

# Building America Special Research Project: Ventilation Efficiency of Controlled Ventilation Systems

Research Report - 1007

15 November 2010

Daniel Bergey and Armin Rudd

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Abstract:

*A wide variety of ventilation systems are installed in US houses to reduce interior contaminant levels and safeguard occupant health. The relative merits of these systems are subjects of ongoing research. Prior work by Building Science Corporation has investigated the effects of air distribution and mixing on pollutant levels within the building. The present work is aimed at discovering the energy costs of various ventilation approaches in operation, through modeling of typical houses across the TMY2 location set. Both measures are helpful in recommending a particular ventilation system.*

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# Research Project: Ventilation Efficiency of Controlled Ventilation Systems

Highlights for the last quarterly report/year-end report to NETL

D. Bergey and A.Rudd, 11/12/2010

A wide variety of ventilation systems are installed in US houses to reduce interior contaminant levels and safeguard occupant health. The relative merits of these systems are subjects of ongoing research. Prior work by Building Science Corporation has investigated the effects of air distribution and mixing on pollutant levels within the building. The present work is aimed at discovering the energy costs of various ventilation approaches in operation, through modeling of typical houses across the TMY2 location set. Both measures are helpful in recommending a particular ventilation system.

Research for Building America and ASHRAE Committee 62.2 has established the desirability of distributing ventilation air within the house, of mixing air within the house at a rate much higher than the desired outdoor air rate, and of continuous ventilation. Continuous mixing and distribution can be achieved through central air handler operation, however, the energy cost of this approach is very high. Central fan integrated ventilation is energy efficient when concurrent with heating or cooling, but relatively expensive when the fan is not otherwise required.

BSC is evaluating a controller (independently conceived and patented by Armin Rudd) which will afford continuous ventilation and intermittent mixing, taking advantage of central fan operating period. The controller will open a damper to admit outdoor air when the air handler is operating for heating or cooling. It will also engage the AHU and outside air damper when there is not a call for heating and cooling, to reach 10 to 20 minutes per hour operation for mixing and full distribution of ventilation air. Outside of times when the air handler is operating, the controller will activate an exhaust fan (typically in a bathroom, where it is required for local ventilation by occupant demand) or an HRV/ERV to provide fill-in ventilation.

This novel ventilation strategy is modeled in the present work. The other systems modeled are for reference and are representative of common ventilation strategies today or in the recent past, but make various compromises on these three objectives of distribution, mixing, and continuous ventilation.

Computer modeling allows the comparison of houses which are identical in all respects except for their ventilation system. It also permits tabulating data for a very large number of buildings (more than 20,000 in the present work), which is necessary in order to capture the variety of climate and construction practice encountered in the US. A custom TRNSYS model was developed by Hugh Henderson of CDH Energy for this project. The model uses the TRNSYS building enclosure model, with components for heating and cooling equipment from previous CDH Energy research. The model was

adapted to run on a 2-minute timestep, rather than the more typical 1-hour timestep, in order to accurately model the real behavior of controllers. Finally, the heat recovery ventilator (HRV) model was improved by BSC to represent both HRVs (which exchange heat but not moisture) and ERVs (which exchange both heat and moisture).

Eight ventilation systems were simulated, as described below. Each system was modeled at 3 settings of AC tonnage, 2 settings of thermostat setpoints, and with two settings of air handler efficacy. Each of these HVAC scenarios was modeled at the 216 TMY2 locations which are available in the contiguous 48 states, for a total of 20,736 simulation years.

The ventilation systems are:

- 1) Exhaust only at 100% runtime at the ASHRAE Standard 62.2 (62.2) continuous rate
- 2) Central fan integrated (CFI) at 33% minimum runtime at 62.2 continuous rate (no max damper open time)
- 3) same as 2 with 33% max damper open time
- 4) CFI at 33% minimum runtime at 3x 62.2 continuous rate (no max damper open time)
- 5) same as 4 with 33% max damper open time
- 6) CFI-G2, same as 2 but with fill in exhaust when the air handler is not running
- 7) CFI-G2, same as 6 but with fill in 60% heat recovery (60% energy recovery in climate zones 1 and 2a)
- 8) 60% HRV (ERV in climate zones 1 and 2a) at 100% runtime at 62.2 rate, independently ducted

The model house is a single story, 36' by 56', with a vented attic. Building enclosure specifications vary by climate zone, as shown below:

Attribute	Zone									
	1	2A	2B	3A	3B	4A	4B	5	6	6
slab-edge R-value	0	0	0	5	5	5	5	10	10	10
slab-edge insul depth (ft)	0	0	0	2	2	2	2	2	4	4
ceiling R-value (vented attic)	30	30	38	30	38	30	38	38	49	49
wall R-value	11	19	19	19	19	26	26	26	29	29
glazing U-value	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.28	0.28	0.28
glazing SHGC	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.35	0.35	0.35

The AC tonnage for each TMY2 location was calculated according to Manual J using RHVAC v8.01, using the house specifications just described. In practice, it is common for cooling systems to be sized above the Manual J specification, despite the increased cost and decreased moisture removal which results. Larger systems will run for less time during cooling, reducing the period during which concurrent ventilation is possible. The air handler fan is rated at 400 CFM/ton in all cases. Therefore the simulation array includes both the Manual J sizing and two oversized scenarios as follows:

- z) Manual J
- h) Manual J + 1/2 ton
- o) Manual J + 1 ton

The houses were modeled with a narrow range and a wider range of space temperature setpoints, to capture some of the impacts of occupant preference as follows:

- n) 72 heating, 75 cooling
- w) 70 heating, 77 cooling

Finally, the impact of AHU fan motor selection was modeled as follows:

- P) Permanent split capacitor (PSC) motor, 0.5 W/CFM
- E) Variable speed brushless DC (ECM) motor, 0.3 W/CFM

Appendix A includes a subset of charts created from the ventilation systems simulation results. Using the letter and number designations listed above as a key to the abbreviated naming scheme shown in the charts, the simulation configurations have names such as, for example, z1En, which refers to: Manual J sizing, ventilation system 1, ECM motor, and narrow setpoints.

This project will continue into 2011 and will culminate into a full technical paper to be submitted to a national conference.

## **Appendix A**

### **Subset of charts created from the ventilation simulation results**

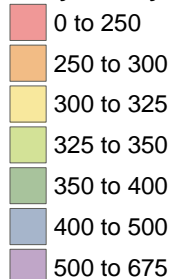
Daniel: This should be enough for now. You should work with Honorata to get the PDF charts in the Appendix with a Figure caption that expands the abbreviated naming scheme into the full description (as in the example above).

As we have talked before, the total HVAC cost charts have a different and important story to tell as well, but I suspect that these are not ready to go in this report, is that correct?

Also, we eventually need to run ventilation systems 6 and 7 with fan cycling of only 10 minutes/h for mixing and with zero minutes per hour as a lowest cost reference to compare to exhaust only for those that may not care about the mixing.

# Exhaust Only Man J ECM 70-77 Ventilation kWh

## F4 by County

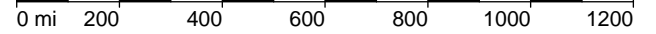
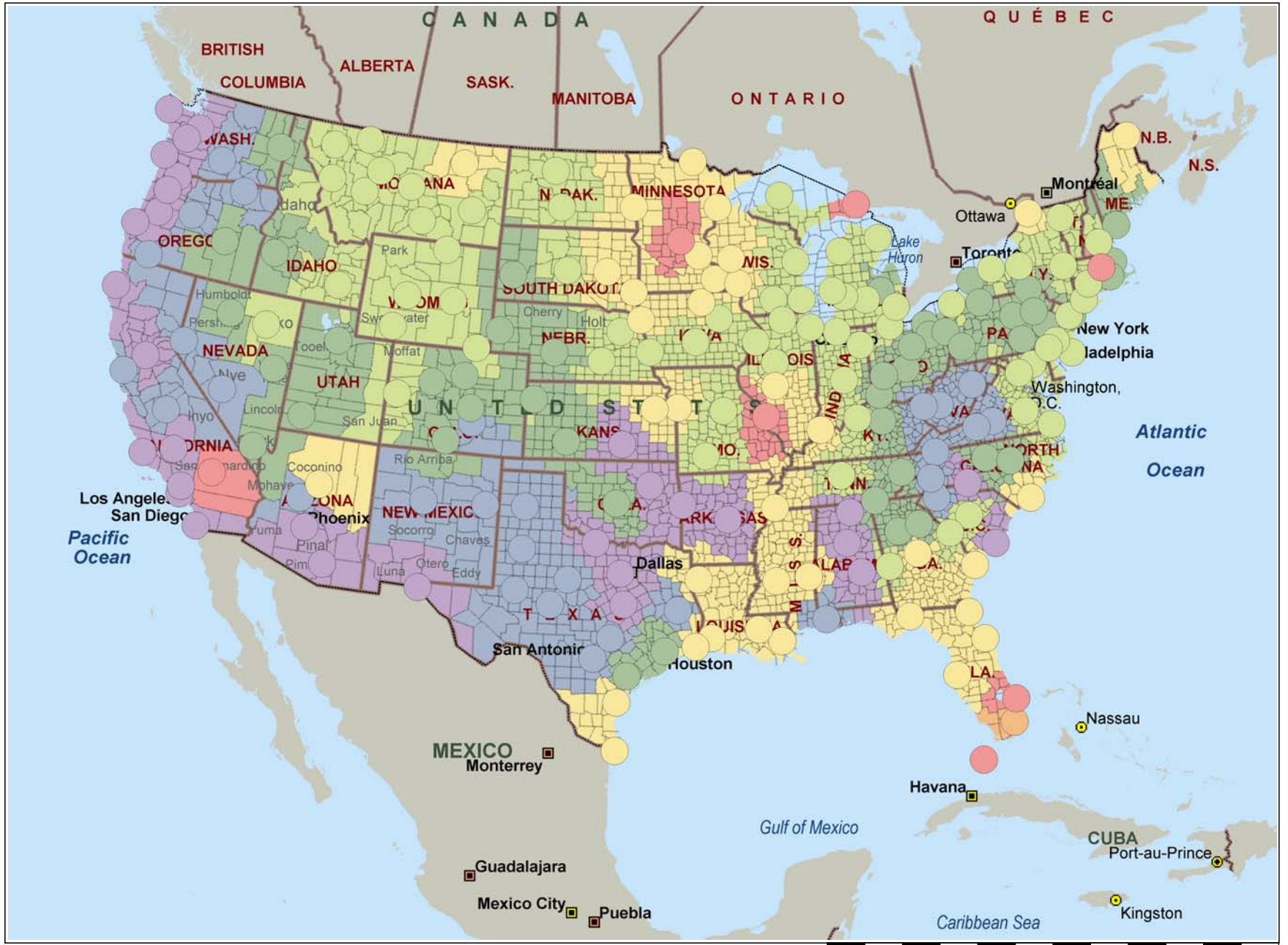
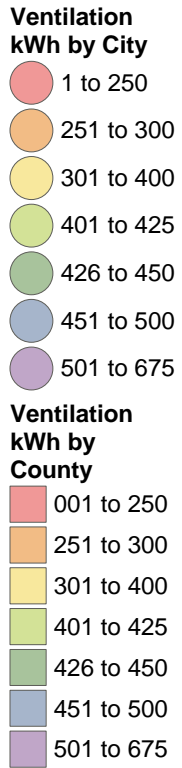


## Ventilation kWh by City



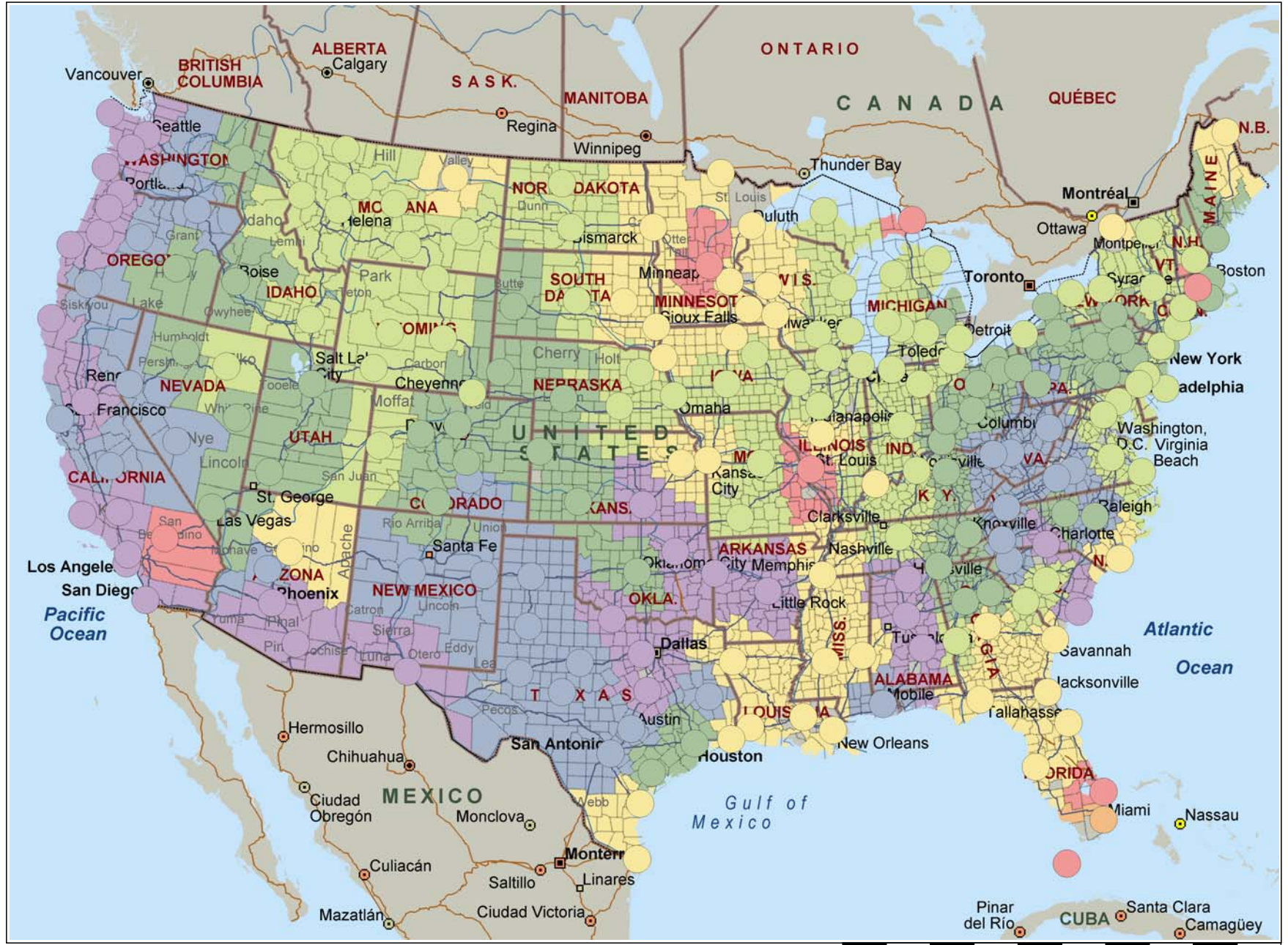
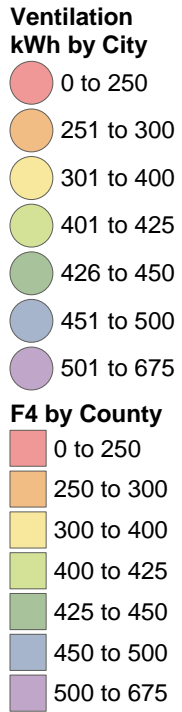
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# CFI 33% min Man J ECM 70-77 Ventilation kWh



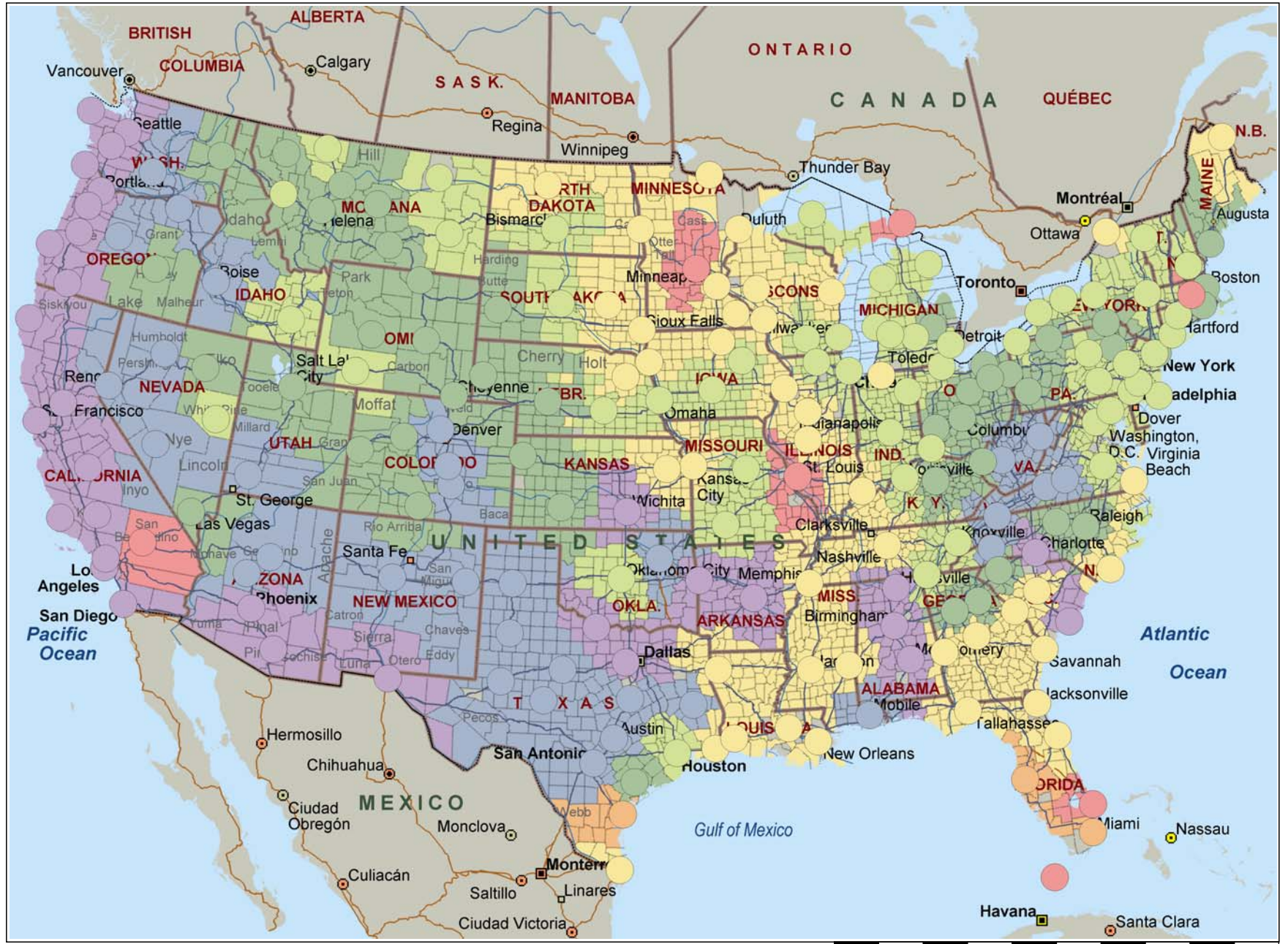
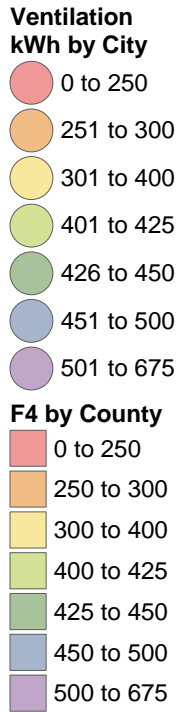
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# CFI 33% min-max Man J ECM 70-77 Ventilation kWh



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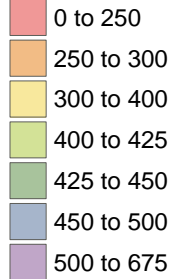
# CFI 33% min 3x 62.2 Man J ECM 70-77 Ventilation kWh



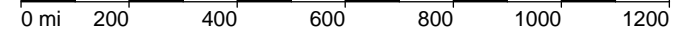
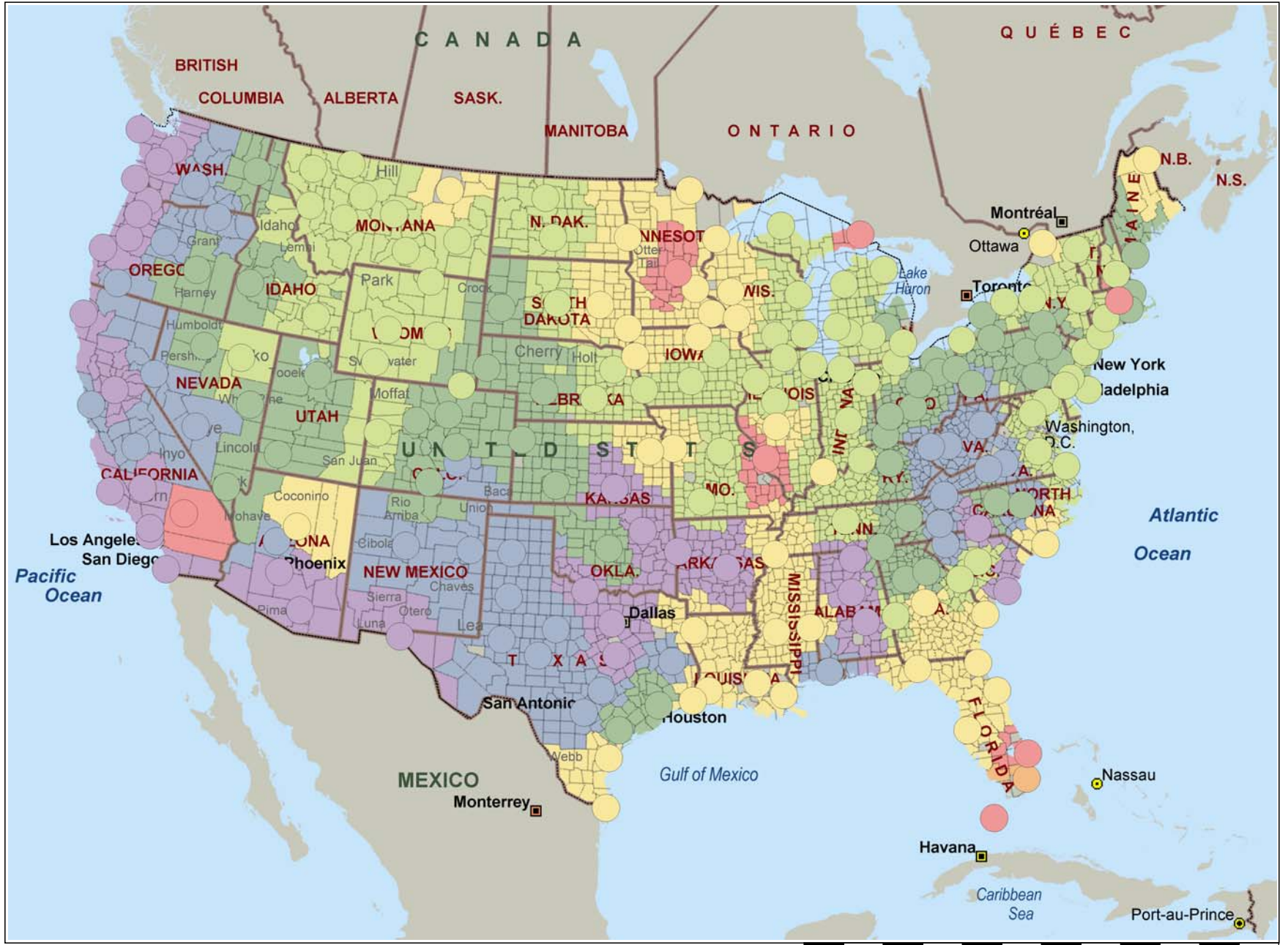


# CFI-G2 w. fill-in exhaust Man J ECM 70-77 Ventilation kWh

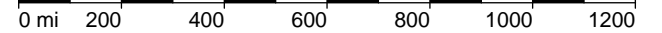
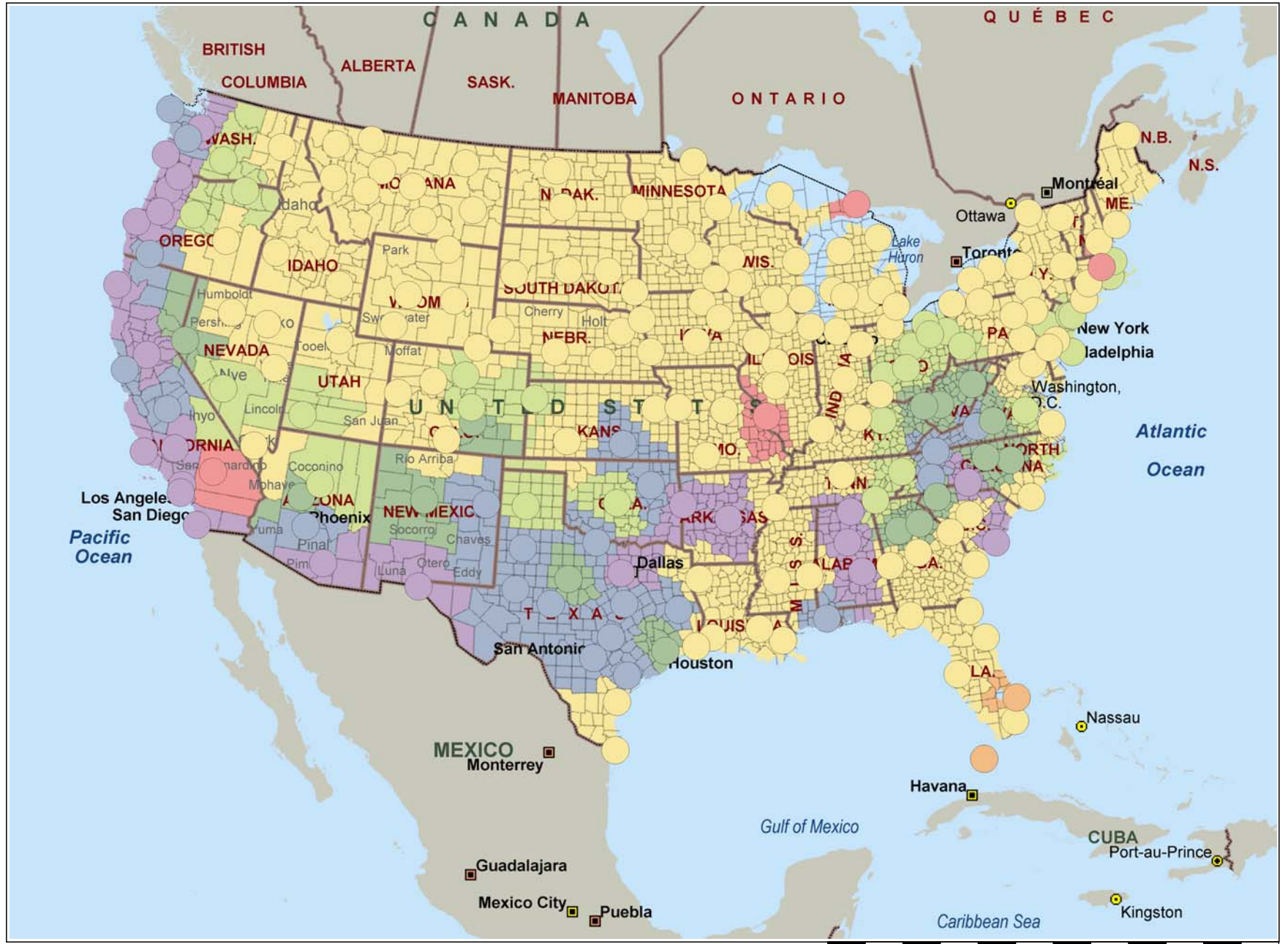
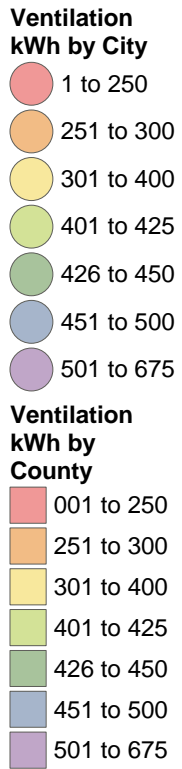
## F4 by County



## Ventilation kWh by City



# CFI-G2 w. fill-in HRV Man J ECM 70-77 kWh



## **RR-1007: Building America Special Research Report Ventilation Efficiency of Controlled Ventilation Systems**

### About this Report

This report was prepared with the cooperation of the U.S. Department of Energy's, Building America Program.

### About the Authors

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