

# Comparing Household Greenhouse Gas Emissions Across Canadian Cities

Juan Fercovic and Sumeet Gulati

University of British Columbia  
Faculty of Land and Food Systems & Food and Resource Economics

# Motivation

- In 2004, households contributed 46% of the overall CO<sub>2</sub> emissions in Canada. A third of these were direct emissions generated at the household—comprising emissions from motor, and residential fuel use for heating (Clark and Gagnon, 2008)

# Motivation

- In 2004, households contributed 46% of the overall CO<sub>2</sub> emissions in Canada. A third of these were direct emissions generated at the household—comprising emissions from motor, and residential fuel use for heating (Clark and Gagnon, 2008)
- Studies find that household emissions are influenced by household and urban characteristics. For instance, a larger, richer family is likely to consume more fuel, and increasing neighbourhood density induces lower levels of driving (Glaeser and Kahn (2008) among others)

# Research Questions

- How do Canadian Census Metropolitan Areas differ in the CO<sub>2</sub> emissions produced by a standardized household?
- If an average Canadian Household (with mean income, household size, and age of the head of the household) were to locate to a randomly chosen Census Metropolitan Area, what would be their expected direct CO<sub>2</sub> emissions?

# Research Questions

- How do Canadian Census Metropolitan Areas differ in the CO<sub>2</sub> emissions produced by a standardized household?
- If an average Canadian Household (with mean income, household size, and age of the head of the household) were to locate to a randomly chosen Census Metropolitan Area, what would be their expected direct CO<sub>2</sub> emissions?
- How are the average household emissions in Canada changing over time?
  - Are the rankings of Canadian cities with respect to household emissions, changing over our sample period?
  - Are population changes systematically related to emissions across Canadian cities?

# Which Emissions?

- Quantify GHG household emissions from three typical sources of energy used by a Canadian household: gasoline, electricity and natural gas
- Three sources account for almost all of an average household's emissions (Clark and Gagnon, 2008)
- Gasoline is responsible for a third (33%), natural gas and heating oil for 39%, and electricity consumption approximately 28%

- Sources:
  - 17 Census Metropolitan Areas (CMAs)
  - Survey of Household Expenditures (1997–2009) –12 years
  - Statistic Canada
  - [www.weatherstats.ca](http://www.weatherstats.ca)
  - Hydro Quebec (2009), [www.ontario-hydro.com](http://www.ontario-hydro.com), [www.hydro.mb.ca](http://www.hydro.mb.ca)

# Data

<b>Variable</b>	<b>Mean</b>	<b>SD</b>	<b>N</b>
Gasoline Q (Lt)	2162.40	327.15	187
Natural Gas Q ( $m^3$ )	1972.72	1074.89	112
Electric Q (kWh)	11982.40	4133.25	187
Gasoline price ( <i>cents/Lt</i> )	79.12	19.19	187
Natural Gas price ( <i>cents/m<sup>3</sup></i> )	33.07	16.85	119
Electricity price ( <i>cents/kWh</i> )	9.25	2.95	187
Density (person/ $Km^2$ )	267.06	287.38	187
Income (\$)	65550.60	14394.56	187
Avg. household size	2.52	0.18	186
Age of the reference person (years)	48.23	2.18	187
Heating Degree Days	4696.12	1167.74	187
HH with more than 2 vehicles	0.35	0.09	186
Number of rooms per dwelling	6.14	0.43	186
HH with Natural Gas in ppal heating system	0.75	0.27	106
Houses built between 1961 and 1970	0.16	0.04	155
Houses built between 1981 and 1990	0.18	0.04	165



# Methodology

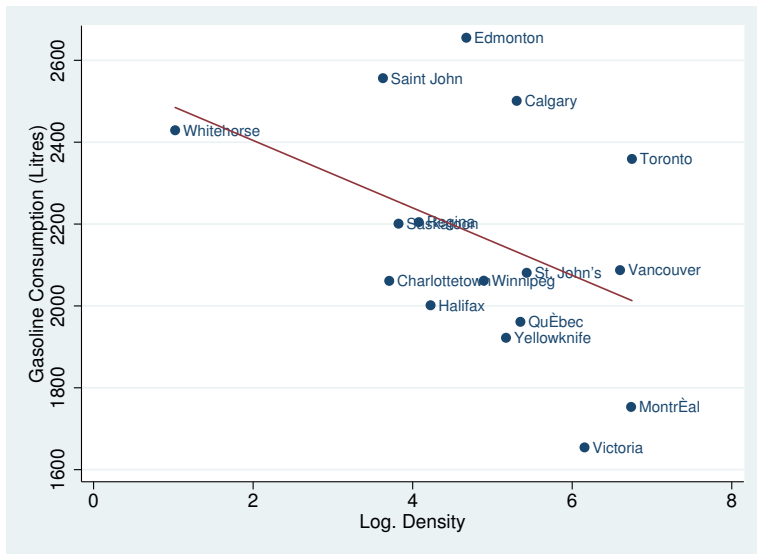
- Modeling

$$Q_{i,t} = \alpha + \beta * D_{i,t} + \gamma * Pr_{i,t} + \delta * HDD_{i,t} + \rho' HHCh_{i,t} + \mu_i + \nu_t + \epsilon_{i,t} \quad (1)$$

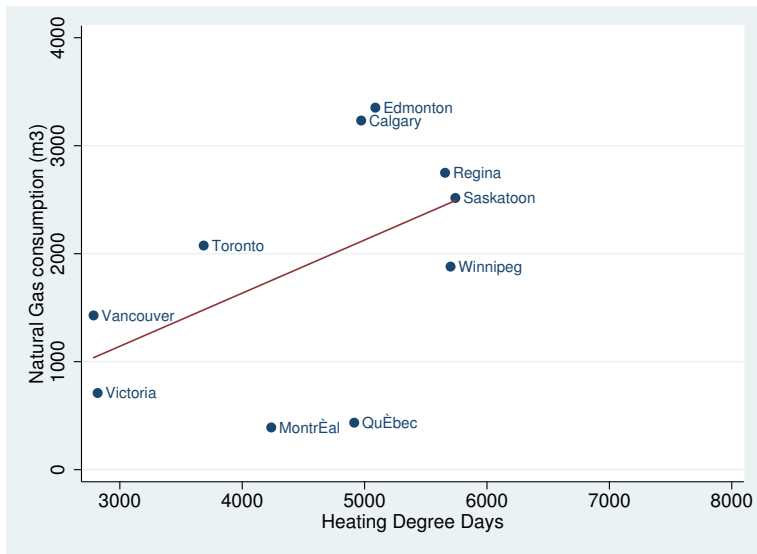
- Imputation

- GHG conversion

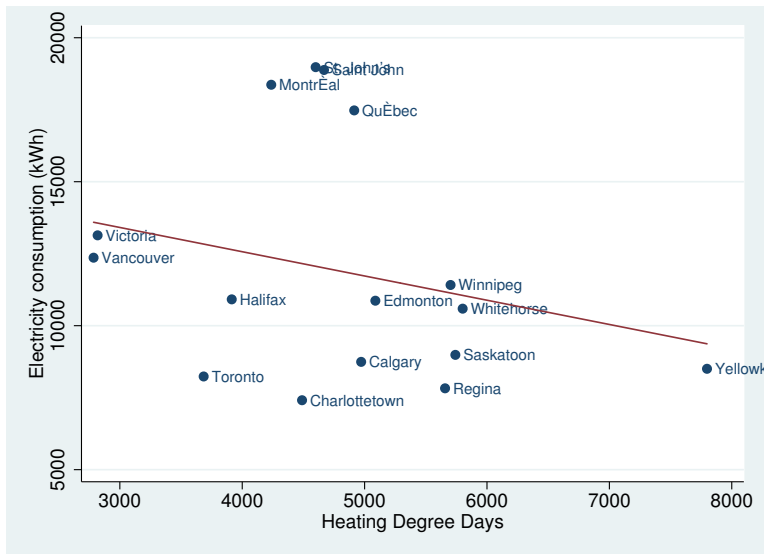
# Gasoline consumption (Litres) and CMA density (pop/km<sup>2</sup>)



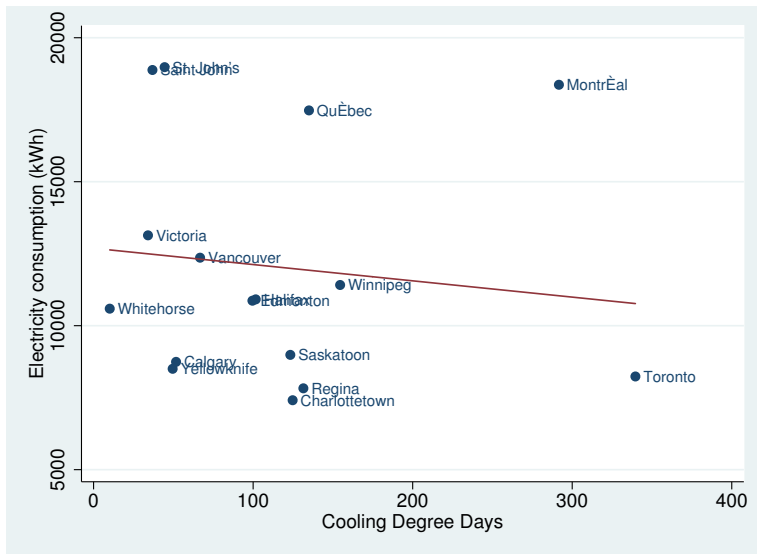
# Natural Gas consumption and CMA Heating Degree days



# Electricity Consumption and CMA Heating Degree days



# Electricity Consumption and CMA Cooling Degree Days



# Estimation results

	Gasoline (Lt)	Natural Gas (m <sup>3</sup> )	Electric (kWh)
Log Price	-1126.9*** (-3.45)	-1223.4*** (-5.97)	-3161.9*** (-3.40)
Log Density	-540.4 (-1.63)	1833.6* (1.81)	-3068.8 (-1.18)
Log Income	520.0*** (2.68)	626.0 (1.06)	4119.0*** (2.80)
Avg. household size	547.1*** (3.85)	-588.8 (-1.19)	1364.0 (1.38)
Age of the reference person	-5.415 (-0.61)	-31.75 (-1.01)	21.59 (0.32)
Heating Degree Days	0.0261 (1.12)	0.201 (1.65)	0.0114 (0.07)
CMA controls	Yes	Yes	Yes
Year controls	Yes	No	Yes
Observations	186	92	186
R <sup>2</sup>	0.859	0.924	0.951
CMAs	17	8	17
Years	12	12	12

Standard deviation in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

# Imputation

- Predict 2009 fuel consumption for a representative household in Canada.
- Using country averages for our controllable Household Characteristics.
- Income of 80,756 dollars.
- 2.45 persons per household.
- 48 years the age of reference person.

# Standardized Fuel Consumption

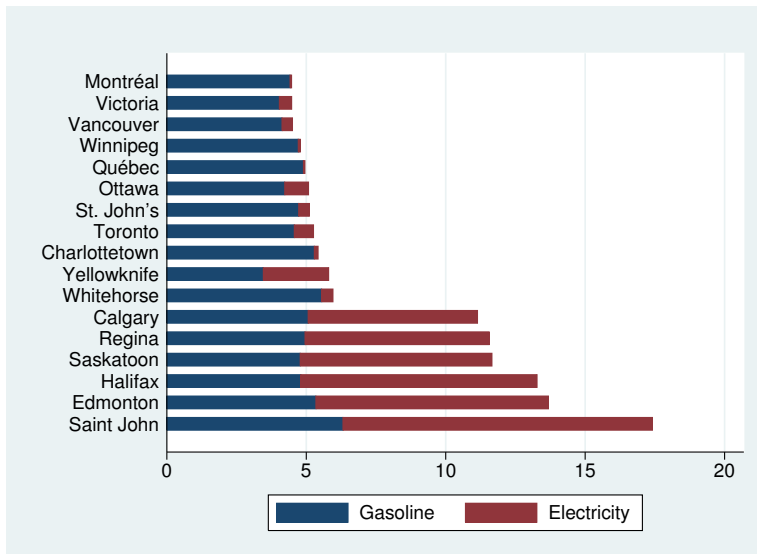
- Gasoline
  - From 500 annual litres (Yellowknife) to 2700 litres (Saint John)
  - High population density in Yellowknife (188 persons per  $\text{KM}^2$ )
- Electricity
  - from 7000 annual kWh (Toronto) to 19000 kWh (Montreal and Saint John)
  - Variation mainly from the differences in the fuel use within the households
  - Québec and New Brunswick uses electricity for heating.
  - Western provinces use natural gas, and Prince Edward Island heating oil
- Natural Gas
  - From 350  $m^3$  (Montréal) to more than 3000  $m^3$  yearly (Alberta)
  - Variation from the differences in the fuel use within the households and weather effect



# Provincial Fuel Emission Factors

- Gasoline
  - 2289  $CO_2$  g/Lt
  - $CO_2$  emissions from fuel combustion activities that depend upon the amount of fuel consumed, the carbon content of the fuel and the IPCC default oxidation value
- Natural Gas
  - 1820 to 2454  $gr/m^3$
  - Dependent primarily on fuel properties such as carbon content, density and heating value and, to a lesser extent, on the combustion technology
- Electricity
  - 3 to 850  $g/kWh$
  - Vary according to the specific type of fuel used, the quality of that fuel, the conversion technology used and the efficiency of the combustion unit. Form coal (Alberta) to hydro (Québec, Manitoba and British Columbia)

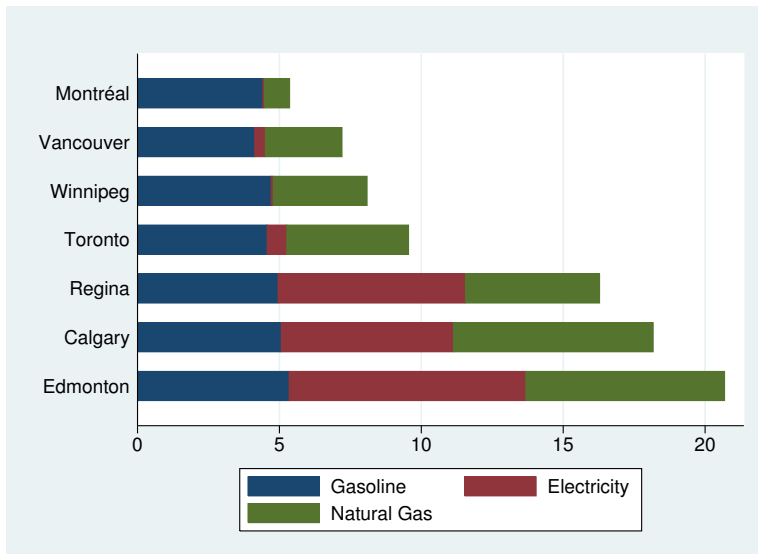
# CMA projected CO<sub>2</sub> emissions in Tonnes (Gasoline+Electricity)



# CMA projected CO<sub>2</sub> emissions in Tonnes (Gasoline+Electricity)

- Gasoline
  - CO<sub>2</sub> emissions same consumption patterns as the conversion factor is constant
  - From 3.4 CO<sub>2</sub> Tons per year (Yellowknife) to 6.2 (Saint John) (4.7 average)
- Electricity
  - From 0.05 tons in Montréal to 10 tons in Saint John (Alberta, New Brunswick and Saskatchewan more than 6 tons of CO<sub>2</sub> emission)
  - Differences in the use of the fuel.
  - Differences in the sources of production (High conversion factors from coal, nuclear and RPPs)

# CMA projected CO<sub>2</sub> emissions in Tonnes (3 fuels)



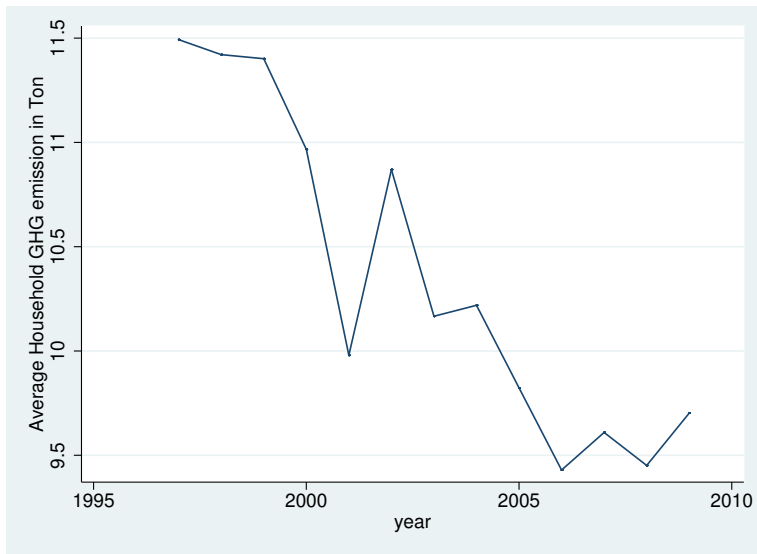
# CMA projected CO<sub>2</sub> emissions in Tonnes (3 fuels)

- Natural Gas
  - Highest emissions in cities of Alberta, greater than 5.7 tons of CO<sub>2</sub> yearly.
  - Lowest in Montreal with only 0.6 tons of CO<sub>2</sub> yearly.
- Totals
  - Alberta and Saskatchewan generates the highest CO<sub>2</sub> emissions (over 20 tonnes per family in Edmonton, and approximately 15 tonnes for the other cities).
  - Lowest emissions are in Montréal with 5 tonnes.
  - Vancouver is second at 7.2 tonnes.

# The Evolution of Average Canadian Household Emissions

- 8 CMAs: Edmonton, Calgary, Saskatoon, Regina, Toronto, Winnipeg, Vancouver, and Montréal
- Total GHG emissions in tons, from gasoline, electricity and natural gas consumption
- Emissions decline in time
- Consistency in the ranking of emissions
- Weighted average emissions over 8 CMAs using population weights (Accounts for population changes, and emission changes across CMAs)

# Yearly total CO<sub>2</sub> Emissions (tonnes)

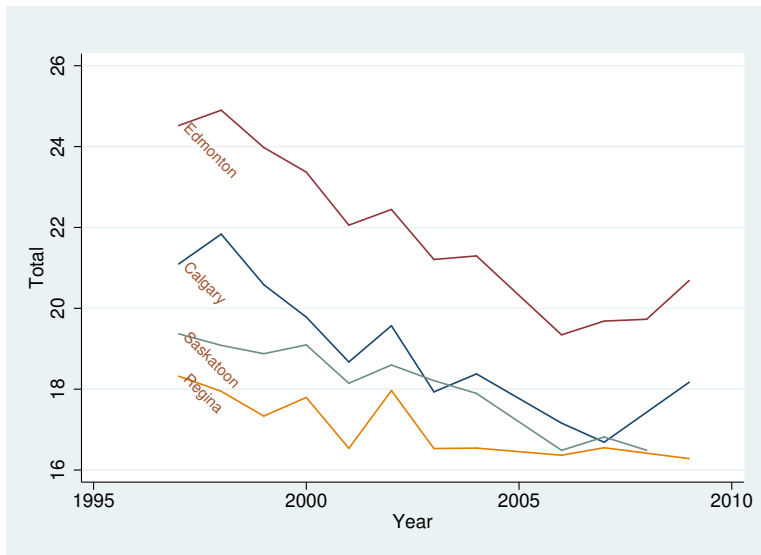


# Yearly total CO<sub>2</sub> Emissions (tonnes)

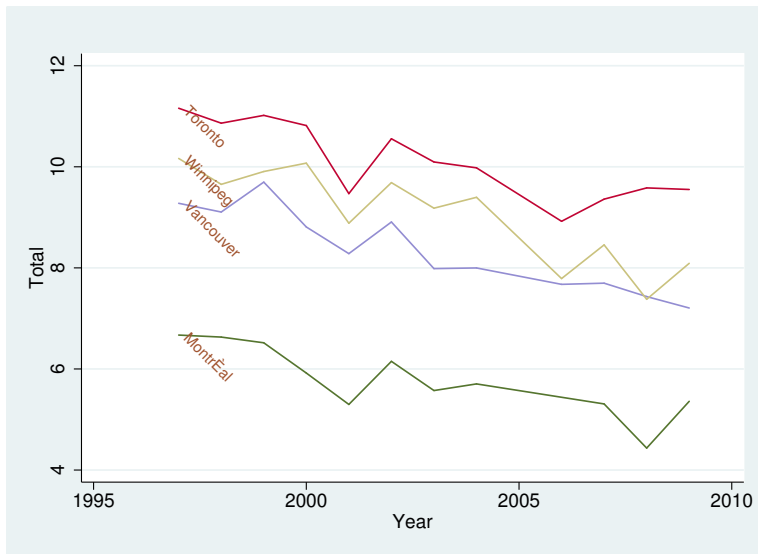
- Average household emission fell from approximately 11.49 tonnes/year in 1997 to 9.7 tonnes/year in 2009
- Reduction of almost 16% over 12 years



# Cities with high CO<sub>2</sub> Emissions (tonnes) in time



# Cities with low CO<sub>2</sub> Emissions (tonnes) in time



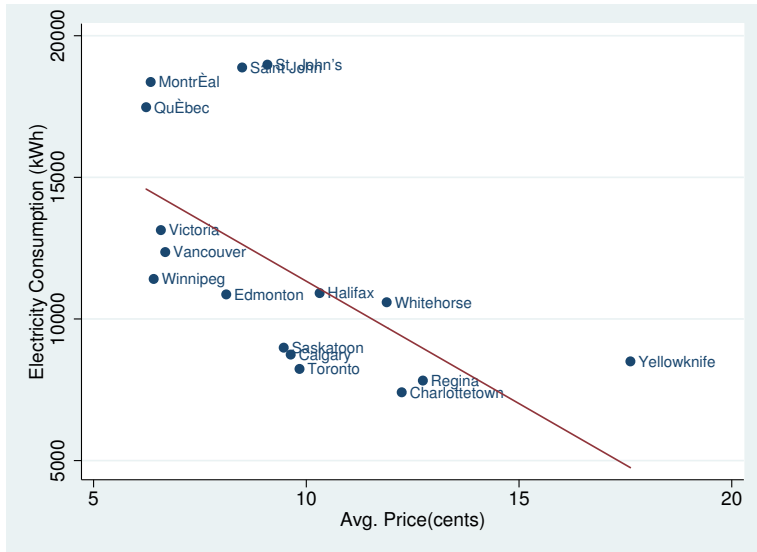
# Total CO<sub>2</sub> Emissions (tonnes)

- Population growth not reflected in population shares
- Simple correlation coefficient between changes in population vs emissions. The result is -24.3% (population changes were higher at CMA's where emission reductions were larger)

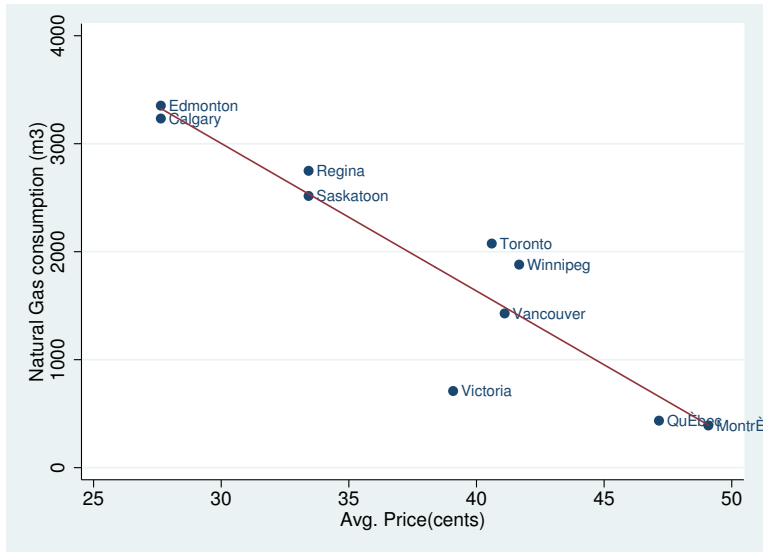
# Why Montréal? Or the Choice of Electricity vs. Natural Gas in Heating

- Higher population density induces less driving, and likely smaller dwellings.
- Moderate temperatures lower energy needs for dwelling level temperature control.
- The source of a province's electricity is also important.
- Why Montréal?
  - Residents use electricity for heating.
  - Why do households in Montréal substitute natural gas for electricity in their heating?

# Electricity Prices and Consumption (averages by CMA)



# Natural Gas Prices and Consumption (averages by CMA)



# Why Montréal? Or the Choice of Electricity vs. Natural Gas in Heating

- Average natural gas prices in Québec are the highest in the country (49.08 cent/m<sup>3</sup>)
- 78% higher than Alberta
- 25% higher than British Columbia

# Conclusion

- Policy implications are fairly straightforward
  - Encourage high density development
  - Development of low carbon sources of energy
- Importance of prices determining the choice of heating fuel
- Our estimates just reflect CMA averages
  - Do not reflect emissions for hypothetical new immigrants
  - Unable to recognize systematic differences that occur in carbon emissions by a new resident when compared to an existing residential average



# THANK YOU

# Apendix

# Provincial Fuel Emission Factors

<b>Province</b>	<b>Electricity (CO<sub>2</sub> g/kWh)</b>	<b>Natural Gas (CO<sub>2</sub> g/m<sup>3</sup>)</b>	<b>Gasoline (CO<sub>2</sub> g/Lt)</b>
Alberta	850	1918	2289
British Columbia	31	1916	2289
Manitoba	6	1877	2289
New Brunswick	569	1891	2289
Newfoundland and Labrador	20	1891	2289
Northwest Territories	367	2454	2289
Nova Scotia	770	1891	2289
Ontario	100	1879	2289
Prince Edward Island	17	.	2289
Quebec	3	1878	2289
Saskatchewan	760	1820	2289
Yukon	40	.	2289

Source: Greenhouse Gas Division, Environment Canada, National Inventory Report, 1990-2010.

# CMA projected CO<sub>2</sub> emissions in Tonnes (3 fuels)

<b>CMA</b>	<b>Gasoline</b>	<b>Electricity</b>	<b>N. Gas</b>	<b>Total</b>	<b>95% CI</b>	<b>Monetized(\$)</b>
Montreal	4.415	0.058	0.886	5.360	[4.540 , 6.180]	267.996
Vancouver	4.127	0.378	2.701	7.206	[6.511 , 7.901]	360.302
Winnipeg	4.710	0.073	3.307	8.090	[7.320 , 8.861]	404.516
Toronto	4.568	0.692	4.291	9.551	[8.334 , 10.768]	477.544
Calgary	5.065	6.075	7.031	18.172	[16.040 , 20.303]	908.587
Regina	4.953	6.605	4.723	16.282	[14.860 , 17.704]	814.101
Edmonton	5.342	8.342	7.003	20.687	[19.119 , 22.255]	1034.355
<b>Total</b>	<b>4.740</b>	<b>3.175</b>	<b>4.278</b>	<b>12.193</b>	<b>[10.961 , 13.425]</b>	<b>609.629</b>

*Source:* Authors calculations

# Predicted Household CO<sub>2</sub> Emissions (tonnes) for Gasoline & Electricity

CMA	Gasoline	Electricity	Total	95% CI
Montreal	4.415	0.058	4.474	[4.214 , 4.733]
Victoria**	4.034	0.442	4.476	[4.189 , 4.762]
Vancouver	4.127	0.378	4.505	[4.226 , 4.785]
Winnipeg	4.710	0.073	4.783	[4.534 , 5.032]
Quebec**	4.896	0.056	4.952	[4.661 , 5.244]
Ottawa*	4.225	0.856	5.081	[4.753 , 5.409]
St. John's	4.725	0.386	5.111	[4.849 , 5.373]
Toronto	4.568	0.692	5.260	[4.861 , 5.658]
Charlottetown	5.286	0.138	5.424	[5.097 , 5.751]
Yellowknife	3.458	2.345	5.802	[4.772 , 6.833]
Whitehorse	5.550	0.407	5.958	[5.611 , 6.305]
Calgary	5.065	6.075	11.140	[9.852 , 12.429]
Regina	4.953	6.605	11.559	[10.709 , 12.409]
Saskatoon	4.780	6.878	11.658	[10.776 , 12.539]
Halifax	4.800	8.476	13.276	[12.425 , 14.126]
Edmonton	5.342	8.342	13.684	[12.737 , 14.632]
Saint John	6.313	11.101	17.414	[16.518 , 18.309]
Total	4.779	3.136	7.915	[7.340 , 8.490]

Note: Prediction for 2009 information / \* 2006 information

\*\* 2007 information / 95% Coefficient Intervals for the totals.

# Standardized Gasoline Consumption

<b>CMA</b>	<b>Gasoline (Lt)</b>	<b>se</b>	<b>95% CI</b>
Calgary	2212.9	82.2	[2050.8 , 2375.0]
Charlottetown	2309.2	68.4	[2174.3 , 2444.0]
Edmonton	2334.0	54.5	[2226.4 , 2441.6]
Halifax	2097.0	50.7	[1996.9 , 2197.0]
Montreal	1928.9	56.9	[1816.7 , 2041.2]
Ottawa*	1845.9	54.3	[1738.7 , 1953.0]
Quebec**	2139.1	63.9	[2013.0 , 2265.1]
Regina	2164.0	49.8	[2065.8 , 2262.2]
Saint John	2757.9	68.4	[2623.0 , 2892.8]
Saskatoon	2088.3	61.9	[1966.2 , 2210.5]
St. John's	2064.3	54.5	[1956.8 , 2171.8]
Toronto	1995.6	65.7	[1866.1 , 2125.1]
Vancouver	1803.1	56.9	[1690.9 , 1915.3]
Victoria**	1762.2	57.7	[1648.3 , 1876.1]
Whitehorse	2424.9	68.0	[2290.8 , 2558.9]
Winnipeg	2057.9	54.1	[1951.1 , 2164.6]
Yellowknife	1510.7	96.1	[1321.0 , 1700.3]
Total	2088.0	62.6	[1964.5 , 2211.4]

Source: based on author projections for an average family across CMAs.  
 Prediction for 2009/ \* 2006/ \*\* 2007

# Standardized Electricity Consumption

<b>CMA</b>	<b>Gasoline (Lt)</b>	<b>se</b>	<b>95% CI</b>
Calgary	7147.1	547.2	[6067.5 , 8226.7]
Charlottetown	8129.8	541.5	[7061.6 , 9198.0]
Edmonton	9814.0	418.3	[8988.7 , 10639.2]
Halifax	11007.2	409.2	[10200.0 , 11814.5]
Montreal	19379.0	438.4	[18514.1 , 20244.0]
Ottawa*	8559.1	419.2	[7732.1 , 9386.1]
Quebec**	18651.8	499.7	[17666.0 , 19637.6]
Regina	8691.3	417.1	[7868.4 , 9514.3]
Saint John	19509.2	522.4	[18478.7 , 20539.7]
Saskatoon	9049.5	401.5	[8257.4 , 9841.6]
St. John's	19285.1	408.3	[18479.5 , 20090.6]
Toronto	6915.8	515.7	[5898.5 , 7933.1]
Vancouver	12191.6	375.1	[11451.7 , 12931.6]
Victoria**	14257.3	425.1	[13418.7 , 15095.9]
Whitehorse	10177.1	507.9	[9175.1 , 11179.0]
Winnipeg	12146.7	392.2	[11373.0 , 12920.4]
Yellowknife	6388.5	823.8	[4763.3 , 8013.7]
Total	11841.2	474.3	[10905.6 , 12776.8]

*Source:* based on author projections for an average family across CMAs.  
 Prediction for 2009/ \* 2006/ \*\* 2007

# Standardized Natural Gas Consumption

CMA	Natural Gas ( $m^3$ )	se	95% CI
Calgary	3666.0	221.3	[3226.5 , 4105.4]
Edmonton	3651.1	162.9	[3327.5 , 3974.6]
Montreal	472.0	150.3	[173.5 , 770.5]
Regina	2595.2	158.1	[2281.1 , 2909.3]
Toronto	2283.8	219.3	[1848.2 , 2719.5]
Vancouver	1409.6	109.2	[1192.7 , 1626.5]
Winnipeg	1761.8	139.9	[1484.1 , 2039.6]
Total	2262.8	165.9	[1933.4 , 2592.2]

*Source:* based on author projections for an average family across CMAs.  
Prediction for 2009/ \* 2006/ \*\* 2007