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AIR BARRIER EDUCATION TRACKS FOR THE CONSTRUCTION INDUSTRY

Web-Based Energy Savings Calculator for Building Envelope Air Tightness

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EDUCATION

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DURABILITY + DESIGN
ARCHITECTURAL COATINGS FOR THE BUILT ENVIRONMENT

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ARCHITECT'S NEWSPAPER

Presentation summary

- Why is air leakage important?
- Web-based tool that estimates energy savings associated with air tightness
- Some examples

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Buildings use a lot of energy

40% of all energy and 75% of all electricity used in the US

Source: US Department of Energy

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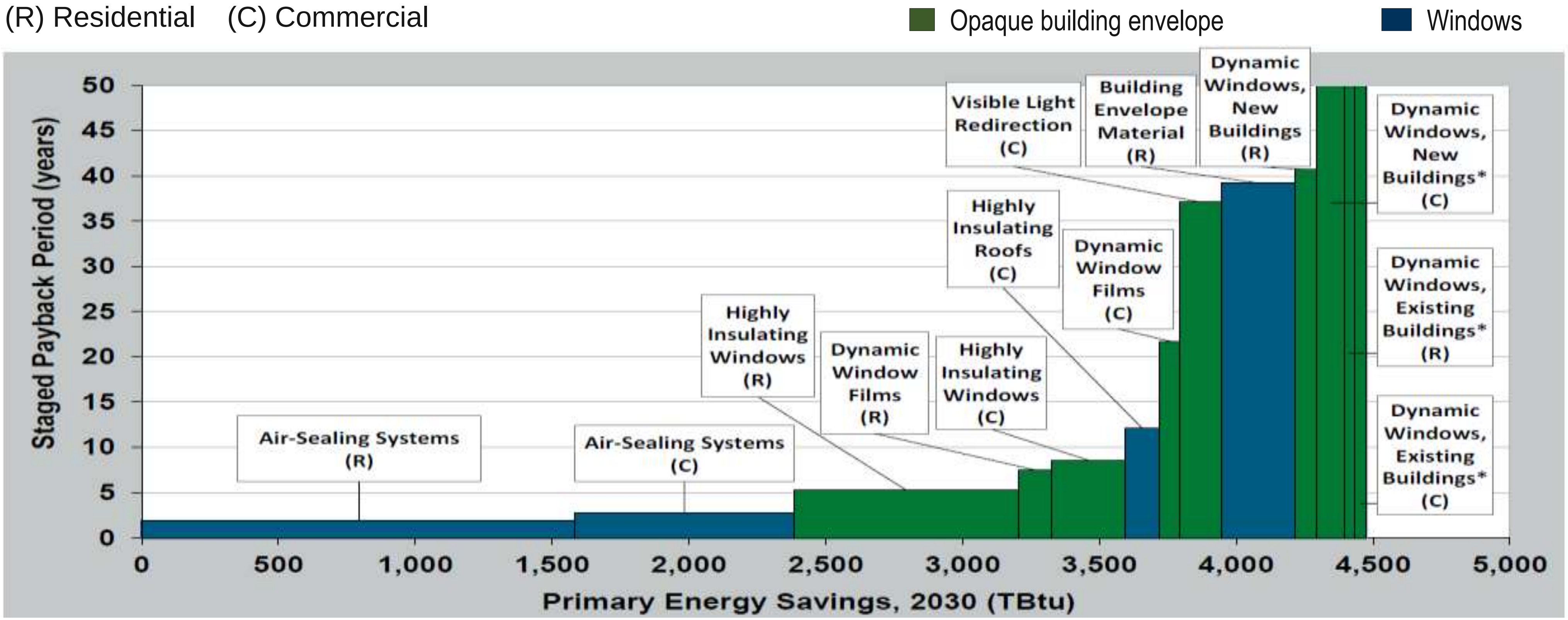
Windows and building envelope R&D ET roadmap



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Develop an air leakage calculator

Challenges

- Air leakage rates depend on multiple variables
  - Envelope airtightness
  - HVAC system operation
  - Occupancy
  - Weather
  - Stack effect
- Typical assumptions
  - Constant leakage rate
  - Leakage rates from simplified algorithms

Under- or over- estimated energy use

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Infiltration modeling in EnergyPlus

- ZoneInfiltration:DesignFlowRate
  - DOE commercial prototype building models
- ZoneInfiltration:EffectiveLeakageArea
  - DOE residential prototype building models
- ZoneInfiltration:FlowCoefficient
- AirflowNetwork
  - Future effort

Typically
do not take into account
- Temperature difference
- Stack effect
- Wind direction

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ZoneInfiltration:DesignFlowRate
DOE commercial prototype buildings

$$Air\ leakage\ rate =$$

$$(I_{design})(F_{schedule})[A + B|T_{zone} - T_{odb}| + C(WindSpeed) + D(WindSpeed^2)]$$

Default values

$A = 0$

$C = 0.224$

$D = 0$

$B = 0$ → Does not take into account effects of temperature difference

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ZoneInfiltration:DesignFlowRate DOE commercial prototype buildings

$$Air\ leakage\ rate =$$

$$\left(I_{design}\right)(F_{schedule})[A + B|T_{zone} - T_{odb}| + C(WindSpeed) + D(WindSpeed^2)]$$

I_{design} in most DOE prototype buildings building

- Air leakage rate when HVAC is off = 1 L/s·m^2 at 75 Pa
- Air leakage rate when HVAC is on = 0.25 L/s·m^2 at 75 Pa

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Objective

- Create an easy-to-use online tool using the simulation results of the best-in-class building energy simulation tool EnergyPlus and the whole building airflow simulation tool CONTAM.
- Online calculator estimates the potential energy and cost savings from improvements in airtightness.
- Further increase market penetration of air barriers.

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NIST National Institute of Standards and Technology

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Calculations flow

Pre-Run Simulations of DOE Commercial Prototype Buildings

Max HVAC/ventilation airflow rates

Hourly infiltration rates

EnergyPlus
- Envelope airtightness
- Building details
- Weather

CONTAM
- Envelope airtightness
- Building details
- Weather
- HVAC/ventilation airflow rates

EnergyPlus
- Building Details
- Weather
- Hourly infiltration rates from CONTAM

Pre-Run Results

Energy use and cost as a function of envelope airtightness

+

User Specified
- City
- Building type
- Footprint area
- Before / after retrofit airtightness
- Energy rates

Potential Energy and Cost Savings

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The tool

OAK RIDGE National Laboratory Infiltration

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Welcome to

Web-Based Energy Savings Calculator for Building Envelope Air Tightness

Uncontrolled heat, air, and moisture transfer through the building envelope has a significant impact on energy usage. A comprehensive strategy for concurrently regulating these factors will have a major impact on reducing energy consumption. The DOE Windows and Building Envelope Research and Development Roadmap for Emerging Technologies shows that in 2010, infiltration was responsible 4 quads of space conditioning primary energy use in the residential and commercial sectors. In aggregate, infiltration accounted for greater energy losses than any other component of the building envelope, including fenestration and is responsible for over 4 percent of all the energy used in the United States. Furthermore, the Roadmap shows that the payback for the addition of air barrier systems would have a payback that is much less than 5 years.

The Roadmap further states that "computational tools are critically important for the design of commercial buildings with energy efficient envelope materials. As new technologies are developed, models and simulation tools must be updated to account for increased performance." An impediment for the wider adoption of air barrier systems into buildings is the lack of a simple credible tool that can be employed by building architects, designers, and owners that accurately estimates the energy savings that could be expected if an air barrier system was added to the design. This calculator fills this void, is based on the best science available, and is easy to use.

Start your evaluation

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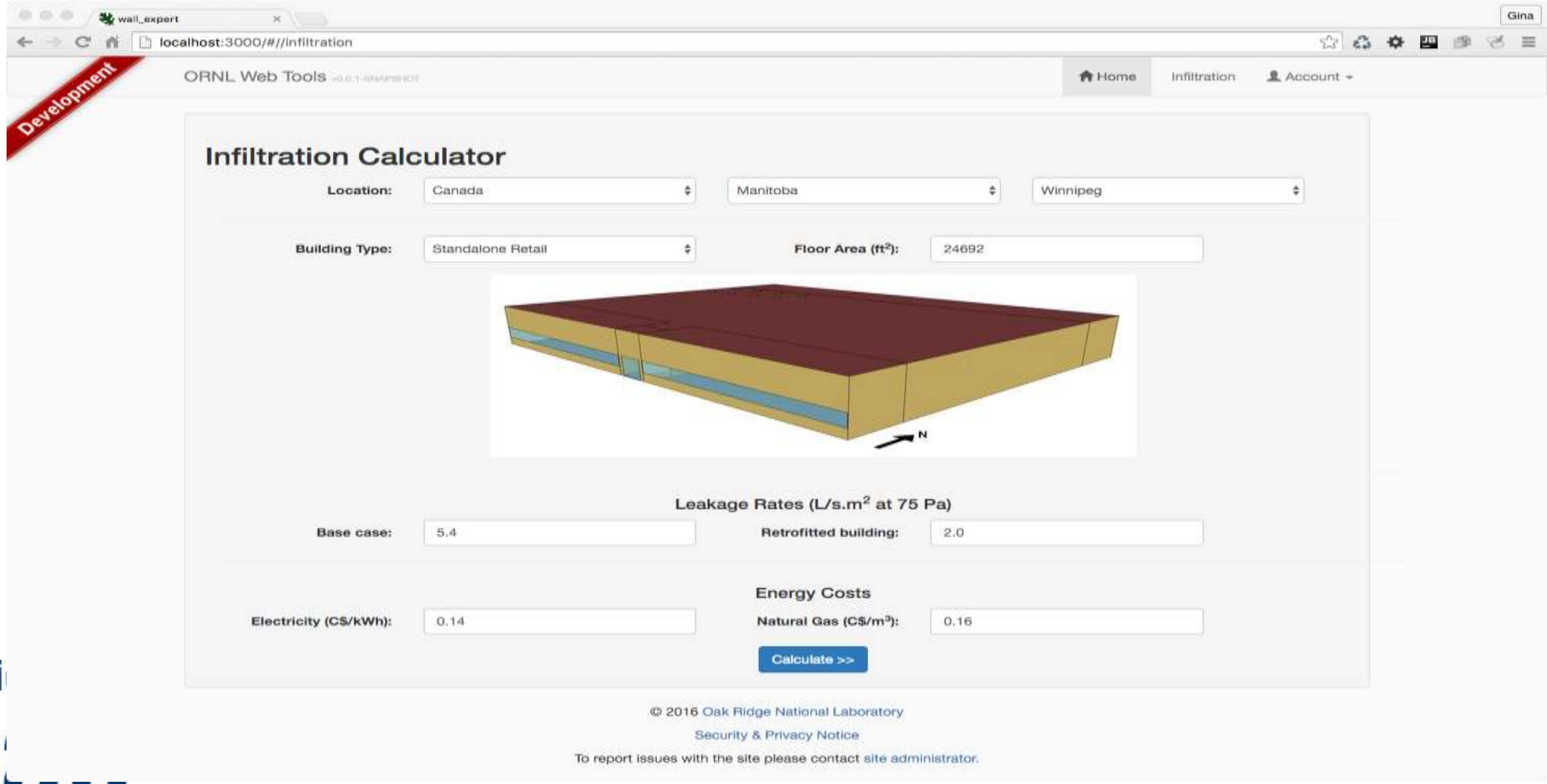
Calculator input



The tool: location

The first phase in the development of the calculator analyses the air tightness energy benefits in 52 cities in the US, 5 cities in Canada, and 5 cities in China. Selecting the country unlocks the states or provinces where the air tightness benefits have been determined. Choosing the state or province unlocks the cities within that state that have been evaluated. The selection of cities was based on trying to obtain a reasonable distribution of major metropolitan areas throughout the country; therefore not every state or province is represented. If the specific city you are interested in obtaining results from does not appear on the list, select a city that has similar meteorological conditions (wind, temperature, solar radiation, and rain). This is not always the city geographically closest to your target city.

Locations

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The tool: building types

The calculator uses the DOE commercial reference building models (DOEb 2016) and represent about 80% of new construction. Moreover, these prototypes cover 16 commercial building types, including mid- to high-rise residential buildings in 17 climate locations defined in ASHRAE Standard 90.1-2013. The variables that are prescribed in these models include building envelope components, HVAC equipment types and efficiency, and occupancy schedules. Features of the building models and a detailed description of their development are provided in the Building Energy Codes Program website (DOEa 2016). Click on the building image to see a summary of these features.

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The tool: building types

The first phase in the development of the calculator covers three prototype building models: standalone retail, medium office, and mid-rise apartment. Models that represent typical commercial buildings in Canada and China are not available in the public domain; therefore, the DOE prototypes are also used in these two countries.

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The tool: floor area

The air leakage calculations have been performed on a building whose size is defined by the DOE commercial prototype building models (DOEa 2016). However, the energy and monetary savings associated with improved air tightness was calculated on a per unit floor area basis. To determine the annual savings of your particular building, the actual floor area can be input into this window in lieu of the default floor area from the prototype building.

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DOE commercial prototype building models (ASHRAE 90.1-2013) used

Building	Total Floor Area, ft^2	Number of Floors	Construction Volume Weights
Standalone Retail	24,695	1	15.3%
Mid-Rise Apartment	33,700	4	7.3%
Medium Office	53,600	3	6.0%
High-Rise Apartment	84,360	10	9.0%
Hospital	241,410	5	3.4%
Large Hotel	122,132	7 (including basement)	5.0%
Small Hotel	43,200	4	1.7%
Large Office	498,600	13 (including basement)	3.3%
Small Office	5,500	1	5.6%
Outpatient Healthcare	40,950	3	4.4%
Restaurant Fast Food	2,500	1	0.6%
Restaurant Sit Down	5,502	1	0.7%
Stripmall	22,500	1	5.7%
Primary School	73,960	1	5.7%
Secondary School	210,900	2	10.4%
Warehouse	49,495	1	16.7%

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Standalone retail building specs

Characteristic	Description
Floor area (m^2)	2300 (Length 54.3 m × width 42.4m)
Number of floors	1
Floor to ceiling height (m)	6.1
Window-to-wall ratio (%) Windows on south-facing façade	25.4
Building Envelope	
Walls	20.3 cm concrete masonry block + insulation per ASHRAE 90.1 + 1.3 cm drywall
Roof	Roof membrane + insulation per ASHRAE 90.1 + metal decking
Window U-factor and SHGC	Per ASHRAE 90.1
Foundation	15.2 cm concrete slab-on-grade + insulation per ASHRAE 90.1
Air leakage rates for prototype buildings (not used in the present study)	HVAC off = 1 L/s·m^2 at 75 Pa HVAC on = 25% of HVAC off rate = 0.25 L/s·m^2 at 75 Pa
HVAC	
Heating type	Gas furnace inside the packaged air conditioning unit
Cooling type	Packaged air conditioning unit
Size	Autosized to design day
Efficiency	Based on climate location and design cooling/heating capacity and ASHRAE 90.1 requirements
Thermostat setpoint (°C)	23.9 cooling / 21.1 heating
Thermostat setback (°C)	29.4 cooling / 15.6 heating
Ventilation	Per ASHRAE 62.1

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The tool: air leakage rates

The user has the option to either select one of the default values listed below or to input their own air leakage rates if they have that information available or want to evaluate the potential energy savings from improved air tightness.

The tool will interpolate between the baseline air leakage rates (5.4 $L/s{\cdot}m^2$ (1.06 CFM/ft^2) for standalone retail, 6.2 $L/s{\cdot}m^2$ (1.22 CFM/ft^2) for medium office, and 6.7 $L/s{\cdot}m^2$ (1.33 CFM/ft^2) for mid-rise apartment) and 0.25 $L/s{\cdot}m^2$ (0.049 CFM/ft^2) at 75 Pa. No extrapolation is allowed.

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The tool: air leakage rates

Case	Air Leakage Rate at 75 Pa ($L/s{\cdot}m^2$)	Air Leakage Rate at 75 Pa (CFM/ft^2)	Source
Baseline	5.4	1.06	Emmerich et al (2005)
1	2.0	0.39	IECC (2015)
2	1.25	0.25	USACE (2012)
3	0.25	0.049	DOE (2014)

Emmerich and Persily (2014) analyzed the NIST U.S. commercial building air leakage database and found that the 79 buildings categorized as having an air barrier had an average 6-sided leakage of 1.39 $L/s{\cdot}m^2$ (0.27 CFM/ft^2) at 75 Pa, which was 70% below the average leakage of the 290 buildings without an air barrier (i.e., 4.33 $L/s{\cdot}m^2$ or 0.85 CFM/ft^2 at 75 Pa) and is similar to the second target level. Zhivov (2013) reported the average 6-sided leakage for a set of 285 new and retrofitted military buildings constructed to the USACE specifications to be 0.9 $L/s{\cdot}m^2$ (0.18 CFM/ft^2).

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The tool: energy costs

The user has the option to either select the default value for energy prices from the following references or to input their own electricity and natural gas prices.

Electricity and natural gas prices were collected from numerous sources. Prices for electricity for US cities are maintained by the U.S. Energy Information Administration and 2016 year-to-date average prices for commercial customers were used in the calculations (EIA, 2016a). For natural gas, average 2015 prices for commercial customers were obtained (EIA, 2016b). Energy prices for Canada were taken from the rates used to develop the National Energy Code of Canada for Buildings 2011(NECB 2011). 2015 electricity costs for China were obtained from Chinese sources.

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Some examples

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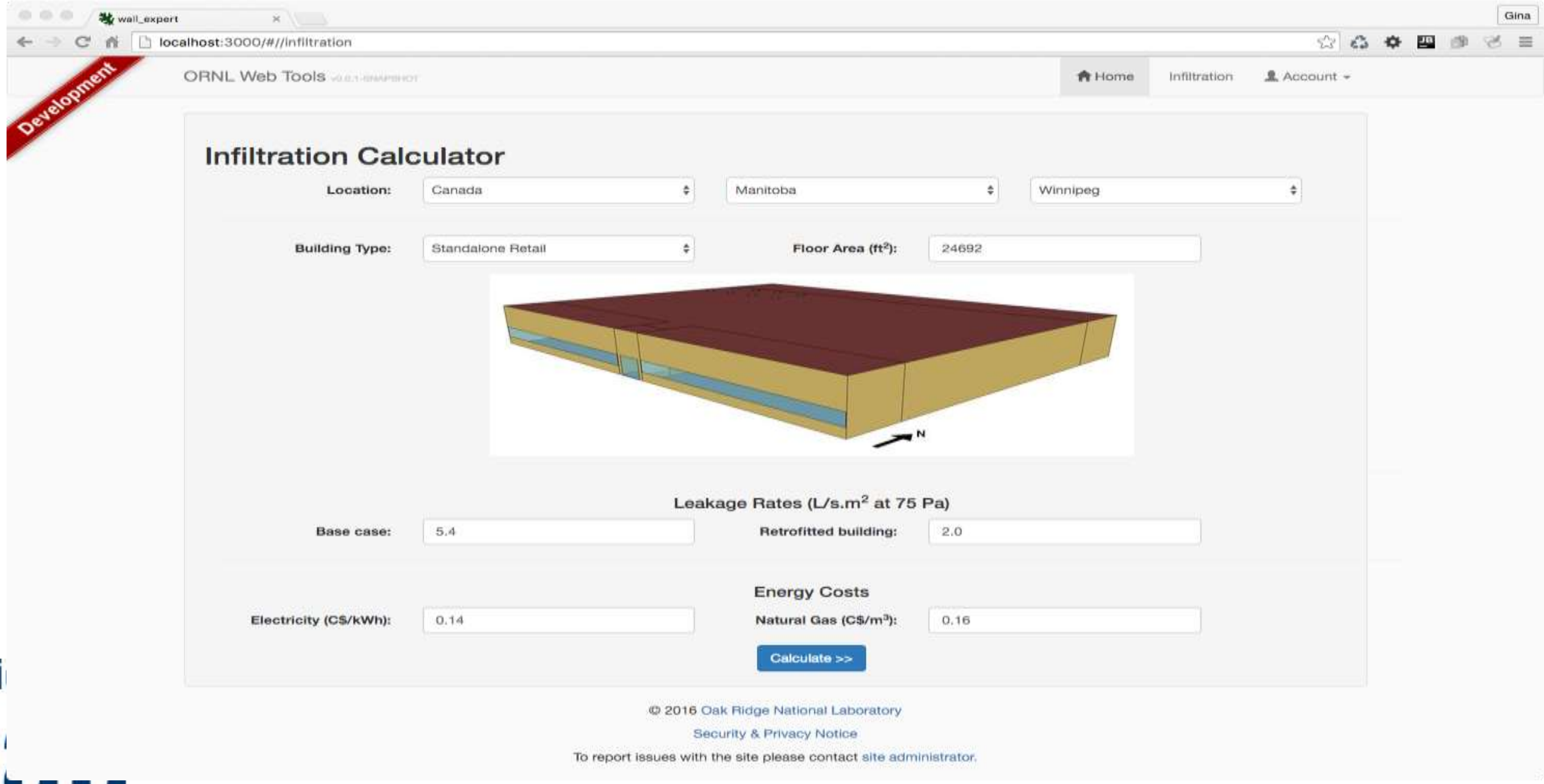
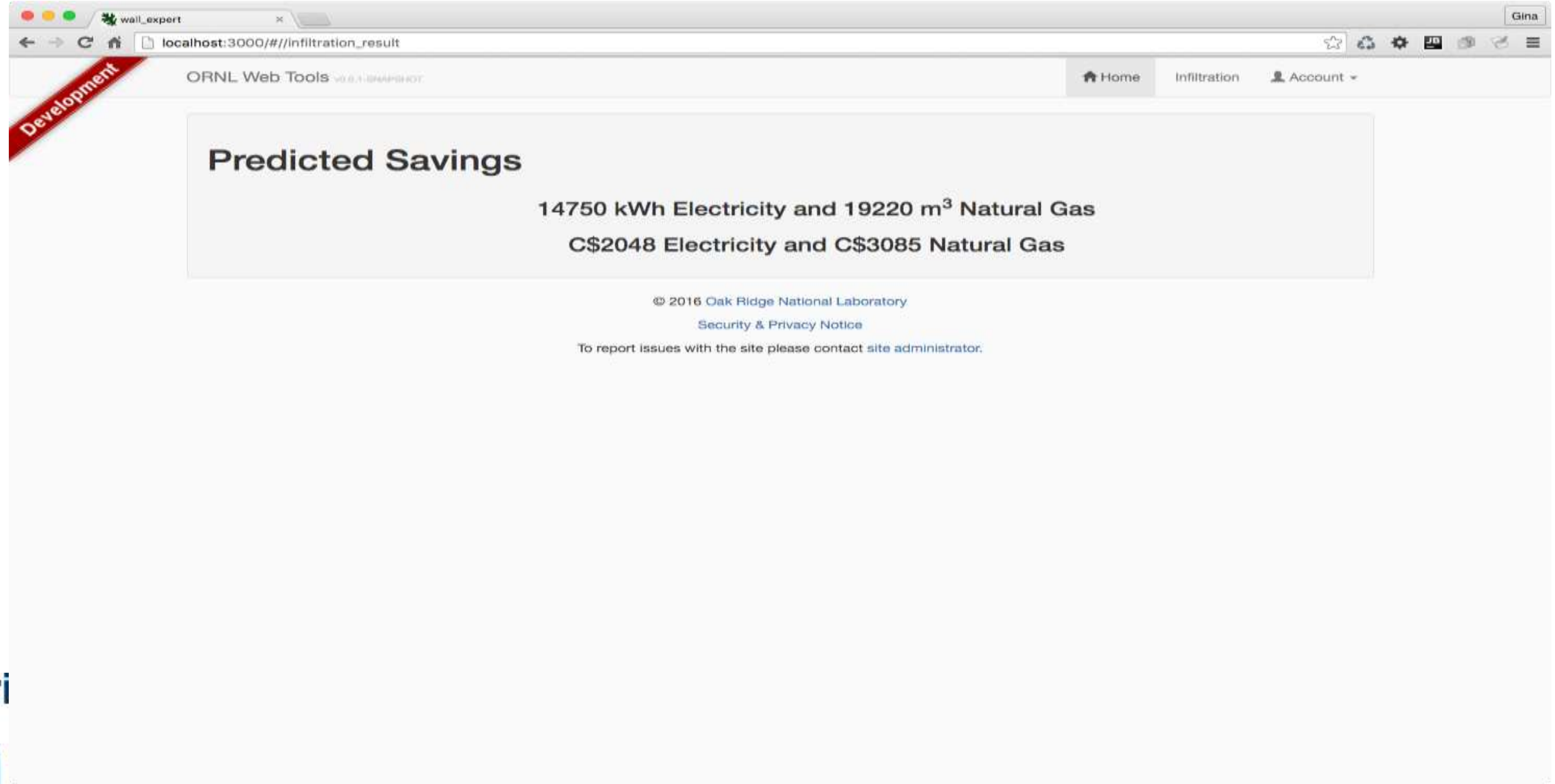
Calculator input



Calculator output

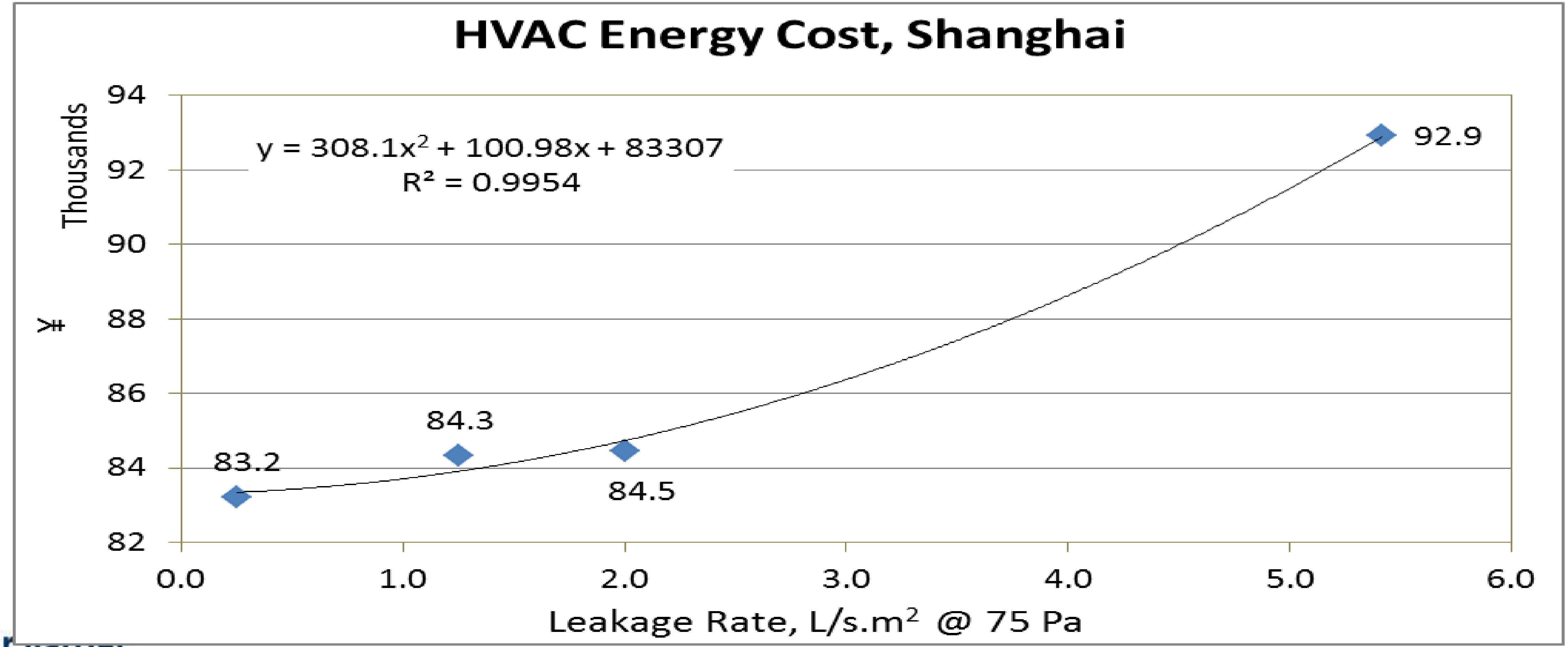


Evaluated cities

City	DOE Climate Zone	Prototype Building Model Used in Calculator	Electricity Price	Natural Gas Price
Shanghai, China	3A (warm, humid)	Memphis, TN	¥0.781/kWh[e] (≈$0.12/kWh)	¥3.65/m^3 [f] (≈$15.9/1000 ft^3)
Chicago, IL	5A (cold, humid)	Chicago, IL	$0.0933/kWh[a]	$8.86/1000 ft^3 [b]
Winnipeg, Canada	7 (very cold)	Duluth, MN	C$0.14/kWh[c] (≈$0.10/kWh)	C0.1605m^3$ [d] (≈$3.4/1000 ft^3)

[a] http://www.eia.gov/electricity/sales_revenue_price/
[b] http://www.eia.gov/dnav/ng/ng_sum_lsum_a_EPG0_PCS_DMcf_a.htm
[c] https://www.ovoenergy.com/guides/energy-guides/average-electricity-prices-kwh.html
[d] http://www.economicdevelopmentwinnipeg.com/uploads/document_file/natural_gas_rates.pdf?t=1433529826
[e] http://news.asean168.com/a/20150413/5318.html
[f] http://gas.gold600.com/

Preliminary results - Shanghai



HVAC energy cost for a prototype standalone retail building in Shanghai

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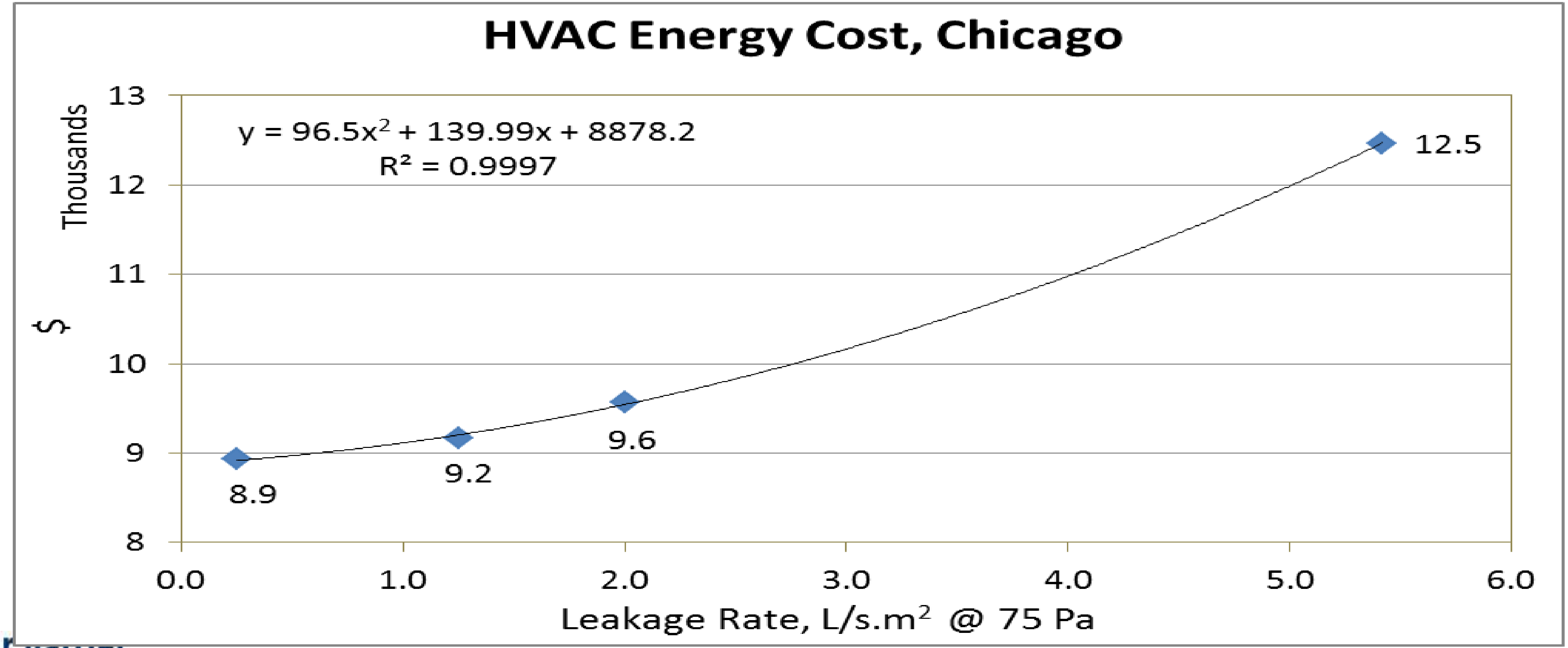
Preliminary results - Chicago



HVAC energy cost for a prototype standalone retail building in Chicago

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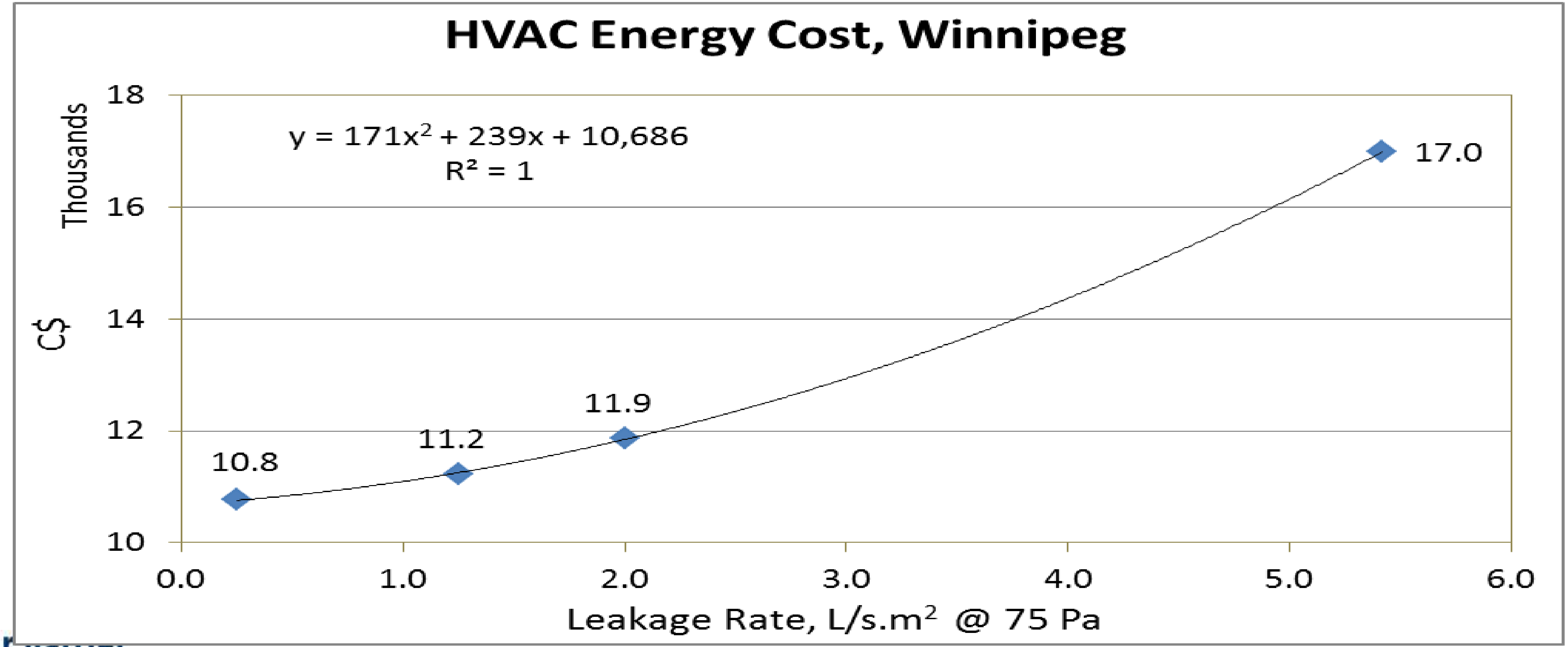
Preliminary results - Winnipeg



HVAC energy cost for a prototype standalone retail building in Winnipeg

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