Energy 141 (2017) 483–491

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Greenhouse gas emissions of local wood pellet heat from northeastern US forests

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ARTICLE INFO

Article history:
Received 12 April 2017
Received in revised form
1 July 2017
Accepted 7 September 2017
Available online 18 September 2017

Keywords:
Wood pellets
Greenhouse gas
Carbon emissions
Life cycle assessment
Northeastern US forests
Bioenergy

ABSTRACT

We explored greenhouse gas (GHG) implications of locally-sourced and produced wood pellets to heat homes in the US Northern Forest region. Using data from regional pellet industries, forest inventories and harvests, we analyzed pellet GHG emissions across a range of harvest and forest product market scenarios over 50 years. We expanded an existing life cycle assessment (LCA) tool, the Forest Sector Greenhouse Gas Assessment Tool for Maine (ForGATE) to calculate GHG balances associated with the harvest, processing, and use of wood pellets for residential heating vs. alternative heating fuels. Market assumptions and feedstock mix can create diverging GHG emission profiles for pellet heat. Outcomes are predominantly influenced by biogenic carbon fluxes in the forest carbon pool. An industry-average pellet feedstock mix (50% sawmill residues, 50% pulpwood) appeared to generate heat that was at least at parity with fossil-fuel heating alternatives when harvest levels remain unchanged due to pellet production. If harvest levels increase due to pellet production, using pellet heat increased GHG emissions. If baseline harvest levels drop (e.g., following the loss of low-grade markets), GHG emissions from pellet heat would at least remain stable relative to fossil alternatives.

1. Introduction

1.1. Rationale

Wood pellet heat is a new and growing heating alternative in the US and has been proposed as a climate-beneficial energy source to replace fossil-fuels. However, little work has been done to assess this claim. The opportunity for switching to wood pellet heat is particularly great for the Northern Forest region of northern Maine, New Hampshire, Vermont and New York which is home to more than 2 million people who live in rural communities, larger towns, and small cities surrounded by the largest intact forest in the eastern US (1). Around 42% of all energy consumed is for space heating [1] and the predominance is derived from fossil-fuels [2]. New York and the five New England states comprise 88% of the entire US consumption of home heating oil [3], which is a distillate fuel similar to diesel fuel. Though natural gas is used widely for heat throughout the northeastern US, the northern states of Maine, New Hampshire, Vermont, and the northern portion of New York still rely on home heating oil as a heat source (62%, 45%, 43%, and 50% of homes respectively; [4]. Propane and electricity account for the majority of the balance of heating fuel sources in the region.

Use of wood for heat is variable throughout the region, ranging from 17% of homes in Vermont to 8% in New Hampshire and northern New York [4]. Though the use of wood pellets is increasing, cord wood represents almost 82% of wood use for heat in the five-state New England region [5]. Wood pellet heating systems are up to 15% more efficient than non-catalytic cord wood stoves [6] and prices per Gigajoule of energy for pellets are competitive or better than split wood. For instance, pellet fuel for home heating was 12% less expensive than split wood for the same energy generation in Maine as of December 2016 [7].

GHG emissions from residential energy consumption in the New England states are responsible for 18% of the total GHG emissions for the region [8]. The widespread use of home heating oil contributes disproportionately to these emissions because of the low efficiency of heat conversion and high GHG emissions rates per

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https://doi.org/10.1016/j.energy.2017.09.062
0360-5442/

thermal unit relative to other fossil-fuels [9]. In 2014, about 14.8 billion liters of heating oil were sold to residential consumers in New York and the five New England states [3]. An estimate for the broader northeastern US (Maine to Pennsylvania), suggests enough wood is economically available to replace 16% of the liquid fossil-fuels (i.e., home heating oil) used in the residential heating sector [10]. Though some are encouraging movement towards technology such as air-source heat pumps to meet heating needs and GHG reduction goals [11], others are advocating the conversion to modern wood heat systems such as wood pellet stoves and boilers that rely on locally-derived fuel (i.e., wood) and can support forest-based economies hit hard by recent solid wood and pulp and paper mill closures [12]. While forest-based bioenergy can be renewable if harvest does not exceed growth, these systems can also provide GHG benefits compared to fossil-fuel alternatives under specific conditions [13,14].

A declining marketplace for low-grade wood in the Northern Forest region creates a sense of urgency for local forest sector economies to replace these markets or face the further loss of jobs and logging infrastructure that have been essential elements of the economy. In Maine alone, paper mill and biomass electric facility closures since 2014 have resulted in the loss of more than 3.6 million green metric tonnes (MT) of the low-grade wood market for landowners and loggers [15]. Wood pellet manufacturing represents one growing aspect of the forest sector that could be developed to replace a portion of the lost low-grade marketplace. In early 2015, ten pellet manufacturing facilities were in operation within the Northern Forest region, though low oil prices and the warm winter of 2015–2016 forced many to curtail operations or temporarily shut down [16]. To create incentives for converting to wood pellet heating systems, states such as New Hampshire are offering rebates to homeowners of 40% of the installed cost of qualifying new residential bulk-fed, wood-pellet central heating boilers or furnaces [17]. Similar programs exist in Maine, Vermont, and New York [18]. One underlying assumption of these incentive programs, since funding typically comes from the Regional Greenhouse Gas Initiative carbon auction proceeds, is that the conversion to modern wood heat systems results in GHG reductions.

1.2. Wood energy emissions and study purpose

Much of the research conducted to date to study the potential GHG impacts of switching from fossil-fuel derived energy to woody biomass energy has focused on the electricity sector and has not addressed comprehensively the thermal uses of wood [14]. Greenhouse gas emissions implications are often expressed in terms of the carbon "payback period", which is the time required by the forest sequester an equivalent amount of carbon dioxide from woody biomass energy combustion. Modeling has shown that payback periods for electricity uses can be long (e.g., 45–75 years) when harvest rates must be increased to meet the demand of a new wood-consuming facility [13]. But models also show the payback period can be relatively short, especially when the new market creates incentives for landowners to plant trees in previously unforested areas [19]. When modern thermal uses of wood were evaluated, carbon payback times were generally shorter than when wood is used for electricity [13,14]. Greater efficiency of wood for thermal uses compared to electricity as an end use is the key factor in this difference.

To date, only one study we are aware of has looked at the atmospheric implications of switching from fossil-fuel heat sources to wood heat in the northeastern US [13]. This study was focused on one state (Massachusetts) and only looked at wood chips used for industrial thermal and combined heat-and-power outputs and did not evaluate wood pellet systems.

The goal of the study presented below was to explore the GHG impacts of locally sourced, produced, and consumed wood pellets (referred to hereafter as "pellets") for heating applications including both the biogenic and fossil-fuel carbon cycle. The approach included a rigorous LCA framework that considered a range of plausible forest market scenarios to capture an uncertain future.

We focus on a case study area in Maine and discuss the relevance to the broader region through an analysis of survey data from pellet manufacturing facilities throughout Maine, New Hampshire, Vermont, and northern New York.

2. Materials and methods

2.1. Study area

One representative softwood dominated wood supply area in Maine was chosen to evaluate the impacts of adding a pellet manufacturing facility to the forest landscape. The wood supply areas each were defined by an 83 km (50 mile) radius centered on an existing wood pellet manufacturing facility. We queried USDA Forest Service Forest Inventory and Assessment (FIA) data to categorize the current acreage within the radius based on forest cover type, tree diameter size class, and stand density. FIA data also allowed us to categorize forest acreage as available or unavailable for harvest. We categorized the delta between "forest land" total acreage minus "timberland" acreage as "reserve".

Baseline forest sector and alternative future pellet sector silvicultural regimes need to be designated for each forest cover type

Table 1
Harvest acreage allocation to silvicultural regimes as a percentage of total harvestable land base (excluding reserve acreage). The total study area forested landscape was 504,081 ha (1,245,612 acre).

Harvest regime	Reserve (% of total landscape)[a]	Partial harvest[b]	Heavy harvest[c]	Selection harvest[d]	Shelterwood harvest[e]	Clearcut harvest[f]
Current harvest Level	3%	16%	16%	16%	41%	7%
Increased harvest	3%	5%	78%	8%	0%	7%
Low demand	9%	15%	11%	11%	9%	46%

See Hennigar et al. [9] for more details on the silvicultural regimes described below. Totals do not equal 100% due to rounding.

[a] Baseline reserve percentage of total forested land base was determined from USFS FIA acreage summary of study areas.

[b] Partial Harvest regime involves a thin from above (remove trees with a larger diameter at breast height first) harvest entry every 30 years or more when stands reach 23 m^2/ha of Basal Area (BA). Target BA removal was ≤30%.

[c] Heavy Harvest regime is a thin from above harvest of ≥60% of BA every 50 years or more. Harvest entry threshold was 175 m^2/ha of merchantable volume.

[d] Selection Harvest regime is a thin from below (remove trees with a smaller but still merchantable diameter at breast height small first) harvest to create uneven-aged stands with entries every 30 years or more that reduce no more than 30% of the BA.

[e] Shelterwood Harvest regime is two stage process that involves an initial thin from below every 70 years or more that removes ≤60% of the BA. The second harvest entry is a 100% overstory removal 10 years after the first entry.

[f] Clearcut Harvest regime is a 100% removal when merchantable volume reaches 175 m^2/ha (generally every 60 years).