AIM/Energy Snapshot Tool (ESS)

AIM Training Workshop

Tokyo, Japan Oct 16-20, 2006

MIZUHO

Mizuho Information & Research Institute

Contents

- Background
- Structures & Flows
- Operation
  - Demand Settings (Residential Sector)
  - Demand Settings (Other Sector)
  - Transformation Sector (Electricity, Other)
  - Analysis

Contents

Background

Background of development

- In LCS/SD scenario developing processes, a tool with following feature would be useful
  - Clear assumptions & calculation processes
  - Easy interpretation of the results
  - Easy sensitivity analysis (assumptions can be changed manually)
  - Quick calculation
  - Overview of general energy flow (keep balance)

- Tools for describe future (ex. 2050) Energy Balance Table (EBT) in a spreadsheet: **Energy Snapshot Tool （ESS）**

AIM/Energy snapshot tool

- Excel format
- Based on EBT
- Step by step approach
- The tool can be used for;
  - Developing and designing preliminary LCS/SD scenarios
  - “What if” analysis
  - Check the consistency among the sectors
  - Analyze the impacts of countermeasures package
  - Communication among stakeholders

General Energy Flow

Production

Total Primary Energy Supply

Import/Export

Energy stock

Transformation & Distribution Technologies

Final Energy Consumption

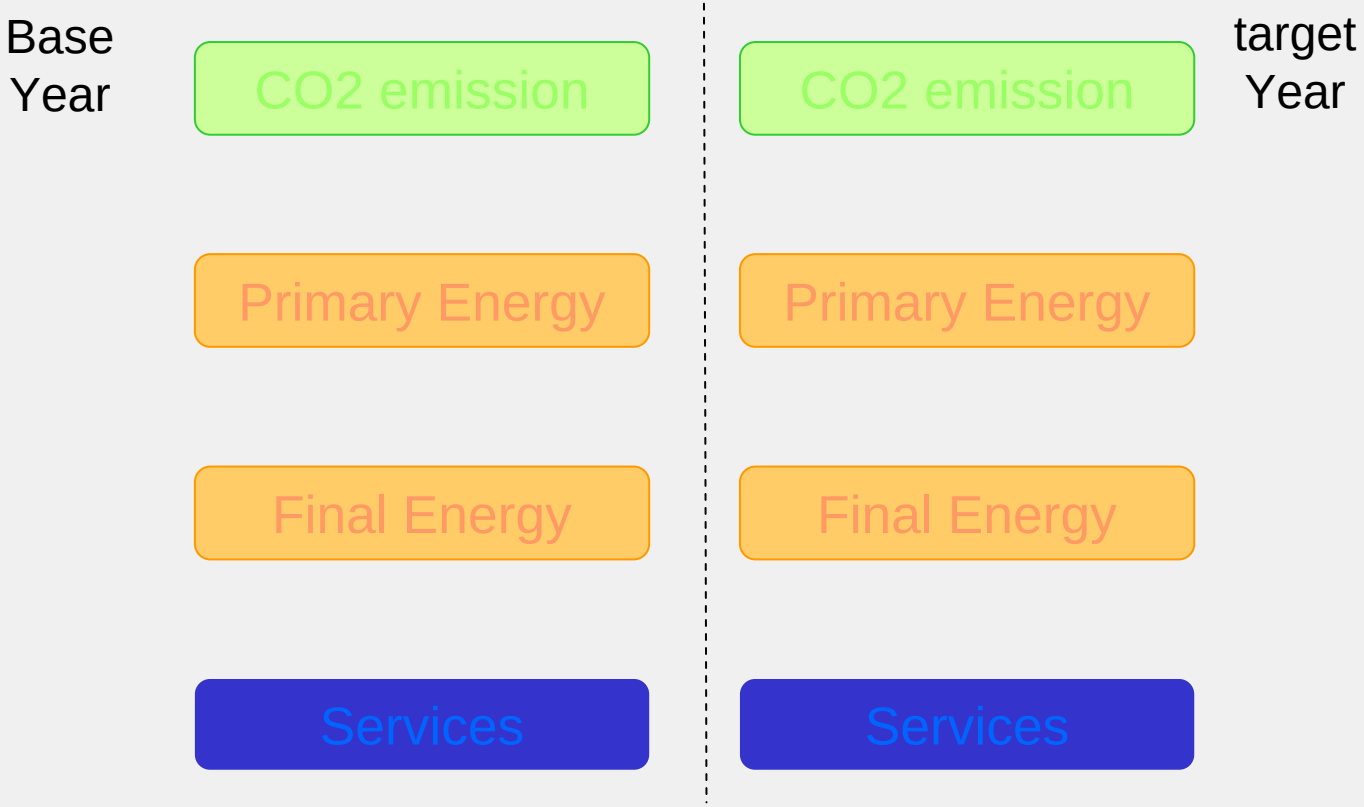
Losses

Technology producing the demanded services

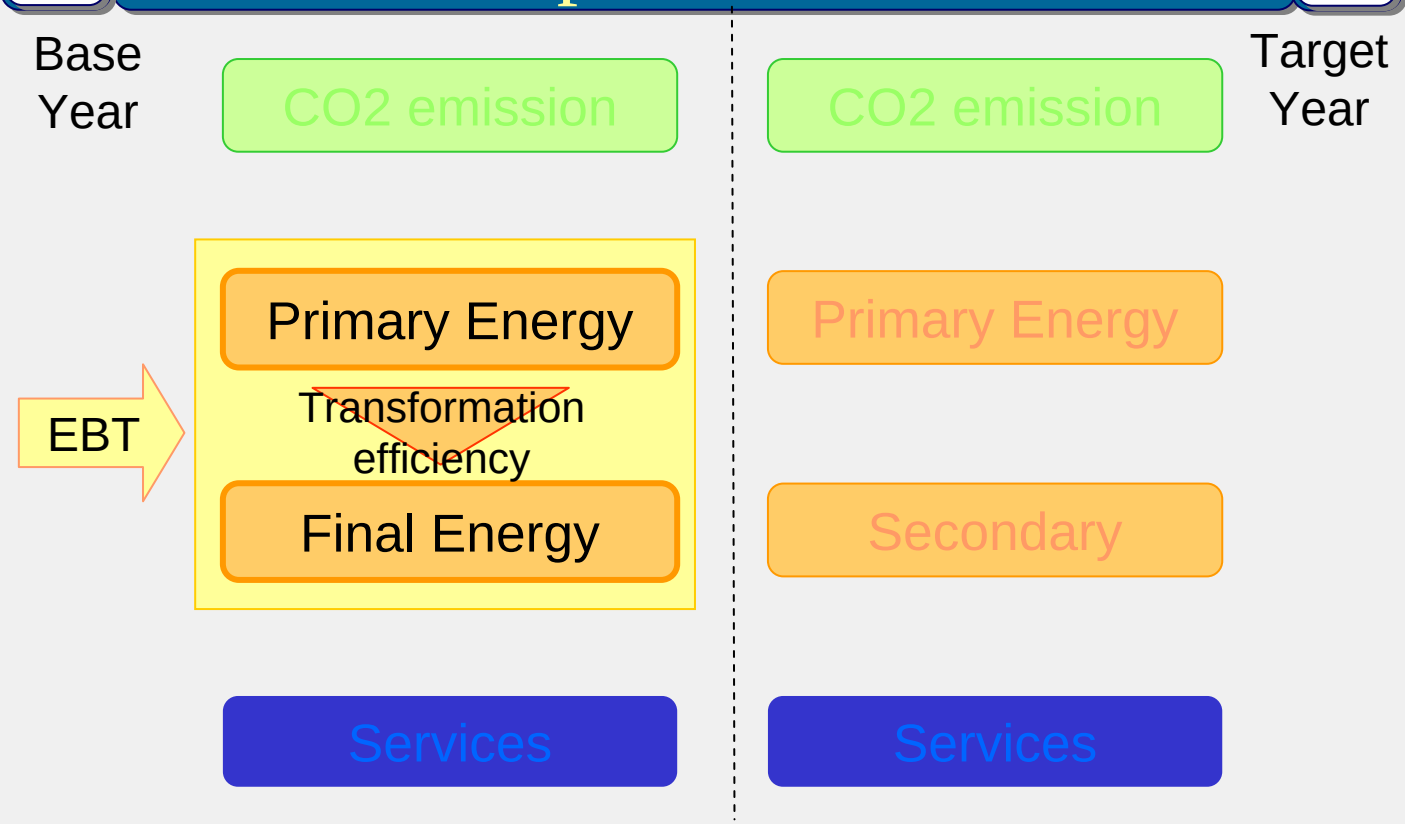
Services

Structure & Flow

Calculation processes

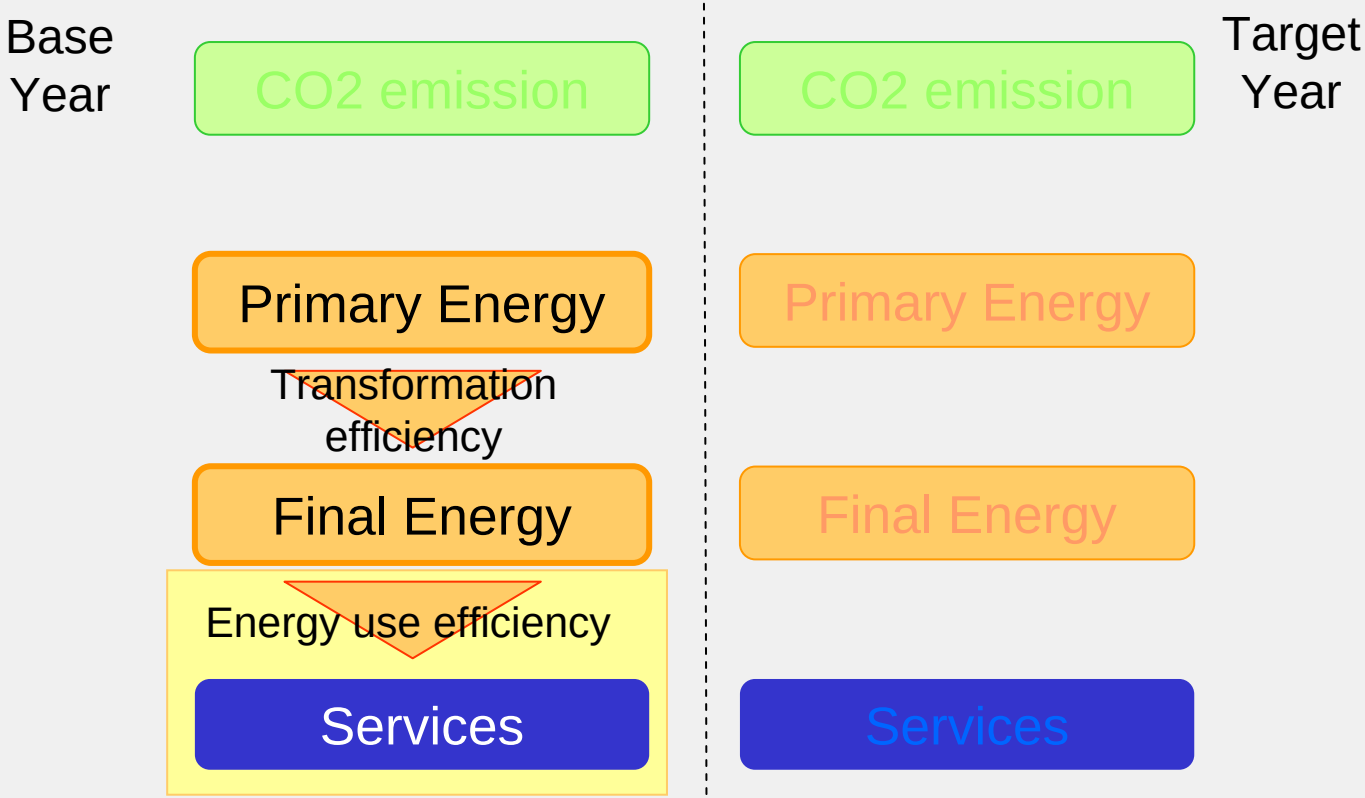


Calculation processes



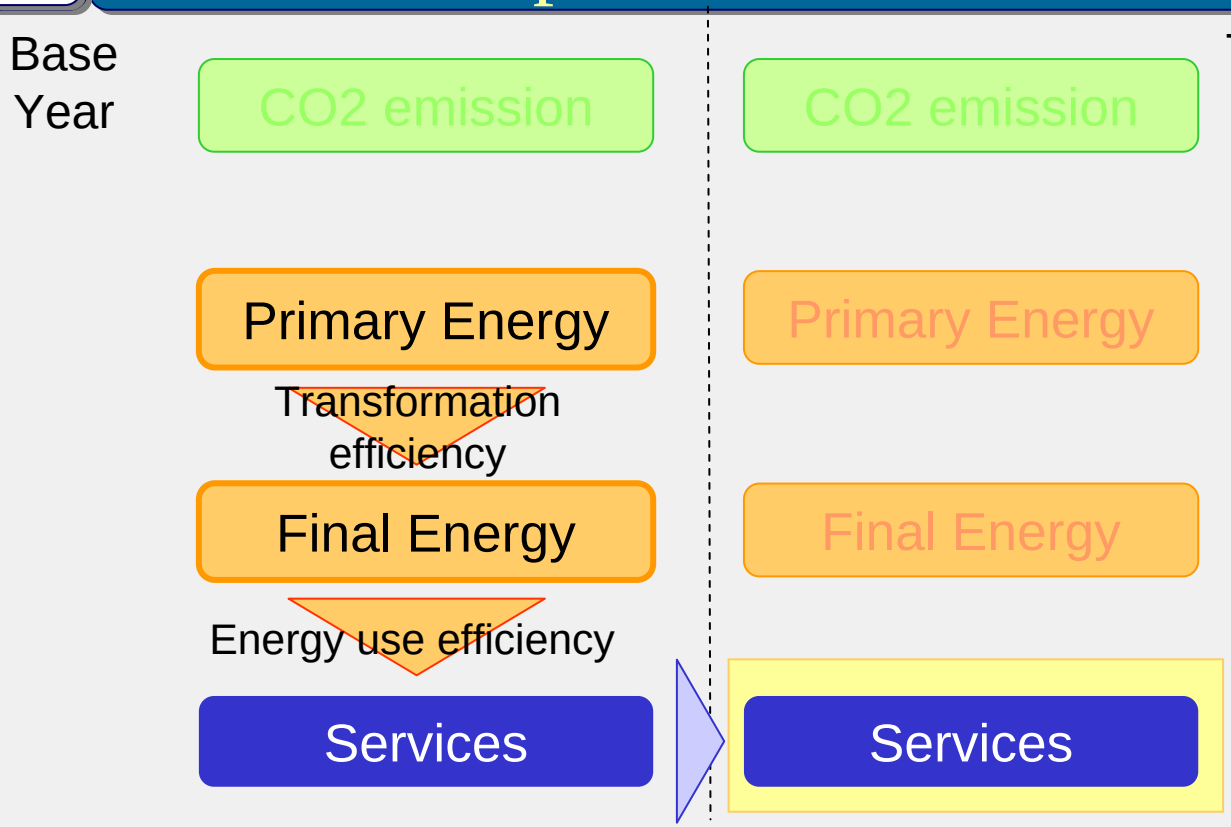
1. Obtain EBT from national statistics etc. (Base Year)

Calculation processes



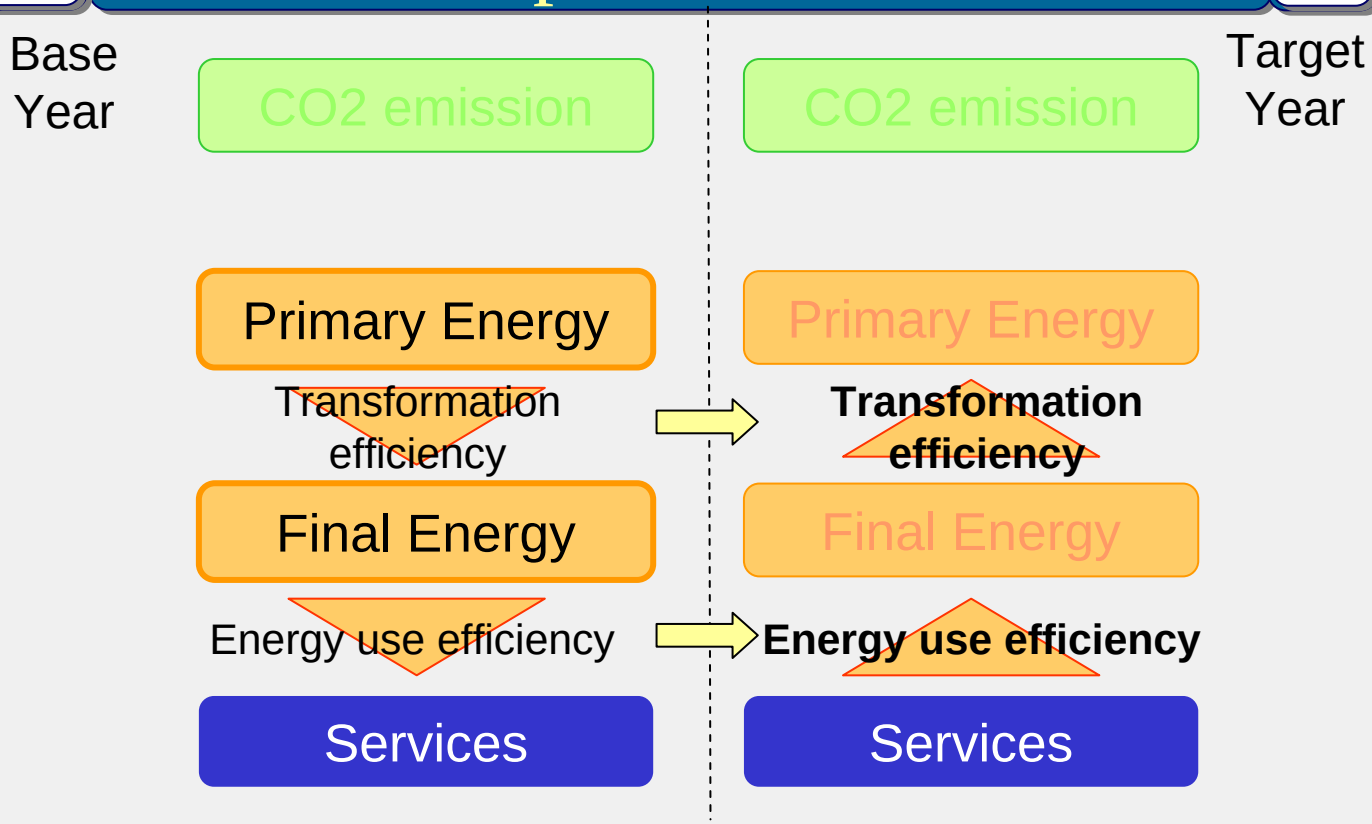
2. Set energy use efficiency & Services demand
   Services/Final Energy (C/S) ratio (Base Year)

Calculation processes



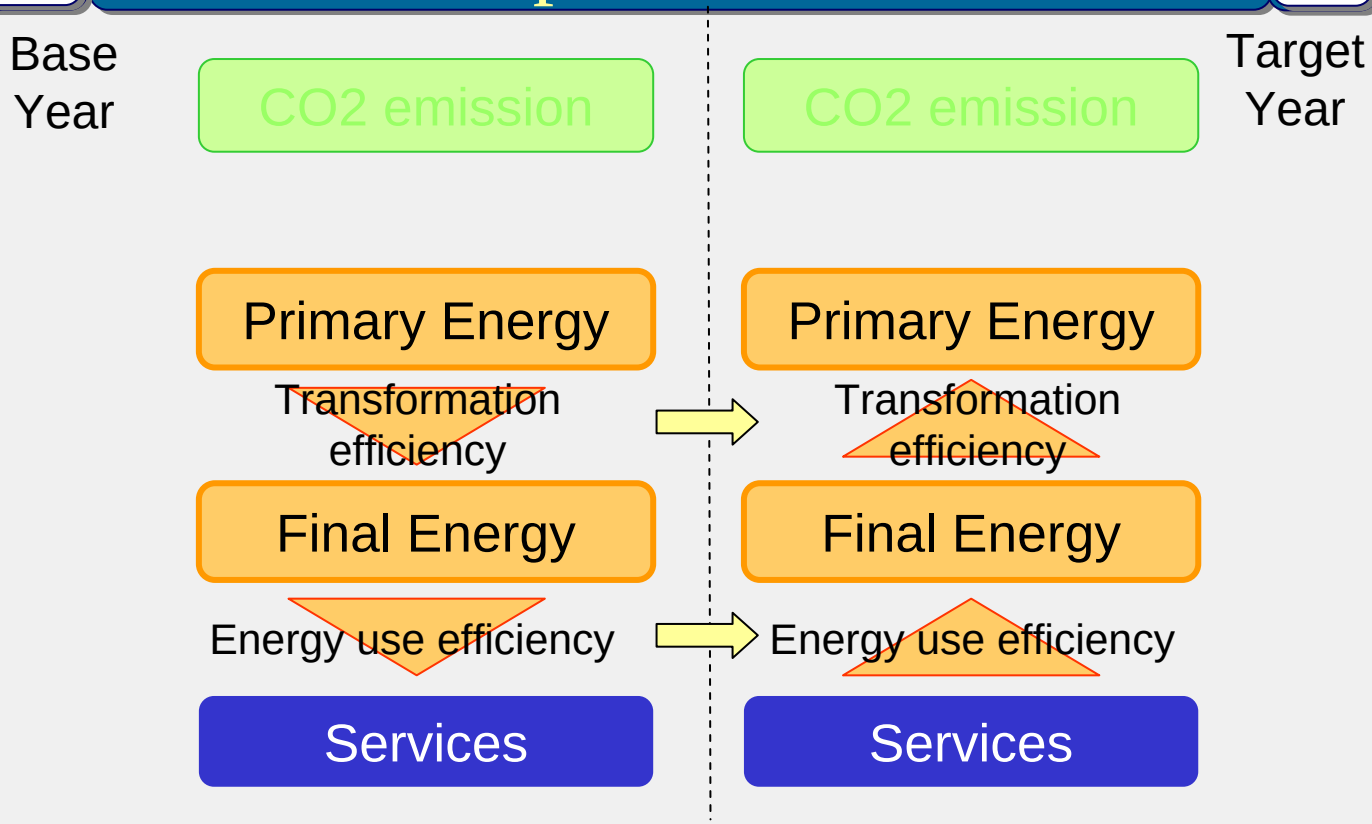
3. Assume changes in “Energy service demand” in Target Year (Scenario)

Calculation processes



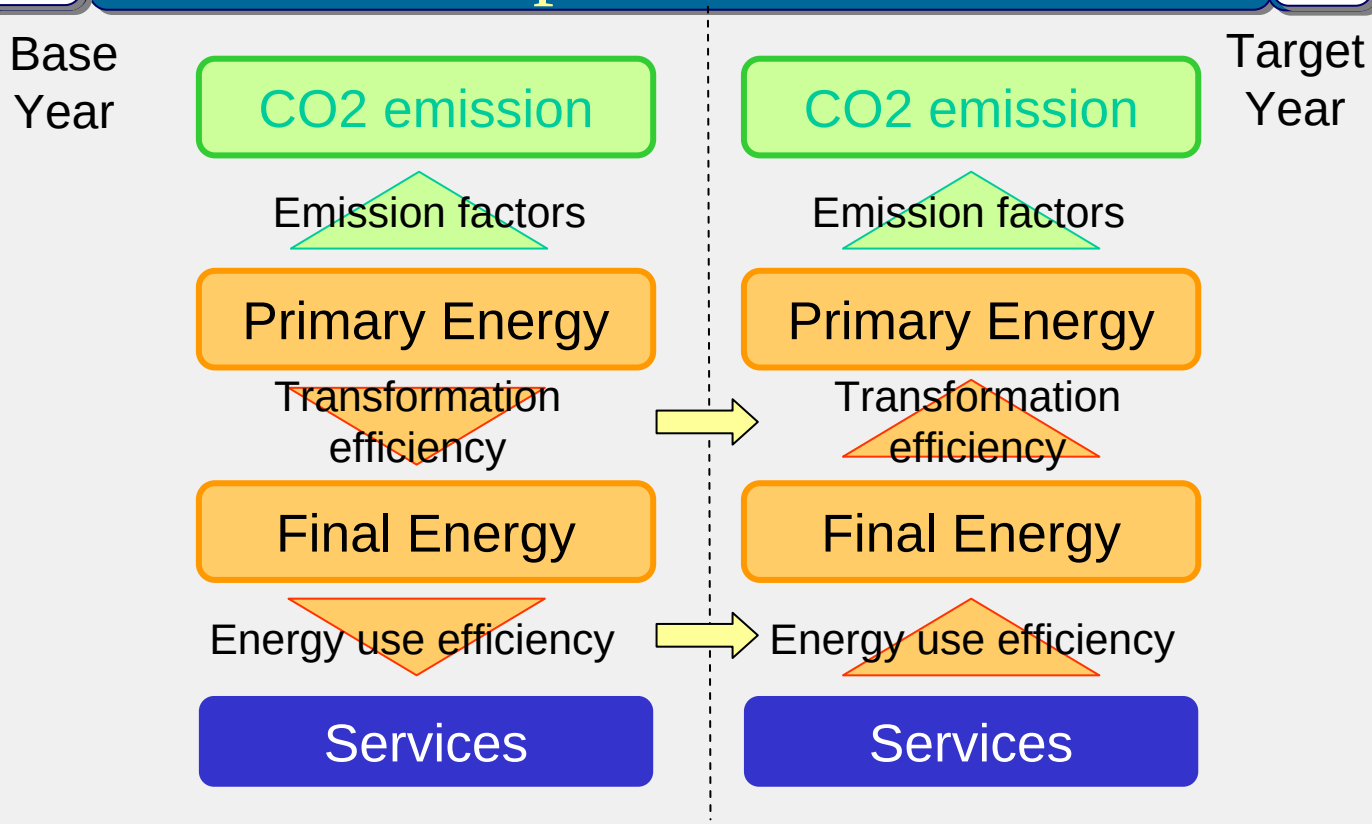
3. Assume changes in parameters in Target Year (Scenario)

Calculation processes



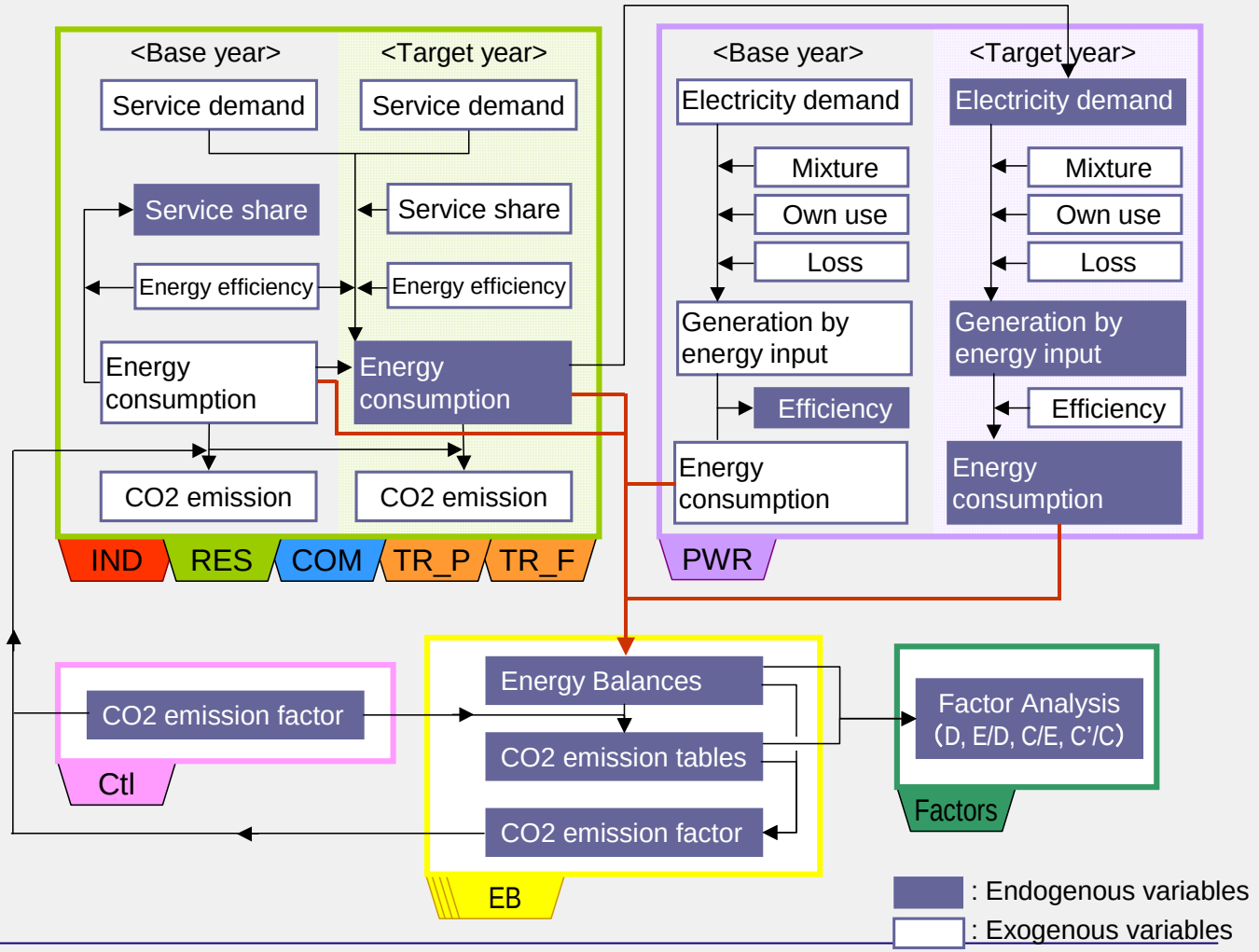
4. Calculate energy Primary Energy and Final Energy in Target Year

Calculation processes



5. Calculate CO2 emissions by multiplying "emission factors" of each energy

Structure of the model



Worksheets

Name	Contents
Title	Cover of ESS
CTL	Unit, simulation year, scenario name and CO2 emission factor
RES	Residential sector
IND	Industrial sector
COM	Commercial sector
TR_P	Passenger transportation sector
TR_F	Freight transportation sector

Worksheets

Name	Contents
EB_SD	Energy balance table (Service & Demand side countermeasures)
EB_S	Energy balance table (Service side countermeasures)
EB_D	Energy balance table (Demand side countermeasures)
EB_0	Energy balance table (No counter measures = Reference case)
Factors	Factors analysis of CO_2 reduction
EneEms	Graphs of energy cons. and CO_2 emissions

Operation

Fundamental settings (CTL)

Unit, Simulation Year, Scenario Name, Emission Factor

Unit

Energy	CO2
Mtoe	MtC

Simulation Year

Base Year	Target Year
2000	2050

Scenario Name

Scenario 1	Scenario 2
A	B

Emission Factor

COL	OIL	GAS	BMS	NUC	HYD	S/W
1.05	0.8	0.55	0	0	0	0

Unit: MtC / Mtoe

General rules

- White cells: User input
- Colored cells: Automatically calculated values

Demand Settings

Residential

Commercial

Transportation_P

Transportation_F

Industry

Residential sector

1 Energy service demand

	Unit	2000	2050					
			REF		CM		CM/REF	
			A	B	A	B	A	B
Cool	Mtoe	4	4	4	4	4	90%	100%
Warm	Mtoe	81	81	81	65	81	80%	100%
Hot Water	Mtoe	55	55	55	55	55	100%	100%
Cooking	Mtoe	60	60	60	30	60	50%	100%
Others	Mtoe	5	5	5	5	5	100%	100%
	Mtoe				0	0		
	Mtoe				0	0		
	Mtoe				0	0		
	Mtoe				0	0		
					0	0		
					0	0		

REF = Reference case
CM = Countermeasure case

4-6 Energy consumption / CO2 Emission

		Unit	COL	OIL	GAS	BMS	S/W
4 Energy Consumption	2000	Mtoe	45	13	5	213	0
	2050 A (CM)		53	12	38	86	0
	2050 B (CM)		45	13	5	214	0
5 Emission Factor	2000	MtC/Mtoe	1.05	0.80	0.55	0.00	0.00
	2050 A (CM)		1.05	0.80	0.55	0.00	0.00
	2050 B (CM)		1.05	0.80	0.55	0.00	0.00
6 CO2 Emission	2000	MtC	47	10	3	0	0
	2050 A (CM)		56	10	21	0	0
	2050 B (CM)		47	10	3	0	0

2 Service Share

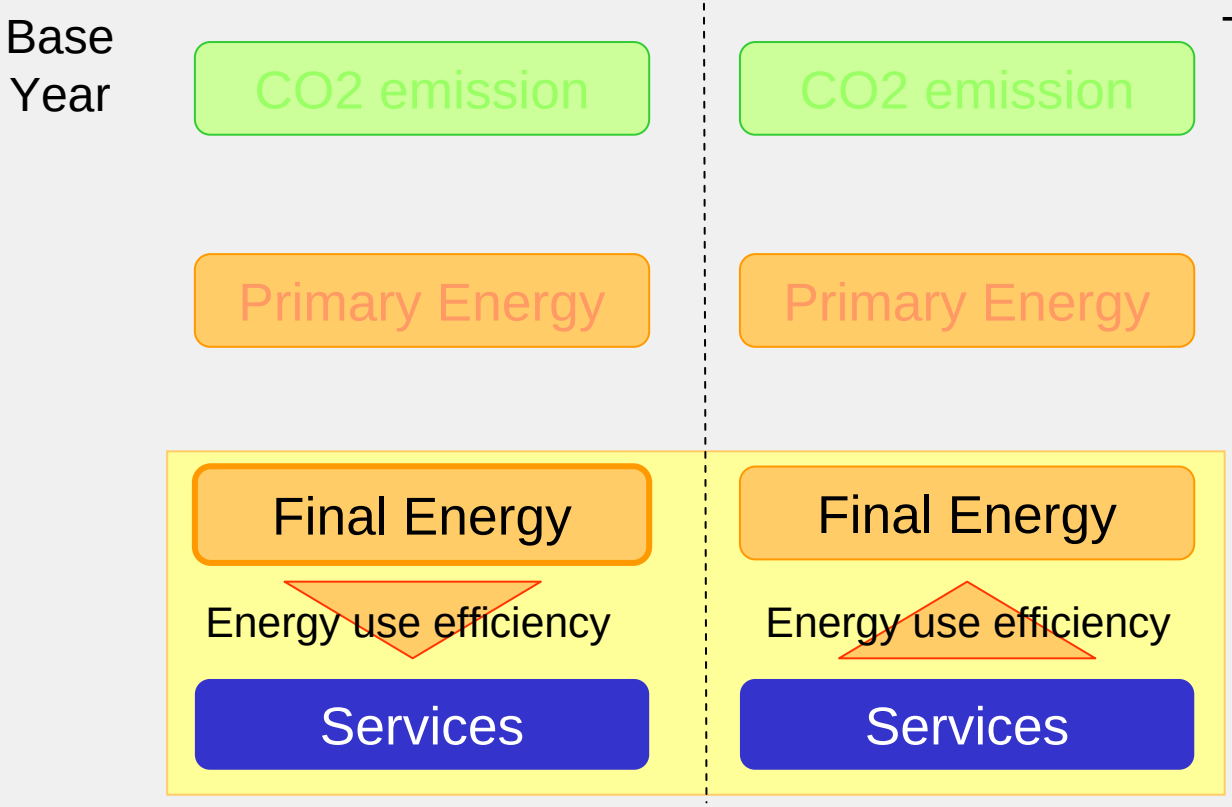
	Unit	2000								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
Warm	-	23%	8%	2%	48%	0%	3%	0%	16%	100%
Hot Water	-	14%	4%	1%	71%	0%	5%	0%	4%	100%
Cooking	-	7%	0%	1%	92%	0%	0%	0%	0%	100%
Others	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%

	2050 A (CM)								
	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	0%	0%	0%	0%	0%	0%	0%	100%	100%
Warm	61%	8%	2%	10%	0%	3%	0%	16%	100%
Hot Water	0%	6%	50%	30%	0%	10%	0%	4%	100%
Cooking	7%	0%	1%	92%	0%	0%	0%	0%	100%
Others	0%	0%	0%	0%	0%	0%	0%	100%	100%
	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0%	0%	0%	0%	0%	0%	0%	0%	0%

	2050 B (C				
	COL	OIL	GAS	BMS	S/W
Cool	0%	0	0	0%	0%
Warm	23%	8%	2%	48%	0%
Hot Water	14%	4%	1%	71%	0%
Cooking	7%	0%	1%	92%	0%
Others	0%	0%	0%	0%	0%
	0%	0	0	0%	0%
	0%	0	0	0	0
	0%	0	0	0	0
	0%	0	0	0	0
	0%	0	0	0	0

Demand Setting 1 (Residential Sector)

Demand Setting 1



0. Classification of service demand

- Set classification of energy service demand & its unit in residential sector
- Scenario name, base year and target year set in CTL sheet will shown in each table

	Unit	2000	2050					
			REF		CM		CM/REF	
			A	B	A	B	A	B
Cool	Mtoe	12	12	12	12	12	100%	100%
Warm	Mtoe	72	72	72	72	72	100%	100%
Hot Water	Mtoe	34	34	34	34	34	100%	100%
Cooking	Mtoe	2	2	2	2	2	100%	100%
Others	Mtoe	11	11	11	11	11	100%	100%
					0	0		
					0	0		
					0	0		
					0	0		
					0	0		
					0	0		

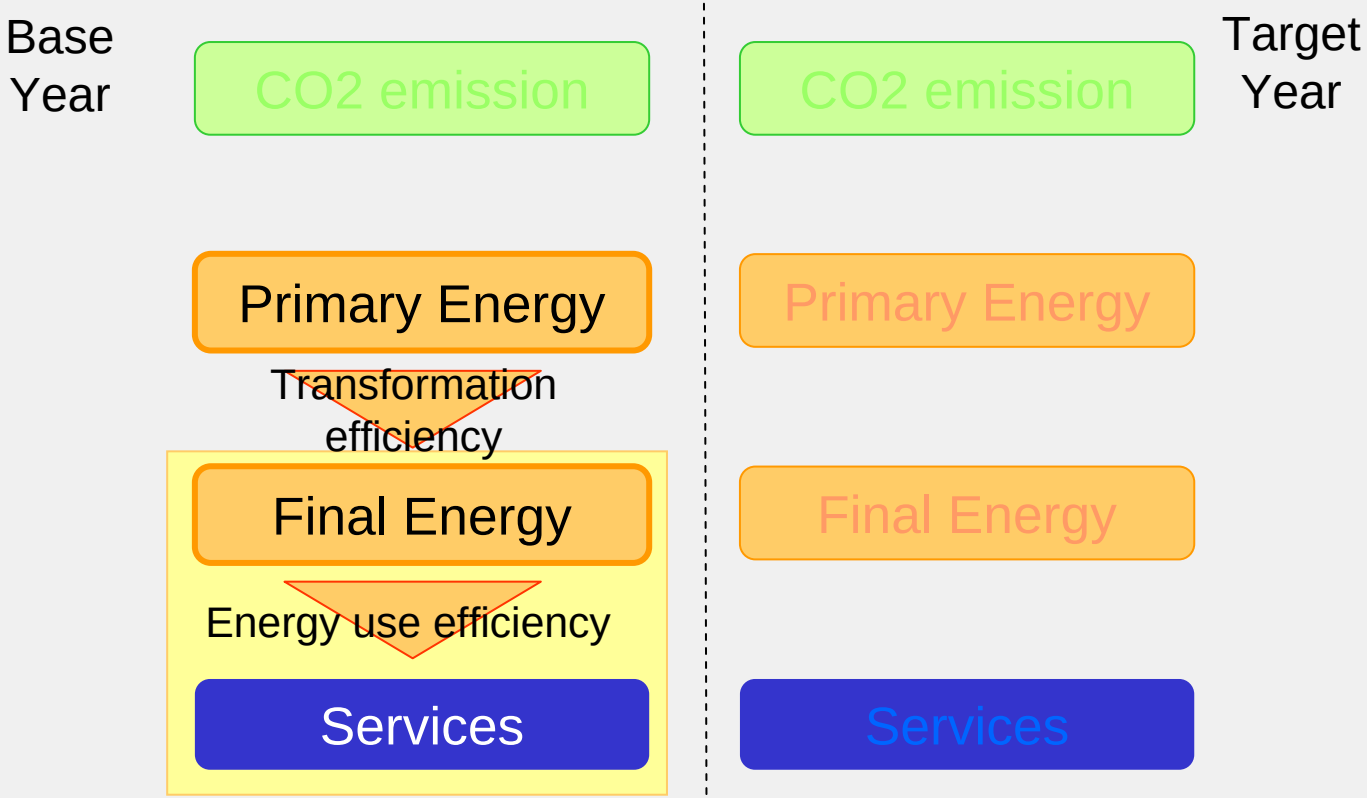
Contents

1. Energy Cons. in base year

- Past record of energy use in residential sector
- If the appropriate data is not available, use data of EBT (one sector), or make a guess!!

		2000								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0
Warm	Mtoe	30.0	10.0	3.0	50.0	0.0	3.0	0.0	5.0	101.0
Hot Water	Mtoe	10.0	3.0	1.0	50.0	0.0	3.0	0.0	2.0	69.0
Cooking	Mtoe	5.0	0.0	1.0	113.0	0.0	0.0	0.0	0.0	119.0
Others	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Generation	Mtoe									0.0
Cogeneration	Mtoe									0.0
	Mtoe									0.0
Total	Mtoe	45	13	5	213	0	6	0	14	296

Demand Setting 1

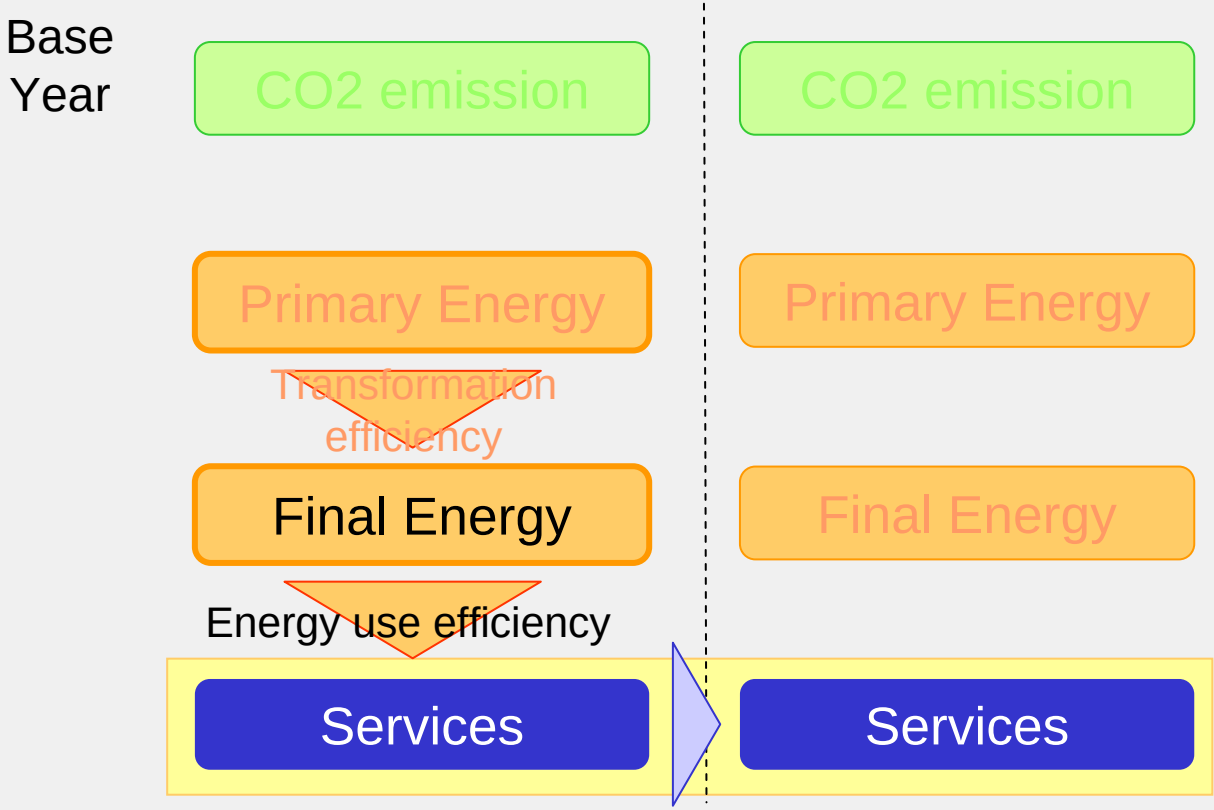


2. Energy use eff. in base year

- Set energy efficiency of each energy use
  - Energy use efficiency: Ratio between the consumption of energy to service demand
  - Keep consistency
  - The value can be relative value (Base Year=1.00)

	Unit	2000								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	toe/toe								2.00	-
Warm	toe/toe	0.70	0.70	0.70	0.90		1.00		3.00	-
Hot Water	toe/toe	0.80	0.80	0.80	0.80	1.00	1.00		1.00	-
Cooking	toe/toe	0.80		0.50	0.45	0.45			0.70	-
Others	toe/toe								1.00	-
	toe/toe									-
	toe/toe									-
	toe/toe									-
	toe/toe									-
										-
										-

Demand Setting 1

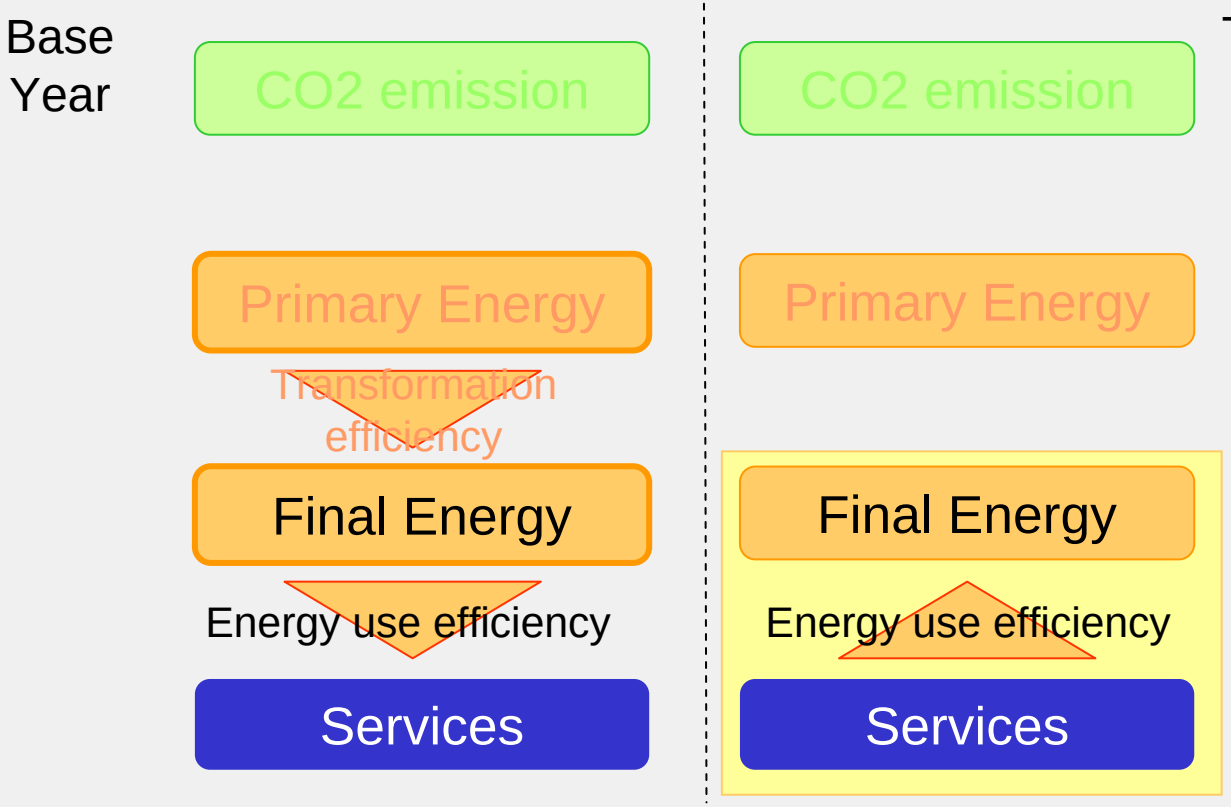


3. Service Demand

- Service demand in base year
  - Service demand (Mtoe) = Final Energy/EE
- Assume service demand in target year
- Reference case, Countermeasure case

	Unit	2000	2050					
			REF		CM		CM/REF	
			A	B	A	B	A	B
Cool	Mtoe	4	4	4	4	4	90%	100%
Warm	Mtoe	81	81	81	65	81	80%	100%
Hot Water	Mtoe	55	55	55	55	55	100%	100%
Cooking	Mtoe	60	60	60	30	60	50%	100%
Others	Mtoe	5	5	5	5	5	100%	100%
	Mtoe				0	0		
	Mtoe				0	0		
	Mtoe				0	0		
	Mtoe				0	0		
					0	0		
					0	0		

Demand Setting 1



4. Service share in target year

- Set service share to fulfill the service demand
  - Assume the technology used
  - Check “total value” (=100%)

	Unit	2050 A (CM)								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
Warm	-	61%	8%	2%	10%	0%	3%	0%	16%	100%
Hot Water	-	0%	6%	50%	30%	0%	10%	0%	4%	100%
Cooking	-	7%	0%	1%	92%	0%	0%	0%	0%	100%
Others	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%

5. Energy use eff. in target year

- Set energy efficiency of each energy use in Target Year
  - Keep consistency
  - The value can be relative value (Base Year=1.00)

	Unit	2050 A (CM)								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	toe/toe								2.00	-
Warm	toe/toe	0.90	0.70	0.70	0.90		1.00		3.00	-
Hot Water	toe/toe	0.80	0.80	0.80	0.80	1.00	1.00		1.00	-
Cooking	toe/toe	0.80		0.50	0.45	0.45			0.70	-
Others	toe/toe								1.00	-
	toe/toe									-
	toe/toe									-
	toe/toe									-
	toe/toe									-
										-
										-

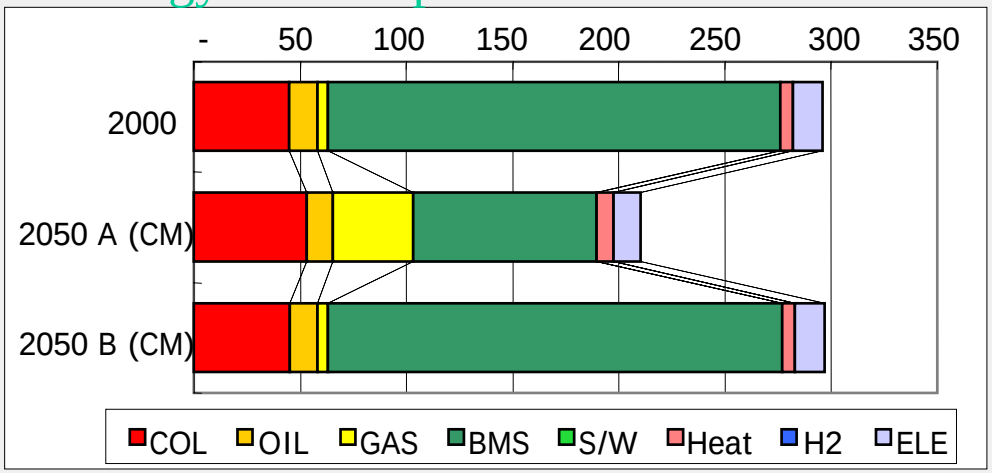
6. Energy Cons. in Target year

- Calculated automatically
- Additional Input
  - Generation: PV etc.
  - CHP: Fuel cells, Gas engine etc.

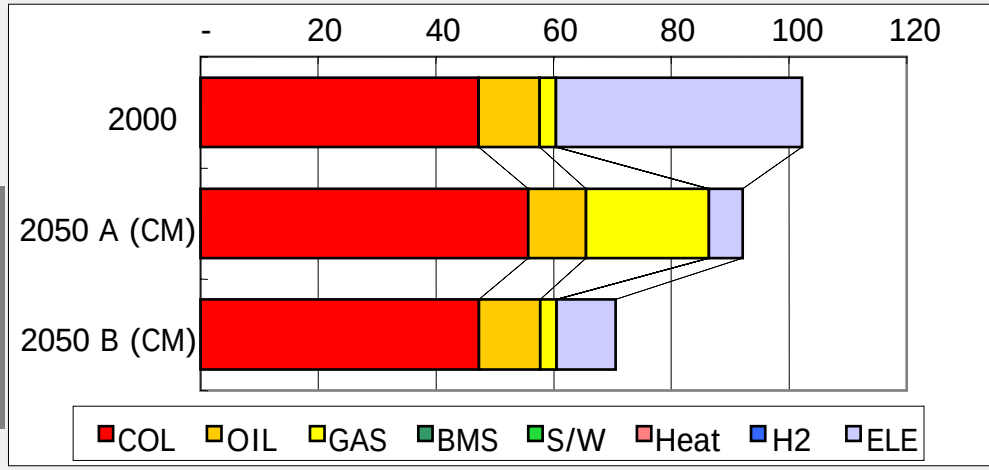
		2050 A (CM)								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.8
Warm	Mtoe	50.6	8.0	2.4	8.3	0.0	2.4	0.0	4.0	75.7
Hot Water	Mtoe	0.0	4.2	35.0	21.0	0.0	5.6	0.0	2.0	67.8
Cooking	Mtoe	2.5	0.0	0.5	57.0	0.0	0.0	0.0	0.0	60.0
Others	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Generation	Mtoe									0.0
Cogeneration	Mtoe									0.0
	Mtoe									0.0
Total	Mtoe	53	12	38	86	0	8	0	13	210

7. Check the results

Energy Consumption



CO2 Emission



Note: Before implement CO2 analysis, assumption of energy transformation needed to be made

Contents

Exercise 1

Exercise 1

- Make residential energy demand scenario(s) of your own country !!
  - Create dataset of final energy consumption in residential sector in base year by using EBT
  - Set energy use efficiency (base year)
  - Calculate service demand in base year
  - Assume “service demand”, “service share”, and “energy efficiency” in target Year
  - Check the results
  - Change the parameters and play around!!

Contents

Demand Setting 2 (Ex. Other sectors)

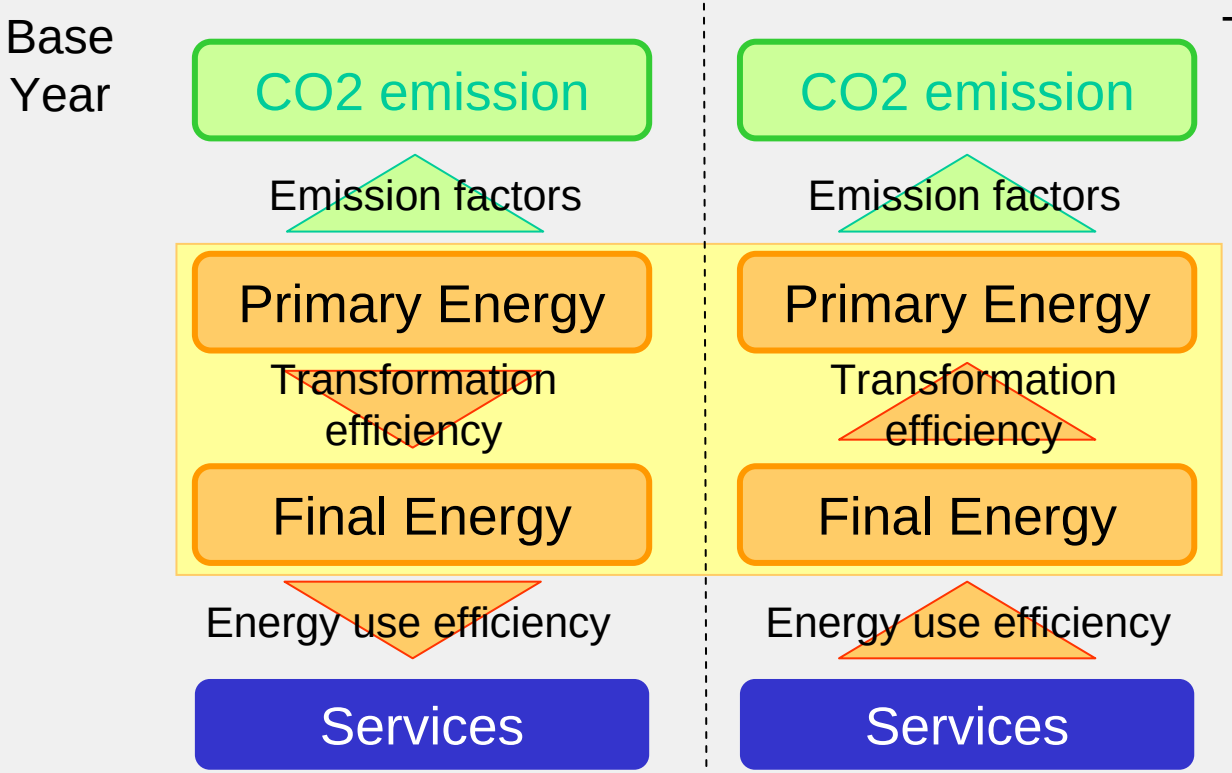
Exercise 2

- Make industrial, commercial, and transportation sector energy demand scenario(s) of your own country !!
  - Create dataset of final energy consumption in sectors above in base year by using EBT
  - Set energy use efficiency (base year)
  - Calculate service demand in base year
  - Assume “service demand”, “service share”, and “energy efficiency” in target Year
  - Check the results
  - Change the parameters and play around!!

Contents

Transformation Sector

Transformation Sector



5. Calculate CO2 emissions by multiplying "emission factors" of each energy

Electricity Generation

- Goal: Primary energy consumed for electricity generation in target year.

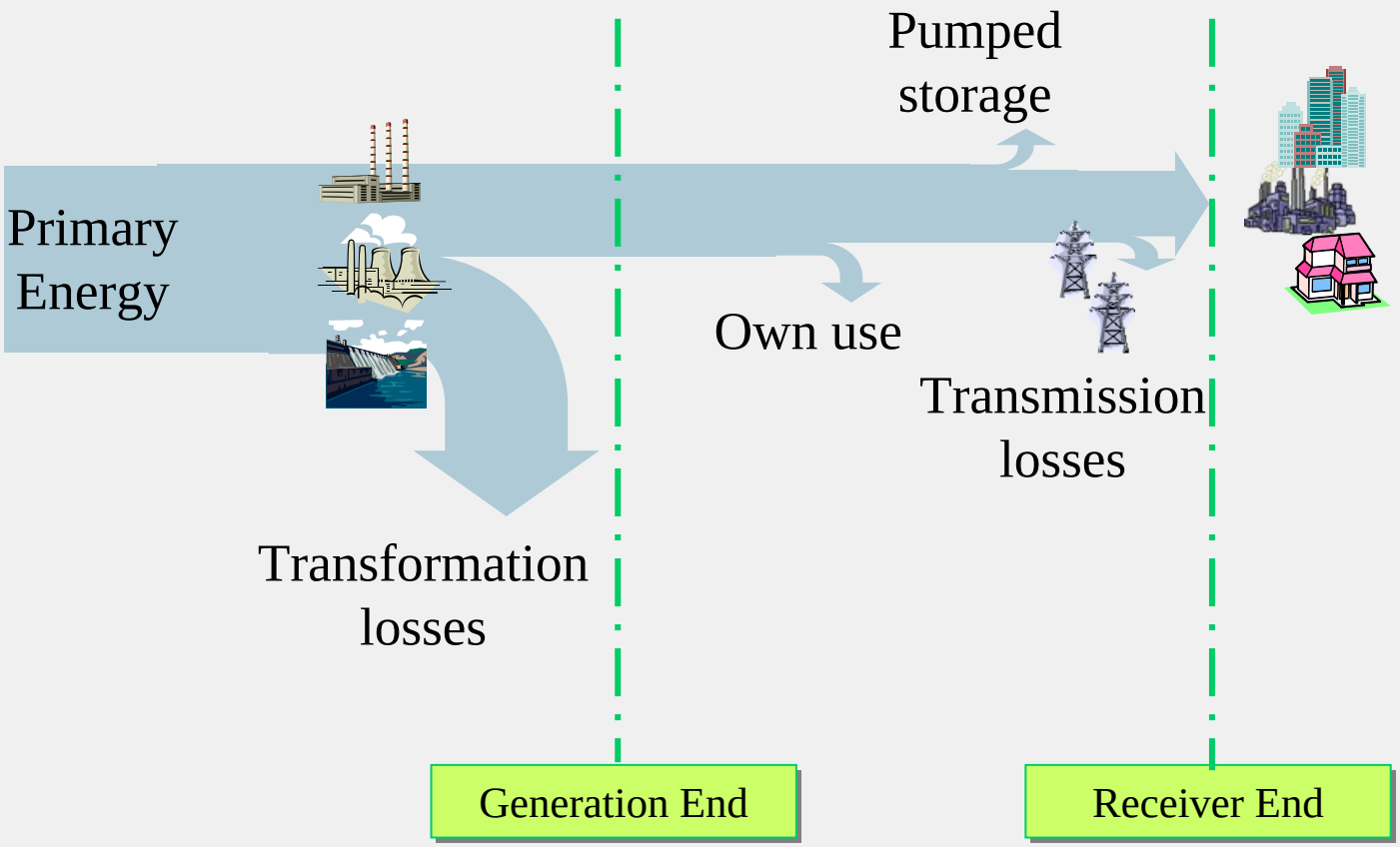
Power generation sector

Solver

		2000	2050							
			Supply & Demand		Only Demand		Only Supply		No	
			A	B	A	B	A	B	A	B
1. Electricity demand at receiver end										
	Mtoe	98	88	86	88	86	98	98	98	98
2. Difference between demand and supply										
	Mtoe	12.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Electricity supply at receiver end										
Electricity supply	Mtoe	103	88	86	88	86	98	98	98	98
Transmission Loss		6.84%	5.31%	5.31%	5.3%	5.3%	5.3%	5.3%	5.3%	5.3%
4. Electricity supply before tranmission										
Electricity supply	Mtoe	111	93	91	93	91	104	104	104	104
Pumped storage (PS)										
Ele. demand of PS	Mtoe	0	1	1	0	0	1	1	0	0
Efficiency		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Generation of PS	Mtoe	0	1	1	0	0	1	1	0	0
Own use										
Own use in plant	Mtoe	6	4	4	5	5	5	4	6	6
Own use rate										
COL		6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
GAS		4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
OIL		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
NUC		4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%
HYD		0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
HYD(P)		0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
GEO		8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%

P
S

Electricity Generation

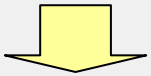


Electricity Generation

- Data setting for reference year
  - Electricity demand at receivers end (EBT or "EB_SD")
  - Electricity Transmission (& distribution) losses (EBT)
  - Efficiency of pumped storage (Def: ratio between consumed energy while pumping and generated energy)
  - Own use rate of electricity plant (EBT; Only aggregated data. Detailed information needed)
  - Electricity supply at generation end (EBT)
  - Primary Energy Consumption (EBT)

Electricity Generation

- Data setting for target year (scenario)
  - Transmission losses
  - Efficiencies of pumped storage
  - Own use rate
  - Mixture of energy
  - Thermal efficiency



- Click “Solver”!!
  - “Electricity supply at generation end” is controlled automatically so that the electricity demand of the end-user would be fulfilled
  - Primary energy supply for electricity generation is calculated
  - Check if differences between demand & supply; 0

Note: Solver

The Solver Add-in is an Excel add-in (add-in: A supplemental program that adds custom commands or custom features to Microsoft Office.) program that is available when you install Microsoft Office or Excel. To use it in Excel, however, you need to load it first.

1. On the **Tools** menu, click **Add-Ins**.
2. In the **Add-Ins available** box, select the check box next to **Solver Add-in**, and then click **OK**. **Tip** If **Solver Add-in** is not listed, click **Browse** to locate it.
3. If you see a message that tells you the Solver Add-in is not currently installed on your computer, click **Yes** to install it.
4. Click **Tools** on the menu bar. When you load the Solver Add-in, the **Solver** command is added to the **Tools** menu

Other energy transformation

- Click “EB_SD” sheet
- EBT (demand) is there !!

Name	Contents
EB_SD	Energy balance table (Countermeasures in energy enduse & transformation sector)
EB_S	Energy balance table (Countermeasures in energy transformation sector)
EB_D	Energy balance table (Countermeasures in energy enduse sector)
EB_0	Energy balance table (No counter measures = Reference case)

Other energy transformation

- Excluding electricity generation (already calculated)
- CCS: Energy use for CCS (a) & amount of carbon captured in appropriate unit (b) .
- Heat & Hydrogen: Put the negative value of heat used in demand side (c) and inputs of feedstock
- Coal/Oil/Gas: Losses during refining processes etc.

2000

	COL	OIL	GAS	BMS	NUC	HYD	S/W	Heat	H2	ELE	Total	'90=100
Energy Balances (Mtoe)												
Power Gnr.	275	12	2	1	4	19	0			-100	213	
CCS					(a)						0	
Heat	35	4	1					-25			15	
Coal/Oil/Gas	31	3									34	
Hydrogen											0	
Industrial	177	69	12	0			0	19	0	63	339	
Residential	45	13	5	213			0	6	0	14	296	
Commercial	0	15	9	0			1	0	0	22	46	
Trans. Prv.	6	67	0	0			0	0	0	1	74	
Trans. Frg.	0	0	0	0			0	0	0	0	0	
Enduse	227	164	26	213			1	25	0	100	756	
Total	569	182	28	214	4	19	1	0	0	0	1,017	
Feedstock in total		2										
Emission Factor (MtC/Mtoe)	1.05	0.80	0.55	0.00	0.00	0.00	0.00	-	-	-		
CO2 Gnr. (MtC)	597	145	16	0	0	0	0	-	-	-	757	267
CO2 Dsp. (MtC)								-	-	-		
CO2 Ems. (MtC)	597	144.6	16	0	0	0	0	-	-	-	757	267

(b)

Contents

Exercise 3

Exercise 3

- Input energy transformation data from EBT in base year and assume the changes in target Year
  - Fill in white cells in “PWR” sheets based on EBT in your country and developed scenario
  - Click “solver” and check the results
  - Fill in the following sheets based on EBT in your country and developed scenario
  - Fill in white cells in “EB_SD” sheets based on EBT in your country and developed scenario

Contents

Analysis

Factor analysis

- Extended Kaya Identity

$$C = D \times \frac{E}{D} \times \frac{C'}{E} \times \frac{C}{C'}$$

$$\frac{\Delta C}{C} = \frac{\Delta D}{D} + \frac{\Delta (E/D)}{(E/D)} + \frac{\Delta (C'/E)}{(C'/E)} + \frac{\Delta (C/C')}{(C/C')} + \text{Cross term}$$

D: Driving forces (service demand)

E: Energy Consumption

C': CO_2 emission without measures in transformation sector

C: CO_2 emission with measures in transformation sector

E/D: Energy Intensity

C'/E: CO_2 intensity in end-use sector (without measures in transformation sector)

C/C': Change of CO_2 intensity by measures in transformation sector

Data input for factor analysis

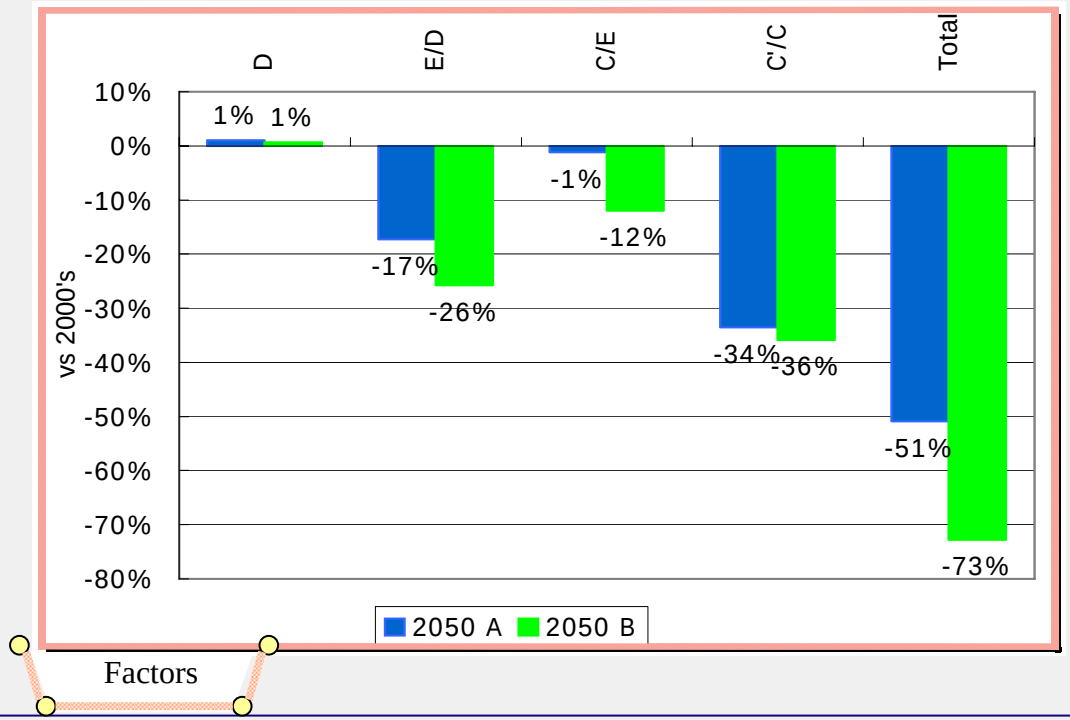
- Differentiate the contribution of CO2 reduction from supply side and demand side
- Consistent scenario required

Name	Contents
EB_SD	Energy balance table (Countermeasures in energy enduse & transformation sector)
EB_S	Energy balance table (Countermeasures in energy transformation sector)
EB_D	Energy balance table (Countermeasures in energy enduse sector)
EB_0	Energy balance table (No counter measures = Reference case)

Factor analysis

- Kaya Identity

$$\frac{\Delta C}{C} = \frac{\Delta D}{D} + \frac{\Delta(E/D)}{(E/D)} + \frac{\Delta(C'/E)}{(C'/E)} + \frac{\Delta(C/C')}{(C/C')} + \text{Cross term}$$



Contents

Please do not hesitate to ask questions!!

Energy transformation

- “EB_SD”, “EB_S”, “EB_D”, “EB_0”
- Click “EB_SD” sheet
- EBT (demand) is there !!

File Name	Description
EB_SD	Energy balance table (Countermeasures in energy enduse & transformation sector)
EB_S	Energy balance table (Countermeasures in energy transformation sector)
EB_D	Energy balance table (Countermeasures in energy enduse sector)
EB_0	Energy balance table (No counter measures = Reference case)

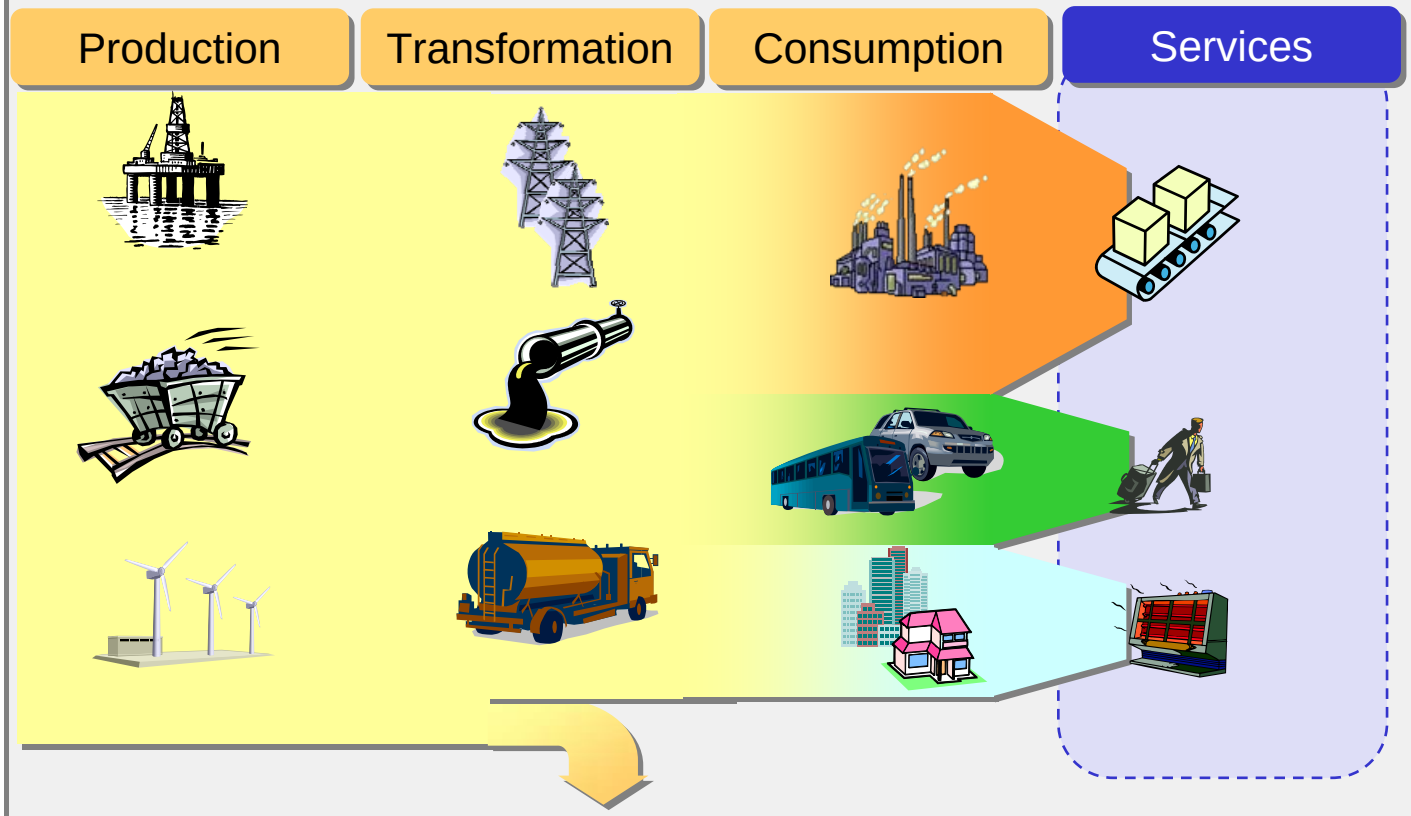
Energy transformation

- Excluding electricity generation
- CCS: Energy use for CCS [a] & amount of carbon captured in appropriate unit [b] .
- Heat: Put the negative value of heat used in demand side [c] and inputs of feedstock

2000

	COL	OIL	GAS	BMS	NUC	HYD	S/W	Heat	H2	ELE	Total	'90=100
Energy Balances (Mtoe)												
Power Gnr.	275	12	2	1	4	19	0			-100	213	
CCS					(a)						0	
Heat	35	4	1					-25			15	
Coal/Oil/Gas	31	3									34	
Hydrogen											0	
Industrial	177	69	12	0			0	19	0	63	339	
Residential	45	13	5	213			0	6	0	14	296	
Commercial	0	15	9	0			1	0	0	22	46	
Trans. Prv.	6	67	0	0			0	0	0	1	74	
Trans. Frg.	0	0	0	0			0	0	0	0	0	
Enduse	227	164	26	213			1	25	0	100	756	
Total	569	182	28	214	4	19	1	0	0	0	1,017	
Feedstock in total		2										
Emission Factor (MtC/Mtoe)	1.05	0.80	0.55	0.00	0.00	0.00	0.00	-	-	-		
CO2 Gnr. (MtC)	597	145	16	0	0	0	0	-	-	-	757	267
CO2 Dsp. (MtC)					(b)			-	-	-		
CO2 Ems. (MtC)	597	144.6	16	0	0	0	0	-	-	-	757	267

Concept



- Energy consumption is derived demand of other activities.
- Analysis of energy demand should take into account changes in energy services.

Factor analysis

- Kaya Identity

$$C = D \times \frac{E}{D} \times \frac{C}{E}$$

D: Driving forces (service demand)

E: Energy Consumption

C: CO_2 emission with measures in transformation sector

E/D: Energy Intensity

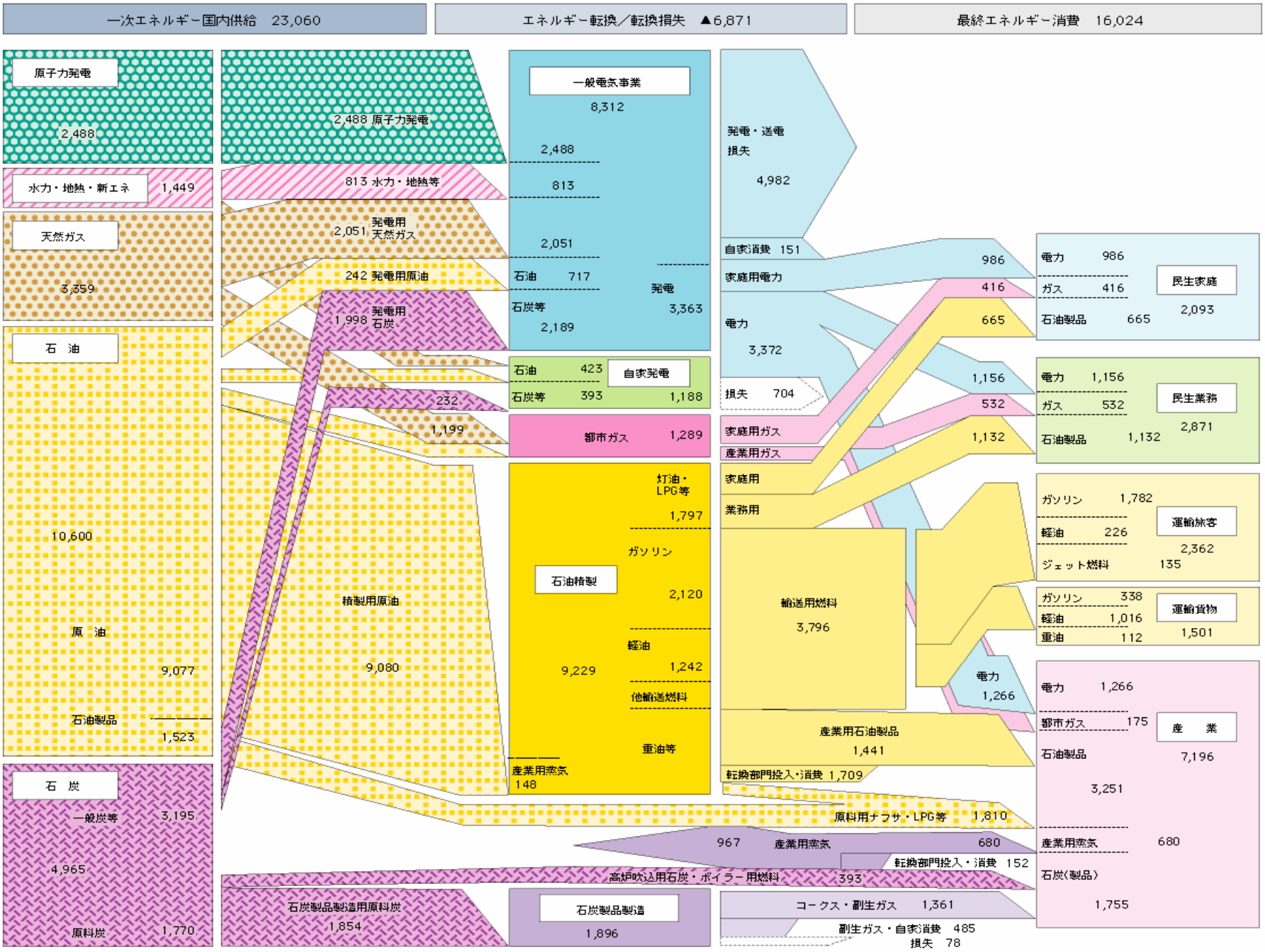
C/E: CO_2 intensity

$$\frac{\Delta C}{C} \approx \frac{\Delta D}{D} + \frac{\Delta (E/D)}{(E/D)} + \frac{\Delta (C/E)}{(C/E)}$$

Changes in service demand

Changes in Energy Intensity

Changes in Carbon Intensity


一次エネルギー国内供給　23,060
エネルギー転換／転換損失　▲6,871
最終エネルギー消費　16,024
原子力発電
2,488
水力・地熱・新エネ
1,449
天然ガス
3,359
石　油
10,600
原　油
9,077
石油製品
1,523
石　炭
一般炭等
3,195
4,965
原料炭
1,770
2,488 原子力発電
813 水力・地熱等
2,051 発電用 天然ガス
242 発電用原油
1,998 発電用 石炭
232
1,199
精製用原油
9,080
一般電気事業
8,312
2,488
813
2,051
石油　717
石炭等
2,189
発電
3,363
石油　423
自家発電
石炭等　393
1,188
都市ガス　1,289
灯油・LPG等
1,797
ガソリン
2,120
軽油
1,242
他輸送燃料
重油等
9,229
石油精製
産業用蒸気
148
発電・送電損失
4,982
自家消費　151
家庭用電力
986
416
665
電力
3,372
損失　704
1,156
532
1,132
家庭用ガス
産業用ガス
家庭用
業務用
輸送用燃料
3,796
電力
1,266
産業用石油製品
1,441
転換部門投入・消費　1,709
967
産業用蒸気
680
転換部門投入・消費　152
高炉吹込用石炭・ボイラー用燃料
393
石炭製品製造用原料炭
1,854
石炭製品製造
1,896
原料用ナフサ・LPG等　1,810
コークス・副生ガス　1,361
副生ガス・自家消費　485
損失　78
電力　986
ガス　416
石油製品　665
民生家庭
2,093
電力　1,156
ガス　532
石油製品　1,132
民生業務
2,871
ガソリン　1,782
軽油　226
ジェット燃料　135
運輸旅客
2,362
ガソリン　338
軽油　1,016
重油　112
運輸貨物
1,501
電力　1,266
都市ガス　175
石油製品
3,251
産業用蒸気　680
石炭(製品)
1,755
産　業
7,196