

# Weather Sensitivity in Residential Energy Consumption

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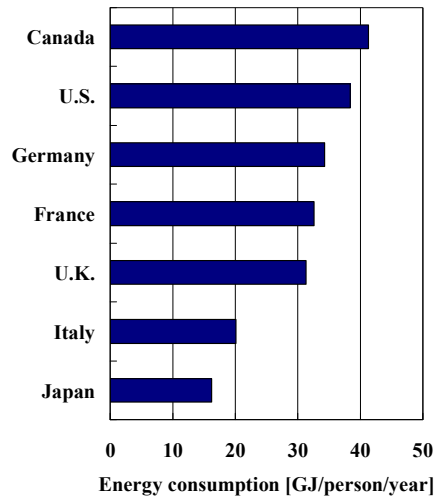
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Japan

## Outline

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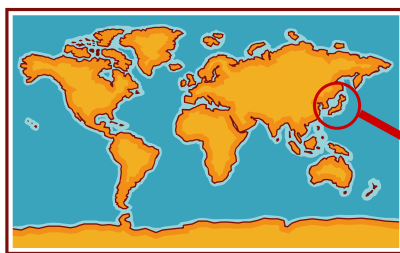
- Motivation
  - Energy consumption in Japan
  - Weather sensitivity
  - Conclusion
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## Motivation



- The energy consumption per capita in Japan is the lowest among the G7 countries.
- However, the residential energy consumption in Japan has increased as the standard of living rose.
- Therefore, the factors that influence the residential energy consumption need to be investigated for energy savings in Japan

## Energy consumption in Japan

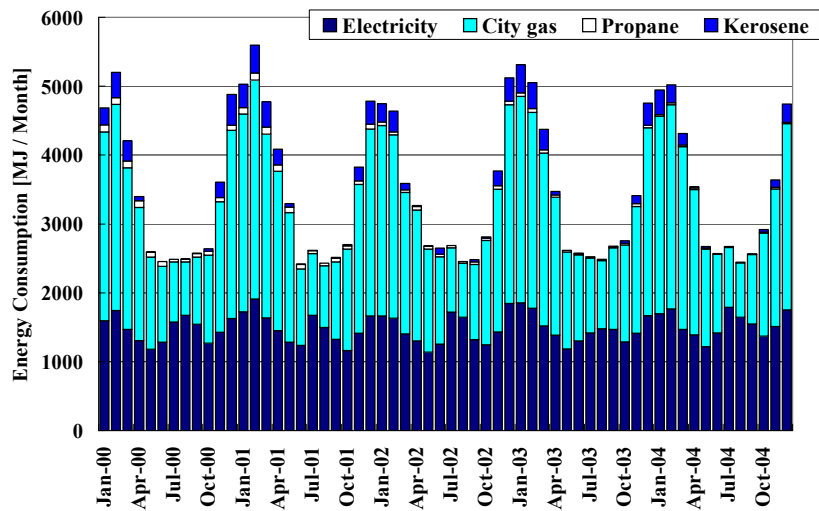


- Monthly energy consumption per household in ten cities in Honshu Island, Japan was estimated
- The estimated values were validated by the measured values



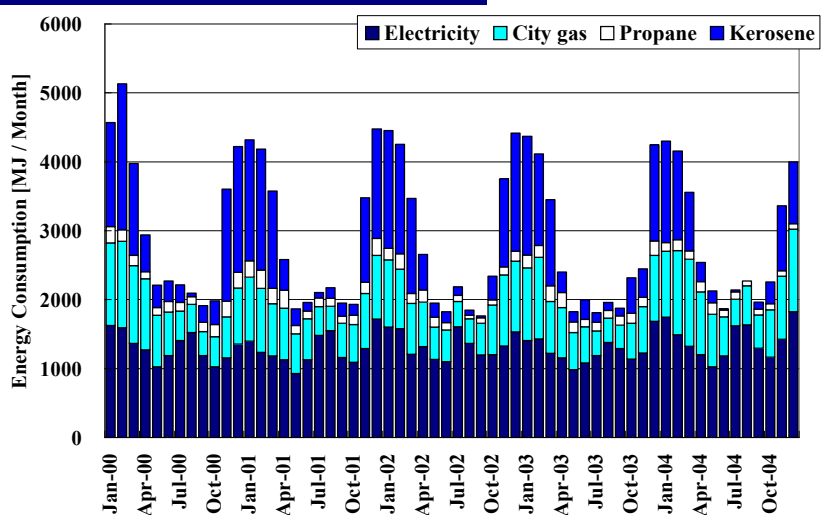
Location of the investigated cities

## Total energy consumption 1



Total energy consumption per household in **Tokyo**

## Total energy consumption 2



Total energy consumption per household in **Yamaguchi**

## Weather sensitivity

- **Weather variables**
- **Housing unit characteristics**
- **Prevalence rate of appliances**
- **etc.**

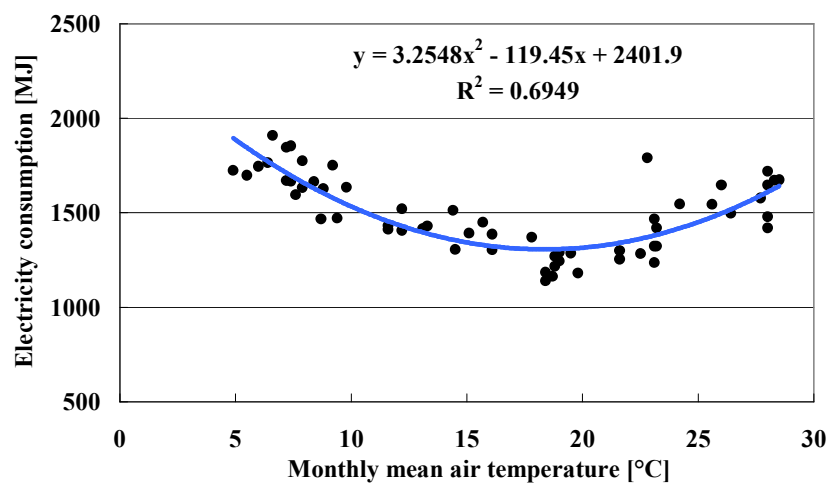
↓ Input

**Human Behavior**

↓ Output

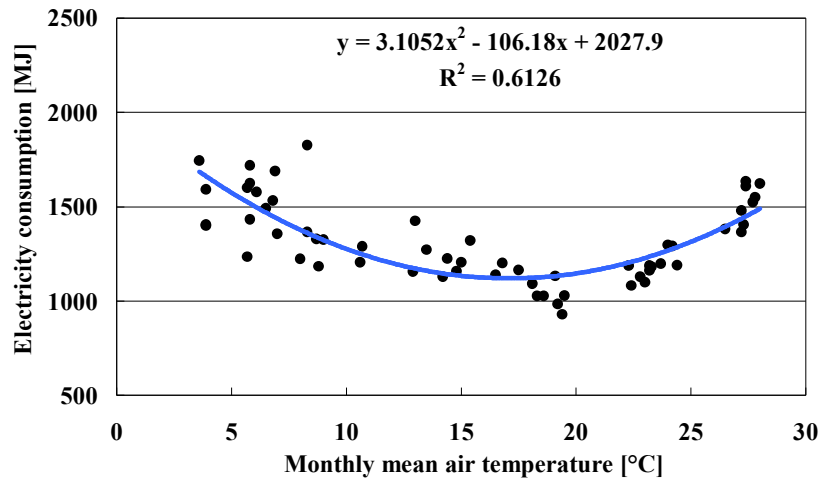
**Energy Consumption**

## Sensitivity in electricity 1



Monthly mean air temperature vs. Electricity consumption in Tokyo

## Sensitivity in electricity 2

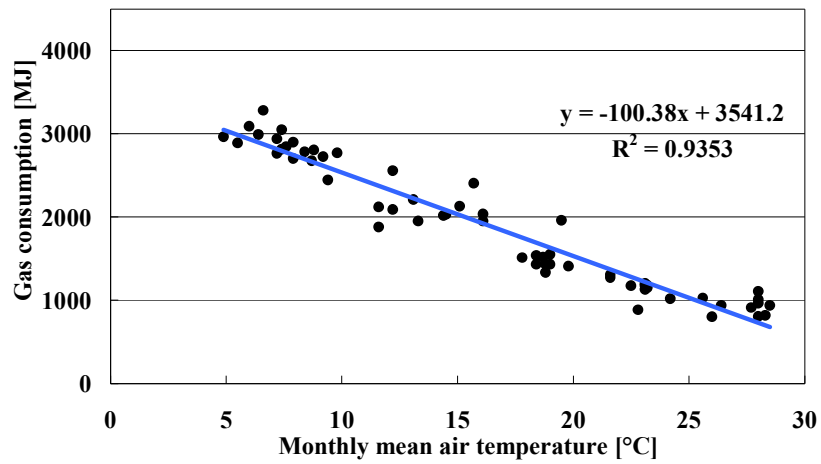


Monthly mean air temperature vs. Electricity consumption in Yamaguchi

## Regression formulae for electricity

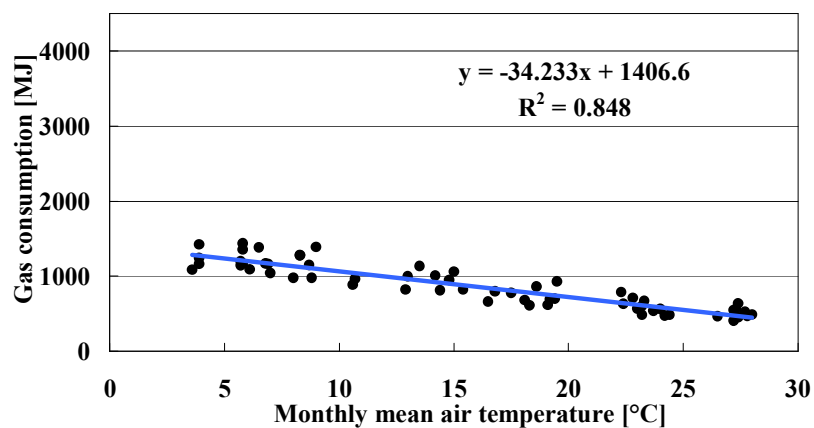
City	Formula [MJ / month]	R <sup>2</sup>
Tokyo	$E = 3.26 t^2 - 119.5 t + 2402$	0.695
Yokohama	$E = 3.86 t^2 - 135.3 t + 2445$	0.813
Shizuoka	$E = 3.57 t^2 - 125.6 t + 2465$	0.603
Nagoya	$E = 3.24 t^2 - 107.9 t + 2176$	0.625
Osaka	$E = 4.47 t^2 - 149.7 t + 2415$	0.745
Tottori	$E = 2.11 t^2 - 77.0 t + 1856$	0.639
Matsue	$E = 3.11 t^2 - 110.0 t + 2166$	0.733
Okayama	$E = 3.85 t^2 - 133.3 t + 2326$	0.691
Hiroshima	$E = 3.83 t^2 - 142.8 t + 2447$	0.801
Yamaguchi	$E = 3.11 t^2 - 106.2 t + 2028$	0.613

## Sensitivity in gas consumption 1



Monthly mean air temperature vs. gas consumption in Tokyo

## Sensitivity in gas consumption 2



Monthly mean air temperature vs. gas consumption in Yamaguchi

## Regression formulae for gas

City	Formula [MJ / month]	R <sup>2</sup>
Tokyo	$G = -100.4 t + 3541$	0.935
Yokohama	$G = -81.2 t + 2991$	0.936
Shizuoka	$G = -39.7 t + 1927$	0.748
Nagoya	$G = -66.4 t + 2661$	0.945
Osaka	$G = -87.3 t + 3320$	0.910
Tottori	$G = -25.1 t + 1193$	0.648
Matsue	$G = -30.1 t + 1335$	0.849
Okayama	$G = -33.0 t + 1447$	0.877
Hiroshima	$G = -46.9 t + 1914$	0.902
Yamaguchi	$G = -34.2 t + 1406$	0.848

## City size and gas consumption 1

Population Density



Collective Housing Ratio

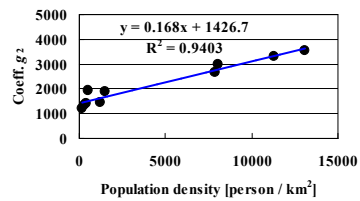
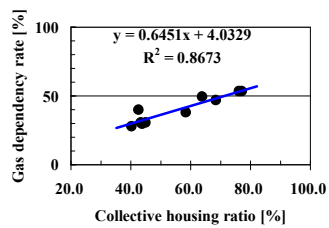
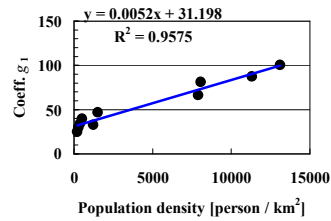
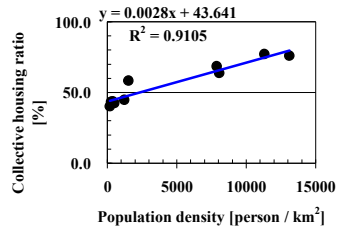


Gas Dependency Ratio



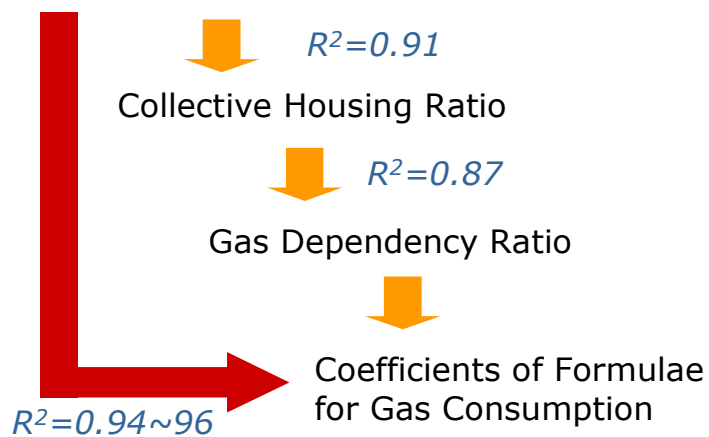
Coefficients of Formulae  
for Gas Consumption

## City size and gas consumption 2



## Population affects Gas Consump. 1

Population Density





## Population affects Gas Consump. 2

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Regression Formula for Gas Consumption

$$G = -(0.0052 p + 31.2) t + 0.168 p + 1427$$

$G$  : monthly gas consumption per household [MJ]

$p$  : population density [person / km<sup>2</sup> ]

$t$  : monthly mean temperature [C]

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## Conclusion

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- Air temperature strongly affects energy consumption
  - Electricity consumption is a quadratic function of air temperature
  - Gas consumption is a linear function of air temperature
  - Population density also affects gas consumption
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