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**AIR QUALITY EFFECTS OF  
THE RUSSELL BIOMASS PROJECT  
COMPARED TO RESIDENTIAL WOODSTOVES  
MAY 25, 2007**

**Emission Rates**

The starting point for a comparison to Russell Biomass of wood stove emissions and air quality impacts is to ascertain the emissions from different stove types and the Russell Biomass plant. Because of its superior combustion conditions the Russell Biomass Project will be approximately 100 times cleaner than an EPA-certified woodstove in terms of the emissions per pound of wood burned or million BTUs<sup>1</sup> of heat input. EPA considers one pound of wood (on a dry basis) to typically have a heating value of 8,500 BTUs. Air pollution regulations generally measure emissions per million BTUs of heat input. This memo focuses on carbon monoxide (CO) and fine particulate matter (PM<sub>2.5</sub>) emissions and air quality impacts. These are the air pollutants emitted from wood burning in the largest quantities, for which air quality standards have been established. Here are the facts for different types of woodstoves and for the Russell Biomass Project:

	Carbon Monoxide (CO) <u>(lb/million BTU)</u>	Particulate Matter (PM) <u>(lb/million BTU)</u>
EPA-certified woodstove <sup>2,3</sup>	8.140	1.140
Conventional Woodstove <sup>4</sup>	13.34	1.77
Pellet Wood Stove <sup>5</sup>	2.28	0.24
Russell Biomass Project <sup>6</sup>	0.075	0.012

<sup>1</sup> British Thermal Units, a measure of heat content.

<sup>2</sup> U.S. EPA, "Air Pollutant Emission Factors," Publication AP-42, pages 1.10-2 through 4. CO emission rate is 140.8 lb/ton or 8.14 lb/million BTU.

<sup>3</sup> U.S. EPA, "Long-Term Performance of EPA-Certified Phase 2 Woodstoves, Klamath Falls and Portland, Oregon, 1998-1999," EPA-600/R-00-100, November 2000, p. 43, Table 3-9. The average of 43 EPA tests on 16 certified woodstoves as they were actually operated in people's homes produced a PM emission rate of 9.7 g/kg-dry or 1.14 lb/million BTU. Some stoves emitted up to twice the average emissions rate in the EPA tests.

<sup>4</sup> U.S. EPA, "Air Pollutant Emission Factors," Publication AP-42, Table 1.10-1, page 1.10-4. CO emission rate is 230.8 lb/ton or 13.34 lb/million BTU; PM emission rate is 30.6 lb/ton or 1.77 lb/million BTU.

<sup>5</sup> U.S. EPA, "Air Pollutant Emission Factors," Publication AP-42, Table 1.10-1, page 1.10-4. CO emission rate is 39.4 lb/ton or 2.28 lb/million BTU; PM emission rate is 4.2 lb/ton or 0.24 lb/million BTU.

<sup>6</sup> Tech Environmental, Inc., "Major Comprehensive Plan Approval Application, Russell Biomass Power," submitted to Massachusetts DEP, September 2005, page 6.

Russell Biomass has the best air pollution controls available, and those controls will remove over 99% of the air pollutants (e.g., 99.7% of the particulate matter) that would otherwise go into the air, for example if the same amount of wood were burned in a certified woodstove.

**Air Quality Standards for PM<sub>2.5</sub> and CO**

The US EPA has established National Ambient Air Quality Standard (NAAQS) for PM<sub>2.5</sub> and CO. The Commonwealth of Massachusetts has established the same air quality standards. These standards have been designed to protect public health and welfare with a margin for safety for sensitive people (e.g. asthmatics). The NAAQS for PM<sub>2.5</sub> consist of a 24-hour average standard of 35 ug/m<sup>3</sup> and an annual average standard of 15 ug/m<sup>3</sup>. The 24-hour standard uses the three-year average of the 98<sup>th</sup> percentile 24-hour average PM<sub>2.5</sub> concentration; while the annual standard uses the three-year average of the average annual concentrations. When performing air quality dispersion modeling with five years of meteorological data, five-year averages are considered to be representative of the three-year average concentrations for determining compliance with the air quality standards. The NAAQS for CO consist of a 1-hour average standard of 40 mg/m<sup>3</sup> and an 8-hour average standard of 10 mg/m<sup>3</sup>, each not to be exceeded more than once per year. This memo focuses on the 24-hour PM<sub>2.5</sub> and the 8-hour CO NAAQS since they have the greatest possibility of being exceeded.

The greater the frequency and magnitude of exceedances of the NAAQS, the greater the potential for adverse health effects. For example, if the PM<sub>2.5</sub> NAAQS is exceeded for a significant number of days during the wintertime by a significant amount, the margin for safety inherent in the NAAQS would be diminished. A person in good health may not be affected, but an asthmatic could be put at some higher health risk.

**Wood Firing Rates and Emissions**

On a cold winter's day, a conventional or EPA-certified woodstove will be fired with 7 to 8 lb/hour of wood (dry basis) which is the same as 10 lb/hour of cordwood (25% moisture). A pellet stove will be fired with 3 to 4 lb/hour of processed wood pellets. This represents a heat input of 0.07 million BTU/hour to a conventional or an EPA-certified woodstove and 0.03 million BTU/hour for a pellet stove. At maximum possible capacity, Russell Biomass has a heat input of 740 million BTU/hour. Applying these figures to the emission rates listed above, results in the following emissions:

	Carbon Monoxide (CO) <u>(lb/hour)</u>	Particulate Matter (PM) <u>(lb/hour)</u>
EPA-certified woodstove	0.57	0.08
Conventional woodstove	0.93	0.12
Pellet woodstove	0.07	0.007
Russell Biomass Project	55.5	8.9

Due to the differences in the size of the plant vis-à-vis a wood stove, the maximum particulate matter emissions from Russell Biomass are approximately equal to those from 110 EPA-certified woodstoves. There are two important differences however. First, a woodstove's flue gas is released from a relatively short stack, sometimes a house chimney which is just above the roof or from a separate short stack that might be only 8 feet tall, while Russell Biomass will have a 300-foot stack to ensure its flue gas is not released near ground-level. Second, the flue gas exits the house chimney at a very low velocity (natural draft), whereas the Russell Biomass plant flue gas will exit at a high (43 feet/sec) velocity created by a high-speed, heavy duty exhaust fan, and will quickly disperse. To find out the effects on breathing-level air quality where people live and work, air dispersion modeling was applied. First, the Russell Biomass Project was compared to one pellet stove and one EPA-certified woodstove and then to three multiple stove scenarios (15 and 60 assorted woodstoves and 15 pellet woodstoves) in the Town of Russell.

### **Air Quality Effects**

#### **Task 1 – Comparison of the Air Quality Impacts from a Single Pellet Stove and a Single EPA-Certified Woodstove to the Impacts from the Russell Biomass Project**

The EPA and Mass. DEP measure of health impacts is the concentration of a pollutant in the air, measured in micrograms per cubic meter. Dispersion modeling was performed for the Russell Biomass Project, pellet stoves, and EPA-certified woodstoves. All dispersion modeling was performed with the US EPA AERMOD model, using five years (1991-1995) of hourly meteorological data from Westover AFB processed with the AERMET program, and using the actual local terrain characteristics for Russell. The AERMOD dispersion model includes the effects of aerodynamic downwash as wind blows over buildings. Downwash can quickly bring the stack exhaust plume down to the ground, resulting in relatively high concentration impacts near the stack. Generally a stack has to be at least 2.5 times as tall as a nearby building to avoid downwash effects and to be classified as a good engineering practice (GEP) stack. For example, a residential chimney near an 18-foot tall house would have to be at least 45 feet tall to be a GEP stack and avoid downwash effects from the house. The Russell Biomass stack at 300 feet is close to its GEP height (309 feet) and is only marginally influenced by building downwash effects. The AERMOD model also accounts for different meteorological conditions such as atmospheric temperature inversion conditions that tend to trap particulates at ground level below a cold layer of air.

The maximum air concentrations of CO and fine Particulate Matter (PM<sub>2.5</sub>) were predicted in the Town of Russell from the operation of: 1) an EPA-certified woodstove with a short 8-foot stack; 2) an EPA-certified woodstove that exhausts through a 20-foot house chimney 2 feet above the roof peak; 3) a pellet woodstove with a short 8-foot stack; 4) a pellet woodstove that exhausts through a 20-foot house chimney 2 feet above the roof peak; and 5) the Russell Biomass Project with its 300-foot stack. Figure 1 shows the location of the Russell Biomass stack and modeled receptors. The maximum predicted air concentrations are as follows:

**WINTER SEASON IMPACT ANALYSIS**

	Carbon Monoxide (CO) (8-hour milligrams/meter <sup>3</sup> )	Fine Particulate Matter (PM <sub>2.5</sub> ) (24-hour micrograms/meter <sup>3</sup> )
Fully-Fired Pellet stove with 8-foot stack <sup>7</sup>	0.134	6.1
Fully-Fired Pellet stove with 20-foot chimney <sup>7</sup>	0.078	4.1
Russell Biomass Project <sup>8</sup>	0.002 (near residences)	0.08 (near residences)
Russell Biomass Project <sup>8</sup>	0.034 (mountainside)	0.9 (mountainside)
EPA Air Quality Standard <sup>9</sup>	10.0	35.0
Background Concentrations <sup>8,10</sup>	3.565	26.7

The results reveal that the breathing-level air quality concentrations from Russell Biomass are much less than from one pellet stove or one EPA-certified woodstove, and are safely in compliance with the EPA air quality standards. The modeling also reveals that a single 8-foot or 20-foot tall EPA-certified woodstove stack located next to a house may cause a violation of the 24-hour PM<sub>2.5</sub> NAAQS (see footnote 7 below). These high concentrations would occur close to the house, due to downwash effects, and would likely occur during those winter days when the wood stove would operate most of the day to maintain a home at a temperature of 60 °F – 70 °F. Removing a single woodstove of any type or replacing an EPA-certified or conventional woodstove with a pellet stove would reduce the 24-hour PM<sub>2.5</sub> air quality impacts around that house by an amount that will more than offset the maximum residential PM<sub>2.5</sub> impact from the Russell Biomass Project.

**Task 2 – Comparison of the Air Quality Impacts from 15 and 60 Woodstoves Located Throughout the Town of Russell to the Impacts from the Russell Biomass Project**

Additional air quality dispersion modeling was performed with the AERMOD model for both 15 and 60 separate woodstoves placed at various locations within the Town of Russell, and the results were compared to the impacts from the Russell Biomass project. Each woodstove was modeled with 20-foot tall chimney on an 18-foot tall house with a footprint of 40-foot x 50-foot. These analyses are meant to be representative of a range of multiple wood stove locations.

<sup>7</sup> Woodstove exhaust assumed to be at 350 °F. The stack or chimney is on a one-story house with an 18-foot roof peak. Note that the modeling results for a fully-fired EPA-certified wood stove with an 8-foot stack are 1.02 for 8-hour CO and 60.2 ug/m<sup>3</sup> for 24-hour PM<sub>2.5</sub>; and the modeling results for a fully-fired EPA-certified wood stove with a 20-foot chimney are 0.53 ug/m<sup>3</sup> for 8-hour CO and 39.5 ug/m<sup>3</sup> for 24-hour PM<sub>2.5</sub>.

<sup>8</sup> Tech Environmental, Inc., “Supplement to the Major Comprehensive Plan Approval Application, Russell Biomass Power,” submitted to Massachusetts DEP, April 2007, Section 9, Table 5B (Stoker Design at 100% Load).

<sup>9</sup> Massachusetts and National Ambient Air Quality Standards (NAAQS) established by EPA to protect the most sensitive persons in the population with a margin of safety. The 24-hour NAAQS for PM<sub>2.5</sub> was recently lowered from 65.0 ug/m<sup>3</sup>.

<sup>10</sup> Background concentrations are from representative Mass. DEP air monitors for the period 2004 – 2006.

Figures 2a and 2b show the locations assumed for the 15 and 60 woodstove modeling scenarios, respectively, and the locations of the receptors (geographic location of the concentrations). These locations are not informed by a survey of residential properties; they simply represent an even distribution of the 15 or 60 woodstoves over the area near the Town center. Three cases were analyzed: 1) 15 assorted wood stoves were divided between 5 EPA-certified woodstoves, 5 conventional woodstoves, and 5 pellet woodstoves, 2) 60 assorted woodstoves were divided between 20 of each type of stove, and 3) 15 wood stoves all modeled as pellet woodstoves. The maximum predicted air concentrations are as follows:

	<u>Carbon Monoxide (CO)</u> <u>(8-hour milligrams/meter<sup>3</sup>)</u>	<u>Fine Particulate Matter (PM<sub>2.5</sub>)</u> <u>(24-hour micrograms/meter<sup>3</sup>)</u>
Range of Residential Location		
Results for 60 Assorted Woodstoves with 20-foot Chimneys <sup>11</sup>	0.086 – 0.916	5.2 - 53.9
Range of Residential Location		
Results for 15 Assorted Woodstoves with 20-foot Chimneys <sup>11</sup>	0.021 – 0.907	0.5 – 48.3
Range of Residential Location		
Results for 15 Pellet Woodstoves with 20-foot Chimneys <sup>11</sup>	0.002 – 0.086	0.1 – 4.5
Maximum Impact for 60 Assorted Woodstoves with 20-foot chimneys <sup>11</sup>	0.916	53.9
Maximum Impact for 15 Assorted Woodstoves with 20-foot chimneys <sup>11</sup>	0.907	48.3
Maximum Impact for 15 Pellet Woodstoves with 20-foot chimneys <sup>11</sup>	0.086	4.5
Russell Biomass Project <sup>12</sup>	0.002 (near residences)	0.08 (near residences)
Russell Biomass Project <sup>12</sup>	0.034 (mountainside)	0.9 (mountainside)
EPA Air Quality Standards <sup>13</sup>	10.0	35.0
Background Concentrations <sup>12,14</sup>	3.565	26.7

<sup>11</sup> Woodstove exhaust assumed to be at 350 °F. The stack or chimney is on a one-story house with an 18-foot roof peak.

<sup>12</sup> Tech Environmental, Inc., “Supplement to the Major Comprehensive Plan Approval Application, Russell Biomass Power,” submitted to Massachusetts DEP, April 2007, Section 9, Table 5B (Stoker Design at 100% Load).

<sup>13</sup> Massachusetts and National Ambient Air Quality Standards (NAAQS) established by EPA to protect the most sensitive persons in the population with a margin of safety. The 24-hour NAAQS for PM<sub>2.5</sub> was recently lowered from 65.0 ug/m<sup>3</sup>.

<sup>14</sup> Background concentrations are from representative Mass. DEP air monitors for the period 2004 – 2006.

The modeling results reveal that the residential breathing-level air quality concentrations from Russell Biomass are two orders of magnitude smaller than those from 15 or 60 assorted residential woodstoves in the Town, and are safely in compliance with the EPA air quality standards. The breathing-level air quality concentrations from Russell Biomass are also predicted to be significantly smaller than the impacts from 15 pellet woodstoves in the Town. The modeling also reveals that the simultaneous operation of 15 or 60 woodstoves of various types in the Town, which could occur on a cold winter's day, may cause a violation of the 24-hour PM<sub>2.5</sub> NAAQS at numerous locations throughout the Town. Figures 2a and 2b show the locations where the maximum predicted 24-hour PM<sub>2.5</sub> concentrations occurred for the 15 assorted wood stove and 60 assorted wood stove analyses, respectively. The modeling results show that the wood stove concentration impacts are dominated by the downwash effects near each stack. Figure 3 shows the mountain location where the maximum predicted impact from the Russell Biomass Project occurs as well as some representative impacts from the Russell Biomass Project within the Town of Russell. Figure 4 shows where the maximum and minimum PM<sub>2.5</sub> impacts are predicted to occur within the Town for the 15 and 60 assorted woodstove air quality dispersion modeling analyses.

### **Russell Biomass Project Air Concentrations Much Less Than Those for a Woodstove**

There are a number of scientific reasons why the PM concentrations (the key health measure) resulting from the Russell Biomass plant are so low compared to a wood stove. These include: 1) increased dispersion over the larger distance between the Russell Biomass plant and the Town, 2) the localized building downwash effects from houses on woodstove stacks, and 3) the larger concentration of PM in the woodstove stack exhaust compared to the Russell Biomass stack exhaust.

The Russell Biomass stack will be located significantly farther from the Town than the woodstoves and at a higher elevation. When the wind blows from the Russell Biomass stack towards the Town, the air pollutants in the stack plume have a much larger volume of air in which to disperse, lowering their concentration.

Woodstove stacks are much shorter than the Russell Biomass stack and are not tall enough to avoid downwash from the homes they are attached to. This building downwash can cause the emissions from the woodstoves to be drawn down to the ground around each home without much dispersion, creating localized areas with high PM concentrations near each house with a woodstove. The Russell Biomass stack is tall and avoids most downwash effects. The Russell Biomass stack also will have a much larger gas exit velocity than the woodstove stacks, which helps increase the effective height of its exhaust plume.

The Russell Biomass plant will have cyclone and electrostatic precipitator PM emission controls which will remove 99.7% of the particulate matter before it reaches the stack. As a result of these exceptional emission controls, the concentration of PM in the Russell Biomass stack will be significantly lower than the PM concentrations found in woodstove stacks. The PM concentrations in conventional, EPA-certified, and pellet woodstove stacks will be 42 times, 26 times, and 6 times, respectively, the PM concentration in the Russell Biomass stack as shown below.

	Stack PM <sub>2.5</sub> Concentration ( <u>milligrams/meter<sup>3</sup></u> )	Stack PM <sub>2.5</sub> Concentration Ratio to <u>Russell Biomass</u>
Russell Biomass	7.6	-
Conventional Woodstove	201.2	42
EPA-certified Woodstove	321.9	26
Pellet Woodstove	46.3	6

The EPA AERMOD dispersion model takes into account all of these factors as it predicts the dispersion of air pollutants over varying distances, including the effect of changes in the terrain around Russell and meteorological conditions. The AERMOD model has been tested for accuracy by the US EPA and is recommended for a wide variety of dispersion modeling applications.

**Conclusions**

The emissions and air quality effects of the Russell Biomass Project have been compared to those from a single EPA-certified residential woodstove, a single pellet woodstove, to groups of 15 and 60 residential woodstoves of different types, and to a group of 15 pellet woodstoves. The results reveal:

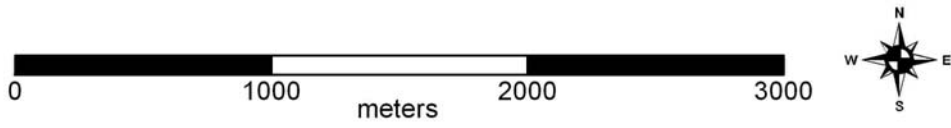
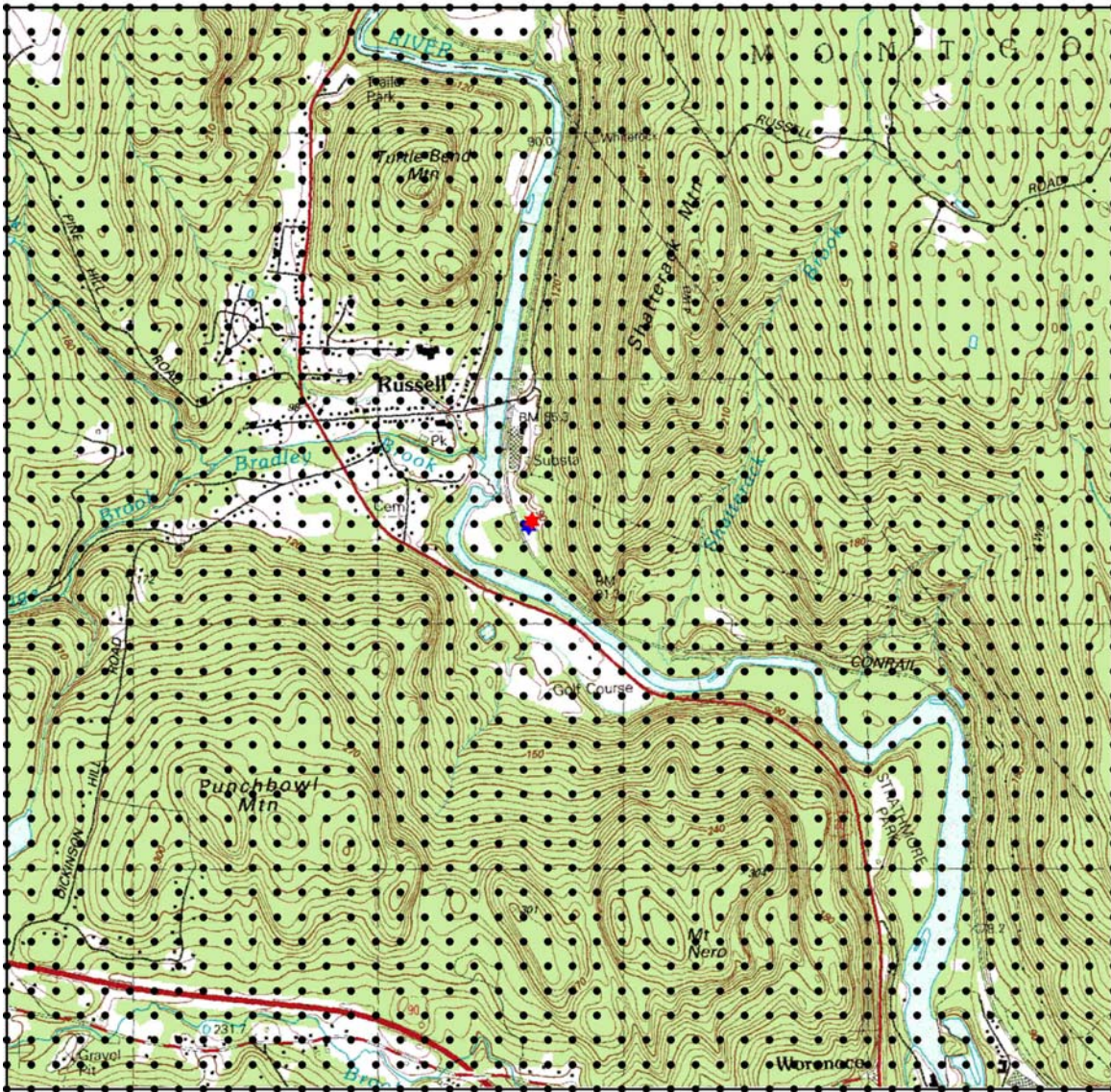
- For PM<sub>2.5</sub>, the Russell Biomass Project will be 95 times cleaner than an EPA-certified woodstove and 20 times cleaner than a pellet woodstove in terms of the emissions of particulate matter per pound of wood burned.
- Breathing-level air quality impacts (concentrations) in the Town of Russell from the Russell Biomass Project will be much less than those from one residential pellet woodstove or EPA-certified woodstove, and are safely in compliance with the EPA air quality standards.
- The operation of assorted woodstoves may cause a violation of the 24-hour PM<sub>2.5</sub> NAAQS at locations near some homes in the Town of Russell.
- The Russell Biomass plant impacts will be below the level of significance for health impacts.<sup>15</sup>
- Replacing existing woodstoves with cleaner-burning pellet woodstoves can reduce 24-hour average PM<sub>2.5</sub> air quality concentrations in many areas of Russell by an amount that would more than offset the increase in residential PM<sub>2.5</sub> concentrations resulting from the Russell Biomass plant.

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<sup>15</sup> The US EPA has not yet established Significant Impact Levels (SILs) for PM<sub>2.5</sub>. The overall maximum predicted 24-hour average PM<sub>2.5</sub> concentration from the Russell Biomass plant is less than 1 ug/m<sup>3</sup>. This concentration is below the US EPA designated SIL of 5 ug/m<sup>3</sup> for 24-hour average coarse particulate matter (PM<sub>10</sub>), and is below the 1.2 ug/m<sup>3</sup> SIL that the Northeast States for Coordinated Air Use Management (NESCAUM) has recommended for 24-hour average PM<sub>2.5</sub>.

- Replacing any single conventional or EPA-certified woodstove with a pellet stove would reduce 24-hour average PM<sub>2.5</sub> air quality concentrations around any house that does so by an amount that would more than offset the potential increase in PM<sub>2.5</sub> concentrations resulting from the Russell Biomass plant.

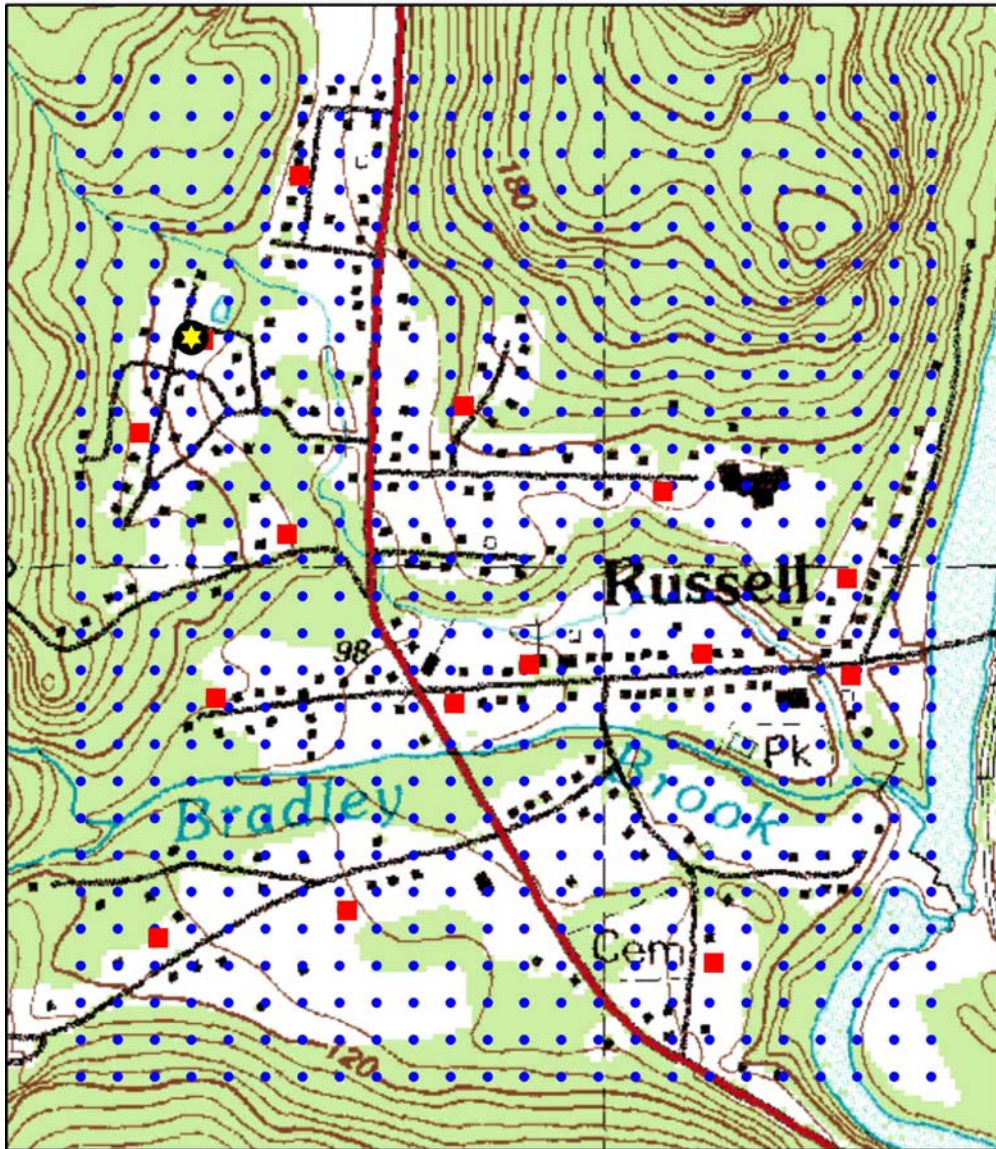
- = Modeled Receptor
- ★ = Russell Biomass Power Project Stoker Design Stack
- ★ = Russell Biomass Power Project BFB Design Stack



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**e** **Figure 1. Refined Modeling Receptor Grid and Source  
Russell Biomass Power Project  
Russell, Massachusetts**

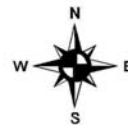
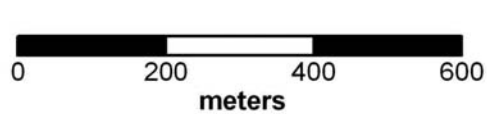
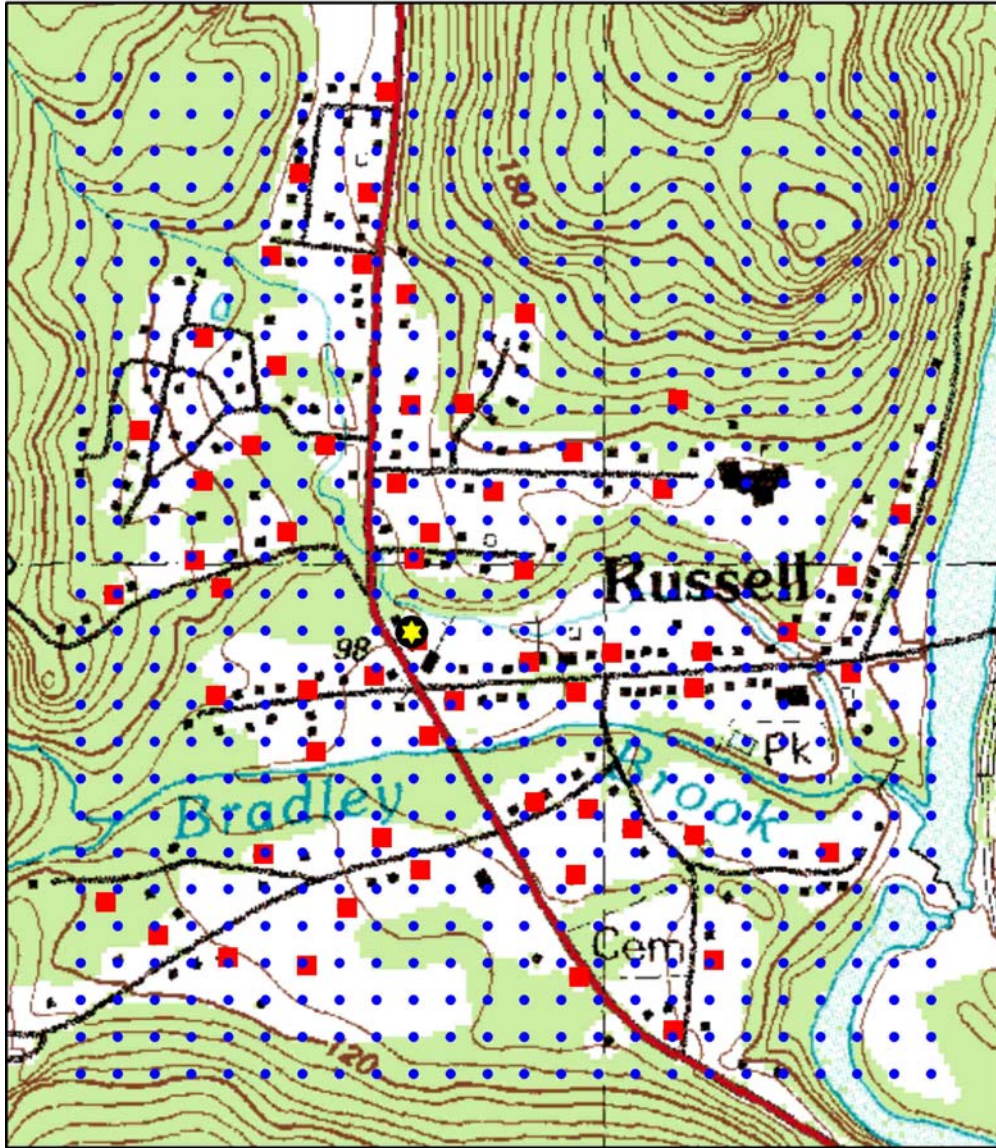
- ★ = location of maximum predicted PM2.5 concentration
- = modeled receptor
- = modeled building and wood stove



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Figure 2a. Refined Modeling Receptor Grid, Sources and Maximum Predicted Concentration - Wood Stove Modeling of 15 Assorted Woodstoves Russell, Massachusetts



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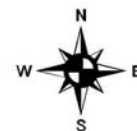
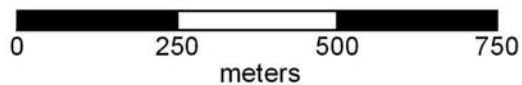
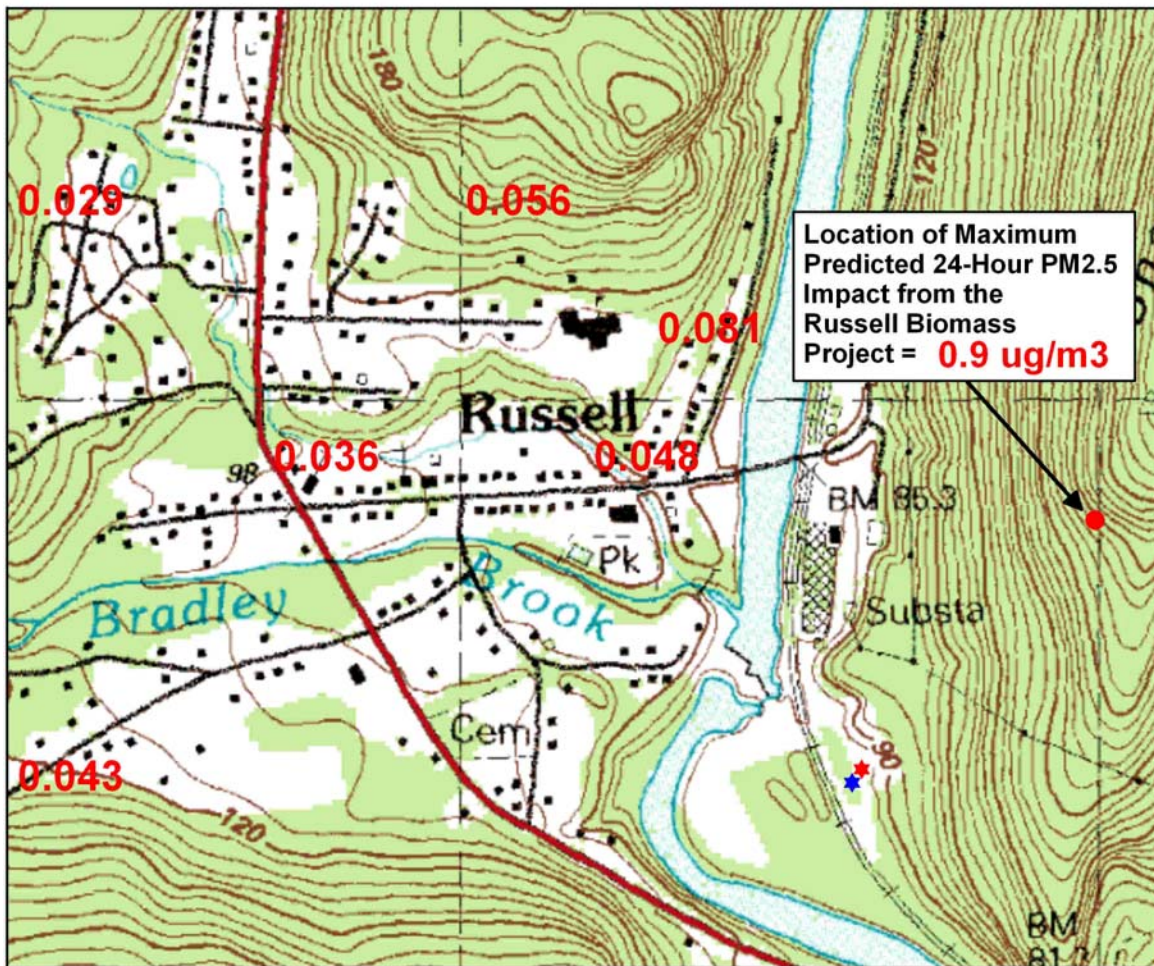


**Figure 2b. Refined Modeling Receptor Grid, Sources and Maximum Predicted Concentration - Wood Stove Modeling of 60 Assorted Woodstoves Russell, Massachusetts**

0.XXX = Predicted 24-Hour PM2.5 Concentrations from Russell Biomass (ug/m3)

★ = Russell Biomass Power Project Stoker Design Stack

★ = Russell Biomass Power Project BFB Design Stack

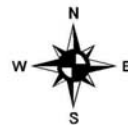
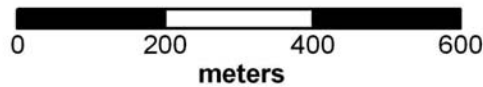
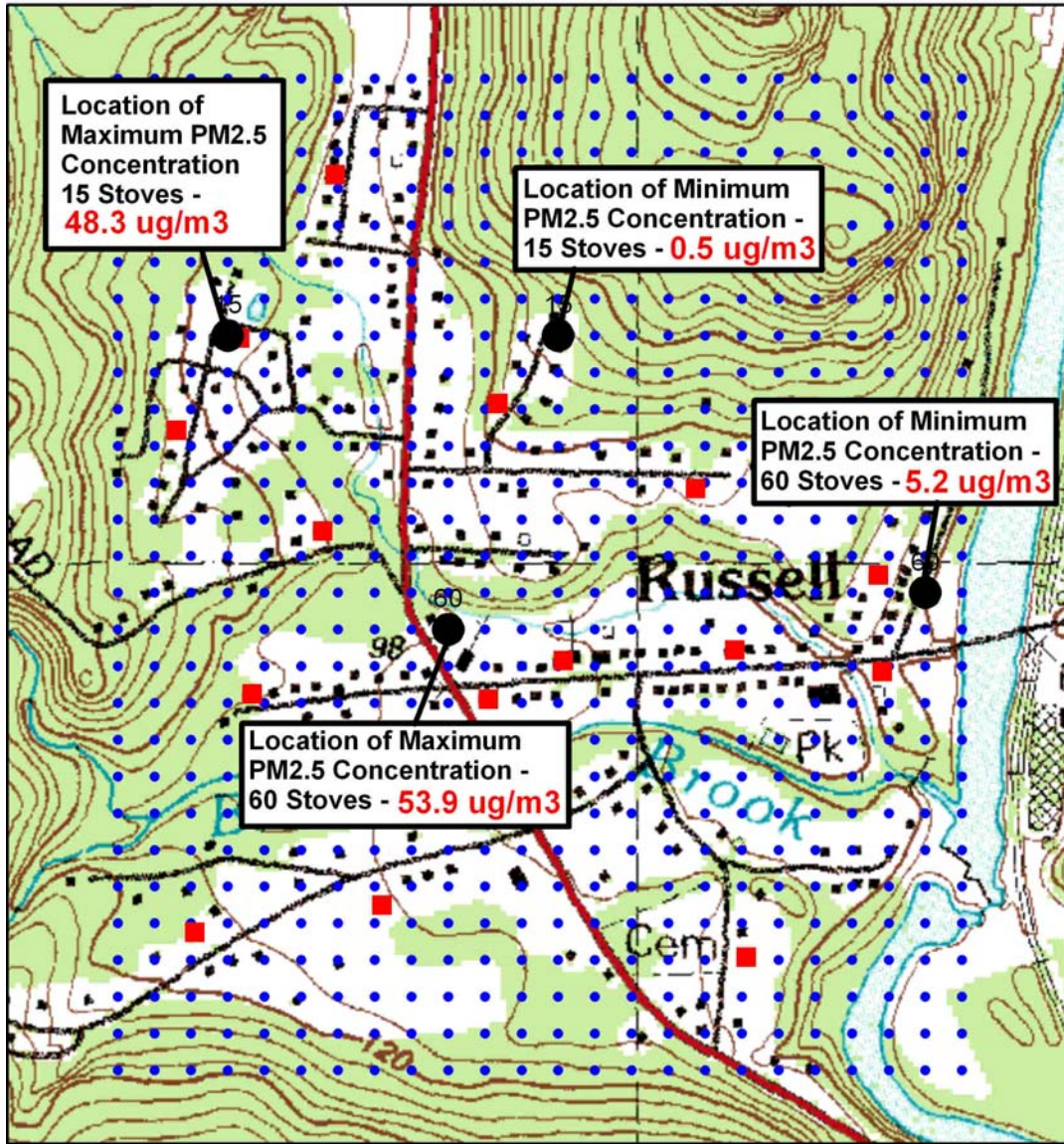


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Figure 3. Location of Maximum Russell Biomass 24-hour PM2.5 Impact and Some Russell Biomass 24-hour PM2.5 Impacts in Russell (ug/m3) Russell, Massachusetts

● = location of maximum predicted PM<sub>2.5</sub> concentration  
 ● = modeled receptor      ■ = modeled building and wood stove



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Figure 4. Location of Residential Maximum and Minimum 24-hour PM<sub>2.5</sub> Impacts From 15 and 60 Assorted Woodstoves (ug/m<sup>3</sup>) Russell, Massachusetts