Estimating Winter Space Heating Emissions in Fairbanks: The Importance and Challenge

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Overview

- Background
- Initial Gridded Inventory Development
- Recent Studies and Insights
- Conclusions

Background – PM$_{2.5}$ in Fairbanks

- Fairbanks has been designated non-attainment for the 24-hour federal ambient PM$_{2.5}$ standard

- Elevated winter concentrations are caused by:
  - Severe dispersion-limiting meteorology
  - Poorly understood atmospheric chemistry
  - Seasonal activity increase and relatively dirty fuel mix for space heating

- ORD currently configuring CMAQ to represent winter episodes

- Initial inventories suggest space heating is a key source

Initial Gridded Inventory – Key Data Sources

- <u>Home Heating Survey Data</u> – telephone survey of Fairbanks household heating practices

- <u>Energy Demand Models</u> – building energy demand estimates specific to Fairbanks

- <u>Spatial Surrogate Data</u> – parcel-level GIS database of taxable structures in Fairbanks

Initial Gridded Inventory - Methods

- Energy Demand Method
  - CCHRC estimates of building energy intensity (BTU/ft²/HDD/year)
  - Based on <u>Alaska</u> building construction and insulation practices, normalized for Fairbanks using heating degree days (HDD)
  - Assessor GIS database for spatial allocation
  - Fuel use splits from 2007 Home Heating Survey
  - Adjustments for heating efficiency by device

Initial Gridded Inventory – Methods (cont.)

$$FuelUse = DeviceEnergy / (FuelEnergyContent \times HeatingEfficiency)$$

Heating Efficiency Estimates for Space Heating Devices				
Device Type	Device	Heating Efficiencies		
		Low	High	Assumed
Wood-Burning Devices	Fireplace, No Insert	-10%	30%	10%
	Fireplace, With Insert	35%	50%	40%
	Woodstove, Conventional	25%	60%	54%
	Woodstove, Catalytic	60%	80%	68%
	Woodstove, Low-Emit. Non-Catalytic	60%	80%	68%
	Pellet Stove	65%	90%	68%
Oil-Burning & Other Devices	Residential Oil Furnaces & Heaters	70%	85%	81%
	Natural Gas Boiler	75%	85%	81%

Initial Gridded Inventory – Methods (cont.)

- Home Heating Survey Method
  - 2007 Home Heating Survey used to apportion household winter usage fractions to area households
  - Usage fractions normalized to account for multi-device usage
 - Fuel use estimated by multiplying households using each device by Survey-based usage rates

Initial Gridded Inventory – Comparison of Methods

- Reasonable agreement in fuel use (±15%) for most devices
- Wide discrepancy in fireplace estimates
  - Heating efficiency
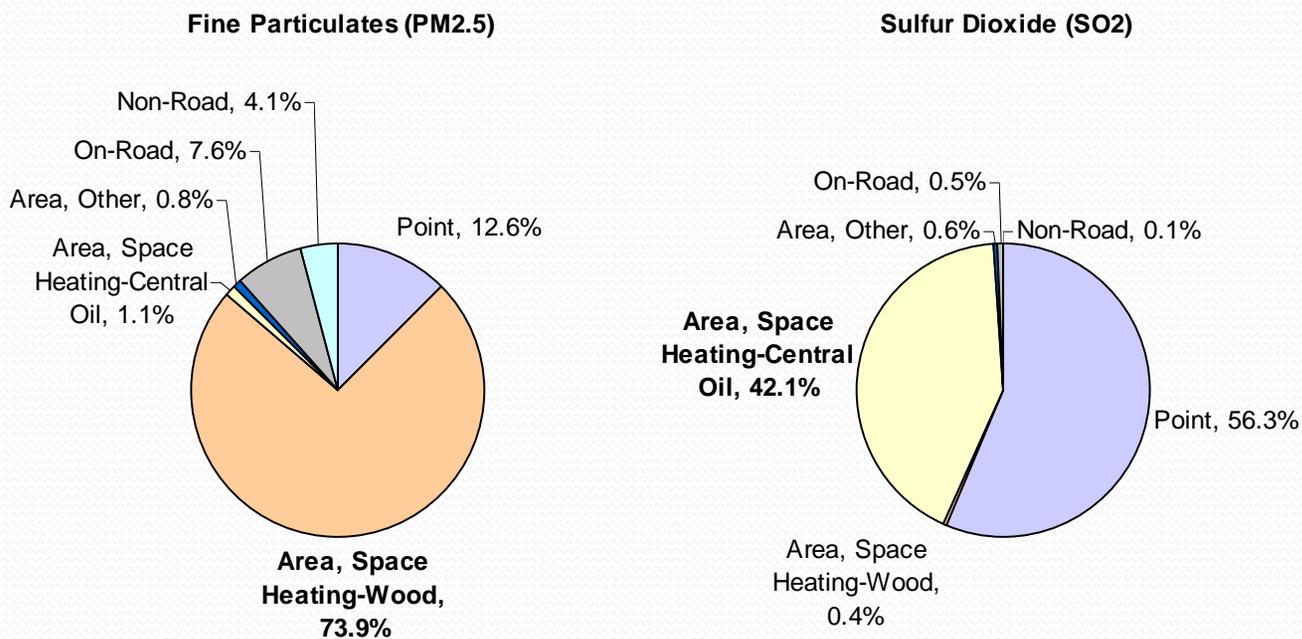 - Not able to discern wood use allocations in multi-device homes

Initial Gridded Inventory – Comparison of Methods

Comparison of Fairbanks Residential Winter Fuel Use, Energy Demand vs. Survey Methods
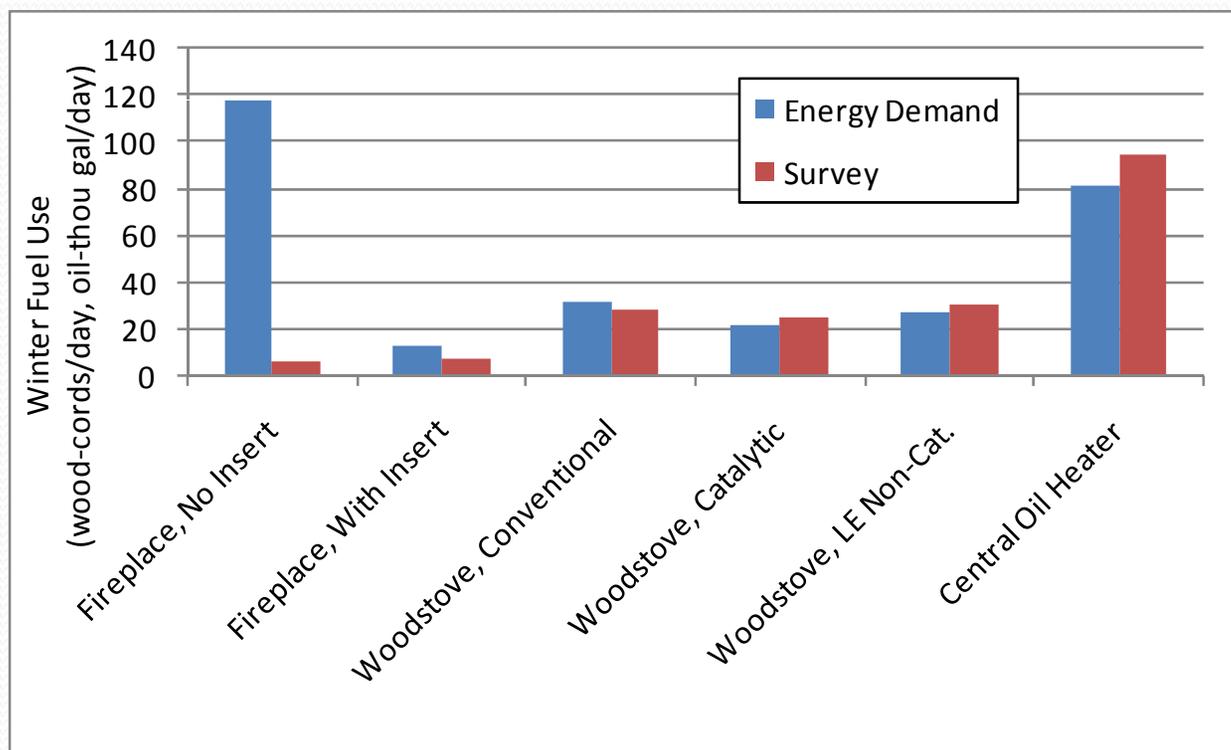
Initial Gridded Inventory – Source Contributions

Fairbanks Average Winter Day (October-March)
PM$_{2.5}$ and SO$_2$ Emission Contributions (% of Total) by Source Sector

Fine Particulates (PM2.5)

Non-Road, 4.1%
On-Road, 7.6%
Area, Other, 0.8%
Area, Space Heating-Central Oil, 1.1%
Point, 12.6%
Area, Space Heating-Wood, 73.9%

Sulfur Dioxide (SO2)

On-Road, 0.5%
Area, Other, 0.6%
Non-Road, 0.1%
Area, Space Heating-Central Oil, 42.1%
Point, 56.3%
Area, Space Heating-Wood, 0.4%

2010 Follow-On Studies

- Heating Appliance Operation Survey
  - Instrumented devices in 12 homes for roughly one month of measured activity
  - 3 wood only, 3 oil only, 2 outdoor wood boilers, 4 mixed wood & oil homes
  - Data logging used to collect oil pump activity
  - Thermocouple-measured wood device flue temperature as a proxy for activity
  - Wood log "diaries" used to calibrate these proxy data

2010 Follow-On Studies (cont.)

- 2010 Home Heating Survey
  - Follow-on to earlier 2006, 2007 phone surveys
  - 300 randomly-selected households
  - New questions on outdoor wood boilers, coal-fired heaters and home size (ft^2)
- Wood Storage Study
  - CCHRC collected wood samples from 49 homes
  - Moisture measured in 8-10 pieces per home
 - Documentation of wood storage practices

Follow-On Studies – Initial Analysis

- Data reviewed and quality assured
- Assessment of appliance use as a function of ambient temperature
- Results well-behaved for oil-only homes
- Mixed-use homes relationship more complex
- Diurnal activity patterns by heating device

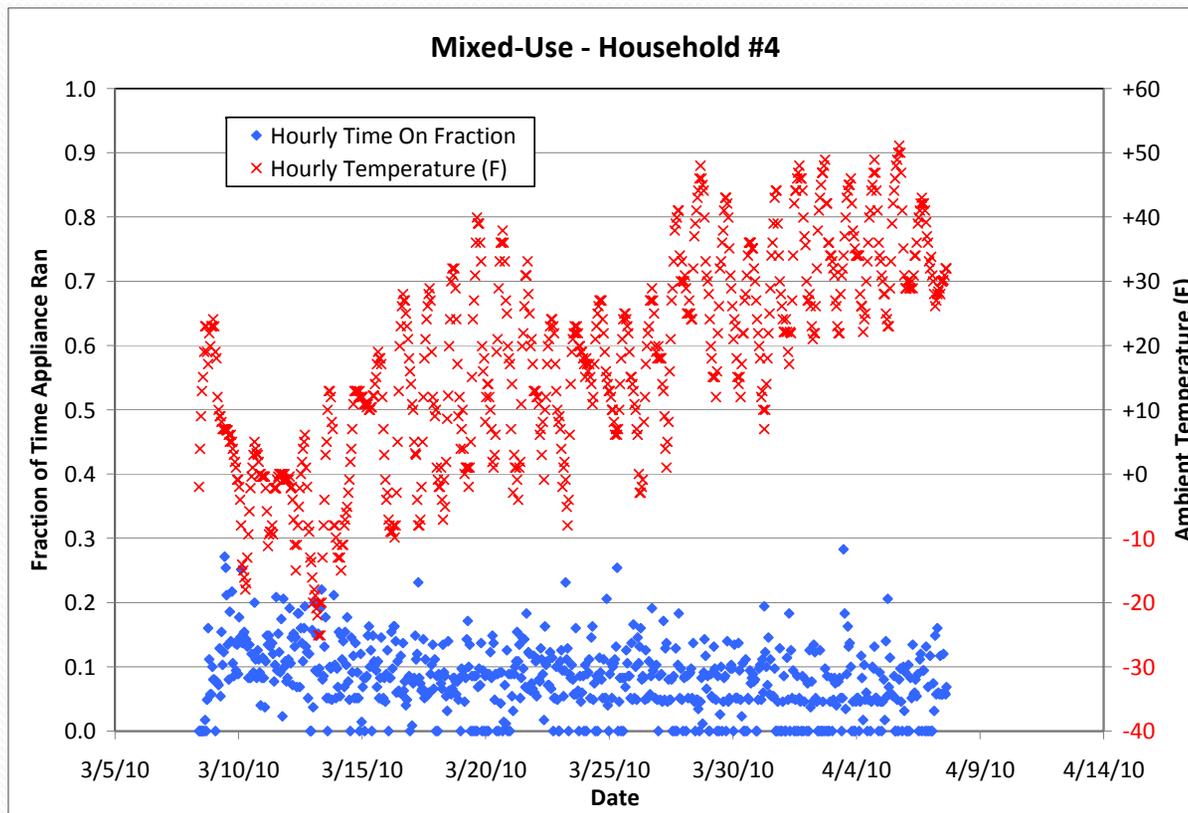# Follow-On Studies – Initial Analysis
Ambient Temperature

Oil Device On-Time Fraction vs. Ambient Temperature, Oil Only Household

Oil Only - Household #2
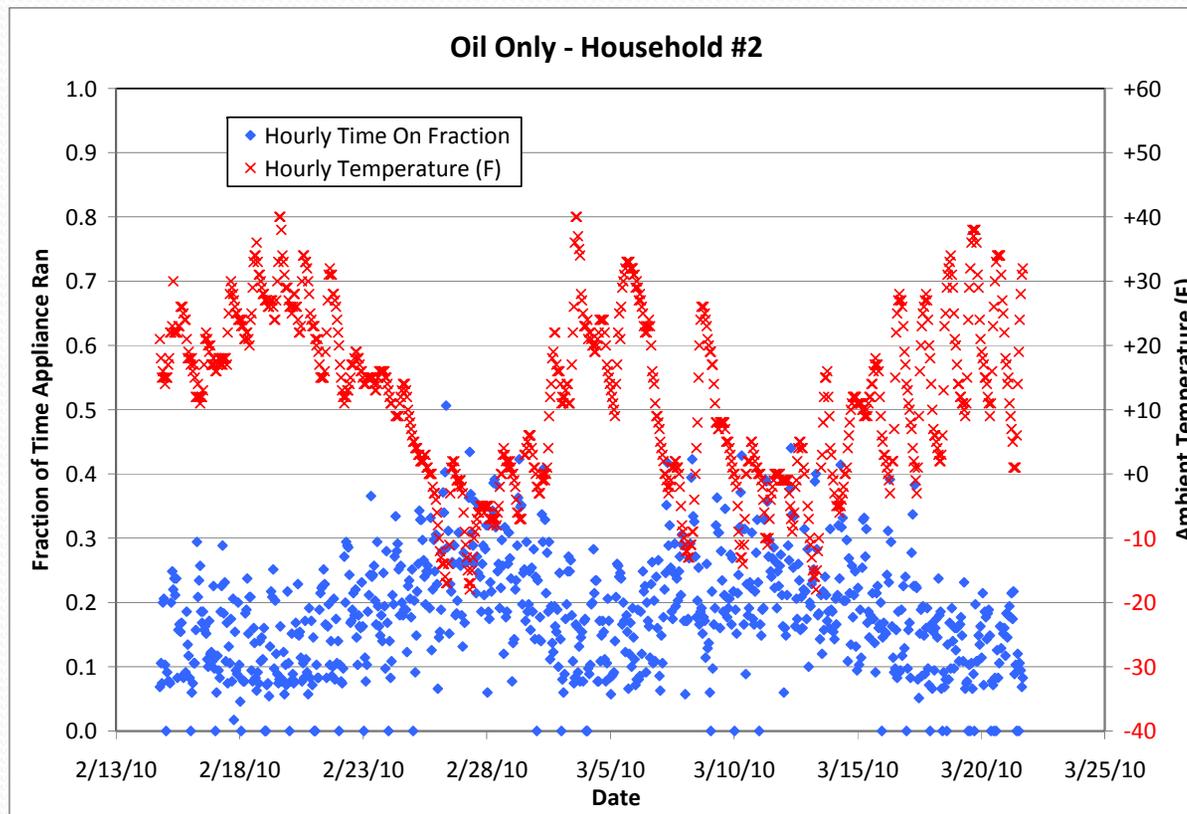
Follow-On Studies – Initial Analysis Ambient Temperature (cont.)

Oil Device On-Time Fraction vs. Ambient Temperature, Mixed-Use Household

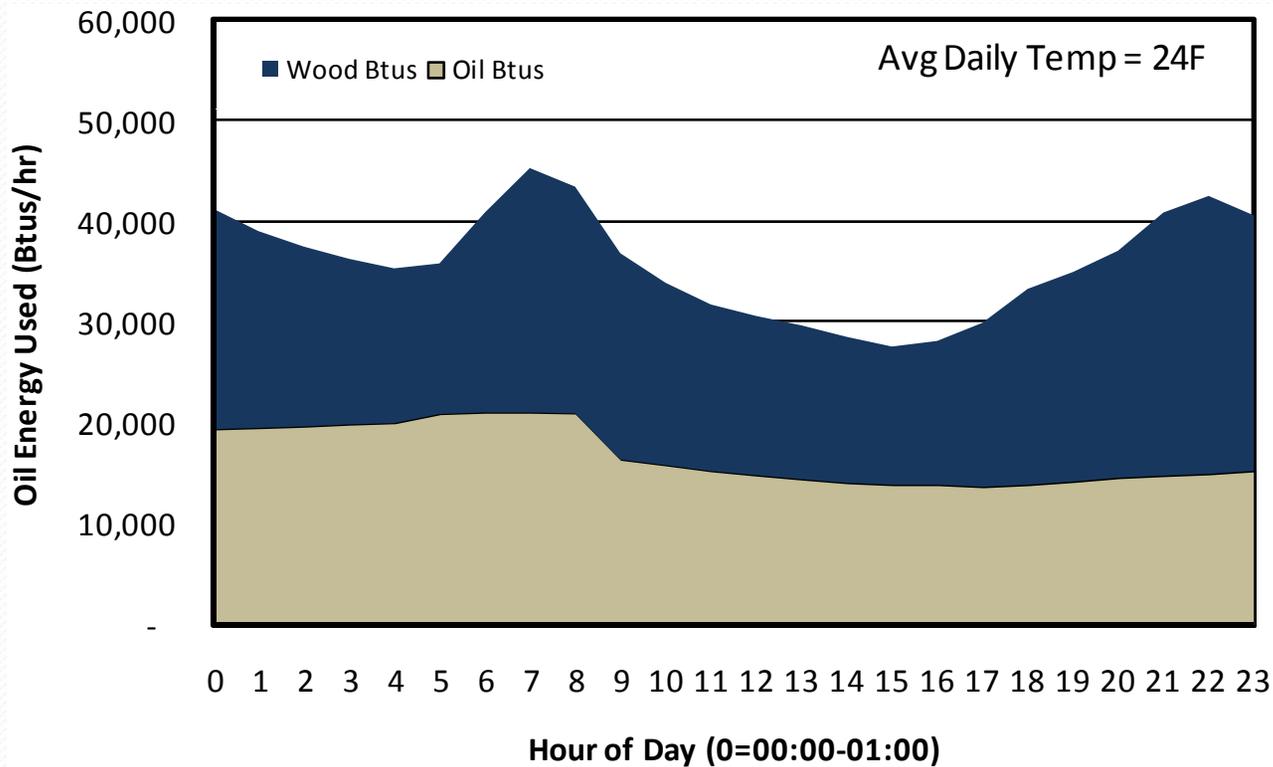# Follow-On Studies – Initial Analysis
Diurnal Activity Patterns

Diurnal Profile of Oil-Only Heating Use (Average Day Temperature)
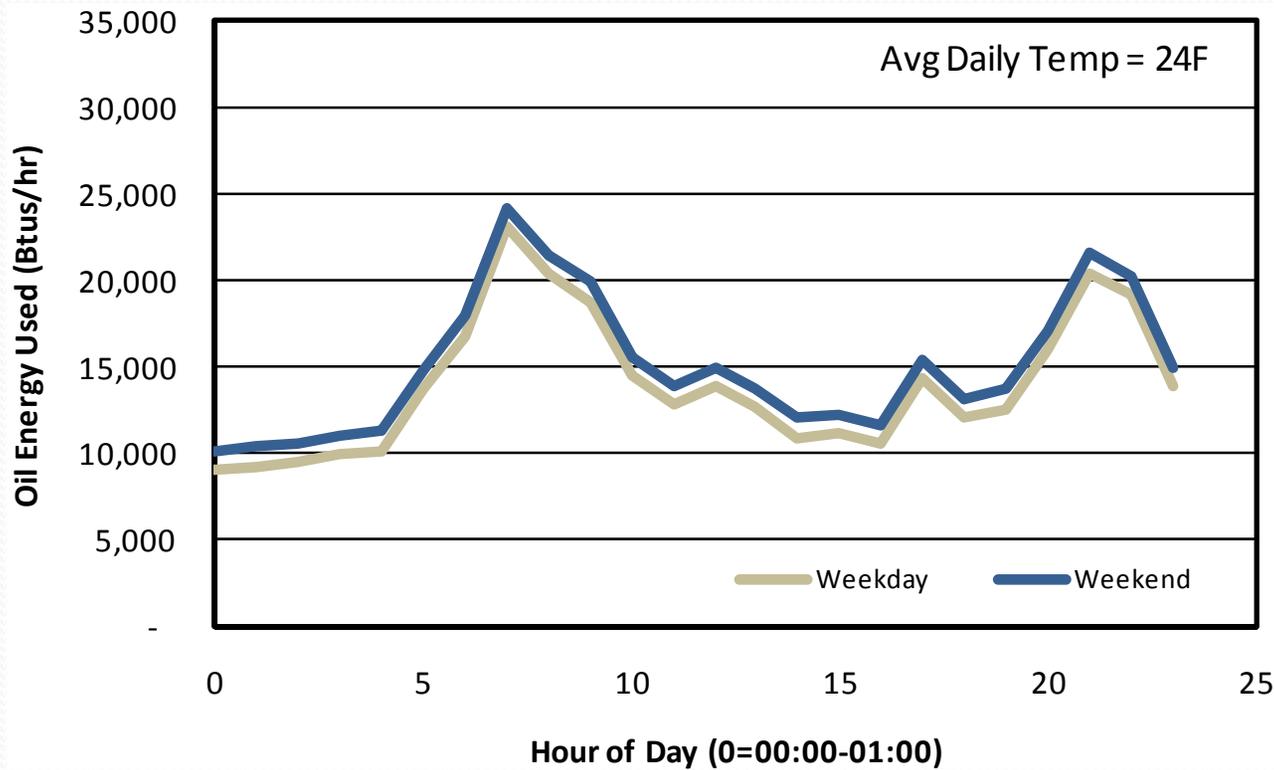
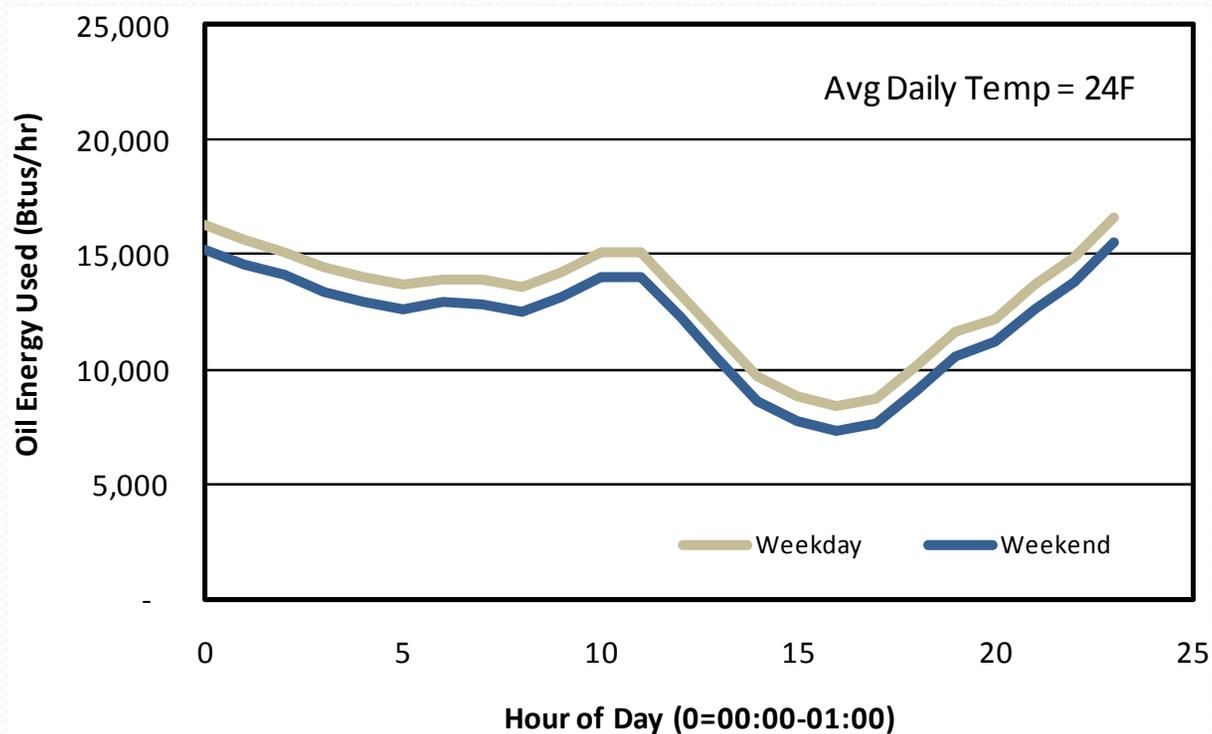# Follow-On Studies – Initial Analysis Diurnal Activity Patterns (cont.)

Diurnal Profile of Mixed Oil-Wood Heating Use (Average Day Temperature)

Follow-On Studies – Initial Analysis Diurnal Activity Patterns (cont.)
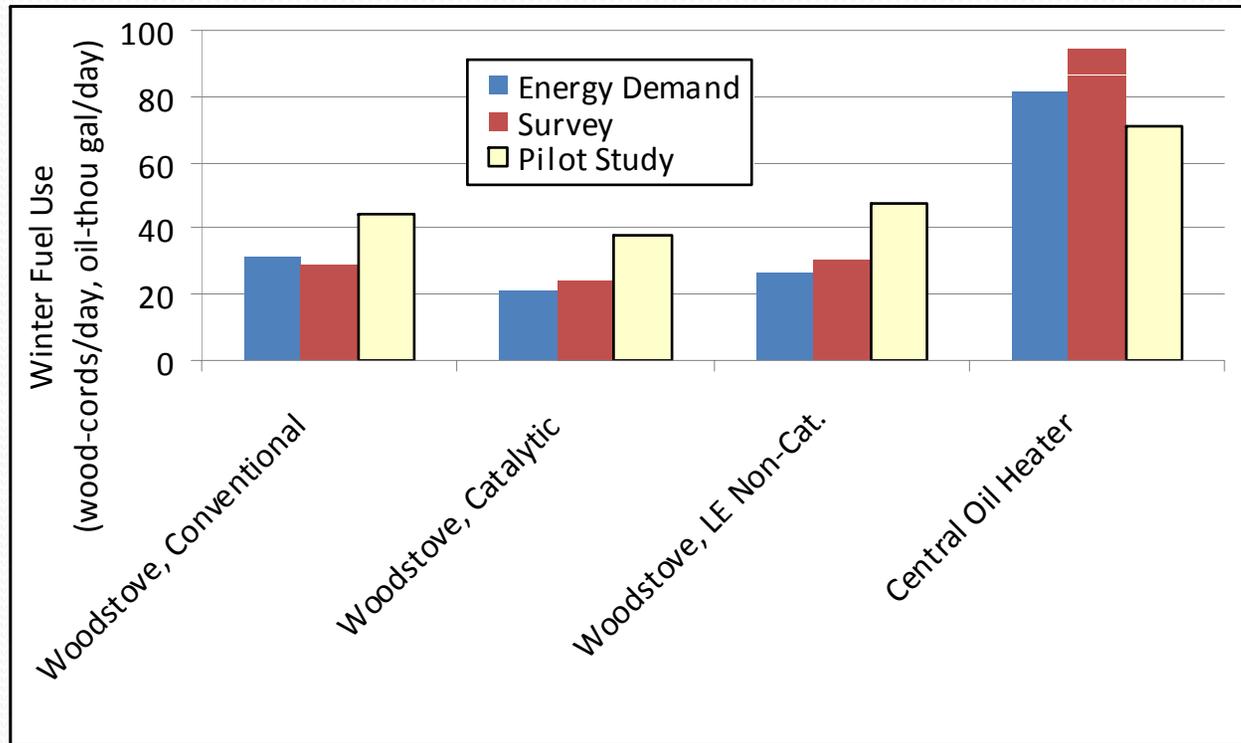
Diurnal Profile of Wood-Only Heating Use (Average Day Temperature)

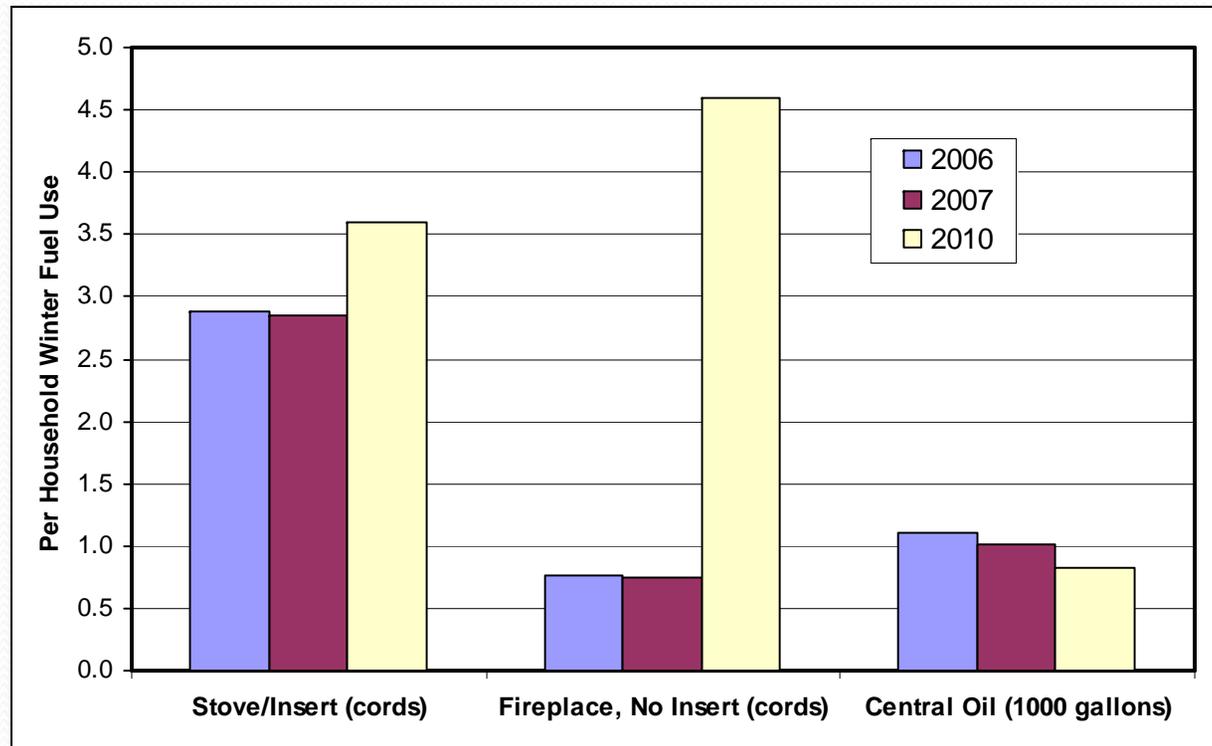# Follow-On Studies – Initial Analysis Fuel Use Comparisons

Comparison of Fairbanks Residential Winter Fuel Use,
Preliminary Pilot Study Estimates vs. Energy Demand and Survey Methods

Follow-On Studies – Initial Analysis Historical Survey Trends

Comparison of Winter Fuel Use per Household by Device from 2006, 2007 and 2010 Fairbanks Home Heating Surveys

Conclusions

- Estimates of space heating fuel use evolving

- Telephone surveys indicate shift toward dirtier fuel mix (wood) over time

- Energy Demand method unreliable when applied to fireplaces

- Diurnal profile of fuel use more complex than represented by HDD hours

- Additional measurements of fuel use needed to confirm pilot study results