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Engineering economic assessment of whole-house residential wood heating in New York

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ABSTRACT

Wood devices increasingly are being used for residential space heating in New York. Motivations include avoiding high and variable fuel costs, promoting energy independence, mitigating climate change, and stimulating local economic development. In this study, the influence of fuel prices, device costs, and device efficiencies on heating costs was examined. Lifetime costs of alternative heating technologies were calculated for a house in Syracuse, New York. Calculations were repeated to explore discount rates and fuel price projections. Combinations of wood price and device cost and efficiency were identified at which wood is competitive with other fuels. The results suggest that fuel costs drive competitiveness more than capital and installation costs. At typical wood prices, natural gas often is the least expensive option. Many rural areas do not have access to gas, however, and high-efficiency wood-heating devices can be very competitive with heat pumps, propane boilers, and fuel-oil boilers. Availability of low-cost or on-site wood can make wood the least expensive option. However, even "free" wood is not free when the equipment, labor, space and time required are considered. Furthermore, efficiencies of wood devices and their pollutant emissions can differ greatly. High emission rates have led to restrictions on use of specific wood-heating devices in some locations. Improved information and tools should be available to consumers for evaluating the suitability of wood heating for their particular situations. The work presented here is an example of such information.

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1. Introduction

The market share of wood for residential heating in the United States (US) has declined dramatically over the past century [1,2]. For example, between 1940 and 2000, this share fell from 23% to 1.7% at the U.S. level, and from 4.2% to 1.2% in the State of New York (NY). The transition away from wood heating recently has begun to reverse, however. By 2010, the US market share for wood had increased to 2.1%, and the NY market share had nearly doubled to 2%. The escalating and highly variable prices for electricity, natural gas, and fuel oil were factors in the resurgence of wood [3–5]. Faced with an economic recession and some of the highest energy bills in

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memory, many households found relief by turning to wood heating [6–9]. Rising concerns about energy independence and a growing awareness of potential risks of climate change also may have played a role for many households. Wood fares well because it is a domestic resource that typically is considered to be renewable and to have net-zero carbon emissions over its lifecycle. Whether a particular supply of wood is renewable is determined by management practices, however, and the assumption that biofuels are carbon-neutral has been challenged [10]. Given its perceived benefits, some governments have incentivized wood heating by making wood tax exempt or by providing tax credits for the purchase of residential biomass-fueled heating systems [11]. Furthermore, a number of organizations have actively promoted much higher utilization of biomass [12].

Much of the recent increased demand for wood heating has been met by woodstoves and fireplaces. These devices typically are used to supplement oil, gas, propane, and electricity when temperatures are particularly low or fuel prices are high. Consumers also use woodstoves and fireplaces for aesthetic reasons or for zone heating, providing heat only to specific parts of the house when needed. An array of new or improved *whole-house* wood heating technologies has emerged since the late 1990s, however, including high-efficiency indoor wood boilers (HEIWBs) and furnaces, outdoor wood hydronic heaters (OWHHs), and automatic-feeding pellet stoves and boilers. An example of the increasing demand for whole-house wood heating is the sales growth of OWHHs in NY. In 1999, an estimated 606 of these units were sold [13]. By 2008, annual statewide sales had increased to more than 13,000 units [14].

Many considerations arise when determining whether wood heat is a good option for a particular household. The availability of a low-cost, reliable source of seasoned firewood and space for storage are two such considerations. Some households on wooded or rural land may have ample wood supply onsite, and may consider this wood to be "free." However, Burkhard [15] estimated that it would require approximately six person-hours to haul, cut, split, and stack a cord of wood, where a cord is defined as being 4 ft by 4 ft by 8 ft, or 3.62 m^3. Excluding equipment costs and assuming a labor rate of \$8.33 h^{-1}, this free wood would have an intrinsic value of approximately \$13.80 m^{-3}. Physical labor also is required to load firewood into the heating device, which may be seen as a positive or negative, depending on the preferences of the household. Gas, electricity and liquid fuels do not have this requirement and are capable of providing heating on demand.

Environmental considerations are also important in evaluating residential wood heating options. Extraction of wood resources can impact forest ecosystems and water resources [16–18]. Furthermore, wood combustion is a major source of fine particulate matter (PM), a category of air pollutants that has been linked to decreased lung capacity and cancer [13,19–21]. The US EPA recently estimated that residential wood combustion contributes 17% of NY fine PM emissions from anthropogenic sources, nearly as much as is produced by mobile sources (19%) [22]. In response to air quality and health concerns, NY and several other states have introduced rules to address emissions from some high-emitting wood-heating devices [23,24]. These issues are not unique to the US, as recent studies have identified air pollution from wood burning as an emerging issue even in major European capitals such as London, Paris and Berlin [25].

Federal and state environmental agencies are seeking to understand the motivations for the resurgence wood heating devices, as well as the resulting environmental impacts. Perceived cost savings over other fuels is one such motivation. However, limited information and tools are available for households to compare the cost of residential heating options. The calculations used to determine heating costs may be too time consuming or complicated for many consumers. Furthermore, many of the inputs are uncertain and vary both geographically and temporally. For example, heating load is dependent on local climate and building details, such as orientation, foundation, insulation, and windows. Wood prices are a function of local supplies and the costs of competing fuels. The efficiency of a heating device is affected by its size, installation, capacity utilization, and operation.

The US Energy Information Administration (EIA) has developed the Heating Fuel Comparison Calculator, a spreadsheet that can be used to generate an estimate of the annual fuel costs associated with alternative heating devices [26]. While many common heating technologies are represented, a "room heater" is the only wood-heating option. The calculator does not consider capital or installation costs, fuel price projections or variability, or the time value of money. Kroetz and Friedland [27] provided a more detailed analysis of heating options, comparing the lifetime costs of woodstoves to those of fuel oil, natural gas, and propane. Calculations were made using estimated fuel prices in New England, examining both residential and commercial heating applications. The net present value (NPV) of lifetime costs, including capital and fuel costs over a 15-yr device lifetime, was used as the cost metric. For rural residences, the authors recommended replacing electric heating with woodstoves. The study did not evaluate other wood heating devices, and geographic and temporal variability in the prices of wood and other fuels were not considered.

Similar to the Kroetz and Friedland study, the US EPA conducted an engineering economic analysis of wood heating options, comparing their NPV lifetime costs with fuel oil boilers, natural gas boilers, and electric heat pumps [28]. An important conclusion was that fuel costs dominate upfront capital and installation costs. Thus, wood price and device efficiency are critical factors in determining competitiveness. A cursory market survey found advertised wood prices ranging from \$55.20 m^{-3} to \$110 m^{-3}. Efficiencies of wood heating technologies also varied considerably, with tested values ranging from 22% to 80%. These variations suggest that competitiveness is highly dependent on the specific devices being considered and on the local wood market. The study had several limitations that provide opportunities for expansion. For example, it did not explore the impact of fuel price projections and examined only a single discount rate. Furthermore, the EPA study focused on OWHH units, and many of the results were not readily applicable to other wood whole-house heating devices. In the work presented here, the EPA study is expanded to include these additional factors.