

Energy Demand Model of Residential and Commercial Sectors of Cities: A Case Study of Tokyo

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Research Objectives & Today's Topics

- to construct a model for the prediction of energy consumption in the residential/commercial sectors of Asian megacities
- Target City: Tokyo Metropolitan Area
- Target Year: 2020

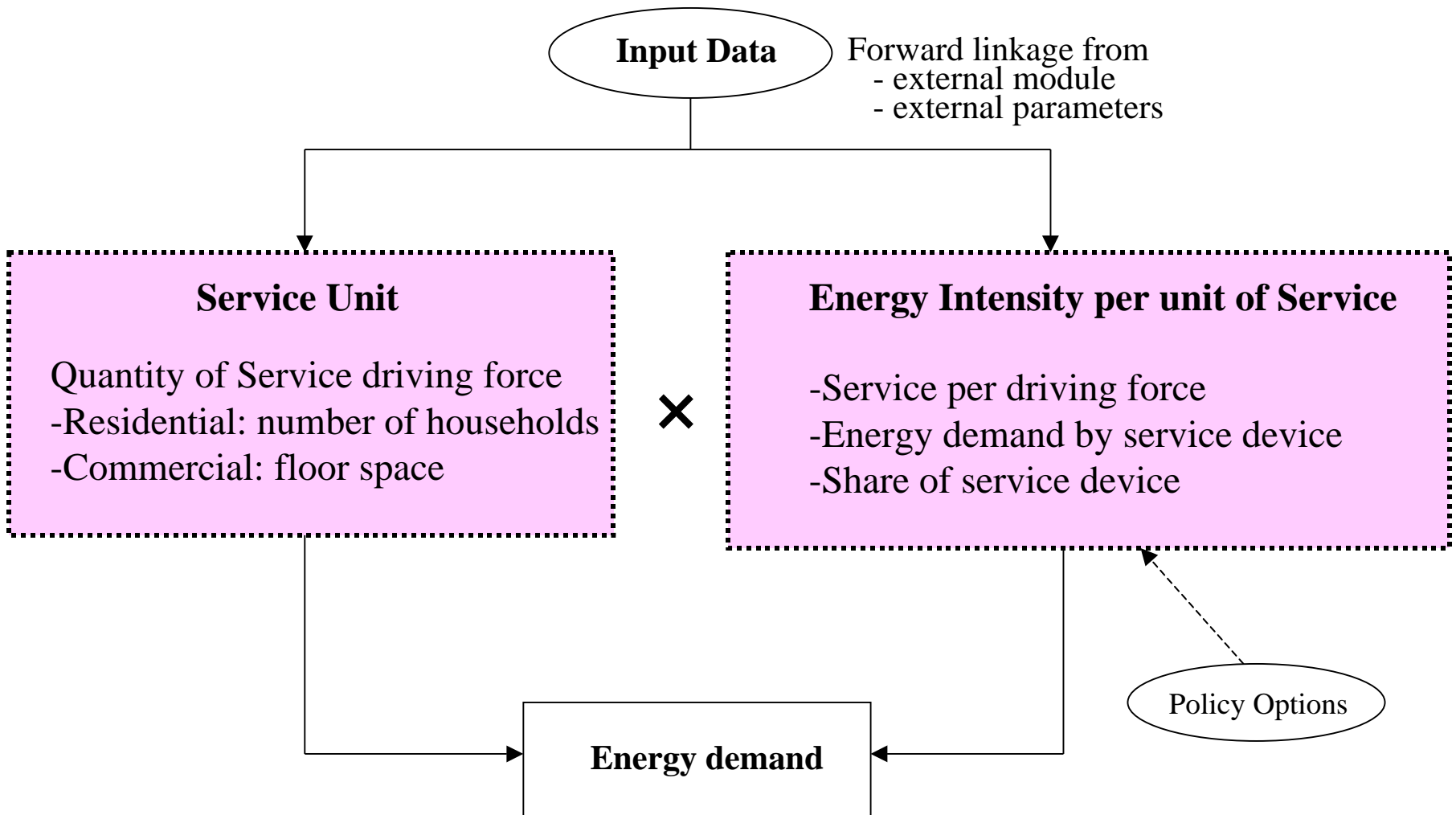
Basic Concept & Model Structure

attach importance to the applicability to other Asian mega-cities

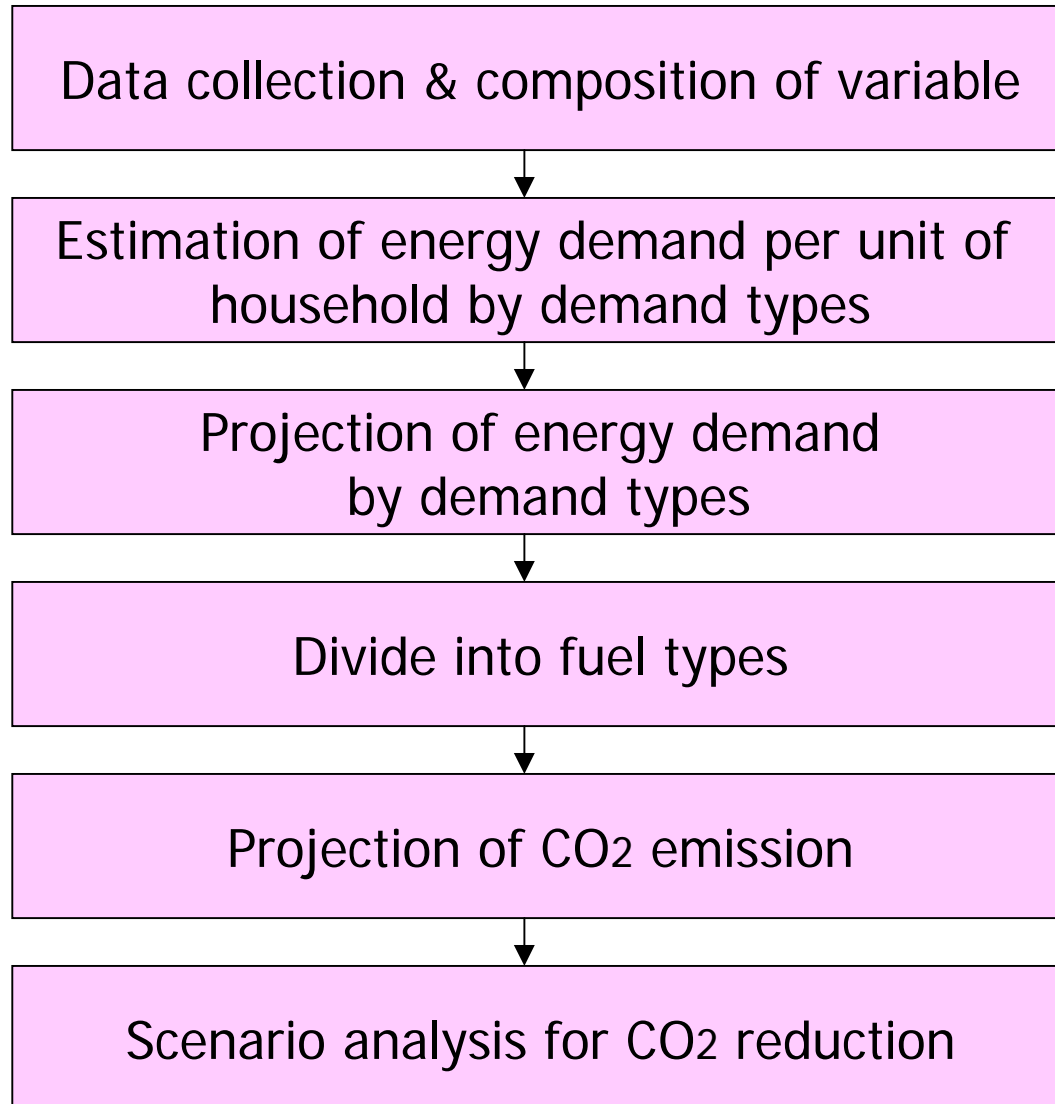
1. data availability

2. to keep up with the varying rates of growth in the region

Basic Concept of Analysis



Analytical Flow Chart for Model development & Scenario Analysis of Res sector



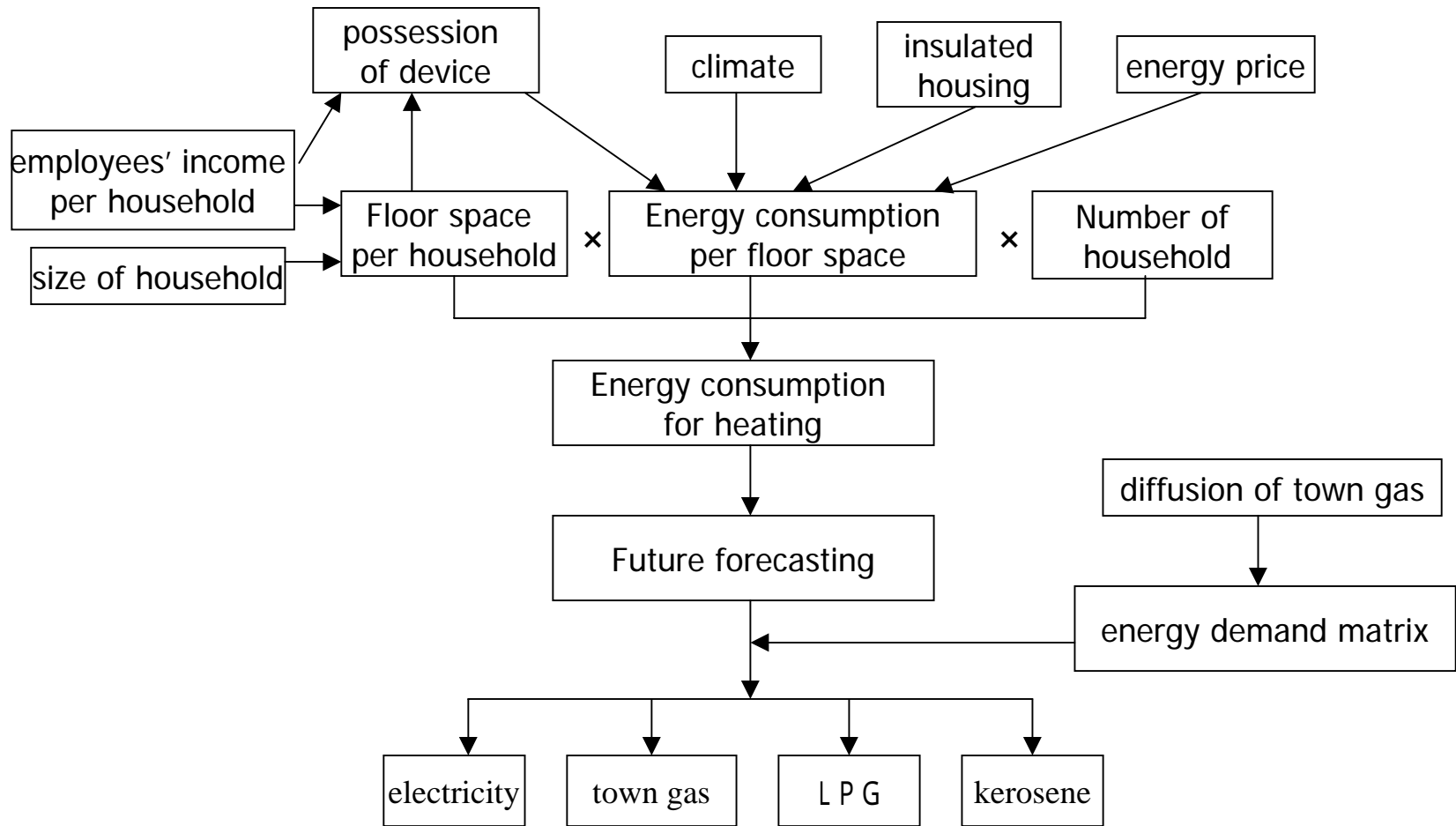
Estimating Procedure of CO₂ Emission by Demand Types of Res sector

STEP

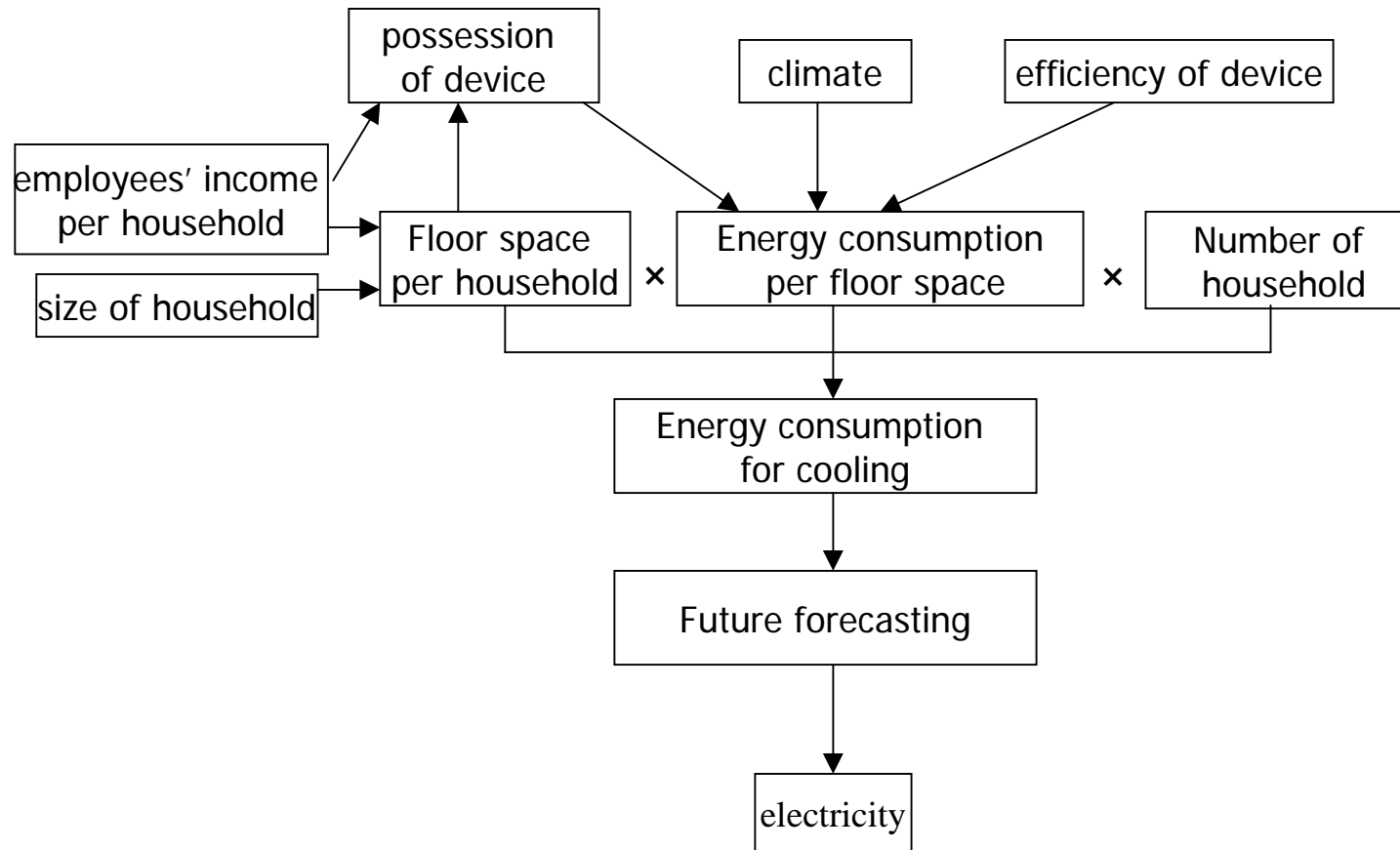
- Composition of explanation variable
- Multiple regression analysis for development of regression model to estimate energy intensity by demand types
- Future forecasting of energy intensity by demand types
- Divide into fuel types
- Future forecasting of CO₂ emission

(Estimating Procedure depends on data availability of each city.)

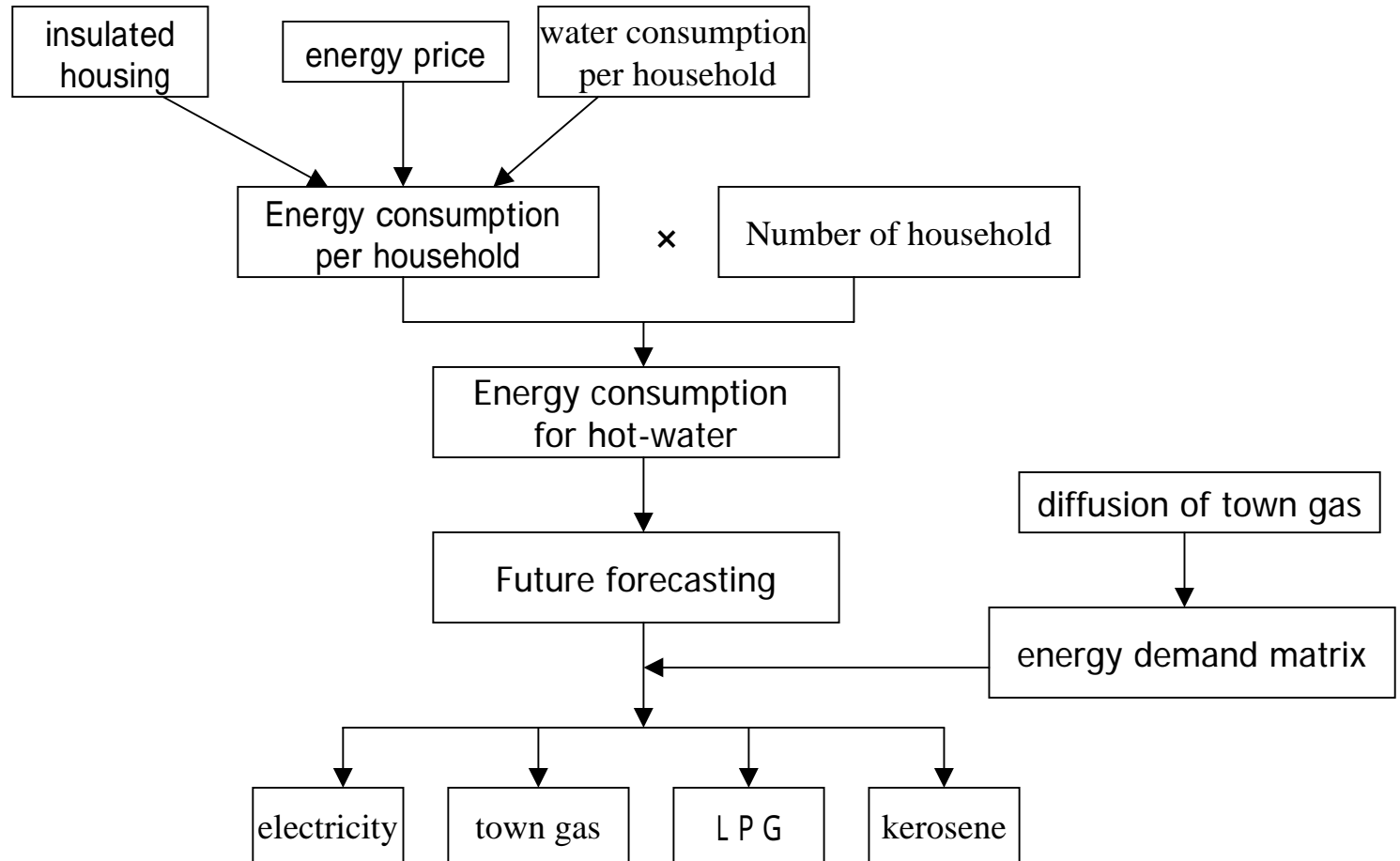
Flow Chart of the Estimation of Energy Consumption for heating



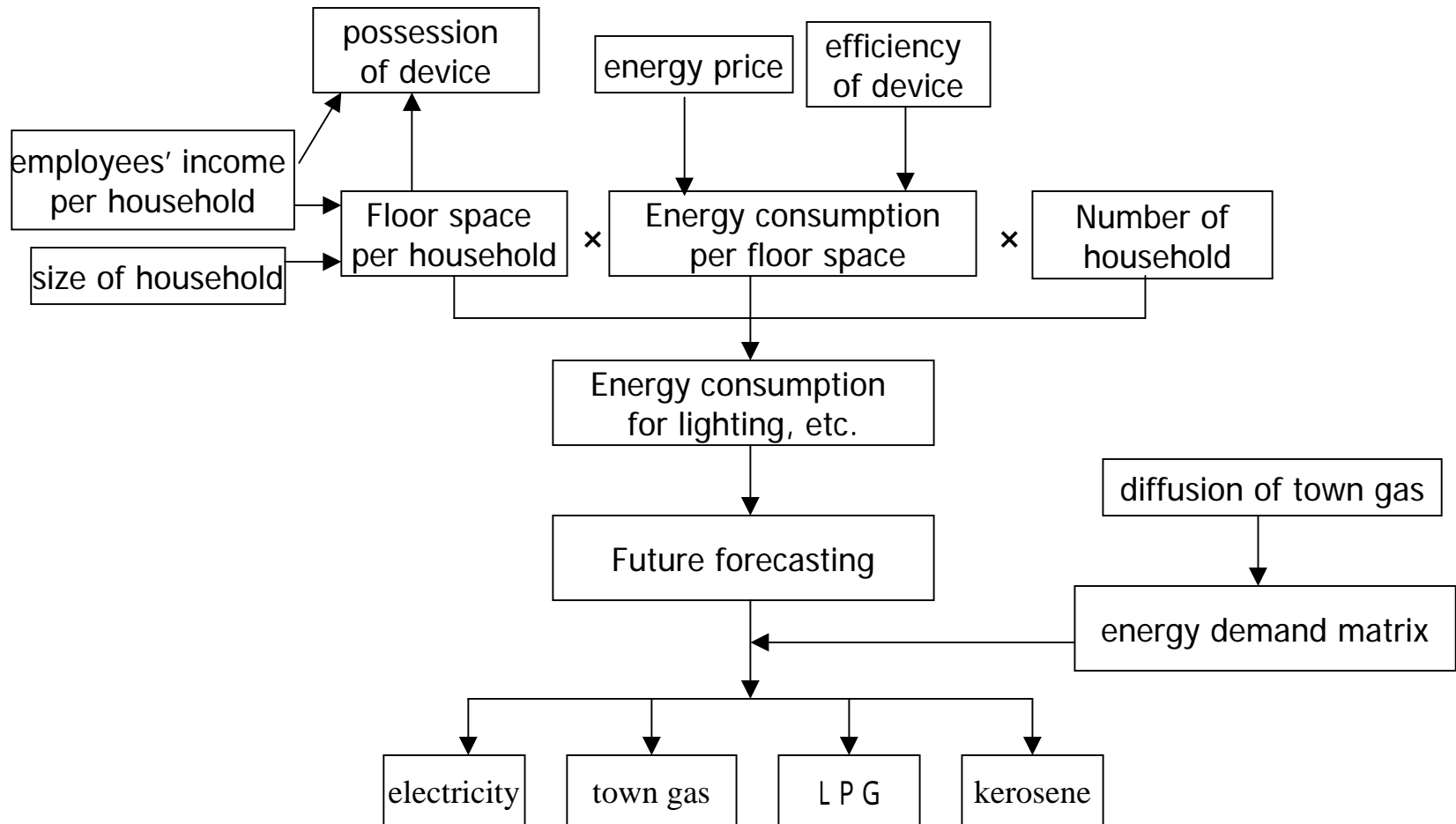
Flow Chart of the Estimation of Energy Consumption for Cooling



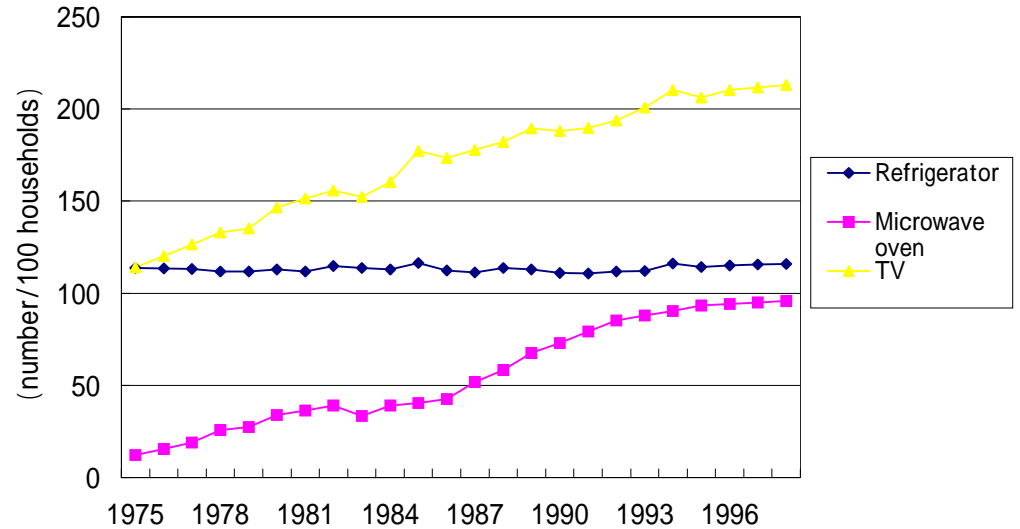
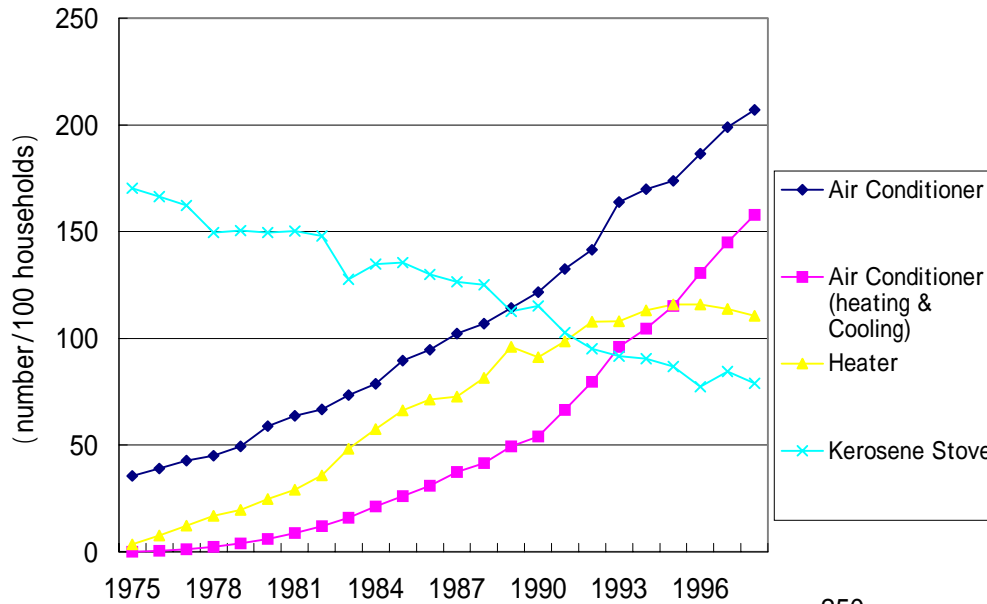
Flow Chart of the Estimation of Energy Consumption by Hot-water Supply



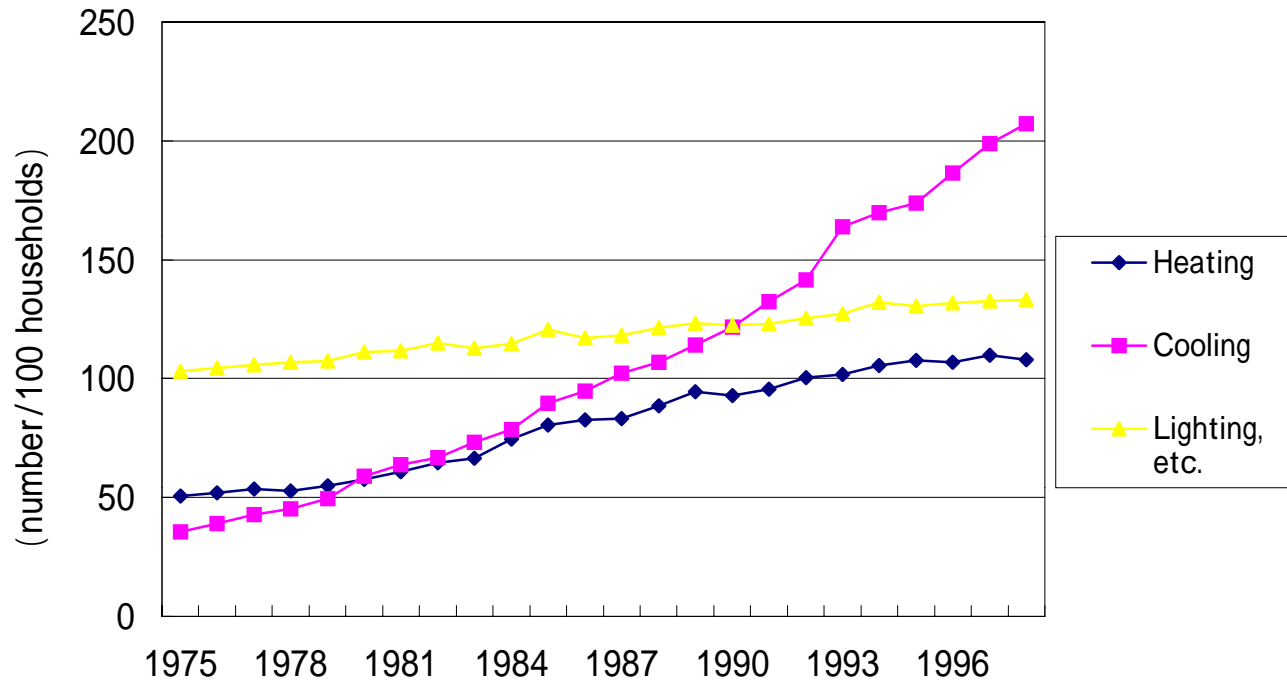
Flow Chart of the Estimation of Energy Consumption for Lighting, driving, etc.



Trends of Service Device (1)

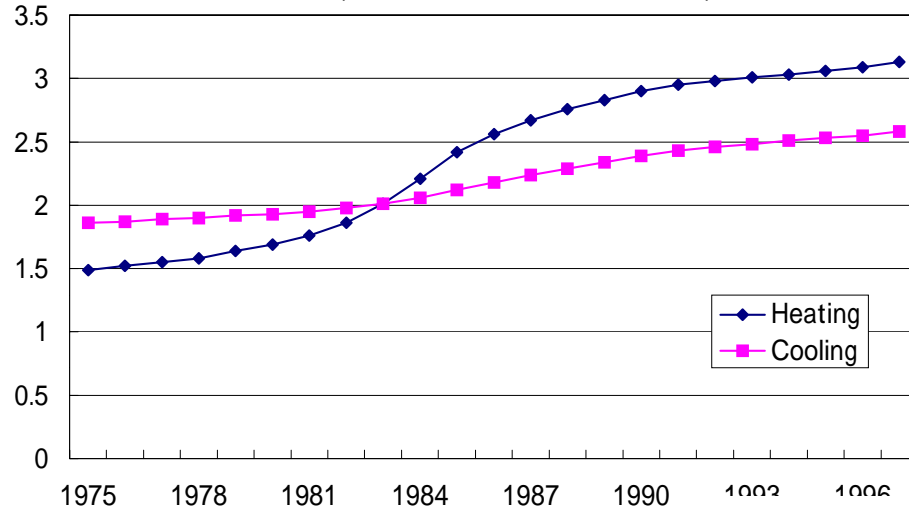


Trends of Service Device (2)

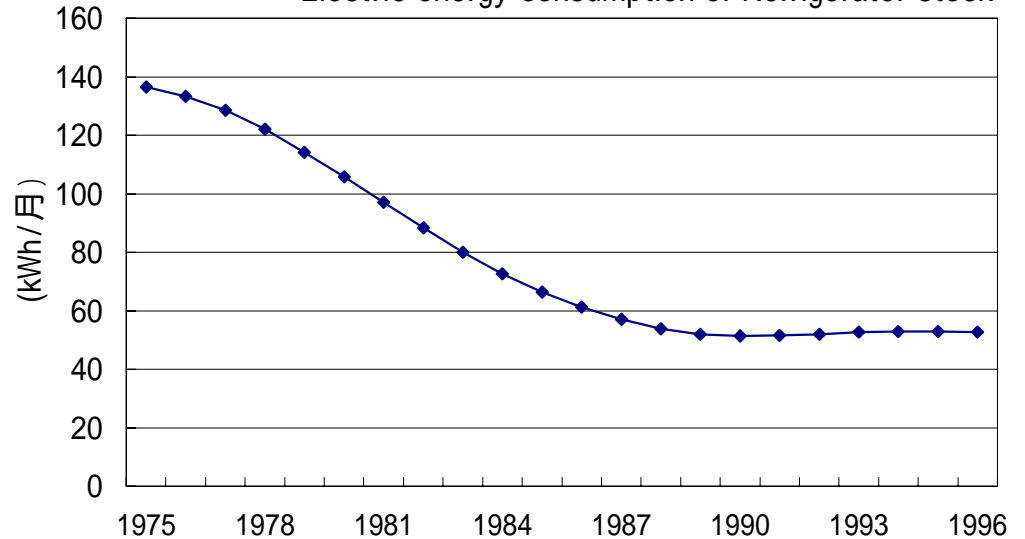


Trends of Energy Efficiency

C O P (Coefficient of Performance)

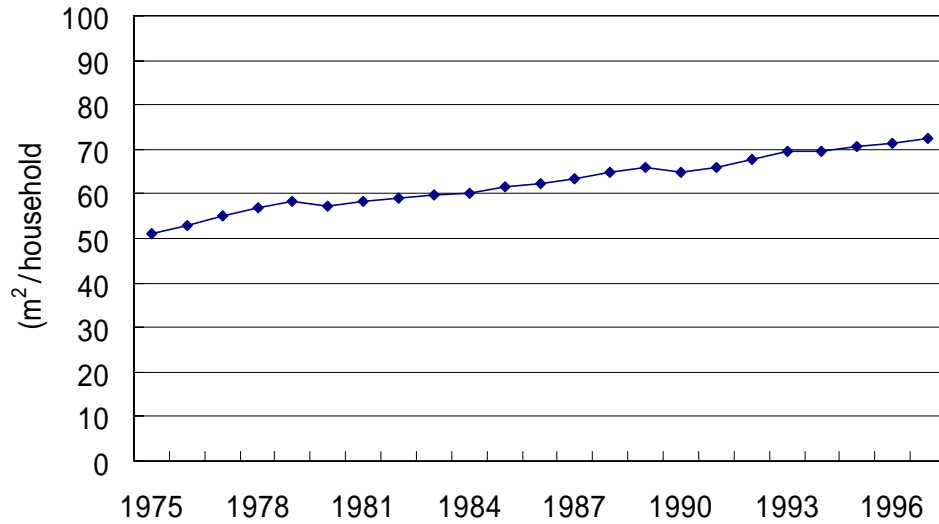


Electric energy consumption of Refrigerator stock

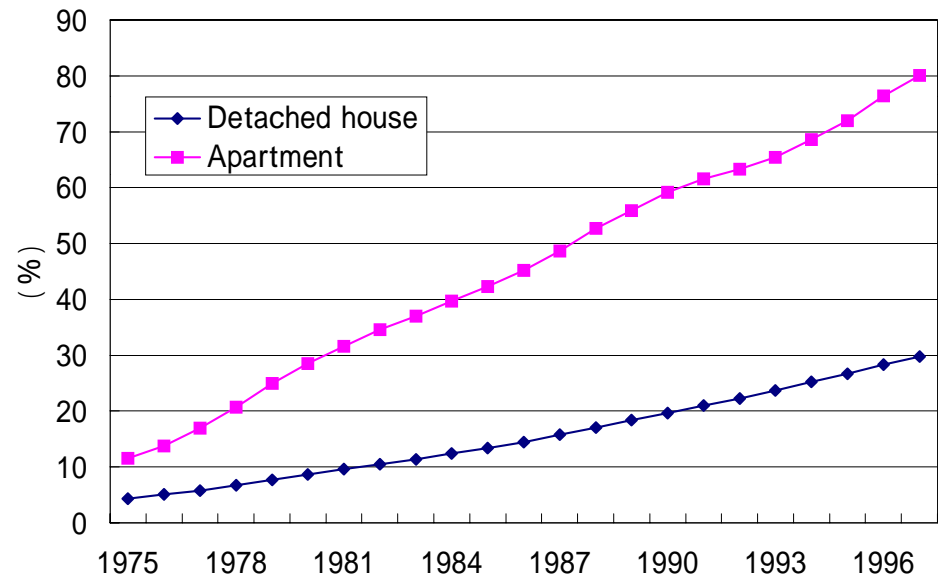


Trends of Housing Property

Floor Space per unit of household



Share of insulating housing



Setting up the Exogenous Variable

- Degree: average (1975-99)
- Energy price: average (1991-99)
- Water consumption: Straight line approximation of water consumption per capita (1975-99)
- Number of household: estimated by National Institute of Population, Japan
- Size of household : estimated by National Institute of Population, Japan
- Employees' income: average of increasing rate (1989-99)

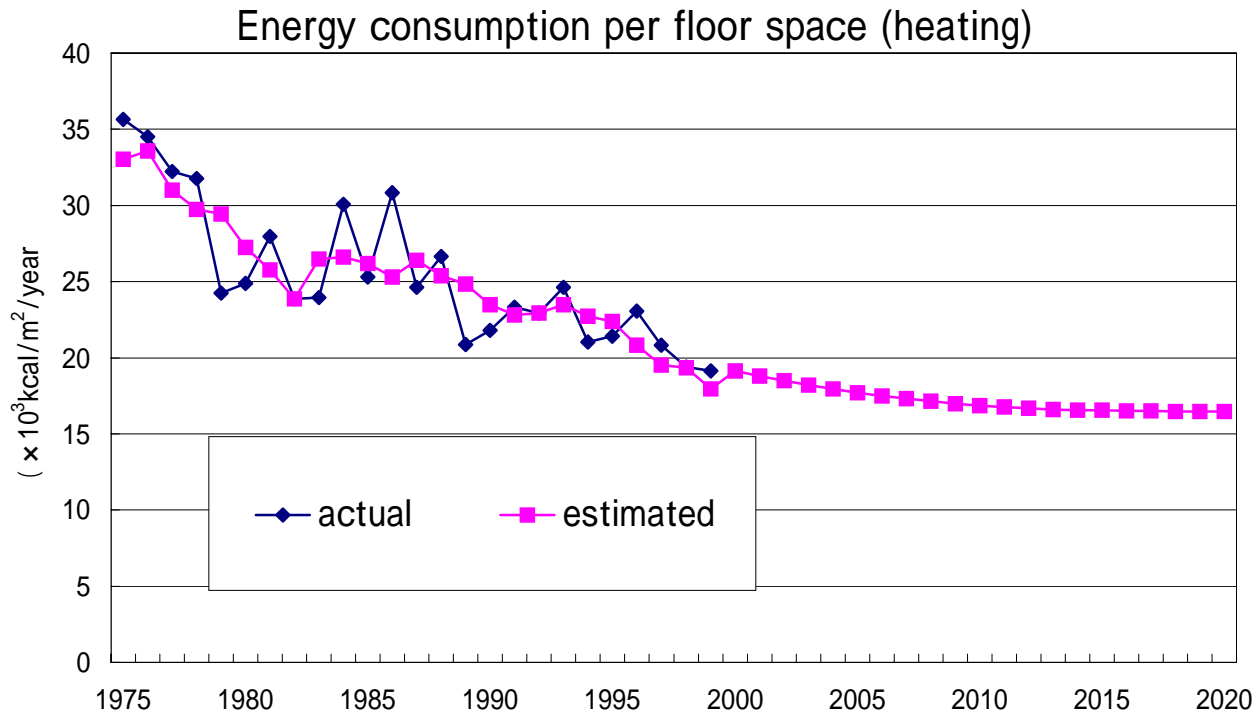
Multiple Regression Analysis: expression

$$Y = a_0 + \sum_{i=1}^n a_i X_i$$

a_i : Partial regression coefficient

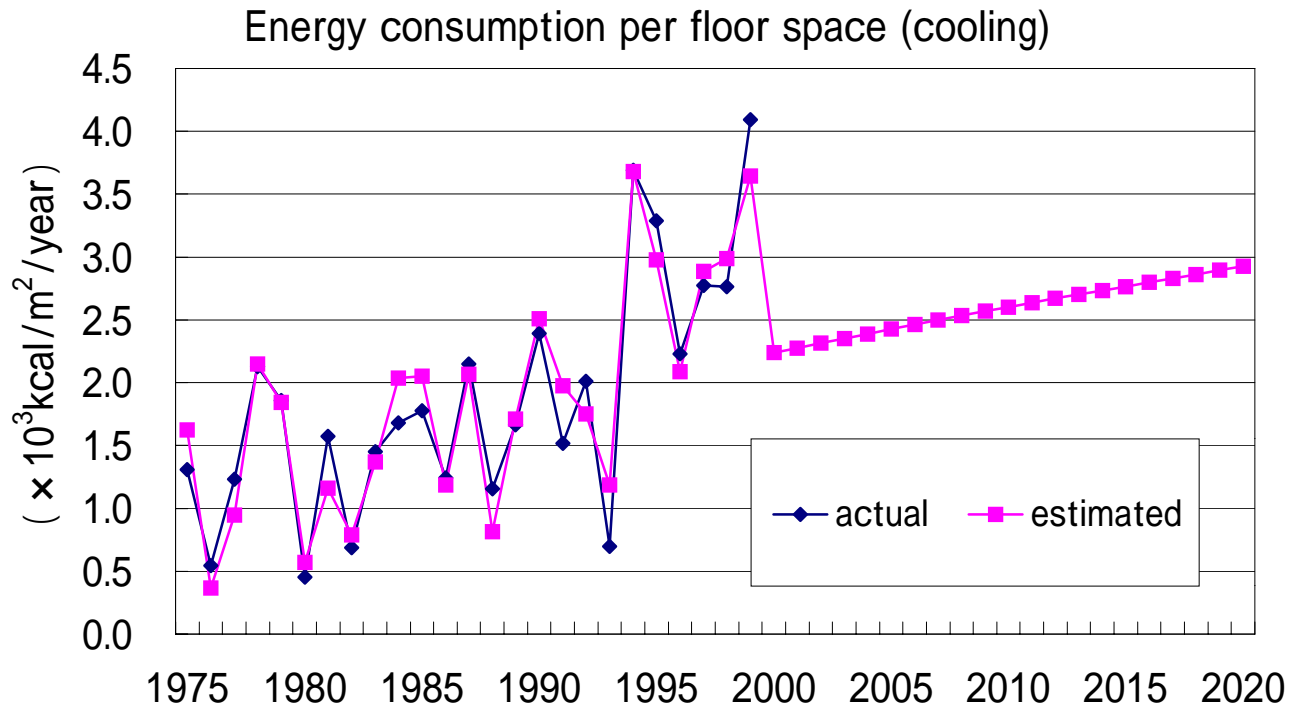
X_i : explanation variable

Multiple Regression Analysis: Heating



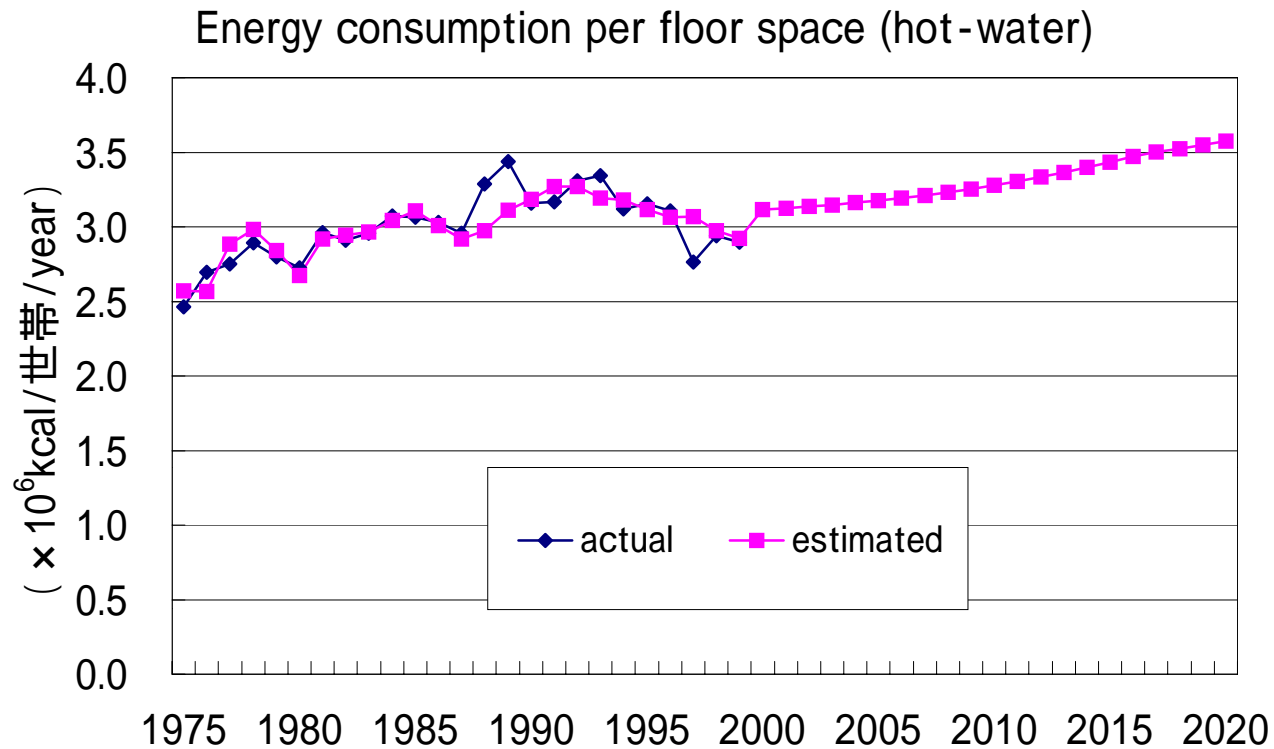
variable	partial regression coefficient	T-value
share of insulated	-229.79782	2.6507
energy price	-667.7481354	2.5251
heating degree	8.019210137	1.4266
possession of device	1033.45472	1.2045
constant	25531.16526	2.8028
r^2	0.7817	

Multiple Regression Analysis: Cooling



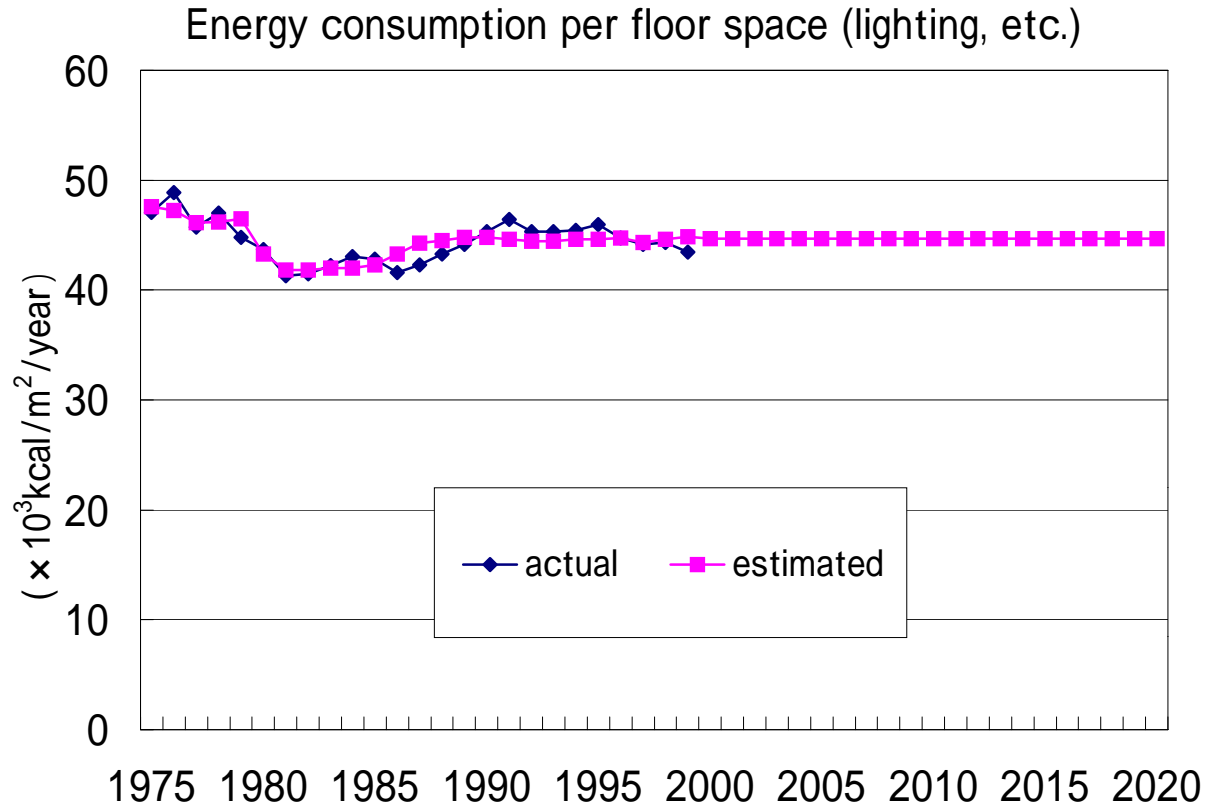
variable	partial regression coefficient	T-value
cooling degree	7.195972461	11.0573
possession of device	170.5389333	3.4079
cooling COP	-1974.34968	1.8780
constant	1391.431423	1.0497
r^2	0.9218	

Multiple Regression Analysis: Hot-water



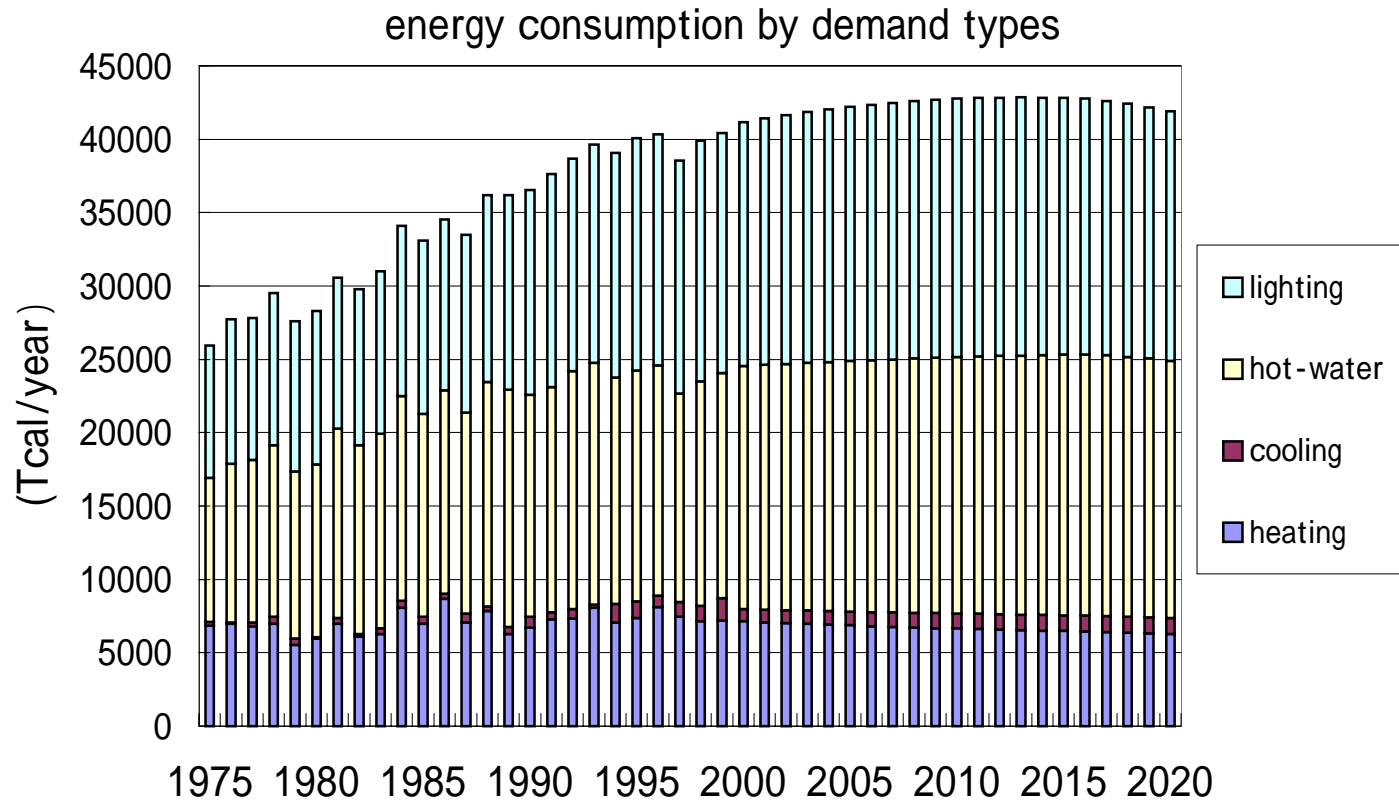
variable	partial regrestion coefficient	T-value
share of insulated	13239.47198	5.6510
water consumption per household	18920.8201	4.5669
energy price	97717.24918	4.2791
constant	-4665114.739	6.0589
r^2	0.6529	

Multiple Regression Analysis: lighting, etc.

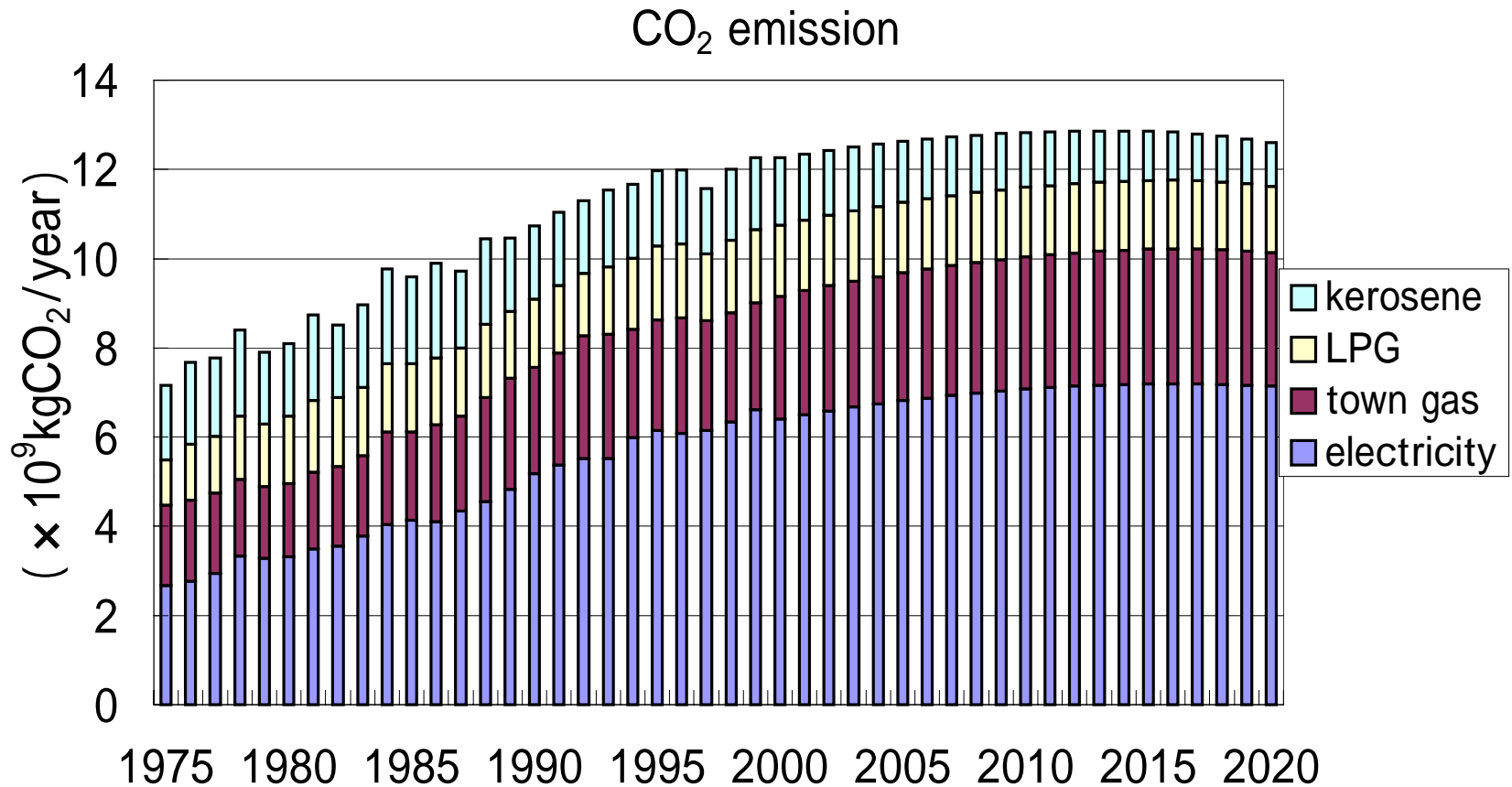


variable	partial regression coefficient	T-value
energy price	-527.6088344	6.4988
efficiency of refrigerator	-27.60258671	2.6128
constant	59755.84263	35.9663
r^2	0.6956	

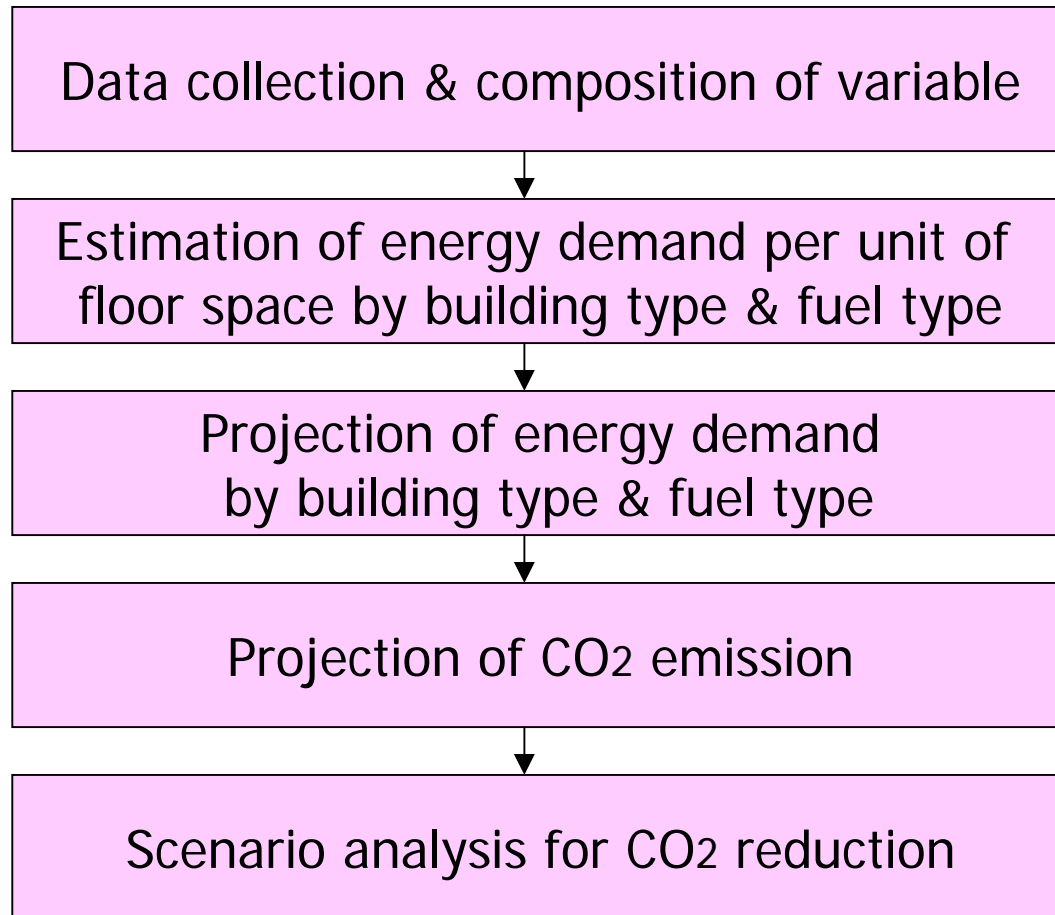
Result of Future Forecasting : energy consumption by demand types



Result of Future Forecasting : CO₂ emission by fuel types



Analytical Flow Chart for Model development & Scenario Analysis of Com sector



Estimating Procedure of CO₂ Emission by Demand Types of Com sector

STEP

- Composition of explanation variable
- Multiple regression analysis for development of regression model to estimate energy intensity by building type & fuel type
- Future forecasting of energy intensity by building type & fuel type
- Future forecasting of CO₂ emission

(Estimating Procedure depends on data availability of each city.)

Result of Regression in Commercial Sector

	buildin g type	fuel type	explanation variable				constant	notes	
			climate		energy price	activities			computer per floor space
			heating degree	cooling degree					
profit sector	office	electricity	-101.21	-16.22	-1457.41	-778.12	72.06	activity: Real GRP of Tertiary Industry / floor space	
		town gas	13.08	8.68	-2647.52	-180.83	***		
		LPG	0.10	***	15.22	3.00	***		
		A heavy oil	-9.21	***	1192.69	***	***		
		B• C heavy oil	***	***	***	***	***		
		kerosene	-7.03	***	626.91	6.53	***		
	other	electricity	71.18	74.61	1638.37	111.49	***	activity: Real GRP of Tertiary Industry / floor space	
		town gas	200.63	90.74	-14969.33	66.41	***		
		LPG	-1.70	***	53.73	-2.51	***		
		A heavy oil	30.73	***	2875.39	18.36	***		
		B• C heavy oil	***	***	***	***	***		
		kerosene	6.36	***	365.73	3.30	***		
non-profit sector	hospita	electricity	-273.12	-26.29	***	-59.54	***	activity: number of patient / floor space	
		town gas	-53.77	***	-3394.05	-22.44	***		
		LPG	1.67	***	***	0.54	***		
		A heavy oil	-82.94	***	7790.82	0.00	***		
		B• C heavy oil	***	***	0.00	0.00	***		
		kerosene	-55.65	***	4299.19	0.00	***		
	school	electricity	-23.59	-6.22	-602.22	-221.92	***	activity: number of student/ floor space	
		town gas	13.43	8.76	-3492.11	-217.35	***		
		LPG	0.09	***	22.57	3.71	***		
		A heavy oil	-17.31	***	1603.89	***	***		
		B• C heavy oil	0.00	***	***	***	***		
		kerosene	-1.32	***	94.56	1.68	***		

Future Works & Discussion

- Scenario analysis for CO₂ reduction in Tokyo
- collecting data of other cities
- development of res/com sector model of other cities

Data Requirements for This Model (Residential Sector)

	Inputs	detail	past	future
Overall	economic indicators	households income population	data data	
	energy demand	energy demand by energy type by demand type (matrix)	data	
	Service unit	number of households	data	
Energy Intensity per unit of Service	household property	number of people	data	
	housing property	type (detached / apartment)	data	
		insulated rate	data	
		floor space	data	
	number of service device	possession rate of equipment	data	
		water consumption per household	data	
	energy efficiency factor	energy demand * by equipment	data	
COP(coefficient of performance) by equipment		data		
energy price	energy price by energy types *	data	scenario	
climate factor	cooling degree	data	scenario	
	heating degree	data	scenario	

*: coal, kerosene, LPG, town gas, electricity, solar heat

Data Requirements for This Model (Commercial Sector)

	Inputs	detail	past	future
Overall	economic indicators	production by category of business	data	
	energy demand	energy demand by energy type by demand type (matrix)	data	
Service unit	floor space	floor space by business type (if available)	data	
Energy Intensity per unit of Service	business activity	production value (or sales value) by business type *	data	
		performance ** by business type	data	
	energy price	energy price by energy types ***	data	scenario
	climate factor	cooling degree	data	scenario
heating degree		data	scenario	

*: office, small shop, department store, supermarket, hotel, entertainment, school, hospital, others (public facility, etc.)

** : labor force, number of bed (hospital), number of student (school), number of guest (hotel, entertainment)

***: coal, kerosene, heavy oil, town gas, electricity, solar heat