustainable biomass utilization when compared with nearly every other technology discussed in this chapter.

Approximately 18% of Maryland's households have at least one form of RWC appliance installed, representing 344,341 tons of wood combusted every year (Table 17) (Houck and Eagle, 2006). The majority of these installed RWC units are less efficient than modern RWC systems, such as wood pellet appliances.

Table 17. Residential wood combustion in Maryland.

	Number Installed	Percentage of Total Housing	Wood Consumed (dry tons/yr)
Total RWCs	366,710	18.0%	344,341
Conventional Wood Heater	141,670	7.0%	199,526
Non-Catalytic Wood Heater	34,906	1.7%	39,043
Catalytic Wood Heater	14,587	0.7%	16,293
Fireplace with Insert	76,629	3.8%	54,248
Fireplace for Aesthetics	79,510	3.9%	7,340
Centralized Cordwood Heating Systems	6,125	0.3%	10,355
Pellet Heaters	13,284	0.7%	16,618

Source: Houck and Eagle (2006)

On July 1, 1990, the U.S. EPA enacted a New Source Performance Standard (NSPS) for RWC devices to control emissions (U.S. DOE, 2010). The program, now in Phase II, offers certification to certain device types, and should Maryland consider promoting RWC as part of its wood biomass program, a program to replace old, uncertified devices with NSPS certified appliances would be prudent and relatively cost-effective, especially since Maryland is now adopting the Phase II regulation for outdoor wood boilers.

Conventional Cordwood Heaters – **Cordwood** heaters are a category of room-space heaters that burn cordwood for room-space, or zone heating in a home. This type of heater utilizes cordwood, or logs, as the primary fuel source, a distinct advantage in terms of fuel availability, but requires frequent restocking and maintenance due to particulate buildup.

Catalytic Wood Heaters – NSPS certified catalytic wood heaters and fireplace inserts have a ceramic honeycomb inside of the stove. Incompletely combusted exhaust gasses and particles are trapped inside this honeycomb for further combustion, increasing overall efficiency and reducing total emissions. Catalytic wood stoves and inserts have advertised efficiencies of 70 – 80% (U.S. DOE, 2010).

Advanced Combustion Woodstoves – Advanced combustion woodstoves, also known as secondary burn stoves, have several components that allow them to burn combustible gasses and particulates following initial combustion. Much like gasifiers, secondary burn stoves burn extremely hot (around 1,100° F) and volatile gasses are trapped in a low-oxygen, high-heat environment, allowing them to be combusted in a secondary process. New advanced combustion stoves have efficiencies between 60 – 70% (U.S. DOE, 2010). In general, these stoves are NSPS certified.

Masonry Heaters – Masonry heaters, also known as "Russian," "Siberian," or "Finnish" fireplaces produce more heat and less pollution than any other available RWC technology (U.S. DOE, 2010). These fireplaces capitalize on the heat content of smoke by running exhaust through long, twisting channels in a masonry mass (i.e., bricks), which in turn radiates heat over a period of 12 – 20 hours (U.S. DOE, 2010). These stoves have efficiencies around 90%, but are difficult to control for temperature, and can take quite a while to warm a room at initial startup. Masonry heaters can cost $5,000 or more, depending on size, and given the distinct disadvantages associated with temperature control and zone heating, may not be the best avenue for investment in a state incentive program.

Centralized Cordwood Heating Systems – Centralized cordwood heating systems are furnaces or boilers that burn logs, or cordwood, rather than chips or pellets. This category has an approximate efficiency of 47%, meaning that less than 50% of the wood's heating potential is realized (Houck and Eagle, 2006). In Maryland, there are approximately 6,125 homes with centralized cordwood heaters, accounting for approximately 10,355 dry tons of wood combusted, likely from in-state sources (Houck and Eagle, 2006).

Wood boilers, also called hydronic heaters because the water is not actually boiled, can supply heat through traditional radiator systems or may be tied in to a radiant floor system (Pahl, 2003). These systems have the advantage of being able to readily supply household hot water when coupled with storage tanks, but can vary considerably with regards to emissions released. Recently, **outdoor wood boilers** have faced considerable scrutiny by health and environmental agencies in regards to particulate emissions.

A typical 100,000 Btu cordwood furnace runs between $2,000 and $3,000 installed, while a boiler system is generally between $3,000 and $5,000 installed (Pahl, 2003). These systems have the distinct advantage of a readily available fuel supply, but need to be frequently supplied with wood, and efficiency and emissions concerns suggest that only EPA Phase II options should be considered.

Residential Pellet Utilization – An estimated 13,284 homes in Maryland have installed residential pellet heaters, representing approximately 0.7% of total housing (Houck and Eagle, 2006). The state's residential pellet appliances consume approximately 16,618 dry tons of wood biomass annually, which likely comes from outside of the state, as there are currently no pellet manufacturers located within Maryland (Houck and Eagle, 2006).

Based on currently available options, homeowners can choose between three different pellet appliance types for home heating: stoves, furnaces and boilers. Pellet stoves are by far the most common of the pellet appliances used in the U.S. They are relatively inexpensive, typically ranging from $1,700 to $3,300 for the stove, and $350 to $550 for installation[65] (Terroba *et al.*, 2009). Pellet stoves are somewhat limited in utility for household heating, as they do not have a whole-house distribution system, and are best used in zone heating applications or as a secondary heating system during cold months.

With typical heating capacities ranging from 8,000 to 90,000 Btu per hour, pellet burners can provide heat outputs more than suitable for whole-house heating.[66] Pellet boilers and furnaces capitalize on this capacity to distribute heat through buildings using the same infrastructure as traditional heating appliances.

Pellet furnaces use traditional forced-air ducting for heat distribution. Furnace burners are typically installed inside the residence in a basement or utility room and are connected to an outside fuel hopper. Furnaces can also be connected to a boiler system and storage tank to supply a home's hot water. It costs approximately $4,000 – $5,000 to replace an existing furnace system with a pellet furnace, and the incorporation of a boiler system can add an additional $2,000 – $3,000 to this expense (Houck and Eagle, 2006).

Pellet-fired central heating boilers were developed during the 1990s, and now hold a significant share of Europe's domestic heating market. As of 2008, pellet boilers are the most common household heating appliance type in Austria, Germany, and Denmark (Van Loo and Koppejan, 2007). Pellet burners can replace oil burners in existing boiler systems, but it is critical to match the burner to the boiler system due to emissions and safety concerns. Currently, the availability of retrofit burners in the U.S. is extremely limited. Pre-manufactured burner-boilers present a more immediate option in the U.S., with costs ranging from $4,000 to well over $10,000, depending on whether the system is designed for indoor or outdoor application, existing infrastructure, and hot-water system tie-in.

Nearly all pellet burners are controlled by thermostat and/or aquastat, with burning rate controlled by the rate of fuel supply rather than by restricting primary air. Pellet appliances

[65] The low cost of installation can make pellet stoves less expensive than conventional wood stoves when comparing total installed cost (U.S. DOE, 2010).
[66] U.S. DOE (2010) estimates that a stove rated at 60,000 Btu can provide enough heat for a 2,000 ft^2 home, while a 1,300 ft^2 space would demand 42,000 Btu.

commonly have combustion efficiencies of 78 – 85%, are the cleanest burning of all solid fuel-burning household heating appliances. "Good pellet burners show very low emissions levels of hydrocarbons and carbon monoxide. However, NO_x emissions are significant despite the rather low nitrogen content in the pellets. In fact, the conversion of fuel nitrogen to NO_x is in many cases close to 100 percent (Van Loo and Koppejan, 2008)." Additionally, some pellet burners can release significant amounts of particulate matter resultant of incomplete combustion. Pellet stoves and furnaces are currently exempt from the U.S. EPA smoke-emission testing requirements (U.S. DOE, 2010), but it is possible that increased installation numbers may suggest a need for the EPA to reevaluate stove emissions, particularly in areas of non-attainment of air pollution standards.

All pellet-burning appliances require electricity to power augers and fans, making residential pellet heating systems susceptible to power outages. It is therefore recommended that households with pellet appliances as the primary source of space and/or water heating have a back-up power supply available (i.e., back-up generator). According to U.S. DOE (2010), pellet appliances typically demand about 0.38 to 0.75 kW of electricity for operation.

Maintenance is also a drawback for pellet appliances. Although automatic ash removal is being developed, most pellet burner ash boxes must be cleaned out every few days. Pellet appliances should also be cleaned periodically to maintain efficiency and a professional should sweep the chimney annually. While conversion to a pellet appliance does incur some additional cost and headache, the realized fuel savings can be substantial, as shown by Table18.

Table18. Alternative energy source price equivalent to one ton of wood pellets at $200/ton, average residential price in Maryland, and potential fuel savings.

	Equivalent Price	Average Residential Price in MD	Fuel Savings by Pellet Stove Conversion	Percentage of Home Heating in MD
No. 2 Heating Oil	$1.67/gal	$2.88/gal	42%	16%
Propane	$1.18/gal	$2.73/gal	56%	3%
Natural Gas	$12.50/1,000 ft^3	$15.66/1,000 ft^3	20%	46%
Electricity	$0.04/kWh	$0.14/kWh	71%	33%

Source: BERC (2007); EIA (2010); US Census Bureau (2000)

As shown by the table above, 33% of homes in Maryland heat with electricity. Electricity is one of the least-efficient and most-costly options for household space and water heating. On average, space heating[67] accounts for 10.4% of the total electrical demand of a Maryland home and water heating accounts for an additional 12.4% (EIA, 2006). Since pellet burners require approximately 100 kWh/month of electricity to operate, conversion to standalone pellet space heating devices would represent a relatively negligible electricity savings when compared to the

[67] Value is for heating only. Air conditioning accounts for an additional 21.4 % of total demand (EIA, 2006).

"average home." Since the "average home" for the region represents all heating appliance types in the state, and homeowners are likely to realize savings by converting from electrical to pellet heat, but for the sake of discussion here, energy savings will be considered minimal.

If all electrically heated homes in Maryland (33% or 655,468 residences) were to convert to pellet appliances for 100% of the home's space heating demand and these homes incorporate a boiler system and storage tank for water heating, the state would realize a savings of more than 975,000 MWh annually,[68] conceivably offsetting enough electricity to power more than 81,000 standard new homes. Similarly, if the 16% (316,734 residences) of Maryland homes heated with heating oil switch to wood pellet systems for space and water heating, Maryland's annual fuel oil consumption could decrease by as much as 230 million gallons, or as much as 28% of total annual in-state fuel oil consumption.

Zoning restrictions may prohibit the installation of pellet-burning appliances in some areas of Maryland. However, of all factors limiting the widespread adoption of pellet systems in the state, the most limiting is fuel availability. As mentioned before, Maryland currently has no in-state pelletization facilities, nor bulk delivery services available. If the state should choose to pursue a pellet appliance program, a simultaneous program to promote the establishment of pelletization facilities may be necessary to ensure a steady fuel supply.

2.8 Liquid Biofuels Potential

Between 2000 and 2008, the federal government's liquid biofuels program received the single largest share of the $29 billion in federal funding allocated to total renewable energy expenditure during this time (ELI, 2009). Offsetting liquid petroleum consumption is the main concern of policies like the 2007 Energy Independence and Security Act (EISA) (P.L.110-140), which set a nationwide Renewable Fuel Standard (RFS) of 36 billion gallons of biofuels to be produced per year by 2022, 21 billion gallons of which are to come from advanced liquid biofuels like **cellulosic ethanol** produced from **lignocellulosic feedstocks** such as wood fiber.

Technologies to produce large volumes of advanced liquid biofuels are not yet commercially viable. The federal government's biofuels program aims to reduce the cost of cellulosic ethanol production to $1.33/gallon by the end of 2012 (BRDI, 2008). The main strategy of the biofuels development program is to improve the efficiencies of conversion technologies. Due to

[68] More than 655,000 electricity-heated homes (U.S. Census Bureau, 2000), each consuming 12,000 kWh of electricity each year (PPRP, 2010), 12.4% of this electricity is dedicated to water heating (EIA, 2006). As the EIA estimate includes all forms of water heating, and electricity-heated homes are likely to have electricity-heated water, actual electricity savings may be significantly greater than the estimate. Additionally, the census number is now a decade old, and Maryland has experienced growth. New homes are more likely to be electrically heated (EIA, 2006), which also suggests that the potential electricity savings estimates provided here may be understated.

investments made through this program, the cost of biofuel conversion has fallen at a faster rate than the costs of feedstock production. With feedstock costs representing approximately 40% of the cost of cellulosic ethanol and transportation costs representing approximately 40% of the cost of woody biomass feedstocks, coordinated investments in biomass supply chain improvements may be key to reducing the total cost of liquid biofuel production (Dwivedi *et al.*, 2009).

Moreover, the cost of refining lignocellulosic biomass into cellulosic ethanol requires production levels of at least 50 million gallons/year to attain economies of scale (Richard, 2010). A plant of this size would require 1 – 1.2 million green tons of biomass annually. This equates to 50 – 90 trailer trucks delivering more than 1,700 dry tons of biomass per day and 16 – 20 tanker trucks or railcars transporting the finished product to market each day (Richard, 2010).

If landowner participation, feedstock quality, and procurement costs are not a limitation, the maximum volume of cellulosic ethanol that could be produced from Maryland's available supply of woody biomass would be 62 million gallons of cellulosic ethanol per year, constraining biorefineries to producing approximately 30 million gallons per year in two subregions. This volume of ethanol represents a volume by energy content that is only about 2% of the total gasoline consumed in Maryland in 2008 (DOE EIA). It is worth reiterating that this volume of ethanol is limited to a 50 mile procurement radius and does not include potential units of biomass from energy crops or agricultural residues for reasons discussed in chapter one.

The Chesapeake Bay Commission determined that when and if cellulosic ethanol is commercialized, woody biomass from forests may become a major source of supply in the Mid-Atlantic (CBC, 2010). This study also found that if 42 million gallons of biofuel refining capacity is created from 2010 to 2022, 6,174 construction jobs and 12,385 jobs at these new biofuel refineries would be created (CBC, 2010). The existing forest products industry is estimated to provide as much as 140,000 jobs across the Chesapeake Bay watershed, $6 billion in income, and a total industry output of $22 billion to the region's economy annually (Sprague *et al.*, 2006).

If a new large-scale biofuels industry were to develop in the region, wood prices may rise significantly, with the value of energy wood possibly exceeding pulpwood prices in some locations. In addition to Maryland's only pulp and paper plant in Luke, Maryland, at least three other pulp mills routinely draw some supply from Maryland. If market conditions are such that a biofuels facility is willing to pay more for feedstock than the region's pulp and paper mills, it is reasonable to assume that primary and secondary wood residues, would be diverted from the pulp and paper supply chain. While the development of energy crops and other biomass sources would likely dampen this competition, energy crops are not available without subsidy. Another consideration is that commercial wood from timber management operations does not help fuel producers meet their RFS targets because of definitional constraints placed on such biomass (see section 3.3.1). Forthcoming regulations for BCAP also attempt to prevent the raw material for pulp and paper and other markets from being used for production of liquid biofuels for transportation (Sedjo, 2010).

While energy crops are unlikely to be planted without price supports, it is worth understanding the sheer magnitude of land area required for supplying a commercial-scale biorefinery with energy crops. If hybrid poplar, willow, or switchgrass were cultivated at production levels of 8.8 ODT/ha/year, 11.1 ODT/ha/year, or 14.4 ODT/ha/year, respectively, the approximate land area needed to meet the total supply needs of a 50 million gallon/year cellulosic biofuel refinery with dedicated energy crops would be between 102,933 – 168,539 acres; more than four times the size of Washington, D.C. If the same 50 million gallon/year cellulosic biorefinery was operating exclusively on biomass from forest harvests, it would require that at least 800,000 acres of the region's forests be managed if this type of harvesting would occur on a sustained yield basis.[69]

Another potential future for large-scale liquid biofuels production would be the development of regional aggregation facilities that specialize in the densification of biomass feedstocks for more cost-effective transport to biorefineries. This model would be part of the type of robust supply chains that could facilitate the development of commodity markets in which biorefineries procure large volumes of biomass in fluid markets that connect feedstock buyers and sellers through efficient transportation systems. This market structure is highly unlikely to develop in the region in the near future, but it is difficult to see how the huge volumes of biomass required by commercial-scale biorefineries could otherwise be brought to market. Thus the prospect for a commercial-scale liquid biofuels market to develop in the region is limited, at least in the near-term.

2.9 Developing Technologies

Torrefaction – Torrefaction is a treatment process by which biomass is heated in an oven at low temperatures (200-300° C) in the absence of oxygen, partly decomposing the material and releasing various volatile compounds (Jackson *et al*., 2010). The remaining solid fuel material has nearly one-third more energy content per unit of mass, very low moisture content, and a markedly lower O/C ratio (Jackson *et al*., 2010). Torrefied wood is more easily pulverized along coal, reduces size reduction energy requirements by 50 – 80%, and can significantly increase gasification efficiency (Jackson *et al*., 2010). According to Jackson *et al*. (2010), "when compared to conventional pelletization processes, torrefied biomass is more economic in a biomass-to-liquids gasification and subsequent Fisher-Tropsch conversion to liquids process."

[69] This assumes a net annual growth of 45 cubic feet/acre and a wood demand of 36 mmcf (1.2 million GTs) annually, and that annual removals would not exceed net growth.

Biomass torrefied at 250° C for 30 minutes has a Low Heating Value (LHV) of 18.4 MMBtu/ton and biomass torrefied at 300° C for 10 minutes has a LHV of 19.9 MMBtu/ton (Jackson *et al*., 2010).

ORC Optimized CHP – One developing method to improve the efficiency of small-scale biomass CHP facilities is by substituting an organic working medium (hydrocarbons such as iso-pentane, iso-octane, tolune, or silicon oil) for water in a traditional Rankine process. An Organic Rankin Cycle (ORC) optimized CHP system maximizes a system's thermal efficiency, and may one-day reach gross efficiencies of 98%, while simultaneously reducing system maintenance requirements (Obernberger *et al.*, 2003).

Stirling Engines – Stirling engines use hot and cold gasses to drive a piston to create electricity in a manner quite similar to traditional combustion engines (Obernberger *et al.*, 2003). However, because Stirling engines are driven by gas exchange, which is fueled by a heat exchanger connected to a combustion system, the nominal electrical output represents a net gain in gross efficiency. Stirling engines are extremely quiet, can be scaled to very small applications, and may one day be able to supply electricity to power a home. The theoretical system examined in this study shows a 2 kW engine connected to a residential central pellet boiler system.

2.10 Conclusions and Recommendations on Energy Technologies

Woody biomass has potential to contribute to renewable energy expansion in Maryland. However, the many different utilization technologies produce different types of energy and demand different amounts and types of biomass. Policy will strongly influence which options are pursued.

Support technologies that are well matched to Maryland

Based on the available biomass resource and feedstock requirements, large-scale electric power production and biofuels production appear to be marginally feasible in Maryland. While there may be enough biomass available within central Maryland to supply a small-to-medium biopower facility, co-firing at the Dickerson power plant, or production of cellulosic biofuels in a small facility, the vast majority of the available supply comes in the form of urban wood waste, which may present obstacles for some technologies.

Appropriately scaled options are those whose demand for biomass are matched with what can be supplied on an economically, ecologically, and socially sustainable basis. In Maryland, this is likely to be smaller-scale and highly efficient options that are more easily reconciled with locally available volumes of biomass.

With this in mind, Maryland should seriously consider small to moderately scaled CHP and thermal systems as the primary options for utilization of the limited biomass resource available. There are as many as 3,000 sites across Maryland that could feasibly implement CHP, some of which are good candidates for biomass conversion. Downtown districts, housing developments, hospitals, prisons, university campuses, greenhouses, and possibly poultry houses and other agricultural settings, all appear to be excellent settings for biomass thermal and CHP. Interestingly, while Maryland could theoretically support one 50 MW biopower facility in the central subregion, the same amount of electricity could be generated by several distributed CHP units, albeit with the cogeneration of up to 1.4 billion BTUs of usable renewable thermal energy.

Thermal energy projects in institutional and commercial settings (e.g., district energy projects and Fuels for Schools projects) also hold significant promise to be appropriately scaled to the available resource. For institutional settings, a Fuels for Schools and Beyond-type program is a sound option for Maryland. This study suggests that several facilities can be supplied with economically and environmentally sustainable biomass feedstocks in each subregion with acceptable rates of return on initial investment in thermal facilities, but site level due diligence is still necessary for projects of this scale.

Thermal energy has already been identified by Maryland's Climate Action Plan as an important strategic focus for biomass, as a full 40% of Maryland's energy consumed is thermal energy, a large chunk of which occurs in the residential sector. The main fuel sources for residential heating are propane (3%), natural gas (46%), number 2 heating oil (16%), and electricity (33%). Substituting wood pellets for these options provides fuel cost savings of between 20 – 71%, but upfront costs can be prohibitive for landowners, although financial incentives exist (see chapter three).

Presently, 1.1% (22,469) of Maryland's homes use wood as a primary or exclusive heating source. In Montgomery County, only 0.1% of homes use wood in this manner, whereas, nearly 13% of homes in Garrett County use wood as their primary or exclusive heat source. The bulk of these homes use outdated and inefficient cordwood stoves and outdoor wood boilers, both of which have poor emissions profiles when compared to pellet stoves and other residential scale pellet applications. Swapping out these systems for wood pellet and other high-efficiency cord wood heating systems would likely improve air quality and continue to offset fossil fuel consumption.

While there is likely not enough biomass to supply all of Maryland's homes and potential district energy projects, small-scale in-state biomass pellet or briquette production may present a viable option in some locations. If scaled appropriately, such facilities could likely bolster the state's struggling forest products industry by providing value-added processing of mill residues, the byproducts of pre-commercial thinning, and possibly even dedicated energy crops.

Chapter 3

Energy Policy and Biomass Markets

3.1 Introduction

Long-term price projections for energy markets suggest that biomass may play a significant role in providing heat, electricity, and liquid transportation fuels. However, exactly how these market trends will play out over time remains uncertain. What is clear is that policy will continue to strongly influence the trajectory of bioenergy development. Energy policy, especially in relation to biomass, often establishes multiple, and sometimes conflicting objectives.

Defining a clear vision of what constitutes a *sustainable* bioenergy system is complex. Designing effective policies to realize such a vision is another challenge altogether. In recent years, bioenergy policy can best be described as a patchwork of seemingly unconnected production mandates and incentives for renewable electricity and liquid biofuels, with renewable thermal energy receiving much less focus.

This chapter offers an overview of the most relevant policies and programs influencing renewable energy development and biomass production. This list is not exhaustive, as it is only intended to illustrate some of the key federal and state policies that currently influence biomass markets in Maryland.

3.2 Maryland Rules, Regulations, and Policies

3.2.1 State regulations and standards

Maryland Renewable Portfolio Standard (RPS)

Maryland's RPS, enacted in May 2004 and revised in 2007, 2008, and 2010 requires electricity suppliers (all utilities and competitive retail suppliers) to generate 20% of their electricity using approved renewable technologies by 2022 (COMAR 20.61.01 et seq.). Administered by the Maryland Public Service Commission, Maryland's RPS defines both "Tier 1" and Tier 2" renewable energy resources that must comprise a certain percentage of overall generation. In 2022 and beyond, 20% of generation must come from Tier 1 resources; 2.5% may come from Tier 2 resources up to 2018. The RPS policy defines qualifying biomass as a Tier 1 resource. This definition includes most forest-derived biomass, but it excludes wood shavings and sawdust from primary and secondary wood processing facilities.

Electricity suppliers demonstrate compliance with the RPS by accumulating **renewable energy credits (RECs)**. One REC is generated for each megawatt-hour (MWh) of renewable electricity generated and each has a three-year life during which it may be transferred, sold, or otherwise redeemed (MD PSC, 2010). Under Maryland's RPS any REC generated within the PJM electrical grid transmission region, in states adjacent to the PJM, or delivered into the PJM, can be bought or sold to comply with Maryland's RPS. Each electricity supplier must submit a report to the Maryland Public Service Commission annually to demonstrate compliance with the RPS. In the event that an electricity supplier falls short of their standard, they are charged an *alternative compliance fee* of $20 per MWh.[70] Revenue generated by such compliance payments is invested into the Maryland Strategic Energy Investment Fund (SEIF), which is administered by the Maryland Energy Administration to fund grant and loan programs for Tier 1 renewable energy projects.

As of the 2008 compliance year 2,684,815 RECs were retired at a total cost of $2,039,583, with RECs trading between $0.50 and $1.50 each (mean cost of $0.76) (MD PSC, 2010). This price is significantly lower than the rest of the PJM, which averaged somewhere between $10 and $25 per REC (Roenbeck, 2008). Biomass was the largest contributor (68%) to the REC market in Maryland in 2008 with 38% coming from black liquor and 30% coming from wood. Wind and solar together contributed less than 1% (MD PSC, 2010).

[70] This alternative compliance payment increases to $40 per MWh in 2011.

Table 19. Maryland renewable energy credits generated by wood biomass in 2008.

Plant Name	State	Fuel Type	Capacity (MW)	Quantity of RECs Retired in 2008 (MWh)
Luke Mill*	MD	Black Liquor	65	58,145
Escabana Paper Co.	MI	Black Liquor & Wood/Wood Waste Solids	103	43,000
Cadillac RE	MI	Wood/Wood Waste Solids	40	75,328
Hillman Power Co.	MI	Wood/Wood Waste Solids	20	6,686
VP Cravenwood	NC	Wood/Wood Waste Solids	47	4,756
Coshocton Mill	OH	Wood/Wood Waste Solids	16.5	5,300
PH Glatfelter -Chillicothe	OH	Black Liquor	92.8	162,215
Covington Facility	VA	Black Liquor & Wood/Wood Waste Solids	96.5	117,922
Franklin Mill**	VA	Black Liquor	73	40,921
Hopewell Mill	VA	Black Liquor & Wood/Wood Waste Solids	47.6	67,600
Multitrade of Pittsylvania LP	VA	Wood/Wood Waste Solids	80	257,213
Quantity of Wood-Based Tier I RECs Retired by Maryland in 2008 (MWh)				**839,086**
Total Quantity of Tier 1 RECs Retired by Maryland in 2008 (MWh)				**1,184,401**
Percentage of Total Tier I REC's Retired from Wood Fuel Utilization				**67.6%**
Percentage of Total Tier I REC's Retired from Black Liquor				**37.6%**
Percentage of Total Tier I REC's Retired from Wood/Wood Waste Solids				**29.9%**

*Maryland also banked 151,297 MWh of Tier I Vintage RECs from the Luke Mill in 2008
**International Paper shut down the Franklin Mill in April, 2010

The allowance of black liquor in the RPS is a somewhat unique to Maryland. This source of energy does not represent an additional source of renewable energy unless pulp and paper facilities increase their capacity for biomass utilization beyond what is consumed by the facility. In 2008, six pulp and paper mills sold RECs into Maryland's RPS program; three from Virginia, one from Maryland, and the remainder from the mid-west. Seven other facilities sold RECs into Maryland's RPS under the "waste wood" definition (see table 19) (MD PSC, 2010).

The inclusion of black liquor as a Tier 1 resource likely contributes to Maryland's comparatively low REC prices in 2008. The state's REC prices may rise if black liquor is removed as an option. If Maryland's utilities had purchased RECs for the PJM *lower-bound* REC price of $10 each, REC expenditure would have been $26,848,150, more than *13 times* the amount actually paid that year (difference of $24,808,567).

From an energy policy perspective, additionality is a legitimate concern because unless new renewable energy is produced, the RPS may not be fulfilling its policy intent. The state may chose to terminate black liquor eligibility because of these concerns. If REC prices become significantly more expensive, RPS compliance may pose a greater challenge. Hypothetically, this could be handled in a number of ways:

(1) Regulated entities pay the increased market price for RECs, incurring an additional expense that may be passed on to consumers.
(2) Depending on REC market prices, regulated entities may opt to simply pay alternative compliance payments; however, it remains to be seen if the price of RECs will rise above the alternative compliance payment or would remain above the cost of RECs. If the compliance fee option is pursued by many, MEA will have to produce new projects using the SEIF financing mechanism, suggesting that the state will have to determine what biomass options may qualify.
(3) The state may be forced to scale back RPS requirements or make additional investments in other more costly renewable energy options.
(4) Rather than outright exclusion to minimize market impact the state may choose to include additionality requirements for black liquor resources (e.g., a need to increased facility capacity).
(5) The state may choose to incorporate the thermal energy generated from dedicated renewable thermal technologies or CHP systems as Tier 1 resources, much like Massachusetts' Alternative Portfolio Policy (225 CMR 16.0).

Maryland Net Metering Law

Maryland's net metering law allows for small-scale (2 MW or micro-CHP units capable of producing 30 kilowatts) electricity generators to "run the meter backwards" and sell surplus electricity generated into the electricity grid (Md. Public Utility Companies Code § 7-306). This law applies to all renewable energy technologies, including biomass. Qualifying systems must be primarily intended to offset all or a portion of a customer's on-site energy requirements. The law permits outright ownership by the customer-generators as well as third-party ownership structures (e.g., leases and power purchase agreements between an industrial facility with a CHP unit and an electric utility). The law limits the statewide aggregate distributed generating capacity from net metering to 1,500 MW.

State distributed generation interconnection standards

Renewable electricity generating facilities up to 10 MW in size must comply with Maryland-specific rules for interconnection to the electrical grid (COMAR 20.50.09). The Maryland Public Service Commission recently revised rule for small generator interconnection, and employs a four-tiered approach to determine the level of review required before a system may be connected to the grid. Review processes are more extensive for larger systems, and can be quite costly. In general, interconnection policy for distributed generation is a complex and technical area with various levels of regulations at the state and federal level.

Regional Greenhouse Gas Initiative (RGGI)

As a member of the northeast's Regional Greenhouse Gas Initiative (RGGI), Maryland has agreed to cap greenhouse gas (GHG) emissions in fossil fuel-fired electricity generators with a capacity of 25 megawatts or greater. The agreement requires participating states to cap carbon dioxide emissions from the electrical generation sector and to reduce those emissions by 10 percent by 2018 through an emissions **cap and trade system**. Each RGGI state has been allotted a certain number of CO_2 allowances, which collectively equal the state's CO_2 emissions cap. The Maryland Department of the Environment continues to participate in RGGI through the auction of CO_2 allowances, and has made offset project applications and guidance documents publically available (MDE, 2009).

As of July 2010, eight of the ten RGGI states recognize biomass as a "carbon-neutral" fuel source and have made emissions reductions associated with switching to biomass eligible for RGGI auction. The 60 MW Luke Maryland Paper Mill is a capped facility under RGGI and has included increasing the biomass component of its fuel mix as a primary compliance strategy.[71]

Currently, Maryland's CO_2 auction money is invested in the SEIF, which has accumulated $128,120,106 to date. Between July 2009 and February 2010, approximately $600,000 from alternative compliance penalties was combined with $3.4 million from RGGI auction revenues to fund additional Tier 1 renewable energy resources in Maryland (MD PSC, 2010).

3.2.2 State non-regulatory policy goals

Maryland Climate Action Plan

The Maryland Greenhouse Gas Emissions Reduction Act of 2009 (GGRA) calls for Maryland to reduce GHG emissions by 25% by 2020 and prepare a plan to meet a longer-term goal of a 90% reduction by 2050. The Maryland Climate Action Plan was developed as a means to implement GGRA. The Climate Action Plan includes a number of agriculture and forestry related tasks, some of which establish goals and objectives for biomass utilization for the production of bioenergy. These biomass relevant objectives include AFW-1, AFW-6, AFW-2, AFW-7b, ES-5, and ES-8 (MDE, 2009).

- **AFW-1** seeks to promote sustainable forestry practices in existing Maryland forests on public and private lands to increase carbon dioxide sequestration in forest biomass, carbon storage in durable wood products, and available biomass for energy production.
- **AFW-2** seeks to promote the utilization of urban wood waste and explicitly calls for the development of incentives directed towards the "highest-order wood product" (not defined), with the remainder allocated for energy.

[71] This was determined through personal discussions with the Maryland Department of the Environment.

- **AFW-6** seeks to promote the use of local biomass from sustainable supplies of chicken litter, methane, switchgrass, corn stalks, food processing waste, etc. for generating electricity and thermal energy. Strategies include installing community manure digesters, Fuels for Schools, and biomass loan programs. AFW-6 also specifies that "lifecycle energy costs and carbon emissions would be evaluated for each feedstock to ensure net energy and GHG reductions are achieved" and that, "current laws could be amended to increase and/or equalize incentives for biomass energy production and use, and Fuels for Schools and biomass loan programs could be expanded. Maryland's energy policy could be adjusted to recognize thermal loads (40% of the State's energy budget)." AFW-6 calls for "10% of available forest residue biomass for electricity, steam, and heat generation [CHP] by 2015. Increase growth of energy crops and use 50% of available energy crop biomass for electricity, steam, and heat generation by 2020." This section specifies that wood supplies from higher-value wood products are not to be diverted for energy purposes, but does not provide any guidance on how this should be assured.
- **AFW-7b** seeks to promote sustainable in-state production and consumption of transportation biofuels, including ethanol and bio-diesel from agriculture or agro-forestry feedstocks, to displace the use of fossil fuels in an effort to reduce the net GHG emissions from the transportation sector.
- **ES-5** seeks to use financial incentives and other strategies to encourage investment in distributed energy and CHP such that by 2020, 1% of all electricity sales are from distributed renewable generation and 15% of CHP technical potential is recognized at commercial and industrial facilities.
- **ES-8** seeks to identify and pursue emissions reductions from existing fossil fuel electricity generation units, and includes biomass co-firing and repowering as an option such that by 2014, 8% of total energy input to coal-fired plants in Maryland would be biomass.

Maryland Biofuels Policies

While Maryland does not have any significant state level policies in place for liquid biofuels for transportation, there is considerable interest in cellulosic biofuels in the state and the Mid-Atlantic region (CBC, 2008; CBC, 2010). Following a series of reports from the Chesapeake Bay Commission related to biofuels, Maryland drafted a Biofuels Action Plan[72] in 2009. This action plan includes 10 detailed actions (some of which relate directly to wood-based biofuels) and recommendations to carry out these actions.

[72] Information on Maryland's Biofuels Action Plan was obtained from the Maryland Department of Natural Resources.

One recommendation of the action plan is that a multi-agency team should conduct a "sustainable biomass inventory," which would include an evaluation of "the impact of competing uses such as co-firing for electricity and heat" to assess the "economic viability of an in-state biofuels industry." Moreover, the action plan identifies that such a sustainable biomass inventory would: (1) Develop an inventory of agricultural and forest residues in Maryland; (2) develop a methodology for determining what portion of the residues can be sustainably harvested so as not to adversely affect long-term soil quality, erosion control, wildlife habitat, nutrient loadings to streams and the Bay, and carbon emissions; (3) develop an inventory of biofuels crop yield potential on agricultural land in Maryland not otherwise available or suitable for food and animal feed production; and 4) determine whether sufficient feedstocks exist for biofuels production in Maryland after addressing sustainability issues and competing uses, such as electricity generation.

The Biofuels Action Plan also recognizes that "supply of the many forms of biomass is dependent on many factors, some of which are relatively stable and easy to predict while others are highly variable and near impossible to estimate without direct observation," and states that "at a minimum, a reassessment of biomass inventories every five-years is recommended."

In addition to the Maryland Biofuels Action Plan, other planning processes specifically support development of a regional advanced biofuels industry. The Maryland Climate Change Adaptation and Response workgroup of the Maryland Climate Action Plan recommended subsidizing "cellulosic biomass in the agricultural and forestry industries" and partnering with other states that support this "development path," (MDE, 2009), which is likely in reference to Pennsylvania's cellulosic biofuels production mandate.

Similarly, in 2008 the Chesapeake Bay Executive Council, which is comprised of the governors of New York, Pennsylvania, Delaware, Maryland, Virginia, and West Virginia, signed Executive Council Directive (08-1) *Leading the Nation in Development of a Sustainable Next-Generation Biofuels Industry*. This Directive calls for states in the region to develop Biofuels Action Plans and a "regional next-generation biofuels production goal that includes a plan for market and facility development along with best management practices implementation necessary to support an environmentally sustainable biofuel feedstock." A 2010 Bay Commission report recommends that a biofuels production goal of 500 million gallons of liquid biofuels could be established, assuming that no forests or active agricultural land are converted to energy crops and that these lands are managed in a manner that would benefit the region's water quality. It is worth noting that while the Bay Commission's report concerns liquid biofuels, they also recognize the potential significant demand for biomass for production of electricity and thermal energy (CBC, 2010).

In 2009, Maryland also joined ten other states in the Northeast (Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey New York, Pennsylvania, Rhode Island, and Vermont) in signing a Letter of Intent to develop a regional Low Carbon Fuel Standard (LCFS).[73] The LCFS is a technology-neutral, performance-based standard intended to function as a market-based approach for regulating the lifecycle GHG emissions from the transportation sector. In concept, the LCFS is intended to displace carbon-intense fuels with less carbon intense alternatives such as low carbon biofuels and electricity generated with low carbon renewable sources. Maryland's Climate Action Plan also specifically mentions using idle agricultural land to grow energy crops for an LCFS.

3.2.3 State financial incentives

Clean Energy Production Tax Credit (PTC)

In addition to a federal PTC, Maryland offers a production tax credit (PTC) equal to $0.85/kilowatt-hour against the state income tax for a five-year period for electricity generated by renewable energy technologies, including biomass (Md. TAX-GENERAL Code § 10-720). The list of eligible resources is generally the same as those eligible for the federal renewable energy PTC, except the Maryland law contains added provisions related to biomass and biogas technologies. Eligible forest-derived biomass is largely consistent with the qualifying biomass under the Maryland RPS and eligible mill residues include bark, chips, slabs, and edgings, with sawdust and shavings being excluded. Coal-fired power plants that elect to cofire biomass with coal are eligible for the Maryland PTC. As of March 2010, a total of 10 qualifying facilities have taken advantage of this tax credit, none of which are biomass facilities.

Bio-Heating Oil Tax Credit

Maryland allows individuals and corporations to take a $0.03/gallon income tax credit for purchases of bio-oil used for space or water heating, up to a maximum of $500 per year. The tax credit is only available for purchases made during the 2008 – 2012 tax years. This policy is specific to biodiesel; other types of biomass fuels do not qualify (Md. TAX-GENERAL Code Ann. § 10-727).

Clean Energy Home Owner Loan Program

This Clean Energy Home Owner Program is a municipality-based program that allows residents to receive up to $3,000 in loans to pay for residential-scale renewable energy projects.

Wood Heating Fuel Exemption

All wood or "refuse-derived" fuel used for heating purposes is exempted from the state sales tax

[73] www.nescaum.org/documents/lcfs-factsheet.pdf

(Md. TAX-GENERAL Code § 11-207). The law applies to residential scale heating only (Aguilar and Saunders, 2010).

Jane E. Lawton Conservation Loan Program (JELLP)
Administered by MEA, this financial assistance program offers low interest loans (2%) to local governments and nonprofits up to $300,000, with larger loans being considered on a case-by-case basis after March 01, 2010. The JELLP funds approximately $1.5 million in new projects each fiscal year (Md Code: State Government §9–20A–01 et seq.). This program helps finance the identification and installation of energy conservation improvements in hospitals, schools, local government building complexes, community colleges, and other public and/or non-profit institutional settings. Borrowers use the cost savings generated by energy conservation actions as the primary source of revenue for repaying the loans. This program may help design and install institutional-scale CHP and thermal energy systems, which are often cost-prohibitive upfront, but pay off reasonably quickly through reduced fuel costs. The only qualifying criteria for projects are that they save energy and have a simple payback of 10 years or less. This time horizon is consistent with the payback period of many community-scale CHP and thermal facilities installed in other states.

State Agency Loan Program
The State Agency Loan Program (SALP) is a revolving loan fund that provides zero interest loans to state agencies for cost-effective energy efficiency improvements in state facilities. Loan repayments are made from the agency's fuel and utility budget, based on the avoided energy costs of the project. This loan repayment method results in a self-sustaining fund able to make additional loans each year.

The SALP was originally capitalized in the 1990s with approximately $3 million, but an additional $800,000 was added to the fund in 2009 from RGGI. Under SALP, approximately $1 million in new loans are awarded each year, but a total of $4.9 million is expected to be available for in 2010; due in large part to $3.65 million in State Energy Program (SEP) funds made available through the American Recovery and Reinvestment Act (ARRA).

3.3 Federal Rules, Regulations and Policies

3.3.1 Federal regulations and standards

Energy Independence and Security Act of 2007
The Energy Independence and Security Act (EISA) of 2007 (P.L. 110-140) includes a number of provisions related to the production of biofuels, including an expansion of a national Renewable Fuel Standard (RFS). The RFS mandates the production and use of 36 billion gallons of advanced biofuels by 2022, and is likely to serve as a primary market driver for liquid biofuels in

the future. The EISA also includes a definition of “renewable biomass,” which defines what forest-derived biomass is eligible for credit under the RFS. This definition includes “planted trees and tree residue from actively managed tree plantations on non-federal land cleared at any time prior to enactment…” and, “slash and pre-commercial thinnings that are from non-federal forestlands.” This definition excludes commercial trees harvested from naturally-regenerated private forest lands (other than pre-thinnings), while including commercial trees from plantations that were established prior to enactment of the legislation.

Federal distributed generation interconnection standards

Prior to a regulatory shift in 2005, the federal Public Utility Regulatory Policy Act (PURPA) required that electric utilities purchase electricity from distributed renewable energy generators through fixed-price long-term contracts, which committed utilities to buy renewable electricity at prices equivalent to the avoided cost of constructing a new generation facility (16 U.S.C. § 2623). This policy led to a significant amount of biomass-fired CHP coming online in the 1980s and 1990s, most of which were cited in wood products facilities. In recent years, federal policy has tended towards investments in liquid biofuels development, while investments in projects that would have previously been implemented as a result of PURPA have largely dropped off.

The Federal Energy Regulatory Commission (FERC) has "small generator" interconnection regulations for distributed energy systems up to 20 MW. The FERC's standards generally do not apply to distribution-level interconnection, which is regulated by state public utilities commissions, like the Maryland Public Service Commission. The FERC's standards include procedures and legal agreements for establishing new distributed generation systems. These standards increase in complexity from small 10kW systems, systems that are 2 MW or less, on up to systems no larger than 20 MW.

3.3.2 Federal financial incentives

Federal Renewable Energy Production Tax Credit (PTC)

The federal Renewable Electricity Production Tax Credit (PTC) offers a per-kilowatt-hour tax credit for the production of renewable energy in the amount of $0.011 per kWh for **open-loop biomass** and $0.22 for **closed-loop biomass** (26 USC § 45). Biomass combusted through co-firing is ineligible for the PTC. The duration of the PTC is 10 years for closed-loop biomass and five years for open-loop biomass. The PTC is a key federal incentive for biopower production.

Business Energy Investment Tax Credit (ITC)

Unlike the PTC, the amount of the ITC allowable for an open-loop biomass facility is the same as that allowed for a closed-loop facility. The federal Business Energy Investment Tax Credit includes provisions for **micro-turbines**, up to 2 MW with an electricity-only generation efficiency of 26% or higher and CHP systems, that are at least 60% efficient up to 50 MW in size. The efficiency requirement does not apply to CHP systems using biomass for 90% or more of the system's energy source, but the credit may be reduced for less-efficient systems (26 USC § 48).

American Recovery and Reinvestment Act (ARRA) Financing Options

The American Recovery and Reinvestment Act (ARRA) of 2009 (P.L. 111-5) includes a variety of low-cost financing mechanisms for renewable energy projects. These include, but are not limited to:

- An adjustment to the PTC to allow eligible entities to substitute the PTC for the ITC or a grant for up to 30% of capital costs for new facilities. Grants are available to eligible projects completed by 2013. The ARRA legislation also extends the PTC until 2013.
- Loan guarantees for projects that generate electricity or thermal energy (available until September 30, 2011).
- Grants for microturbines up to 2 MW with efficiency of at least 26%, and grants for CHP projects up to 50 MW and at least a 60% efficient, with the efficiency requirement not applying to CHP systems using biomass for at least 90% of the system's fuel requirements.
- Extension of the $1,500 residential energy efficiency tax credit for biomass stoves purchased between 2009 – 2010 that use "plant-derived fuel available on a renewable or recurring basis, including agricultural crops and trees, wood and wood waste and residues (including wood pellets), plants (including aquatic plants), grasses, residues, and fibers."

Farm Bill Programs

The Food, Conservation, and Energy Act (Farm Bill) of 2008 (P.L. 110-246) contains an energy title for bioenergy market development, but many of these programs in this title have not seen appropriations. The energy title includes a number of financial incentives for liquid biofuels production, including a sizable cellulosic biofuels tax credit of $1.01 per gallon. The 2008 farm bill also includes several programs intended to assist thermal, CHP, and biopower projects.

The Community Wood Energy Program (CWEP) is a notable program authorized to provide grants to local governments to assist with capital cost of installing small-scale (<2MW or 50 MMbtu) thermal or CHP systems. The CWEP also allows funds to be spent on project planning and design.

The Rural Energy for America Program (REAP) grants program promotes energy efficiency and renewable energy for agricultural producers and rural small businesses. Limited funding is also available for feasibility studies.

The Biomass Crop Assistance Program (BCAP) is perhaps the best-known biomass program from the 2008 Farm Bill. This program authorizes payments to agricultural producers for the establishment, maintenance, collection, harvest, transport, and storage of eligible biomass energy feedstocks, including woody biomass from non-industrial private forestlands. The program was at least in part envisioned as a means to stimulate the production of energy crops. Under this program, agricultural producers can collect payments for up to five years for perennial grasses and 15 years for woody biomass (e.g., SRWCs) in an amount equivalent to 75% of the upfront establishment and management costs.

In addition to the payment program for energy crop establishment, BCAP also includes a two year subsidy to help offset the costs of biomass collection, harvest, transport, and storage. This matching payment offers a $45/ton one-to-one match. This portion of the program has largely functioned as a transportation subsidy, and has been very controversial (Sedjo, 2010).

Given the predominant federal policy focus on liquid transportation fuels, BCAP was conceived of as a way to facilitate large volumes of supply for biorefineries. However, the biofuels industry proved to be too immature[74] to participate in the program, and existing CHP, biopower, and pellet facilities became the primary recipients (Sedjo, 2010).

While BCAP applied to all sources of cellulosic biomass in the first round, woody biomass was the largest recipient of payments, with 4,326 contracts totaling $184,629,439. The program supported the transport of bark, edgings, slash, thinning materials, fuelwood, woodchips, and "post disaster debris." Maryland tied with Indiana for the fewest number of reported contracts of any state (4) during the first round of BCAP awards, and received the least funding ($76,372) of all participating states.[75]

3.4 Conclusions and Recommendations on Energy Policy

Like all energy markets, bioenergy markets are largely created and/or propped up by public policy. Public policy objectives for bioenergy are many, with the main areas of focus being energy security, renewable energy production, climate change mitigation, and economic development. Not surprisingly, different policy mechanism can have dramatically different impacts on the economic feasibility of the various energy technologies explored in chapter two. The tradeoffs associated with supporting one utilization option over another makes developing effective energy policy a significant challenge.

[74] The federal government has invested heavily in research into both enzymatic and thermo-chemical pathways for producing cellulosic ethanol, yet no commercial scale plants (≥50 million gallon/year), are currently operational, EIA estimates that the average capitalization cost of such facilities will be $365 million per plant (EIA, 2007).
[75] USDA FSA BCAP CHST Summary Report FY 2009 and FY 2010, as of Monday, June 07, 2010.

Reconsider the role of biomass in Maryland's RPS

At the state level, several policies interact and discerning the role of biomass can be difficult. However, the RPS will likely play a central role in bioenergy market development. Electricity consumption in Maryland is growing at 2.7% per year, or just over 40,000 billion BTUs annually.[76] In 2008, just over 3% of Maryland's total energy consumed came from renewable sources, approximately 34% of which came from biomass. As previously discussed, the majority of the bioenergy sold into Maryland's REC market comes from out of state sources, mostly from the combustion of black liquor and mill residues in traditional forest products facilities.

Maryland has limited capacity for biopower (see Table 14) and renewable electricity generated through co-firing. If black liquor is excluded from REC eligibility, the state may face challenges regarding RPS compliance as REC prices rise. Biomass-fired CHP systems may alleviate some of this burden, as they can provide more usable BTUs per unit of biomass than electricity-only options. Massachusetts' APS policy allows for both the renewable electricity and the renewable thermal component of CHP systems to qualify for APS compliance. Given the efficiencies offered by CHP and the relative in-state scarcity of biomass and other renewable energy resources, Maryland may wish to consider adopting a similar approach, or include biomass thermal and CHP projects in the list of options to be financed through SEIF, which is the repository for funds from RGGI auctions and RPS compliance payments.

Maryland's Climate Action Plan includes the ES-5 policy recommendation, which calls for the use of "financial incentives and other strategies to encourage investment in distributed energy and CHP such that by 2020, 1% of all electricity sales are from distributed renewable generation and 15% of CHP technical potential is recognized at commercial and industrial facilities." Maryland's net metering and interconnection policies may provide impetus for such CHP projects, but the framework of state and federal policies that govern interconnection and CHP should be reviewed by energy planners to determine whether an expansion of biomass fired CHP is a realistic option.

Maryland's Climate Action Plan identifies that a full 40% of Maryland's energy consumption comes in the form of thermal energy. The Climate Action Plan identifies a number of steps to pursue the development of biomass thermal energy development at the residential, commercial, and institutional scales. For example the AFW-6 policy recommendation calls for "10% of available forest residue biomass for electricity, steam, and heat generation by 2015."

Consider all options for financing

[76] DOE EIA, August, 26, 2010.

For the most part, existing energy policies overlook the potential contribution of small to medium scale options. However, given the amount of federal funding currently available through ARRA, there are likely opportunities to finance such projects in the very near future. Over the long-term, a number of state and federal funding mechanisms may help finance larger-scale distributed CHP, district energy, and small scale thermal projects.

Funding from existing programs could be used to launch a pilot “Fuels for Schools and Beyond” program, which may be accompanied by a residential wood pellet program. Such a program could assess the feasibility of small regional pellet plants capable of serving local and regional markets for residential, commercial, and institutional needs.

The state may also consider including wood pellets and higher-efficiency cordwood appliances in existing residential heating tax credit programs. This may be bolstered by residential tax credits offered from the federal government to stimulate highly efficient residential-scale combustion technologies.

Improve supply chain logistics

While additional analysis of the human dimensions of wood supply in Maryland is necessary, this study identifies potential barriers within the current structure of the state’s wood products industry that may prevent investment in biomass supply chains. If biomass is to significantly contribute to the renewable energy future of Maryland, it is likely that the supply chain will also require investment. Given the significant skepticism already inherent across much of Maryland’s traditional wood products industry, suspicions of material diversion by loggers may result with expanded adoption of supply chain incentives.

The Maryland Climate Action Plan creates a vision for biomass utilization in Maryland, while cautioning that “wood supplies [including urban wood recovery] for higher value wood products [should] not [be] diverted for energy purposes.” Care should be given to identify areas of potential synergy and competition among existing forest industry and new biomass entrepreneurs when crafting policy. Care should also be taken to ensure that incentives to develop biomass supply chains are tied to measures for sustainable management.

Given the number of administrative hurdles and observed market distortions associated with BCAP, USDA is in the process of issuing new regulations for the program that will seek to avoid diverting higher-value material into the energy-wood stream. However, markets for wood are not readily differentiated and some predict that wood suitable for higher-value uses will be diverted into the energy markets as prices for biomass rise (Sedjo, 2010). Non-subsidized wood markets will likely find it difficult to compete with BCAP-subsidized wood.

Chapter 4

Environmental Considerations Associated with Forest Biomass Harvesting

4.1 Introduction

This chapter provides a review of scientific literature regarding the tradeoffs associated with the removal of biomass from forests. This review is not constrained to studies based in Maryland, and includes studies of forests that are similar to those found within the state. This chapter includes: an overview of Maryland's forests; an outline of the role of deadwood in forest ecosystems; the impacts of management on forest soils; the potential nutrient-cycling impacts of biomass harvesting, and; the potential impacts of woody biomass harvesting on wildlife habitat, biodiversity, and water quality. This chapter also addresses the role of silviculture and opportunities for short rotation woody crops.

The intention of this chapter is not to offer a detailed scientific analysis of the potential outcomes associated with forest biomass harvests in Maryland, but to explore the wealth of existing scientific and management-relevant literature to inform future management recommendations related to biomass harvests. As such, this review also serves as the technical support document on which Maryland's voluntary biomass harvesting guidelines were produced to: (1) increase the level of practical knowledge about the potential risks involved with forest biomass harvests, (2) and encourage responsible forest management.

Maryland's forest types

Forest ecosystems can be classified as mesic (broadleaf forests habitats with deep and well drained loamy soils), xeric (barrens with grass, and sparse cover by herbs and trees) or hydric (forested wetlands and some riparian forests). All of these forest types occur in Maryland.
Covering five major physiographic provinces (Lower Coastal Plain, Upper Coastal Plain, Piedmont, Ridge and Valley, and Allegheny Plateau), Maryland clearly has a wide diversity of forest resources (including 150 native tree species) relative to its small geographic size (MD DNR, 2005; MD DNR, 2006a).

Natural forest types and conditions vary greatly from one end of the state to the other, and areas of non-natural plantation forests are common in the coastal plain. Oak/hickory forests, comprised mainly of tulip poplar, oak and red maple, account for 60% (approximately 1 million acres) of Maryland's forestlands, with oak and poplar being the species most often harvested. Loblolly/shortleaf pine constitutes around 12% (approximately 310,000 acres) of Maryland's forests, and can be found on the coastal plain alongside loblolly pine/hardwood forests. Forests comprised of oak/gum/cypress are found in the low lying riparian areas of the Chesapeake Bay's tidal rivers and forested wetlands which are flooded for at least part of the year. Virginia pine/oak forests are also common on the coastal plain and piedmont. Western Maryland's forests are largely a diverse mix mixed-hardwood forest types. These forests include stands of northern hardwoods, white pine, Appalachian hardwoods, and hemlock (MD DNR, 2003; (MD DNR, 2006a).

While there is great variety regarding forest types, there are certain structural and functional elements common to all forest ecosystems. This allows for some base observations about the potential positive and negative impacts of biomass harvesting across the state.

4.2 The Role of Deadwood

Standing dead trees, and **down woody material (DWM)** comprise important structural characteristics of Maryland's forests. Down woody material is categorized as **coarse woody debris (CWD)** and **fine woody debris (FWD)**. Material greater than three inches in diameter is generally considered CWD; smaller material is considered FWD. This debris can range in composition, but usually consists of primary branches, trunks, tree tops, and intact dead trees with upturned root wads.

Deadwood results from both natural and anthropogenic disturbances. In unmanaged forests, inputs of deadwood into the ecosystem are a function of random events and natural succession, and are characterized by wide variability across space and time. This accumulation of DWM in forests generally follows a U-shaped timeline, as evidenced by the data from a study of Appalachian hardwood forests in Western Maryland (see Table 20).

Table 20. Mass of DWM in western, MD Appalachian hardwoods.

Age of Stand	(Tons DWM/Acre)
2 years	22
25 years	7
80 years	8
>100 years	14

Source: Berg and McClaugherty, 2008

During early successional stages, trees compete with each other for light and nutrients, and many young trees die-off creating **snags** and new DWM inputs to the forest floor. As forests mature towards **canopy closure**, this mortality cycle slows, resulting in a reduced rate of DWM inputs. In the mid-stages of ecological succession, new deadwood recruitment is largely a result of disturbance. In general, managed forests are characterized by lower volumes of DWM than unmanaged forests. Down woody material accumulation generally decreases as the time period between rotations decreases and when more intensive harvesting practices are employed (Lonsdale *et al*., 2008). In unmanaged stands, a significant amount of deadwood is also created in the later stages of forest succession as mature trees die, producing large-diameter snags, which subsequently become new accumulations of DWM.

A study of 229 USDA Forest Service inventory plots across the northeastern U.S. provides a conservative estimate of 3.7 tons of DWM per acre. The study attributes the relatively low amount of DWM in many of these plots to historic forest clearing across the region, which interrupted natural succession and altered rates of deadwood accumulation. This same study estimates an average of 7.7 tons (2.3 tons as snags, 2.6 tons as CWD, and 2.8 tons as FWD) of deadwood per acre in Maryland's forests (Chojnacky *et al*., 2004). This estimate may be smaller than actual conditions, as other studies have shown a wide range of DWM in eastern forests, with an average of 15 tons per acre (Benjamin, 2009; *Walker et al.*, 2010). Variation in DWM volumes can be attributed to forest type, age, as well as, management and disturbance history.

Deadwood is important in forest ecosystems for many reasons, but is generally acknowledged to provide three major benefits: (1) maintenance of soil productivity, (2) protection of water quality and aquatic ecosystems, and (3) wildlife habitat (Brown *et al*., 2007).

4.2.1 Managing risks associated with the removal of DWM

Forest thinning can positively affect wildlife habitat and forest productivity, but the removal of dead or dying standing trees will alter the rate of accumulation of DWM. Moreover, certain forest types and silvicultural practices (e.g., clear-cutting and **windrowing**) often make it difficult to distinguish between pre-existing DWM and logging slash. In some areas, it is common practice to treat all of this material equally during slash collection and disposal (Bragg and Kershner, 1999; Moseley *et al*., 2008). Janowiak and Webster (2010) suggest that biomass harvests pose high levels of risk to the forest floor because of this.

Lonsdale *et al.* (2008) provide a thorough review of a number of studies that call for silvicultural practices to maintain sustainable levels of deadwood and deadwood-associated biodiversity, while minimizing economic drawbacks to the forest products sector. These authors conclude that management criteria aimed at CWD retention are relevant for practical forest management, and point out that third-party certification programs currently encourage, or require, the retention of high volumes of deadwood in managed forests. While CWD is widely recognized as important, there is no apparent consensus as to which management actions maximize the protection of these ecosystem service values while maintaining practicality.

Some voluntary forest certification programs and state-level forest harvest Best Management Practices (BMPs) specifically address the creation of new CWD and snags during harvests. Best Management Practices designed to protect water quality during and after harvests often call for the retention of higher volumes of CWD than would otherwise be retained in harvests without BMPs (Benjamin, 2009). One study of three Appalachian oak-hickory forests found that 18 years after harvest, the various decay classes of CWD were more evenly represented in plots where 50-foot **streamside management zone (SMZ)** BMPs were effectively implemented. In these instances, more CWD was distributed across the site when compared to traditional harvests, where residual CWD was largely left as slash piles. The study concludes that the inclusion of retention areas (i.e. the streamside management zone) creates opportunities for increased CWD input within 18 years following harvest (McClure *et al*., 2004).

Determining the maximum sustainable amount of CWD supply that can be removed has been a key challenge in the development of all biomass harvesting guidelines developed to date (Evans *et al.*, 2010; Fernholz *et al*., 2009). This is largely a subjective question that depends highly on site-specific conditions, and is thus often left to the judgment of foresters and loggers. However, it is important to offer clear guidance for these professionals in reference documents, such as BMP manuals and biomass harvesting guidelines. In the absence of scientific certainty, other state guidelines (e.g., Minnesota, Wisconsin, and Pennsylvania), have recommended that the effects of removing CWD be monitored and that this monitoring information be used to modify guidelines over time. However, such monitoring efforts are often left unfunded (Pinchot Institute and Heinz Center, 2010).

At least three states (Pennsylvania, Missouri, and Minnesota) recommend that biomass harvests take place at the same time as sawtimber harvests. Economic modelers with the USDA Forest Service assume that this will be common practice, as the economics of biomass harvesting are directly linked to other wood markets (Skog *et al*., 2009). Seemingly contrary to this, Minnesota's biomass harvesting guidelines recommend that slash should not be harvested until leaves and needles have fallen off of limbs and tops to ensure that foliar nutrients are left on site. This sort of **transpiration drying** is the standard practice in Nordic countries, which have long-term experience with intensive forestry and biomass harvesting. This practice may not translate to the U.S. widely, as it directly conflicts with recommendations to avoid repeated entries to harvest sites to minimize the risk of sedimentation, soil compaction, and disruption of stand regeneration (Hood *et al*., 2002; Abbas *et al.*, 2009).

Existing biomass harvesting guidelines for several states are fairly prescriptive as to how much dead wood should be left onsite, although the specific quantities vary. State biomass harvesting guidelines also vary in their recommendations for which forest types and locations may need special consideration before biomass is removed. Some specify that all pre-existing DWM should be left onsite, and that a certain number of snags to be left per acre in a given harvest block. Some (e.g., Minnesota and Wisconsin) have identified particular ecological communities (e.g., Natural Heritage areas) where snag and DWM removal should be avoided altogether

(Wisconsin Department of Natural Resources, 2008; Minnesota Forest Resources Council, 2007).

4.3 Protection of Forest Soils

Down woody material plays an integral role in soil nutrient cycling in forests by facilitating the transfer of energy through the ecosystem over time. In unmanaged forests, DWM accumulates sporadically over space and time, with the size, shape, volume, and composition of DWM all affecting decomposition rates and the cycling of nutrients within the ecosystem (Harmon *et al.*, 1986; Wu *et al*., 2005; Li *et al*., 2007; Berg and McClaugherty, 2008). The recruitment of DWM also varies substantially by forest type; the shortleaf and loblolly pine stands of the coastal plain generate far less CWD when compared to mixed-hardwood forests. Coarse woody debris typically has a much lower nutrient content than FWD. Fine debris also decomposes quickly, making it a more immediately available source of forest nutrients. Coarse woody debris does however, play an integral role in the formation of soils over the long-term, by providing significant inputs to the organic horizon. This relationship is especially important in forest soils with limited soil organic matter (SOM), such as those often found on ridge tops and the coastal plain.

While the rates of decomposition vary by forest type and site, CWD in mid-latitude temperate forests generally breaks down over a period of 25 to 85 years, following an initial pulse of nutrients released through the decomposition of FWD in just a few years (Harmon *et al*., 1986). Over time, the decomposition of deadwood improves the physical and chemical characteristics of forest soils by protecting and enhancing SOM and nutrient content, and by increasing rates of nitrogen fixation through associations with **ectomychorryzal fungi** (Harmon *et al*., 1994; Hafner *et al*., 2005). Fungi remove nutrients from DWM, making these nutrients available in forest soils. Many fungal communities have associations with specific tree species, sizes, and decay classes of DWM, and the diversity of fungal communities in a stand is a useful indicator of overall forest ecosystem health and productivity.

4.3.1 Potential impacts to soil nutrients

The maintenance of soil fertility and productivity is most often the primary concern of managers when it comes to identifying the potential impacts of forest biomass harvests. Forest soils require sufficient amounts of essential nutrients (Calcium, Magnesium, Nitrogen, Phosphorus, Potassium, and others) to maintain soil fertility and forest productivity. Biomass harvests have the potential to deplete long-term site nutrient capital. This potential is elevated in locations with less fertile soils and where other factors (e.g., acid deposition) impact soil productivity.

Studies in Sweden and Finland, two countries where biomass harvesting is practiced widely, have noted significant loss of the abundance of liverworts and fungi on sites where CWD was removed during successive harvests (Amaranthus *et al.*, 1994). Likewise, on intensively managed sites in Finland, researchers noted a 10% drop in forest productivity where significant amounts of CWD and FWD were removed over successive rotations for biomass fuel (Mahendrappa and Salonius, 2006; Stupak *et al.*, 2008; Eriksson, 2010). In Finland, real-world experience with this issue has prompted forestry officials to adopt biomass harvesting guidelines that call for *all* large dead wood, standing or on the forest floor, to be retained; with exception made for salvage harvests associated with storm events, disease, and insect impacts. While key differences exist between the forests of Nordic countries and Maryland (e.g., Nordic forests are slower growing and are comprised of a much higher percentage of coniferous tree species), it is often prudent to consider the experience of others. In southern Sweden, biomass harvests have contributed to productivity losses on forests above sandy soils, especially in areas with high historic rates of acid deposition (Eriksson, 2010). Likewise, sandy soils in Maryland's coastal plain may encounter productivity losses if precautions are not taken to maintain soil buffering capacity.

Impact of harvests on nutrient capital

There is some concern that forest biomass harvests will be more intense than typical sawtimber harvests, and that this will alter the natural recruitment of DWM, with negative impacts over the long-term. For example, whole-tree removal can reduce the long-term availability of soil nutrients, due at least in part to the removal of FWD and CWD nutrient pools. With WTH, the parts of the tree containing the most nutrients, small diameter limbs and foliage, are transferred to the landing with stem wood. Limbs are subsequently removed and chipped at the roadside. Although some foliage and branches break off and are distributed across the cutblock during skidding, WTH can sometimes significantly reduce DWM volume. This can be further exacerbated by subsequent intensive site preparation. A study by Johnson and Todd (1998) in an oak-hickory forest in the Appalachian Mountains, found that whole-tree harvests, resulted in reduced concentrations of cations in foliage and soil after 15 years.

Data collected over the first decade of the USDA Forest Service Long Term Soil Productivity study (LTSP) of 26 sites across the nation indicate that the removal of biomass during sawtimber harvests had no detectable influence on forest growth within the first 10 years after harvest (Powers *et al.*, 2005). However, the complete removal of surface organic matter did lead to a reduction of available nutrients. Other studies have determined that, in addition to factors out of the control of managers (e.g., soil texture and nutrient capital), the intensity of vegetative removal is the primary controllable factor determining site nutrient loss potential, with more-intensive harvesting activities generally increasing the risk of accelerated nutrient leaching (Mann *et al.*, 1988; Powers *et al.*, 2005; Huntington and Ryan, 1990).

Whole-tree harvesting may not be an appropriate practice for some sites, given concerns related to soil nutrient cycling and impacts to site-level biodiversity. Several studies examined by

Huntington and Ryan (1990) conclude that WTH operations had a net effect of 10% soil nitrogen reduction. It is worth noting that some of the studies reviewed by Huntington and Ryan (1990) focused on understanding the dynamic between whole-tree harvesting and acid deposition, focusing on sites with high rates of nitrogen and sulfur deposition; similar to conditions in parts of Garrett County and a few other areas of Maryland. Productivity losses have even been found in industrial managed loblolly pine plantations on the coastal plain of the Gulf Coast following WTH clear-cutting operations, with one long-term study finding an average productivity reduction of 18% (Scott and Dean, 2006).

A number of common tree species in Maryland store a significant amount of calcium in their stems (hickories, oaks, and yellow-poplar). This may make forests primarily composed of these species more susceptible to base cation depletion if intensive removals are undertaken. Forest soils vulnerable to base cation depletion include: highly-weathered soils, soils with low base **cation exchange capacity (CEC)**, and soils with moderate to low base saturation (pH < 4.5). Soils originating from parent material with large amounts of available base cations, such as limestone, are less sensitive (Adams *et al.*, 2003). The potential for soil nutrient depletion is very much site specific. Highly productive sites with deep, fine-textured, loamy soils and sufficient **buffering capacity**, rapid rates of nutrient inputs, and low risk of acidification are usually less likely to have long-term negative effects under normal harvests (Grigal, 2000; McEvoy, 2004). Conversely, sites with low nutrient capital are more likely to be damaged by intensive biomass removal. It may not be prudent to perform even light biomass harvests on sites with extremely vulnerable soils.

Acid deposition

Entire geographic areas may also be at greater risk of nutrient depletion than others due to acid deposition. This phenomenon can cause the leaching of base cations, particularly calcium and magnesium, from sites with vulnerable soils. Adams (1999) concluded that the long-term productivity of mixed-hardwood forests in the central Appalachian region is at risk due to changes in base cation availability due to regional acid deposition, and that increasing harvest intensity and reducing rotation lengths will elevate this risk. A study by Sverdrup *et al*. (1996) used soil mineralogy and texture, as well as air deposition data to model critical loads of acid deposition (nitrogen and sulfur) for Maryland. This study determined that up to 56% of Maryland's forest soils likely suffer acid deposition in excess of their critical loads, and that 14% of the state's forests experience acid deposition in amounts sufficient for severe damage potential. The forests of Garrett County, Allegany County, western Washington County, southwestern Frederick County, Anne Arundel County, Charles County, and parts of St. Mary's County were all found to be at elevated risk (Sverdrup *et al.*, 1996).

Soil compaction
Soil disturbance and compaction is another concern associated with biomass harvests. Operating heavy equipment on forest soils, especially water saturated soils, may cause **compaction**; increasing soil density and reducing water and nutrient flow (Grigal, 2000; Van Hook *et al.*, 1982; McEvoy, 2004). Compaction also damages organic conglomerates within the soil profile, which are essential in retaining soil moisture, maintaining healthy flora and fauna within the soil itself, and ensuring nutrient availability to roots through fungal symbiosis (Abbas *et al*., in press; Berg and McClaugherty, 2008; Li *et al*., 2007; Powers *et al*., 2005).

Heavy equipment traffic may also cause rutting and increased **sheet flow**. On the other hand, Huntington and Ryan (1990) found a positive relationship between surface disturbance and nutrient availability due to the mixing of soil horizons. Still, the negative impacts of compaction resulting from the operation of heavy equipment may outweigh any potential benefit. One study of the impact of compaction on loblolly pine plantation productivity found that tree diameter was reduced by 25 – 35% following harvest in areas where compaction occurred on three and four sides of each tree in the stand (Moehring and Rawls, 1970).

The cumulative impacts of multiple stressors, such as soil nitrogen saturation, foliar ozone deposition, soil acidification, base cation depletion, natural disturbances, and intensive harvest, may combine to exacerbate nutrient leaching and disrupt the availability of soil nutrients. Indeed, there are cases where the cumulative impacts of multiple stressors can lead to declines in forest productivity and poor-quality stands. However, data from long-term studies is often conflicting, and debates continue over the impact of timber management on the biological and chemical characteristics of forest soils (Grigal, 2000). Some studies suggest that intensive harvest reduces site nutrient capital, resulting in productivity losses (Van Hook *et al*., 1982; Adams *et al*., 2003), while other studies reveal that intensive harvests have little to no discernable impact on forest productivity in the short-term (Huntington and Ryan, 1990; Powers *et al*., 2005). This lack of consensus suggests that soil nutrient monitoring should be a key consideration regarding biomass harvest in Maryland.

4.3.2 Managing the risks to soil resources
Some factors that contribute to site degradation and impacts on soil resources are within the control of forest managers and landowners, while other factors remain largely outside their influence (Ares *et al*., 2007; McEvoy, 2004).

In depth soil data analysis is needed to determine actual site nutrient budgets and potential for leaching and nutrient loss as a result of harvesting and other uncontrollable factors. However, such analyses are prohibitively expensive, forcing managers to rely on soil survey information and **site index** as means of making a best professional judgment about their actions.

Partial harvests remove fewer nutrients than clearcutting or whole-tree harvesting over the short-term; however, over the course of a rotation, multiple interventions may remove more nutrients and result in greater soil compaction due to more frequent entrance to the site with heavy equipment. Boyle *et al*. (1973) found that harvesting during the winter after leaf fall can reduce nutrient loss from 10 – 20%, but as the winter months are generally quite wet in Maryland, harvests undertaken at this time of year may result in detrimental impacts from operating equipment on water-saturated soils.

Although collection following transpiration drying has been shown to minimize site nutrient depletion, reentering harvest areas a season later can interfere with forest regeneration, increase soil compaction, and remove material that has become suitable wildlife habitat. A watershed modeling study of the Ridge and Valley province of Virginia and the Allegheny Plateau of West Virginia, calculated sediment yields following a variety of harvest techniques to determine impact on water quality. This study determined that the number of site entries, as a function of road and skid trail activity, has a much larger impact on water quality than the harvesting practices themselves (Hood *et al*., 2002).

Forests have the capacity to restore nutrient levels over time following traditional timber harvests, provided that steps are taken to ensure sufficient DWM retention and that regeneration occurs. However, poorly planned harvests may negatively impact soil nutrient pools if management activities do not allow for restoration of soil nutrient capital. For example, managers in Massachusetts determined that the removal of all small trees during biomass harvest would likely cause a depletion of calcium (a key nutrient for tree growth) for 71 years (Evans *et al*., 2010). Minnesota's biomass harvesting guidelines suggest that the soil nutrient capital could be replenished for most sites within 50 years of biomass removal, and that future harvests should be timed appropriately (Minnesota Forest Resources Council, 2007). Comparable data is not currently available for Maryland.

4.3.3 Forest fertilization

Fertilization provides an option to landowners looking to augment soil nutrient availability to increase growth, shorten rotation length, and/or ameliorate nutrient depletion due to intensive forest management or other disturbance. In general, fertilization is only used in Maryland on medium to intensively managed plantations, with particular focus on the most productive loblolly pine plantations. In the southeastern U.S., "rates of return from fertilization typically average 8 – 12%, but can be as high as 25 – 30% depending on fertilizer cost, extra wood grown, and product class values (Dickens *et al.*, 2003)."

The traditionally slower growth rates, less intensive management, longer rotations, and lower stumpage prices of Maryland's pine plantations, as compared to the southeast, suggests that the rate of return for fertilizer application in Maryland will be towards the lower end of this range.

Fertilization is not particularly common in Maryland, most likely due to landowner perception of low rates of return and the low percentage of forest industry landownership (approximately 1% of all MD timberland) (Lynch and Tjaden, 2004).

If intensive biomass harvests become commonplace, the potential for observed productivity losses due to nutrient depletion may be elevated, possibly leading to an increase in fertilization. In a study of the effects of whole-tree harvests in the southeast, Scott and Dean (2006) conclude that "a relatively small one-time application of nitrogen and phosphorus fertilizer maintained productivity of whole-tree harvested plots and increased productivity by an additional 47% above the stem-only harvest level." While a 47% productivity increase may not be realized in Maryland, the site index maintenance effects may be similar.

While many of the nutrient concerns associated with biomass removal from plantation forests can be addressed through relatively modest fertilization regimes, recent unpublished research in North Carolina indicates that just the coarse woody component of this material accounts for a significant amount of carbon (3 – 4 Mg/ha), much of which would normally contribute to available soil organic carbon (SOC). Whole-tree harvest effects on SOC have been studied to some degree, but research into the impacts that biomass harvests will have on SOC is nascent. Soil organic carbon is intimately related to soil water holding capacity, biodiversity, assimilative ability, and cation exchange capacity, all of which are important to forest productivity. Significant reductions of SOC may or may not have deleterious effects on site index.

The traditional fertilizers used in forestry are diammonium phosphate (DAP; 18-46-0), urea (46-0-0), and triple super phosphate (TSP; 0-46-0).[77] Poultry litter has been widely used as a cropland fertilizer in Maryland for a number of years. With limited land area available to apply poultry litter for row crop fertilization, interest in the usage of litter as a forest fertilizer has increased in the last several years because of decreased runoff potential and higher assimilative capacity of forest soils. Lynch and Tjaden (2004) suggest that 1.5 to 2 tons per acre of poultry litter can be applied to Delmarva pine plantations during establishment, and 4 to 6 tons per acre can be applied at mid-rotation thinnings and at subsequent five- to seven-year intervals, resulting in a predicted 20% cumulative increase in growth.[78]

Fertilization is not without drawbacks. If fertilizers are applied too heavily, nutrient loads may exceed soil assimilative capacity, resulting in runoff, and degraded water quality. Water quality is significant concern in the Chesapeake Bay watershed, where the majority of Maryland's pine

[77] The numbering system (x-y-z) used for fertilization indicates (% Nitrogen (N) - % Phosphate (P_2O_5) - % Potash (K_2O)).

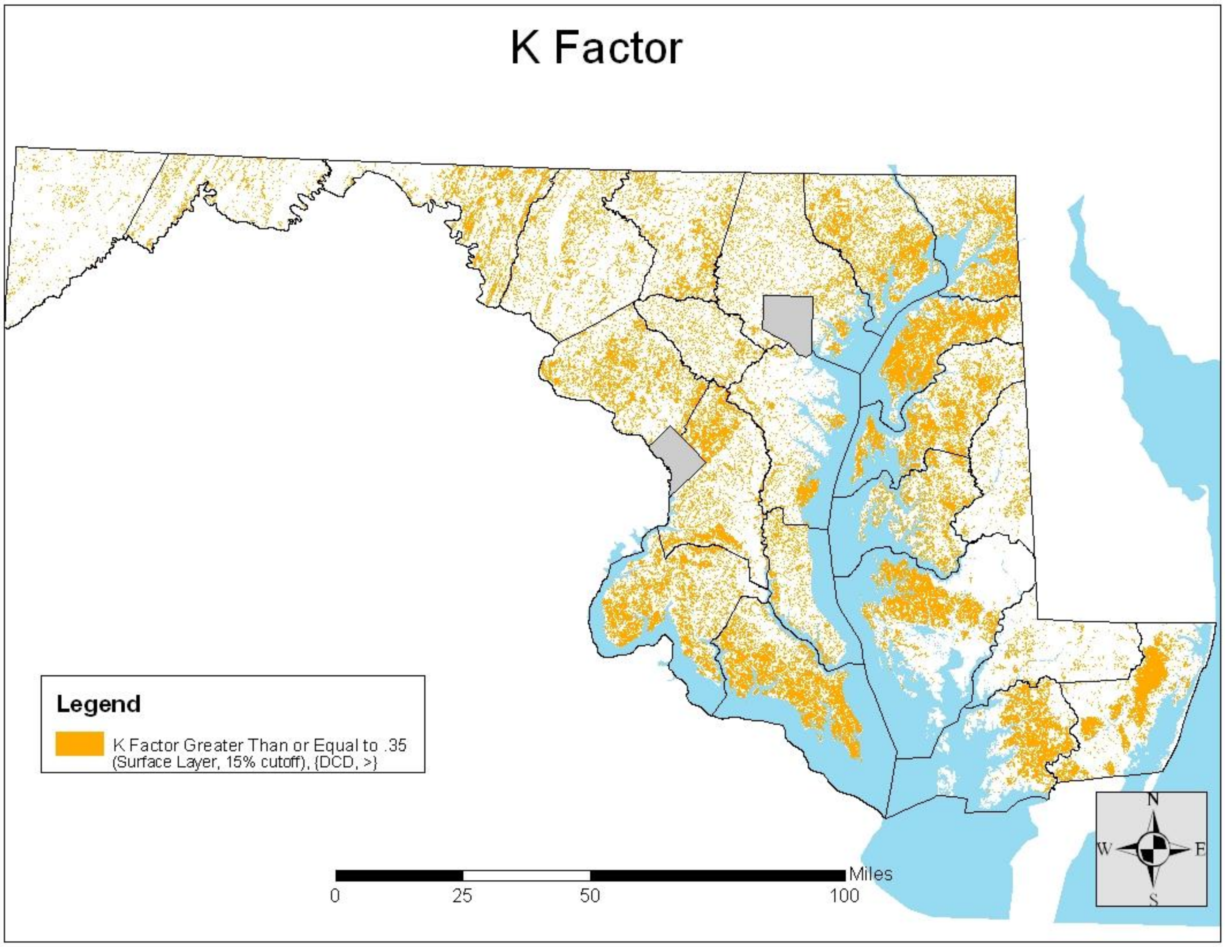
[78] Under the assumption that approximately 13,000 acres (3,000 to 5,000 newly established and 8,000 to 10,000 mid-rotation) are available for litter application annually, 10 – 20% of all available litter could be used for forest fertilization (Lynch and Tjaden, 2004).

plantations are located. Due to these concerns, it is imperative that fertilization rates are tailored to individual site requirements and that nutrient management plans are implemented.

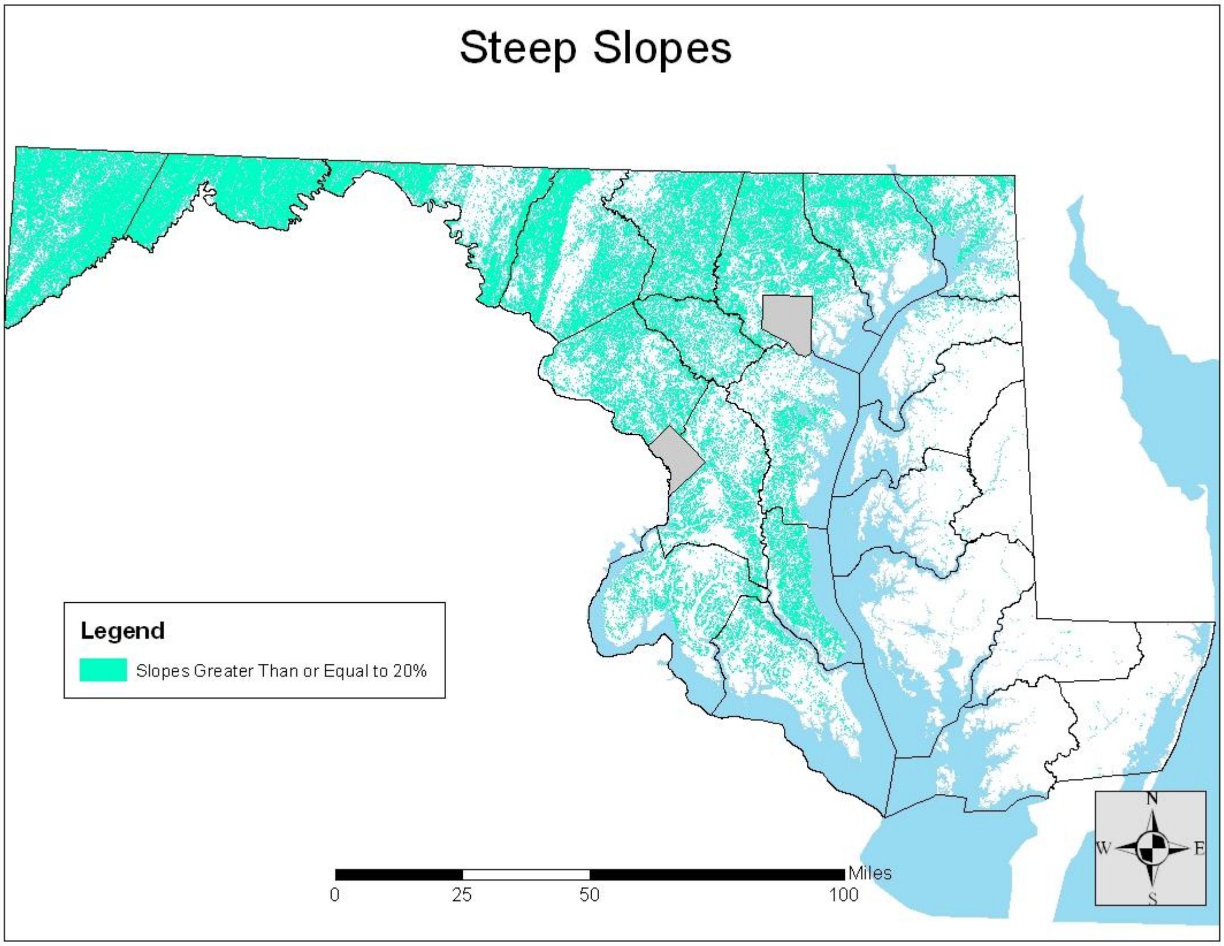
4.3.4 Maryland's soils in context

Soil data from the USDA NRCS Soil Data Mart for all the Maryland counties were used by MD DNR Forest Service staff to generate maps using the USDA NRCS Soil Data Viewer tool. The data that underlies the maps in these sections were gathered at different points in time, some of which date back as far back as the 1970s. Soil data collection and analysis has changed significantly since that time, and the maps created for this report reflect that soil data was gathered through different surveys. These maps presented in this section and in the biomass harvesting guidelines should this be approached carefully. These maps are not included to guide management decisions that can only be made at the local level, but rather to supplement local natural resource data and management.

Soil data was broken up into physical and chemical attributes. Physical attributes include soil erosion factor, **K factor**, and slope. K factor indicates the susceptibility of a soil to sheet and **rill erosion** by water and is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. These estimates are based primarily on percentage of silt, sand, and organic matter, and on soil structure and **saturated hydraulic conductivity (Ksat)**. Values of K range from 0.02 to 0.69, and other factors being held equal, the higher the value, the more susceptible a soil is to sheet and rill erosion by water. As shown in the K factor map, most of Maryland's most highly erodible soils are located in the coastal plain.

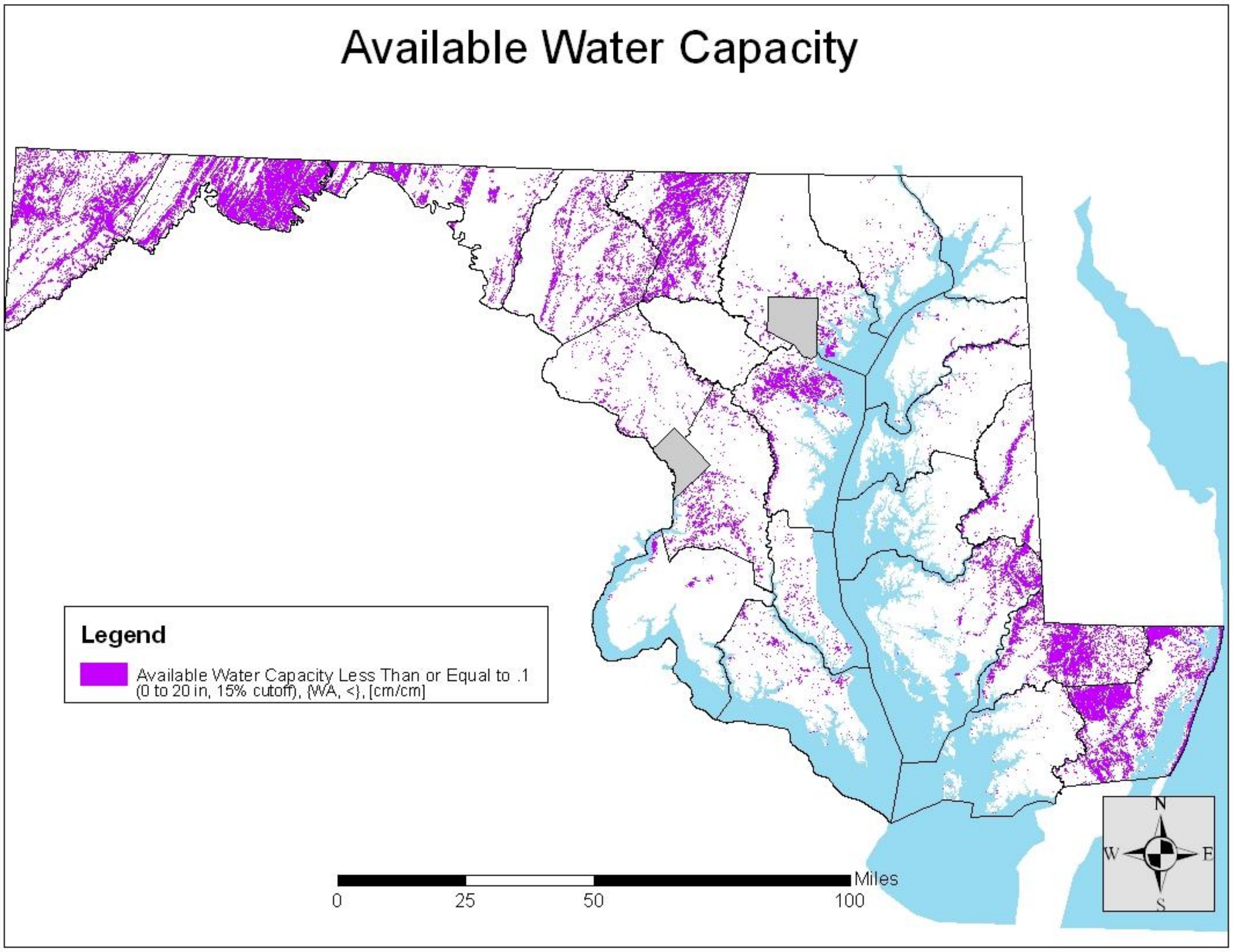


Steep slopes are another factor of concern. If harvests occur on steep and longer slopes, sheet and rill erosion may occur if insufficient logging residues are left on site to slow water velocity and soil particle detachment from areas with exposed soils. A state-wide 30 meter Digital Elevation Model (DEM) was used to identify slopes greater than or equal to 20%. Slopes greater than or equal to 20% were demarcated by Maryland's Sediment and Erosion Control Standards which are used in the state's forestry BMPs. Most of the steep slopes occur in the piedmont and Appalachian Mountains of western and central Maryland. For the most part, major areas of steep slopes do not overlay with areas with highly erodible soils. While soil K factor and slope are two factors beyond the control of forest managers, the application of BMPs, logging equipment selection, and the amount of vegetation removed from a site are all factors under the control of managers and loggers. If soil physical characteristics of a site are compromised by poor harvest practices, forest regeneration may be negatively impacted.

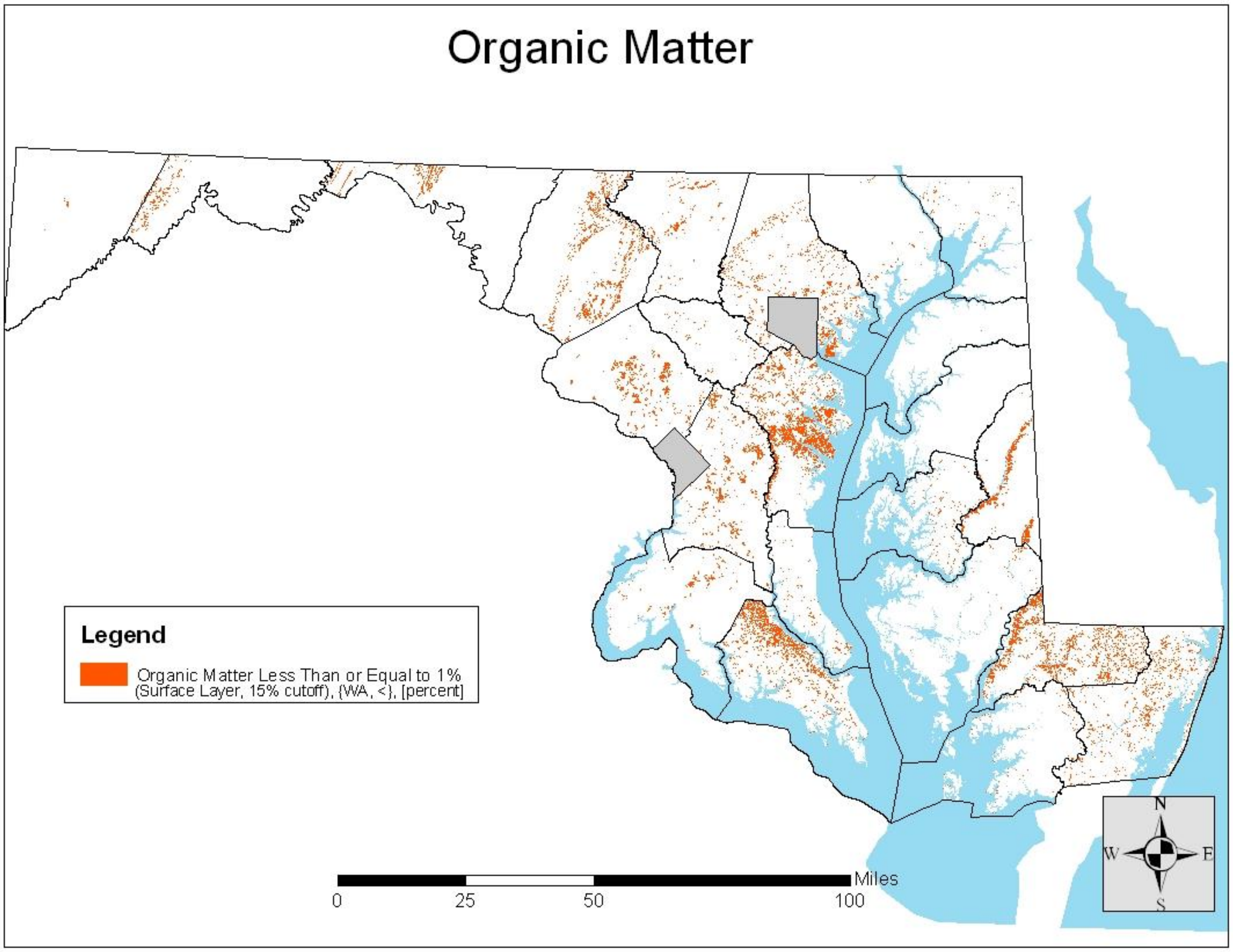


As previously discussed, cation-exchange capacity (CEC) is an important soil chemical property and a large determinant of soil nutrient availability. CEC is also related to buffering capacity, or the ability of soils to hold and transfer base cations through tree roots is essential for tree growth, and much of this occurs in the first 20 inches of soil depth. Two other soil characteristics that are related to CEC are **available water capacity (AWC)** and soil organic matter (SOM). Instead of mapping CEC, both AWC and SOM were mapped because these factors were determined to be more intuitive and useful from a management perspective. In this context, these factors are essentially surrogates for CEC. Areas with low AWC and SOM are very likely to have low CEC and poor buffering capacity.

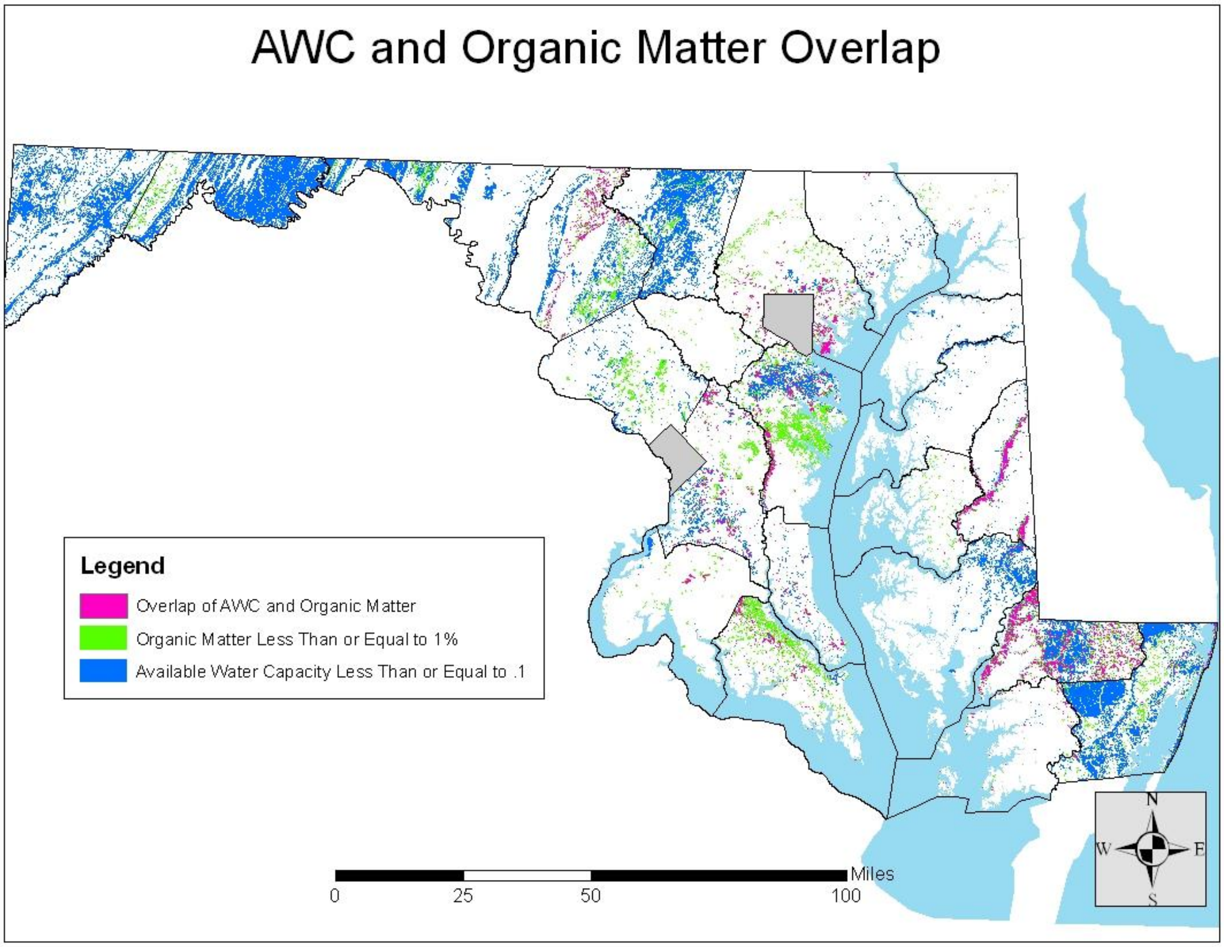
Available water capacity (AWC) refers to the quantity of water that the soil is capable of storing for use by plants, but it is not an estimate of the quantity of water actually available to plants at any given time. The capacity for water storage is given in centimeters of water per centimeter of soil for each soil layer. This capacity varies, depending on interrelated soil properties that affect retention of water, the most important of which being SOM, soil texture, bulk density, and **soil structure**. To create the map of AWC in Maryland, only values for the first 20 inches of soil were used, as this zone is likely to be the most impacted by removal of surface vegetation. In the map below, areas highlighted in purple are areas with soils having an especially low AWC. Many, but not all, of the sandy and coarse textured soils in Maryland exist in these areas.



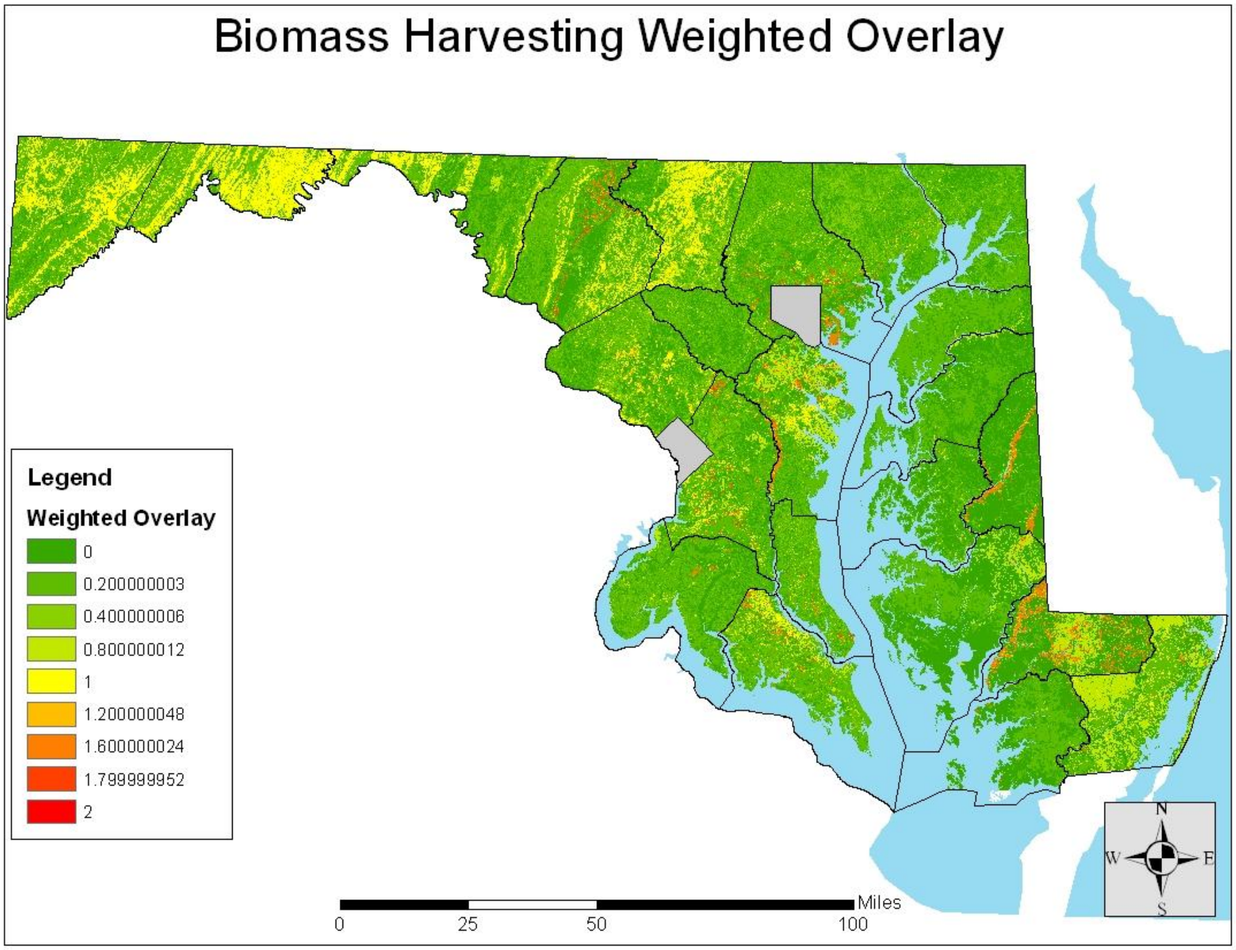
Soil organic matter is plant and animal residue in soils at various stages of decomposition. The estimated content of organic matter is expressed as a percentage, by weight, of the soil material less than two millimeters in diameter. Soil organic matter in forest soils largely comes from decomposed vegetation and DWM. Organic matter has a positive effect on available water capacity, **water infiltration**, soil organism activity, and buffering capacity. Soil organic matter is also an important source of nitrogen, base cations, other nutrients, and soil carbon. While areas of Maryland (e.g., the coastal plain and ridge tops) may have low levels of both AWC and SOM due to several factors, some areas containing especially low levels (<%1) of organic matter were mapped because they are likely the most sensitive to removal of logging residues and other biomass.



The interactions of AWC, SOM, and other soil characteristics are important as well. Areas containing both low amounts of organic matter and low AWC may be of particular concern within the context of biomass harvest. The removal of additional biomass from areas with low SOM and AWC may lead to long-term losses of nutrients and a reduction of forest productivity. These overlaps were mapped to identify areas of concern. This composite also captures variables such as depth (less than 20 inches to bedrock) and texture. Again, the variables mapped were the areas with the lowest amounts of SOM and AWC. Other regions in the state may also have low SOM and AWC and may be ill suited for biomass harvest as well. Indicators of these areas include shallow soils (<20 inches to bedrock), dry sandy soils, very coarse textured soils, soils with thin litter layers, and highly-weathered soils.



A map (*Biomass Harvesting Weighted Overlay*) was developed based on a composite ranking combining erodibility and productivity factors to identify areas where these variables overlap. This ranking includes slopes greater than 20% (receiving a value of 0.2), K-factor greater than 0.35 (receiving a value of 0.2), areas where SOM represents less than 1% of total constituents (receiving a value of 0.8), and areas with low AWC (receiving a value of 0.8). The chemical properties of soil were given a higher ranking because it is presumed that the physical factors of soils will largely be safeguarded through existing BMPs, while chemical factors play a more direct role in nutrient cycling. Values in this ranking span from zero, when soils do not possess any of these factors to two, when soils have posses all of these factors. While the map does not show an abundance of areas where these factors overlap, the *AWC and Organic Matter Overlap* map and the *Biomass Harvesting Weighted Overlay*, do identify some regions (represented by areas of yellow and red coloration) where biomass harvesting should be approached with added caution.



4.4 Conservation of Wildlife Habitat and Biological Diversity

4.4.1 Wildlife habitat

Habitat complexity is a main determinant of species diversity across forest landscapes; in general, the more variation in plant species, age class, and forest structure there is, the greater the diversity of species there will generally be. A high diversity of habitat allows for greater niche diversification, resulting in species richness of both specialist and generalist plants and animals. In some cases, biomass harvesting may aid managers in maintaining a diversity of habitats, while in other cases, biomass harvests may run contrary to management objectives.

In Maryland, more than 30 "Key Wildlife Habitats" have been identified as important for supporting the more than 500 native species listed as having the **greatest need of conservation (GCN)** in the state's Wildlife Diversity Conservation Plan (MD DNR, 2005). Note that only a handful of these Key Wildlife Habitats are forest communities (i.e., old growth forests, early successional forests, maritime forests and shrublands, loblolly pine-oak forests, northern conifer-hardwood forests, forested seepage wetlands, barrens and dry glades) that may be subject to potential biomass harvests. Most of these habitats are fragmented and occur in relatively small patches. For example, there are only approximately 40 small old-growth forest patches remaining in Maryland (MD DNR, 2005).

In addition, some small-patch habitat types support unique assemblages of species not found in more widely distributed forest systems. These include vernal pools, seasonal wetlands, seeps, springs, riparian areas, caves, and rocky outcrops. Many of these non-forested habitats will not be subject to silviculture or timber harvest, and retention of cavity trees, snags, and DWM will enhance wildlife and biodiversity in and around these locations.

4.4.2 Site level biodiversity and DWM

Studies have shown that more organisms typically inhabit deadwood than live trees. Deadwood provides habitat and a food source for a number of invertebrates (e.g., arthropods, earthworms and beneficial microbes) and terrestrial vertebrates (e.g., small mammals, amphibians, reptiles, and birds) (Harmon *et al*., 1986). Snags provide nest sites for 20 – 40% of birds in forests, and studies have shown that they play an especially critical role as nesting and foraging sites for birds in oak-hickory forests, Maryland's dominant forest type (Hagan and Grove, 1999; Brawn *et al*., 1982).

In unmanaged forests, natural disturbance regimes (e.g., windthrow, insect infestations, pathogens, fire, etc.) are the primary processes through which stand structure is modified, and stand age class diversified. As discussed in section 4.2, disturbance events create new deadwood in forests, and a large proportion of forest biota depend on that resource. Management prescriptions for **salvage** or **sanitation harvests** in stands impacted by disturbance events should weigh both the opportunity for harvest of fallen trees and the opportunity to increase DWM abundance (Lang *et al*., 2009). This is an important consideration for land owners and consulting foresters, as deadwood abundance can accumulate faster in stands where silvicultural practices are used in an attempt to increase biodiversity (Lonsdale *et al*., 2008).

In loblolly pine plantations on the coastal plain, it is common practice to masticate and leave logging residues or chip and remove slash following harvests because excess residue may impede forest regeneration. Still, in natural loblolly pine forests, DWM remains an important structural component, with one study of southern loblolly pine forests finding that breeding bird abundance declined by nearly 50% with CWD removal (Lohr *et al*., 2002). Lonsdale *et al*. (2008) concluded that, "modern forestry needs to retain appropriate levels of deadwood in managed forests, ideally in all its forms and density levels, in order to cover the full spectrum of habitat conditions."

In the present market context, the limited investment in thinning and other management activities in Maryland's plantation forests, coupled with the low density of final harvest stands, suggests that these forests likely have a relatively high degree of stand complexity and biodiversity. If plantation forest landowners are so inclined, additional steps can be taken to help ensure that plantation forests can serve as suitable wildlife habitat. If achieving the optimal growth rate of pines is less of a priority for landowners, steps can be taken to build stand complexity by creating snags and increasing rates of DWM accumulation. Mechanical thinning of pine stands, without the application of herbicides, can facilitate volunteer species recruitment, allowing for a more structurally and genetically diverse stand. Other options include retaining patches of standing trees and DWM at final harvest, retaining and buffering snags and cavity trees with unharvested trees, and by feathering cutblock edges (MD DNR, *Water Quality and Wildlife Habitat in Pine Stands on Delmarva*).

It is important to note that silvicultural prescriptions intended to benefit one species may act to the detriment of another. For example, the creation of small canopy openings (skips and gaps) might benefit small mammals that forage or nest in transitional habitats, while interior forest-loving bird species may decline (Lynch and Whigham, 1984).

Wildlife trees are particularly important, as they provide both habitat and a food source for a variety of forest-dwelling species. Benjamin (2009) notes four types of wildlife trees, these include: (1) decaying live trees that provide habitat for insects and fungi and serve as future supply of deadwood for the ecosystem, (2) cavity trees that provide habitat for birds and mammals, (3) snags, dead standing trees that provide habitat for insects not found in living trees, and, (4) mast trees, which provide a high-energy food source such as nuts and berries that is important for wildlife, especially during winter months.

Invasive woody plants, such as the Bradford pear, present challenges for landowners and natural resource managers in Maryland. In many cases, these invaders are allowed to persist because of the high costs of eradication. Appropriate precautions should be taken when removing invasive plants to avoid further dispersal of invasive plants, particularly during transport.

Like other forested states in the east, Maryland has periodic insect infestations. In recent years, the Hemlock Woolly Adelgid and the Emerald Ash Borer have presented challenges for forest managers, as entire species of trees face insect-related die-off. In some instances, sanitation harvests may be appropriate, and the resulting biomass often needs to be combusted to prevent the further dispersal of insects. The extent to which biomass salvage harvest for energy production can be consistent with the need to manage risk of further insect infestation remains to be seen.

4.4.3 Restoration of early successional habitats

Early-successional forests are dominated by shrubs and small trees less than 24 feet tall (MD DNR, 2005). These habitats develop in the first 20 years following timber harvest, and support a diverse assemblage of species not usually present after canopy closure (MD DNR, 2005). In Maryland, the majority of early-successional forest habitat occurs in the form of forest edges and recently harvested areas, which comprise nearly 5% of Maryland's land area (MD DNR, 2005). As expected, this habitat type is fairly common in the areas of the state that produce most of the commercial timber (i.e., the lower eastern shore, southern Maryland, and the western most counties).

As much as 15% of the 231 bird species identified as regularly breeding in the northeast are dependent on early successional habitats (Dettmers, 2003). Of the 126 neotropical-migrant bird species in the northeast, 74 require disturbance-generated habitats or young forests (Lorimer and White, 2003). Early-successional habitats have declined in the Mid-Atlantic by 17% since the 1950s; largely due to forest cover has maturation (Oehler, 2003). Some suggest that biomass harvest could contribute to the expansion and maintenance of early-successional habitats by providing markets for small diameter trees; making "the harvest of low quality stands more economically feasible for public agencies as well as private landowners (Oehler,2003)."

4.4.4 Plant and animal communities of special concern

While the Maryland Strategic Forest Lands Assessment identified upwards of 20 forest types across the state, the Maryland Natural Heritage Program has documented that more than 50 forest habitat types actually occur in the state, and has classified them as part of the National Vegetation Classification. Some of these are forested wetlands (e.g., Atlantic White Cedar bogs), and others occur on unusual geologic substrates (e.g., serpentine barren woodlands, ancient sand ridge forests/woodlands). Many of these uncommon forest communities are small (only a few acres or tens of acres in size), and are patchily distributed across the landscape. Including forests, Maryland has well over 100 different natural plant communities, a number of which are home to rare, threatened and endangered species (RTEs). In total, Maryland is home to approximately 900 vertebrate species (mammals, birds, amphibians, reptiles, fish), and 3,900 vascular plant taxa, as well as 160 butterflies, 22 freshwater mussels and countless thousands of other invertebrate species. The MD DNR Wildlife & Heritage Service has identified 502 native species in Maryland as those in Greatest Need of Conservation (GCN) in the Wildlife Diversity Conservation Plan (2007) and the State Wildlife Action Plan (MD DNR, 2005).

Many of the GCN species in Maryland (and many RTE species more in general) occur in uncommon or rare community types around the state. Uncommon habitats that support RTE's, especially herbaceous plant species, are open-canopy (e.g., Delmarva bays, coastal plain bogs & meadows, salt marsh complexes, serpentine barrens, shale barrens, and mountain peatlands), which have no timber resources, making them unlikely sites for biomass harvesting. However, some RTEs do live in forest habitats that might be used for timber or biomass harvest (e.g., the federally endangered Delmarva fox squirrel). Appropriate precautions should be taken when planning harvest activities on tracts known, or thought to support such species. Harvest activities are regulated in the Critical Area around the Chesapeake Bay, and in wetland habitats designated as Nontidal Wetlands of Special State Concern (see chapter 5 for a review of these regulations). Animal species listed as Endangered or Threatened by the Natural Heritage Program cannot be “taken” or “harmed” under Maryland’s Endangered Species Act. Natural Heritage Program Regional Ecologists review many proposed timber harvest plans, and have a successful history of working with both the MD DNR Forest Service and private landowners to avoid, minimize or mitigate impacts to RTE’s and sensitive habitats on lands slated for harvest operations.

4.5 Protection of Water Quality and Aquatic Resources

Across the U.S., logging operations are the second largest source of sediments in streams, after agriculture (Edwards and Stuart, 2002). From a water quality perspective, forested lands contribute the least nutrient and sediment runoff to streams and rivers as compared to agricultural lands and stormwater flows from developed lands (Edwards and Stuart, 2002; Benjamin, 2009). In addition, many resources in Maryland are devoted to restoring and/or reestablishing forested riparian areas to cool streams and filter nutrients and sediments. The harvest of timber is allowed in these areas under certain constraints (see Chapter 5), although harvesting biomass is discouraged in these areas because of the importance of DWM inputs.

In general, the greater the amount of vegetation removed from a watershed, the greater the potential for decreased precipitation interception and decreased transpiration by vegetation. Interception is the process by which precipitation lands on vegetation and reduces the velocity with which precipitation hits the ground, which in turn reduces overland flow and potential detachment of sediments from the soil surface. Transpiration is an important factor in plant growth and is the process by which plants draw up nutrients and water from soils, eventually passing water vapor through stomatal pores in foliage. The removal of trees from a watershed reduces the net transpiration rate for the watershed, which in turn increases surface runoff, which can accelerate rates of sedimentation into surface waters if precautions are not taken to buffer areas of exposed soil (e.g., logging roads, skid trails, landings, and site access points) (Patric, 1978; Patric, 1980).

4.5.1 Water quality BMPs

Best Management Practices are intended to minimize the disturbance of soils and the litter layer, facilitate rapid regeneration, and control overland sheet flow of water (Aust and Blinn, 2004). Nationwide, forest operations are responsible for around 10% of water quality impairments, largely due to sedimentation associated with roads and stream crossings and the improper implementation of BMPs (Edwards and Stuart, 2002). The Federal Clean Water Act exempts silviculture from non-point source pollution permits, on the basis that each state has a legal requirement to develop and implement BMP programs. Even with many of these programs being voluntary, approximately 86% of timber harvests nationwide apply BMPs (Edwards and

Stuart, 2002). In Maryland, forestry BMPs were implemented at a rate of 81% from 2004 – 2005, similar to the 82% implementation rate observed in 1995 (Koehn and Hairston-Strang, 2009). It is worth noting that BMPs associated with haul roads and landings, the two areas associated with the greatest risk of sedimentation, were determined to be implemented correctly in over 90% of all harvests in Maryland in the 2004 – 2005 survey (Koehn and Hairston-Strang, 2009).

When BMPs are correctly applied, most water quality impacts associated with site entrance can be successfully mitigated so that there are no long-term impacts on stream temperature, benthic macro invertebrates, and total suspended solids (TSS). Studies in the Ridge and Valley physiographic province of the Mid-Atlantic have evaluated the effects of logging and BMP's on water quality and water yield. In Pennsylvania, a 15 year study determined that there was a small, but statistically significant, increase in stream temperature and concentrations of nitrogen and phosphorus following clearcuts, but these effects dissipated within a year or two following harvest. Water yield also increased but returned to preharvest levels within four years (Lynch and Corbett, 1990).

While it is anticipated that existing BMPs will be sufficient to address most areas of concern regarding water quality protection during and immediately after harvests, it is important to consider whether the removal of a higher percentage of biomass during timber harvests would in any way interfere with successful BMP implementation (Shepard, 2006). In particular, it is important to consider the importance of woody biomass retention to minimize rain velocity impacts to soil surfaces and the hydrology of riparian areas (Benjamin, 2009; Patric, 1978).

4.5.2 The role of deadwood in the protection of water quality

Deadwood plays an essential role in riparian forests and aquatic ecosystems, and riparian forests are the most important areas of recruitment of wood for aquatic ecosystems (Harmon *et al.*, 1986; Bragg and Kershner, 1999; Hornbeck and Kochenderfer, 1999; Warren *et al.*, 2009). Streams receive varying inputs of large woody debris which provide myriad ecological and hydrologic services such as: altering and slowing the flow of water, creating habitat for fish and macro invertebrates, retaining sediments and organic matter and slowing their release following storm events, and impacting aquatic nutrient cycling (Harmon *et al.*, 1986; Flebbe and Dolloff, 1995; Bragg and Kershner, 1999; Hornbeck and Kochenderfer, 1999; Warren *et al.*, 2009).

Woody debris inputs are especially important in silt and sand bottomed streams, like those found on Maryland's Coastal Plain, as this material provides substrate for filter-feeding aquatic invertebrates (Braccia and Batzer, 2001). Small headwater streams of the eastern U.S. receive between 60 – 90% of their primary productivity from the surrounding forest (Sprague *et al.*, 2006).

There is also evidence that deadwood is an important driver of the microbial denitrification processes necessary for removing excess nitrogen from waterways (Okay, 2009). There is a strong link between the amount and type of CWD that enters aquatic systems and forest management decisions made on the land (Flebbe and Dolloff, 1995; Hedman *et al*., 1996; Hornbeck and Kochenderfer, 1999; Warren *et al.*, 2009), and the Pennsylvania biomass harvesting guidelines state that biomass harvesting in riparian areas is “unacceptable” because of the importance of aquatic DWM (PA DCNR, 2008). Recent research commissioned by the Chesapeake Bay Program suggests that maintaining deadwood, especially CWD, in riparian zones is important for reducing nutrient and sediment transport by slowing sheet flow and reducing the incidence of channelization (Simpson and Weammert, 2007; Okay, 2009). Other research suggests that CWD has substantial water storage capacity, providing reservoirs of moisture during dry periods, and modulating the water balance of small watersheds after storm events (Fraver *et al*., 2002).

4.6 Silvicultural Practices

4.6.1 Interest in biomass harvesting as a silvicultural tool

Most of the eastern U.S. forest landscape, including Maryland, has a legacy of extensive land clearing for agriculture during the 18th and 19th centuries. Over the last century, however, agricultural acreage has declined significantly and forests have grown back across many of these landscapes. Total forest acreage is declining again, largely due to urban and suburban development, and by the 1990s, Maryland’s historical forest cover had declined by half (MD DNR, 2005). Over the same period, high-grading has decreased timber and wildlife habitat values in these forests. Biomass harvesting is viewed by many as having the potential to offset the negative impacts of these past events. Foresters seeking markets for low-quality and non-commercial species welcome the opportunity to improve wildlife habitat, forest stand complexity, and tree growth by offsetting at least a portion of the costs of precommercial thinning and uneven-aged management regimes, which have historically been cost-prohibitive. Others warn that while regeneration harvests might be helped by new markets, if biomass removals are too heavy, forest structure may be altered in undesirable ways.

Dettmers (2003) suggests that silvicultural treatments will be necessary to mimic natural disturbance regimes in order to create and maintain forest landscapes dotted by early successional patches of varying sizes and shapes. While harvesting blocks in a fashion mimicking natural disturbance and restoring a matrix of early successional habitats across the landscape might benefit populations of birds and other species adapted to these habitats, this is difficult to achieve, given the fragmented nature of forest parcel ownership. DeGraaf and Yamasaki (2003) recommend that even-aged management systems be maintained as a tool in the silviculturist’s toolbox to effectively periodically create small openings. Biomass harvests could play a role in making such management activities feasible.

4.6.2 Forest management planning

Forest management plans (FMPs) are an important silvicultural practice for ensuring forest sustainability. Forest management planning is relatively costly and the benefits of this investment are not immediately noticeable, which is likely why so few plans are developed. Across the Northeast and Maryland, only 5% of private landowners (representing 29% of the forest land) have FMPs (Birch, 1996; ELI, 2000). Consultation with a licensed professional forester capable of performing forest inventory, planning and other services is one of the most important ways to ensure that silvicultural prescriptions will meet the goals of the landowner. It is widely recognized that high-grading harvests are more likely to occur on lands that do not have a long-term forest management plan.

In forests that have been lightly high-graded, only minor thinning may be needed to promote the growth of desirable trees and increase stand complexity. Forests that were extensively high-graded may require larger openings using selection, group selection or small clear cuts, and careful replanting and care to reestablish the desired species and age-class diversity (USDA Forest Service, 2004). Hornbeck and Kochenderfer (1999) found that group selection with individual opening of about 2.5 acres in size is desirable in the mixed Appalachian hardwood forests of Western Maryland. Sturtevant and Seagle (2004) also note that **seed-tree** and **shelterwood harvests** are more applicable on ownerships under 10 acres. Each of these harvest systems will generate different amounts of biomass at different points of the rotation.

4.6.3 Plantation forest management

Biomass harvesting may complement some of the standard silvicultural practices used for managing loblolly pine plantations and mixed loblolly-hardwood forests of the eastern shore and southern Maryland. The definitional language of qualifying biomass in Maryland's Renewable Portfolio Standard recognizes this market dynamic in that it specifically includes "pre-commercial softwood thinning" in the definition.

Even-aged softwood plantation forestry is quite different than uneven-aged mixed hardwood forestry, with timber management activities typically being more intensive in plantation forestry (i.e., site preparation, thinning, use of fertilizers and herbicides). Investments in silviculture in Maryland's plantation forests are largely a function of access to markets. Given the current forest industry market dynamics of Maryland, plantation activities are geared toward encouraging a final harvest of large diameter sawtimber. The low market price of pulpwood in the area contributes to most of Maryland's plantations only being pre-commercially thinned once, with some larger parcels being thinned twice. Ideally, the 40 to 60 year average rotation length of Maryland's pine plantations suggests that final harvest sawtimber value would be maximized by thinning the stand three times, but interim material (biomass) market price is low enough to dissuade much mid-rotation management.

Forest plantations host a suite of environmental, social and economic advantages and disadvantages. Bowyer (2001) notes that, "foremost among the advantages is that establishment of highly productive forest plantations can provide large quantities of wood [in] small land areas, raising the possibility that pressures for harvesting within natural forests can be markedly reduced…every crop cycle offers the opportunity for planting superior genetic stock, designed to grow better quality faster." Over the past several decades, most forest plantations have been established in areas previously used for agriculture, but suitable land scarcity and low land value may encourage the conversion of already forested areas being converted into plantations (Friedman, 2006). When examining the environmental effects of forest plantation establishment, it is important to compare it to the land use that it replaced (Paquette and Messier, 2010). In some instances, plantation establishment may enhance ecosystem services, while in other cases plantations may negatively impact these conditions.

For the most part, levels of deadwood and DWM are kept purposefully low in pine plantations through management, as creating wildlife habitat and supporting high levels of biodiversity are generally not primary management objectives. Since Maryland's plantations are usually managed over longer rotations (i.e., up to 45 years), this allows for more snags and DWM to accumulate than in plantations of the southeastern U.S. While excess DWM following harvests may impede regeneration, retaining some DWM is important for forest regeneration in that it can offer important reservoirs of above and below ground moisture, and also provides nutrients for tree seed germination and seedling development.

4.7 Management of Short Rotation Woody Crops

Short rotation woody crop (SRWC) plantations have been investigated heavily as feedstock sources for bioenergy projects across the globe. Fast-growing **coppice** hardwoods like poplar (*Populus spp.*), willow (*Salix spp.*), sycamore (*Platanus occidentalis*), sweetgum (*Liquidambar styraciflua*) and loblolly pine (*Pinus taeda*) are all well suited for the climate and soil types of Maryland. Each species type offers its own set of advantages and disadvantages, but in general, the management considerations of SRWC plantations are more closely aligned with agricultural crop production than traditional forestry (Blanco-Canqui, 2010). Short-rotation woody crop cultivation is part forestry and part agronomy (agroforestry), and requires knowledge of both fields to succeed (Shepard, 2006).

The increased density and shorter rotation times of SRWCs may have significant effect on the soil texture and fertility of plantations. Like with traditional intensively managed plantations, concerns have been voiced about nutrient depletion, erosion, compaction and runoff from SRWC plantations (Shepard, 2006). However, when compare to traditional agriculture and idle and/or degraded land, established SRWC plantations have a less homogenous and more stable soil structure, and the presence of tree litter on soil surface at various stages of decomposition, compounded with the establishment of a fine and coarse tree-root layer makes the soil less susceptible to crusting, surface sealing, erosion, and compaction (Blanco-Canqui, 2010; Volk *et al*., 2006). Despite the evidence that SRWC plantations may be a net benefit in terms of soil health and water quality when compared to traditional crop production, BMP controls may need to be revisited to ensure adequate protection for regional soil and water health, with particular regards to roadway and stream crossing durability and erosion controls during crop establishment (Shepard, 2006).

While the potential impacts to biodiversity are less studied in a SRWC setting, largely due to the fact that very few SRWC plantations currently exist in the U.S., early studies indicate that establishment of SRWCs could provide water quality benefits. A study by Updegraff *et al*. (2004) shows that cropland conversion to hybrid poplar SRWC plantations reduced cumulative annual stream flows, sediment, and nitrogen loads by 9%, 28%, 15%, respectively in an agricultural watershed of Minnesota. Short Rotation Woody Crops may be an option for establishment of riparian buffers, or as "halos" around row crops, in part because of rapid and extensive fine root development capable of absorbing nutrients in shallow groundwater. In addition, after initial establishment, careful harvests of SRWC riparian buffers on a 3 – 5 year rotations may improve overall productivity by maintaining the crops in a juvenile state, with heavy nutrient demands, reducing the chances that upslope nutrient runoff will reach waterways (Volk *et al*., 2006; Turhollow, 2000).

Chapter 5

Regulatory and Non-regulatory Tools that Govern Forest Management in Maryland

5.1 Introduction

The management of private forest land in the U.S. is influenced by a number of regulatory and non-regulatory approaches. In Maryland, as in other states, private landowners and loggers are encouraged to adopt desired forest management practices through a framework of voluntary and regulatory programs. As currently structured, this framework may or may not adequately address the potential risks to natural resource sustainability associated with increased biomass harvests. Similarly, the current system of landowner education and technical assistance programs may prove inadequate in helping landowners weigh the potential risks and rewards that new markets for forest biomass may present.

This chapter identifies additional safeguards, above and beyond those already present in Maryland's regulatory and non-regulatory programs, which may be necessary to address the potential impacts of increased harvest of forest-derived biomass. This chapter also identifies gaps in informational resources and provides some options to close these gaps. In order to better assess Maryland's current forest management policy framework, this chapter includes:

(1) A review of the regulatory and non-regulatory programs that presently govern forest management and timber harvests in Maryland, and an analysis of the ability of these programs to address the potential risks and rewards associated with forest biomass removals;
(2) A review of the technical assistance outlets, educational resources, and other sources of information about forest management available to private forest landowners and loggers in Maryland, and an analysis of whether biomass removals are currently addressed through these outlets, and;
(3) Recommendations for the augmentation of existing programs to ensure that should forest biomass harvesting become a more significant component of forest management in Maryland, such harvests will be undertaken in a sustainable manner.

5.2 Approaches to Forest Management

The overarching charge for forest management in Maryland is found in the Natural Resources Title Section 5-602 of the Annotated Code of Maryland, which says that:

> Forests, timberlands, woodlands, and soil resources of the State are basic assets, and the proper use, development, and preservation of these resources are necessary to protect and promote the health, safety, and general welfare of the people of the State. It is the policy of the State to encourage economic management and scientific development of its forest and woodlands to maintain,

> conserve, and improve the soil resources of the State so that an adequate source of forest products is preserved for the people. Floods and soil erosion must be prevented and the natural beauty of the State preserved. Wildlife must be protected, while the development of recreational interest is encouraged and the fertility and productivity of the soil is maintained.

Over time, this basic charge has resulted in the development of a framework of policies and programs. The sustainable management of Maryland's forest resources depends on both the design specifications of management practices, and the frequency with which these practices are adopted. Policy makers and agency administrators have the difficult task of designing forest management programs to maintain the ecosystem services that forests provide, while simultaneously addressing myriad social concerns, and minimizing program costs.

The ability of policy makers and agency administrators to design cost-effective forest management programs is all the more difficult when the scientific information necessary to design such programs is inadequate, incomplete, or contradictory. In instances where the potential risks and rewards are unclear, policy makers and agency administrators may elect to proceed with caution by adopting an **adaptive management** approach that assesses risk relative to measurable management criteria and indicators (Lattimore *et al*., 2009; MPCI, 2009; Wintle and Lindenmayer, 2008). All state and eco-regional biomass harvesting guidelines developed to date adopt such an approach (Evans *et al*., 2010; Fernholz *et al*., 2009).

Regulatory approaches (e.g., procedural rules, legislatively prescribed practices, reporting, monitoring, compliance, and enforcement) and non-regulatory approaches (e.g., extension education, information sharing networks, technical assistance, tax incentives, and other financial incentives), can both be useful means of attaining certain desired outcomes. Regulatory programs can result in many desired socioeconomic, political, and biophysical outcomes, but other effects of regulatory programs (e.g., excessive administrative costs) may be undesirable to society at large if programs are ill conceived or poorly applied. For example, simple and direct regulations that require harvested areas to be reforested through leaving seed-trees or replanting may help secure forest resources for future generations. Conversely, regulations that are too economically or administratively cumbersome to implement, may inadvertently limit the ability of private forest landowners to retain their land as forest. It is often the case that a conscientious mix of voluntary and regulatory programs offers the best potential outcomes for society.

In an attempt to better understand the confluence of regulatory and non-regulatory approaches, a 2003 study by the University of Minnesota reviewed policies and programs designed to encourage desired forest management practices on private forests of all 50 states (Ellefson *et al*., 2004). This study surveyed administrators of state forestry programs to evaluate the effectiveness of: extension education, technical assistance, tax incentives, financial incentives, and regulatory programs. At both the program level and the practice level, Ellefson *et al*. (2004) used the following categories to evaluate various types of forest management practices:

- **Road and trail practices** (e.g. water crossings, erosion control practices, skid trails, logging roads, winter use)
- **Timber harvesting practices** (e.g. landings, site layout, slash management/disposal, residual stand damage, felling, bucking)
- **Reforestation practices** (e.g. species selection, seed tree selection, supplemental planting, site preparation, timing, natural or artificial regeneration)
- **Cultural practices** (e.g. mid-rotation thinning and other timber stand improvement activities)
- **Chemical application practices** (e.g. which chemicals, mixing, timing, method of application)
- **Forest protection practices** (e.g. salvage and sanitation cutting, insect and pathogen prevention, animal damage)
- **Administrative practices** (e.g. planning, notifying, reporting, monitoring, evaluating)

This chapter adopts this typology as an organizing framework to review and classify the existing policies and programs that influence the forest management activities of private forest landowners in Maryland. This review identifies potential gaps where practices and programs may not adequately address key issues related to forest biomass harvesting (i.e., deadwood management, protection of forest soils, and conservation of wildlife habitat and biological diversity), detailed in chapter 4. Section 5.4 includes an assessment of Maryland's regulatory programs and their applicability to forest biomass harvesting.

5.3 Non-Regulatory Programs

Nationwide, voluntary programs most often take the form of cost share payments, technical assistance, grants and loans, education programs, preferential access to contracts with forest product companies, and third party certification programs (Kilgore and Blinn, 2004). Non-regulatory programs are widespread and generally viewed as an effective way of reaching desired outcomes on the ground. Ellefson *et al.* (2004) found that state administrators feel that extension education and technical assistance were the most effective means to encourage a variety of forest management practices, from best management practice (BMP) implementation, to silviculture. Thus, sections 5.3.1 through 5.3.9 detail the predominant non-regulatory programs active in Maryland in an effort to identify potential gaps in these programs relative to the environmental considerations involved with forest biomass harvesting. Table 21 summarizes the information presented in these sections. This table is organized using the forest practice typology adopted by Ellefson *et al.* (2004) and key issues related to forest biomass harvesting (i.e., deadwood management, protection of forest soils, and conservation of wildlife habitat and biological diversity) detailed in chapter 4.

5.3.1 Forest Stewardship Planning

In Maryland, forest stewardship plans are one of the most effective means to ensure responsible management of the woodlots of private landowners.[79] Prepared by either a licensed forester or the MD DNR Forest Service, these plans should be written for a 10 – 15 year period, but may also be updated within this time period, as needed. Forest stewardship plans typically include: (1) An articulation of the objectives of the woodland owner, (2) forest inventory data, (3) maps denoting relevant property-specific information (e.g., location, boundaries, individual stands, soil types, tree retention areas, key conservation features, and future harvest areas), and (4) detailed descriptions and chronology of silvicultural treatments for each forest stand (UMD, 2000; Viana *et al.*, 1996).

Since planning is a first step in furthering forest conservation and sustainable management, a number of programs are used in Maryland to encourage the development of forest stewardship plans. For example, a forest stewardship plan is required to apply for state and federal cost-share programs. Federal incentive programs (e.g., Farm Bill programs like BCAP) also require that landowners have a FMP for their property. Legislation introduced in the U.S. Congress aimed to determine which sources of biomass are eligible for federal tax credits also called for eligible biomass to come from lands managed under a written forest management plan developed by a licensed professional forester.

The state once provided funding to pay for development of forest stewardship plans, but this is now largely an out-of-pocket expense for private landowners. While non-industrial private forests represent approximately 79% of all non-federal forestland nationwide, it is estimated that only 5% of these private forests have written forest management plans (ELI, 2000). Despite mechanisms to encourage forest stewardship plan development and implementation, it is estimated that only 7,000 (4.5%) of Maryland's non-industrial private forest landowners have some kind of written management plan (MD DNR, 2006a).

Foresters for the MD DNR Forest Service prepare an average of 425 Forest Stewardship Plans for roughly 25,000 acres each year (MD DNR). In general, forest stewardship plans do not include specific recommendations pertaining to forest biomass harvest, as this type of management is not currently a priority for most forest landowners in Maryland. This may be due in part to the lack of biomass markets, but it is more likely because private forest landowners are managing lands for objectives other than biomass production.

[79] Forest stewardship plans are for all intents and purposes the same thing as forest management plans (FMPs) and both terms are thus used interchangeably in this report.

5.3.2 Woodland Stewards Program

The Maryland Woodland Stewards Program is an educational program of Maryland Extension and the National Wild Turkey Federation, which trains private landowners in forest and wildlife management practices. This peer-to-peer mentoring program focuses on ecological succession, wildlife habitat, biodiversity, general vegetation management, and silviculture. Participants in the Maryland Woodland Stewards Program agree to develop and implement forest stewardship plans for their own property and to mentor other landowners in doing this as well. This voluntary educational program does not currently address forest biomass harvesting.

5.3.3 Forest Conservancy District Boards

Maryland Forest Conservancy District Boards (Forestry Boards) act as county level forestry consultants in each of Maryland's 23 counties and Baltimore City, which have both a non-regulatory and regulatory function (Maryland Code, Natural Resources § 5-605). This landowner education and outreach program is unique to Maryland, and serves as a core component of Maryland's regulatory programs. Forestry Boards are comprised of five or more individuals knowledgeable in forestry and natural resource management, one of which is a MD DNR forester. Forestry Boards provide technical assistance upon the request of landowners to assist in the development of forest harvest plans. This technical assistance is mandatory for parcels within the Chesapeake Bay Critical Area.[80] The Forestry Boards do not typically provide technical assistance related to forest biomass harvesting, although they may be approached about any number of issues relevant to responsible biomass harvests (e.g., design of salvage harvests, slash disposal methods, wildlife habitat considerations, etc.).

5.3.4 Forestry for the Bay

Forestry for the Bay is a landowner outreach and education program that seeks to inform landowners of forest management practices that benefit water quality in the Chesapeake Bay region. Forestry for the Bay is intended to increase landowner access to state and federal conservation programs and facilitate the development of forest stewardship plans. The program is supported by an advisory committee and active partnerships with state forestry agencies (i.e., MD DNR Forest Service, the Pennsylvania Bureau of Forestry, and the Virginia Department of Forestry), forest industry representatives, landowner groups, environmental conservation organizations, and land trusts.

Forestry for the Bay provides technical assistance to landowners through two online forest planning modules designed to educate landowners about the benefits of managing their woodlots. The first plan, the Woodland Objective Plan, introduces landowners to forest management and by educating them on how forest management can be used as a tool to meet

[80] It is also the responsibility of the Forestry Boards to review proposed harvest activities on land protected by long-term forest conservation agreements per the Forest Conservation and Management Act (FCA) (see section 5.4.1).

multiple objectives, including income generation. The second plan, the Woodland Conservation Plan is a more in-depth, six-step process through which landowners begin to consider specific management actions. Neither of these plans currently integrates information pertaining specifically to forest biomass harvests.

5.3.5 Maryland Master Logger Program

The Maryland Master Logger program[81] is a professional training and certification program designed to promote responsible logging practices in Maryland. The program benefits landowners seeking ecologically conscientious and credible harvest crews, and loggers interested in distinguishing themselves within their field.

The program consists of four basic components: (1) A commitment by the logger to responsible practices by signing the Master Logger Code of Ethics, (2) completion of a number of core courses, (3) two harvest reviews (self-assessments) within the first two years of completing Master Logger training, and (4) completion of an annual continuing education course following the completion of the initial training course.

The basic Master Logger training course includes the following subjects: proper implementation of Maryland's BMPs, logging aesthetics, forest management from a logger's perspective (i.e., forest science, ecology, and wildlife management), silviculture, sustainable forestry, wildlife management/endangered species management, logger activism, logging safety, OSHA certification, first aid and CPR, and a field practicum focused on proper site layout (e.g., location of landings, BMPs, logging roads, and skid trails). Continuing education courses provide an opportunity for loggers to stay abreast of the most current laws, logging techniques, and emerging issues. As of May 2010, 173 loggers have completed the training course and have enrolled in continuing education courses (MD DNR). The Maryland Master Loggers program does not currently include any formal training material related to biomass harvesting and bioenergy.

5.3.6 Sustainable Forestry Act

The Maryland Sustainable Forestry Act of 2009 (S.B. 549) was signed in to law in 2009 to promote the sustainable management of Maryland's private forests. This law has five main components: (1) Recognition of the importance of private forests to the economic and ecological health of Maryland, (2) promotion of the importance of forest stewardship plans and the Forestry boards as a method of developing such plans, (3) promotion of wood-based bioenergy as a tool to achieve Maryland's renewable energy goals (specifically mentioning the state Renewable Portfolio Standard), (4) promotion of sustainable forestry by encouraging local governments to support forest management activities in local zoning laws, and (5) highlighting the linkages between the agricultural and forest sectors.

[81] More information, including a list of certified Master Loggers, can be found at: http://md-demasterlogger.com/

The Maryland Sustainable Forestry Act of 2009 also established the Sustainable Forestry Council, a committee comprised of forest conservation and forest management experts, charged with addressing pertinent issues related to the conservation and sustainable management of Maryland's forest resources. The Sustainable Forestry Act also defines timber harvest practices, silvicultural practices, and sustainable forestry in a regulatory, or quasi-regulatory, nature for the first time in Maryland's history. Specifically, the law defines "**sustainable forestry**" or "sustainable forest management" as an "internationally accepted and applied stewardship concept for the use of forest and forest lands in a manner and at a rate that maintains a forest's: biodiversity, productivity, regeneration capacity, nutrient reduction benefits, vitality, and ecological, economic, and social purposes at local and national levels that do not cause damage to other ecosystems."

5.3.7 Woodland Incentives Fund

The Sustainable Forestry Council oversees the administration of the Woodland Incentives Fund, which is meant to offset the costs to the MD DNR Forest Service for the development and approval of forest stewardship plans on privately owned forest lands. Funding for such activity was previously provided to the Forestry Boards to facilitate outreach efforts encouraging forest stewardship plan development.

For owners of at least five, but not more than 1,000 forest acres, the Woodland Incentives Fund will reimburse up to 65% of the cost of eligible management practices (i.e., pre-commercial thinning, pruning, prescribed burning, crop tree release, site preparation for regeneration, herbicide treatments, and planting of seedlings) to encourage management for the production of forest products including sawlogs, pulpwood, firewood, woodchips, poles, posts and other primary forest products.

Landowners interested in this program must apply through a licensed forester and have a forest stewardship plan to qualify. It is the responsibility of the forester to inspect the management practices carried out to ensure proper implementation and to seek reimbursement from the state. The Sustainable Forestry Act of 2009 doubled the cap of this program from $100,000 to $200,000 annually. At the $100,000 level, approximately 75 – 100 landowners, comprising 1,500 – 2,000 acres, took advantage of this program (MD DNR). This program is dependent on funds being made available in the state budget. Because biomass markets may change the economics of implementing some silvicultural practices that the Woodland Incentives Fund is set up to promote, these markets may allow for the Woodland Incentives Fund to target areas where biomass markets do not exist, or towards specific practices (e.g., replanting) that biomass markets will not necessarily directly support.

5.3.8 Relevant State Tax Incentives

Forest Management Plan (FMP) Income Tax Modification Program – Private forest landowners owning five or more acres of forest land are eligible for reduced property taxes upon the creation of a forest management plan (FMP) by a licensed forester and approval by the MD DNR Forest Service.

Timber Stand Improvement (TSI) and Reforestation Income Tax Modification Program – This financial incentive program allows for forest landowners to deduct double the cost of reforestation and TSI activities from their federal adjusted gross income on their Maryland state income tax. Participants must own or lease between 10 and 500 acres of forestland, capable of growing more than 20 cubic feet of wood per acre per year for the primary purpose of timber production. Only forest management practices carried out on 10 to 100 acres may receive the tax modification in any one year. Practices receiving the deduction must remain in effect for at least 15 years. If periodic inspections determine that practices are not maintained, tax savings must be repaid. Approximately 30 – 50 landowners take advantage of this program annually (MD DNR). Arboricultural operations (e.g., Christmas tree and ornamental tree operations) are not eligible for this program, and as of now this policy does not address SRWCs.

Forest Conservation Management Agreement (FCMA) Income Tax Modification Program – This financial incentive program is designed to encourage landowners with five or more contiguous acres to enter into an agreement with the MD DNR to conserve their forest land for at least 15 years through a reduced and/or frozen property tax assessment. Under this agreement, the landowner agrees to develop and implement a "forest conservation and management plan" to dictate harvest activities, as approved by the local Forestry Board. The program also specifies that ownership must be retained for at least 15 years or a penalty payment applies, although new landowners can continue active agreements. Inspections are made by a state forester every five years to monitor progress and provide technical assistance. The program specifies that cropland does not qualify, but land used to grow Christmas trees does, provided that trees are cut at harvest rather than excavated. Like with the Timber Stand Improvement (TSI) and Reforestation Income Tax Modification Program, SRWCs are not currently included in this program. Statewide, there are approximately 84,000 acres covered in 1,300 agreements.

5.3.9 Forest Certification Systems

Forest certification programs are voluntary environmental management frameworks that evaluate the overall supply chain of forest products against a set of agreed upon standards. Most certification programs use this system of standards evaluation to track forest products from harvest, through procurement, processing, and manufacture, and on to purchase by the consumer. While the specific objectives and designs of various forest certification programs vary, the general formula most often includes: general and/or region-specific certification standards, forest management unit assessment and audit, chain-of-custody assessment and audit, trademark registration and labeling, certifier accreditation, and market education and promotional materials (Viana *et al.*, 1996; Wintle and Lindenmayer, 2008).

American Tree Farm System (ATFS)[82] – Maryland strongly supports the American Tree Farm System of forest certification; at least partly because it does not require a fee and is flexible for smaller landowners (down to 10 acres), which comprise the bulk of forest ownership in the state. Tree Farm certification covers both planted forests and naturally-regenerating forests. In Maryland there were over 269,000 acres managed under Tree Farm in 2000 (ELI, 2000), or approximately 14% of all private forestland in the state, however this dropped to 157,174 in 2008.[83] The Maryland Tree Farm program is sponsored by the Maryland Forests Association, MD DNR Forest Service, and the Maryland Extension Service.

This second or third-party certification[84] program requires forest landowners to work with a forester to develop and implement a forest management plan that includes the "owners goals appropriate to the management objectives, a tract map noting stands and conditions, important features including special sites, and management recommendations that address wood and fiber production, wildlife habitat, owner-designated fish, wildlife and plant species to be conserved/enhanced, environmental quality, and, if present and desired by the landowner, recreational opportunities" (AFF, 2010). After the forest management plan is developed, the property is inspected by an ATFS volunteer forester at least every five years to determine if the management plan is being implemented. ATFS does not have a supply chain certification, but forests certified by ATFS can sell their product into facilities certified by the Sustainable Forestry Initiative (SFI).

Sustainable Forestry Initiative (SFI) [85] – Currently an independent certification program, SFI was originally established by the American Forest and Paper Association (AF&PA), as a means to help ensure that AF&PA members use responsible forest management practices. The specific objectives of SFI include reforestation, protection of water quality, enhancement of wildlife habitat, improvement of harvest operation aesthetics, protection of unique sites, considerations for biological diversity, continued improvements in wood utilization, and the responsible use of pesticides and fertilizers. Each of these objectives has specific performance measures approved by a Sustainable Forestry Board composed of external experts. SFI certified entities verify standards conformance through a first-party (self verification), second-party (verification by a

[82] www.treefarmsystem.org
[83] Information compiled by Seneca Creek Associates, LLC
[84] Second-party certification involves forest landowners' practices being evaluated by a second party; in this case, the second party is most likely their approved forester. In instances where a landowner adopts ATFS standards, their property may be evaluated by a third-party (i.e., a certified ATFS forester).
[85] www.sfiprogram.org

customer or another company), or third-party system (verification through an independent third-party). SFI objectives and performance measures do not currently include specific protocols for biomass harvesting. There were 58,000 acres of SFI certified forest in Maryland as of 2008.[86]

Forest Stewardship Council (FSC)[87] – FSC is an independent, non-profit organization that promotes responsible forest management of the public and private forest lands across the globe. FSC develops national and regional forest management standards and undertakes the accreditation of third-party certifying entities, which in-turn evaluate the performance of a forest management unit against FSC standards. The program offers three types of certification: (1) forest management certification, in which individual land management units are certified, (2) forest manager certification, in which a forester agrees to manage a private forest (or a group of private forests) according to FSC standards, and (3) chain-of-custody certification, in which the entire process of forest product development is certified along the supply chain (i.e., foresters, loggers, mills, etc.). FSC certification standards are organized into 10 principles and more than 50 associated criteria, which are used by certifiers to evaluate forest management activities.

To date, FSC management standards for the U.S. do not directly address biomass harvests, as the key environmental considerations associated with biomass are theoretically addressed within the existing management framework. For example, principle 6 addresses the environmental impacts of harvesting operations, and indicator 6.3.f requires that "management maintains, enhances, or restores habitat components and associated stand structures, in abundance and distribution that could be expected from naturally occurring processes," which includes "live trees with decay or declining health, snags, and well-distributed coarse down and dead woody material" (Evans *et al*., 2010). In Maryland, there were nearly 50,000 acres of FSC certified forests in 2008[88] and has now increased to over 100,000 acres, as additional units of Maryland's state forests have come under FSC certification. While FSC often proves to be cost-prohibitive for small forest landowners, the program does allow for the grouping of several small parcels to receive FSC certification when they are managed by a single FSC certified forester or organization.

Council on Sustainable Biomass Production **(CSBP)**[89] – This third-party certification program was developed through the collaboration of several environmental organizations and energy and forest industry interests. The program is intended to regard the full chain-of-custody (from feedstock production to energy generation) of both the biofuels and bioenergy industries. A draft standard for feedstock production has been released, and a standard for energy conversion facilities is currently under development. The feedstock production draft standard applies to both forest and agricultural landowners, although its applicability for smaller landowners is not

[86] Information compiled by Seneca Creek Associates, LLC
[87] www.fscus.org
[88] Information compiled by Seneca Creek Associates, LLC
[89] www.CBSP.org

clear. Since the standard was originally conceived as a means to certify the supply chain of large biofuel and bioenergy facilities, it may prove too cost prohibitive for the majority of landowners in Maryland; however, this may prove to be a great opportunity for energy facilities to catalyze sustainability in the future.

Although it does apply its own principles for forest biomass, the CSBP draft standard also addresses how it may best integrate with the standards and processes of existing forest certification standards like ATFS, SFI and FSC to avoid duplication and additive costs for landowners. The program was originally conceptualized as a way to ensure that the short-rotation energy crop plantations of the burgeoning liquid transportation biofuels industry are grown in a manner that complies with the Clean Water Act and the recent U.S. EPA liquid biofuel GHG emissions threshold requirement of the federal Renewable Fuels Standard. The CSBP standard addresses a wide range of principles including: land management planning, soil quality, biological diversity, water quantity and quality, lifecycle GHG emissions, and socio-economic considerations (e.g., labor law compliance). Additional topics covered in the draft standard include land conversion, invasive and non-native species, and a number of agricultural practices related to agro-chemical inputs.

Table 21. Summary of non-regulatory policies and programs directly affecting forest management in Maryland.

	Description and Relevance for Biomass Harvesting	Level of Governance	Target Audience	Timber Harvesting Practices /1	Reforestation/ Regeneration Practices /2	Silvicultural Practices /3	Administrative Practices /4	Water Quality BMPs	Deadwood Management	Protection of Forest Soils Beyond BMPs	Wildlife Habitat and Biological Diversity
Forest Stewardship Plans	Plans are developed for a 10 – 15 year management period and delineate the management objectives for private landowners including timber harvest schedules. Plans do not presently integrate biomass harvesting schedules or identify areas where biomass harvesting may not be suitable for a given site.	Local level (i.e., the forest parcel).	Landowners and their foresters.	Plans schedule and describe timber harvesting practices. Biomass harvests are not presently widely included.	Plans detail reforestation practices. Plans do not widely evaluate the impact of biomass harvests for reforestation.	Stewardship plans include TSI activities.	The contents of forest stewardship plans vary, and generally address a variety of topics related to forest sustainability.	Forest stewardship plans often do not include BMPs as these are specific to the harvests and are included in harvest plans.	Forest stewardship plans often do not include management of deadwood unless it is within the context of improving wildlife habitat.	Forest stewardship plans may include identification of soil types.	Forest stewardship plans may include objectives for wildlife management and protection of biological diversity.
Maryland Woodland Incentives Fund	Provides cost-share for TSI practices and regeneration/replanting practices. Biomass markets may "pay" a portion of the costs of these management practices (e.g., pre-commercial thinning).	State level (i.e., Sustainable Forestry Council).	Program is limited to landowners with 5 - 1,000 acres wishing to produce forest products, including biomass.	Cost-share intended to offset the cost of a number of timber harvesting practices.	Cost-share intended to offset the cost of forest regeneration/replanting practices.	Cost-share intended to offset the cost of a number of timber management practices (i.e., TSI practices).	Requires the landowner to have a forest stewardship plan developed by a licensed forester.	NA	NA	NA	NA
Maryland Master Logger Program	Program provides training/Information sharing and professional development for loggers. Training includes various aspects of forest management and laws and emerging issues like biomass that are of relevance to loggers.	State level (i.e., extension).	Timber harvesters.	A core training module addresses timber harvesting practices. Biomass harvest techniques are not addressed.	A core training modules address legal requirements for reforestation and appropriate methods.	A core training modules addresses silviculture and sustainable forestry.	A core training modules instructs loggers to help landowners achieve the objectives of their forest stewardship plan.	A core training module addresses the water quality BMP program. A continuing education course addresses "advanced BMPs."	Addressed as part of core training, but not in reference to biomass harvests.	Addressed as part of core training, but not in reference to biomass harvests.	Addressed as part of core training, but not in reference to biomass harvests.
Maryland Woodland Stewards Program	This program is a peer-to-peer mentoring program that trains a select group of landowners in various forestry and natural resource management topics. These individuals in turn train other landowners and encourage the development of plans. Biomass harvesting is not currently addressed in the program.	State level.	Landowners	Addresses the basics of timber harvests as addressed in forest stewardship plans.	Addresses the basics of forest regeneration.	Addresses the basics of silviculture and vegetation management.	Requires the participating landowner develop a forest stewardship plan and encourage others to do so.	NA	NA	NA	Offers basic information on woodlot management for wildlife habitat and biodiversity.
Maryland Forest Conservancy District Boards	Forestry boards provide technical assistance to landowners developing proposed harvests. Forestry boards approve harvests in the Chesapeake Bay Critical Area and areas covered by long-term forest conservation agreements per the Forest Conservation Act (FCA). Forestry boards do not presently provide technical assistance on biomass harvests.	County level.	Landowners and foresters	Forestry boards provide technical guidance for landowners designing timber harvests.	Forestry boards may provide technical guidance in forest regeneration and replanting.	Forestry boards may provide technical guidance in silvicultural practices.	Forestry boards have authority to approve harvest plans on any parcel in the state, but only apply this authority in certain instances.	Forestry boards may provide technical guidance on BMP design (e.g., location of forest roads and skid trails).	NA	NA	NA

	Description and Relevance for Biomass Harvesting	Level of Governance	Target Audience	Timber Harvesting Practices /1	Reforestation/ Regeneration Practices /2	Silvicultural Practices /3	Administrative Practices /4	Water Quality BMPs	Deadwood Management	Protection of Forest Soils Beyond BMPs	Wildlife Habitat and Biological Diversity
Maryland Sustainable Forestry Act	Reinforces the Sustainable Forestry Council to promote bioenergy and could promote responsible biomass harvesting techniques. Raises the cap of the Woodland Incentives Fund and calls for additional focus on the development of Forest Stewardship plans. Defines sustainable forestry, timber practices, and silviculture practices.	State level.	Landowners, foresters, and timber harvesters.	The Sustainable Forestry Act sets up definitions for timber harvest practices	NA	The Sustainable Forestry Act sets up definitions for silvicultural practices	NA	NA	NA	NA	NA
American Tree Farm System (ATFS)	2nd- and 3rd-party certification program that helps landowners work with a forester to complete and implement a management plan that meets tree farm standards.	NGO – Applicable Statewide.	Landowners and foresters.	Program includes provisions for timber harvesting, but does not address biomass harvests.	Program includes provisions for forest regeneration.	Program includes provisions for silviculture.	Program requires inspection by a ATFS registered forester once every 5-years.	Program provides guidance on the implementation of BMPs.	May include provisions for management of residual deadwood following harvests, but this is currently not specific for biomass harvests.	Does not require additional protections for forest soils past what is included in Maryland's BMP program	Includes identification of special sites of high conservation value, and provisions for wildlife habitat management
Sustainable Forestry Initiative (SFI)	1st-, 2nd- or 3rd-party certification program for forest management and forest products supply chain of custody.	NGO – Applicable Statewide.	Landowners, foresters, timber harvesters, and utilization facilities.	Program includes provisions for timber harvesting, but does not address biomass harvests.	Program includes provisions for forest regeneration.	Program includes provisions for silviculture.	Requires landowners to have a forest management plan and 1st, 2nd, or 3rd-party field audits.	Requires landowners to implement all applicable BMPs.	Includes guidance for the management of residual deadwood following harvests is not currently specific for biomass harvests.	Does not require additional protections for forest soils past what is included in Maryland's BMP program	Includes specific principles, objectives, and indicators related to wildlife habitat and biodiversity.
Forest Stewardship Council (FSC)	3rd party certification program for forest management and forest products chain of custody certification.	NGO – Applicable Statewide.	Landowners, foresters, timber harvesters, and utilization facilities.	Program includes provisions for timber harvesting, but does not address biomass harvests.	Program includes provisions for forest regeneration.	Program includes provisions for silviculture.	Requires the landowner to have a forest management plan and 3rd-party field audits.	Program includes comprehensive framework for water quality management.	Includes guidance for the management of residual deadwood following harvests is not currently specific for biomass harvests.	Includes comprehensive framework protection of forest soils, but does not include specific metrics related to biomass harvests.	Includes comprehensive framework for the conservation of wildlife habitat and biodiversity, but does have specific guidance for biomass.
Council on Sustainable Biomass Production (CBSP)	3rd party certification program designed for biomass harvests, but mainly geared to energy crops and agricultural biomass.	NGO – Applicable Statewide.	Landowners (mostly agricultural).	Program includes provisions for biomass harvests.	Program includes provisions for forest regeneration.	Program includes limited provisions for silviculture as biomass is the main objective.	Requires the landowner to have a forest management plan and 3rd-party field audits.	Program includes comprehensive framework for water quality management.	Does not include specific criteria and indicators for deadwood management.	Includes provisions for protecting forest soils, but does not have specific biomass retention requirements.	Includes provisions for identifying high value conservation areas and rare, threatened, and endangered species.
Forestry for the Bay	Information sharing and outreach program to help landowners develop forest management plans geared toward improving water quality and wildlife habitat.	NGO – Applicable Statewide.	Landowners.	Helps landowners conceptualize and plan timber harvests.	Helps landowners plan for reforestation.	Helps landowners conceptualize and plan silvicultural activities.	Helps landowners develop forest management plans.	NA	NA	NA	NA

	Description and Relevance for Biomass Harvesting	Level of Governance	Target Audience	Timber Harvesting Practices /1	Reforestation/ Regeneration Practices /2	Silvicultural Practices /3	Administrative Practices /4	Water Quality BMPs	Deadwood Management	Protection of Forest Soils Beyond BMPs	Wildlife Habitat and Biological Diversity
Timber Stand Improvement and Reforestation Income Tax Modification Program	Program allows landowners to deduct up to twice the cost of TSI/other forest management activities. Markets for biomass may alter the applicability of this program to emphasize the reforestation portion more than the TSI portion.	State level.	Program is limited to landowners – owning 10 - 500 acres capable of growing 20 cubic feet of wood per acre per year.	Program provides a financial incentive to invest in TSI activities and reforestation activities for the purpose of producing timber.	Provides a financial incentive for reforestation.	Provides a financial incentive for landowners to invest in silviculture (i.e., TSI practices).	Requires a landowner to invest in the practices and then work through their forester to receive payment from the state.	NA	NA	NA	NA
Forest Management Plan (FMP) Income Tax Modification Program	Voluntary financial incentive-tax mod. Program that reduces the assessed tax rate if a FMP is completed. Requires landowners to have a forest conservation and management plan that must be completed by a licensed forester and approved by MD DNR	State and County level.	Program is limited to landowners with ≥ 5 acres.	NA	NA	NA	Provides a financial incentive for landowners to develop a forest management plan.	NA	NA	NA	NA
Forest Conservation Management Agreement (FCMA) Income Tax Modification Program	Voluntary financial Incentive - Tax Mod. Program that freezes property taxes at $100/acre or less for acres for which a forest conservation and management agreement is developed.	State and County level.	Program is limited to landowners with ≥ 5 acres.	Timber harvests may occur undertaken under a written forest conservation and management plan.	Reforestation must occur following timber harvests and must follow a written forest conservation and management plan.	TSI may be undertaken under a written forest conservation and management plan.	A forest conservation and management plan must be developed and approved by the Forestry boards.	NA	NA	NA	NA

/1 Timber harvesting practices include construction of landings, site layout, slash management/disposal, addressing residual stand damage, felling, and bucking.
/2 Reforestation, regeneration, and replanting practices include selection of appropriate species to leave/maintain in the stand, seed tree selection, supplemental planting, site preparation, and regeneration practices.
/3 Silvicultural practices include mid-rotation thinning and other timber stand improvement activities.
/4 Administrative practices include planning, notifying, reporting, monitoring, and evaluating harvests.
NA Indicates instances where a policy or program does not specifically address certain practices or key issue areas with relevance for biomass harvesting.

5.4 Regulatory Programs

Following the diverse cultural views of forest management across the U.S., the regulation of management activities on private forest land occurs along a spectrum. Some states have detailed forest practices acts that delineate how, when, and where each management activity is to be undertaken. Other states rely on a less prescriptive framework of seemingly disconnected laws bound together by voluntary programs. A handful of states rely almost exclusively on voluntary approaches, with forest industry playing a larger role than government (Ellefson *et al*., 2004; AF&PA, 1993).

In Maryland, there are a variety of policies effecting forest management that can be considered regulatory or quasi-regulatory. For example, the Maryland Department of Environment (MDE) has the authority to halt forest management activities causing erosion and sedimentation and to limit harvests in tidal wetlands. Similarly, the MD DNR Forest Service can require the reforestation of plantation forests after harvest and to limit harvests within 1,000 feet of the tidal waters of the Chesapeake Bay. In some instances, oversight-authority is delegated to county governments and Forestry Boards. As discussed below, Maryland has a layered regulatory policy framework that requires an array of entities to interact; often facilitated by the non-regulatory programs addressed in section 5.3 (e.g. the Master Logger program and Forestry Boards). Table 22 summarizes the information presented in section 5.4, and is organized using the forest practice typology adopted by Ellefson *et al*. (2004) and the key issues related to forest biomass harvesting.

5.4.1 Forest Conservancy District Law

The Forest Conservancy District Law, which authorizes the MD DNR to "promulgate rules and regulations," and "enforce the law," to "administer forest conservation practices on privately owned forest land" has in many ways, been delegated to the county Forestry Boards (Maryland Code, Natural Resources § 5-601 et seq.). This law states that for any private forest parcel of three acres or greater on which commercial timber harvests occur: (1) the land must be left "in a favorable condition for regrowth," (2) young growth must be retained as much as feasible during logging, (3) restocking after harvest must occur through leaving seed trees, or by other means, and (4) operators are to maintain adequate growing stock after selective cutting. Since the law does not specify what "adequate growing stock" is, it is typically determined at the local level by the forester and Forestry Board. In forestry site-prescriptive management requirements often do not offer the necessary flexibility for effective management.

The Forestry Boards mainly serve a non-regulatory function, by providing technical assistance at the request of forest landowners. The regulatory functions of the Forestry Boards include promulgation of "safeguards for proper forest use" (Maryland Code, Natural Resources § 5-605) that will: (1) provide for adequate restocking, after cutting, of trees of desirable species and condition, (2) provide a sufficient growing stock of thrifty trees of desirable species to keep the land reasonably productive, and (3) prevent clear-cutting, or limit the size of a tract to be clear-cut in areas where clear-cutting will seriously interfere with the protection of a watershed, or in order to maintain a suitable growing stock to ensure natural reproduction. Some counties have also modified zoning ordinances to provide additional requirements.

Landowners must apply for a site inspection at least 30 days prior to cutting, and the Forestry Board must provide for examination "by a qualified person," which may include a licensed forester or the Forestry Board themselves. Although the law gives the Forestry Board the authority to review all proposed harvests, only timber harvests planned for special areas (i.e., the Chesapeake Bay Critical Area, non-tidal wetlands, areas covered by a long-term Forest Conservation Act agreement) are typically reviewed (University of Baltimore School of Law, 2001; Maryland Code, Natural Resources § 5-605).

5.4.2 Pine Tree Reforestation Law

With the exception of white pine and Christmas tree farms, harvests in Maryland's coniferous forests are regulated under the Pine Tree Reforestation law to "provide for the maintenance and reproduction of the pine resources to provide significant recreational, aesthetic, wildlife and environmental benefits as well as wood fiber essential to commerce and industry" (Maryland Code, Natural Resources § 5-501 et seq.). Each year, approximately 40 – 50 harvests, comprising approximately 2,500 – 3,000 acres, are subject to the Pine Tree Reforestation Law (MD DNR Forest Service). The law applies mainly to harvested areas of pine plantations that are at least five acres in size, are at least 25% loblolly, shortleaf, or pond pine prior to harvest, and will not be converted to a non-forest land use. In accordance with Maryland Code, Natural Resources 5-505(a), a "reforestation plan shall be prepared by the landowner or his agent and shall be designed to assure the reproduction and maintenance of growth of young, vigorous pine trees."

The law specifies that these forests must be regenerated to pine through the use of seed trees or through the planting of pine seedlings, as delineated in a reforestation plan, subject to approval by MD DNR Forest Service. A harvest may not take place unless seed trees have been reserved or a reforestation plan has been approved by MD DNR Forest Service.

If seed trees are to be left, there must be at least eight cone-bearing loblolly pine, shortleaf pine, or pond pine trees per acre, each with a minimum of 14 inches dbh. If the specified number and diameter of pine trees are not left, operators or landowners must leave at least two cone-bearing pine trees of the next largest diameter class for every one tree required. The law also requires that trees left uncut are to be "healthy, windfirm, well-distributed throughout each acre, and with well-developed crowns possessing a sufficient number of cones to reforest the areas affected by the cutting operation." In the years following even aged harvests, pine regeneration is deemed successful if at least 400 loblolly, shortleaf or pond pine seedlings (less than 6 inches dbh) per acre are well distributed and are free to grow (Maryland Code, Natural Resources § 5-501 et seq.).

5.4.3 Erosion and Sediment Control Regulations

All 50 states have some derivation of a Best Management Practices (BMP) program to address the requirements of the federal Clean Water Act requirement to control nonpoint source pollutants like sediments that may result from logging operations and other forest management activities. States vary as to whether these BMPs are regulatory or voluntary, and by what issues are addressed in their list of BMPs. Some states go beyond water quality and also address forest regeneration, aesthetics, and wildlife habitat conservation practices.

Forestry BMPs typically follow the same formula (Neary *et al*., 2009):

(1) Minimize soil compaction and exposure of bare ground
(2) Separate exposed bare ground from surface waters
(3) Separate fertilizer and herbicide application from bare waters
(4) Inhibit hydraulic connections between bare ground and surface waters
(5) Avoid disturbance in steep areas
(6) Provide forest buffers around streams and wetlands
(7) Engineer stable road surfaces and stream crossings

The findings of field-based BMP research across the eastern U.S. found that BMP programs adequately protect water quality if they include (Aust and Blinn, 2004):

(1) Careful planning and construction of roads, skid trails, stream crossings, logging decks and exits onto paved roads
(2) Protection of bare soil
(3) Provisions for revegetating the site as quickly as possible
(4) Provisions for implementation of streamside management zones (SMZs)

Formally adopted in 1992, Maryland's forestry BMP program addresses each of these four areas in detail and has a strong performance record (approximately 81% compliance in 2004 – 2005)[90] (Koehn and Hairston-Strang, 2009; MDE, 2005).

State water quality regulations require that an erosion and sediment control plan be approved prior to any action that disturbs 5,000 square feet or more of the soil surface, 100 cubic yards of earth, or involves the crossing of a perennial or intermittent watercourse with a drainage area exceeding 400 acres (100 acres for trout waters) can be undertaken (MD DNR). This is

[90] Compliance rates for individual provisions varied with some implemented more frequently than others.

applicable to the construction of forest roads, skid trails, landings, and any other disturbance associated with forest harvest operations (Maryland Code, Environment § 4-101 et seq.).

The Maryland Department of the Environment (MDE) has jurisdiction over water pollution control in the state, and has worked collaboratively with the MD DNR to develop a system of forestry BMPs, reporting and compliance mechanisms, and spot inspections. While MDE maintains the ultimate authority over water quality regulations, Maryland's Soil and Water Conservation Districts provide technical guidance and oversee the forestry BMP compliance process. Some counties also implement more stringent rules than those existing within the state Standard Erosion and Sediment Control Plan for Forest Harvest Operations (Standard Plan).

The basic concept of the Standard Plan is to target BMPs to harvest site areas with the greatest potential for sedimentation. These areas and corresponding BMPs include: (1) the site access point (gravel, wood chips, corduroy logs, wooden mats, or other erosion protection materials to prevent soil and mud from being tracked onto paved surfaces, and using culverts or some other drainage technique to ensure that site drainage patterns are not altered); (2) the forest access system of roads, skid trails, and landings (planned in a way that avoids or minimizes stream crossings and follows the contours of the land); (3) the edge of streams and other water bodies (buffered by streamside management zones (SMZs), with width determined based on site slope) (MD DNR).[91]

The landowner, forester, or operator must determine if the parcel requires a custom plan based on the individual site characteristics (i.e., size/depth of road cuts, grade of forest roads, slope of landings, grade of skid trails, and the location of streams and SMZs). Custom plans are also required if harvesting is to be undertaken in a SMZ, or a non-tidal wetland. If harvests are to occur in a riparian buffer a special SMZ harvest plan that delineates additional BMPs to be implemented must be prepared by a Maryland-licensed forester.

The Standard Plan prohibits the operation of heavy equipment in buffer areas, and requires that a strip of uncut trees be left, with the width of the strip related to the slope of the land adjacent to the watercourse (i.e., lands with no slope require a 50 foot buffer, slopes of 1 – 10% demand a 75 foot buffer, and slopes of 41% or more must have a minimum buffer width of 250 feet). Limited harvest can occur within SMZs if a licensed forester prepares a Buffer Management Plan. This plan must include a sketch and identification of all trees to be removed within the buffer, leaving a minimum basal area of 60 ft^2/ac of evenly distributed trees, with a minimum of 6 inches dbh. All trees to be removed must be carefully marked, and any harvesting residue that inadvertently falls into the water body must be pulled back to prevent blockage. The Critical Areas Law outlines acceptable harvest type and residual stand requirements.

[91] See: MDE (2005) and www.dnr.state.md.us/forests/landplanning/bmp.html for detailed information about Maryland's BMP program.

Harvesting in a non-tidal wetland requires the implementation of additional wetland-specific BMPs; however, an additional permit is not required from MDE, provided that the wetland remains a forested wetland (MDE, 2005). Non-tidal wetland BMPs are designed to control soil loss, sediment deposition, minimize water quality degradation, minimize adverse impacts to water flow and circulation patterns, prevent land-type conversion, and minimize adverse impacts to chemical, physical, or biological characteristics of non-tidal wetlands.

In an effort to improve the efficiency of administering this program, MDE and MD DNR Forest Service developed a short Compliance Agreement for the Standard Erosion and Sediment Control Plan for Forest Harvest Operations. This agreement between the landowner, operator (anyone directly involved with the harvest), and the local Soil Conservation District makes clear that all parties agree to: (1) "adhere to the terms of the Standard Plan for Forest Harvest Operations," (2) acknowledge "the landowner's responsibility in preventing accelerated erosion and sedimentation during and subsequent to forest harvest operations," and (3) require all operators to conduct forest harvest operations in accordance with the Standard Plan. The Standard Plan is attached to the compliance agreement, signed by a Maryland licensed forester, and must be approved by the Soil and Water Conservation District. The agreement also stipulates that the forest harvest site may be inspected by state and/or local government officials.

If implemented correctly and in conjunction with biomass harvesting and retention guidelines, Maryland's forestry BMPs should be sufficient to address water quality concerns associated with biomass removal.

5.4.4 Chesapeake Bay Critical Areas Law

Sixteen counties and 44 municipalities contain lands within 1,000 feet of tidal waters of the Chesapeake Bay or its tributaries (critical areas). A Critical Areas Forest Buffer Management Plan, prepared by a Maryland licensed forester and approved by the local Forest Board, is required to harvest timber within 1,000 feet of the Chesapeake Bay or its tributaries. To harvest within the critical area the buffer management plan must: (1) identify measures to protect surface and groundwater quality, (2) determine whether harvest activities will disturb Habitat Protection Areas (HPAs) and incorporate protection measures for these areas,[92] (3) identify and conserve Forest Interior Dwelling Species (FIDS) habitat,[93] (4) include measures to mitigate potential impacts through forest management techniques, size, timing, and intensity of harvests.

Certain limitations applying to harvests within critical areas depend on the specific location, and local rules may dramatically limit harvests. The Critical Area Law generally prohibits harvesting

[92] All harvests within buffer areas for HPAs for rare, threatened, or endangered species are prohibited.
[93] The FIDS habitat identification methodology presented by Jones *et al*. (2000) is used to identify whether critical area forests are FIDS habitat.

within 100 feet of the waters edge or contains specific limitations for harvesting within the 100 foot buffer, where permitted. Commercial harvests by tree selection or clear-cutting of loblolly pine and tulip poplar are permitted in buffers up to 50 feet of the riparian area of perennial streams, tidal waters, and tidal wetlands, and to the edge of intermittent streams.

The Critical Area Law will limit what type of harvesting is permissible and the type of residual stand to be left behind. Since biomass is a low-value product, the removal of extra biomass from within the critical area will most likely not be economically justified, as the equipment needed to do this is prohibited from the area, and residual stand requirements will likely restrict removal.

5.4.5 Forest Conservation Act

The Maryland Forest Conservation Act (FCA) is triggered when an application is filed for a sediment and erosion control or grading permit for any action that will disturb an area of soil surface greater than 40,000 square feet (≈ 0.9 acre). FCA requires that a Forest Conservation and Management Plan be prepared by a licensed forester or qualified professional (i.e. licensed landscape architect or natural resource professional with approved credentials). These plans, subject to approval by the county soil conservation district, must include forest stand delineation and proposed actions to conserve forests at the site or offset the impact offsite. Specific compliance requirements for the Forest Conservation Act vary by county, but all require that Forest Conservation and Management Plans identify acceptable limits of site disturbance and individual tree removal, as well as afforestation, reforestation, and maintenance plans.

Long-term forest conservation agreements are one compliance option available in which private landowners agree to abstain from land development for an extended period of time, and manage under a formal plan. Timber harvests are permitted under these agreements, provided that operations maintain at least 100 trees per acre, half of which must have a minimum 2 inches dbh, within seven years (ELI, 2000).

5.4.6 Forester Licensing Law

The licensing of foresters in Maryland is in recognition of the unique professional education, skills, and experience needed to practice good forestry. Participation in a number of the programs discussed in this chapter requires the utilization of a Maryland-licensed forester. In order to receive a license, foresters must have at least two years of experience working in the field of forestry, often through an apprenticeship, and have completed a degree in forestry from a school approved by the Maryland State Board of Foresters or the Society of American Foresters. Biomass harvest undoubtedly requires a degree of care, knowledge and professionalism that calls for a licensed forester.

5.4.7 Forest Products Licensing Law

Maryland requires all forest product manufacturing plants to be licensed through MD DNR on an annual basis (Maryland Code Natural Resources § 5-608). Entities requiring licenses include forest products manufacturing plants, sawmills, loggers under contract with sawmills, loggers not under contract with any particular sawmill, and firewood operations. Forest products licenses are not required for land clearing operations.

5.7.8 Road Side Tree Care Law

Maryland has more than 30,000 miles of improved roads, which are commonly lined with trees that require routine trimming and other assorted tree care activities. A Roadside Tree Project Permit must be acquired from MD DNR Forest Service to trim or care for a specific roadside tree, or group of roadside trees. A roadside tree is any tree that grows within a public road right-of-way. A permit is also needed to plant a tree within the public road right-of-way.

Table 22. Summary of regulatory policies and programs directly affecting forest management in Maryland.

	Description and Relevance for Biomass Harvesting	Level of Governance	Target Audience	Timber Harvesting Practices /1	Reforestation/ Regeneration Practices /2	Silvicultural Practices /3	Administrative Practices /4	Water Quality BMPs	Deadwood Management	Protection of Forest Soils Beyond BMPs	Wildlife Habitat and Biological Diversity
Maryland Forest Conservancy District Boards	Requires that stands are left in a condition following harvests that will promote restocking by desirable species, of diverse size classes distributed throughout the residual stand. Forestry boards are responsible for approval of harvests in the Chesapeake Bay Critical Area and in stands covered by forest conservation agreements.	State and County level.	Landowners, foresters, and timber harvesters.	Harvests to leave forests favorable condition for regeneration, but does not offer specific metrics of this. Leaving much to the deference of foresters.	Requires the use of practices that favor regeneration. Requires that Forestry boards provide technical assistance on reforestation and regeneration techniques as requested by landowners.	Does not prescribe silvicultural practices, but does address selective harvests although much is left up to the deference of foresters, landowners, and loggers. Forestry boards can provides technical assistance on silviculture if this is requested by landowners.	Forestry boards approve timber cutting plans in Critical Area and areas covered by forest conservation agreements.	Forestry boards provide technical assistance on BMPs as requested and in harvest plans undergoing their approval.	NA	NA	NA
Sediment and Erosion Control Plan (the standard plan) and Standard Plan agreement.	Quasi-regulatory requirements call for landowners and timber harvesters to sign a written agreement that stipulates their responsibility for implementing BMPs listed in the states Erosion and Sediment Control Standard Plan. Conservation Districts and MDE have authority to inspect harvests to determine BMPs are implemented correctly.	MDE designates authority to the County level. Counties may provide additional requirements.	Landowners, foresters, and timber harvesters. Applies to harvests that will disturb an area ≥ 5,000 Square ft.	Limits harvests in SMZs and non-tidal wetlands. Certain techniques and equipment are required for sensitive areas (i.e., non-tidal wetland and riparian areas).	Maryland BMPs are mostly about water quality protection and not forest regeneration. Harvests in SMZs are regulated for residual basal area however.	Maryland BMPs are mostly about water quality protection and not silviculture. Certain residual stand conditions are required for SMZs.	The standard plan must be completed by a licensed forester and approved by the Conservation District. Inspection by the Conservation District and MDE is possible. Custom plans are required for SMZ and non-tidal wetlands.	The Standard Plan specifies how, when, and where BMPs are to be implemented.	Standard plan mentions forest residue, but does not provide specific guidance on residue (down woody material) retention.	NA	NA
Maryland Reforestation (Seed Tree) Law	Requires landowners with coniferous plantations (loblolly pine, shortleaf pine, or pond pine) to leave seed trees for restocking or to replant trees for restocking.	State level.	Landowners, foresters, timber harvesters. Applies to pine plantations ≥ 5 acres that are at least 25% pine and will not be converted to a non-forest land use.	NA	Specifies how many pine trees and of what size need to be left per acre. A reforestation plan is required and must be approved by MD DNR Forest Service.	Usually applies to even-aged management systems.	NA	NA	NA	NA	NA

	Description and Relevance for Biomass Harvesting	Level of Governance	Target Audience	Timber Harvesting Practices /1	Reforestation/ Regeneration Practices /2	Silvicultural Practices /3	Administrative Practices /4	Water Quality BMPs	Deadwood Management	Protection of Forest Soils Beyond BMPs	Wildlife Habitat and Biological Diversity
Maryland Critical Area law	To harvest within the critical area a buffer management plan must identify measures to protect surface and groundwater quality, mitigate disturbance to HPAs, mitigate disturbance to FIDS habitat by scheduling the size, timing, and intensity of harvests.	State and County level.	Landowners, foresters, and timber harvesters.	A Critical Area buffer management plan must identify trees to be retained. Trees must be marked at base of stem and breast height.	Guidance on non-directional felling and residual basal area.	Requires a certain amount of trees to be left behind and a residual basal area to maintain water quality and wildlife habitat.	A Critical Area buffer management plan must be prepared to identify trees to be cut and retained. Plan must be approved by Forestry boards.	Prohibits heavy equipment within a certain distance of the tidal waters of the Chesapeake Bay. Provides prescriptive requirements for BMPs.	NA	Use of heavy equipment is excluded from SMZs.	Calls for protection of FIDS and HPAs, but does not offer prescriptive requirements for snags and down woody material.
Maryland Forest Conservation Act	Requires harvests conducted within areas covered by a long-term forest conservation agreement to have a written plan that identifies an amount of trees to present within the forest of a certain DBH in seven years following the harvest.	State and County level.	Landowners, foresters, and timber harvesters.	Plan must specify the size and distribution of trees to be retained following harvests in areas covered by long-term forest conservation agreements.	Plan must specify the size and distribution of trees to be retained following harvests in areas covered by long-term forest conservation agreements.	Specifies the size and distribution of trees to be retained following harvests in areas covered by a long-term forest conservation agreement.	Forest Conservation Act timber or forest conservation plan must be approved by Forestry boards.	NA	NA	NA	NA
Forester Licensing	Requires that foresters meet certain specifications approved by the Maryland State Board of Foresters in order to practice forestry in Maryland. This policy helps ensure that forestry activities are undertaken by professionally trained and educated individuals.	State level.	Foresters	Helps ensure that all FMPs are developed by licensed professionals.	NA	NA	Regulates who can provide forestry services in Maryland.	NA	NA	NA	NA
Forest Products Licensing	Requires that facilities and individuals using wood to produce forest products for sale be licensed within the state and that the location of their facility be approved by MD DNR.	State level.	Forest products companies and timber harvesters.	The location of planned facilities must be approved by MD DNR.	NA	NA	Regulates who can sell forest products.	NA	NA	NA	NA
Road Side Tree Care Law	A permit process for gaining approval to remove trees and brush from the roadside and/or trim roadside trees.	State level.	Foresters and other qualified natural resource professionals.	Limits harvest of roadside trees to permit holders.	Provides a permit process for the removal of individual trees and the permitting of tree care companies disposing or roadside trees.	NA	Regulates who can harvest roadside trees.	NA	NA	NA	NA

/1 Timber harvesting practices include construction of landings, site layout, slash management/disposal, addressing residual stand damage, felling, and bucking.
/2 Reforestation, regeneration, and replanting practices include selection of appropriate species to leave/maintain in the stand, seed tree selection, supplemental planting, site preparation, and regeneration practices.
/3 Silvicultural practices include mid-rotation thinning and other timber stand improvement activities.
/4 Administrative practices include planning, notifying, reporting, monitoring, and evaluating harvests.
NA Indicates instances where a policy or program does not specifically address certain practices or key issue areas with relevance for biomass harvesting

5.5 Relevant Federal Policies

While the bulk of policies governing management of private forest lands have historically occurred at the state and local level, federal policy can also impact biomass harvest. A few of these policies are discussed in this section that are directly relevant to sustainability safeguards for harvests, while other seemingly disconnected federal policies (e.g., estate tax policy) may indirectly impact the type of harvests undertaken.

At the federal level, a number of policies define "renewable biomass" to determine whether energy produced by certain types of biomass will qualify for federal incentives (e.g., the federal renewable electricity production tax credit), and may consequently impact landowner management decisions and behavior. In fact there exists as many as 16 definitions of biomass in federal policy that all have an impact on markets for biomass (Mintz, Levin, Cohn, Ferris, Glovsky and Poper, P.C., 2009).

As previously discussed, recent debates about biomass have centered on BCAP. In terms of sustainability, BCAP had previously required that forest lands producing biomass have a forest management plan, with the determination of what constitutes an "acceptable plan" made by State Foresters. New rules for BCAP are now in development and will seek to create a "wall" between markets for energy wood and traditional wood product markets (Sedjo, 2010).

The Environmental Quality Incentives Program (EQIP), administered by the USDA Natural Resources Conservation Service (NRCS), includes a Forest Stand Improvement practice code eligible for cost-share funding. This practice code provides funding for removal of "slash, debris and other vegetation (biomass) re-moved during stand improvement [and] may be used to produce energy. Management alternatives should consider the amount of energy required to produce and convert the biomass into energy with the amount produced by the biomass."

5.6 Conclusions and Recommendations on Natural Resource Policy

This chapter reviewed Maryland's forest management programs in an effort to identify gaps in existing regulatory and non-regulatory programs where concerns related to biomass harvests may not be adequately addressed. Several recommendations are provided below to ensure that sustainability has a central role in future forest management activities related to biomass harvests.

Promote the use of biomass harvest and retention guidelines

With increased interest in woody biomass harvests in the forestry sector, several states have either developed, or are in the process of developing, forest biomass harvest and retention guidelines. Biomass harvest and retention guidelines have largely been constructed to be voluntary extensions of existing state forest management guidelines; state forest practices acts, and state BMP programs.

Biomass harvests will likely be similar to existing timber harvests, and are thus addressed, at least in part, by Maryland's existing forest management programs. However, additional guidance is needed in areas pertaining to the retention of downed woody material and standing dead trees, the protection of soil fertility, and the management of wildlife habitat and biodiversity. The guidelines developed in parallel to this report were crafted to build off of Maryland's existing programs, which for the most part, appear to be working well, suggesting no need for regulatory augmentation.

Because of the complexity and dynamic nature of forest ecosystems, forest management policies often maintain some flexibility to allow managers to adapt to site-specific conditions. Yet, natural resource management programs also require measurable standards and guidelines to be effective. Measurable standards are also needed for monitoring when practices are new and/or untested in the field, especially when their effectiveness is uncertain.

There are several questions surrounding biomass harvesting that have yet to be resolved, particularly concerning the ability of forests to effectively cycle nutrients and sequester carbon following harvest. State and/or region specific scientific analysis is needed to address these areas of scientific uncertainty. Such analysis should be a central component of any adaptive management program established to assess the effectiveness of guidelines.

Monitoring of guideline implementation and effectiveness

Given that forest biomass harvesting is a relatively new concept in most of the U.S., and certainly for Maryland, impact monitoring will be essential in directing future management decisions and in revising harvest and retention guidelines and forest management policies/programs. Implementation monitoring (how well and how frequent are the guidelines implemented) and effectiveness monitoring (how well are the practices in the guidelines working) are equally necessary.

Ideally, test harvests should be conducted in representative forest stands to determine the implementation feasibility and the effectiveness of harvest and retention guidelines. Such test harvests should be undertaken in locations with a significant amount of historical site characteristic data (i.e., soil data, tree species composition, diameter classes, age classes, etc.). Since biomass markets are nascent, monitoring could also be done on a selection of early harvests to determine if the biomass guidelines are being followed and how they may be adapted given feedback from the field. An early cohort of harvest sites will also provide a valuable data source on which adjustments to the guidelines may be based in the future.

Increase the knowledge about biomass harvest and retention

Knowledge gaps related to biomass exist among key constituencies (i.e., foresters, loggers, and natural resource professionals) that provide crucial services to landowners. Since Maryland's network of technical assistance providers (e.g., Forestry Boards, extension agents, Forestry for the Bay, and public and private foresters) will likely serve landowners as the primary conduits of information regarding biomass markets, steps should be taken to ensure that technical assistance providers are versed in biomass harvesting and retention.

Considering the general lack of knowledge about proper biomass harvesting techniques and the lack of a significant market for forest-derived biomass, it is not surprising that Maryland's technical assistance outlets do not effectively address biomass harvests. The biomass harvesting and retention guidelines developed in conjunction with this report will help fill knowledge gaps, but more active forms of education are likely necessary to engrain the guidelines. For instance, Maryland extension, which runs Maryland's Master Loggers program, may consider developing a continuing education module around the biomass harvesting guidelines.

Ensure that biomass harvests are carefully planned

In general, forest stewardship plans do not currently include recommendations for where and when biomass harvesting is desirable or acceptable, as present market conditions do not justify investing the time and effort to explore this. If markets for forest biomass materialize in Maryland, care should be given to modify forest stewardship plans to account for additional biomass removal. Forest stewardship plans should be a pre-requisite of any harvest, but have extra importance for areas where the removal of forest biomass is a consideration.

In the absence of formal plans, biomass harvests may occur in an unplanned and careless nature, which may prove detrimental to future forest health and productivity. Several programs (i.e., the Maryland Woodland Stewards Program and Forestry for the Bay), designed to encourage landowners to develop forest stewardship plans, do not currently address forest biomass harvesting and retention. Managers of these programs should in the least become familiar with Maryland's biomass harvesting and retention guidelines and be prepared to discuss them with program participants.

The role of the Sustainable Forestry Council

The Sustainable Forestry Act of 2009 promotes wood-based bioenergy and forest management planning, albeit not necessarily in unison. The Sustainable Forestry Council should identify knowledge gaps within the state regarding forest biomass harvests, and promote the adoption of the Maryland's biomass harvesting and retention guidelines to help fill these knowledge gaps.

The Sustainable Forestry Act also specifically promotes the use of woody biomass to produce electricity to help meet the state's RPS. Given the supply constraints discussed in the first chapter of this report, the Sustainable Forestry Council should explore additional options (e.g., CHP, thermal systems, and densification) for utilizing woody biomass feedstocks; as these may prove more economically, socially, and environmentally sustainable, given Maryland's circumstances.

In an effort to promote linkages between the agricultural sector and the forestry sector, the Sustainable Forestry Council should seek to work with other agencies to explore opportunities for SRWCs within the matrix of agricultural and forest lands that exist across Maryland. One potential area of analysis is the determination of the eligibility of short rotation energy crops (e.g., SRWCs and switchgrass) for Maryland's current forestry and agricultural cost-share programs and income tax modification programs. If it is deemed that these programs are not well suited to promote short rotation energy crops, the Sustainable Forestry Council may help envision programs that may be appropriate.

The Sustainable Forestry Council and the Maryland Department of Agriculture (MDA) could also collaborate to develop guidelines for the establishment and management of SRWCs and switchgrass. As the Sustainable Forestry Act charges the Sustainable Forestry Council to address pertinent forest sustainability issues in Maryland, it is a likely candidate to spearhead dialogue between relevant entities (i.e., MDA, MD DNR, and Conservation Districts) to outline establishment and harvest standards for SRWC coppice plantations in Maryland. Researchers at the Harry R. Hughes Agro-Ecology Center, Inc. have field-tested switchgrass management techniques in Maryland, and would likely be an ideal organization to partner with in this process.

A number of key issues to be explored regarding SRWCs include:

- The need to define SRWC-tailored management plans to ensure due-diligence and long-term sustainability.
- The need for SRWC plantations to comply with rules and regulations related to nutrient management (i.e., biomass harvests from SRWC plantations should

occur after leaf fall to minimize nutrient loss and maximize stump-sprout health, should avoid harvest when the ground is saturated, and stream crossings be designed for long-term use).

- The need to determine how to address soil erosion potential at stand establishment (e.g., Should cover crops be used during crop tree establishment? What type of set preparation is acceptable? Are SRWCs acceptable to grow as a riparian buffer? Will CRP or CREP lands be eligible?).

Markets for biomass may alter the applicability of financial incentives

The Woodland Incentives Fund is set up to cover up to 65% of the cost of silvicultural investments (i.e., pre-commercial thinning, pruning, prescribed burning, crop tree release, site preparation for reforestation, herbicide treatment, and forest establishment) to encourage the production of traditional forest products. Theoretically, if markets for forest biomass develop in Maryland, pre-commercial thinning costs may decrease, and may shift the distribution of financial incentives towards reforestation practices. Similarly, financial incentives like the Timber Stand Improvement and Reforestation Income Tax Modification Program may become less relevant if markets for biomass develop.

Applicability of forest certification and procurement standards

As of May 2010, most of the major certification programs have begun to consider how forest biomass harvesting will affect the relevance of their standards. Since most certification programs are outcome based, it is anticipated that state and/or eco-regional biomass harvesting guidelines will help managers determine whether forest biomass harvesting is consistent with the principles and objectives of the certification program.

Program costs and limited returns can make certification cost-prohibitive for some landowners. While FSC often proves to be cost-prohibitive for small forest landowners, the program does allow for groups of several small parcels to receive certification under the management of a single FSC-certified forester or organization. The ATFS also offers a group certification program, and the Sustainable Forestry Initiative offers an umbrella certification option. Considering the disconnect between the small average parcel size in Maryland and the wishes of biomass facilities that seek long-term fuel supply agreements, the certification of small woodlots could be linked with ensuring a predicable supply of biomass.

Another approach to ensuring the sustainability of biomass supply chains that Maryland may consider is to encourage individual bioenergy facilities to develop procurement standards that only source biomass from lands harvested under a certain management framework. One example of such an arrangement is Burlington, Vermont’s 50 MW McNeil generating station, which has been in operation more than 25 years. This plant has developed a multi-tiered wood procurement standard to ensure that biomass is supplied in a sustainable manner. The facility employs a professional forester to monitor each harvest, ensuring that procurement standards are adhered to. Each of these planned harvests must also be approved by the Vermont Department of Fish and Wildlife.

New York State has indicated that it does not have intentions to develop independent state biomass harvesting guidelines. Rather, the state will require that any new bioenergy facility source biomass in a manner similar to the McNeil Generating Station, with exceptions for lands certified by FSC, SFI, or ATFS. New York State also has the only FSC chain-of-custody certified bioenergy facility in the country.

In Maryland, the Forest Product Licensing Law provides a mechanism by which the MD DNR Forest Service can evaluate each new proposed wood utilization facility in the state. Any proposed biomass facilities will likely fall under this law as well, providing an invaluable opportunity for MD DNR to scrutinize a facility's due-diligence regarding biomass feedstock availability and sustainability.

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Appendix

Glossary of Terms

Acid deposition - Acid deposition is any combination of airborne dry acidic particles and precipitation that falls to the earth. The impact of acid deposition to forests includes damage to foliage and soils. At first, acid deposition may actually supply essential elements for soil nutrition. Over time soil pH is altered causing nutrients, especially base cations like calcium and magnesium, to leach from soils. The loss of these buffering agents, may negatively impact forest productivity.

Adaptive management - Adaptive management is a way to use management intervention as a tool to strategically assess the functioning of an ecosystem. Adaptive management identifies uncertainties, and then establishes methodologies to test hypotheses concerning those uncertainties. It uses management as a tool not only to change the system, but as a tool to learn about the system. It is concerned with the need to learn and the cost of ignorance, while traditional management is focused on the need to preserve and the cost of knowledge.

Ash content - Amount of ash produced, relative to the amount of fuel combusted. An ash content of 1% would yield 20 lbs of ash for every ton of pellets burned.

Available Water Capacity (AWC) - Available water capacity (AWC) refers to the quantity of water that the soil is capable of storing for use by plants, but it is not an estimate of the quantity of water actually available to plants at any given time. The capacity for water storage is given in centimeters of water per centimeter of soil for each soil layer. This capacity varies, depending on soil properties that affect retention of water, with the most important of these properties being the content of organic matter, soil texture, bulk density, and soil structure.

Best Management Practices (BMPs) - **S**tructural and/or nonstructural techniques to prevent or reduce the movement of sediment, nutrients, pesticides and other pollutants from the land to surface or ground water.

Biomass aggregators - Firms that specialize in consolidation of disparate sources of biomass for sale to biomass utilization facilities.

Biomass harvesting - The removal of forest-derived biomass with mechanized equipment for commercial use; sometimes used interchangeably with biomass removal. The process by which logging slash, small-diameter trees, tops, limbs, or trees that cannot be sold as higher-value products, such as sawtimber, is removed from forests.

Biomass-sheds - An area or landscape from which biomass may be effectively procured.

Black Liquor - The liquid material remaining from pulpwood cooking in the soda or sulfate papermaking process.

Bolewood - Wood from the stem of a tree.

Briquettes - Biomass that is densified into dense fiber bricks.

Buffering Capacity - The physical and chemical characteristics of soils that make them more or less susceptible to changes in pH and nutrient loss. Soils with high buffering capacity tend to be rich in calcium and other base cations, and are able to neutralize acid inputs.

Canopy closure - A measure of the amount of canopy overlying the forest. Closure is the point in time during ecological succession when the tree canopy reaches a closed state.

Cap and Trade System – A pollution control and prevention policy mechanism that involves setting the annual level of emissions across an economic sector(s) (or entire economy) and allocating pollution reduction targets for each firm in that sector, followed by issuing emission permits that allow a certain amount of pollution. If individual emitters produce more emissions than they have permits, they can purchase additional permits from other polluters that have excess permits to sell. As an economic approach to emissions reduction, cap and trade systems allow governments to set the level of emissions (providing quantity certainty) by choosing the number of permits to issue, but the price of permits is set by the market, and is thus uncertain.

Cation Exchange Capacity (CEC) - The capacity of a soil for ion exchange of cations between the soil and the soil water solution, which is used as a measure of soil fertility, nutrient retention capacity, and the capacity to protect soils from acidification.

Cellulosic Ethanol - Cellulosic ethanol is a biofuel produced from wood, grasses, or the non-edible parts of plants, as opposed to starch-based ethanol that is most often produced from corn.

Closed-loop Biomass - Any organic material from a plant which is planted exclusively for purposes of being used at a qualified electricity facility.

Coarse Woody Debris (CWD) – Stumps and fallen trunks or limbs of more than 3 inches in diameter at the large end and more than 3 feet in length.

Co-firing - Cofiring is the combustion of a mixture of feedstocks. For the sake of this discussion, this mixture will almost exclusively be some combination of biomass and coal.

Conservation Lands - Lands enrolled in USDA Farm Bill programs such as, the Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), Farmable Wetlands, or lands enrolled in the Wetlands Reserve Program.

Cooling Degree Day (CDD) - Simplified unit of measure, depicting the number of degrees a building must be cooled to reach a baseline temperature (65°F) over a number of days.

Coppice - Coppice species are defined as density-tolerant species that have a high degree of regeneration capability following harvest (stump-sprouting propensity). The form of coppice SRWC species is shrub-like, rather than a traditional stem-canopy form.

Cordwood - Firewood piled and/or sold in cords.

Corduroy logs - Corduroy logs are an erosion control product that are used to create roads and skid trails to minimize soil compaction and rutting.

Critical Areas - A regulated are of land located within 1,000 feet of the Chesapeake Bay.

Cull - Woody material that does not meet regional merchantability standards, usually due to small diameter or defect.

Densified Biomass - Biomass that is compressed to increase energy content and bulk density.

Down Woody Material (DWM) - Woody material on the forest floor. This debris can range in composition, but usually consists of primary branches, trunks, tree tops, and intact dead trees with upturned root wads.

Dry Tons / Oven Dry Tons (ODT) - A measure of woody biomass weight that assumes 0% moisture content.

Ectomychorryzal fungi - Fungi that form associations with tree roots and are important for nitrogen fixation and tree growth.

Ecosystem Services - Ecosystem services are defined here as the collection of goods and services provided by forest that include both presently monetized benefits such as timber and biomass and largely non-monetized benefits such as clean water, clean air, wildlife habitat, aesthetic values, and climate regulation.

Edges - The inner portion of the residual portion of the residual material left when lumber is cut to standard widths.

Early-successional forests - A forest in an early state of ecological succession in which old fields are comprised of brushy shrubby type plants, with species that are shade intolerant.

Efficiency - The ratio of the wood's *potential* energy to *harnessed* energy (includes electricity, thermal, force [through liquid, gaseous or powdered wood], or any combination of these) Efficiency losses include the physical and environmental losses attributed to operations within the plant, but do not include transmission losses beyond the plant's doors.

Energy Wood – Wood (solid wood, tree trimmings, wood chips, sawdust, bark, and shavings) harvested in a sustainable manner that is used to produce heating, electricity, or other forms of energy.

Fine Woody Debris (FWD) – Tops, limbs, other woody debris, and foliar biomass of less than 3 inches in diameter at the large end.

Forest Fragmentation - Islands of forest habitat that persist on the land when the intervening forest has been removed.

Forest Management Plan - A written document prepared by a landowner and a licensed professional forester that includes: (1) An articulation of the objectives of the woodland owner, (2) forest inventory data, (3) maps denoting relevant property specific information (e.g., location, boundaries, individual stands, soil types, tree retention areas, key conservation features, and future harvest areas) and (4) detailed descriptions and chronology of silvicultural treatments for each forest stand. In Maryland, forest management plans include: forest stewardship plans, Tree Farm Management plans, and USDA NRCS Practice Code 106 plans.

Forest Sustainability - "Sustainable forest management involves practicing a land stewardship ethic that integrates the reforestation, managing, growing, nurturing, and harvesting of trees for useful products, with the conservation of soil, air and water quality, wildlife and fish habitat, and aesthetics" from UN Conference on Environment and Development, Rio De Janeiro, 1992 (Helms, 1998).

Forest-derived biomass – Logging slash, small-diameter trees, tops, limbs or trees that cannot be sold as higher-value products, such as sawtimber. Understory vegetation (e.g., brush) is also considered forest biomass.

Fuel Gas - Any of several gases burned to produce thermal energy.

Fuels for Schools and Beyond - The Fuels for Schools and Beyond program is a partnership between the USDA Forest Service's State & Private Forestry Division, the State Foresters of Montana, North Dakota, Idaho, Nevada, Utah and Wyoming, and the Bitter Root Resource Conservation and Development (RC&D) Area, Inc., to promote and facilitate the use of forest biomass waste for heating, cooling and power in public and private buildings. The Fuels for Schools Initiative came out of directives from the National Fire Plan of 2001 which included specific grant dollars under Economic Action Programs (under USDA Forest Service State and Private Forestry) for pilot projects to demonstrate new uses of small diameter and underutilized woody material, as well as projects using proven technologies to use such material. The intent of this focused funding was to develop new markets for woody material that has historically been considered waste, so that the substantial cost of thinning hazardous fuels, which generates little in the way of what is traditionally considered "commercial" timber, could be partially offset by the economic value of "non-commercial" biomass.

Fuelwood - Refers to timber sold for firewood. It may also refer to wood used for the production of energy in the forest products sector. Fuelwood used for firewood includes poorer quality trees, dead trees, and tree tops.

Gasification - Gasification is a process that converts biomass into carbon monoxide and hydrogen by reacting the raw material a controlled amount of oxygen and/or steam.

Gatewood - Wood delivered to a processing facility by individual contractors. The processing facility does not directly control the amount of wood harvest from a site.

Green Tons - A measure of woody biomass weight that assumes a 40 – 50% moisture content.

Growing stock - Classification of timber inventory that includes live trees of commercial species meeting specified standards of quality or vigor; cull trees are excluded.

Heat Value (HV) - The amount of heat produced by combustion of a unit quantity of a fuel.

Heating Degree Day (HDD) - Simplified units of measure, depicting the number of degrees a building must be heated to reach a baseline temperature (65°F) over a number of days.

High Conservation Value Forests (HCVF) - Rare forest types of particular ecological and social importance.

High Heating Value (HHV) - High heating value is the amount of heat produced by the complete combustion of a unit quantity of fuel.

High-grading – Selective harvest of only the highest-value, most-desirable trees. This practice frequently removes all of the genetically-superior trees and highest-valued species from a stand, leaving only genetically-inferior and undesirable trees to establish the next forest succession.

Hog fuel – Biomass fuel that is made from grinding up different types of wood. It could include mill scrap, bark, slash and sawdust. Generally hog fuel refers low-quality fuel with variable content that usually does not find itself into higher value markets.

Idle Cropland - Land that is idle or used for cover crops, soil improvement, but not harvested and not pastured or grazed. Cropland idle included any other acreage which could have been used for crops without any additional improvements and which was not reported as cropland harvested, cropland on which all crops failed, cropland in summer fallow, or cropland used for pasture or grazing. This category includes: (1) Land used for cover crops or soil improvement but not harvested or grazed, (2) Land in Federal or State conservation programs that were planted to trees for future harvest timber, pulp, or Christmas trees, (3) Land in skipped rows between crops, and (4) Land enrolled in the Conservation Reserve Program (CRP), Wetlands Reserve program (WRP), Farmable Wetlands Program (FWP), or Conservation Reserve Enhancement Program (CREP).

Integrated Harvest Operations - Harvests that remove multiple timber product classes (sawtimber, pulpwood, poletimber) including biomass.

Interception - Interception is the process by which precipitation lands on vegetation and reduces the velocity with which precipitation hits the ground, which in turn reduces overland flow and potential detachment of sediments from the soil surface.

Interconnection - The ability of distributed electricity generation systems to connect to the electrical utility grid and supply and receive electricity.

K Factor - K factor indicates the susceptibility of a soil to sheet and rill erosion by water and is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity (Ksat). Values of K range from 0.02 to 0.69. Other factors being held equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

Lignocellulosic Feedstocks - Biomass feedstocks that are composed of cellulose, hemicellulose, and lignin.

Low Heat Value (LHV) - The energy released during complete combustion of a quantity of fuel assuming the energy released during complete combustion of a fuel assuming latent heat of vaporization is lost.

Logging Slash - Low-value non-commercial residue left on site following harvest that is largely composed of tree limbs and tops and foliage.

Mast Trees - Seed and fruit bearing trees of important to wildlife and regeneration.

Microturbine - A small-scale gas turbine generation system to combust gas and generate electricity.

Natural disturbance regimes - The primary processes through which stand structure is modified, and age class diversified in unmanaged forests (e.g. windthrow, insect infestations, pathogens, fire, etc.).

Natural Wood Waste (NWW) - Tree stumps and limbs, brush, root mats, logs, leaves, grass clippings, unadulterated wood wastes, and other natural vegetative materials that are generated when land is cleared for construction purposes.

Net Metering - An arrangement by which electricity produced by a customer's distributed electricity generating technology is supplied to the electrical utility grid, causing the customer's electric meter to spin backwards and generate credit to the customer's electric utility account.

New Source Performance Standards (NSPS) - Air emission standards applied to new industrial or commercial installations that are generally more stringent than those of existing plants.

Open-loop Biomass - Any agricultural livestock waste nutrients, or any solid, nonhazardous, cellulosic waste material which is segregated from other waste materials and which is derived from - any of the following forest-related resources: mill and harvesting residues, pre-commercial thinnings, slash, and brush, solid wood waste materials, including waste pallets, crates, dunnage, manufacturing and construction wood wastes (other than pressure-treated, chemically-treated, or painted wood wastes), and landscape or right-of-way tree trimmings, but not including municipal solid waste, gas derived from the bio-degradation of solid waste, or paper which is commonly recycled, or agriculture sources, including orchard tree crops, vineyard, grain, legumes, sugar, and other crop by-products or residues.

Outdoor Wood Boiler (OWB) - The outdoor wood boiler is a variant of the classic wood stove adapted for set-up outdoors while still transferring the heat to interior buildings.

Parcelization - The result when wooded areas are cleared for residential, industrial, or commercial development, leaving the remaining fragments disconnected and smaller.

Pellets - A type of wood fuel, generally made from compacted sawdust. They are usually produced as a byproduct of sawmilling and other wood transformation activities.

Plantations - Tree crops planted on lands that have been converted from an alternate land use. Plantation lands are usually former agricultural lands (degraded and productive), abandoned mining sites or naturally vegetated areas that have been cleared specifically for establishment. Planted species may be of one or many, native or exotic, natural, selectively enhanced or genetically modified.

Poletimber - Trees that are sized between a sapling and a sawtimber tree. Hardwood trees ranging in size from 5 to 11 inches dbh, and conifers ranging in size from 5 to 9 inches dbh.

Pre-commercial Thinning - Thinning of low-value trees from a forest stand to allow for the increased growth of more desirable trees.

Procurement Radii - Area from which wood is procured around a wood utilization facility.

Pulpwood - Harvested wood that is used to produce paper products also denotes a timber diameter classification that is usually a minimum of four inches in diameter.

Pyrolysis - The process of heating wood to temperatures around 500° C, while maintaining the low-oxygen environment, resulting in a mixture of usable liquids, gases, and solids.

Pyrolysis oils (bio-oils) – Oils that are a product of pyrolysis.

Qualifying forest biomass – Forest-derived biomass that qualifies for Maryland's Renewable Portfolio Standard. This includes pre-commercial softwood thinning, logging slash, and brush. This does not include old growth timber (i.e., timber from a forest that is at least 5 acres in size with a preponderance of old trees, of which the oldest exceed at least half the projected maximum attainable age for the species, has shade-tolerant species present in all age and size classes, includes randomly distributed canopy gaps, a high degree of structural diversity characterized by multiple growth layers reflecting a broad degree of structural diversity characterized by multiple growth layers reflecting a broad spectrum of ages, an accumulation of dead wood of varying sizes and stages of decomposition accompanies by decadence in live dominant trees, and pit and mound topography. Also excluded are sawdust and wood shavings from primary and secondary wood processing facilities.

Qualifying woody biomass - Woody biomass that qualifies for Maryland's Renewable Portfolio Standard. This includes qualifying forest biomass, mill residue (except sawdust and wood shavings) yard waste, pallets, crates, dunnage, tree crops, vineyard materials or a plant that is cultivated exclusively for the purpose of being used at an electricity production facility. Woody biomass from exotic plant species is excluded.

Recruitment Trees - Large live tree that will be permanently retained (i.e., will never be harvested) and will eventually contribute to the snag, cavity tree, and downed woody material for wildlife and other biodiversity benefits. Typically, these are large trees with significant decay or other cull defect, or beech with evidence of bear use.

Regeneration harvests - Harvests that are undertaken in forest stands with stagnated growth potential, stands that have been high-graded, and stands that are overwhelmed with invasive species. Such harvests allow for the regeneration of a new forest stand of higher quality trees that may be desirable for timber and wildlife habitat.

Roundwood - Roundwood harvest refers to a timber harvest where only the main stems of trees are removed from the site. For purposes of this definition, main stem refers to those parts of the tree that meet the utilization standards for pulpwood, posts, bolts or sawtimber.

Rill erosion - Erosion from concentrating water into innumerable, closely-spaced small channels.
Salvage Harvest - Salvage harvests entail the removal of dead or dying trees that is associated with a particular disturbance event.

Sanitation Harvest - Sanitation harvests are harvests entail the removal of trees in an effort to control the spread of pathogens and insects.

Saturated Hydraulic Conductivity (K_{SAT}) - The ability of water to move through soil when the soil is saturated.

Sawtimber - Typically trees above 12 inches in diameter at breast height and have at least one 8-foot log that can be harvested. Sawtimber trees are used for boards, railroad ties, and other products.

Shadow Conversion – Loss of forest acres eligible for timber management due to local factors such as development and population density.

Sheet flow/Erosion - An overland flow or downslope movement of water taking the form of a thin, continuous film.

Shelterwood harvest - The method of regenerating trees underneath the canopy of older trees, which creates a two-aged stand. The environment for which the new stand starts to grow is partially shaded by the older stand, which allows certain species that thrive in a moderate amount of sunlight to flourish.

Short Rotation Woody Crops (SRWC) - Woody crops such as willows and hybrid poplar with coppicing abilities that are grown on short rotations. Rotation length varies, but is less than pine grown in plantations and longer than cropping cycles for annual row crops.

Site Index - A statistical value based on tree height, age, and diameter at breast height (dbh), used to estimate overall site productivity.

Slabs - The outer, rounded pieces of sawtimber when milled.

Slagging - The formation of molten or partially fused deposits on boiler walls or convection surfaces exposed to radiant heat.

Small-Diameter Trees - Small trees of little to no commercial value, which are not classified as sawtimber, pole timber, or pulpwood.

Snags - Dead, standing trees.

Soil Organic Matter (SOM) - Soil organic matter is plant and animal residue in soils at various stages of decomposition. The estimated content of organic matter is expressed as a percentage, by weight, of the soil material that is less than two millimeters in diameter. Soil organic matter in forest soils largely comes from decomposed vegetation, particularly, with FWD and CWD comprising the bulk of this material. Organic matter has a positive effect on available water capacity, water infiltration, soil organism activity, and buffering capacity. Soil organic matter is also an important source of nitrogen, base cations, other nutrients, and soil carbon.

Soil structure - The arrangement of soil particles into larger particles or aggregates.

Standby Requirements – Requirements levied on CHP facilities by electric utilities, often being comprised of standby charges to cover the additional costs of the generating, transmission, or distribution capacity required to supply intermittent electricity to the a CHP facility when the CHP unit is down for service.

Streamside Management Zone (SMZ) - A forested area immediately adjacent to stream channels. Managed for forest resources with specific attention given to measures that can be taken to protect both in-stream and downstream water quality as well as other beneficial uses.

Stumpage - A volume of wood as it stands uncut in a forest. Under stumpage contracts, the processing facility directly controls the amount of wood harvested and delivered.

Sustainable forestry - In Maryland this means: internationally accepted and applied stewardship concept for the use of forest and forest lands in a manner and at a rate that maintains a forest's: biodiversity, productivity, regeneration capacity, nutrient reduction benefits, vitality, and ecological, economic, and social purposes at local and national levels that do not cause damage to other ecosystems.

Terminal harvest - A final harvest in a forest stand that removes all trees from a site that is not allowed to regenerate naturally or artificially following harvest.

Thinning - The practice of reducing the density of trees in a forest stand, usually involves the removal of small diameter and low quality trees.

Timber stand improvement (TSI) - Performing forestry practices such as pruning, thinning, and controlling invasive vegetation to improve the quality of a forest stand over time.

Timberland - Land producing at least 20 cubic feet of commercially salable wood per year.

Torrefaction - Torrefaction is a treatment process by which biomass is heated in an oven, partly decomposing the material and releasing various volatile compounds. The remaining solid fuel material has nearly one-third more energy content per unit of mass. Torrefied wood can also be more easily pulverized along with coal.

Transpiration - Transpiration is an important factor in plant growth and is the process by which plants draw up nutrients and water from soils, eventually passing water vapor through stomatal pores in foliage.

Transpiration drying – The process of allowing biomass to remain on site following harvest until leaves and needles have fallen off of limbs and tops. This may be done to lower moisture content prior to transport to an energy facility and/or to help ensure that the nutrients in needles and leaves are left on site.

Tree-length harvesting system - A mechanized harvesting system that includes felling a tree, followed by cutting the top off and delimbing it before transport to a mill.

Trim ends - Material removed when lumber is cut to standard lengths.

Urban wood waste - Wood material originating from urban areas. The primary components are used lumber, shipping pallets, trees, branches, and other wood debris from construction and demolition clearing.

Veneer quality timber - Typically timber that is of larger diameter, coming from the bottom log of the tree, without branches or imperfections. This is the highest value timber that is used in the production of wood veneer.

Volunteer trees - Volunteers are non-planted trees in plantations. They may be hardwood or softwood species that sprout from stump sprouting, existing seeds in the soil or seed from inside or outside of the stand. Volunteers compete with planted trees, and are frequently regulated in intensive management scenarios by herbicide utilization and/or thinning operations.

Water infiltration - The processes through which water enters soil.

Whole-tree harvesting - Complete removal of trees (stems, limbs, and tops) from a harvest site using mechanized equipment.

Wildlife Trees - Trees of particular importance for wildlife and biodiversity. Includes decaying live trees (provide habitat for insects and fungi and serve as future supply of deadwood for the ecosystem), cavity trees (provide habitat for birds and mammals), snags (dead, standing trees that provide habitat for insects not found in live-wood), and mast trees (provide a high-energy food source such as nuts and berries that is important for wildlife, especially during winter months).

Windrowing - Silvicultural activity, associated with intensive site preparation that removes logging debris and unmerchantable woody vegetation into rows or piles to decompose or be burned.

Woody biomass - Wood materials, such as wood, bark, sawdust, timber slash, and mill scraps.

Relevant Conversions

Feedstock conversion factors
1 green ton (GT) of woodchips = 2000 lbs.
1 oven dry ton (ODT) of woodchips = 2 GT
1 oven dry ton (ODT) = 1000 lbs.
1 cord = 128 cubic feet of wood
30 cubic feet of wood = 1 ton
1 standard chip truck = 20 GT

Energy conversion factors
Wood-fueled electric power plant: 1.5 green tons of wood per thousand KWh
Wood-based cellulosic ethanol plant: 1 ton of green wood per 43 gallons ethanol
Wood pellet plant: 10 tons of wood per 5 tons of finished pellets
100 MW = 1.0 - 1.2 million green tons of wood annually
1MW = 10,000 green tons annually (i.e. 5,000 ODTs annually)
1MW = Power for 750 – 1000 homes annually
500,000 dry tons per year = 1.0 million green tons of wood annually
Energy content of wood biomass = 7 MMBTU per green ton
Energy content of wood with 20% moisture = 12.8 MMBTU/ton
Energy content of wood pellets = 16 MMBTU/ton
Energy content of oven dried wood = 16 MMBTU/ton
Energy content of coal = 20 MMBTU/ton
1 ton coal = 0.82 ton carbon
1 gallon gasoline = 0.00265 ton carbon
1 gallon heating oil = 0.003 ton carbon
3.67 tons of CO_2 = 1 ton of carbon
100MW = 286,000 tons of coal annually or 2,860 tons of coal per MW

Table A-1. Estimated potential switchgrass yields and production costs** on idle cropland* and lands enrolled in conservation programs.*

			Potential Switchgrass Yield** (odt/yr)		Potential Switchgrass Energy Yield*** (GJ/yr)		Estimated Production Costs** ($/yr)		Estimated Production Costs** ($/GJ)
County	**Idle Cropland (ac)***	**Conservation Lands (ac)***	**Idle Cropland**	**Conservation Lands**	**Idle Cropland**	**Conservation Lands**	**Idle Cropland**	**Conservation Lands**	**$1.10**
Allegany	505	952	2,950	5,562	49,528	93,368	$54,561.29	$102,856.14	
Anne Arundel	1,069	184	6,245	1,075	104,843	18,046	$115,497.07	$19,879.76	
Baltimore	1,330	651	7,770	3,803	130,441	63,847	$143,696.08	$70,335.45	
Calvert	910	204	5,316	1,192	89,249	20,007	$98,318.37	$22,040.60	
Caroline	2,904	557	16,966	3,254	284,811	54,628	$313,754.44	$60,179.48	
Carroll	6,494	7,697	37,939	44,967	636,903	754,888	$701,625.81	$831,600.53	
Cecil	2,191	2,540	12,800	14,839	214,884	249,112	$236,720.38	$274,427.09	
Charles	2,075	1,335	12,122	7,799	203,507	130,931	$224,187.49	$144,236.29	
Dorchester	8,123	9,283	47,456	54,232	796,668	910,435	$877,626.49	$1,002,955.40	
Frederick	5,721	6,743	33,423	39,393	561,090	661,324	$618,109.22	$728,528.31	
Garrett	2,574	1,364	15,038	7,969	252,447	133,775	$278,100.53	$147,369.51	
Harford	1,539	2,134	8,991	12,467	150,938	209,293	$166,276.89	$230,561.98	
Howard	1,851	446	10,814	2,606	181,538	43,742	$199,986.04	$48,186.80	
Kent	3,937	4,770	23,000	27,867	386,124	467,820	$425,362.00	$515,361.12	
Montgomery	2,886	2,154	16,860	12,584	283,046	211,255	$311,809.68	$232,722.82	
Prince George's	1,226	715	7,162	4,177	120,241	70,124	$132,459.69	$77,250.15	
Queen Anne's	4,230	10,059	24,712	58,766	414,860	986,542	$457,018.35	$1,086,796.12	
St. Mary's	2,372	1,961	13,858	11,456	232,635	192,326	$256,276.01	$211,870.68	
Somerset	1,486	5,269	8,681	30,782	145,740	516,760	$160,550.65	$569,274.16	
Talbot	3,844	5,050	22,457	29,503	377,002	495,282	$415,314.08	$545,612.92	
Washington	2,230	2,213	13,028	12,929	218,709	217,041	$240,934.02	$239,097.31	
Wicomico	5,482	7,163	32,027	41,847	537,650	702,515	$592,287.14	$773,906.02	
Worcester	3,976	6,602	23,228	38,570	389,948	647,495	$429,575.64	$713,294.36	
Total	**68,955**	**80,046**	**402,844**	**467,639**	**6762,801**	**7,850,557**	**$7,450,047.37**	**$8,648,343.01**	

*Idle Cropland and Conservation Lands as defined in USDA 2007 agriculture census, Maryland Table #8: Farms, Land in Farms, Value of Land and Buildings, and Land Use (http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Maryland/st24_2_008_008.pdf)
** Potential yield estimate of 13.1 (odMg/ha/yr) and p.v. production cost of $20.38/odMg (US$1997) from Walsh et al (2003)
*** Potential energy yield calculated using HHV of 18.5 GJ/odMg from McLaughlin et al (2002)

TableA-2. Estimated potential hybrid poplar yields and production costs** on idle cropland* and lands enrolled in conservation programs.*

			Potential Hybrid Poplar Yield** (odt/yr)		Potential Gross Hybrid Poplar Energy Yield*** (GJ/yr)		Estimated Production Costs** ($/yr)		Estimated Production Costs** ($/GJ)
County	**Idle Cropland (ac)***	**Conservation Lands (ac)***	**Idle Cropland**	**Conservation Lands**	**Idle Cropland**	**Conservation Lands**	**Idle Cropland**	**Conservation Lands**	**$1.51**
Allegany	505	952	1,802	3,396	32,404	61,087	$48,884.41	$92,154.37	
Anne Arundel	1,069	184	3,814	656	68,594	11,807	$103,480.06	$17,811.35	
Baltimore	1,330	651	4,745	2,323	85,342	41,773	$128,745.07	$63,017.32	
Calvert	910	204	3,247	728	58,392	13,090	$88,088.73	$19,747.36	
Caroline	2,904	557	10,361	1,987	186,341	35,741	$281,109.54	$53,918.05	
Carroll	6,494	7,697	2,3169	27,461	416,700	493,893	$628,624.43	$745,075.80	
Cecil	2,191	2,540	7,817	9,062	140,590	162,984	$212,090.56	$245,874.05	
Charles	2,075	1,335	7,403	4,763	133,146	85,663	$200,861.67	$129,229.08	
Dorchester	8,123	9,283	28,980	33,119	521,228	595,662	$786,312.94	$898,601.88	
Frederick	5,721	6,743	20,411	24,057	367,099	432,678	$553,797.41	$652,727.83	
Garrett	2,574	1,364	9,183	4,866	165,166	87,524	$249,165.27	$132,036.30	
Harford	1,539	2,134	5,491	7,613	98,753	136,932	$148,976.44	$206,572.92	
Howard	1,851	446	6,604	1,591	118,773	28,618	$179,178.29	$43,173.16	
Kent	3,937	4,770	14,046	17,018	252,625	306,076	$381,104.77	$461,739.84	
Montgomery	2,886	2,154	10,296	7,685	185,186	138,216	$279,367.12	$208,508.94	
Prince George's	1,226	715	4,374	2,551	78,669	45,879	$118,677.79	$69,212.58	
Queen Anne's	4,230	10,059	15,091	35,888	271,426	645,455	$409,467.41	$973,719.30	
St. Mary's	2,372	1,961	8,463	6,996	152,204	125,831	$229,611.51	$189,826.38	
Somerset	1,486	5,269	5,302	18,798	95,352	338,096	$143,846.00	$510,043.44	
Talbot	3,844	5,050	13,714	18,017	246,658	324,043	$372,102.30	$488,844.07	
Washington	2,230	2,213	7,956	7,895	143,092	142,001	$215,865.80	$214,220.18	
Wicomico	5,482	7,163	19,558	25,555	351,763	459,628	$530,662.02	$693,384.17	
Worcester	3,976	6,602	14,185	23,554	255,128	423,630	$384,880.00	$639,078.92	
Total	**68,955**	**80,046**	**246,011**	**285,581**	**44,24,632**	**5,136,308**	**$6,674,899.55**	**$7,748,517.28**	

*Idle Cropland and Conservation Lands as defined in USDA 2007 agriculture census, Maryland Table #8: Farms, Land in Farms, Value of Land and Buildings, and Land Use (http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Maryland/st24_2_008_008.pdf)
** Potential yield estimate of 8.0 (odMg/ha/yr) and p.v. production cost of $29.90/odMg (US$1997) from Walsh et al (2003)
*** Potential energy yield calculated using HHV of 19.82 GJ/odMg from McLaughlin et al (2002)

TableA-3. Estimated potential willow yields and production costs** on idle cropland* and lands enrolled in conservation programs.*

			Potential Willow Yield** (odt/yr)		Potential Willow Energy Yield*** (GJ/yr)		Estimated Production Costs** ($/yr)		Estimated Production Costs** ($/GJ)
County	**Idle Cropland (ac)***	**Conservation Lands (ac)***	**Idle Cropland**	**Conservation Lands**	**Idle Cropland**	**Conservation Lands**	**Idle Cropland**	**Conservation Lands**	**$1.25**
Allegany	505	952	2,275	4,288	39,837	75,099	$49,641.58	$93,581.76	
Anne Arundel	1,069	184	4,815	829	84,328	14,515	$105,082.88	$18,087.23	
Baltimore	1,330	651	5,991	2,932	104,918	51,354	$130,739.22	$63,993.41	
Calvert	910	204	4,099	919	71,786	16,093	$89,453.15	$20,053.23	
Caroline	2,904	557	13,080	2,509	229,083	43,939	$285,463.68	$54,753.19	
Carroll	6,494	7,697	29,250	34,669	512,282	607,181	$638,361.28	$756,616.38	
Cecil	2,191	2,540	9,869	11,441	172,838	200,369	$215,375.66	$249,682.42	
Charles	2,075	1,335	9,346	6,013	163,687	105,312	$203,972.84	$131,230.72	
Dorchester	8,123	9,283	36,588	41,813	640,786	732,293	$798,492.25	$912,520.44	
Frederick	5,721	6,743	25,769	30,372	451,303	531,924	$562,375.25	$662,838.02	
Garrett	2,574	1,364	11,594	6,144	203,051	107,600	$253,024.63	$134,081.43	
Harford	1,539	2,134	6,932	9,612	121,405	168,341	$151,283.96	$209,772.55	
Howard	1,851	446	8,337	2,009	146,017	35,183	$181,953.61	$43,841.87	
Kent	3,937	4,770	17,733	21,485	310,572	376,283	$387,007.75	$468,891.79	
Montgomery	2,886	2,154	12,999	9,702	227,663	169,919	$283,694.28	$211,738.56	
Prince George's	1,226	715	5,522	3,221	96,713	56,403	$120,516.00	$70,284.62	
Queen Anne's	4,230	10,059	19,053	45,308	333,685	793,508	$415,809.70	$988,801.37	
St. Mary's	2,372	1,961	10,684	8,833	187,116	154,694	$233,167.99	$192,766.63	
Somerset	1,486	5,269	6,693	23,733	117,224	415,647	$146,074.05	$517,943.57	
Talbot	3,844	5,050	17,314	22,746	303,235	398,371	$377,865.84	$496,415.84	
Washington	2,230	2,213	10,044	9,968	175,914	174,573	$219,209.37	$217,538.27	
Wicomico	5,482	7,163	24,692	32,264	432,450	565,056	$538,881.51	$704,124.09	
Worcester	3,976	6,602	17,909	29,737	313,648	520,801	$390,841.46	$648,977.70	
Total	**68,955**	**80,046**	**310,589**	**360,546**	**5,439,541**	**6314459**	**$6,778,287.94**	**$7,868,535.08**	

*Idle Cropland and Conservation Lands as defined in USDA 2007 agriculture census, Maryland Table #8: Farms, Land in Farms, Value of Land and Buildings, and Land Use (http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Maryland/st24_2_008_008.pdf)
** Potential yield estimate of 10.1 (odMg/ha/yr) and p.v. production cost of $24.05/odMg (US$1997) from Walsh et al (2003)
*** Potential energy yield calculated using HHV of 19.3 GJ/odMg from Goglio & Owende (2009)

Table A-4. Biomass availability by subregion at varying price estimates adjusted for harvestable acreage.

Biomass (dry tons) available at $30 per ton delivered cost.

Subregion	Total Biomass: Landowner Preference Ignored	Adjusted for Parcels ≥ 10 acres	Adjusted for Parcels ≥ 25 acres	Urban Wood Waste	Mill Residues	Total Biomass: Landowner Preference Ignored	Total Biomass-Adjusted for Parcels ≥ 10 acres	Total Biomass-Adjusted for Parcels ≥ 25 acres
Western	146,885	14,689	8,813	60,020	39,956	**246,861**	**81,099**	**73,731**
Central	48,403	1,452	484	417,800	4,013	**470,216**	**385,078**	**383,323**
Southern	63,711	4,460	2,549	89,110	2,666	**155,487**	**71,428**	**68,716**
Upper eastern shore	13,938	767	488	87,350	-	**101,288**	**88,883**	**88,326**
Lower eastern shore	15,743	2,047	1,260	28,670	-	**44,413**	**24,189**	**23,027**
Maryland Total	**281,711**	**23,414**	**13,593**	**682,950**	**46,636**	**1,018,265**	**650,676**	**637,123**

Biomass (dry tons) available at $50 per ton delivered cost.

Subregion	Total Biomass: Landowner Preference Ignored	Adjusted for Parcels ≥ 10 acres	Adjusted for Parcels ≥ 25 acres	Urban Wood Waste	Mill Residues	Total Biomass: Landowner Preference Ignored	Total Biomass-Adjusted for Parcels ≥ 10 acres	Total Biomass-Adjusted for Parcels ≥ 25 acres
Western	290,386	29,039	17,423	60,020	39,956	**415,347**	**96,433**	**82,259**
Central	119,554	3,587	1,196	417,800	4,013	**605,642**	**393,106**	**388,724**
Southern	139,916	9,794	5,597	89,110	2,666	**246,125**	**73,759**	**68,199**
Upper eastern shore	34,848	3,834	2,440	87,350	-	**135,301**	**81,861**	**79,459**
Lower eastern shore	66,889	8,696	5,351	28,670	-	**99,860**	**28,315**	**24,203**
Maryland Total	**651,593**	**54,948**	**32,006**	**682,950**	**46,636**	**1,502,276**	**673,474**	**642,844**

Biomass (dry tons) available at $70 per ton delivered cost.

Subregion	Total Biomass: Landowner Preference Ignored	Adjusted for Parcels ≥ 10 acres	Adjusted for Parcels ≥ 25 acres	Urban Wood Waste	Mill Residues	Total Biomass: Landowner Preference Ignored	Total Biomass-Adjusted for Parcels ≥ 10 acres	Total Biomass-Adjusted for Parcels ≥ 25 acres
Western	299,236	29,924	17,954	60,020	39,956	**424,197**	**97,067**	**82,528**
Central	121,266	3,638	1,213	417,800	4,013	**607,354**	**392,280**	**387,845**
Southern	143,901	10,073	5,756	89,110	2,666	**250,110**	**73,747**	**68,058**
Upper eastern shore	34,848	3,834	2,440	87,350	-	**135301**	**81860.698**	**79458.73**
Lower eastern shore	68,763	8,939	5,501	28,670	-	**101734**	**28493.551**	**24284.53**
Maryland Total	**668,014**	**56,407**	**32,864**	**682,950**	**46,636**	**1,518,697**	**673,449**	**642,174**

Biomass (dry tons) available at $90 per ton delivered cost.

Subregion	Total Biomass: Landowner Preference Ignored	Adjusted for Parcels ≥ 10 acres	Adjusted for Parcels ≥ 25 acres	Urban Wood Waste	Mill Residues	Total Biomass: Landowner Preference Ignored	Total Biomass-Adjusted for Parcels ≥ 10 acres	Total Biomass-Adjusted for Parcels ≥ 25 acres
Western	299,644	29,965	17,979	60,020	39,956	**424,605**	**97,097**	**82,541**
Central	121,372	3,641	1,214	417,800	4,013	**607,460**	**392,228**	**387,791**
Southern	148,515	10,396	5,941	89,110	2,666	**254,724**	**73,748**	**67,910**
Upper eastern shore	34,848	3,834	2,440	87,350	-	**135,301**	**81860.698**	**79458.73**
Lower eastern shore	71,397	9,282	5,712	28,670	-	**104,368**	**28,750**	**24,405**
Maryland Total	**675,776**	**57,117**	**33,284**	**682,950**	**46,636**	**1,526,459**	**673,685**	**642,105**

Table A-5. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential in western Maryland. *

	Delivered Green Ton Price	$30		$50		$70		$90	
	Landowner Response	**Low (19.5%)**	**Ignored (100%)**	**Low (19.5%)**	**Ignored (100%)**	**Low (19.5%)**	**Ignored (100%)**	**Low (19.5%)**	**Ignored (100%)**
	Biomass Available (green tons)	**182,246**	**418,731**	238,212	705,733	241,663	723,433	241,822	724,249
	Biopower Potential (MW) (Electricity Only)	**18**	**42**	24	71	24	72	24	72
Number of 300 MW Coal Plants that Could Cofire With Available Supply	**5% Biomass**	**1**	**3**	2	5	2	5	2	5
	10% Biomass	**1**	**1**	1	2	1	2	1	2
	20% Biomass	**0**	**1**	0	1	0	1	0	1
Number of 700 MW Coal Plants that Could Cofire With Available Supply	**5% Biomass**	**1**	**1**	1	2	1	2	1	2
	10% Biomass	**0**	**1**	0	1	0	1	0	1
	20% Biomass	**0**	**0**	0	1	0	1	0	1
CHP Potential (Direct Combustion)	**Electricity (MW)**	**8**	**19**	**11**	**31**	**11**	**32**	**11**	**32**
	Thermal (MMBtu)	**242,752**	**557,750**	**317,299**	**940,037**	**321,896**	**963,613**	**322,107**	**964,700**
CHP Potential (Gasification)	**Electricity (MW)**	**9**	**21**	**12**	**35**	**12**	**36**	**12**	**36**
	Thermal (MMBtu)	**237,416**	**545,490**	**310,324**	**919,373**	**314,820**	**942,431**	315,027	943,494
	Cellulosic Ethanol (Million Gallons)	**8**	**18**	**10**	**30**	**10**	**31**	10	31
	Wood Pellets (tons)	**91,123**	**209,366**	**119,106**	**352,867**	**120,832**	**361,717**	120,911	362,125
Thermal Energy (MMBtu)	**Wood-chip District Energy**	**1,093,478**	**2,512,388**	**1,429,274**	**4,234,400**	**1,449,980**	**4,340,600**	**1,450,934**	**4,345,496**
	Cordwood (not EPA certified)	**874,783**	**2,009,911**	**1,143,420**	**3,387,520**	**1,159,984**	**3,472,480**	1,160,748	3,476,397
	Cordwood (EPA certified)	**991,420**	**2,277,899**	**1,295,875**	**3,839,190**	**1,314,649**	**3,935,478**	1,315,514	3,939,917
	Pellet Stove	**1,166,377**	**2,679,881**	**1,524,559**	**4,516,694**	**1,546,646**	**4,629,974**	**1,547,663**	**4,635,196**
ORC Optimized Direct Combustion CHP	**Electricity (MW)**	**6**	**13**	**8**	**23**	**8**	**23**	**8**	**23**
	Thermal (MMBtu)	**388,404**	**892,400**	**507,678**	**1,504,059**	**515,033**	**1,541,781**	515,372	1,543,520
	Number of 2 kW Stirling Engine CHP units*	**4,873**	**11,197**	6,370	18,871	6,462	19,344	6,466	19,366

* Total potential given available biomass supply as defined in Table 14. Area highlighted yellow with bolded numbers indicates that there is no estimated cost limitation for a given technology at a given biomass procurement cost (assumes current technology). Areas that are not highlighted indicate an estimated cost limitation for a given technology at a given biomass procurement cost. This also assumes that all technologies evaluated are able to use the aggregate wood biomass volume for the region (i.e., urban wood waste, logging residues and material from thinnings, and mill residues), which may not reflect the operational fuel requirements of these technologies (e.g., certain technologies will only use "clean chips" or pellets).

Table A-6. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential in central Maryland. *

	Delivered Green Ton Price	$30		$50		$70		$90	
	Landowner Response	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)
	Biomass Available (green tons)	**504,965**	**582,894**	532,714	725,196	533,382	728,620	533,423	728,832
	Biopower Potential (MW)	**50**	**58**	53	73	53	73	53	73
Number of 300 MW Coal Plants that Could Cofire With Available Supply	5% Biomass	**3**	**4**	4	5	4	5	4	5
	10% Biomass	**2**	**2**	2	2	2	2	2	2
	20% Biomass	**1**	**1**	1	1	1	1	1	1
Number of 700 MW Coal Plants that Could Cofire With Available Supply	5% Biomass	**2**	**2**	2	2	2	2	2	2
	10% Biomass	**1**	**1**	1	1	1	1	1	1
	20% Biomass	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**1**
CHP Potential (Direct Combustion)	Electricity (MW)	**22**	**26**	**24**	**32**	**24**	**32**	**24**	**32**
	Thermal (MMBtu)	**672,614**	**776,415**	**709,575**	**965,961**	**710,465**	**970,522**	**710,520**	**970,804**
CHP Potential (Gasification)	Electricity (MW)	**25**	**29**	**27**	**36**	**27**	**37**	**27**	**37**
	Thermal (MMBtu)	**657,828**	**759,348**	**693,977**	**944,728**	**694,848**	**949,188**	694,901	949,464
	Cellulosic Ethanol (Million Gallons)	**22**	**25**	**23**	**31**	**23**	**31**	23	31
	Wood Pellets (tons)	**252,483**	**291,447**	**266,357**	**362,598**	**266,691**	**364,310**	266,712	364,416
Thermal Energy (MMBtu)	Wood-chip District Energy	**3,029,791**	**3,497,365**	**3,196,285**	**4,351,177**	**3,200,293**	**4,371,721**	**3,200,539**	**4,372,993**
	Cordwood (not EPA certified)	**2,423,833**	**2,797,892**	**2,557,028**	**3,480,942**	**2,560,235**	**3,497,377**	2,560,431	3,498,395
	Cordwood (EPA certified)	**2,747,011**	**3,170,944**	**2,897,965**	**3,945,067**	**2,901,599**	**3,963,694**	2,901,822	3,964,847
	Pellet Stove	**3,231,777**	**3,730,523**	**3,409,371**	**4,641,256**	**3,413,646**	**4,663,169**	**3,413,908**	**4,664,526**
ORC Optimized Direct Combustion CHP	Electricity (MW)	**16**	**19**	**17**	**23**	**17**	**23**	**17**	**23**
	Thermal (MMBtu)	**1,076,182**	**1,242,264**	**1,135,321**	**1,545,538**	**1,136,744**	**1,552,835**	1,136,832	1,553,287
	Number of 2 kW Stirling Engine CHP units*	**13,502**	**15,586**	14,244	19,391	14,262	19,483	14,263	19,489

* Total potential given available biomass supply as defined in Table 14. Area highlighted yellow with bolded numbers indicates that there is no estimated cost limitation for a given technology at a given biomass procurement cost (assumes current technology). Areas that are not highlighted indicate an estimated cost limitation for a given technology at a given biomass procurement cost. This also assumes that all technologies evaluated are able to use the aggregate wood biomass volume for the region (i.e., urban wood waste, logging residues and material from thinnings, and mill residues), which may not reflect the operational fuel requirements of these technologies (e.g., certain technologies will only use "clean chips" or pellets).

Table A-7. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential in southern Maryland. *

	Delivered Green Ton Price	$30		$50		$70		$90	
	Landowner Response	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)
	Biomass Available (green tons)	**131,056**	**233,631**	160,776	386,041	162,330	394,011	164,130	403,239
	Biopower Potential (MW) (Electricity Only)	**13**	**23**	16	39	16	39	16	40
Number of 300 MW Coal Plants that Could Cofire With Available Supply	5% Biomass	**1**	**2**	1	3	1	3	1	3
	10% Biomass	**0**	**1**	1	1	1	1	1	1
	20% Biomass	**0**	**0**	0	1	0	1	0	1
Number of 700 MW Coal Plants that Could Cofire With Available Supply	5% Biomass	**0**	**1**	0	1	0	1	1	1
	10% Biomass	**0**	**0**	0	1	0	1	0	1
	20% Biomass	**0**	**0**	0	0	0	0	0	0
CHP Potential (Direct Combustion)	Electricity (MW)	**6**	**10**	**7**	**17**	**7**	**18**	**7**	**18**
	Thermal (MMBtu)	**174,567**	**311,197**	**214,154**	**514,207**	**216,224**	**524,823**	**218,622**	**537,115**
CHP Potential (Gasification)	Electricity (MW)	**7**	**12**	**8**	**19**	**8**	**20**	**8**	**20**
	Thermal (MMBtu)	**170,730**	**304,356**	**209,447**	**502,904**	**211,471**	**513,287**	213,816	525,308
	Cellulosic Ethanol (Million Gallons)	**6**	**10**	**7**	**17**	**7**	**17**	7	17
	Wood Pellets (tons)	**65,528**	**116,816**	**80,388**	**193,021**	**81,165**	**197,006**	82,065	201,620
Thermal Energy (MMBtu)	Wood-chip District Energy	**786,338**	**1,401,788**	**964,658**	**2,316,248**	**973,982**	**2,364,068**	**984,782**	**2,419,436**
	Cordwood (not EPA certified)	**629,071**	**1,121,431**	**771,727**	**1,852,999**	**779,186**	**1,891,255**	787,826	1,935,549
	Cordwood (EPA certified)	**712,947**	**1,270,955**	**874,624**	**2,100,065**	**883,077**	**2,143,422**	892,869	2,193,622
	Pellet Stove	**838,761**	**1,495,241**	**1,028,969**	**2,470,665**	**1,038,915**	**2,521,673**	**1,050,435**	**2,580,732**
ORC Optimized Direct Combustion CHP	Electricity (MW)	**4**	**7**	**5**	**12**	**5**	**13**	**5**	**13**
	Thermal (MMBtu)	**279,307**	**497,915**	**342,647**	**822,731**	**345,959**	**839,717**	349,795	859,384
	Number of 2 kW Stirling Engine CHP units*	**3,504**	**6,247**	4,299	10,323	4,341	10,536	4,389	10,782

* Total potential given available biomass supply as defined in Table 14. Area highlighted yellow with bolded numbers indicates that there is no estimated cost limitation for a given technology at a given biomass procurement cost (assumes current technology). Areas that are not highlighted indicate an estimated cost limitation for a given technology at a given biomass procurement cost. This also assumes that all technologies evaluated are able to use the aggregate wood biomass volume for the region (i.e., urban wood waste, logging residues and material from thinnings, and mill residues), which may not reflect the operational fuel requirements of these technologies (e.g., certain technologies will only use "clean chips" or pellets).

Table A-8. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential on the upper eastern shore. *

	Delivered Green Ton Price	$30		$50		$70		$90	
	Landowner Response	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)
	Biomass Available (green tons)	103,171	114,391	114,044	170,149	114,044	170,149	114,044	170,149
	Biopower Potential (MW) (Electricity Only)	10	11	11	17	11	17	11	17
Number of 300 MW Coal Plants that Could Cofire With Available Supply	5% Biomass	1	1	1	1	1	1	1	1
	10% Biomass	0	0	0	1	0	1	0	1
	20% Biomass	0	0	0	0	0	0	0	0
Number of 700 MW Coal Plants that Could Cofire With Available Supply	5% Biomass	0	0	0	1	0	1	0	1
	10% Biomass	0	0	0	0	0	0	0	0
	20% Biomass	0	0	0	0	0	0	0	0
CHP Potential (Direct Combustion)	Electricity (MW)	5	5	5	8	5	8	5	8
	Thermal (MMBtu)	137,424	152,369	151,907	226,638	151,907	226,638	151,907	226,638
CHP Potential (Gasification)	Electricity (MW)	5	6	6	9	6	9	6	9
	Thermal (MMBtu)	134,403	149,019	148,567	221,657	148,567	221,657	148,567	221,657
	Cellulosic Ethanol (Million Gallons)	4	5	5	7	5	7	5	7
	Wood Pellets (tons)	51,586	57,196	57,022	85,075	57,022	85,075	57,022	85,075
Thermal Energy (MMBtu)	Wood-chip District Energy	619,026	686,346	684,264	1,020,894	684,264	1,020,894	684,264	1,020,894
	Cordwood (not EPA certified)	495,221	549,077	547,411	816,715	547,411	816,715	547,411	816,715
	Cordwood (EPA certified)	561,250	622,287	620,399	925,611	620,399	925,611	620,399	925,611
	Pellet Stove	660,294	732,102	729,882	1,088,954	729,882	1,088,954	729,882	1,088,954
ORC Optimized Direct Combustion CHP	Electricity (MW)	3	4	4	5	4	5	4	5
	Thermal (MMBtu)	219,878	243,790	243,051	362,622	243,051	362,622	243,051	362,622
	Number of 2 kW Stirling Engine CHP units*	2,759	3,059	3,049	4,550	3,049	4,550	3,049	4,550

* Total potential given available biomass supply as defined in Table 14. Area highlighted yellow with bolded numbers indicates that there is no estimated cost limitation for a given technology at a given biomass procurement cost (assumes current technology). Areas that are not highlighted indicate an estimated cost limitation for a given technology at a given biomass procurement cost. This also assumes that all technologies evaluated are able to use the aggregate wood biomass volume for the region (i.e., urban wood waste, logging residues and material from thinnings, and mill residues), which may not reflect the operational fuel requirements of these technologies (e.g., certain technologies will only use "clean chips" or pellets).

Table A-9. Effect of biomass procurement cost limitations and biomass availability on total wood-based bioenergy potential on the lower eastern shore. *

	Delivered Green Ton Price	$30		$50		$70		$90	
	Landowner Response	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)	Low (19.5%)	Ignored (100%)
	Biomass Available (green tons)	39,111	64,457	59,058	166,749	59,789	170,497	60,816	175,765
	Biopower Potential (MW) (Electricity Only)	4	6	6	17	6	17	6	18
Number of 300 MW Coal Plants that Could Cofire With Available Supply	5% Biomass	0.3	0.4	0.4	1	0.4	1	0.4	1
	10% Biomass	0.1	0.2	0.2	1	0.2	1	0.2	1
	20% Biomass	0.1	0.1	0.1	0.3	0.1	0	0.1	0.3
Number of 700 MW Coal Plants that Could Cofire With Available Supply	5% Biomass	0.1	0.2	0.2	1	0.2	1	0.2	1
	10% Biomass	0.1	0.1	0.1	0.3	0.1	0.3	0.1	0.3
	20% Biomass	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1
CHP Potential (Direct Combustion)	Electricity (MW)	2	3	3	7	3	8	3	8
	Thermal (MMBtu)	52,096	85,857	78,665	222,110	79,639	227,102	81,007	234,119
CHP Potential (Gasification)	Electricity (MW)	2	3	3	8	3	9	3	9
	Thermal (MMBtu)	50,951	83,969	76,936	217,227	77,888	222,110	79,226	228,973
	Cellulosic Ethanol (Million Gallons)	2	3	3	7	3	7	3	8
	Wood Pellets (tons)	19,556	32,229	29,529	83,375	29,895	85,249	30,408	87,883
Thermal Energy (MMBtu)	Wood-chip District Energy	234,666	386,742	354,348	1,000,494	358,734	1,022,982	364,896	1,054,590
	Cordwood (not EPA certified)	187,733	309,394	283,478	800,395	286,987	818,386	291,917	843,672
	Cordwood (EPA certified)	212,764	350,646	321,276	907,115	325,252	927,504	330,839	956,162
	Pellet Stove	250,310	412,525	377,971	1,067,194	382,650	1,091,181	389,222	1,124,896
ORC Optimized Direct Combustion CHP	Electricity (MW)	1	2	2	5	2	5	2	6
	Thermal (MMBtu)	83,353	137,371	125,864	355,375	127,422	363,363	129,611	374,590
	Number of 2 kW Stirling Engine CHP units*	1,046	1,724	1,579	4,459	1,599	4,559	1,626	4,700

* Total potential given available biomass supply as defined in Table 14. Area highlighted yellow indicates that there is no estimated cost limitation for a given technology at a given biomass procurement cost (assumes current technology). Areas that are not highlighted indicate an estimated cost limitation for a given technology at a given biomass procurement cost. This also assumes that all technologies evaluated are able to use the aggregate wood biomass volume for the region (i.e., urban wood waste, logging residues and material from thinnings, and mill residues), which may not reflect the operational fuel requirements of these technologies (e.g., certain technologies will only use "clean chips" or pellets).

Table A-10. Co-firing potential of Maryland's pulverized coal boilers. /1

			5% Biomass**			10% Biomass**		
Plant Name	**Unit #**	**Co-firing Potential***	**Tons/Yr**	**MW**	**Economic Costs (Savings) *** $/Yr ($1000)**	**Tons/Yr**	**MW**	**Economic Costs (Savings) *** $/Yr ($1000)**
Warrior Run	2	Poor						
R.P. Smith	3	**Neutral**	**17,162**	**1.45**	**$0.50**	**34,323**	**2.9**	**($4)**
	4	Poor						
Brandon Shores	1	Poor						
	2	Poor						
C.P. Crane	1	**Neutral**	50,367	9.5	($184)	100,735	19	($399)
	2	**Neutral**	55,271	9.5	($210)	110,541	19	($455)
	Total (1-2)		**105,638**	**19**	**($394)**	**211,276**	**38**	**($854)**
H.A. Wagner	2	Poor						
	3	Poor						
Chalk Point	1	**Neutral**	73,959	17.05	($110)	147,919	34.1	($247)
	2	**Neutral**	82,851	17.1	($210)	165,701	34.2	($329)
	Total (1-2)		**156,810**	**34**	**($320)**	**313,620**	**68**	**($576)**
Dickerson	1	**Good**	34,857	9.55	($55)	69,713	19.1	($120)
	2	**Good**	31,900	9.55	($39)	63,801	19.1	($87)
	3	**Good**	38,739	9.55	($75)	77,478	19.1	($161)
	Total (1-3)		**105,496**	**29**	**($169)**	**210,992**	**57**	**($368)**
Morgantown	1	Poor						
	2	Poor						

*As defined by PPRP (2006a)

** For this analysis, researchers weighted biomass feedstock type by $/Btu and abundance to estimate a weighted-mean heat content and feedstock price for "biomass." Because of low cost and relative abundance, weighted "biomass" values are highly influenced by urban wood waste (dry) and mill residue (dry) values.

*** Economic costs and savings factor in incremental costs [annual incremental retrofit capital costs and fuel costs] and incremental savings [SO_2 emissions allowances ($700 ea), NOx Sip Call allowances ($3,000), renewable energy credits (RECs) ($1.75/MWh), MD RPS Tier 1 resource values ($20/MWh), federal production tax credits ($.019/kWh)]

/1 Adapted from PPRP (2006a)

Table A-11. Comparison of wood biomass feedstock estimates for counties sourcing potential co-firing facilities.

	Estimated Forest Biomass** (tons)	Forest Residue (tons)	Difference (tons)	Urban Waste (tons)	Urban Waste (tons)	Difference (tons)	Mill Residue (tons)	Mill Residue (tons)	Difference (tons)	Estimated Total Biomass (tons)	Estimated Total Biomass (tons)	Difference (tons)
Maryland												
Anne Arundel	2,514	7,422	(4,908)	29,160	13,249	15,911	-	5,443	(5,443)	31,674	26,114	5,560
Baltimore	7,585	3,474	4,111	79,160	88,442	(9,282)	-	11,332	(11,332)	86,745	103,248	(16,503)
Carroll	878	3,089	(2,211)	9,480	2,294	7,186	-	10,424	(10,424)	10,358	15,807	(5,449)
Frederick	1,449	1,677	(228)	13,090	15,536	(2,446)	-	10,458	(10,458)	14,539	27,671	(13,132)
Harford	3,452	4,553	(1,101)	13,380	23,432	(10,052)	-	4,185	(4,185)	16,832	32,170	(15,338)
Prince George's	4,439	4,553	(114)	46,770	77,573	(30,803)	-	7,100	(7,100)	51,209	89,226	(38,017)
Pennsylvania												
Adams	22,029	28,034	(6,005)	3,720	-	3,720	1,450	15,136	(13,686)	27,199	43,170	(15,971)
Bedford	27,137	24,653	2,484	1,950	3,397	(1,447)	5,604	33,286	(27,682)	34,691	61,336	(26,645)
Chester	-	6,729	(6,729)	17,690	7,670	10,020	62	12,362	(12,300)	17,752	26,761	(9,009)
Franklin	25,687	26,509	(822)	5,150	21,035	(15,885)	-	35,341	(35,341)	30,837	82,885	(52,048)
Lancaster	9,429	8,057	1,372	18,480	7,828	10,652	1,450	54,540	(53,090)	29,359	70,425	(41,066)
York	9,734	10,917	(1,183)	15,170	58,334	(43,164)	1,527	34,521	(32,994)	26,431	103,772	(77,341)
Virginia												
Caroline	35,246	8,773	26,473	2,000	-	2,000	2,666	22,655	(19,989)	39,912	31,428	8,484
Fairfax	6,571	462	6,109	90,890	237,306	(146,416)	-	8,400	(8,400)	97,461	246,168	(148,707)
Fauquier	9,438	1,570	7,868	5,250	5,341	(91)	-	6,708	(6,708)	14,688	13,619	1,069
Frederick	15,157	1,696	13,461	-	10,849	(10,849)	99	22,806	(22,707)	15,256	35,351	(20,095)
Stafford	12,445	1,940	10,505	-	3,855	(3,855)	-	9,756	(9,756)	12,445	15,551	(3,106)
Westmoreland	8,127	4,918	3,209	1,500	-	1,500	-	22,439	(22,439)	9,627	27,357	(17,730)

Yellow Columns = Estimates from this study, White Columns= Estimates from PPRP (2006a) **Estimated Forest Biomass at $30 odt with Landowner Preference Ignored.

TableA-12. Difference between facility demands and estimated feedstock availability.

Plant Name	Estimated Total Woody Biomass Available (tons)	Difference (tons)
R.P Smith	117,624	(101,381)
	219,005	
C.P. Crane	274,690	(190,645)
	465,335	
Chalk Point	127,881	(49,300)
	177,181	
Dickerson	317,455	(244,941)
	562,396	

*Yellow Columns = Estimates from this study, White Columns = Estimates from PPRP (2006a).

Table A-13. Comparison of facility demands on estimated feedstock availability.

Plant Name	Estimated Biomass Demand at 5% (Tons/Yr)	PPRP Estimated Total Wood Biomass Availability (Tons/Yr)	Annual Biomass Demand of Available Supply (%)	Estimated Biomass Demand at 10% (Tons/Yr)	PPRP Estimated Total Wood Biomass Availability (Tons/Yr)	Annual Biomass Demand of Available Supply (%)
R.P. Smith	17,162	219,005	**8%**	34,323	219,005	**16%**
C.P. Crane	105,638	465,335	**23%**	211,276	465,335	**45%**
Chalk Point	156,810	177,181	**89%**	313,620	177,181	**177%**
Dickerson	105,496	562,396	**19%**	210,992	562,396	**38%**

Plant Name	Estimated Biomass Demand at 5% (Tons/Yr)	Estimated Biomass Availability (Tons/Yr)	Annual Biomass Demand of Adjusted Available Supply (%)	Estimated Biomass Demand at 10% (Tons/Yr)	Estimated Biomass Availability (Tons/Yr)	Annual Biomass Demand of Adjusted Available Supply (%)
R.P. Smith	17,162	117,624	**15%**	34,323	117,624	**29%**
C.P. Crane	105,638	274,690	**38%**	211,276	274,690	**77%**
Chalk Point	156,810	127,881	**123%**	313,620	127,881	**245%**
Dickerson	105,496	317,455	**33%**	210,992	317,455	**66%**

Yellow Columns = Estimates from this study, White Columns = Estimates from PPRP (2006a).

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