Smart Zoned HVAC
Field test results of a centrally zoned forced air system with peak demand load control

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What is Smart Zoned HVAC?

**In-house Smart Controls**
- Smart Thermostats / Home Energy Management Systems / Load Control Devices

**Smart Grid**
- 2-way communication, Smart Meters & Time-of-Use Electricity Rates

**Advanced HVAC**
- **Example**: multi-stage or modulating heating & cooling equipment, ECM fans

- Zoned Combo System
- Zoned Furnace System

**CanmetENERGY**
- Leadership in ecoInnovation

* Conducted by McMaster University in partnership with CanmetENERGY, the OPA & local hydro authorities
What is Smart Zoned HVAC?

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**Advanced HVAC**
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**Zoned Combo System**
- Hi-Efficiency Heat Source
- Zoned Air Handler with ECM motor

**Zoned Furnace System**
- Zoning Dampers
- Zoning Controller
- Hi-Effic. 2-stage Furnace with ECM motor

*Mini-split System*

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Smart Zoned HVAC Project: Overview

Focus:
- To monitor summer peak period energy consumption and indoor comfort of:
  - Zoned combination system with and without load control vs. non zoned system with and without load control

Rationale:
- Pursuit of energy savings
  - GHG and air pollutant reductions
- Lowered stress on grid capacity during peak periods
- Improvement on Peaksaver® program in terms of:
  - Energy savings and occupant comfort

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Key Question

- Can temperature set points in unoccupied zones be set-forward to enable peak demand reductions without negatively affecting occupant comfort?
Precursor Study: Zoning Annual Field Trial

Annual Energy* Comparison by HVAC System Type

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Conventional (Non-Zoned)</th>
<th>Zoned-System</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas (m³)</td>
<td>2,117</td>
<td>1,968</td>
<td>-7.0%</td>
</tr>
<tr>
<td>Electricity (kWh)</td>
<td>1,137</td>
<td>969</td>
<td>-14.8%</td>
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</tbody>
</table>

* based on 2,180 SF of finished area (incl. basement); and 2.7 occupants per household

- Dependent on occupant use of differentiated setbacks
- Strong potential for peak period electricity savings
Field Sites

6 Retrofit Sites
Chatham-Kent

Attached 3-level townhomes
Heated floor areas: ~1,800ft²

10 New Construction Sites
Kitchener-Waterloo

Detached, 2-story
Heated floor area: ~ 2,600 ft²
(with basement)

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Field Instrumentation

Electricity Sub-metering & Data Logging Equipment

- SR9 Data Logger
- Watt Pulser
- T & RH Logger
- Temp Logger

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Data Sampling & Collection

- Monitoring equipment recorded 6-values for each house at 20-minute intervals
  - 3 indoor temperatures and 1 relative humidity
  - 2 electric energy values
- Hourly weather information was gathered from local weather stations
  - Outdoor temperature
  - Outdoor dew point temperature
  - Humidex
- Whole-house energy data was gathered from the local distribution companies
  - Electricity – hourly
- Questionnaires were used to collect occupant feedback

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Evaluation Method

Information from Zoned and Non-Zoned Houses in the Field Trial

- Utility Data
  - N.G. & Elect.
- HVAC System
  - Elect. Usage
- Indoor Temp. & Humidity Levels
- Local Weather Conditions
- Homeowner Info. & Feedback

Multi-variable Panel Regression Model of Energy Usage by HVAC Systems in the test houses
(Completed by the DeGroote School of Business, McMaster University)

Average HVAC Energy Usage Estimates for Zoned and Non-Zoned House
(heated floor area: 2,304 ft², 3 occupants)

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Evaluation Method: Normalisation

- AC energy use modeled as a function of:
  - Average humidex (humidity & temperature)
  - Location of house (CK or KW)
  - Heated (cooled) floor area
  - Number of occupants
  - Whether home is zoned or non-zoned
  - Effective capacity of A/C (ton/SEER)
  - Thermostat set points
  - Timing of load control
  - Duration of load control
  - Recovery of AC after load control
  - Household income
  - Whether home faces west
  - Whether A/C is undersized
  - Presence of ancillary motor loads (related to DHW draws)
  - There are weekend and weekday models as well as distinct models for hot months (July and August) and boundary months (May, June and September)

- Average house: 2304 ft², 3.0 residents, $104,615 household income

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HVAC Equipment

NON-ZONED SYSTEMS: FURNACE FAN & A/C
Central A/C = SEER 13
Furnace Fan with PSC motor
Conventional ductwork

ZONED SYSTEMS: COMBI/COMBO & A/C
Central A/C = SEER 13
Zoned air handler with EC motor
Zoned ductwork

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Thermostat Load Control

Kitchener-Waterloo Region

- Used Honeywell Utility PRO thermostats
- 1-way communication via a pager signal
- Used the homeowner remote interface to reprogram the thermostat to simulate “utility” initiated load-control events
Thermostat Load Control Interface

Kitchener-Waterloo Region

- Used the homeowner remote interface to reprogram the thermostat to simulate “utility” initiated load-control events.

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Load Switch Control Equipment

Chatham-Kent Region

- Used Tantalus load control switches
- 2-way communication via Smart Metering network
- Chatham-Kent Hydro dispatched control events

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Load Control Treatment Summary

- Four custom Zonesaver LC treatments were tested with the zoned cooling systems.
- Zonesaver LC interrupted the supply of chilled air to a portion of the house during the control events, while maintaining normal cooling operation in other areas.
- Zonesaver LC treatments were “matched” to the normal occupancy patterns reported by homeowners during a pre-trial interview.
- Zonesaver treatments were dispatched up to 6 times per month in the summer of 2010 (July, Aug & Sept).
- Peaksaver-style treatments were dispatched on the same days in non-zoned houses (up to 6 times per month).

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Results: Summer Peak Electricity Usage

3-House Average Demand by the Cooling System on the System-Peak Day, Aug 17, 2009

- The Zoned Systems ran longer during the night-time to provide cooling to the top floor.
- The Zoned Systems ran less during the daytime.

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<table>
<thead>
<tr>
<th>Hour Ending</th>
<th>Avg. Conv.</th>
<th>Avg. Zoned</th>
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<tbody>
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<td></td>
<td>19.3 kWh</td>
<td>12.9 kWh</td>
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Results: Summer Peak Electricity Usage

Electricity Demand of Residential Cooling Systems during the Afternoon Peak Period

- Non-Zoned-Cooling (baseline)
- Non-Zoned with Peaksaver LC: 22% to 28% Reduction
- Zoned-Cooling with no load control: 12% to 18% Reduction
- Zoned Cooling with upstairs LC: 51% to 57% Reduction

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Results: Summer Peak Electricity Usage

- Substantial savings
- ... but control of whole house
- ... may leave occupants uncomfortable

Electricity Demand of Residential Cooling Systems during the Afternoon Peak Period

- 22% to 28% Reduction
- 12% to 18% Reduction
- 51% to 57% Reduction

Relative Electricity Demand (% of Non-Zoned Cooling System)

- Non-Zoned-Cooling (baseline)
- Non-Zoned Cooling with Peaksaver LC
- Zoned-Cooling with no load control
- Zoned Cooling with upstairs LC
Results: Summer Peak Electricity Usage

Substantial savings... but depends on the homeowners use of aggressive set-forward in peak times.
Results: Summer Peak Electricity Usage

- Aggressive savings
- ... enabled by unoccupied upper zone “floating”
- ... occupants on main floor stay comfortable
- ... recovery time before bed is minimal and off-peak
Occupant Survey Results

- 100% have shared experiences with family members and friends
- 95% would recommend a zoned system to a friend
- 75% felt zoning was very effective
  - 20% felt it was effective
  - 5% felt it was not effective
Our Follow-on and Related Activities

- Partnership initiative with builders (LEEP) led to zoning listed in top 10% of new energy-positive technologies
- Presentation of findings to OPA was successful and peaked interest in demand reduction potential of zoning
- Duct design guide for zoned systems is under development
- Working with Canadian Manufactured Housing Institute to assist interested builders in adopting zoned duct design approach
- Testing of mini-splits as a ductless approach to zoning yielded 60% cooling energy savings
- Simulation of awnings as a peak demand reduction opportunity at CCHT yielded 1 degree temperature reduction throughout house (10-20% cooling energy savings)
Comfort Performance (2 of 2)

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<tr>
<th></th>
<th>Conv. 15.7 kWh</th>
<th>Zoned 15.2 kWh</th>
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Top Floor Indoor Conditions on August 17, 2009

- **Conv.** House:
  - Overnight & morning
  - Evening

- **Zoned** House:
  - Overnight & morning
  - Evening

- **Hot & Humid Region**:
  - Afternoon

- **Cold & Clammy Region**

- **Cool & Dry Region**

- **ASHRAE Summer Comfort Zone**
Mini-Splits

COOLING

Cooling: Daily Electrical Consumption, Central A/C vs. Mini-split

- Mini-Split Upper Floor
- Mini-Split Main Floor
- Condenser
- Furnace fan
- Avg. Outdoor Temperature

A/C Electrical Consumption, kWh

Avg. Outdoor Temp., °C

03-Sep-11 04-Sep-11 05-Sep-11 06-Sep-11 07-Sep-11 09-Sep-11 10-Sep-11 11-Sep-11

Mini-Splits

HEATING

Heating: Daily Energy Consumption, Furnace vs. Mini-split

- Furnace natural gas
- Furnace fan elec
- Mini-Split - Upper Floor
- Mini-Split - Main Floor
- Fireplace
- Temperature

Space Heating Energy Consumption, kWh

Avg Outdoor Temp, °C

01-Feb-12 | 02-Feb-12 | 03-Feb-12 | 04-Feb-12 | 05-Feb-12 | 06-Feb-12 | 07-Feb-12 | 08-Feb-12 | 09-Feb-12 | 10-Feb-12 | 11-Feb-12 | 12-Feb-12

0 | 20 | 40 | 60 | 80 | 100 | 120 | 140 | -14 | -12 | -10 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | 6