Economic Impact Assessment of Wood Chip Heat in Maine

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EXECUTIVE SUMMARY

Maine could reduce its use of fossil fuels for heating by more than 20% using the quantity of wood chips and sawmill waste that stand-alone biomass electric plants currently burn. Doing so would lower Maine's non-transportation energy CO_2 emissions by around 10 percent, saving about $264 million per year based on current levelized costs of oil and propane. Savings on heating costs would average around $140,000 per heated facility per year. Substituting wood heat for fossil fuel heat would also retain $274 million per year in Maine that now flows out of state to purchase heating oil. Savings on fossil fuels would increase spending in Maine's economy and lead to indirect job creation as high as 4,150 jobs over a 20-year wood boiler lifetime. Installation of wood-chip boilers for heating would also support more than 2,000 jobs over a five-year period. Expanded use of wood boilers would preserve trucking and logging jobs and provide a more efficient use of Maine's energy wood than stand-alone biomass plants.

It would take about 1,900 wood-chip heating installations (0.5 to 3 Megawatts in size) to use the volume of chips and sawmill waste that biomass power plants burn. Installation costs for the new boilers would total about $2.21 billion. If Maine invested in this transition over five years, the payback would take about ten years due to savings on oil and propane— even if costs for fossil fuels remain low.

Wood-chip heat boilers can be installed in a mix of commercial and public buildings, including schools and municipal structures, and could occur as older oil-based heating systems reach the end of their lifetime and require replacement. Therefore, governments at various levels in Maine will need to make large capital expenditures on new heating systems over time, spending much of this $2.21 billion in taxpayer funds anyway. There are also innovative ways to finance wood boilers, such as paying incrementally with money saved on fossil fuel costs. Federal money for wood heating systems may also be available. Efficiency Maine illustrates this potential by providing programs and incentives that leverage significant amounts of private investment in residential high-efficiency wood heating.

Although burning biomass emits CO_2, replacing fossil fuel energy sources with woody biomass can reduce overall emissions if burned efficiently and forest harvesting rates remain unchanged[1]. Burning low-grade wood in high-efficiency heating systems would lower Maine's non-transportation total CO_2 emissions by about 750,000 metric tons per year by displacing heating oil and changing the state's electricity generation emissions profile. This assumes that Maine utilities would replace all stand-alone biomass electricity generation with natural gas[2], a conservative assumption because of projected large-scale wind and solar installations in the New England region. Cutting 750,000 metric tons of CO_2 is equivalent to taking 160,000 cars off the road. Air quality will be maintained by installing electrostatic precipitators (ESPs), which capture 99% of particulates, on new chip boilers.

Biomass electricity plants received nearly $2 billion in above-market subsidies between 1995 and 2015[3] and may continue to need subsidies indefinitely. Rather than continue to subsidize aging and inefficient plants that are nearing the end of their typical lifespan, Maine could instead invest in efficient wood-chip heating systems on a large scale. Doing so would save Maine money, reduce CO_2 emissions, and provide a reliable market for low-grade wood.

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[1] Buchholz, T., J.S. Gunn, and D.S. Saah. In Review. Greenhouse gas emissions of local wood pellet heat from Northeastern US forests.

[2] http://www.pressherald.com/2017/03/12/capacity-of-new-england-power-grid-ample-for-demand/

[3] Central Maine Power testimony to the Joint Standing Committee on Energy, Utilities, and Technology March 28, 2016 (Maine Legislature) http://www.mainelegislature.org/legis/bills/getTestimonyDoc.asp?id=37957

INTRODUCTION

BACKGROUND

Maine recently committed additional taxpayer funds toward supporting existing biomass power plants fueled by forest biomass and sawmill residues. The mechanism for this support was a contract between the Maine Public Utilities Commission (PUC) and biomass electricity generators and used $13.4 million from the State's rainy day fund to pay for above-market electricity costs (State of Maine, 2017). The primary impetus behind the contract is to support elements of the forest products economy, particularly the loggers, sawmills, and truckers involved with producing and delivering forest biomass and sawmill residues (including bark, sawdust, and wood chips). These components of the forest products sector have been particularly impacted by the loss of pulp markets over the last two years.

Biomass power plants in Maine average more than 27 years in age and will reach their estimated replacement age of 40 years within the coming 10 to 16 years. According to Central Maine Power[4], stand-alone biomass electricity plants received nearly $2 billion in above-market subsidies between 1995 and 2015, and they may continue to need subsidies indefinitely. This includes revenue from Maine's Renewable Portfolio Standard, more than 90% of which goes to biomass power plants. According to PUC annual reports, biomass plants received more than $13 million in 2013 and more than $6 million in 2014[5].

There is an alternate pathway that could be supported to consume the forest biomass and sawmill residue currently destined for biomass electricity plants. The development of a decentralized and heat-focused infrastructure in Maine using the same feedstock (wood chips, sawdust, and bark) could provide long-term economic and environmental benefits for Maine.

Maine ranks highest in biomass boiler conversion potential in the eastern U.S. (Ray et al., 2014). Maine's electric utilities serve more than 14,000 customers considered medium or large businesses[6], which represent potential beneficiaries of biomass boiler heat systems. Maine has many public buildings, including 737 schools, dozens of buildings on the 14 public college and university campuses, and 73 State-managed buildings on five state government campuses[7]. Municipal buildings in many of the state's nearly 500 towns include police and fire stations, libraries, and public works buildings. In addition, county buildings such as jails and courthouses could also be converted to biomass boilers. Residential wood pellet applications and combined heat and power systems are complementary to the use of chips in commercial-scale heating installations, but are outside the scope of this work[8].

Below, we present an analysis of the economic and greenhouse gas emissions implications of directing public support for the development of commercial-scale biomass heating systems on a large scale. Results are presented first, with detailed methods following.

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[4] Central Maine Power testimony to the Joint Standing Committee on Energy, Utilities, and Technology, March 28, 2016 (Maine Legislature) http://www.mainelegislature.org/legis/bills/getTestimonyDoc.asp?id=37957

[5] Maine PUC. "Annual Report on New Renewable Resource Portfolio Requirement", 2015 (pp. 7-8) & 2016 (pp. 7-8) editions. Available at http://www.maine.gov/mpuc/legislative/reports.shtml

[6] Maine PUC website. "Electricity Statistics (2010)" http://www.maine.gov/mpuc/electricity/delivery_rates.shtml

[7] State of Maine Bureau of General Services: http://www.maine.gov/bgs/

[8] See related work by Buchholz and Gunn at: https://northernforest.org/programs/modern-wood-heat/wood-pellet-greenhouse-gas-emissions-study

RESULTS

HEATING CAPACITY AND MICROECONOMIC BENEFITS

- Redirecting 2.3 million tons of biomass[9] currently used for electricity to heating uses could replace 23% of Maine's annual heating oil consumption to meet heating needs (Figure 1).
- Current levels of biomass consumption could support a wood-chip heat infrastructure of around 2,860 MW total heating capacity distributed to nearly 1,900 locations (mean boiler size of 1.5 MW per installation). The total number of applicable fossil fuel-fired heat boilers available for a wood chip conversion is difficult to specify. However, for context, Maine has 737 schools and 492 municipalities, each with structures in need of space heat (Maine Department of Education, 2015).
- The average installation cost per biomass heating system would be around $1,177,000 or around $784,000 per MW installed. This is a gross cost. The incremental cost compared to replacing an end-of-life oil or propane boiler would be smaller.

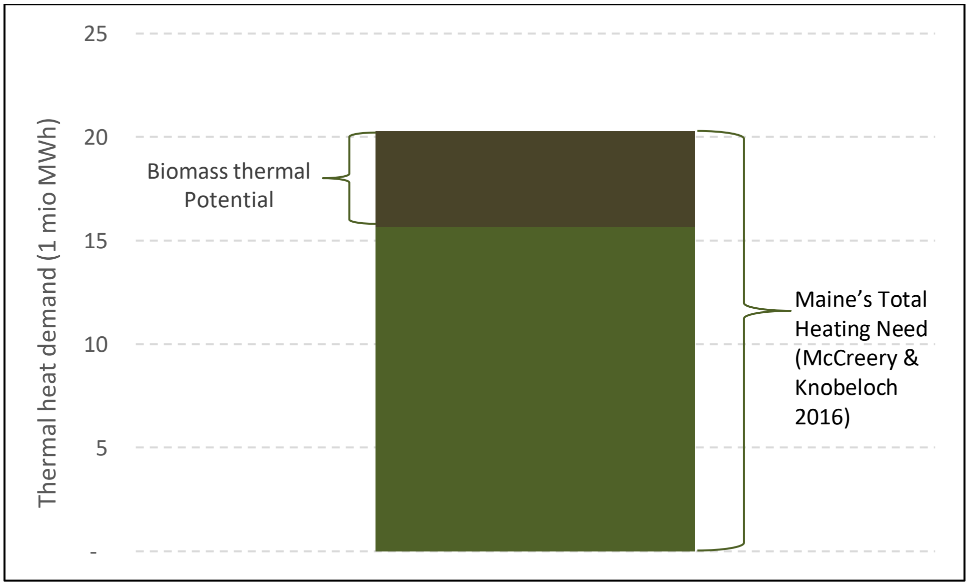

Figure 1. Biomass thermal potential contribution to Maine's heating needs. Converting 2.3 million tons per year of biomass to heat instead of electricity generates 4.6 million MWh of heat (compared to 20.2 million MWh of heat needed statewide). The wood chip based technology explored in this report is applicable to commercial and industrial applications. Wood pellet systems scaled to residential applications are not part of this analysis but could offer additional fossil fuel savings.

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[9] 2.3 million green tons at 40% moisture content; or 2 million green tons at 30% moisture content

MACROECONOMIC BENEFITS

- Installation of wood-chip heating systems to consume current biomass volume would require a gross investment of around $2.21 billion. To put this capital requirement into perspective, Maine spends roughly $1 billion/year on electricity and the commercial sector alone spends $500 million/year on non-electricity heating fuels(Maine Governor's Energy Office, 2014, pp. 10, 17, 22).
- Replacement of out-of-state sourced fossil fuels with in-state sourced woody biomass would retain around $274 million annually in Maine, largely from reduction in heating spending. In contrast, Maine biomass power plants spend $115 million annually in Maine (State of Maine, 2016).
- Biomass heating facility operators would save around $264 million annually on heating costs or an average of $140,000 per year per installation. The $2.21 billion installation costs would be offset within ten years through these annual savings in fuel costs (Figure 2). This trajectory would result in accumulated savings of more than $1 billion within 15 years.
- While a large fraction of biomass electricity costs is retained in-state due to a Maine-based wood chip supply chain, we estimate that Maine ratepayers currently transfer at least $5 million annually to out-of-state utility owners (see Methods below).

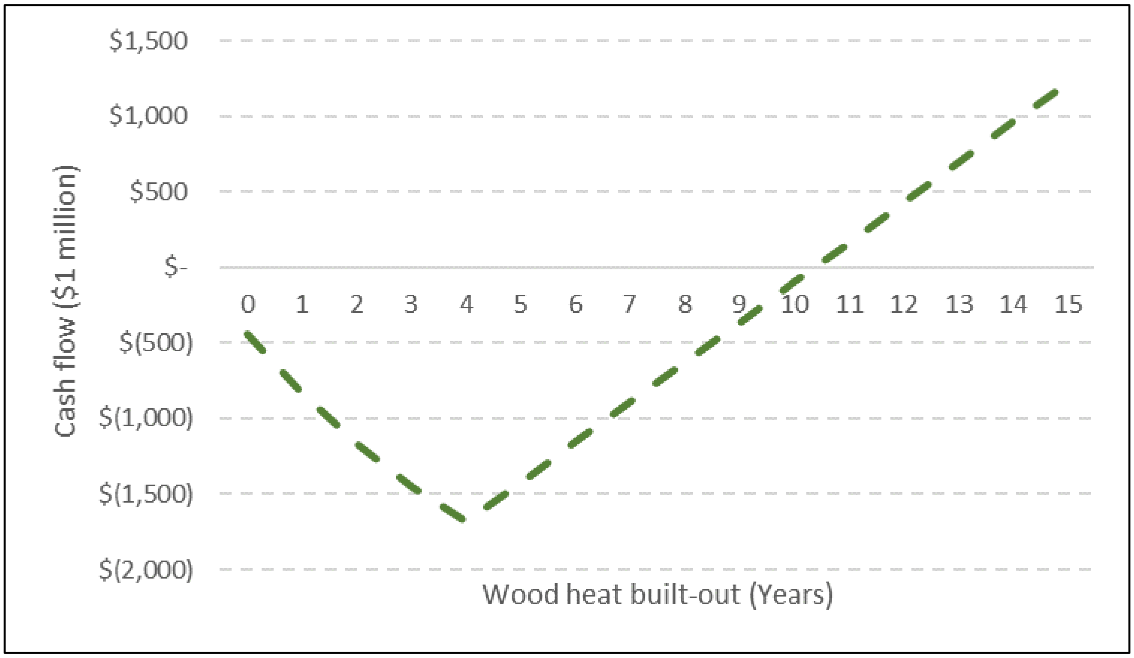

Figure 2: Installation investment payback for heating systems in Maine consuming around 2.8 million green tons of wood chips each year (Table 1) and assuming a gradual conversion of boiler systems over five years.

JOB CREATION BENEFITS

- Construction jobs for installing wood-chip heating systems are in the range of 10,700 job years or 2,140 full-time jobs sustained over a five-year period (Figure 2), assuming an equal five-year time period to convert 1,870 heating units.
- Maintenance jobs to operate the wood-chip boilers would be in the range of 570 FTE, potentially slightly higher than maintenance for less labor-intensive fossil fuel heating systems currently installed.
- Both construction and maintenance jobs for wood-chip heating systems would replace the 148 jobs currently provided by biomass power plants in Maine (see Table 1 in Methods below).
- The avoidance of out-of-state payments for fossil fuels would increase spending in the Maine economy and the indirect job creation through the state economy could be as high as 4,150 FTEs over a 20-year wood-chip boiler lifetime (Connolly, Lund, & Mathiesen, 2016). These jobs would be created in addition to the 900 FTEs retained in Maine's wood chip supply chain currently serving Maine's biomass power plants (State of Maine, 2016).

CLIMATE BENEFITS

- We calculated an aggregated fossil fuel heat CO_2 emissions profile of 0.3025 Mg CO2/MWh_{net}.
- Assuming no change in harvest activities or practices, diverting current wood chip supply from biomass power plants towards wood-chip heating systems would result in a reduction of annual CO_2 emissions of around 754,000 Mg CO_2 (Figure 3).
- This represents a 10% reduction of the statewide total non-transportation energy-related emissions (US Energy Information Administration, 2017). Expressed differently, the annual CO_2 emissions savings would equal the effect of taking more than 160,000 vehicles off the road (assuming average annual passenger vehicle CO_2 emissions of 4.7 Mg CO_2; US Environmental Protection Agency, 2014).

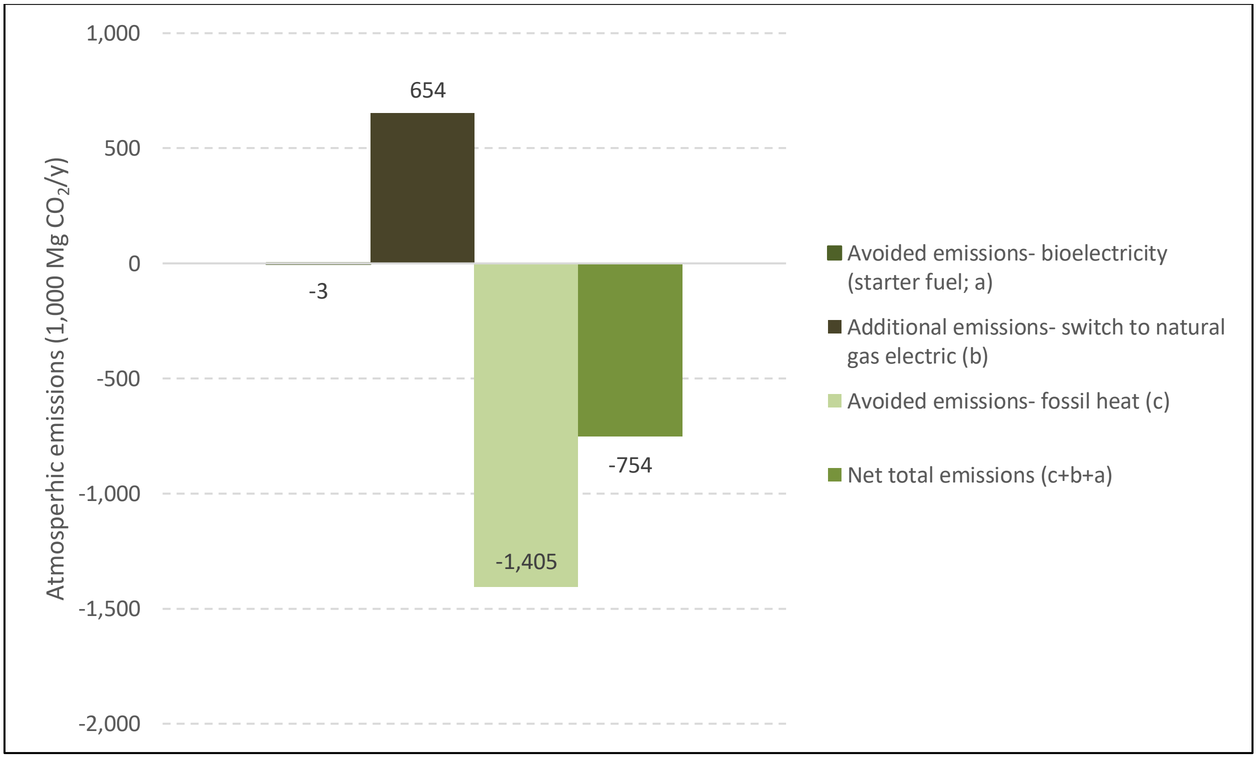

Figure 3. Climate benefits: wood electricity to wood heat switch.

AIR QUALITY IMPACTS

- The installation of ESPs results in the collection of more than 99% of particulates (NESCAUM 2016, p182).
- We priced installation and maintenance costs for ESPs into the financial analysis of installing new wood-chip boilers.

METHODS

WOOD HEAT VS. WOOD ELECTRICITY— WOOD CHIP AND FOSSIL FUEL ASSUMPTIONS

McCreery & Knobeloch (2016) identified a sample of 240 existing fossil fuel boilers in Maine that averaged 1.5 MW for a wood fuel conversion system. Our calculations assume the same average installation size. We further assumed that wood chip systems would need to be at least 0.5 MW in size with smaller systems typically fed by wood pellets (McCreery & Knobeloch, 2016). These systems would burn “in-woods” chips. Some changes in chipping and processing of forestry residuals to produce consistent chip size would likely be helpful to heating system operators. With proper design and staffing to accommodate increased ash loads, these types of heating systems would be able to burn bark waste from saw mills as part of their fuel mix if system operators wished to take advantage of this waste stream. These systems would burn “in-woods” chips that can be produced by chipping otherwise non-merchantable material directly from forest operations. While screening forestry residuals to produce consistent chip size can be helpful to heating system operators, it is not necessary with the proper system design. With slightly more frequent de-ashing schedules to accommodate increased ash loads, these types of heating systems would be able to burn bark waste from saw mills as part of their fuel mix if system operators wished to take advantage of this waste stream (Andrew Haden, Wisewood Energy, pers. com., September 2017). We set the upper limit at 3 MW, which would be a typical size for a larger system similar to what would be expected on a university campus. To evaluate the scaled installation costs, we developed a distribution of system sizes based on the assumption that 30% of all systems would be within two standard variations of the average installation size (Figure 4 and Table 2 below). Residential heat was not considered due to its more demanding feedstock requirements.

To calculate total installed capacity for a given wood chip conversion, we assumed a peak capacity factor of 77%, a mean load of 30%, and a system size of 125% of the peak load (McCreery & Knobeloch, 2016). These assumptions resulted in a system capacity factor of 27% based on the installed size. Detailed heating assumptions for both biomass and fossil fuel systems are provided in Table 3 below.

We assumed that 85% of all new wood-chip boilers would replace fuel oil with the remainder replacing propane installations.

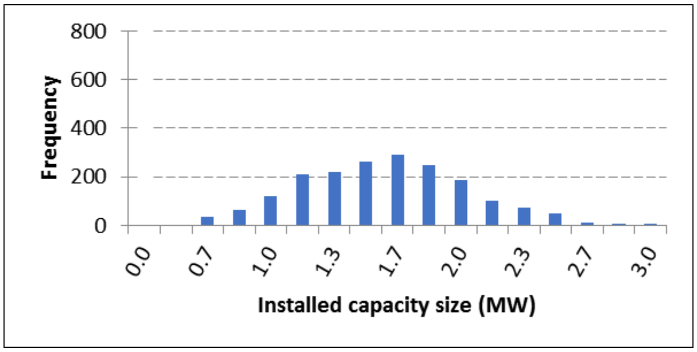

Figure 4: Distribution chart for installed wood-chip boilers. We assumed a mean installation size of 1.0 MW, a coefficient of variation of 30%, and a minimum size of 0.5 MW per unit. A Monte Carlo simulation of up to 5,000 runs to estimate the distribution of unit sizes resulted in a total population size of around 1,870 total units installed.

Table 1: Maine wood chip electricity generation assumptions (Maine Department of Environmental Protection, 2017, and additional sources)

Plant name	Owner	Age (y)	Size	Output	Efficiency[d]	Biomass use[a]	Jobs	Capacity factor	Starter fuel type	Starter fuel use
		y	MW_{gross}	MWh_{net}/y	%	1,000 tons/y	FTE	%		gallons/y
Jonesboro	Stored Solar	30	24.5[b]	197[d]	23%	269	20[b]	92%	Propane	250
West Enfield	Stored Solar	30	24.5[b]	197[d]	23%	269	24[b]	92%	Propane	250
Ashland	ReEnergy	24	39	284[c]	23%	436	25	92%[e]	Fuel oil	429[f]
Livermore	ReEnergy	25	39.6	284[c]	23%	442	25	91%[e]	Fuel oil	434[f]
Stratton	ReEnergy	28	48[c]	355[c]	24%	507	31	94%[e]	Fuel oil	498
Fort Fairfield	ReEnergy	30	37[c]	260[c]	24%	389	24	89%[e]	Fuel oil	382[f]
Total[g]			**213**	**1,577**		**2,312**	**148**			

[a]) Green tons at 40% moisture content on a wet basis. Calculation based on plant-specific numbers detailed in Air Emission Licenses (Maine Department of Environmental Protection, 2017). For comparison, the Maine Forest Service (Maine Forest Service, 2015) indicates that around three million green tons of biomass chips were processed in Maine in 2014 (Doran, 2016), the last year when all six biomass plants were online throughout the year. The report does not specify the moisture content of the green ton unit chosen.

[b]) Ricker & Staff, 2017

[c]) ReEnergy Holdings, 2017

[d]) Calculated based on other inputs in Table 3

[e]) Assuming a 10% internal energy demand

[f]) Assuming the same size to starter fuel ratio as for Stratton

[g]) May not sum to total due to rounding

Table 2: Wood-chip heating systems installed: Monte Carlo simulation inputs and results

	Unit	Measure
Input variables		
Mean boiler size (max. range: 0.5-3.0)	MW	1.5
Coefficient of variation	%	30%
Boiler size range for 68% (two standard deviations)	MW	1.05 to 1.95
Output variables		
Total installed capacity	MW	2,860
Total locations	N	1,870
Total heat (net) generated	GWh_{net}	4,647
Total Maine fossil fuel heat demand replaced	%	23%

Table 3: Commercial heating assumptions for fossil-fuel and wood-chip systems

Fuel	**Embodied CO_2 emissions**	**Energy density**	**Thermal conversion efficiency**	**Fuel cost**		**Cost-share retained in-state**
	$\text{Mg/MWh}_{\text{HHV}}$	MWh_{HHV} per unit	%		$\$/\text{MWh}_{\text{HHV}}$	%
Nat gas	0.1797[a]	0.0293/ therm[c]	80% (43% elec.[f])	$1.5/therm[g]	$51	9%[j]
Fuel oil	0.2473[a]	0.0406/g[c]	80%	$2.6/g[h]	$65	27%[k]
Propane	0.2119[a]	0.0268/g[c]	80%	$1.7/g[h]	$64	27%[l]
Wood chips	0.3471[b]	4.7855/ton[d]	70%	$40/ton[i]	$17	100%

[a]) US Energy Information Administration, 2016

[b]) Assuming 19 GJ per Mg wood chips at 0% moisture, 0.5 Mg C per Mg wood chips and 3.667 Mg CO_2/Mg wood chips

[c]) US Energy Information Administration, 2014

[d]) Short green tons, assuming 50% moisture content

[f]) US average electric conversion efficiency for natural gas plants in 2015 (US Energy Information Administration, 2016d)

[g]) Maine Governor’s Energy Office, 2017

[h]) Hornby, 2016

[i]) McCreery & Knobeloch, 2016

[j]) Assume 1/3 of the fraction as for fuel oil

[k]) US Energy Information Administration, 2016a

[l]) Assume same fraction as for fuel oil

MACROECONOMIC AND JOB ASSUMPTIONS

We calculated wood-chip system installation costs based on Formula 1 (Blanco et al., 2015). This formula assumes that a current system is retrofitted and no new buildings (besides wood chip storage) or distribution systems have to be installed.

$$\text{Installation costs (\$)} = (\$1500-122*LN(MW_{installed}*1000))*MW_{installed}*1000 \qquad \textbf{(Formula 1)}$$

The major reporting metrics for a baseline vs. alternative future scenario is US$ retained in Maine and jobs provided.

Table 4 provides an overview of construction cost and job estimates, as well as low and high estimates for wood-chip system operations. Costs for air emissions control were priced in separately (see 'Air quality impacts' methods section below). Estimates for construction jobs provided in Table 4 are lower-end estimates. Other sources suggest two (e.g., Cambero & Sowlati, 2016) to three (e.g., Malone et al., 2014) times as many construction jobs created from a fuel switch program. Forest sector jobs and revenue streams from procuring and delivering forest biomass and sawmill residues to the roadside are not considered but assumed to be left unchanged. We do not consider additional costs from building of new natural gas (or other electric) plants because existing plants in New England could handle the additional electricity load (Writer, 2017). Additional construction and maintenance assumptions are provided in Table 4.

Table 4: Assumptions on wood-chip heat installation costs and direct job creation. Installation costs are based on Blanco et al. (2015) and Formula 1. For air emission control cost estimates see methods section 'Air quality impacts' below.

Size	Construction cost[a]		Installation jobs		Maintenance jobs	
$MW_{installed}$	$1,000	$1,000/MW	Job years[b]	Job years/MW	FTE[c] (low)	FTE[d] (high)
0.5	$370	$740,000	2.3	4.6	0.1	0.2
1	$660	$660,000	4.1	4.1	0.2	0.3
1.5	$910	$606,667	5.7	3.8	0.3	0.5
2	$1,150	$575,000	7.2	3.6	0.4	0.6
2.5	$1,360	$544,000	8.5	3.4	0.5	0.8
3	$1,570	$523,333	9.8	3.3	0.6	0.9

[a]) Retrofit and heat application costs only excluding new buildings (except wood chip storage), district heating infrastructure or non-heat applications (e.g., cooling, combined heat and power, etc.)

[b]) Based on Blanco et al. (2015); assuming 6.22 job years per $1 million spent

[c]) Based on Blanco et al. (2015); assuming 0.2 FTE per MW in boiler size

[d]) Based on Cambero & Sowlati (2016); assuming 0.6 FTE for a 2 MW boiler

Other assumptions derived from the *Final report of the commission to study the economic, environmental and energy benefits of the Maine biomass industry* (State of Maine, 2016):

- $ leaving Maine annually for oil = $700,000,000/year
- Total spent on oil = $897,435,897/year

Induced jobs: We assume that 74% of 65 job years or 48 job years are created from fossil fuel savings for every $1 million spent (Malone et al., 2014). In other words, 48 job years are created for every $1 million not transferred to out-of-state entities as payment for fossil fuels.

Job numbers in general: The job numbers included in this report do not reflect the loss of maintenance jobs at the biomass plants and do not consider creation of jobs for building new electric generation capacity since we assume that the natural gas plants in the Northeast currently could compensate for the loss of the 213 MW_{gross} biomass plant capacity (Writer, 2017).

The oldest biomass electric plants in Maine are 30 years old (Table 1). Therefore, the plants are not written-off since biomass plant lifetime is assumed to be 40 years (Connolly et al., 2016). We estimate that the ownership profits correspond to 20% of electricity production capital costs (Table 5). The ownership profit is the fraction of the total electricity production costs that are the net gain allocated to the owner of a power plant.

Since both Stored Solar (owned by the French Company Capergy) and ReEnergy Holdings LLC (a portfolio company of Riverstone Holdings LLC) are owned by out-of-state entities we assumed that ownership profits would leave the state.

Table 5: Calculating the share of power plant owner profits as a fraction of the of electricity price

Variables	Unit	Measure	Source
Input variables			
Wholesale electricity price	$/MWh	$34.71	ISO New England (2017)
Levelized capital cost share - biomass	%	48%	Institute for Energy Research (2017)
Owner share of capital cost share	%	20%	US Energy Information Administration (2016a)
Output variables			
Profit to power plant owner	$/MWh	$3.32	

CLIMATE IMPACT ASSUMPTIONS

We assume that harvest activities do not change significantly and wood chip demand simply reflects diversion from biomass electric to heat. We exclude upstream CO_2 emissions (e.g., pre-processing, trucking) and assume the same CO_2 emissions for the distribution of wood heat vs. fossil fuel heat (i.e., trucking). Natural gas emissions do not include methane lost during distribution, which can be a significant greenhouse gas source (Alvarez, Pacala, Winebrake, Chameides, & Hamburg, 2012). We also conservatively assume that natural gas electric replaces biomass and *not* other renewables or a Maine portfolio equivalent. Climate benefits, represented as total avoided CO_2 emissions/year, are calculated using the variables described in Table 6 below.

Table 6: Climate benefits: wood electricity to wood heat switch

Variable	Unit	Measure
Avoided emissions—bioelectricity (starter fuel; a)	1,000 Mg CO_2/y	- 3
Additional emissions—switch to natural gas electric (b)	1,000 Mg CO_2/y	654
Avoided emissions—fossil heat (c)	1,000 Mg CO_2/y	- 1,405
Net total emissions (c+b+a)	1,000 Mg CO_2/y	**- 754**

AIR QUALITY IMPACTS

Particulate emissions from wood chip boilers can be cost-effectively controlled through best available control technologies such as electrostatic precipitators (ESP). ESPs collect more than 99% of particulates (NESCAUM, 2016, p. 182). Being widely used in Europe for biomass applications, these systems are recommended for the Northeast (BERC, 2011). ESPs have a successful regional track record (e.g., Tong, Yang, Hopke, & Zhang, 2017) for wood boilers of the size discussed in this report. Costs for ESPs in the boiler size range relevant for this report are estimated to be \$150k/MW (i.e., \$225k for the average 1.5 MW boiler; see also NESCAUM, 2008) with annual maintenance costs of \$1.5k/MW (see also NESCAUM, 2016, p. 182). Both installation and maintenance costs for ESPs were considered in the financial analysis. Maintenance costs for ESPs were discounted over 20 years at an annual discount rate of 3% and priced into the installation costs.

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