Emissions and biomass energy in Northeast Minnesota

Air quality impacts of biomass energy

Using locally-grown forest biomass for energy is of growing interest in northern Minnesota because of its potential to increase energy independence, lower carbon dioxide in the atmosphere, and reduce buildup of fire-prone materials in forests. This fact sheet focuses on expected air emissions of bio-energy projects being considered in Cook County. It is part of a larger study on the feasibility, impacts, and social support for converting from fossil fuels to forest biomass energy. Other fact sheets in this series describe technical and economic aspects of biomass combustion systems, their wood fuel demands and local supplies, and the environmental impact of biomass harvest. A full report of the study by Dovetail Partners will be available in December, 2012.

Air emissions of energy production

All energy production – whether from fossil fuel sources (petroleum, coal, and natural gas) or non-fossil sources (hydroelectric, nuclear, geothermal, solar, wind, wood, and waste) – impacts air and the larger environment. Air emissions can be categorized as direct (on-site emissions produced at the power station) or as indirect (covering all emissions generated throughout the entire life cycle of energy production and use). Sorting out the overall impact of a given energy system is challenging, involving different fuel types, equipment, pollution controls, and other factors. Per unit of energy, forest biomass energy generates lower emissions than fossil fuels of some air pollutants, and higher levels of others. Locally harvested wood energy does have an advantage in avoiding emissions and environmental impacts associated with activities like offshore drilling, fracking, oil-shale mining, and international transportation systems. Widespread air pollutants are produced by burning fuels are summarized in Table 1.

Direct Emissions

Combustion is the largest source of emissions in the energy production process. Direct, on-site emissions are determined by fuels used, production equipment, and pollution controls.

- **Fuels:** Clean, dry wood fuels deliver superior energy efficiency and are environmentally better than dirty, wet fuels. Emissions are especially dependent on moisture content and percentage of bark. Overall, uniformly-sized fuels provide greater heating value, more uniform burning, lower emissions, and less need for boiler maintenance than wet, dirty, non-uniform fuels[1].
- **Production equipment:** Modern, high-efficiency equipment and optimal size are crucial factors in controlling combustion emissions. For residential scale systems, EPA-certified wood stoves emit 70 percent less particle pollution and are approximately 50 percent more efficient than wood stoves manufactured before 1990[2]. Larger, district heating systems should focus on high-density areas (high energy demand and short piping distances) and use automatic rather than manually-fed boiler systems. Balancing all factors, the largest scale does not necessarily translate to lowest environmental impact. Instead, systems engineered to optimize energy use density and energy transport distance have been found to have the lowest overall impact.
- **Pollution control**: Technologies are available that significantly reduce hazardous emissions. For instance, electrostatic precipitators reduce particulate emissions from combustion of wet forest residue to 13% of uncontrolled emissions, significantly below other wood fuels. Similar devices used with dry fuels can likewise substantially reduce particulate emissions.

Stationary sources of air pollution are regulated by Minnesota Pollution Control Agency under the federal Clean Air Act. Major facilities with a potential to emit (PTE) more than certain threshold amounts of any regulated pollutant must obtain an individual air quality permit. Facilities with emissions below these standard thresh-

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Table 1. Air pollutants produced during the combustion of fuels.

Sulfur dioxide (SO_2)	Acidic gas formed primarily by coal, oil, and diesel combustion. Contributes to fine particulate pollution and acid rain, which can damage lakes, buildings, and plants. High concentrations can affect breathing, cause respiratory illnesses, and aggravate existing cardiovascular diseases.
Nitrogen oxides (NO_X)	Acidic gases (nitrogen dioxide, nitrous acid, and nitric acid) produced by burning fuels at high temperatures (motor vehicles and stationary combustion sources such as electric utilities and industrial boilers). Contributes to ozone and acid rain and adversely impacts respiratory system.
Particulate matter (PM)	Very fine particles, including dust and smoke formed when coal, wood, or oil are burned. Airborne particles can cause haze and lower visibility and the smallest sizes, including PM10, are considered harmful to respiratory health. Wood fuels produce significantly higher particulate matter than fuel oil and natural gas, however modern pollution equipment can all but eliminate PM from smokestacks.
Carbon monoxide (CO)	Colorless, odorless gas produced by incomplete burning of carbon-based fuels, including gasoline, oil, and wood. Approximately 87% of MN emissions are from on-road and off-road vehicle use; approximately 4.8% from residential wood burning. If inhaled, interferes with oxygen absorption in blood and can be harmful to people with heart, lung, and circulatory system diseases.
Methane (CH_4)	Chemical compound that is the main component of natural gas, and is burned as a fuel for electrical generation. A major source of methane is geological (coal) deposits. It is a potent greenhouse gas, with 25 times more global warming potential than CO2. Although it is not toxic, it is highly flammable.
Volatile organic compound (VOC)	A large variety of chemical compounds, including methane, benzene and formaldehyde, some occur naturally or are human-made (paints, protective coatings, fossil fuel combustion). VOCs are major contributors to ground-level ozone (smog) which damages trees and other vegetation and increases susceptibility to respiratory problems.
Polycyclic aromatic hydrocarbons (PAHs)	Emissions resulting from incomplete combustion of wood. Sources of PAHs include home heating fuels, tobacco smoke, and vehicle exhaust. High levels of PAHs increase risk of cancer and asthma, especially in children. EPA-certified stoves and pellet stoves have much lower emissions than conventional stoves built before 1990.
Carbon dioxide (CO_2)	A chemical compound occurring naturally throughout ecosystem. The rapid increase of CO2 in the atmosphere - produced by combustion of fossil fuels used in electricity production, transportation, and industry – is the major driver in climate warming. See below for discussion of biogenic and fossil carbon dioxide.

olds acquire an Option D registration air permit that requires less record-keeping. Table 2 shows direct, on-site emissions estimates of biomass energy options being considered in Grand Marais. Estimates are based on a number of source studies[3] and are not specific to combustion equipment used or moisture content of fuels. Estimates do not include hauling and logging.

All options using automatic feeding systems are within Option D emissions limits. Emissions of PAH and PM could become problematic if emissions limits are tightened or should the number of people relying on wood stoves for heat increase significantly in the future. These emissions could increase when heating with individual wood stoves because of incomplete combustion, intermittent operation, and lack of emission controls. Generating heat through district energy systems lend themselves to installation of automatic feeding systems and pollution control equipment that increase efficiency and reduce or virtually eliminate emissions of a number of pollutants.

Table 3 compares emissions produced by Grand Marais' largest option with emissions from producing equivalent heat from wood stoves or propane generators. To show scale of operation, total emissions from the coal-fired facility at Taconite Harbor are also shown.

Indirect, Life Cycle Analysis

Full life cycle analyses consider all aspects of energy systems, including the manufacture and installation of combustion and distribution equipment, mining, extraction and transport of energy raw materials, energy production, disposal of ash, and end of life issues. The so-called "cradle-to-grave" impacts of Grand Marais bioenergy options have been calculated based on published studies of life cycle and at-combustion site impacts of wood energy systems compared to conventional fossil fuel systems.

For forest biomass energy, local timber harvest and hauling wood are an additional source of emissions. Diesel fuel and lubricant consumption for these activities would increase emissions of most compounds by less than 1% but of CO_2, SOx, and NOx by much larger percentages. Inefficiencies caused by transmission losses from aging or insufficiently insulated piping can also result in higher emissions in district energy systems.

In all scenarios considered, significant impacts for wood pellet and fossil fuel options would occur far outside the local area. The magnitude of these would depend upon a number of factors. For pellets, these would include hauling distance and the type of fuel

Table 2. Estimates of direct, on-site air emissions[1] of biomass energy options (short tons/year) based on reported emissions per MMBtu. *(Note: one short ton is equal to 2000 lbs.)*

Pollutant		SO_2	NO_X	PM_{10}	CO	CH_4	VOC	PAH	Fossil CO_2
Regulatory thresholds									
Standard permit (PTE)[2]		50	100	25	100	---	100	---	100,000
Option D permit[3]		50	50	50	50	---	50	---	100,000
Configurations									
Five hundred supplemental single-family stoves, each 35 MMBtu.[4]	Cordwood	0.36	1.81	13.59	127.29	14.95	62.93	0.69	---
	Pellets	0.36	1.81	2.49	22.66	0.14	3.97	0.00	---
Option 1 (M1): District heat for small resort or business cluster. Annual heat load 5,200 MMBtu.	Chips[5]	0.14	0.87	0.62	2.15	0.12	0.21	0.24	---
	Pellets	0.14	0.58	0.34	1.18	0.05	0.07	0.03	---
Option 2 (L3): District heat for Grand Marais public buildings north of 5th Street N plus courthouse. Annual heat load 11,796 MMBtu.	Chips	0.31	1.93	1.39	4.85	0.28	0.49	0.55	---
	Pellets	0.31	1.32	0.77	2.67	0.12	0.16	0.07	---
Option 3 (L6): District heat for Grand Marais public buildings (above) and business district. Annual heat load 30,562 MMBtu	Chips	0.81	5.10	3.64	12.57	0.72	1.26	1.42	---
	Pellets	0.81	3.42	2.00	6.91	0.31	0.42	0.18	---
Option 4 (Hybrid): Combination of Options 3 and 4 (largest users only). Annual heat load 24,186	Chips	0.64	4.04	2.88	9.95	0.57	1.00	1.12	---
	Pellets	0.64	2.71	1.58	5.47	0.25	0.34	0.14	---

[1]*Data obtained from average of Johansson et al. (2004), USEPA (2005), and the European Environment Agency (2009) (Tables 7 and 16), with supplemental data from IPCC Guidelines for National Greenhouse Gas Inventories Reference Manual. Data for fossil fuels from USEPA Aggregated Emissions Factors. See discussion below on fossil versus biogenic carbon dioxide.*

[2]*Potential to emit*

[3]*Actual emissions*

[4]*Assumes EPA-certified stove*

[5]*All district heat options assume automatic feeding systems with either clean chips or hog fuel.*

used in drying wood in the pellet manufacturing process. Although wood pellets have substantially lower environmental impact at the local level, life cycle emissions cause them to have higher overall environmental impacts per unit of heat than other forms of wood fuels. When emissions of fossil fuels related to extraction, processing, and transportation are considered, total life cycle impacts increase by 30-50%[4].

Carbon dioxide emissions and sequestration

A major driver for replacing fossil fuels with forest biomass energy is the reduction of carbon dioxide (CO_2). Life cycle analyses of biomass energy typically separate "fossil CO_2" from "biogenic CO_2". Biogenic CO_2 refers to the gases absorbed and released by plants as they grow, leaf out, and die. On the other hand, fossil CO_2 is from carbon geologically stored for millions of years that is released when fossil fuels are burned. The addition of billions of tons of fossil CO_2 is considered the largest contributor to global warming. In contrast, burning wood instead of fossil fuels is often considered carbon-neutral because it avoids new releases of geologically-stored carbon. Carbon-neutrality is also based on the premise that forests are growing and storing more biogenic carbon than is being released through mortality or harvest. Annual growth of forest species of northern and northeastern Minnesota far exceeds annual removal.

Per unit of energy (mmBtu), biomass emits more carbon during combustion because it is a less concentrated fuel than coal, natural gas, or oil. When the full life cycle of

Table 3. Comparison of emissions of potential and existing facilities in region (short tons/year), including harvest and transportation.

Emission	30,562 MMBtu Annual Heat Demand					Taconite Harbor, Minnesota Power (2003-04 averages)
	Automatic Wood Boiler, using chips	Wood Boiler using pellets	Equivalent number of wood stoves using cordwood		Propane Generator	
			Worst case	Best case		
SO_2	1.1	1.0	1.2	1.2	0.02	5,538
NO_x	7.4	4.8	8.1	6.7	2.6	3,373
PM_{10}	3.9	2.2	57.9	28.2	0.1	291
CO	13.5	7.4	427.1	261.2	1.5	2,875
CH_4	0.7	0.3	117.6	30.5	0.04	17.0
VOC	1.9	0.5	216.1	128.6	.20	--
PAH	1.4	0.2	1.4	1.4	<0.001	0
CO_2 fossil	151.8	91.1	227.8	227.8	2,636.5	1,752,752

energy production is considered (rather than emissions at power stations only), energy generated from wood results in very low GHG emissions compared to alternatives. For combined heat-and-power (CHP) systems, GHG emissions are lowest for wood in the high efficiency systems, and behind only wind, hydrogen, and biogas systems in the low efficiency systems. Comparing space heating systems, GHG emissions were found to be lowest for wood among all systems examined. Wood pellets produced from short rotation tree plantations have the highest GHG emissions of all wood-based fuels.

[1]*Bowyer, 2012*
[2]*http://www.dovetailinc.org/files/HomeHeatingWithWood.pdf*
[3]*Bowyer, 2012*
[4]*ibid*
[5]*MN DNR, 2012*

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