

# ESTIMATION OF ENERGY CONSUMPTION CONSIDERING ENERGY SERVICE DEMAND AND SUPPLY STRUCTURE

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# Background

- Energy consumption in residential sector is complex in structure.
  - ▣ Energy type used in household has changed
  - ▣ Energy consumption per household has increased as economic growth
- Energy service demand and supply structure in residential sector is not yet understood.
- But we can know a part of information which is related with the structure from survey and studies.

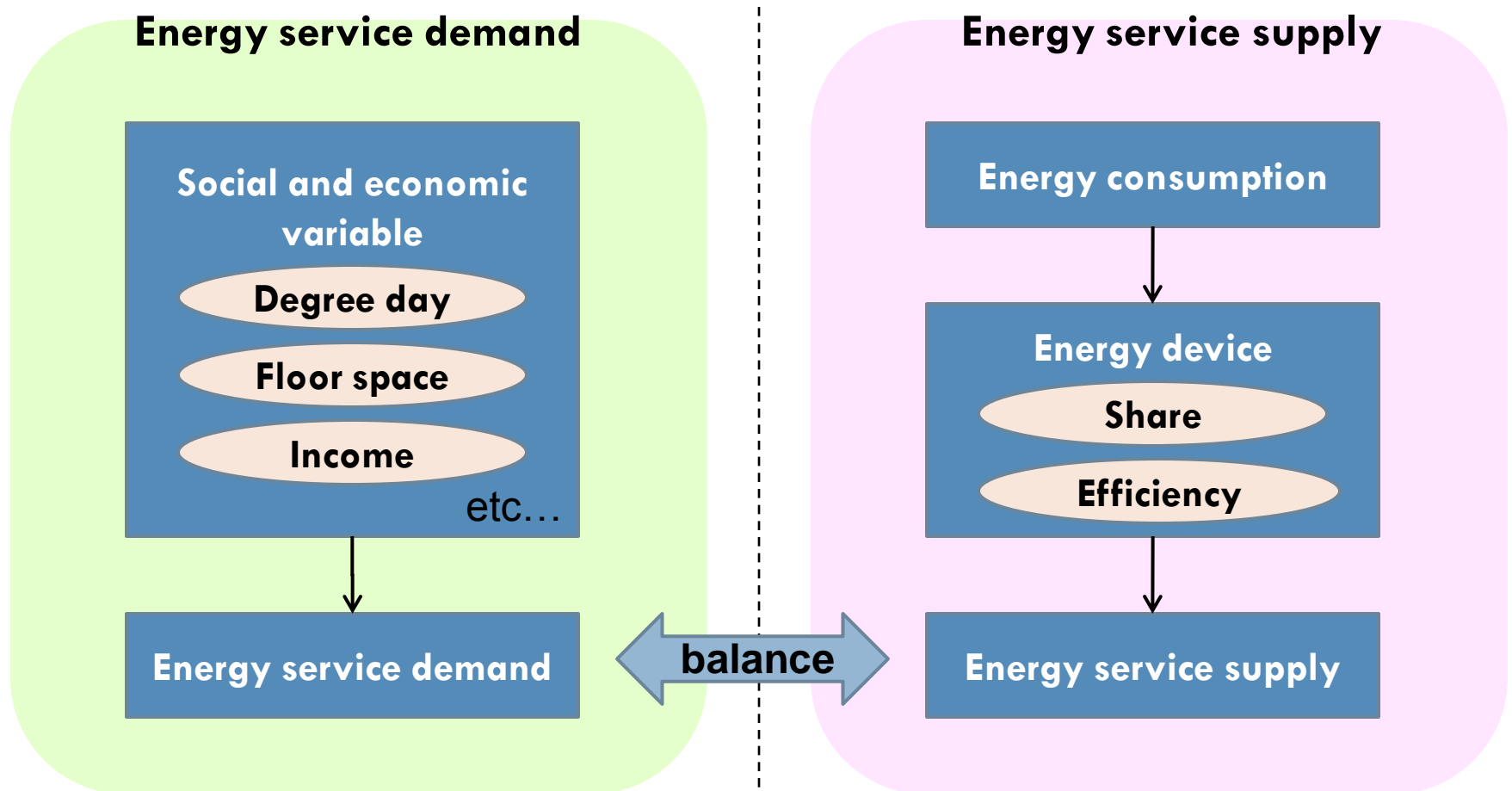
# Objective

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- To be clear a structure of energy service demand and supply quantitatively
- To estimate energy consumption which is adjusted using related various data (energy consumption and social and economic variable)

# Energy service demand and supply structure

- Energy service demand and supply are balanced



# Outline of this study

Description of s	s:Service	D(r, s): Service from driving force	D(r, s): service assumed	D(r, s): service calculated	cnv(r, s, k): Energy device k		ES(r, s): energy consumption by s	ES(r,s) /ES(r, ·) calculated	ES(r,s) /ES(r, ·) assumed	ES(r,s) assumed	ES(r,s) reference	
					Device 1	... Device k						
Heating	RWM	[Green]	[Red]	[Green]	[Pink]		[Green]	[Green]	[Green]	[Red]	[Pink]	
Cooling	RCL											
Hot water	RHW											
cooking	RCK											
Others	ROT											
Weight on D					0	1.0	1.0	Above values are rescaled by E(r, ·)				
Weight on ES								[Red]	[Red]			

Japan's energy service in 2005 is 1

- :Assumed value
- :Calculated value
- :Fixed value or rarely changed value

## Per capita data

Description of l	l: Energy source	ef(r, l, k): Energy intensity	E(r, ,l): Energy consumption by l calculated	E(r, ,l) /E(r, , ·) calculated	E(r, ,l) /E(r, , ·) assumed	E(r, ,l) assumed	E(r, ,l) reference
Biomass	BW	[Pink]	[Green]	[Green]	[Green]	[Red]	[Pink]
Coal	CL						
Kerosene	OK						
LPG	OL						
Natural gas	NG						
Electricity	EL						
Heat	HT						
Solar	SL						
Weight on E(r, , j)			0	1.0	1.0	[Red]	[Pink]

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Heating	RWM				<b>Share</b>							
Cooling	RCL											
Hot water	RHW											
cooking	RCK											
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Kerosene	OK							
LPG	OL							
Natural gas	NG							
Electricity	EL							
Heat	HT							
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Cooling	RCL										
Hot water cooking	RHW RCK										
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Description of l	l: Energy source	ef(r, l, k): Energy intensity	E(r, l): Energy consumption by l calculated	E(r, l) /E(r, ·) calculated	E(r, l) /E(r, ·) assumed	E(r, l) assumed	E(r, l) reference
Coal	CL						
Kerosene							
LP Gas							
Natural Gas							
Electricity	EE						
Heat	HT						
Solar	SL						
			Weight on E(r, l)				
			0	1.0	1.0		

**Minimization**

# Equations

## □ Energy consumption by energy type

$$E_r^{\bullet,l} = \sum_k E_r^{k,l} = \sum_s \left( D_r^s \cdot \sum_{k \in SK(s)} \overline{cnv}_r^{s,k} \cdot ef_r^{l(k)} \right)$$

## □ Energy consumption by service type

$$ES_r^s = D_r^s \cdot \sum_l \left( \sum_{k \in SK(s)} \overline{cnv}_r^{s,k} \cdot ef_r^{l(k)} \right)$$

$r$  : Region

$l$  : Energy type

$k$  : Device

$s$  : Energy service

$SK$  : Subset of  $k$

$E_r^{\bullet,l}$  : Energy consumption by energy type

$ES_r^s$  : Energy consumption by service type

$D_r^s$  : Energy service demand

$\overline{cnv}_r^{s,k}$  : Device share

$ef_r^{l(k)}$  : Device energy efficiency

# Optimization

- To minimize the gap between assumed value and calculated value

minimize  $w1 \cdot (E_r^{\bullet,l} - \bar{E}_r^{\bullet,l})^2 + w2 \cdot (ES_r^s - \bar{ES}_r^s)^2 + w3 \cdot (D_r^s - \bar{D}_r^s)^2$

Weight

Calculated value

Assumed value

The diagram illustrates the objective function for minimizing the gap between assumed and calculated values. The function is  $w1 \cdot (E_r^{\bullet,l} - \bar{E}_r^{\bullet,l})^2 + w2 \cdot (ES_r^s - \bar{ES}_r^s)^2 + w3 \cdot (D_r^s - \bar{D}_r^s)^2$ . The weights  $w1$ ,  $w2$ , and  $w3$  are shown in circles above the terms. The terms  $E_r^{\bullet,l}$ ,  $ES_r^s$ , and  $D_r^s$  are circled in red and labeled as 'Calculated value'. The terms  $\bar{E}_r^{\bullet,l}$ ,  $\bar{ES}_r^s$ , and  $\bar{D}_r^s$  are circled in blue and labeled as 'Assumed value'. A line labeled 'Weight' points to the  $w1$ ,  $w2$ , and  $w3$  terms. Red lines connect the red circles to the 'Calculated value' label, and blue lines connect the blue circles to the 'Assumed value' label.

# Data description

- Reference data of energy consumption
  - ▣ Energy consumption by energy type
    - Is estimated by Dr.Fujimori.
  - ▣ Energy consumption by service
    - Japan, China, India, Canada, USA, Australia
    - Other region: SAGE
- Energy device information
  - ▣ AIM/Enduse[Global]

# Description of service demand calculation

- Reference data of service demand is estimated using sub module.
  - Heating
    - Heating degree day/Floor space/Insulation level
  - Cooling
    - Cooling degree day/Floor space/Insulation level/Possession of air conditioner
  - Hot water
    - Hot water consumption per capita
  - Cooking
    - Ratio of eating in household/Cooking energy intensity
  - Other
    - GDP per capita

# Description of calculation

- Energy type: 8type
  - ▣ Biomass, Coal, Kerosene, LPG, Natural gas, Electricity, Heat, Solar thermal
- Service type: 5type
  - ▣ Heating, Cooling, Hot water, Cooking, Other
- Energy device: 41type
- Region: 35 regions
  - ▣ 15 Asian regions and 20 other regions
- Year: 2005

# Energy Consumption -Japan-

## ●Energy consumption rate by type

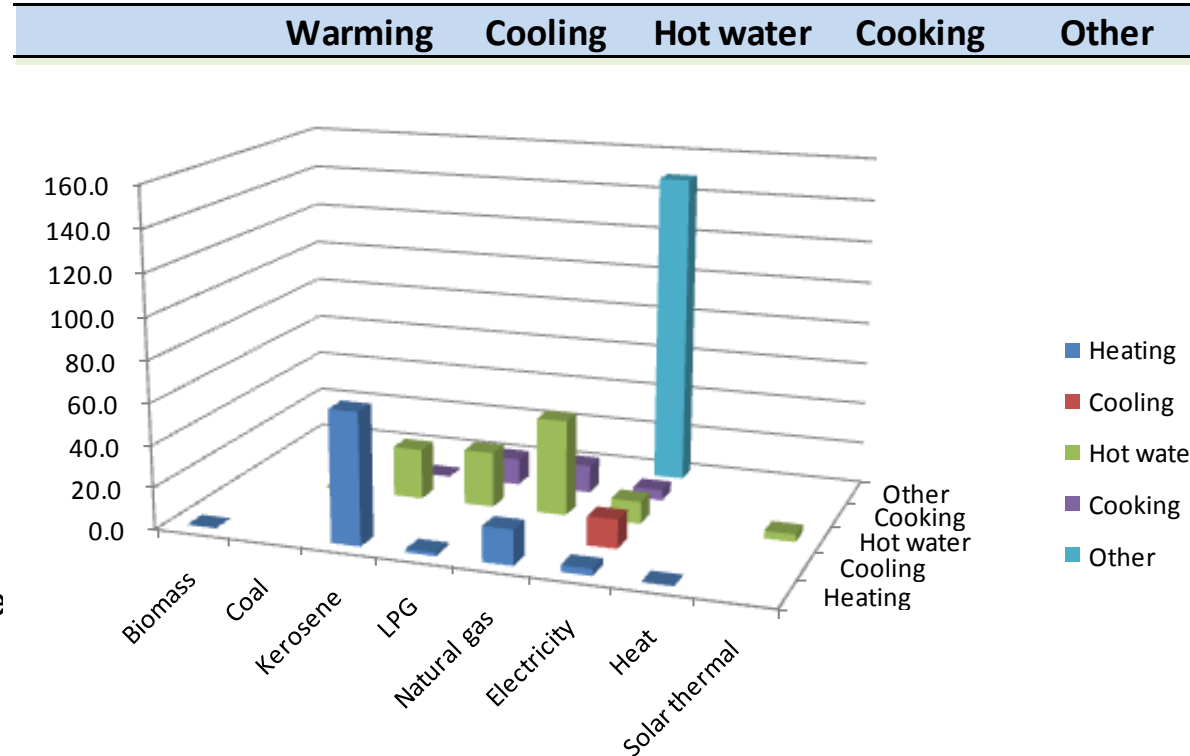
	calculated value	assumed value
Biomass	0.00	0.00
Coal	0.00	0.02
Kerosene	0.22	0.21
LPG	0.10	0.11
Natural gas	0.19	0.19
Electricity	0.47	0.46
Heat	0.00	0.00
Solar thermal	0.01	0.00

## ●Energy consumption rate by service

	calculated value	assumed value
Heating	0.22	0.24
Cooling	0.04	0.03
Hot water	0.28	0.28
Cooking	0.08	0.08
Other	0.38	0.37

## ●Energy consumption per capita

Unit: toe



# Energy Consumption -China-

## ● Energy consumption rate by type

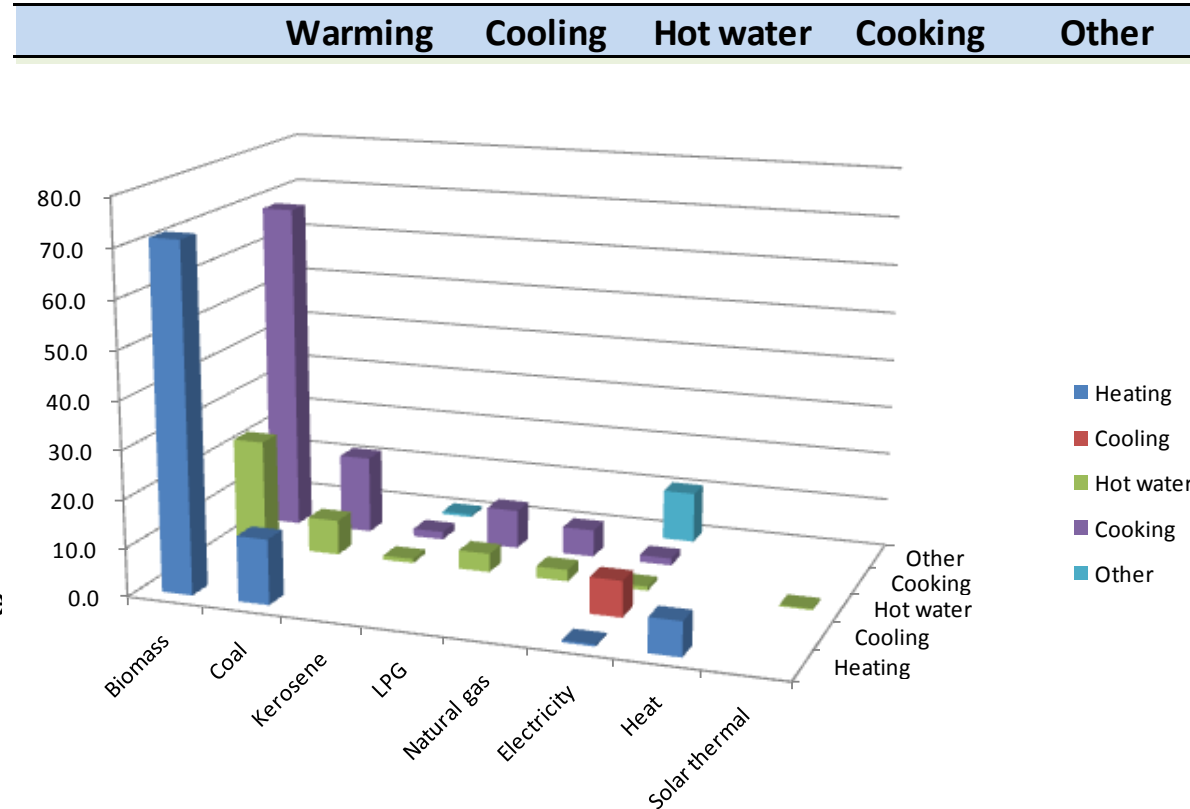
	calculated value	assumed value
Biomass	0.65	0.64
Coal	0.15	0.17
Kerosene	0.01	0.01
LPG	0.05	0.05
Natural gas	0.03	0.03
Electricity	0.08	0.07
Heat	0.03	0.03
Solar thermal	0.00	0.00

## ● Energy consumption rate by service

	value	value
Heating	0.37	0.38
Cooling	0.03	0.02
Hot water	0.15	0.15
Cooking	0.41	0.41
Other	0.04	0.04

## ● Energy consumption per capita

Unit: toe





# Energy Consumption -India-

## ● Energy consumption rate by type

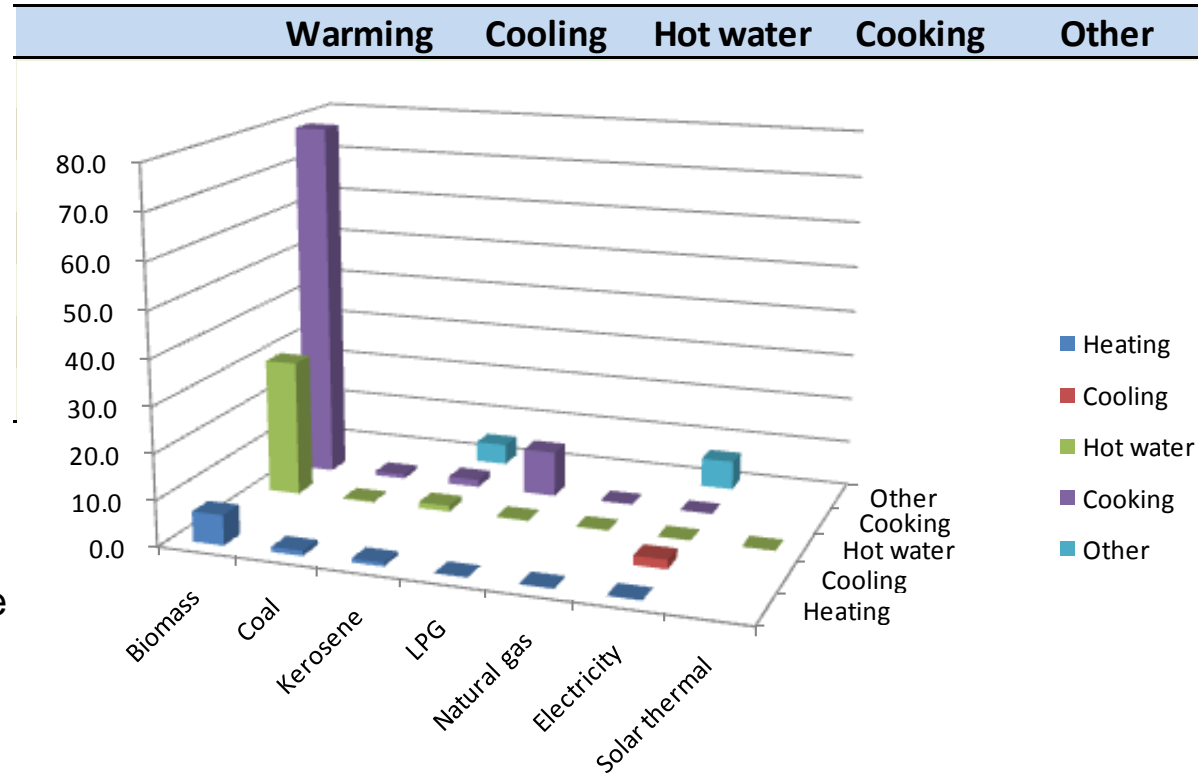
	calculated value	assumed value
Biomass	0.80	0.80
Coal	0.02	0.02
Kerosene	0.06	0.06
LPG	0.07	0.07
Natural gas	0.00	0.00
Electricity	0.06	0.05
Solar thermal	0.00	0.00

## ● Energy consumption rate by service

	calculated value	assumed value
Heating	0.06	0.02
Cooling	0.01	0.01
Hot water	0.22	0.26
Cooking	0.63	0.64
Other	0.08	0.07

## ● Energy consumption per capita

Unit: toe



# Conclusion and future task

- We estimate a structure of energy service demand and supply in 2005.
- We need to check the detail of result.
- We will estimate energy service demand and supply in future.
  - ▣ Future device share and efficiency
  - ▣ Social and economic scenario



**Thank you for your attention!**

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