Available at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

Review of consumption trends and public policies promoting woody biomass as an energy feedstock in the U.S.

Francisco X. Aguilar, Nianfu Song, Stephen Shifley*

University of Missouri, Department of Forestry, 203L Anheuser-Busch Natural Resources, Columbia, MO 65203, United States

ARTICLE INFO

Article history:
Received 17 May 2010
Received in revised form
17 May 2011
Accepted 19 May 2011

Keywords:
Woody biomass
Renewable energy policy
Wood energy growth prospects
Biomass power
U.S.

ABSTRACT

A review of the four main wood energy sectors in the U.S. was conducted to explore historic trends and the impact of alternative energy prices and public policies on wood energy consumption. High oil prices have triggered the adoption of government regulation and financial incentives to promote greater use of wood energy over the last four decades. However, the amount of wood energy consumed in the U.S. industrial sector was driven mainly by the output of the pulp and paper products industry and not by energy prices or any particular public policy incentive. Residential consumption of wood energy was positively correlated with competing energy prices. Public policies seem to have had a greater impact on wood energy consumption in the electric power sector and over the last four decades have concentrated on promoting biopower with a recent shift to liquid cellulosic biofuels. High oil prices and a series of public policies such as tax credits, loans, grants, and renewable energy standards have resulted in higher consumption of wood energy from 2004 to 2009 in the residential, electric power and commercial sectors by an estimated 5, 2, and less than 1 percent annually, respectively. The impact of new federal programs such as the Biomass Crop Assistance Program remains to be observed. Continuation of public incentives and preferential regulations for renewable energy appears to be necessary for a steady increase in U.S. wood energy consumption.

1. Introduction

Rising concerns associated with U.S. dependence on foreign sources of non-renewable fossil fuels have motivated federal and state governments to adopt ambitious renewable energy targets. Greater generation and consumption of alternative renewable energies, including wood energy (or woody biomass energy), to replace the use of non-renewable fuels has been adopted as a public policy at various levels. Numerous government programs that include woody biomass as a renewable energy feedstock have been established to date in the U.S [1–3].

Wood has historically been an important source of energy in the U.S., where it accounted for an estimated 91 percent of domestic consumption in 1850 [4], and it remains a major source of energy for 2000 million people around the world [5]. However, as alternatives to wood energy (e.g., fossil fuels) became more accessible and affordable, wood energy contracted to a small fraction of the U.S. annual energy consumption. By 1973, wood provided about 2 percent of the energy consumed in the U.S. [4], but still represents a major component of the country's renewable energy sector. Woody biomass, or fuel wood, is a renewable energy feedstock if properly managed [6–9]. Woody biomass can be sourced from logging and other tree residues, treatments to reduce fuel buildup in fire-prone forests, fuel wood, forest products industry wastes, urban wood residues and energy plantations

* *Corresponding author.*
E-mail address: aguilarf@missouri.edu (F.X. Aguilar).
0961-9534/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biombioe.2011.05.029

[10]. Different forest sector stakeholders have identified wood-to-energy projects to provide important opportunities to support local economic development [11]. It is imperative to understand how public policies have affected consumption and generation of wood-based energy in the past to evaluate the potential impact of recently adopted government programs on future consumption of wood energy.

This paper reviews historical changes in the U.S. wood energy market since the 1970s and examines the effects of public policy implementation related to wood energy consumption using an exploratory non-parametric approach. We first analyzed the consumption of wood energy by different sectors and explore historical changes in wood energy consumption in conjunction with alternative energy prices. Next, we explored the development of public policy targeting wood energy enacted from 2004 to 2009 to analyze the evolution of approaches to promote renewable energy. By examining the average five-year growth following the enactment of public policies, we make a preliminary estimation for growth in the wood energy sector based on most recent consumption trends and the mean effects of adopted public policies. This historical approach [12] is limited in that it assumes that conditions observed during our policy evaluation should continue unaltered so that their effects may remain unchanged. Nonetheless, it provides a first baseline assessment for the future evaluation of wood energy policy impacts.

2. Current wood energy consumption: industrial, residential, commercial and electric power sectors

In 2007, U.S. wood energy consumption, including wood and wood derived liquid and solid fuel, was 2261 PJ, equivalent to 119 Mt of moisture-free fuel wood [13]. This figure comprised 60 percent of the 3797 PJ of energy generated from all types of biomass, 31 percent of the 7194 PJ of all U.S. renewable energy, and 2 percent of the total 107,218 PJ total U.S. energy consumption [4]. The quantity of woody biomass annually consumed for energy production is about one-third of the estimated 335 Mt of moisture-free fuel wood potentially available for energy production [14]. With current technology and rates of consumption, utilizing all potentially available woody biomass for energy could ostensibly meet about 6 percent of total U.S. energy demand. It would take the equivalent of roughly 5000 Mt of moisture-free woody biomass annually to match total U.S. energy consumption, a quantity that far exceeds the annual growth of all trees on all U.S. forests.

The wood energy sector in the U.S. can be subdivided into four main sectors: industrial, residential, commercial, and electric power [13,15]. Fig. 1 shows the breakdown of energy consumption by each sector in 2007 and identifies specific segments within the industrial sector. In 2007, 1538 PJ of wood energy was used in the industrial sector, corresponding to 68 percent of total U.S. wood energy. The wood energy industrial sector is mainly comprised of (a) the wood products industry (North American Industry Code System -NAICS 321), and (b) the pulp and paper products industry (NAICS 322). The

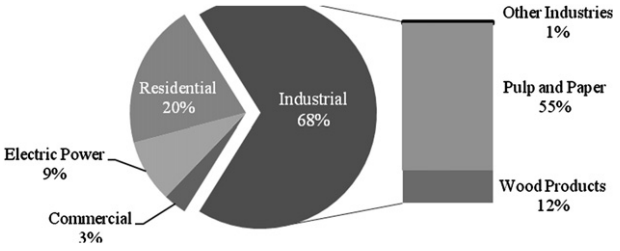

Fig. 1 – Segmentation of U.S. Wood Energy Consumption in 2007 (Total consumption: 2261 PJ, about 119 Mt of fuel wood free of moisture: the total percentage of the bar chart is 68%). Data source U.S. Energy Information Administration [4].

majority of wood energy produced and consumed in the industrial sector was generated using residues from the wood products and pulp and paper mills. The pulp and paper products industry consumed 875 PJ of black liquor (a liquid byproduct of the pulp and paper products industry) and 371 PJ of wood/wood wastes in 2007 [13]. The total 1246 PJ of black liquor and wood/wood wastes used in the pulp and paper industry accounted for 81 percent of wood energy in the industrial sector and 55 percent of U.S. total wood energy in 2007.

The residential energy-use sector consists of all U.S. private homes. They consumed 454 PJ of wood energy and accounted for 20 percent of the total wood energy used in the U.S. in 2007. Wood energy in the residential sector was derived mainly from firewood, pellets, and chips.

The commercial sector consists of service-providing facilities to businesses, government, and other private and public organizations. Stores, schools, churches, banks, restaurants and other service facilities are all included in this sector. This sector used 73 PJ of wood energy and accounted for 3 percent of the total U.S. wood energy consumed in 2007 [4].

The electric power sector consists of private and public facilities involved in generating, transmitting, and distributing electricity. Wood and its derived products have been used as feedstock in some of these facilities. This sector used 196 PJ of wood energy, accounting for 9 percent of U.S. wood energy in 2007 [13]. Wood energy feedstocks in this sector include forest residues, construction waste, and other urban wood wastes [13].

3. Trends in U.S. wood energy consumption

The amount of wood energy consumed in the U.S. has experienced periods of growth, contraction and stability. U.S. consumption of wood energy did not experience sizeable changes from 1949 to 1972. However, it leaped 76 percent from 1661 PJ in 1973, when the oil crisis began, to 2835 PJ in 1985 [4,16]. The domestic annual average real oil price (expressed in constant 2008 dollars) increased from 144 $ m^{-3} in 1973 to 617 $ m^{-3} by 1980. In 1985, the annual average oil price had dropped to 340 $ m^{-3} (Fig. 2). Although the annual real oil price declined over this latter period, wood energy consumption remained at about 2600 PJ until 1989 [4]. From 1988 to 2002,

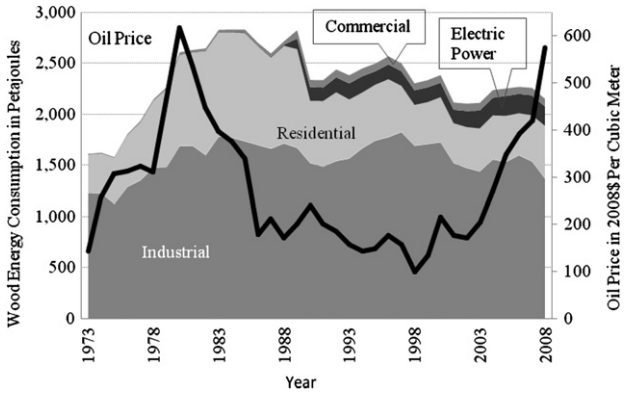

Fig. 2 – U.S. Oil Price and Wood Energy Consumption by Sectors, 1973 to 2008. Data source: U.S. Energy Information Administration [4], Illinois Oil and Gas Association [17].

a period of inexpensive oil with average real price of less than 200 $ m^{-3} [17], U.S. wood energy consumption showed a declining trend. From 2003 to present, U.S. wood energy consumption did not increase in spite of sharply rising oil prices. A closer examination of individual energy sectors using historical data helps explain changes in U.S. wood energy consumption.

3.1. *Industrial sector*

The quantity of wood energy produced in the U.S. industrial sector has been closely associated with production levels for solid wood, pulp, and paper products. The quantity of wood, wood waste, and black liquor available for on-site industrial energy generation rose and fell with the quantity of wood processed into final products. Past trends depict how the amount of wood energy used by the industrial sector has been correlated with production in the pulp and paper products industry and to a lesser extent with oil prices. Wood energy consumption by the U.S. industrial sector increased 41 percent from 1973 to 1985 in step with increasing paper production during the same period [18]. This sector only experienced a minimum decline from 1983 to 1990 following a precipitous drop in oil prices (Fig. 2). From 1991 to 2007, wood energy consumed by the industrial sector was closely tied to levels of paper production (Fig. 3). Even with rising oil prices between 2003 and 2008, wood energy consumption by the industrial sector continued a downward trend amid declining domestic U.S. pulp and paper production [19,20]. By 2008, the consumption of wood energy by the industrial sector had dropped back to its 1977 level.

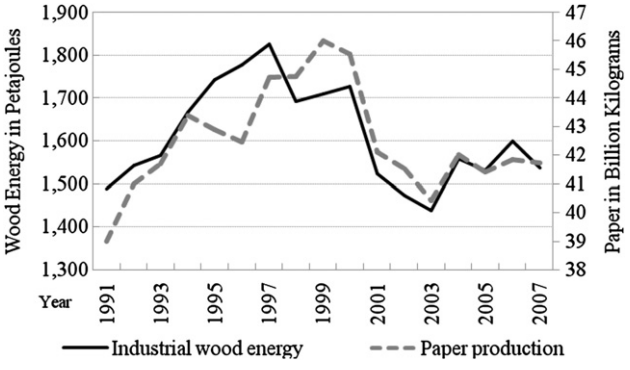

Fig. 3 – Paper Production and U.S. Wood Energy Consumption by Industrial Sector, 1991 to 2007. Data source: RISI [20], U.S. Energy Information Administration [4].

3.2. *Residential sector*

In contrast to the industrial sector, the residential sector's consumption of wood energy has been largely affected by competing energy prices and government policies. From 1973 to 1989 wood energy consumption in the residential sector increased and decreased in a pattern that lagged a few years [21] behind increases and decreases in natural gas prices (Fig. 4). But after 1990 wood energy used in the residential sector was more closely aligned with changes in the price of electricity. It has been shown that non-wood energy sources are substitutes for wood energy [21–23], i.e. the consumption of wood energy in the residential sector is positively correlated to the price of alternative energies.

In 1985, two years after natural gas prices peaked, the residential sector consumed 1066 PJ of wood energy, 186 percent more than it did in 1973 [4]. With the decline of competing energy prices from 1986 to 2002, wood energy consumption by the residential sector shrank to about 401 PJ in 2002, close to 1973 consumption levels. With increasing competitive fuel prices since 2002 and incentive programs such as the Residential Energy Efficiency Tax Credit [3], the residential sector increased its wood energy consumption by 29 percent from 401 PJ in 2002 to 517 PJ in 2008 (Fig. 4).

3.3. *Electric power and commercial sectors*

Wood energy consumption (wood and wood derived solid fuel) in the commercial and electric power sectors increased gradually from 1973 to 1988, but each of these two sectors used less than 1 percent of total U.S. wood energy as shown in Fig. 2. The greatest increase in wood energy consumption by these two sectors occurred in 1989 and 1990, a decade after the run up in oil prices of 1973. In 1989, wood energy consumption by the commercial sector more than doubled from 34 PJ in

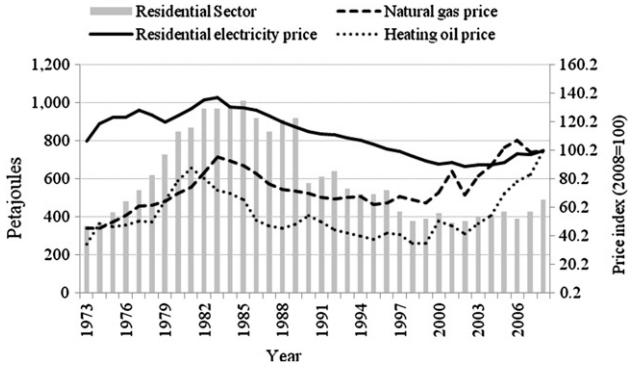

Fig. 4 – Residential wood energy consumption and prices indices of selected non-renewable energy sources. Data sources: U.S. Energy Information Administration [4,13].

1988 to 81 PJ. Wood energy consumption by the electric power sector increased 14-fold from 10 PJ in 1988 to 136 PJ in 1990 (Fig. 5). Variations in wood energy consumption in the two sectors cannot be explained by changes in alternative energy prices (e.g. oil or coal). Nor can electricity price alone explain the rapid growth in wood energy consumption in these two sectors. While real electricity prices had changed moderately in almost half a century [4], wood energy consumption in these two sectors increased dramatically over a short period. We associate the growth in consumption in these sectors with the implementation of public policies discussed next.

4. Public policy promoting wood energy

Public policy has been used to promote U.S. wood energy production and consumption. Government programs can alter cost structures of wood-to-energy production [2] by providing financial incentives to landowners or producers, demanding the use of renewable feedstock, and providing funding to develop and refine technologies [1]. In this section we explore the development of public policy targeting wood energy to analyze how approaches to promoting renewable energy have evolved in recent years. Historically, there has been a parallel tendency to enact or amend policies that favor greater renewable energy generation as oil prices rise [24]. Policies related to biomass energy adopted since 1970 until 2009 are discussed in this section, emphasizing government programs focused on wood energy production. Our historic examination distinguishes public policies into two main energy categories: biopower and liquid vehicle fuels. Within the wood energy biopower set of policies we identify seven main instruments and describe their salient attributes following the chronological order in which they were first instituted. The instruments are: renewable energy mandates, tax credits and grants for renewable electricity, rural energy grants, tax credit for residential biomass energy, green power purchase goal, government bonds, and state-level energy programs. Recent key legislation promoting use of woody biomass to produce liquid vehicle fuels includes the Energy Independence and Security Act of 2007 (EISA) and the Biomass Crop Assistance Program (BCAP) created as part of the Food, Conservation, and Energy Act of 2008 [25,26].

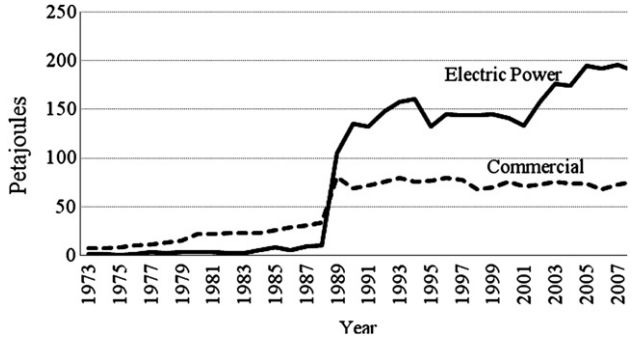

Fig. 5 – Wood Energy Consumption by Electric Power and Commercial Sectors from 1973 to 2008. Source: U.S. Energy Information Administration [4].

4.1. *Biopower: renewable energy mandate*

The Public Utility Regulatory Policies Act (PURPA) [27], a part of the National Energy Act of 1978, was passed by the U.S. Congress amid high oil prices [28]. PURPA required utility providers and distributors to buy electricity at "avoided cost" (i.e., the cost the utility would incur for producing the renewable power by themselves) from qualifying facilities using renewable fuels [29,30]. PURPA resulted in favorable investment conditions for wood-based and other renewable energies. This policy enhanced biomass energy cost competitive advantage and partially explains the growth in the late 1980s of wood energy consumption by the electric power and commercial sectors. The high biomass "avoided cost" purchase price was arguably a major driver behind the increase in biomass power plant energy capacity and associated demand for biomass feedstocks. Many biomass power facilities were built under PURPA, and they explained the leap of wood power in the late 1980s (Fig. 5). As a case in point, about two-thirds of the 35 biomass power facilities in California participated in the fixed price agreement based on PURPA [30].

The Energy Policy Act (EPACT) of 2005 [31] repealed the mandatory purchase requirement. The enactment of this law was followed by a moderate decline in wood energy generation by this sector in recent years (contracts were not due to expire until recently). However, because of PURPA, most of these facilities purchasing renewable energy were able to navigate an extended period of low energy prices in the 1990s and early 2000s.

4.2. *Biopower: tax credits and grants for renewable electricity*

The federal renewable energy production tax credit (PTC) was first established by the EPACT of 1992 [32] for renewable energy closed-loop biomass electricity plants. The term closed-loop biomass means any organic material from herbaceous or woody plants grown exclusively to produce electricity at a qualified facility [33]. U.S. Department of Energy records suggest that including the closed-loop biomass in the PTC had a negligible effect on commercial wood energy consumption from 1992 to 2002 (Fig. 5). During the second period of high oil prices covered in this review, the American Jobs Creation Act of 2004 [33] extended the PTC program to open-loop biomass. Open-loop biomass under this Act includes forest-related resources such as mill and harvesting residues, pre-commercial thinnings, slash, brush and solid wood waste materials used to power electricity plants (e.g. waste pallets, crates, dunnage, manufacturing and construction wood wastes and landscape or right-of-way tree trimmings). The inclusion of open-loop biomass in the PTC expanded the program to a majority of the economically feasible wood energy feedstocks. The American Jobs Creation Act of 2004 also required qualified biomass energy facilities eligible for the PTC to be in service before January 1, 2006. The EPACT of 2005 extended the eligibility term of the PTC for new open-loop biomass facilities (in service before December, 2013) to 10 years. The credit was adjusted to 21 $\$\cdot MWh^{-1}$ for closed-loop biomass and 10 $\$\cdot MWh^{-1}$ for open-loop biomass in 2008 [34] (the average U.S. residential electricity price

including tax was 110 $·MWh^{-1} in 2008). However, the effective period of eligibility for open-loop biomass plants only lasted five years [34]. Because most of the current biomass plants were in service before 2005, the five-year term suggests that most of the current biomass plants will not be eligible for PTC beyond 2010.

Although, the Alternative Fuel Provision tax credit as a part of the Safe, Accountable, Flexible, Efficient Transportation Equity Act of 2005 [35] was intended to promote alternative fuels for motor vehicles, the Internal Revenue Service allowed paper manufacturers to be eligible to receive a tax credit worth 132 $ m^{-3} of black liquor produced since September 2008. To qualify for the tax credit, 0.1 percent of diesel fuel must be mixed into the black liquor. The cost of the black liquor credit to the federal government was estimated to be 4000 M$ a year [36]. By the end of 2009, the credit expired for black liquor [37]. Despite the existence of such credits for the last four months of 2008, wood energy consumption by the industrial sector continued to decline in that year (Fig. 2).

The American Recovery and Reinvestment Act (ARRA) of 2009 expanded the existing federal business energy investment tax credit (ITC) [34,38], as an alternative to the PTC, to all facilities that qualify for the renewable electricity PTC. The PTC and ITC are deemed to be among the most effective incentive policies in the wood electric power sector [39]. Wood energy projects and combined heat and power projects in commercial, industrial and electric power sectors are qualified for this tax credit. This energy tax credit is 10 percent for combined heat and power and 30 percent for other PTC-eligible biomass projects. As an alternative for renewable electricity PTC or ITC, the Renewable Energy Grant program was created in 2009 [40]. Under this program grants could be claimed for energy investment placed in service before 2016 if construction began between 2009 and 2010. There are also loan guarantees available from the U.S. Department of Energy for renewable energy programs of commercial and non-federal projects.

4.3. *Biopower: rural energy grants (feasibility studies)*

The Renewable Energy Systems and Energy Efficiency Improvements Program (RESEEIP) came into effect in 2003 following a spike in oil prices. This grant program created investments in renewable energy systems and renewable energy feasibility studies. Energy projects in the commercial and electric power sectors, including biomass projects could qualify for the grants. This program evolved into the Rural Energy for America Program Grant in 2008 with total funding increasing from 23 M$ in 2003 to 70 M$ by 2012.

4.4. *Biopower: federal Green Power Purchasing Goal*

The federal EPACT of 2005 required that, "to the extent it is economically feasible and technically practicable," the total amount of renewable electric energy consumed by the federal government should be at least 3 percent from 2007 to 2009, 5 percent from 2010 to 2012, and 7.5 percent after 2013 [41]. By 2006 the federal government had purchased or produced 14 PJ of renewable energy, equivalent to 6.9 percent of total federal agency electricity use which is close to the 7.5 target set by 2013 [42]. Even at 7.5 percent of federal electric usage, the amount of renewable energy required by this program is equivalent to only 0.6 percent of the national wood energy utilized in the U.S.

4.5. *Biopower: tax credit for residential biomass energy*

In 2006, the Residential Energy Efficiency Tax Credit (REETC) was available to residents purchasing biomass stoves that use wood, wood residues and their derived products, and other agriculture products and residues. The REETC has covered 30 percent or up to $500 of the cost of biomass stoves installed in homes since 2006. There was a new $1500 limit for the tax credit for purchasing and installation in 2009 and 2010. Nonetheless, it remains a major incentive for wood energy residential consumption [34].

4.6. *Biopower: government bonds*

Clean Renewable Energy Bonds (CREBs) were established by the EPACT of 2005 for renewable power projects. Under this program, borrowers pay back only the principal capital of the bond, and the bondholder receives a federal tax credit. In November 2006, the first 800 M$ of tax credit bonds were assigned to 610 projects. An additional 400 M$ were reserved for 312 projects in February 2008. The Energy Improvement and Extension Act of 2008 [43] and the ARRA [38] placed an additional 2400 M$ in CREBs of which 2200 M$ had been reserved for 805 projects in October 2009.

Another type of policy instrument for financing energy projects powered by renewable energy including biomass was established under the Qualified Energy Conservation Bonds (QECBs) program, part of the Energy Improvement and Extension Act of 2008. Under this program, borrowers pay back only the principal of the bonds, and the bondholders receive federal tax credits in lieu of the traditional bond interest [44]. Initially the bonds which are issued by state and local governments were limited to 800 M$, but this was later expanded to 3200 M$ through the ARRA [38].

4.7. *Biopower: state-level programs*

State programs can also help improve the economics of wood energy power plants [1,45]. These programs include state renewable portfolio standards (RPS), tax credits, tax exemptions, rebates, loans, bonds, and production incentives [46]. Several states have voluntary or mandatory RPS for municipal and/or investor-owned utility facilities to have a certain percent of their capacity powered by renewable energy. RPS have been established in 36 states and the District of Columbia, 11 states enacted RPS before 2003, 17 states and D.C. enacted RPS between 2003 and 2007, and 7 states enacted them in 2008 and 2009. Becker et al. [2] discuss an analytical framework for assessing state-level forest biomass utilization policies such as RPS. Targets of most state RPS range from 15 to 25 percent of total utility power by 2025 [3]. Many state rules and financial incentives have also been created along RPS to ease adoption and improve cost efficiencies. The RPS in California is one of the most ambitious nationwide with a goal of 33 percent renewable energy by 2020. But biomass accounted for less than 5 percent of total growth in renewable energy bid by investor-owned-

utilities in 2009 while wind and solar energy increased exponentially to dominate renewable energy growth [47]. This example shows that RPS effect on wood energy consumption could be small when other renewable energy sources are more price competitive.

Production tax credits, loans, grants, loan guarantees, tax exemptions, and rebates are some of the most commonly adopted state-level financial incentive programs. State incentives, however, do not apply to as many woody biomass facilities as federal incentives do. For example, by November, 2009, there were 53 state rebate programs for renewable energy, but only one of them included biomass (and not limited to woody biomass). Only six states have state-wide production incentives for biomass power by 2009. Production incentives by municipal and investor-owned utilities are more aggressive than other incentives. Some utility providers and distributors have established generation partner programs, and pay a 30 $\$\cdot MWh^{-1}$ incentive for renewable energy, an incentive three times as high as the federal PTC [34]. Renewable energy generated by partner programs can be counted toward the renewable energy target required by state RPS. With such partner programs utility providers or distributors can choose between buying and producing green power. There are nine states that have such utility production incentive programs applicable to woody biomass [34]. But these programs are regional and affect only a small number of communities.

Some states also have loan and grant programs for renewable energy. A preferential interest rate is often charged on these loans. There were 65 state loan programs for renewable energy in 2009, and 37 of them in 26 states included wood energy. About half of these loan programs were enacted between 1990 and 2006, and the remaining were enacted after 2007 [34]. There are 23 state grant programs for renewable energy including biomass. Ten of these programs were enacted between 1990 and 2006, and about half of the grant programs were enacted after 2007 [34]. The applicable sectors of these loan and grant programs vary from state to state, and they can apply to one or more of the residential, commercial, and electric power sectors.

4.8. *Liquid cellulosic biofuels: Energy Independence and Security Act of 2007 and the 2008 Farm Bill's Biomass Crop Assistance Program*

Following the renewable fuel standards enacted by the EPACT of 2005, the EISA of 2007 [25] mandated an increase of national motor vehicle biofuel use to 136 hm^3 a year by 2022 of which no more than 57 hm^3 can be ethanol from corn starch, and no less than 61 hm^3 must be cellulosic biofuels. Cellulosic biofuels are renewable fuels derived from cellulose, hemicellulose, or lignin that must have at least 60% lower lifecycle greenhouse gas emissions relative to gasoline. This includes cellulosic ethanol as well as any biomass-to-liquid fuel such as cellulosic gasoline or diesel. The U.S. Environmental Protection Agency (EPA) is responsible for establishing and implementing regulations to ensure that the nation meets mandated biofuel volumes and the conditions under which targets may be waived [48].

BCAP was authorized by the Food, Conservation, and Energy Act of 2008 [26] to provide financial assistance to owners and operators of agricultural and non-industrial private forest land who wish to establish, produce, and deliver biomass feedstocks [49]). Regarding fuel wood, BCAP provides (a) matching payments for no more than two years to eligible material owners, at a rate of 1$ for each 1$ paid by a qualified biomass conversion facility up to 49.60$ per moisture-free metric ton of delivered biomass to produce heat, power, biobased products, or advanced biofuels; (b) establishment payments up to 75 percent of the cost of establishing a bioenergy perennial crop and (c) and up to 15 years of annual payments for woody crops [50]. Eligible woody material collected or harvested must come directly from the land and if outside BCAP project areas must be a byproduct of preventive treatments to reduce hazardous fuels, reduce or contain disease or insect infestation, or restore ecosystem health. Although BCAP payments can be received for the production of heat or power, the primary objective of BCAP was to reduce the financial risk for landowners to switch to energy crops in preparation for new emerging liquid biofuel markets in an effort to establish large-scale energy crop sources and a viable industrial biomass consumer base [50]. This aim is reflected in a tiered system of reductions to annual payments based on the use for which the material or crops was sold. Conversion to cellulosic biofuels results in the smallest payment reduction (1%), followed by use of the material for production of advanced biofuels (10%) while uses for purposes other than conversion to heat, power, biobased products, or advanced biofuels result in the highest reduction (25%) [49]. The Food, Conservation, and Energy Act of 2008 also established a 0.27$ tax credit per liter as part of its Credit for Production of Cellulosic Biofuel Program [26].

The program formally began in July 2009 and continued through a pilot phase (i.e. Notice of Funding Availability period) that ended in February 2010. Revisions to BCAP were published in the U.S. Federal Register in October 2010. Program changes aimed to, among other things, ensure program additionality (i.e. additional biomass energy production beyond historical levels), enhanced resource stewardship and conservation measures, protect existing wood product markets, spur liquid cellulosic biofuels production, and cap program expenditures. During the Notice of Funding Availability period, 250 M$ were expended through BCAP matching payments. The BCAP final rule estimated total expenditures are expected to total 461 M$ over 15 years [49].

The federal and state policies discussed previously are summarized in Fig. 6. Notice that most of these programs involve electric power related projects and have been enacted within the last decade. RPS in 11 states and PURPA were enacted before 2002, and a majority of other policies related to wood energy have been in effect before 2008. ITC, federal grants, and some CREBs and QECBs are federal policies that have been in effect since 2009. Several state-level RPSs, loans and grants have been adopted since 2009.

5. Exploratory five-year evaluation of the impact of public policy on wood energy consumption by sectors

With the enactment of public policies promoting wood energy, its consumption by individual sectors has grown at

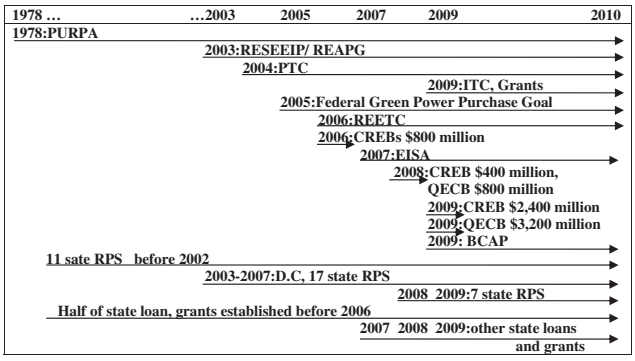

Fig. 6 – Timeline of major federal and state-level and regulations and incentives for wood energy production and consumption enacted between 1978 and 2010.

different rates. This section of the manuscript evaluates average growth rate in wood energy consumption following the enactment of major policies over the 2004–2009 period. We selected this period because it concentrates a large number of newly adopted programs, rules and regulations under different public policies. Because a majority of woody biomass energy policies have been enacted in recent years (Table 1), an extended econometric longitudinal model could not be used to estimate subsequent effects of these policies due to lack of observations following their implementation. For example, in the case of the BCAP program only a pilot period has been established and new guidelines were only recently published, hence, any evaluation would be premature until the program is in full implementation.

We took a simplified exploratory approach based on the premise that the impacts of an effective policy would likely be observed by comparing changes in wood energy consumption before and after the policy was implemented. Because the price of alternative non-wood energy increased from 2004 to 2009, observed changes in wood energy consumption could be caused by changes in competitive energy prices and by newly adopted policies. Under the assumption that similar market and policy conditions (i.e. energy prices maintain a similar trend and there is continuation of public policies) are experienced in the near future, such impacts in the wood energy sector may continue as well. The effects of policies such as PURPA and RPS that have been in place for a longer period were not discernable because these were implemented prior to 2004 which limits our capacity to evaluate their impact over the 2004–2009 period. Due to scope and space limitations of this manuscript, the authors have reserved an econometric analysis over a longer 50-year time frame for a specific analysis to be published in a separate publication. Here, we concentrate on the general five year examination of a number of selected of wood energy public policies in the U.S. only.

Observed growth rates of wood energy for the different sectors and recently enacted policies related to wood energy are listed in Table 1. Three of the four wood energy-use sectors increased their consumption of wood energy while the industrial sector reduced its consumption primarily due to the downturn of the pulp and paper products market. The most influential public incentive for residential wood energy consumption seems to be the 30 percent tax credit for home stoves by REETC in place since 2006. This incentive reduces the cost for installing a biomass heating system at home and promotes use of wood energy [39]. As a result of increasing electricity price and incentive programs, wood energy

Table 1 – Major incentives and their observed impact on growth rates of wood energy consumption 2004 to 2009.[a]

Sector	Major incentives and regulations	Amount of credit and bonds	Years enacted	Observed growth rate of consumption (Years in effect)	Average annual growth following enactment
Residential	Biomass/stove tax credit (Federal) State Incentives	30% of cost, $500 limit ($1500 in 2009 and 2010)	2006 (federal) Before 2007 (most states)	14% (3 years)	5% (25.9 PJ)
Electric Power	PTC[b] or ITC[b] or Renewable Energy Grants[b] Bonds State incentives and RPS	PTC: 10 $·MWh^{-1} in 2008 (for five years) ITC: 10% CHP, 30% other eligible CREB: $800 (2006), $400 million (2008) $2.2 billion (2009)	2004 2004 2009 2004 before 2007 (most states)	8% (5 years)	2% (3.8 PJ)
Commercial	PTC[b] or ITC[b] or Renewable Energy Grants[b] Bonds State incentives and RPS	PTC: 10 $·MWh^{-1} in 2008 (for five years) ITC: 10% CHP, 30% other eligible CREB: $800 (2006), $400 million (2008) $2.2 billion (2009)	2004 2004 2009 2004 before 2007 (most states)	1% (5 years)	<1% (0.4 PJ)

a The wood products and paper industrial sector is not included because the amount of wood energy consumed is directly correlated to wood product outputs and has not been significantly affected by public policies. The effect of CREBs and QECBs after 2008 is estimated to be 62.9 million GJ.

b PTC, ITC, and federal Renewable Energy Grants are exclusive of each other. A facility can only claim one of them.

consumption in the residential sector increased to 517 PJ in 2008, 14 percent more than that in 2005, the year before the REETC came into effect. The average annual growth rate was about 5 percent over this period. We expect this trend to continue if electricity price keeps rising and the 30 percent of tax credit is extended beyond 2010 which is the current expiration date.

As exemplified by PURPA, public incentives and regulations had a significant effect on wood energy consumption in the electric power and commercial sectors. As reflected by the number of instituted biopower public programs, the electric power sector received the most incentives and preferential regulations in 2004–2009. The PTC, ITC, CREBs, QECBs, the federal Green Power Purchasing Goal, many state incentives, and RPS were designed to promote renewable power generation mainly for this sector. Although utilization of wood for energy in the electric power sector may continue to increase in the future, it may represent a declining proportion of total renewable energy as other forms of renewable energy production increase faster [47]. Based on historical data (Fig. 2), wood energy consumption in this sector increased by 8 percent from 2004 (when federal PTC was extended to open-loop biomass) to 2008. The average annual growth rate during this period was 2 percent. With this growth rate, there would be an overall 3.8 PJ of annual growth in wood energy consumption in the electric power sector. As discussed previously, the CREBs, QECBs are loans for new renewable power programs, and have the potential to increase wood energy consumption in this sector by 33 percent when all the intended projects are in service. An additional 62.9 PJ of fuel wood will be consumed by this sector.

Some public incentives and regulations also targeted the commercial sector. PTC, ITC, Renewable Energy Grants, some state incentives, and RPS are applicable to firms in the commercial sector too. The Federal Green Power Purchasing Goal did not appear to increase the overall wood energy consumption. Wood energy consumption in this sector increased from 75.4 PJ in 2003, the year before PTC was extended to biomass, to 76.3 PJ in 2008. The annual growth rate was less than 1 percent. If this trend holds, wood energy consumption in the commercial sector would only increase 0.4 PJ annually.

If all residential, electric power and commercial sectors increase their demand for wood energy by the trends discussed above, U.S. total wood energy could increase by 30.0 PJ, corresponding to 25.9 PJ in the residential sector, and 3.8 PJ in the electric power sector, 0.4 PJ in the commercial sector. This 30.0 PJ figure represents about 2 Mt of additional moisture-free fuel wood consumed per year.

6. Discussion

As suggested by historical trends, the amount of wood energy consumed in the industrial sector was mainly driven by pulp and paper production. Industrial wood energy production has dropped with declines in pulp and paper production but still accounts for more than half of total U.S. wood energy. Although new public policies may be instituted, energy production from this sector will remain to be contingent on demand for pulp and paper products rather than public incentives. Residential consumption of wood energy shows close association with prices of competing energy sources. Residential consumption of wood energy roughly followed natural gas prices before 1990 and electricity prices after 1990, suggesting substitution of energy sources triggered by cross-price effects. Wood energy consumption in the electric power sector has increased considerably since the mid 1980s. Opportunities for co-firing to replace coal may provide the greatest immediate opportunity for wood utilization in this sector, partly driven by state-level RPS and preferential tax programs [51]. The commercial sector also demonstrated growth in wood energy consumption in the period prior 1990, but has had little variation since then.

The majority of national public policy instruments have targeted the production of biopower. Based on observed data, PURPA was associated with growth in wood energy consumption by the electric power and commercial sectors in the 1980s. In the 1990s up to 2002 there was no significant growth in wood energy because of low fossil fuel prices. Rising oil prices after 2003 subsequently encouraged the establishment of various federal and state regulations and incentives favoring biopower production from woody biomass. The Renewable Energy Systems and Energy Efficiency Improvements Program represents a significant shift in public policy as the PTC was expanded to include open-loop biomass in 2004. The ITC was enacted in 2008. The federal Green Power Purchasing Goal set by the EPACT of 2005 required that 7.5 percent of energy purchased by federal agencies be renewable energy. By December 2009, 36 states had established RPS that required proportions of the energy portfolio to be powered by renewable energy. The federal Government enhanced its incentives for renewable energy by issuing additional CREBs and QECBs in 2008 and 2009, and expanded ITC to renewable energy with a rate as high as 30 percent as an alternatives to PTC in 2009. Grants were also made available as alternative for ITC and PTC.

EISA's renewable fuel targets for motor vehicle cellulosic biofuels were shown to be too ambitious as they were waived by the EPA in 2010 due to lack of existing production capacity [52]. The establishment of the BCAP created greater incentives to wood energy production, in particular to the production of vehicle fuels [26]. Although BCAP effects remain to be assessed, early evidence gathered during the public review period, suggests that this is a complex program to implement with significant monitoring costs. Furthermore, it required major modifications to insure that public payments result in additional levels of wood energy generation and that the program prioritizes the creation of a supply chain for the production of cellulosic fuels. BCAP establishment, annual or match payments have aimed to encourage more landowners to adopt energy crops, yet a temporary 2-year matching program or a maximum of 15-year annual establishment payments for woody crops may not be sufficient to trigger the development of an industrial-capacity flow of biomass material. BCAP will have to be comprehensively examined to determine its net benefits (if any) and how these compare to those potentially yielded by alternative programs. As with the PTC, where a tax credit is offered per energy output, BCAP cellulosic fuel incentives may evolve into a similar approach to minimize transaction costs, oversight and allow the market to identify the most efficient liquid fuel feedstocks (or it

should be phased-out). To an extend this is the approach already taken in the Credit for Production of Cellulosic Biofuel Program that has evidently not been sufficient to promote cellulosic biofuel production. A lack of market response to this tax incentive is indicative that manufacturers are still not in a position to compete with traditional vehicle fossil fuels given existing technology. The inadequacy of financial incentives may also point to the potential to invest in research to enhance technology that can reduce cellulosic fuels production costs. It is noticeable that most public policies promoting wood energy do not have investments in research as a central component. This can be another target of public policy that could yield significant returns.

The review of policy instruments illustrates how the nation has relied primarily on financial incentives to promote greater wood energy generation. In the residential sector, after the tax credit for wood and pellet stoves was made available to residents in 2006, wood energy consumption increased 14 percent or 5 percent per year. The most effective incentives implemented since 2004 appear to be the PTC, CREBs and QECBs. Based on the number of biomass facilities financed by CREBs, it was estimated that the federal loans (CREBs and QECBs) may increase wood energy consumption by the electric power sector by 33 percent once all planned biomass facilities are in operation. Over time, financial incentive tools facilitating reduced production costs based on energy output (e.g. PTC), adoption of technology (e.g. REETC), lower capital cost (e.g. CREBs, QECBs, ITC) have been the most successful to promote greater wood energy utilization. Rules and regulations such as RPS and the Federal Green Power Purchasing Goal create markets for renewable energy but their impact is limited by their specific targets. Nonetheless, these regulatory tools may only motivate power utilities to purchase least-cost renewable energy and may fail to provide incentives to invest in new lower-cost energy production technology.

Besides direct financial incentives and regulatory policy, financial disincentives on competing fossil fuels, public investments in research, and corporate sector partnerships may also be effective in making wood energy more price competitive. Taking an example from Scandinavia, bioenergy comprised 19 and 15 percent of total energy consumption in Finland and Sweden, respectively [53]. Strong policies supporting wood energy use and improving its price competitiveness compared to other energy feedstocks have been identified as a central factor behind this large market share [53–55]. The most effective policy instrument in promoting renewable energy in these two countries has been reported to be heavy taxation of competing fossil fuels [53]. Various cap-and-trade systems proposed to help regulate U.S. carbon emissions would give wood energy (if deemed to have zero greenhouse gas emissions) a comparative advantage to compete with fossil fuels. As suggested by the Biomass Research and Development Board [56] there is a need to invest in technology and systems that can reduce biomass production, recovery and feedstock transportation costs. Current industry voluntary greenhouse gas reduction programs such as the Clean Energy-Environment State Partnership, Climate Leader, Combined Heat and Power Partnership, Energy Star, and Green Power Partnership [57] could also promote greater consumption of woody biomass energy feedstocks.

Stable public incentives and preferential regulations will be needed in the future to maintain or increase current size of the U.S. wood energy sector. Frequent shifts in policy approaches may create uncertainty and stall private investment [58]. For example, recent debate over the carbon neutrality of the use of woody biomass to replace coal, ignited by a report by the Manomet Center for Conservation Sciences [59], ask for further investigation on the net benefits of the utilization of woody biomass as an energy feedstock. Partly as a result of this debate, the EPA issued a three-year moratorium on permit requirements for biomass energy production [60]. This time will serve to revisit and thoroughly assess greenhouse emissions from different biomass sources and energy generating technologies. While the re-assessment of net-zero emissions from woody biomass sources to avoid policy failure and reduce further environmental deterioration is most welcome, changes in public policies are not supportive of efforts aimed at a continuous production of wood -based or other renewable energy.

7. Conclusions

Wood energy accounted for 60 percent of biomass energy, 31 percent of renewable energy and 2 percent of the total energy consumption in the U.S. in 2007. Of the four major U.S. wood energy sectors the industrial sector, primarily comprised of the wood products, pulp and paper industry, accounted for 68 percent of this market. The amount of wood energy consumed in the industrial sector has been mainly linked to paper production and not public policies.

The residential wood energy sector represents about 24 percent of U.S. wood energy consumption. Wood energy tendencies in this sector have been associated to the price of competitive energy sources and since 1990 it has closely followed the same trend of electricity prices. Public incentives such as the REETC can support residential wood energy consumption but past evidence suggests that households' decision to use wood as an energy feedstock for heating will be mostly a function of electricity and probably natural gas prices.

The electricity power sector that accounted for 9 percent of U.S. wood energy consumption has been a direct focus of public policy. Market-based programs such as PURPA's avoided electricity cost, PTC, ITC and CREBs have had a strong impact on electricity sector use of wood energy as suggested by historical trends. In particular, the eligibility of open-loop biomass plants under the PTC favored the greater use of woody materials in this sector. Regulatory policy instruments setting renewable energy targets such as the federal Green Power Purchasing Goal and state RPS have facilitated the use of biomass as an eligible renewable energy feedstock but a significant impact on wood energy remains to be observed as renewable energy target levels grow over time and will also depend on its price competitiveness compared to other renewable energy sources. The commercial sector has been eligible for similar public programs but its share of national wood energy portfolio remains to be small at about 3 percent.

This review showed that the two most important wood energy sectors, industrial and residential, have been the target of the fewer public programs. In the case of the industrial sector this seems a logical approach as the energy produced from the

industry is primarily a byproduct of their manufacturing process and will be little influenced by policies targeting secondary products. The residential sector could potentially receive greater public support as it represents a quarter of national wood energy consumption. It can be expected that future legislation may shift attention from biopower to liquid cellulosic biofuels triggered by controversies over the use of biomass to replace coal and lack of a viable alternative to fossil liquid fuels in the transportation sector.

Overall, most wood energy public policy in the U.S. relies on financial incentives and mandatory targets. Besides them, disincentives on fossil fuels and voluntary programs may also be effective in making wood energy more price competitive and the U.S. should consider their adoption. A continuous public policy commitment to renewable energy is deemed critical for the growth in renewable energy generation. The creation of an uncertain climate towards biomass energy can put a halt on any future wood energy developments, either for biopower or cellulosic liquid fuels. A robust national renewable energy policy that combines financial incentives and disincentives along with regulatory targets will be necessary to maintain or increase current U.S. wood energy consumption. Giving existing commercial technologies wood energy will continue to represent a relatively small part of the total U.S. energy consumption. Nonetheless, it can become an even more important component of a diverse national renewable energy portfolio.

Acknowledgements

This research was supported in part by the Northern Research Station under U.S. Department of Agriculture Forest Service Agreement 09-PA-11242305-143. This publication is not intended to reflect the opinions of this Agency. Any errors remain the responsibility of the authors.

Appendix

Definitions of Acronyms.

Acronyms	Definition
ARRA	American Recovery and Reinvestment Act
CHP	Combined Heat and Power
CREB	The Clean Renewable Energy Bonds
EISA	Energy Independence and Security Act
EPA	U.S. Environmental Protection Agency
EPACT	Energy Policy Act
PJ	Petajoules, or 10^{15} joules
ITC	Investment Tax Credit
kWh	Kilowatt hour
NAICS	North American Industry Code System
PTC	Renewable Energy Production Tax Credit
PURPA	Public Utility Regulatory Policies Act
QECB	Qualified Energy Conservation Bonds
REETC	Residential Energy Efficiency Tax Credit
RESEEIP	Renewable Energy Systems and Energy Efficiency Improvements Program
RPS	Renewable Portfolio Standards

REFERENCES

[1] Aguilar FX, Saunders A. Policy instruments promoting wood to energy uses in the continental United States. J For 2010; 108(3):132–40.
[2] Becker DR, Moseley C, Lee C. Supply chain analysis framework for assessing state-level forest biomass utilization policies in the United States. Biomass Bioenerg 2011;35:1429–39.
[3] DSIRE. Incentives/Policies for renewable energy, http://www.dsireusa.org/incentives/index.cfm?EE=1&RE=1&SPV=0&ST=0&sector=Residential&technology=Biomass&sh=1; 2010.
[4] U.S. Energy Information Administration. Annual Energy Review. USDOE EIA Office of energy markets and end use; 2008. Washington, DC. 2009.
[5] Food and Agriculture Organization of the United Nations. Wood energy, http://www.fao.org/forestry/energy/en/; 2009.
[6] Schlamadinger B, Spitzer J, Kohlmaier GH, Lüdeke M. Carbon balance of bioenergy from logging residues. Biomass Bioenerg 1995;8(4):221–34.
[7] Schwaiger H, Schlamadinger B. The potential of fuelwood to reduce greenhouse gas emissions in Europe. Biomass Bioenerg 1998;15(4–5):369–77.
[8] Hoogwijk M, Faaij A, Van Den Broek R, Berndes G, Gielen D, Turkenburg W. Exploration of the ranges of the global potential of biomass for bioenergy. Biomass Bioenerg 2003; 25(2):119–33.
[9] Tilman D, Hill J, Lehman L. Carbon-negative biofuels from low-input high-diversity grassland biomass. Science 2006; 314(5805):1598–600.
[10] Malmsheimer RW, Heffernan P, Brink S, Crandall D, Deneke F, Galik C, et al. Forest management solutions for mitigating climate change in the United States. J For 2008; 106(3):119–71.
[11] Aguilar FX, Garrett HE. Perspectives of woody biomass for energy: survey of state foresters, state energy biomass contacts, and National Council of Forestry Association executives. J For 2009;107(6):297–306.
[12] Cubbage FW, O'Laughlin J, Bullock III CS. Forest resource policy. New York: John Wiley and Sons; 1993. pp. 562.
[13] U.S. Energy Information Administration. Renewable Energy Annual 2008, http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea_sum.html; 2009.
[14] Perlack RD, Wright LL, Thurhollow AF, Graham RL, Stokes BJ, Erbach DC. Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion-ton annual supply. ORNL/TM-2005/66. Oak Ridge, TN: Oak Ridge National Laboratory; 2005. p. 78.
[15] U.S. Energy Information Administration. Definitions of Energy-Use Sectors and Related Terms, http://www.eia.doe.gov/neic/datadefinitions/sectors25B1.htm; 2010.
[16] U.S. Energy Information Administration. Monthly energy review, November 2009, http://www.eia.gov/FTPROOT/monthlyhistory.htm; 2009.
[17] Illinois Oil and Gas Association. History of Illinois Basin Posted Crude oil prices, http://www.ioga.com/Special/crudeoil_Hist.htm; 2010.
[18] Ince P. Outlook for U.S. Paper and Paperboard sector and wood Fiber supply in North America, Geneva Timber and forest Discussion papers, Recycling, energy and market interaction [Chapter 5]; 2000. New York and Geneva.
[19] Energetics Incorporated Columbia. Energy and environmental Profile of the U.S. Pulp and paper industry. USDOE Office of energy Efficiency and renewable energy industrial technologies program, http://www1.eere.energy.gov/industry/forest/pdfs/pulppaper_profile.pdf; 2005. 2010.

[20] RISI. North American Graphic paper annual historical data-Excerpt, http://www.risiinfo.com/Marketing/ahd/Excerpts/na_graphic.pdf; 2008. 2010.
[21] Song N, Aguilar FX, Shifley SR, Goerndt ME. Analysis of U.S. household wood energy consumption: 1967-2009. University of Missouri. Unpublished.
[22] Hardie IW, Hassan AA. An econometric analysis of residential demand for fuelwood in the United States 180-1981. For Sci 1986;32(4):1001–5.
[23] Howard JL, Westby R. U.S. Forest products annual market review and Prospects, 2005–2008. Res Note FPL-RN-0313. For Prod Lab, USDA Forest Service; 2009.
[24] Duffield JA, Collins K. Evolution of renewable energy policy. Choices 2006;21(1):9–14.
[25] Energy Independence and Security Act of 2007, Pub. L. 110–140, 121 Stat. 1492 (Dec. 2007).
[26] Food, conservation, and energy Act of 2008, Pub. L. 110-246. 122 Stat. 1841 (Jun. 2008).
[27] Public utility regulatory policies Act of 1978, Pub. L. No. 95–617, 92 Stat. 3148 (Oct. 1977).
[28] U.S. Energy Information Administration. Policies to promote non-hydro renewable energy in the United states and selected countries. 2005. Washington, DC: USDOE EIA Office of Coal, Nuclear, Electric and Alternate Fuels; 2005.
[29] Abel A. CRS report for Congress, energy policy Act of 2005, P.L. No. 109–58: electricity Provisions. Order code RL33248; 2006.
[30] Morris G. Biomass energy production in California 2002: update of the California biomass Database. National renewable energy Laboratory Subcontractor report. NREL/SR-510–33111; Dec. 2002.
[31] Energy policy Act of 2005, Pub. L. No. 109–58, 119 Stat. 594 (Aug. 2005).
[32] Energy policy Act of 1992, Pub. L. No. 102–486, 106 Stat. 2776 (Oct. 1992).
[33] American Jobs creation Act of 2004, Pub. L. 108–357, 118 Stat. 1418 (Oct. 2004).
[34] DSIRE. Financial incentives for renewable energy, http://www.dsireusa.org/summarytables/finre.cfm; 2009.
[35] Safe, Accountable, Flexible, efficient transportation Equity Act: a legacy for Users, Pub. L. 109–59, 119 Stat 1714 (Aug. 2005).
[36] Mufson S. Obama Seeks to halt alternative fuel tax credit for paper industry. Wash Post; May 26, 2009.
[37] Willis F. Teetering on the Edge: black liquor tax credit Update, http://www.risiinfo.com/techchannels/papermaking/Teetering-on-the-edge-Black-liquor-tax-credit-update.html; 2010.
[38] American recovery and Reinvestment Act of 2009, Pub. L. 111–5, 123 Stat. 234 (Feb. 2009).
[39] Becker DR, Larson D, Lowell EC. Financial considerations of policy options to enhance biomass utilization for reducing wildfire hazards. For Pol Econ 2009;11(8):628–35.
[40] DSIRE. U.S. Department of Treasury - Renewable energy grants, http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US53F&re=1&ee=0; 2010.
[41] DSIRE. Energy goals and standards for federal government, http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02R&re=1&ee=0; 2010.
[42] U.S. Department of Energy. Annual report to Congress on federal government energy management and conservation programs Fiscal year 2006. Washington, DC: USDOE energy Efficiency and renewable energy federal energy management program; 2008.
[43] Energy Improvement and Extension Act of 2008, Pub. L. 110–343, 122 Stat. 3765 (Oct. 2008).
[44] DSIRE. Clean renewable energy bonds (CREBs), http://www.dsireusa.org/incentives/?State=US&ee=1&re=1; 2009.
[45] Lantz E, Doris E. State Clean energy policies analysis (SCEPA): state tax incentives. National renewable energy Laboratory Subcontractor report. NREL/TP-6A2-46567; Oct. 2009.
[46] U.S. Energy Information Administration. Database of State incentives for renewable and Efficiency. Online at, http://www.dsireusa.org/library/index.cfm?ee=0&RE=1; 2009.
[47] California Public Utilities Commission. Renewables portfolio standard Quarterly report Q1 2010, http://www.cpuc.ca.gov/NR/rdonlyres/7DA38E61-9DB9-4B4E-A59C-D0776AF3B0BB/0/Q12010RPSReporttotheLegislature.pdf; 2010.
[48] Schnepf R, Yacobucci B. Renewable fuel standard (RFS): Overview and Issues. CRS Rep. R40155. U.S. Congress Research Service; 2010. p. 29.
[49] U.S. Federal Register. Biomass crop assistance program; final rule. 7 CFR Part 1450, vol. 75; 2010 (207): 66202–66243.
[50] USDA. The biomass crop assistance program (BCAP) - Final rule Provisions, http://www.fsa.usda.gov/FSA/newsReleases?area=newsroom&subject=landing&topic=pfs&newstype=prfactsheet&type=detail&item=pf_20101021_consv_en_bcap.html; 2011.
[51] Aguilar FX, Goerndt M, Shifley S, Miles P, Song N. Regional assessment of woody biomass physical availability as an energy feedstock for combined combustion in the U.S. northern region. University of Missouri (Unpublished).
[52] National Archive and Record Administration. Federal Registry. 40-CFR part 80. In: No 58, rules and regulations, Part II, Vol. 75. Environmental Protection Agency; 2010. 14669–15320.
[53] Ericsson K, Huttunen S, Nilsson LJ, Svenningsson P. Bioenergy policy and market development in Finland and Sweden. Energ Pol 2004;32(15):1707–21.
[54] Hakkila P. Factors driving the development of forest energy in Finland. Biomass Bioenerg 2006;30:281–8.
[55] Okkonen L. From exogenous to endogenous development in Scottish forestry: the feasibility of small-scale wood energy enterprise. J Environ Plan Manage 2008;51(2):221–32.
[56] U.S. Biomass Research and Development Board. Increasing feedstock production by biofuel, Econcomic drivers, environmental Implications and the Role of research. National agricultural Library Cataloging record: biomass research & development Initiative. HD9502.5. B543; 2008.
[57] U.S. Environmental Protection Agency. Current and near-term greenhouse gas reduction initiatives, http://www.epa.gov/climatechange/policy/neartermghgreduction.html; 2010.
[58] Verbong G, Geels FW, Raven R. Multi-niche analysis of dynamics and policies in Dutch renewable energy innovation journeys (1970-2006): hype-cycles, closed networks and technology-focused learning. Tech Anal Strategic Manage 2008;20(5):555–73.
[59] Manomet Center for Conservation Sciences. Biomass Sustainability and carbon policy Study. NCI-2010-03; 2010. p. 182.
[60] U.S. Environmental Protection Agency. EPA to Defer GHG Permitting requirements for Industries that use Biomass/Three-year Deferral allows for further examination of Scientific and Technical Issues associated with counting these emissions, http://yosemite.epa.gov/opa/admpress.nsf/0/4369C709163915B485257816005971BB; 2011. 2011.