EPA Community Scale Monitoring Project:

Evaluation of Wood Smoke Contribution to Particle Matter in CT

and

Outdoor Wood Furnace Stack Sampling

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Residential Wood Combustion Regional Haze SIP Day
July 12, 2007
Timonium, MD

Project Background:

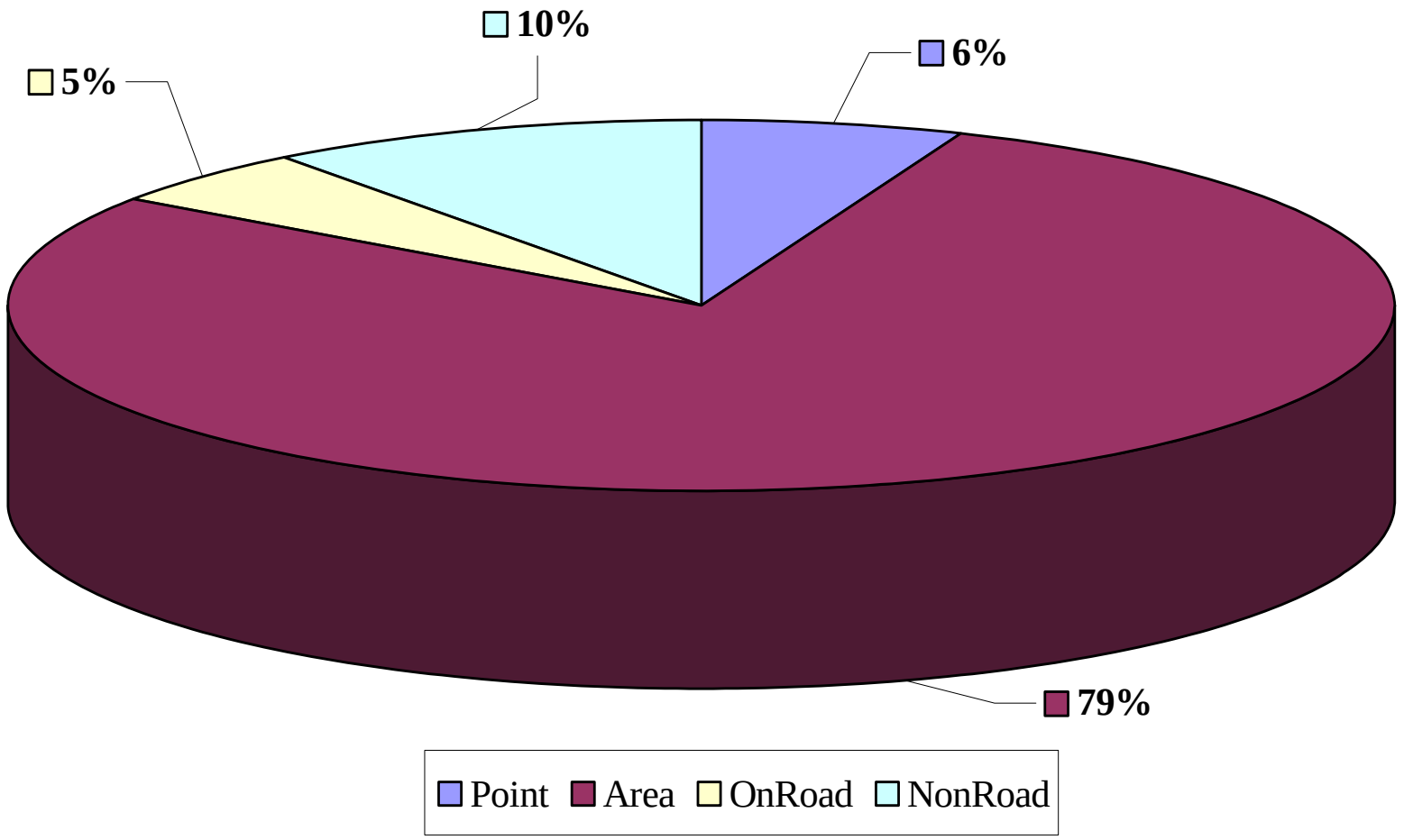
EPA grant funding from “Round 2" (Summer 2005) Air Toxics RFA;
Project Narrative at: http://www.epa.gov/ttn/amtic/toxfy05.html

$500k: CT-DEP lead; NESCAUM subcontractor for
OWB testing and ambient monitoring support
Project Period: Summer 2006 to Summer 2008

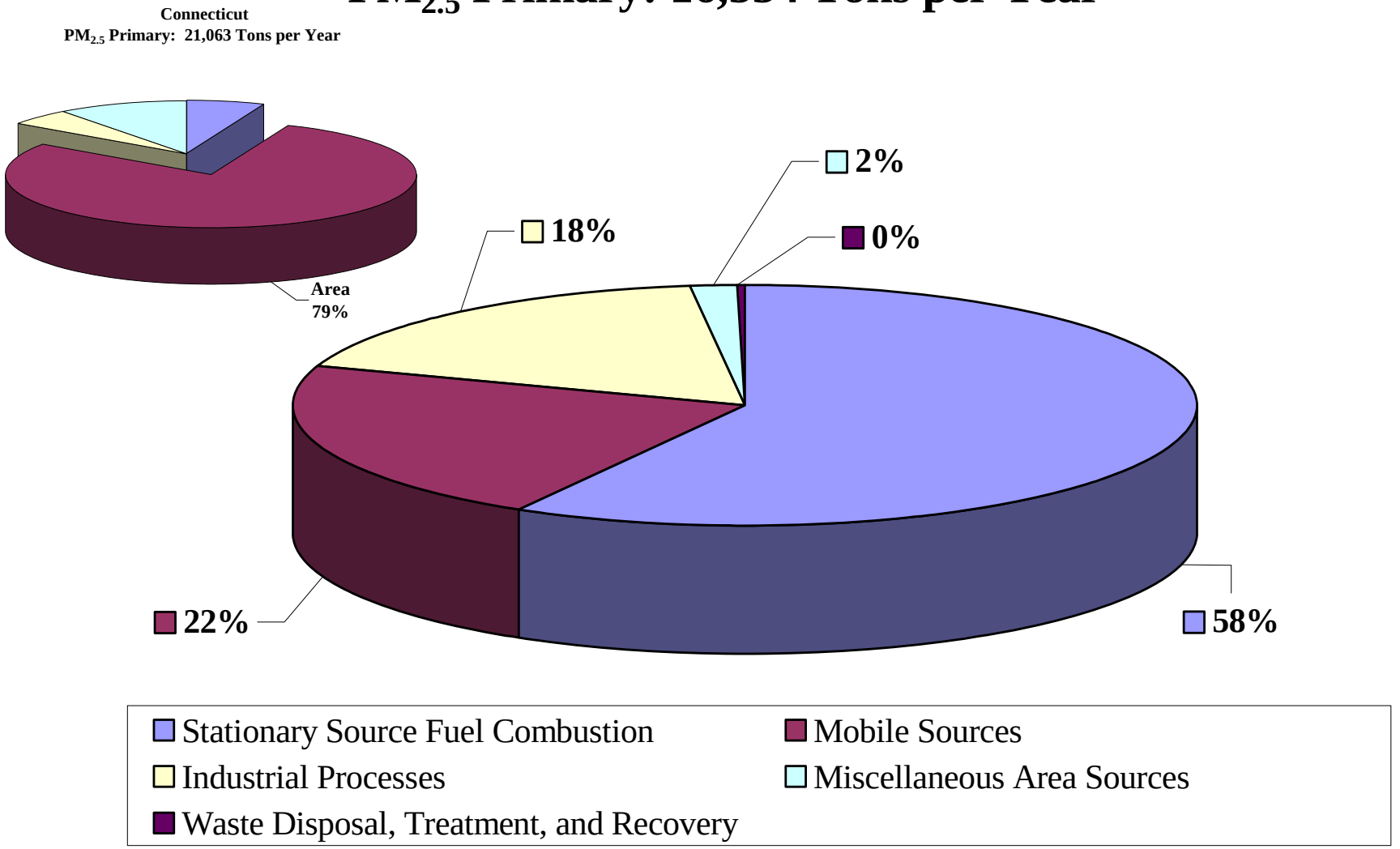
Two Major Project Goals:

- Assess wood smoke contribution to ambient winter PM2.5 in CT (all sources of WS, not just OWB)
- Characterize in-use residential OWB emission rates for PM2.5 (some other pollutants also measured)

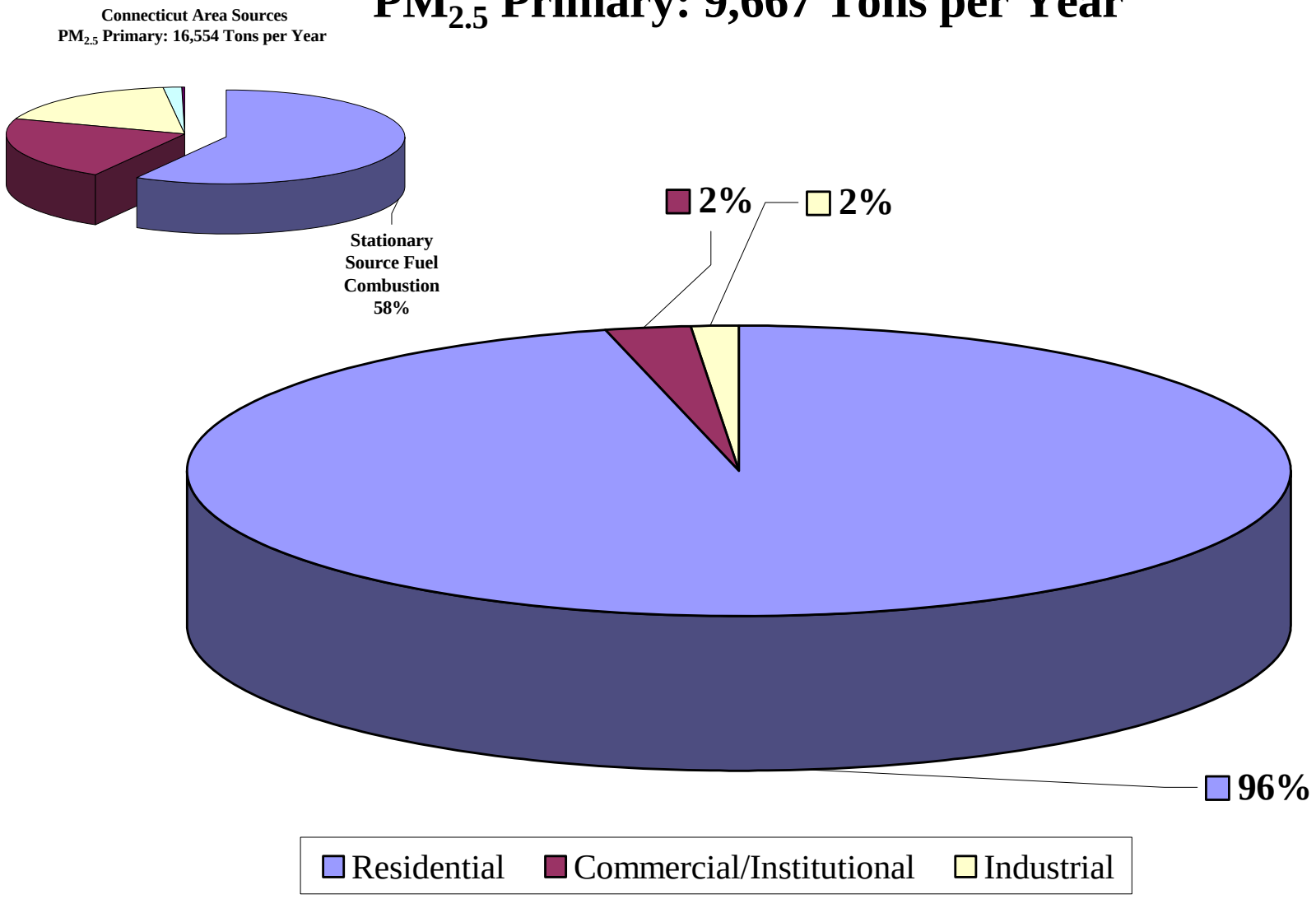
MANE-VU 2002 Connecticut Emission Inventory
$PM_{2.5}$ Primary: 21,063 Tons per Year



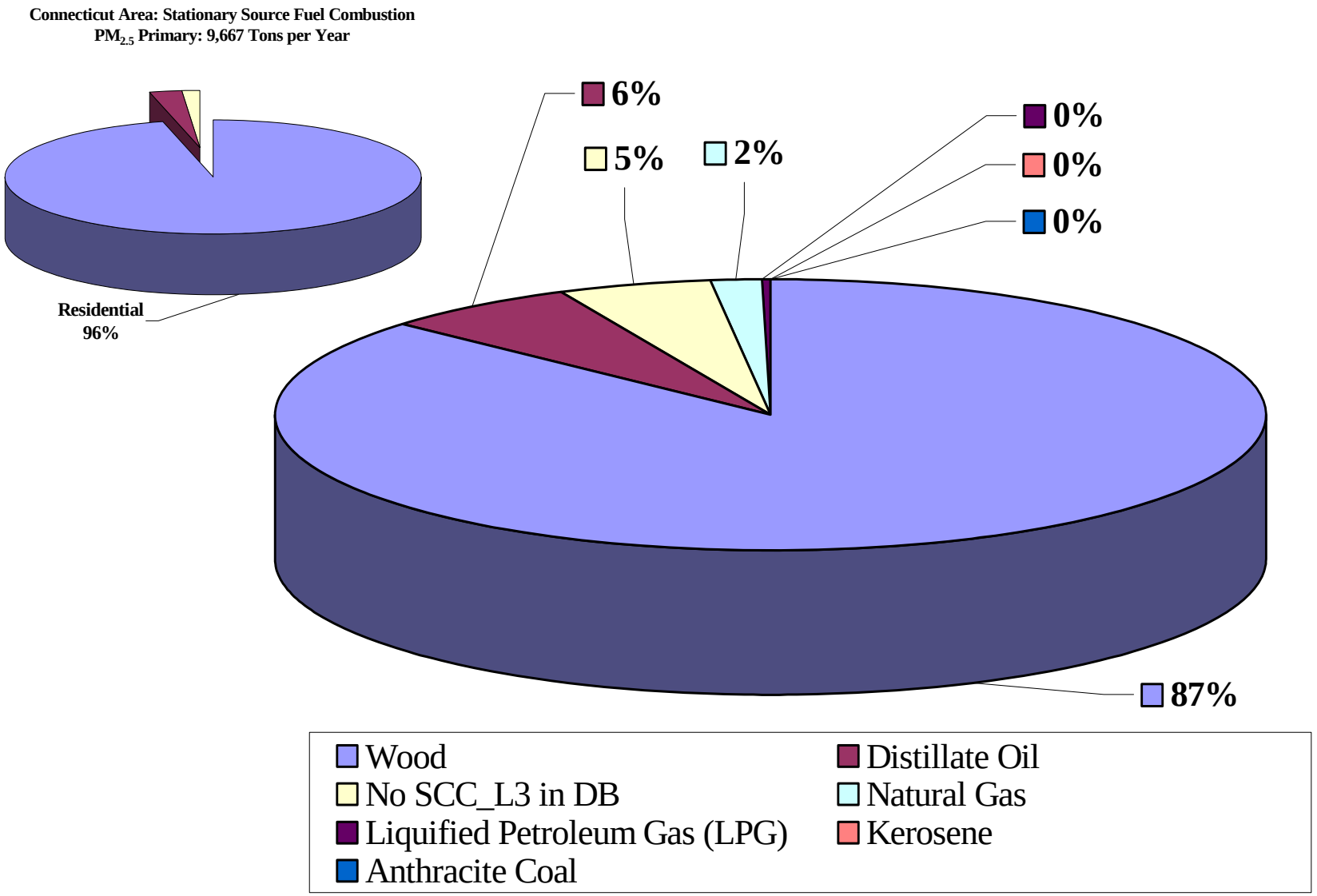
MANE-VU 2002 Connecticut Emission Inventory
Area Sources
$PM_{2.5}$ Primary: 16,554 Tons per Year



MANE-VU 2002 Connecticut Emission Inventory
Area: Stationary Source Fuel Combustion
$PM_{2.5}$ Primary: 9,667 Tons per Year

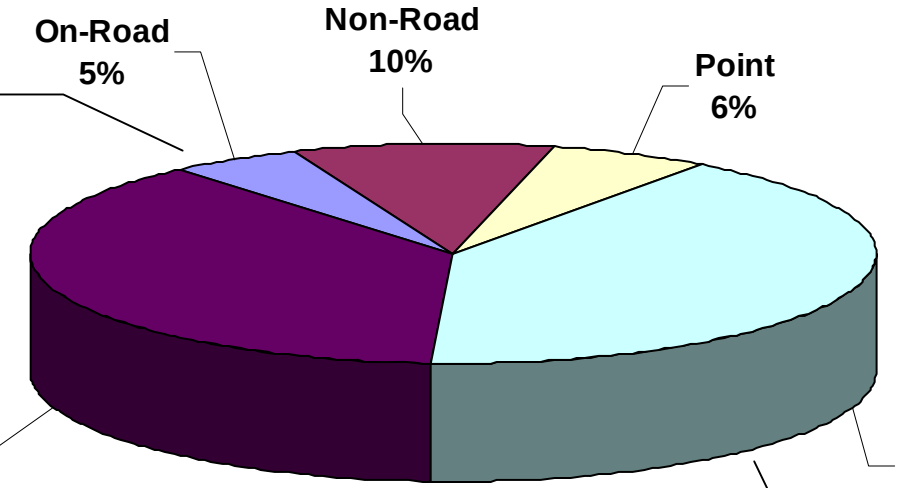


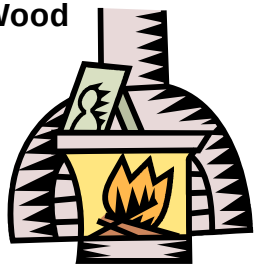
MANE-VU 2002 Connecticut Emission Inventory
Area: Stationary Source Fuel Combustion-Residential
$PM_{2.5}$ Primary: 9,310 Tons per Year



Connecticut Emission Inventory
PM 2.5 - 21,063 Tons/Year

3.5% of the On-Road Emissions are from H.D. Diesel Trucks





Area sources include heating oil (10%) & roadways (22%)

Goal One -- Ambient WS Component:

Use techniques developed in 2004 Rutland VT pilot WS study to semi-quantitatively assess WS-related ambient PM2.5 in real-time.

Details in Rutland Study AWMA conference paper at:
http://tinyurl.com/gqct6

A quick summary:
Ambient WS method: Combination of
- 2 channel (2-wavelength) Aethalometer
- continuous PM2.5 measurements

==> Difference between 2 Aethalometer channels:
qualitative “fresh” WS indicator (not diesel!)

Use these methods and scaling factors derived from models at a “core” site to determine highly time-resolved ambient WS PM contribution.

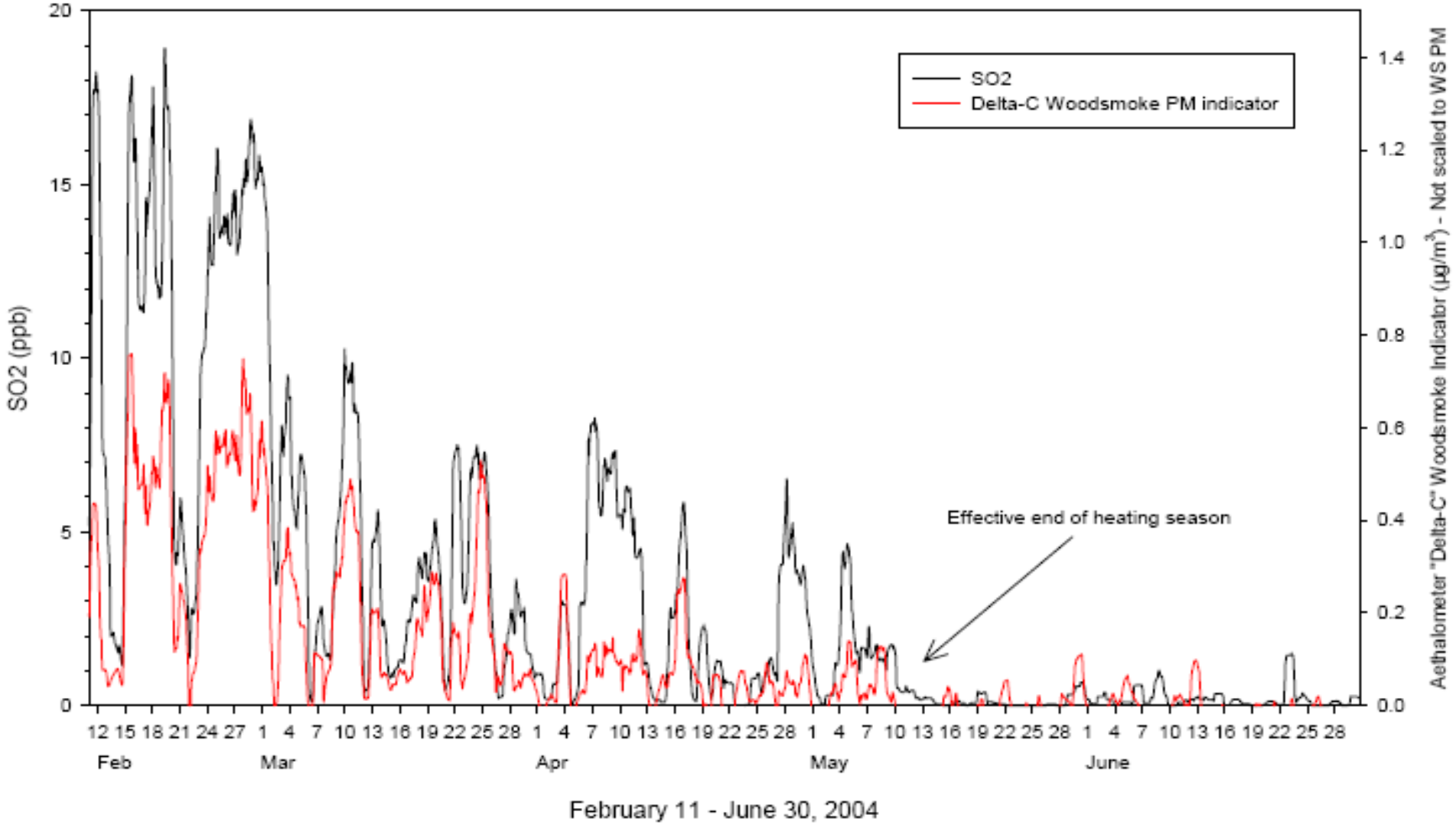
Unmix Modeled Source Compositions for Rutland, VT, 2/11/04 - 4/30/04

Source Mass Compositions and Gaseous Contributions	Wood Smoke	Oil Burning	Fresh MV	Aged MV	Secondary Aerosol
Average Fine Mass (ug/m3)	3.3	3.5	1.4	3.1	2.3
BC (% Source Mass)	4	3	18	9	0
Delta-C (% Source Mass)	7	0	0	0	0
Non-Vol Mass (% Source Mass)	95	100	99	99	20
Volatile Mass (% Source Mass)	5	0	1	1	80
SO2 (Source % of Total SO2)	12	56	25	4	1
NO (Source % of Total NO)	5	5	81	11	0
CO (Source % of Total CO)	12	1	31	55	2

Take-Home: Aethalometer "Delta-C" (UV-C minus BC) signal:

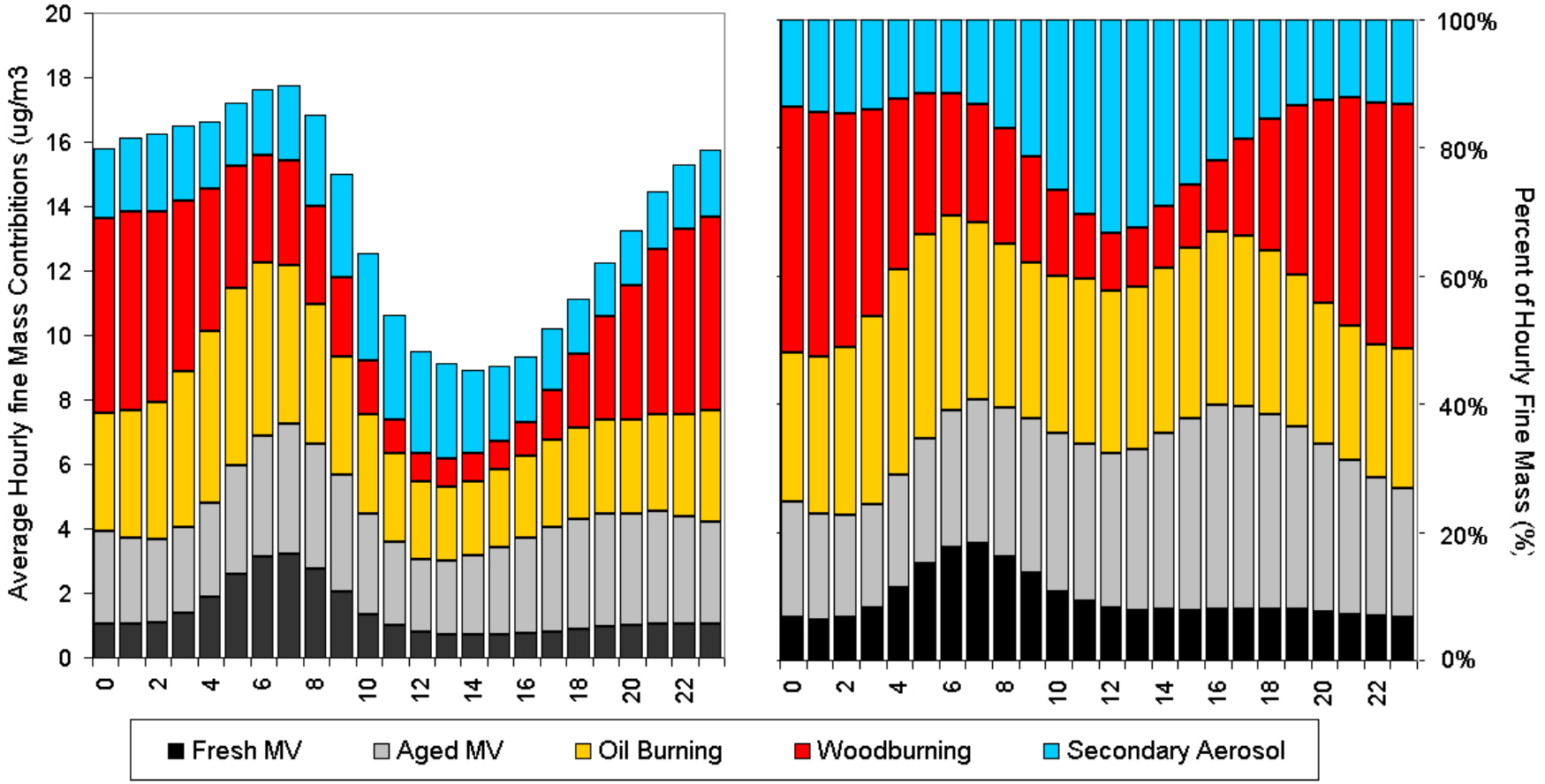
1. IS specific WS indicator even with substantial local mobile source aerosol, other local combustion-related PM-sources
2. Is NOT a significant or useful indicator of fresh diesel sources

SO2 and Delta-C 24-hour running average (February through June, 2004)
SO2 is primarily local oil burning; DC is Wood smoke

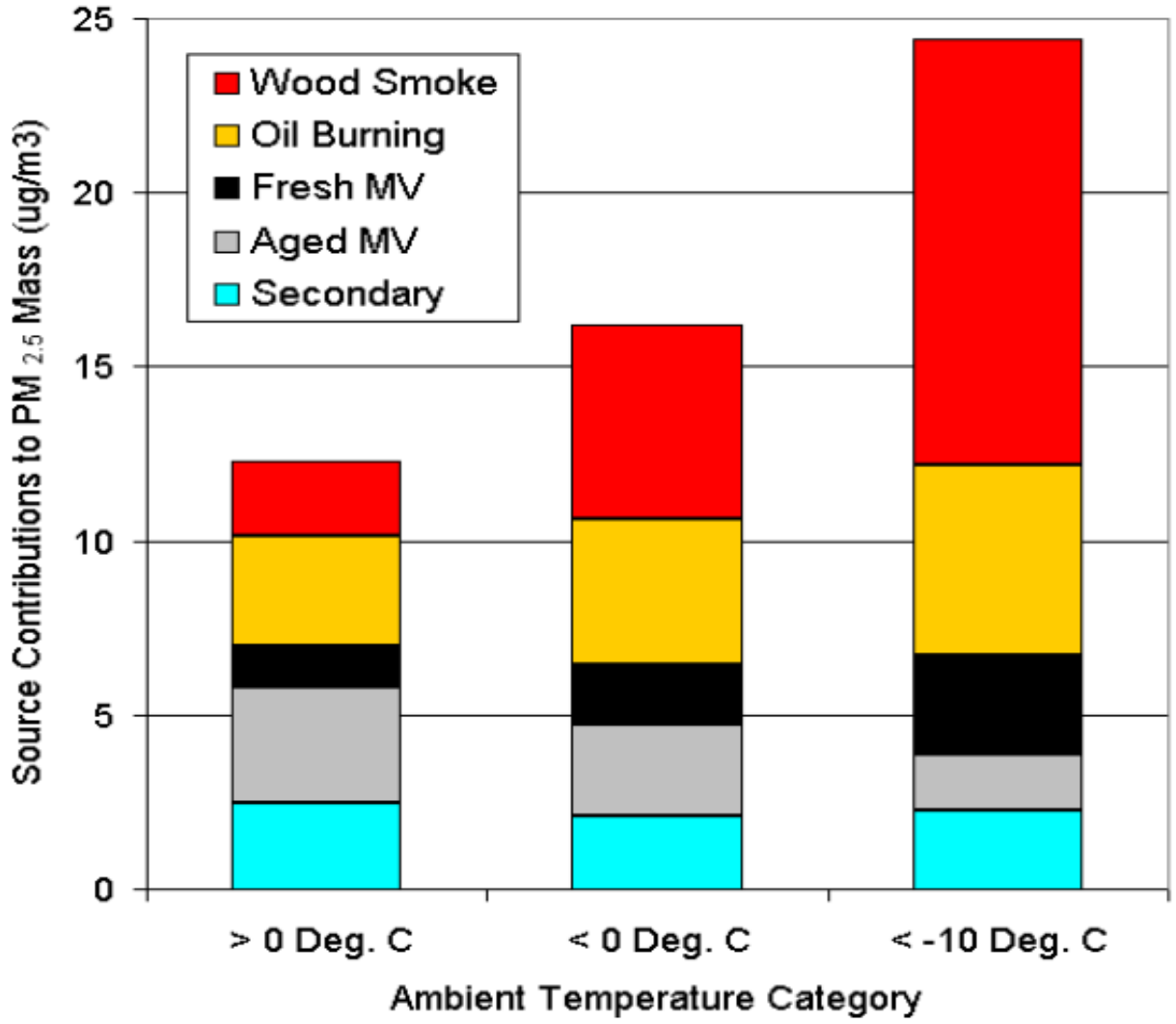


February 11 - June 30, 2004

Absolute and Percent Source Contributions to Hourly $PM_{2.5}$ Mass, by hour of day
Rutland, VT



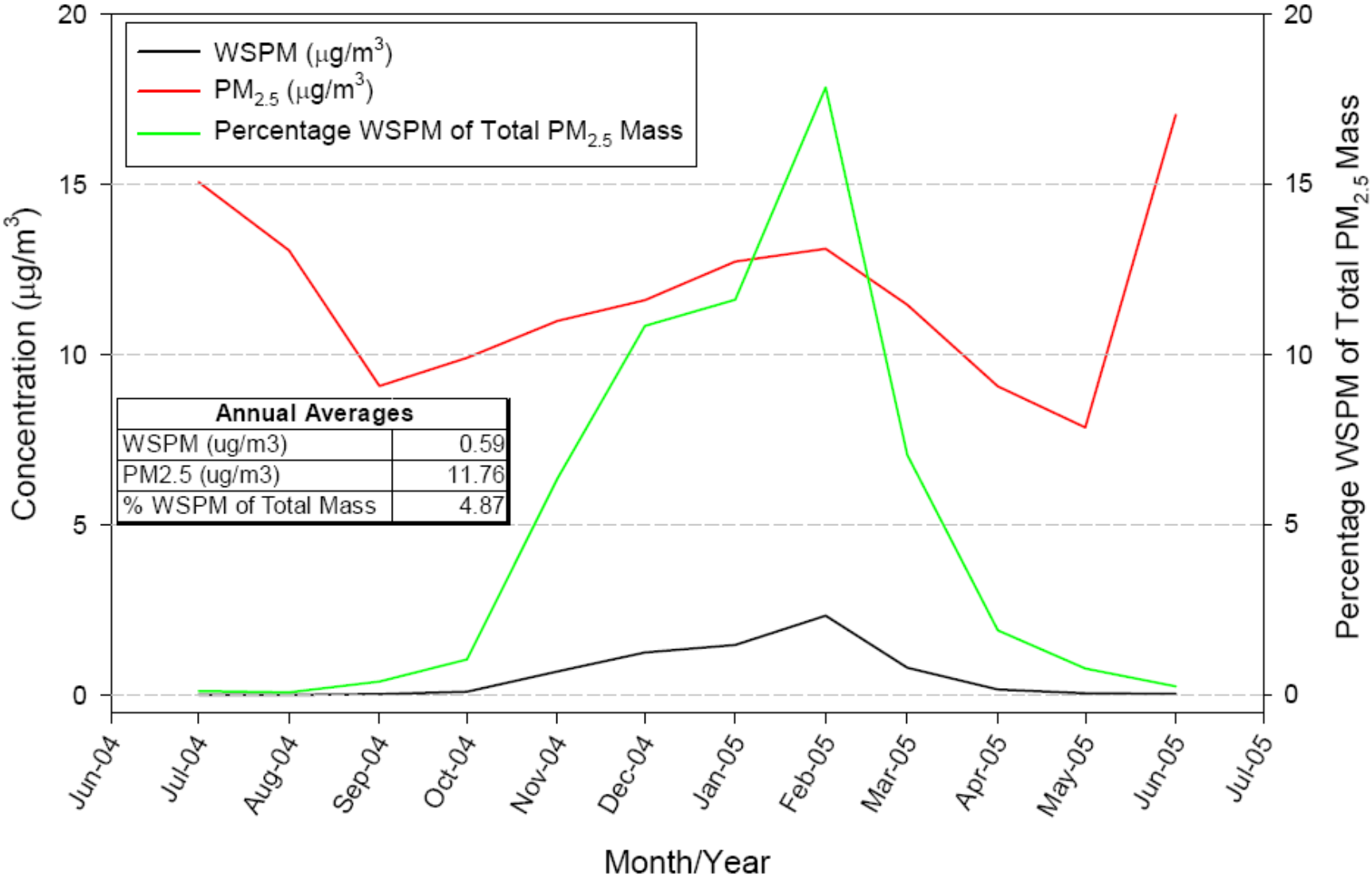
Source categories contribution to PM2.5 by temperature. (Feb-April 2004)



Wood Smoke Particle Matter (WSPM) and Total $PM_{2.5}$ Mass

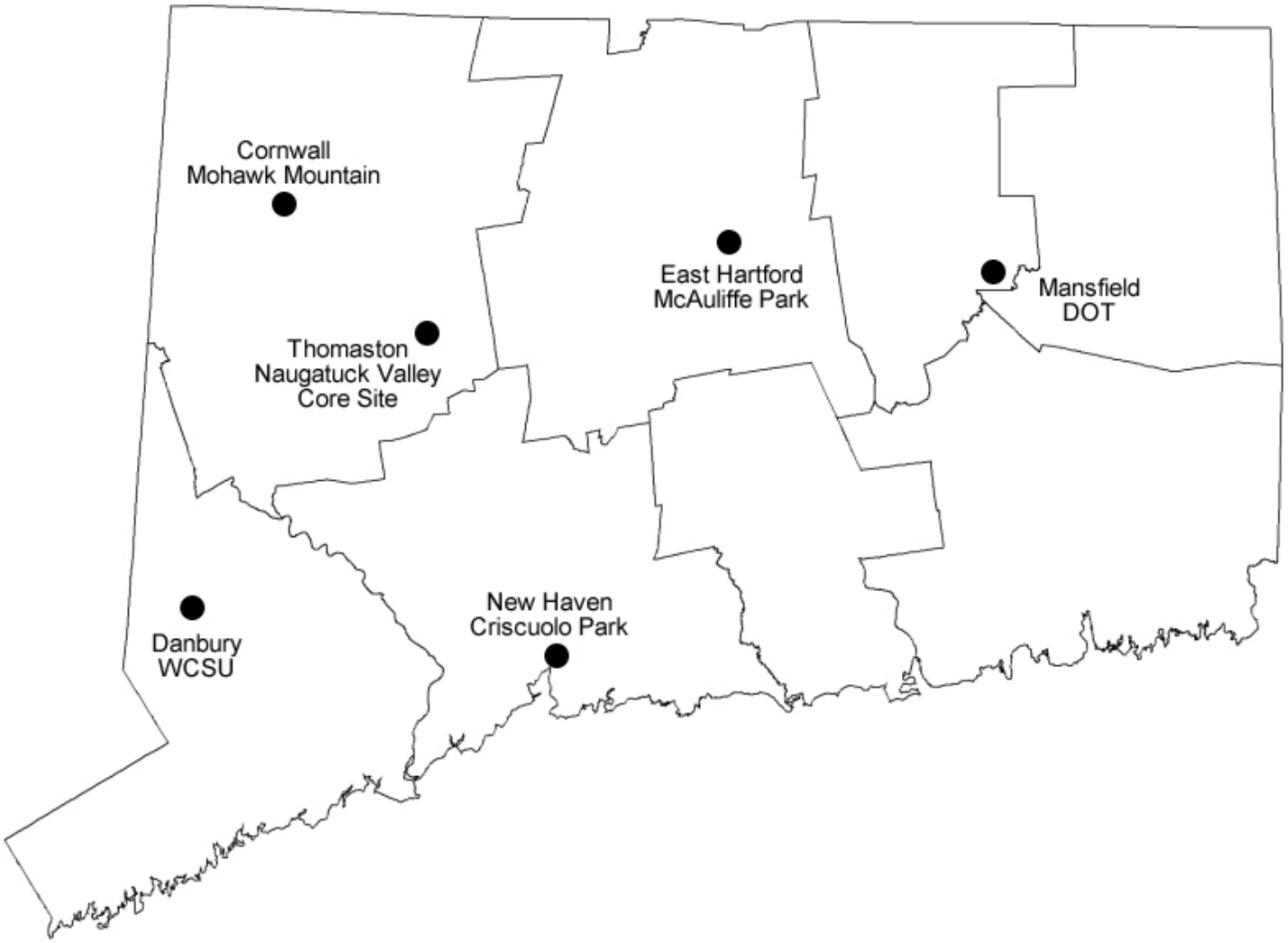
Criscuolo Park, New Haven

July 2004 through June 2005



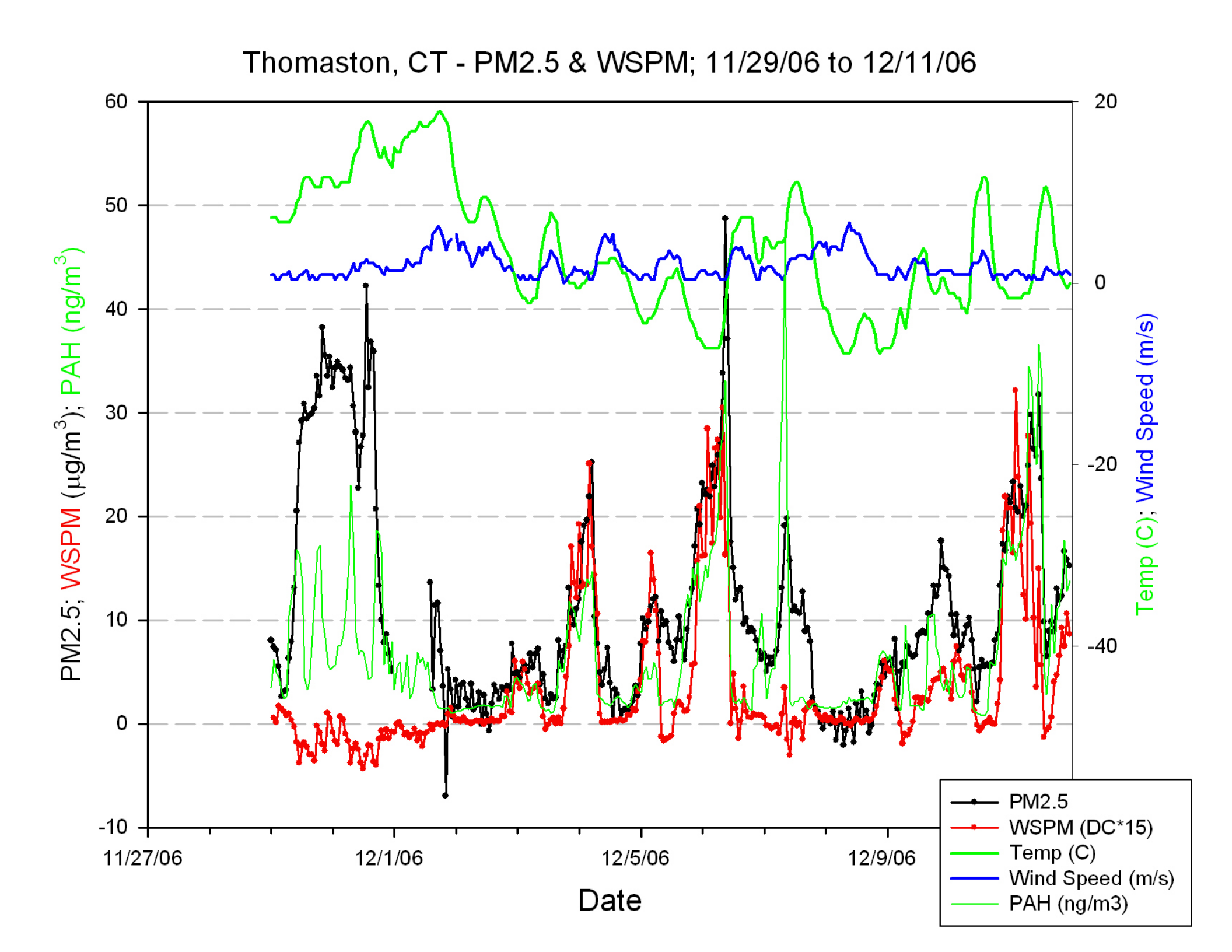
Annual Averages	
WSPM (ug/m3)	0.59
PM2.5 (ug/m3)	11.76
% WSPM of Total Mass	4.87

Wood Smoke Monitoring Network in CT



Existing Methodology for Core and Satellite sites

	Core site	**Satellite sites**				
	Thomaston	**Cornwall**	**Danbury**	**East Hartford**	**New Haven**	**Mansfield**
Specific Wood Smoke Indicator Measurements						
Two-wavelength Aethalometer	X	X	X	X	X	X
$PM_{2.5}$ Mass Measurements						
FDMS TEOM	X			X	X	
MetOne BAM		X	X		X	
$PM_{2.5}$ FRM	1/3	1/3	1/3	1/1	1/1	
$PM_{2.5}$ Speciation Measurements						
Sunset OCEC	X	X			*	
Continuous SO_4	X	X			*	
3-slot DRUM	X					
IMPROVE		X				
STN					X	
Trace-Gas Measurements						
Trace CO	X	X			X	
Trace SO_2	X	X			X	
Trace NO_y	*	*			*	
Criteria Gas (non-Trace) Measurements						
CO				X		
SO_2			X		X	
NO_x	X			X	X	
Ozone		X	X	X	X	
Particle-bound PAHs						
EcoChem PAH	X					
Meteorological Parameters						
Climatronics	X	X	X	X	X	X
Data Acquisition						
Data Acquisition	DRDAS	ESC	ESC	ESC	ESC	ESC


Thomaston, CT - PM2.5 & WSPM; 11/29/06 to 12/11/06
PM2.5; WSPM (µg/m3); PAH (ng/m3)
Temp (C); Wind Speed (m/s)
60
50
40
30
20
10
0
-10
20
0
-20
-40
11/27/06
12/1/06
12/5/06
12/9/06
Date
PM2.5
WSPM (DC*15)
Temp (C)
Wind Speed (m/s)
PAH (ng/m3)

WSPM Monitoring: From (7/1/07) Progress Report . . .

The core site in Thomaston and the five satellite sites located in New Haven, Cornwall, Danbury, Mansfield and East Hartford were all operational by September 1, 2006.

The proposed monitoring period in the Wood Smoke QAPP is September 1, 2006 through September 1, 2007; however the CTDEP plans to continue monitoring through the 2007-08 winter.

The communications and digital data acquisition have been established at the core site in Thomaston.

Due to Aethalometer saturation matrix artifacts, a data correction algorithm is currently being implemented into the statistical package used to reduce and analyze the data. CTDEP has been and pending purchase order with Jay Turner at Washington University to modify the current version of the Aethalometer DataMasher and develop the saturation matrix artifact data correction.

The focus for this next quarter is to validate Aethalometer data and begin data analysis on measurements collected this past winter.

Goal Two -- In-use residential OWB PM emission component:

Phase I: Field PM method lab evaluation (Fall 2006)

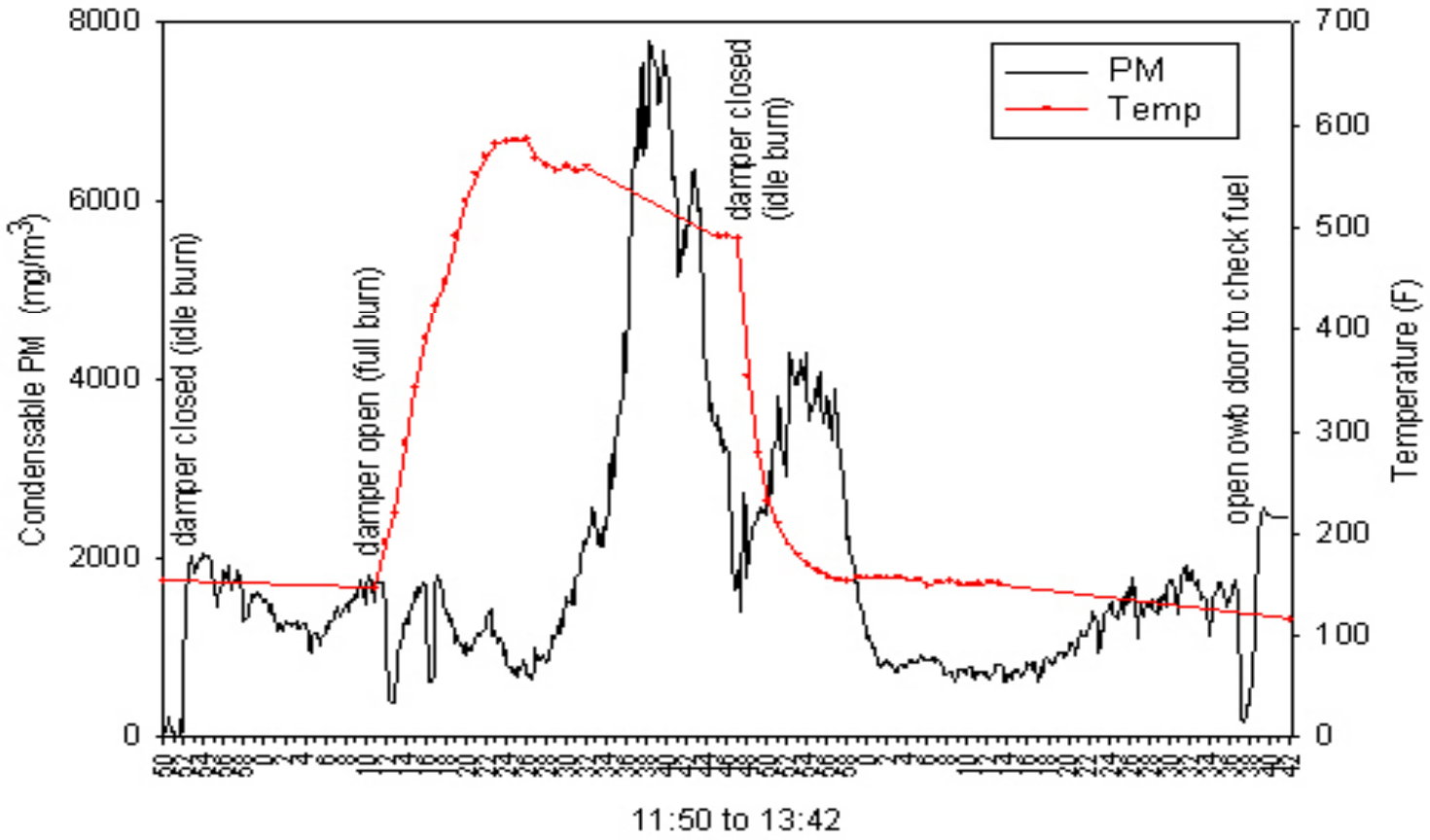
Compare existing EPA woodstove source PM methods (5g) with new continuous WS stack PM technologies developed for this project:

Dekati Micro-Probe/Dilutor with modified FDMS-TEOM
==> Capture all PM (including “condensables” -- volatile PM)

Phase II: Perform in-use OWB stack PM emission rate measurements at 4 field locations

During this summer (2007) and next winter (2007-08)
2-3 days of sampling at each location
3 “dirty” and 1 “clean” OWB (Black Bear/Clean Wood Heat)

NESCAUM OWF Stack Sampling; Continuous $PM_{2.5}$ (DataRAM) - June 22, 2005



From NESCAUM's **Assessment of Outdoor Wood-fired Boilers** (March 2006; revised June 2006)

OWF Stack Measurements: From (7/1/07) Progress Report . . .

CTDEP has subcontracted the Outdoor Wood Furnace Source Characterization work to NESCAUM. The addendum to the QAPP to cover laboratory testing conducted by NESCAUM was approved in November 2006. NESCAUM and Thermo Electron Corporation conducted laboratory testing at the VT Castings/CFM Corp. facilities in Bethel, VT on November 27-29, 2006. Several novel measurement techniques were utilized to characterize wood smoke concentrations on a continuous/real-time basis to compare results with filter-based Method 5g.

The *Progress Report on OWB Source Testing Method Evaluation* was prepared by NESCAUM based on the results of the laboratory testing and submitted to CTDEP on June 5, 2007.

The NESCAUM report summarized the results of the laboratory tests and identified limitations and obstacles that were encountered. The progress report also details the plan to address the shortcomings of the laboratory testing and take corrective action for the upcoming field study.

OWF Stack Measurements: Next Steps . . .

Schedule of Work: We have identified suitable OWB units for testing. The design would include a pair of emissions controlled OWBs with one being domestic sized and the other a small commercial sized unit. A second pair of OWBs would be units without any emission controls, again one being domestic sized and the other being a small commercial sized unit.

We plan to perform testing on two OWBs during the late summer or early fall of 2007. This first round of testing would be on domestic sized systems with heat loads, allowing the work to be performed during warm weather. Those units are:

1. Central Boiler (no controls) in CT:
2. Black Bear (with control technology):
   Clean Wood Heat Inc., Millinocket ME

During the late fall or early winter of 2007, we would perform tests on two OWBs under actual in-use conditions. Those two units are:

1. VT – TBD in consultation with VT DEC and CT DEP (no controls)
2. AMC Highland Center Lodge, Crawford Notch, NH
   Commercial Garn (with controls)

OWF Stack Measurements: Next Steps . . .

Dilution Probe: We have identified another vendor that has the capability to provide a field stack dilution system that would be appropriate for this work. TSI Inc., based in Shoreview, Minnesota, sells and supports a field Thermo-diluter designed for stack measurements. TSI has a local representative based near Albany, New York who has agreed in principal to participate in the OWB field test phase of this project. TSI would supply and operate the field dilution probe system, and NESCAUM would provide and operate the PM measurement methods.

The Matter Rotating Disk Thermodiluter/Conditioner model MD19-2E/ASET15-1 integrated unit is described at: http://www.matter-engineering.com/index.html. This unit is sold by TSI as the model 379020 Diluter and the model 379030 Sample Conditioner; these two systems are integrated into a single 19" rack-mountable cabinet.

OWF Stack Measurements: Next Steps . . .

PM Measurement Method: The stack sample will be diluted using a stack sample probe/diluter from TSI, manufactured by Matter Engineering in Switzerland (TSI is the US sales/service organization for this product). This 2-stage diluter can dilute more than 1000:1 (much higher than the Thermo dilution system), allowing ambient PM sampling methods to be used. It is also much simpler and more compact than the Thermo system. Continuous PM2.5 will be measured with a Thermo/RP model 1400AB TEOM at 30 degrees C or less and a sample flow rate of 1 LPM.

Low volume Teflon filter gravimetric samples will be collected off the dilution probe; the sample interval will be relatively short (1 hour or less), and samples will be chilled after collection to prevent loss of volatiles. We anticipate collecting several samples during each of the eight field test days, resulting in approximately 50 filters.

Other PM Measurements: TSI has also agreed to provide additional equipment to measure particle size distribution and number concentrations, using their SMPS and APS instruments. These detailed physical particle measurements will be useful in better understanding the impact that different burn modes have on aerosol generation. Using the TSI Data Merge software, we can also use these data to estimate the PM concentration, providing a second real-time measurement of the stack PM.

OWF Stack Measurements: Next Steps . . .

Stack flow measurements and field checks of Thermodiluter function:

NESCAUM will make stack temperature measurements and continue to run a standard pitot tube to assess stack gas velocity and volume. We will also introduce a tracer gas (SO2) into the OWB and measure the concentration in the diluted sample to allow a second measurement of stack gas volumes. This same tracer gas source (a cylinder) will be used to field check the TSI Thermodiluter in the field; the cylinder SO2 can be introduced into the dilution probe and measured by the SO2 analyzer. This gives an accurate field assessment of the Thermodiluter's actual dilution ratio.