Development of Low-carbon Society Scenarios in Bhutan 2050

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Contents

1. Concept, methodology and example of Low-carbon Society (LCS) Scenarios

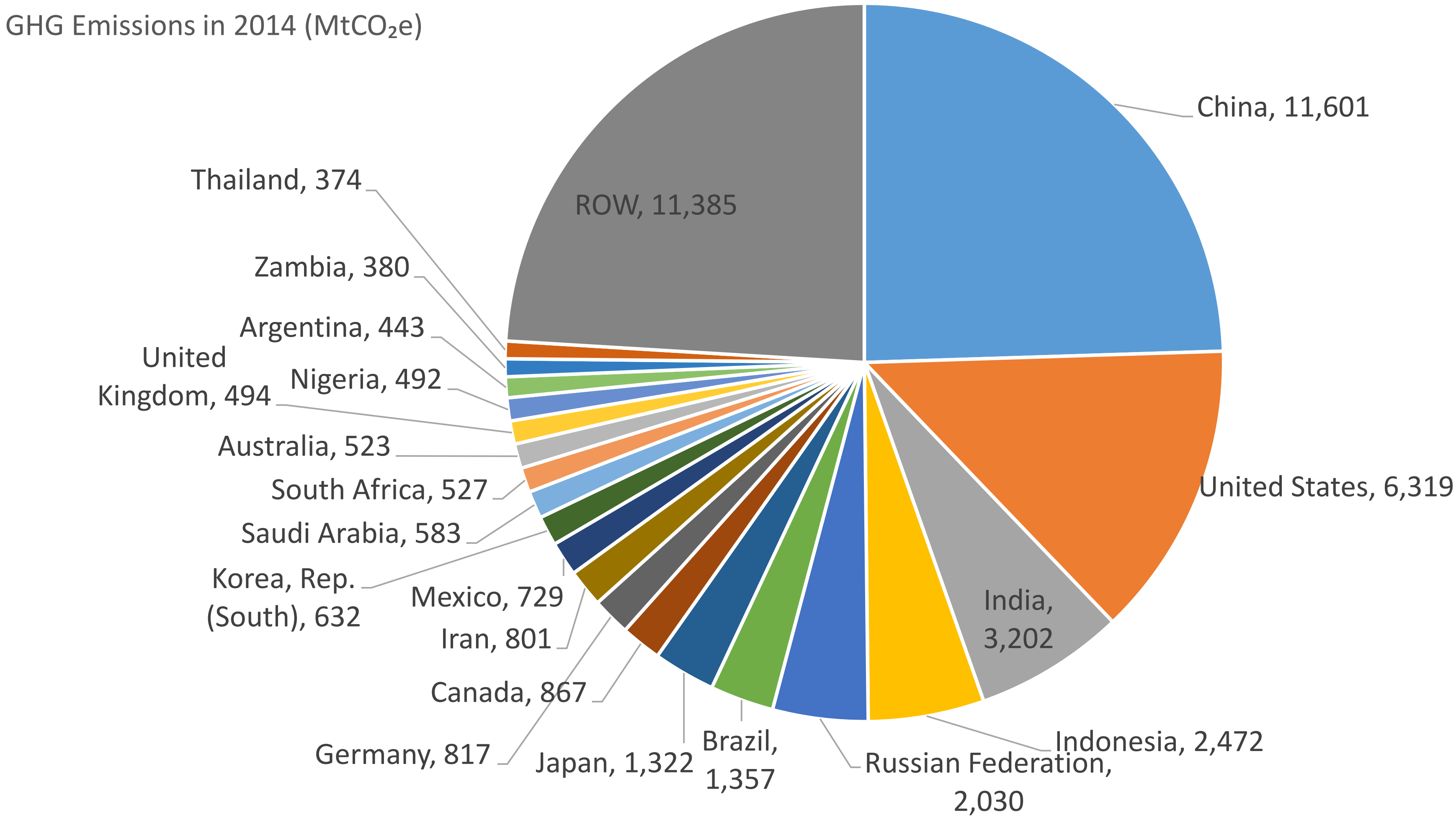
2. Bhutan LCS scenario 2050

3. Exercise: Develop your own scenarios

Concept, methodology and example of Low-carbon Society Scenarios

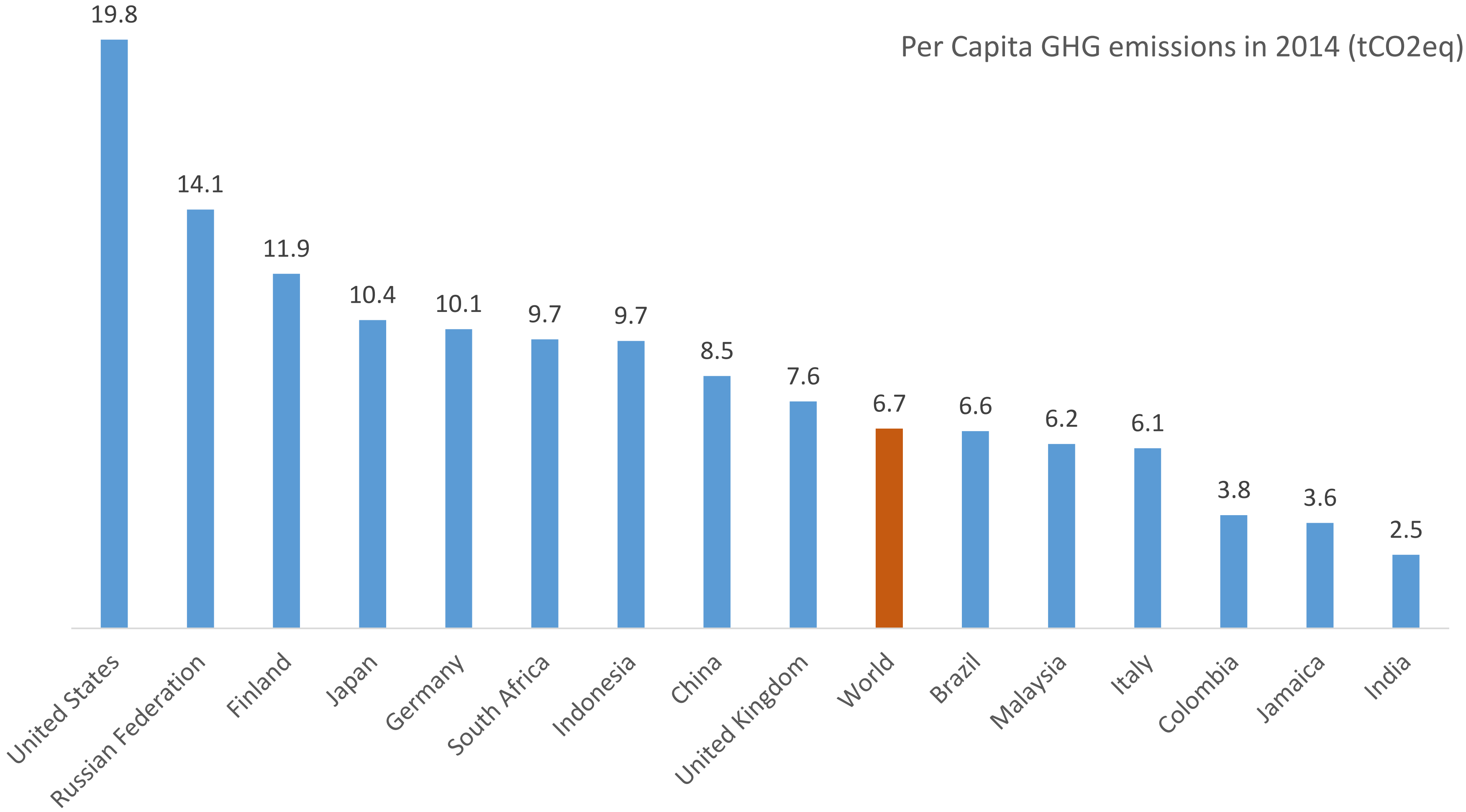
- Mitigation of climate change
  - GHG emissions
  - Mitigation options
- Methodology for developing LCS scenarios
- Case studies in Malaysia and Indonesia

GHG emissions by country



Sources: World Resource Institute http://www.wri.org/

Per Capita Emissions



Sources: World Resource Institute http://www.wri.org/

Emission and Temperature rise

Table SPM.1: Key characteristics of the scenarios collected and assessed for WGIII AR5. For all parameters, the 10th to 90th percentile of the scenarios is shown[1,2]. [Table 6.3]

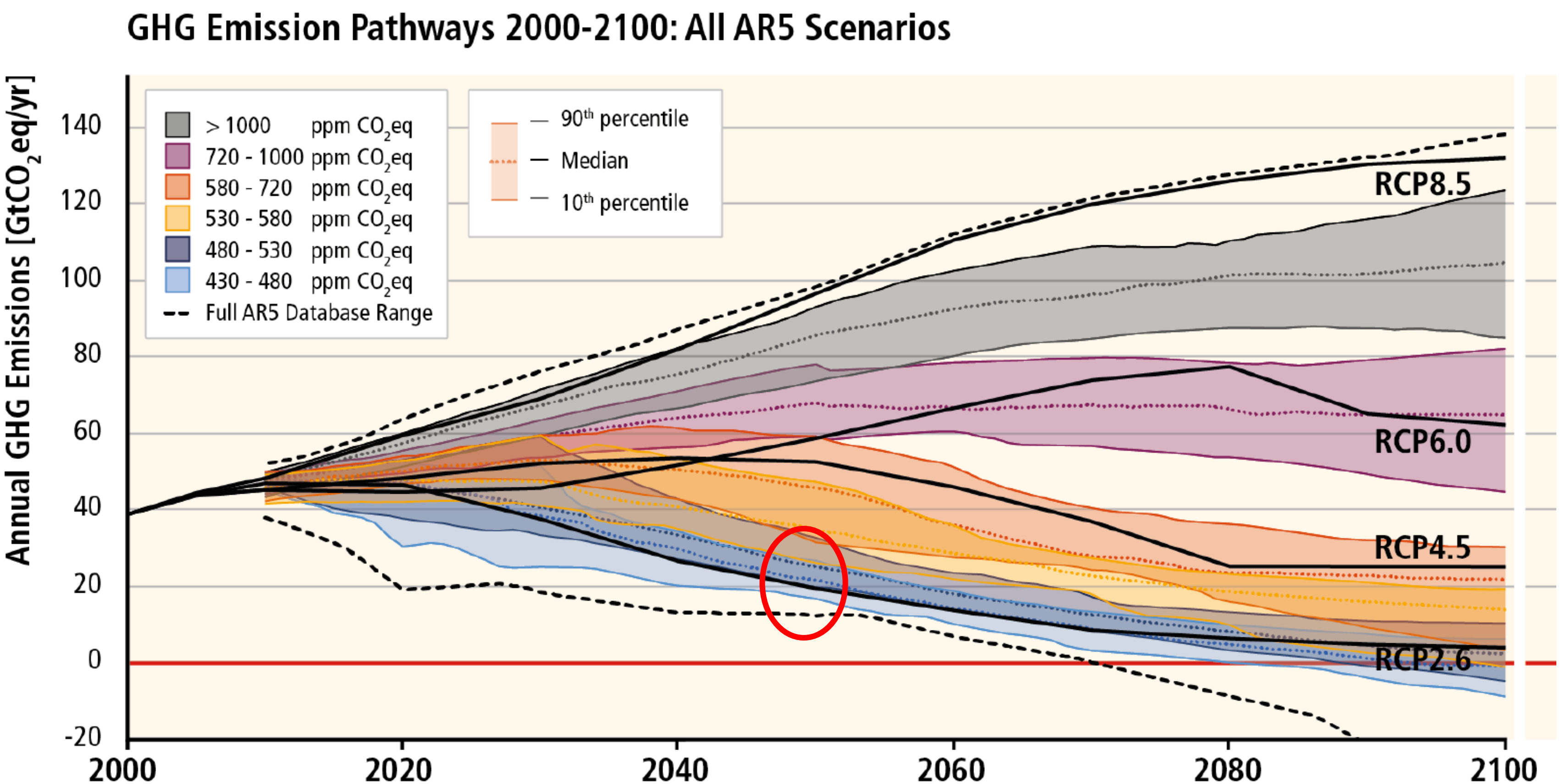
<table>
<tr><th rowspan="3">CO_2eq Concentrations in 2100 (CO_2eq)

Category label (concentration range)[9]</th><th rowspan="3">Subcategories</th><th rowspan="3">Relative position of the RCPs[5]</th><th colspan="2">Cumulative CO_2 emission[3] ($GtCO_2$)</th><th colspan="2">Change in CO_2eq emissions compared to 2010 in (%)[4]</th><th colspan="5">Temperature change (relative to 1850–1900)[5,6]</th></tr>
<tr><th rowspan="2">2011–2050</th><th rowspan="2">2011–2100</th><th rowspan="2">2050</th><th rowspan="2">2100</th><th rowspan="2">2100 Temperature change (°C)[7]</th><th colspan="4">Likelihood of staying below temperature level over the 21st century[8]</th></tr>
<tr><th>1.5°C</th><th>2.0°C</th><th>3.0°C</th><th>4.0°C</th></tr>
<tr><td>< 430</td><td colspan="11">Only a limited number of individual model studies have explored levels below 430 ppm CO_2eq</td></tr>
<tr><td>450 (430–480)</td><td>Total range [1,10]</td><td>RCP2.6</td><td>550–1300</td><td>630–1180</td><td>-72 to -41</td><td>-118 to -78</td><td>1.5–1.7 (1.0–2.8)</td><td>More unlikely than likely</td><td>Likely</td><td rowspan="6">Likely</td><td rowspan="8">Likely</td></tr>
<tr><td rowspan="2">500 (480–530)</td><td>No overshoot of 530 ppm CO_2eq</td><td></td><td>860–1180</td><td>960–1430</td><td>-57 to -42</td><td>-107 to -73</td><td>1.7–1.9 (1.2–2.9)</td><td rowspan="6">Unlikely</td><td>More likely than not</td></tr>
<tr><td>Overshoot of 530 ppm CO_2eq</td><td></td><td>1130–1530</td><td>990–1550</td><td>-55 to -25</td><td>-114 to -90</td><td>1.8–2.0 (1.2–3.3)</td><td>About as likely as not</td></tr>
<tr><td rowspan="2">550 (530–580)</td><td>No overshoot of 580 ppm CO_2eq</td><td></td><td>1070–1460</td><td>1240–2240</td><td>-47 to -19</td><td>-81 to -59</td><td>2.0–2.2 (1.4–3.6)</td><td rowspan="3">More unlikely than likely[12]</td></tr>
<tr><td>Overshoot of 580 ppm CO_2eq</td><td></td><td>1420–1750</td><td>1170–2100</td><td>-16 to 7</td><td>-183 to -86</td><td>2.1–2.3 (1.4–3.6)</td></tr>
<tr><td>(580–650)</td><td>Total range</td><td rowspan="2">RCP4.5</td><td>1260–1640</td><td>1870–2440</td><td>-38 to 24</td><td>-134 to -50</td><td>2.3–2.6 (1.5–4.2)</td></tr>
<tr><td>(650–720)</td><td>Total range</td><td>1310–1750</td><td>2570–3340</td><td>-11 to 17</td><td>-54 to -21</td><td>2.6–2.9 (1.8–4.5)</td><td rowspan="2">Unlikely</td><td>More likely than not</td></tr>
<tr><td>(720–1000)</td><td>Total range</td><td>RCP6.0</td><td>1570–1940</td><td>3620–4990</td><td>18 to 54</td><td>-7 to 72</td><td>3.1–3.7 (2.1–5.8)</td><td rowspan="2">Unlikely[11]</td><td>More unlikely than likely</td></tr>
<tr><td>>1000</td><td>Total range</td><td>RCP8.5</td><td>1840–2310</td><td>5350–7010</td><td>52 to 95</td><td>74 to 178</td><td>4.1–4.8 (2.8–7.8)</td><td>Unlikely[11]</td><td>Unlikely</td><td>More unlikely than likely</td></tr>
</table>

- RCP2.6 (41～72% reduction in 2050) "Likely" achieves the 2 degree target
- RCP4.5(24～38% reduction in 2050) "More unlikely than likely"

Source: IPCC AR5, WG3, SPM, Table SPM.1

-50% by 2050



Source: IPCC AR5, WG3, SPM, Fig.SPM.4

Strategy for Mitigation

- Evaluation of mitigation options
  - Alternative options
  - "Marginal abatement cost curve"
  - Co-benefit / ancillary benefit
- Simulation of society as a whole
  - Integrated modeling
  - Low-carbon society Scenarios

Mitigation Options (Energy)

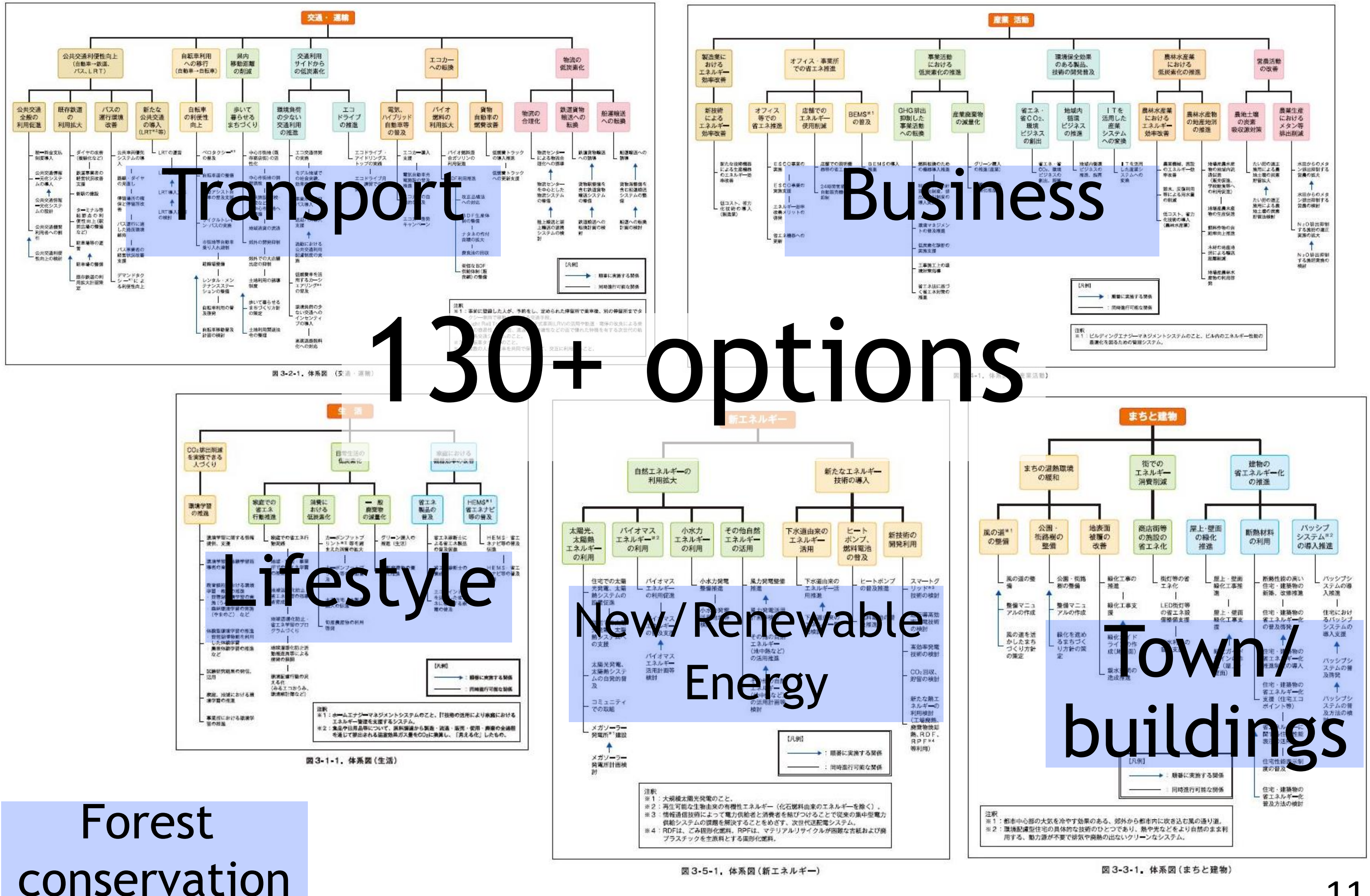
- **Energy efficiency improvement**: Provide utility output with less energy input
  - Demand sectors: Residential, Commercial, Industrial, Transport
  - Supply sectors: Power generation and transmission

- **Fuel switch**: Choosing fuel with less GHG emissions for unit energy output
  - Natural gas, nuclear, renewable energies

- **Energy service reduction/shifting**: Reducing level of activities demanding energy input
  - Compact city structure, modal shift
  - Coolbiz, HEMS/BEMS

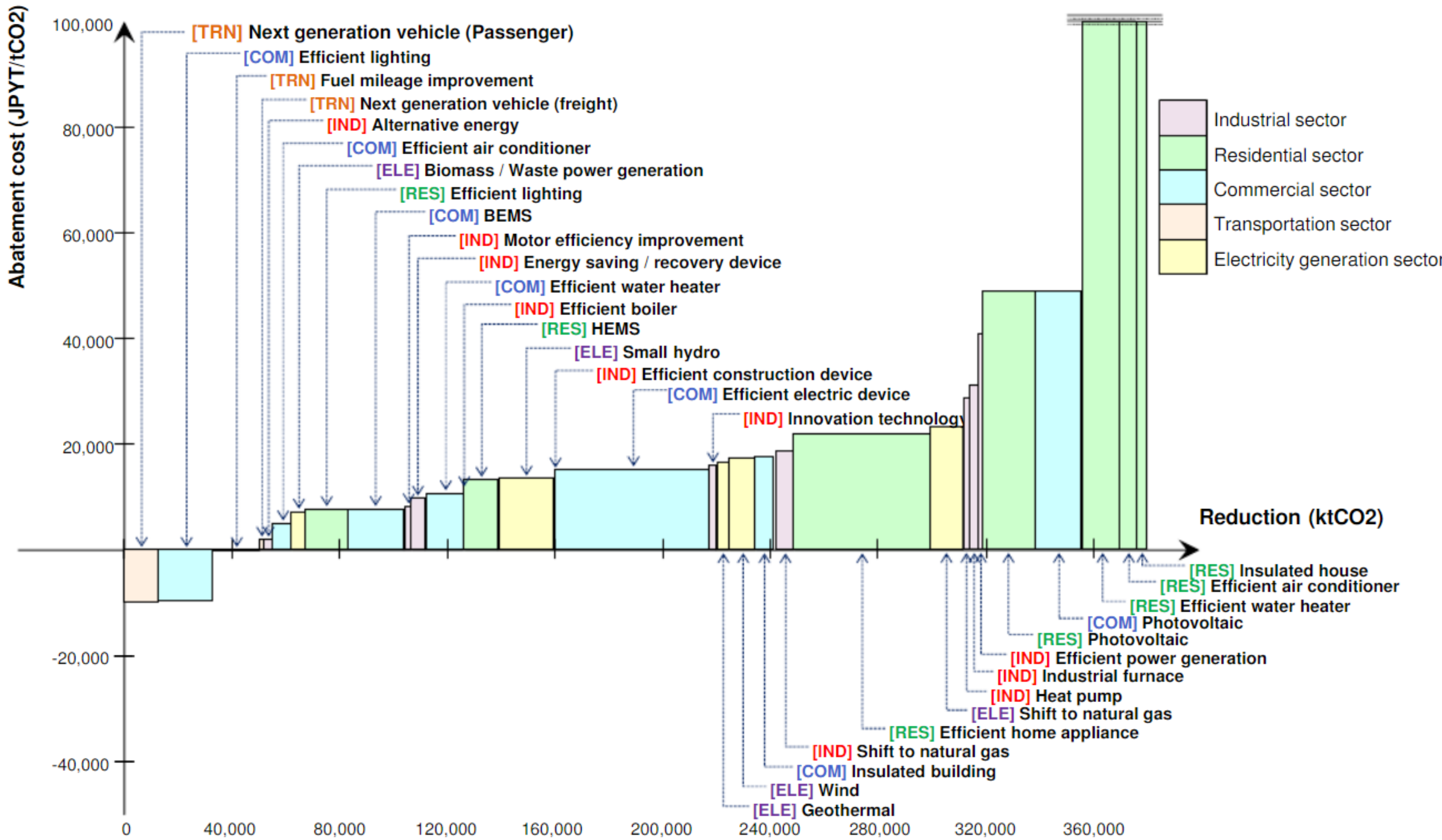
Mitigation Options (Non-energy)

- **Capturing GHG**: Carbon capture and storage (CCS)
    - In powerplant and steal furnace
- **Waste management:** Reduce CH_4 from landfill and CO_2 from fossil carbon combustion
    - 3R (Reduce, Reuse and Recycle)
    - Energy recovery from incineration, CH_4 collection from landfill
- **Agriculture**
    - Shifting feeds, appropriate fertilizer use, paddy field water management, etc.
- **Forestry, Land use and land-use change**
    - Tree planting, reducing deforestation


交通・運輸
Transport
図 3-2-1. 体系図（交通・運輸）
産業活動
Business
130+ options
生活
Lifestyle
図 3-1-1. 体系図（生活）
新エネルギー
New/Renewable
Energy
図 3-5-1. 体系図（新エネルギー）
まちと建物
Town/
buildings
図 3-3-1. 体系図（まちと建物）
Forest
conservation

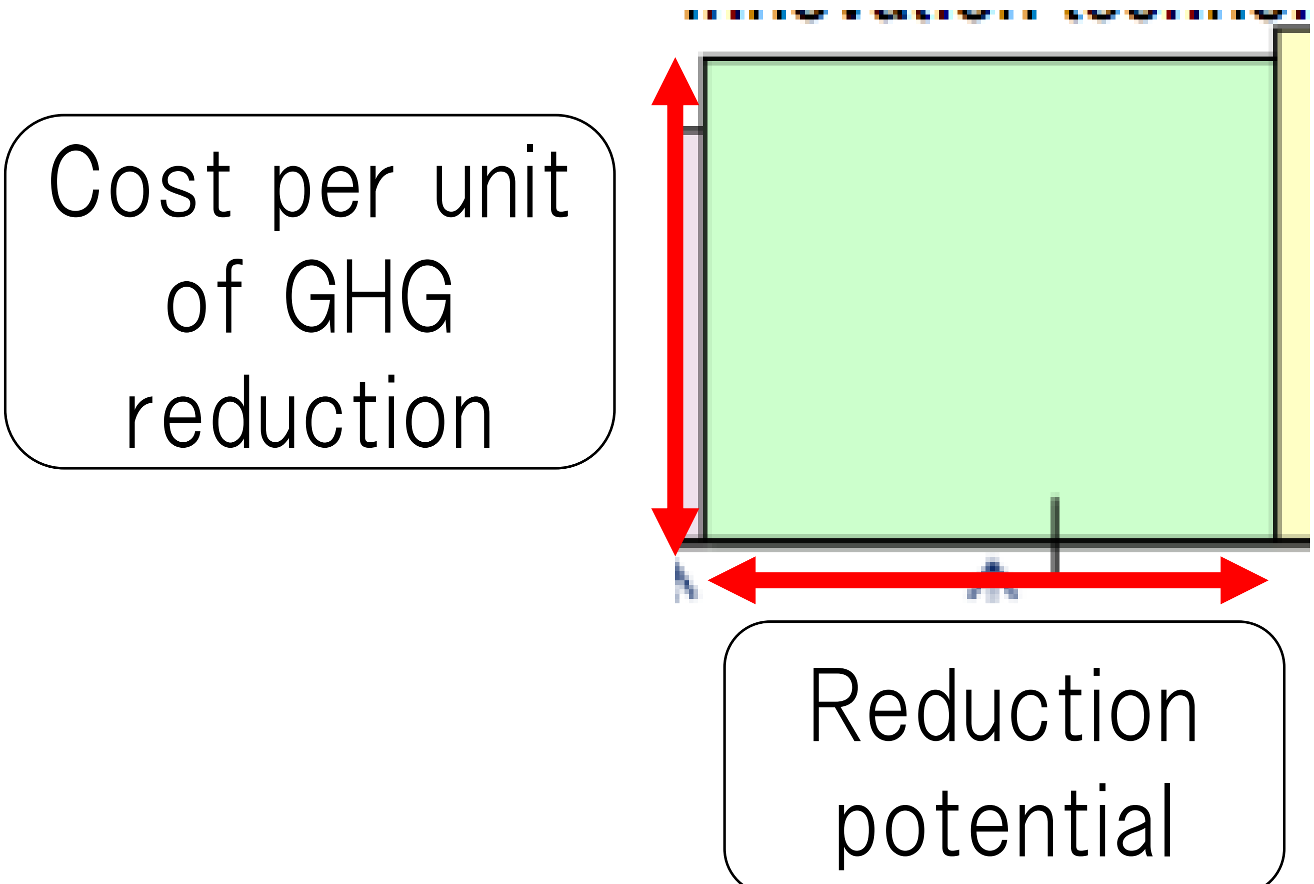
How to choose?

"Marginal Abatement Cost (MAC)" curve (Japan, 2020)



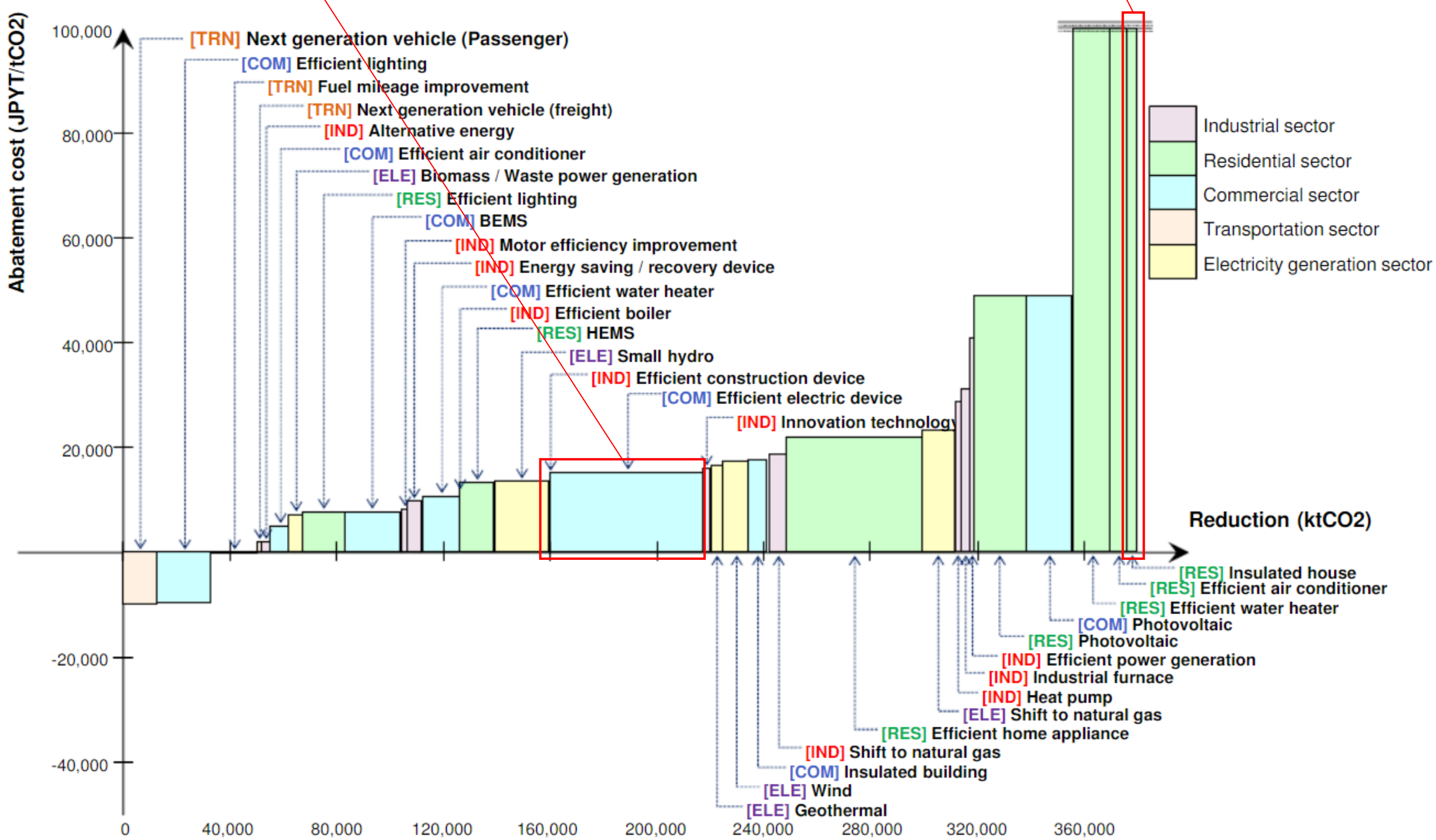
Source: Hibino (2010) Japan's Marginal Abatement Cost Curve Analysis and Mitigation Measures

Wide & Low is better!



Insulated house

Efficient electric device in commercial sector



Your cost is income of someone else.

	Consumption losses in cost-effective implementation scenarios				Increase in total discounted mitigation costs in scenarios with limited availability of technologies			
	[% reduction in consumption relative to baseline]			[percentage point reduction in annualized consumption growth rate]	[% increase in total discounted mitigation costs (2015–2100) relative to default technology assumptions]			
2100 Concentration (ppm CO_2eq)	**2030**	**2050**	**2100**	**2010-2100**	**No CCS**	**Nuclear phase out**	**Limited Solar / Wind**	**Limited Bio-energy**
450 (430–480)	1.7 (1.0–3.7) [N: 14]	3.4 (2.1–6.2)	4.8 (2.9–11.4)	0.06 (0.04–0.14)	138 (29–297) [N: 4]	7 (4–18) [N: 8]	6 (2–29) [N: 8]	64 (44–78) [N: 8]
500 (480–530)	1.7 (0.6–2.1) [N: 32]	2.7 (1.5–4.2)	4.7 (2.4–10.6)	0.06 (0.03–0.13)				
550 (530–580)	0.6 (0.2–1.3) [N: 46]	1.7 (1.2–3.3)	3.8 (1.2–7.3)	0.04 (0.01–0.09)	39 (18–78) [N: 11]	13 (2–23) [N: 10]	8 (5–15) [N: 10]	18 (4–66) [N: 12]
580–650	0.3 (0–0.9) [N: 16]	1.3 (0.5–2.0)	2.3 (1.2–4.4)	0.03 (0.01–0.05)				

Source: IPCC AR5, WG3, SPM, Table SPM.4

What to consider?

- Potential
- Cost
- Co-benefit (Ancillary benefit)
- Certainty
- Risk
- Social acceptance

What to consider?

- Potential
- Cost
- Co-benefit (Ancillary benefit)
- Certainty
- Risk
- Social acceptance

Co-benefit

- Energy security
- Transport convenience
- Air pollution abatement
- Landscape
- Saving landfill site
- Conserving resource
- Employment
- Access to energy
- Fuel poverty

What to consider?

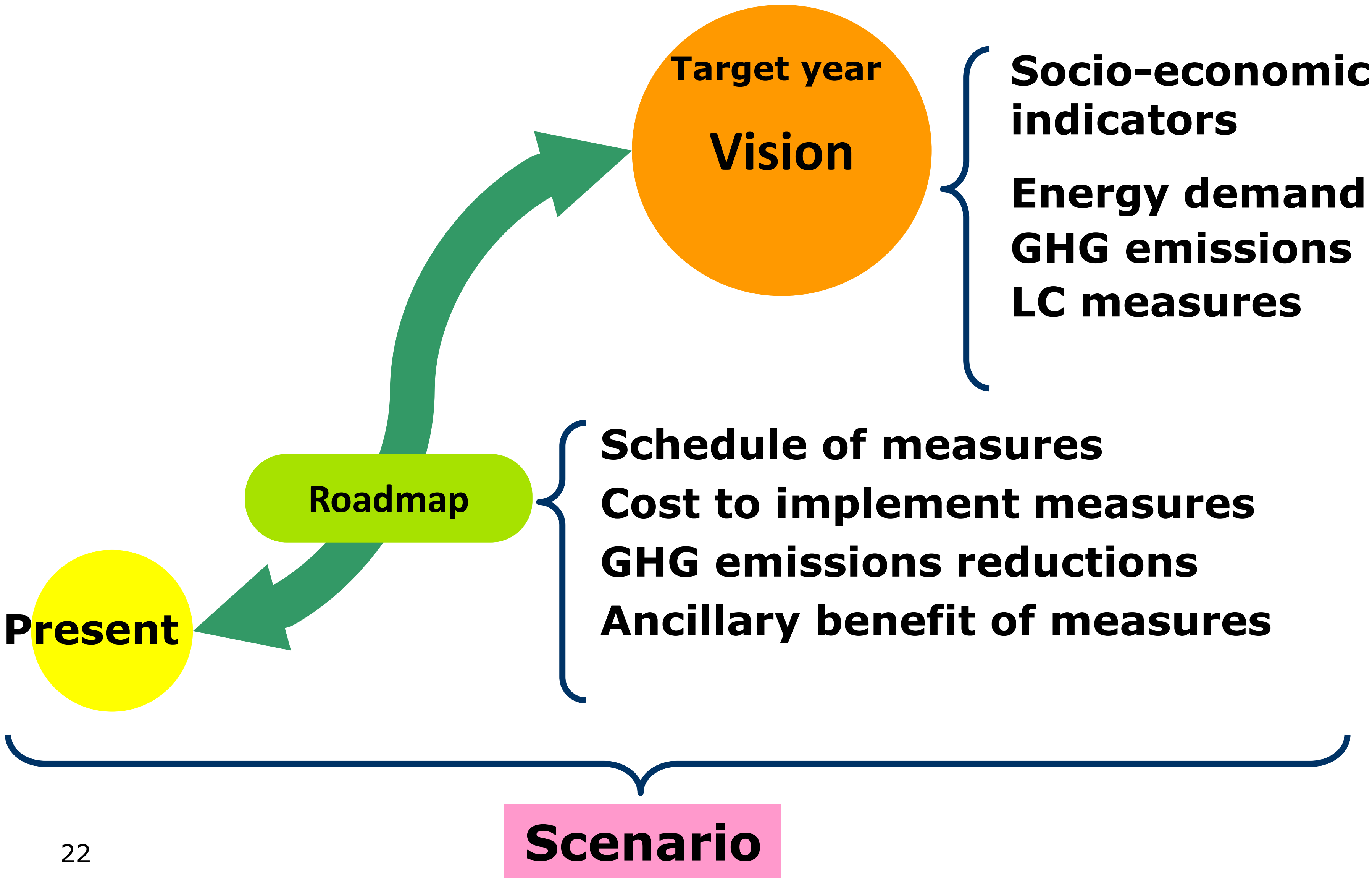
- Potential
- Cost
- Co-benefit (Ancillary benefit)
- Certainty
- Risk
- Social acceptance

Social acceptance: Landscape

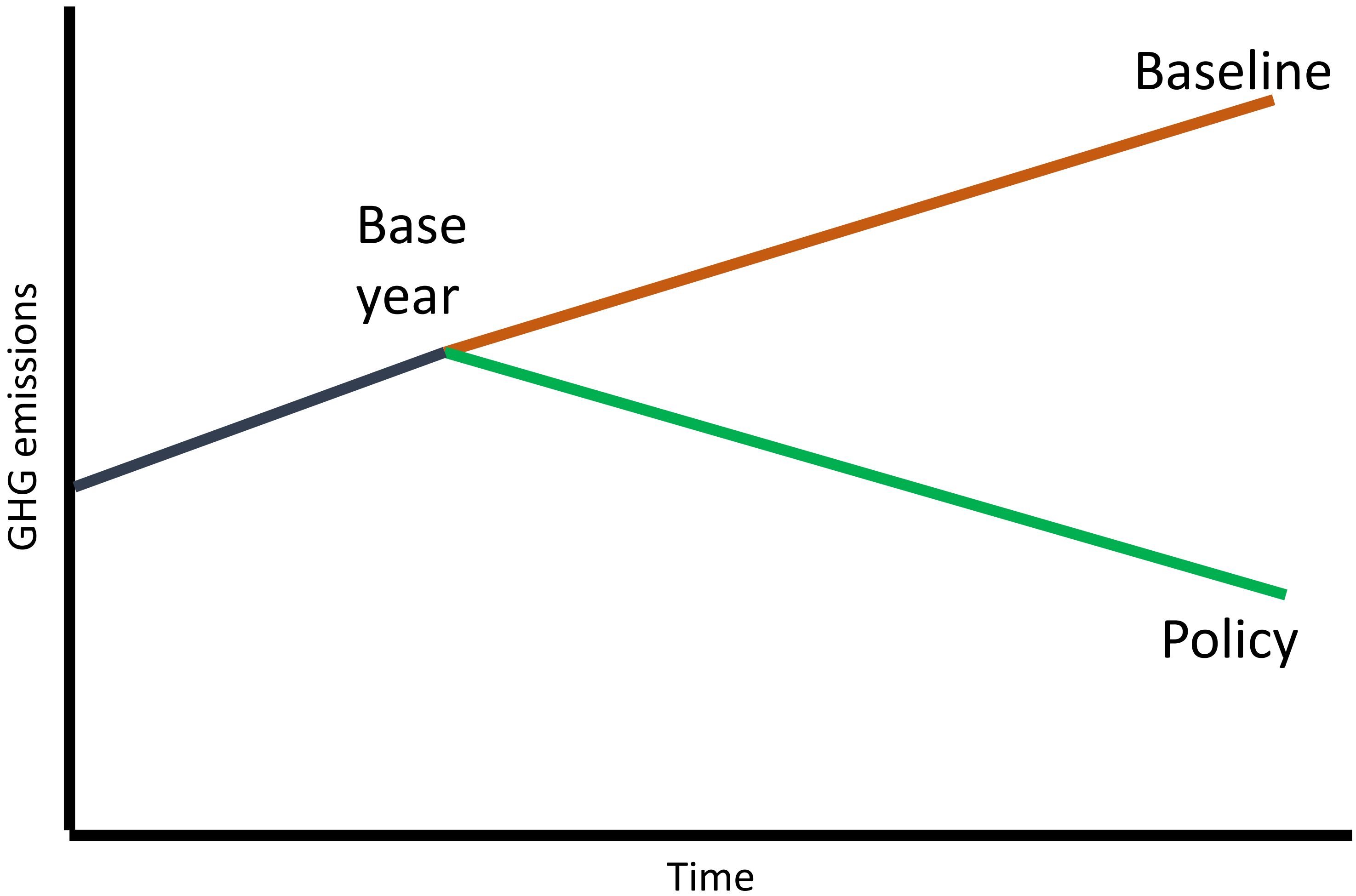
“Low-carbon society scenarios”

- Scenario: future image, computer-aided stories
- Alternative future societies achieving climate goals
- Not “Prediction” !
- “Back-casting”

Back-casting Approach



Basic of
GHG emission ***Projection***


Baseline
Base
year
GHG emissions
Policy
Time

CO2 emissions from energy use

CO2 emission =

$$\text{Driving force} \times \frac{\text{Energy service demand}}{\text{Driving force}} \times \frac{\text{Energy demand}}{\text{Energy service demand}} \times \frac{\text{CO2 emission}}{\text{Energy demand}}$$

CO2 emissions from energy use

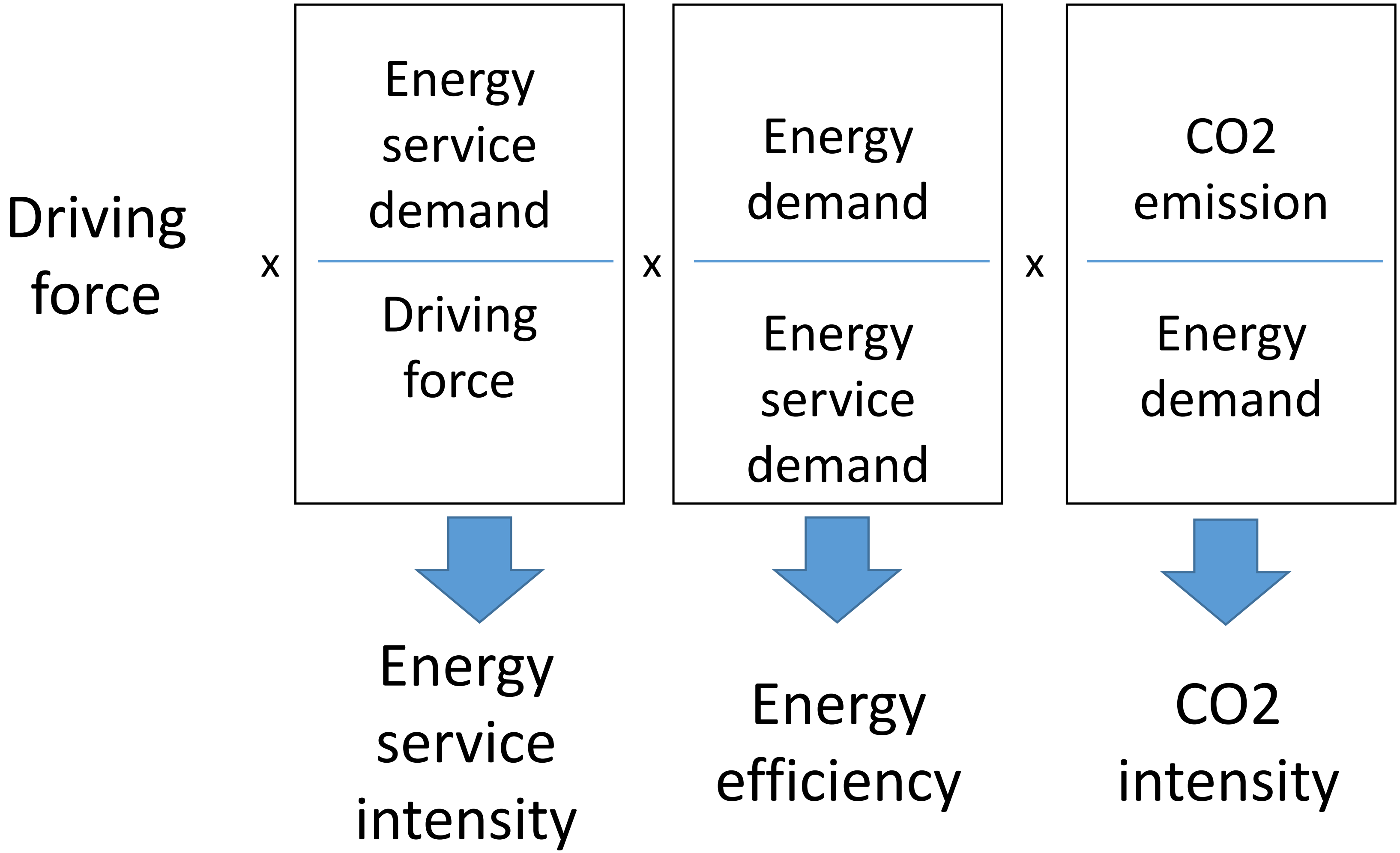
$$\text{CO2 emission} = \text{Driving force} \times \frac{\textbf{Energy service}\ \text{demand}}{\text{Driving force}} \times \frac{\text{Energy demand}}{\text{Energy service demand}} \times \frac{\text{CO2 emission}}{\text{Energy demand}}$$

Energy service :

Utility provided by using energy

Example:

- Watching TV
- Lighting a room
- Cooling of spaces
- Transporting one person by 10km
- Producing iron & steel products


Driving force
x
Energy service demand
Driving force
x
Energy demand
Energy service demand
x
CO2 emission
Energy demand
Energy service intensity
Energy efficiency
CO2 intensity

Driving force x Energy service intensity x Energy efficiency x CO_2 intensity

Driving force x Energy service intensity x Energy efficiency x CO_2 intensity

- Population and/or household
- GDP by industry
- Commercial floor area
- Number of workers
- Number of passenger trips by mode
- Tons of freight transported

Driving force x **Energy service intensity** x Energy efficiency x CO2 intensity

- Air conditioner per household
- Number of computers per office worker
- Average travel distance of passengers
- Average transport distance of freights
- Iron production per GDP

Driving force x Energy service intensity x **Energy efficiency** x CO_2 intensity

- Performance of air conditioner
- Power use of computers
- Fuel cost of vehicles
- Coal input for per ton of iron production

Driving force x Energy service intensity x Energy efficiency x **CO2 intensity**

- Share of fuels for cooking
- Share of fuels for vehicles
- Share of energy sources for power generation
- Efficiency of coal/gas fired-powerplant

In Baseline & Policy Scenarios

Driving force x Energy service intensity x Energy efficiency x CO_2 intensity

Residential
- Urban household
- Rural household

Commercial
- Wholesale & Retail
- Restaurant & Hotel
- Professional services
- Public services

Industries
- Primary industries
- Manufacturing
- Construction

Transport
- Passenger
- Freight

Residential & Commercial
- Air conditioning, Cooking
- Water heating, Lighting
- Others

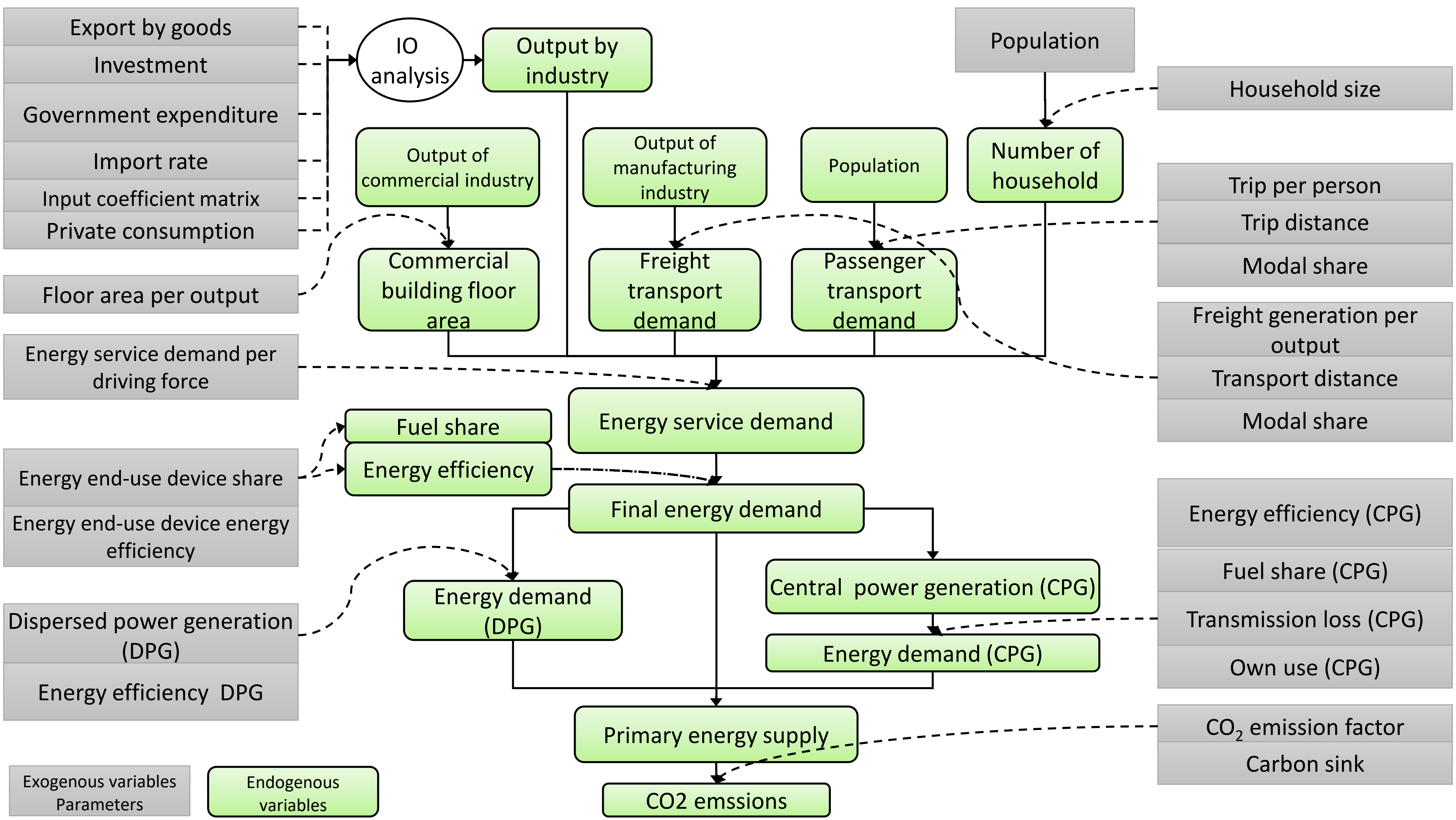
Industries
- Industrial boiler, Industrial motor
- Furnace, Others

Transport
- Passenger cars, Bus, Train
- Motorbike,
- Freight cars

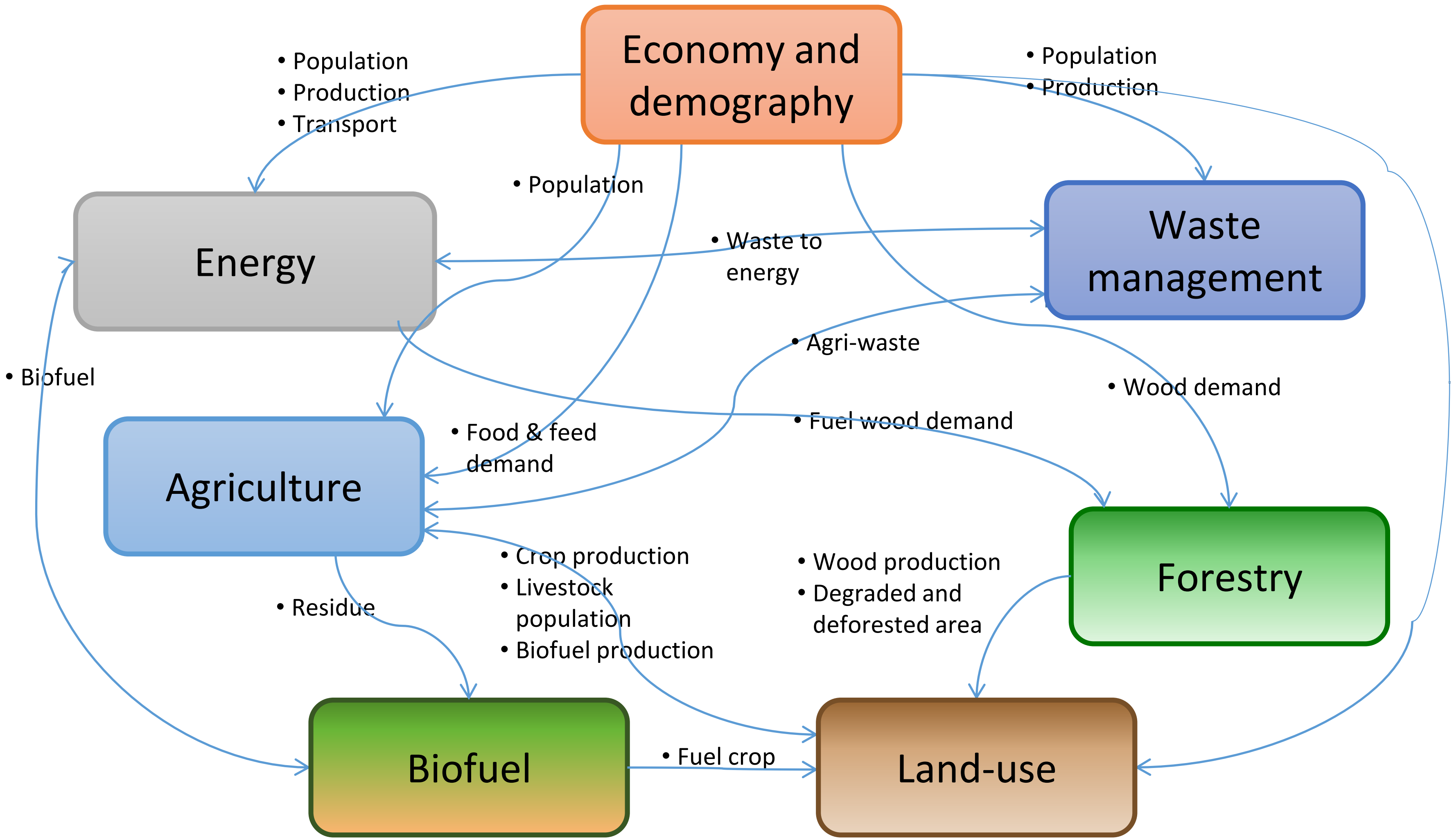
Demand side
- Electricity
- Natural gas
- Gasoline, Coal
- Biomass

Supply side
- Oil, Coal,
- Natural gas
- Hydro energy
- Nuclear energy
- Photovoltaic
- Wind power

Simulation by "Integrated Modelling"



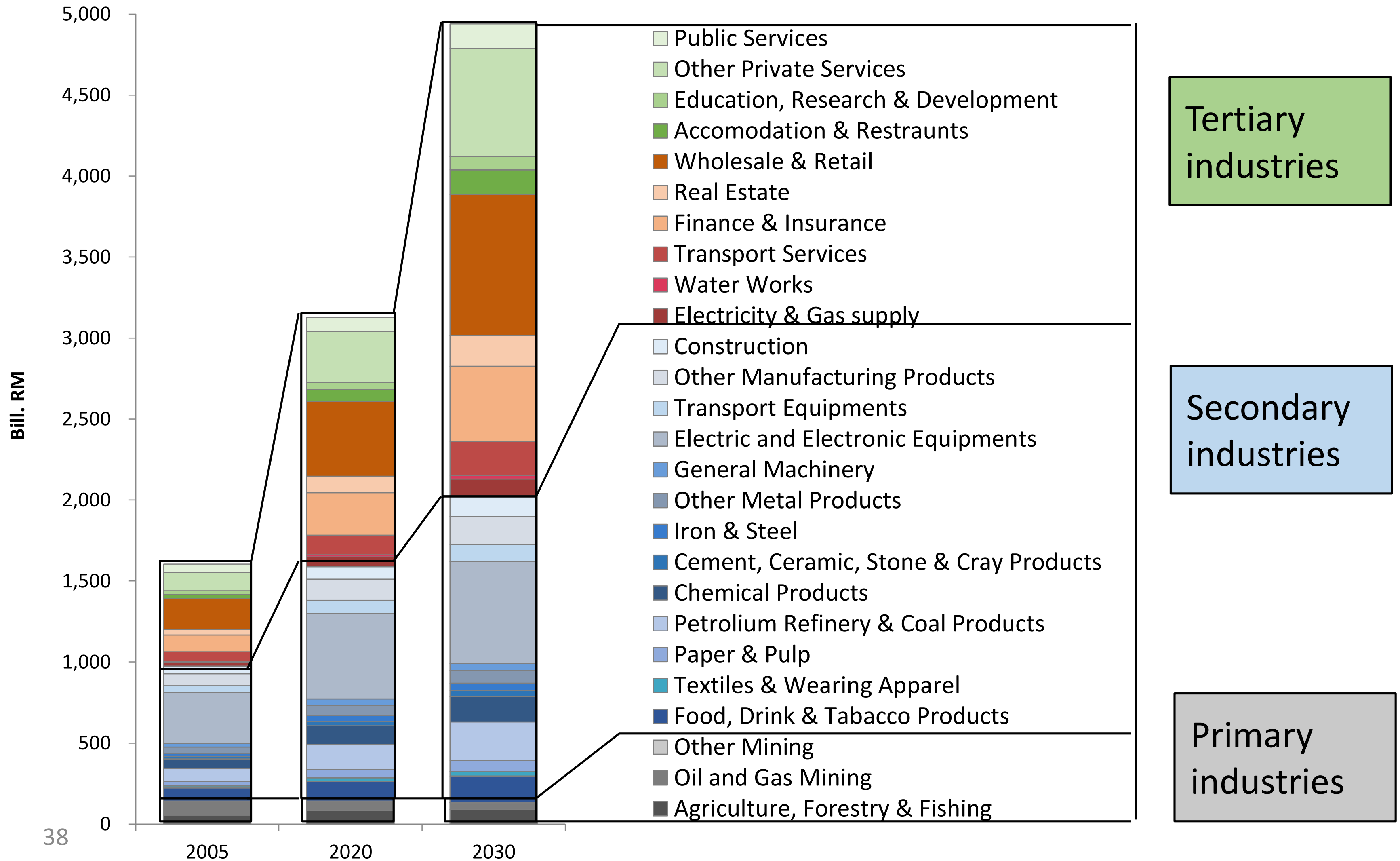
Integration of all emission sectors



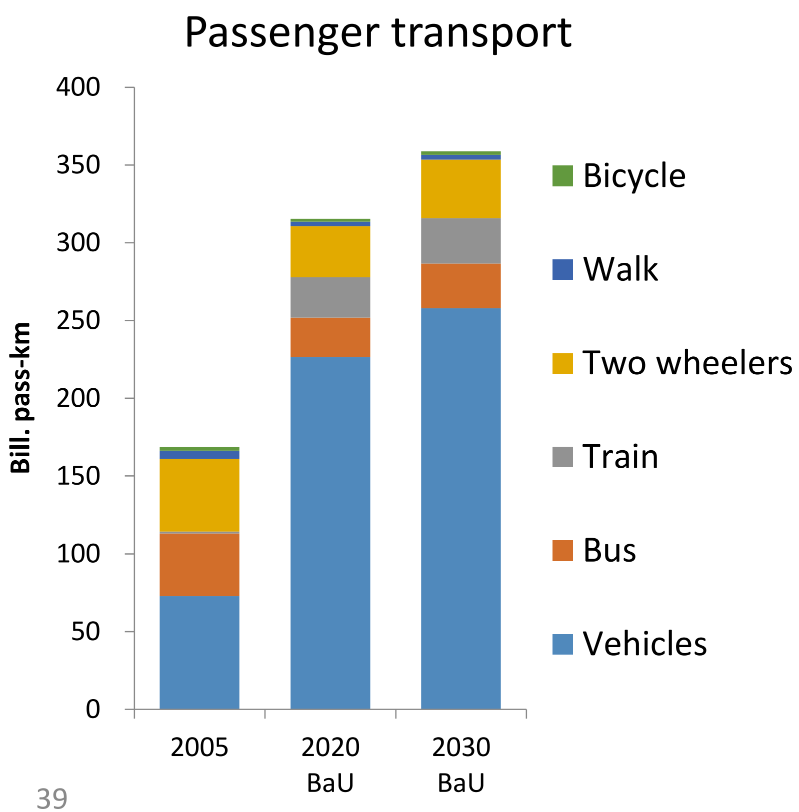
LCS scenario with Integrated Modeling
A case in Malaysia

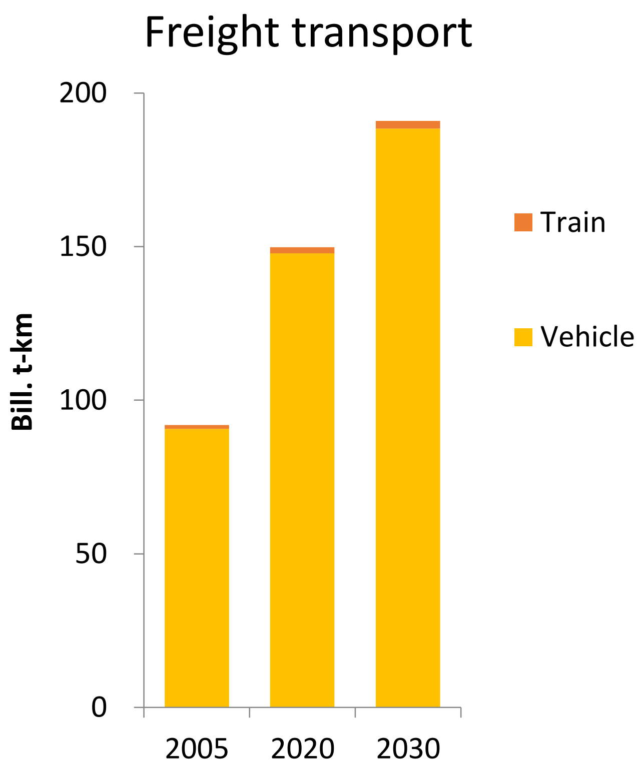
	2005	2020	2030	2020 /2005	2030 /2005	
Population	26.1	32.8	37.3	1.3	1.4	Million
Household	5.8	8.2	9.3	1.4	1.6	Million
GDP	509	996	1,601	2.0	3.1	Bill. RM
Per capita GDP	19.5	30.4	43.0	1.6	2.2	1000.RM
Gross output	1,604	3,135	4,929	2.0	3.1	Bill. RM
Primary	55	84	97	1.5	1.8	
Secondary	920	1,507	2,175	1.6	2.4	
Tertiary	629	1,544	2,657	2.5	4.2	
Passenger transport	169	315	359	1.9	2.1	Bill. pass-km
Freight transport	92	150	214	1.6	2.3	Bill. t-km

Projected output by 26 sectors



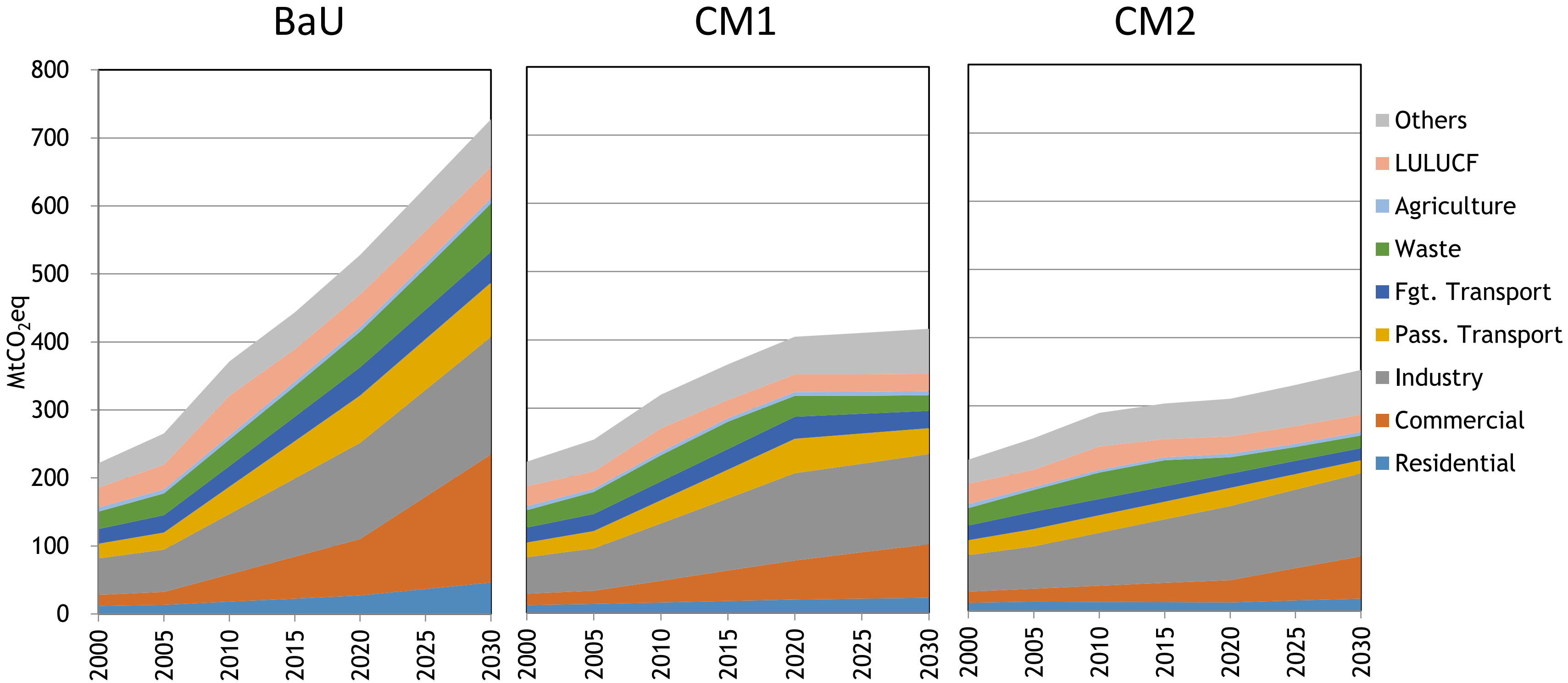
Projected transport volume





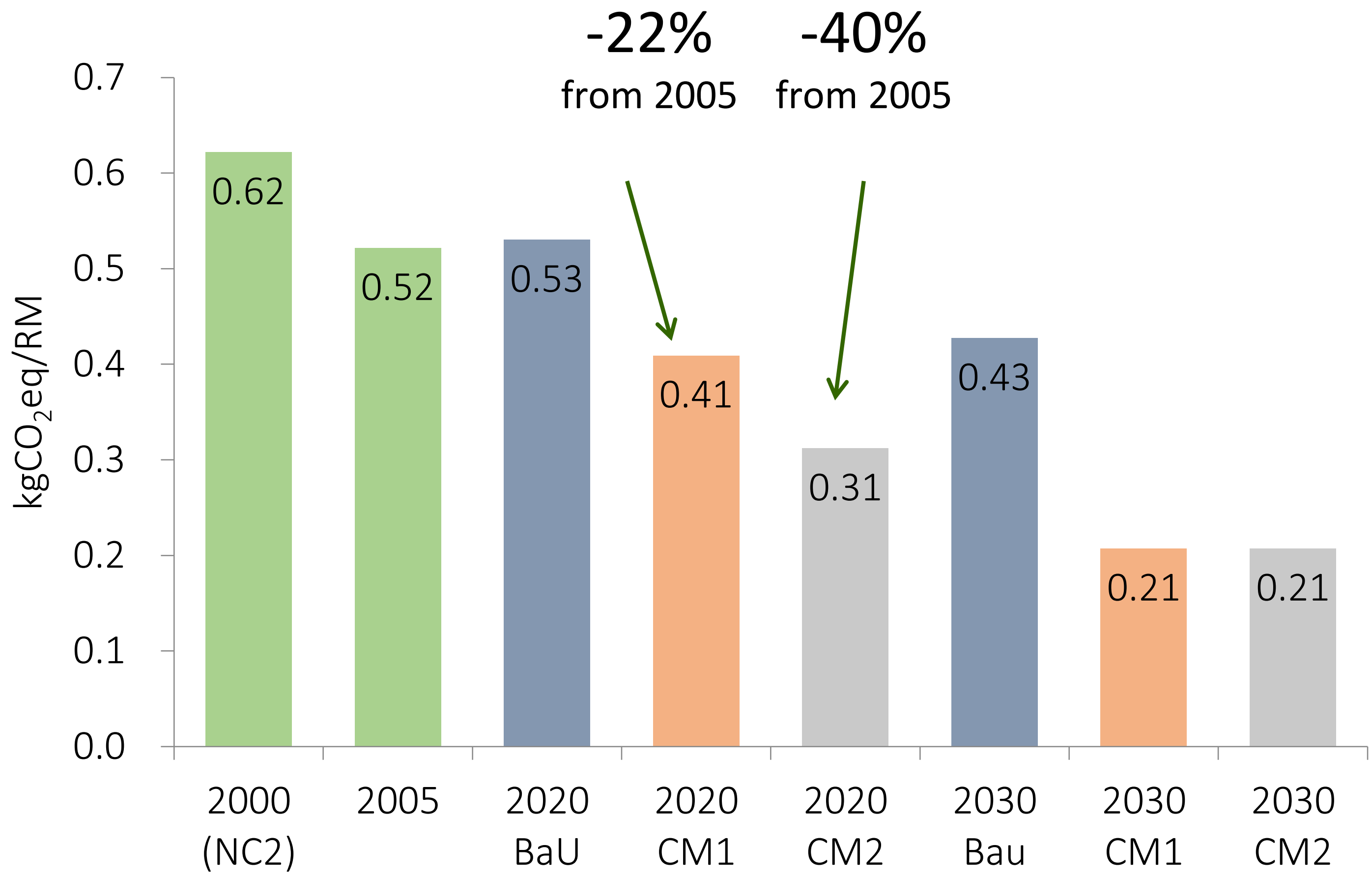
LCS scenario with Integrated Modeling A case in Malaysia

- GHG emissions

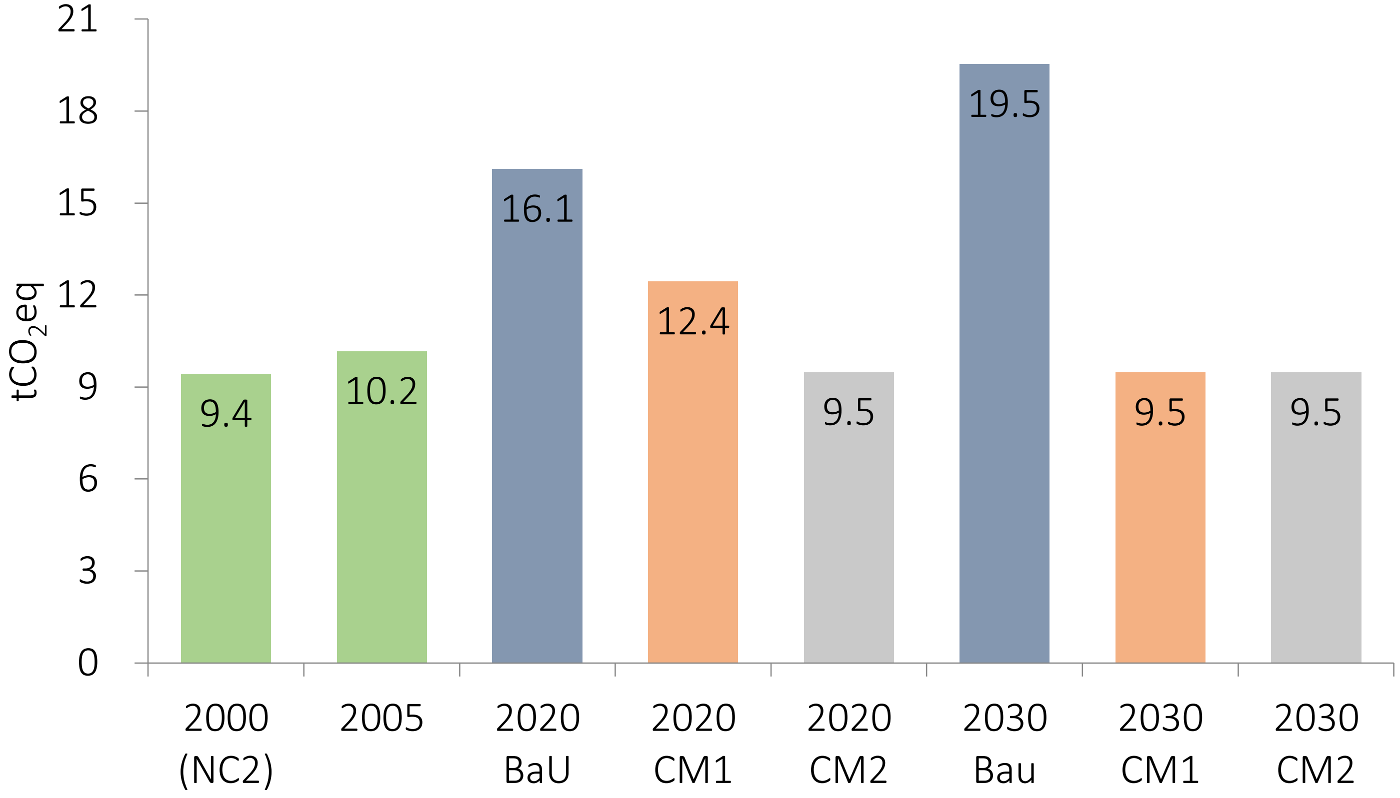


Periods between projected years were interpolated linearly.

Emission intensity (GHG emission per GDP)

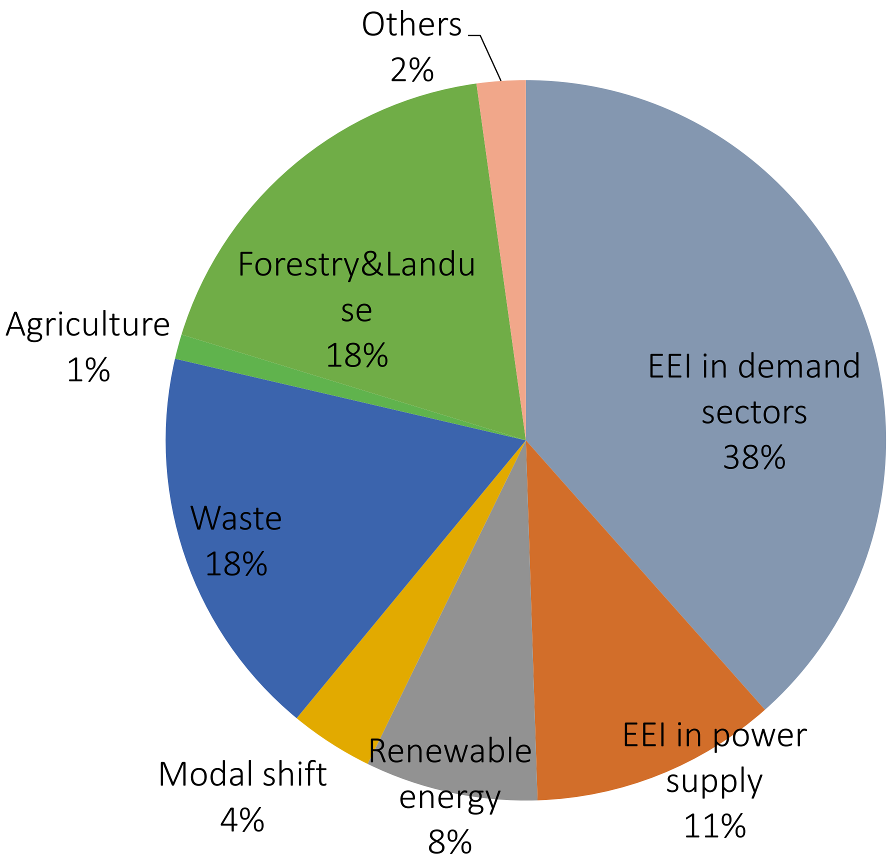


Per capita GHG emission

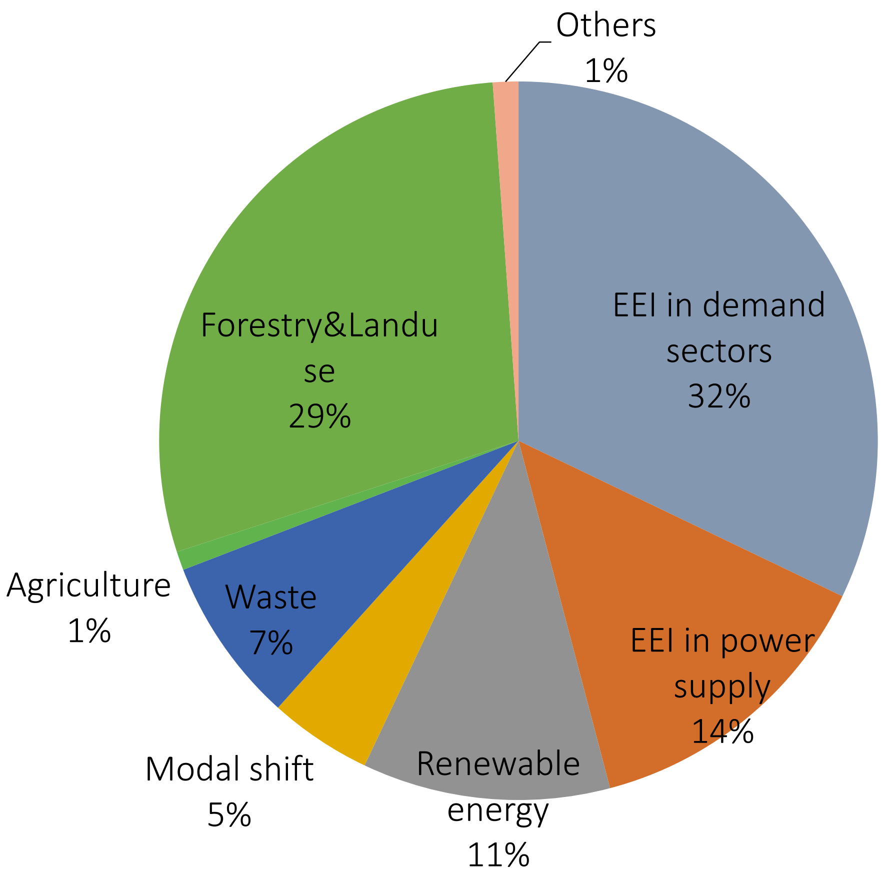


Contribution to emission reduction in 2020

CM1

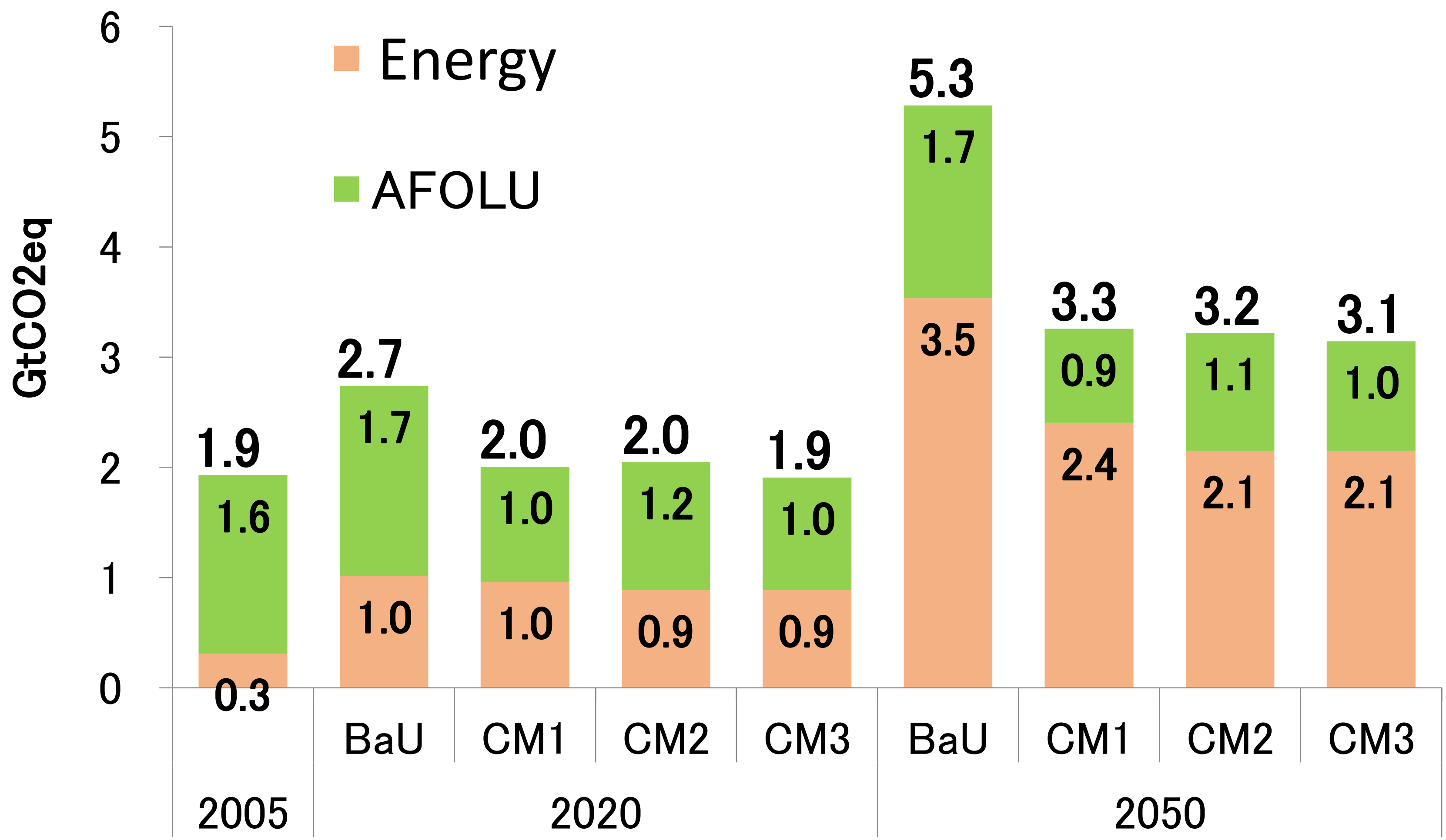


CM2

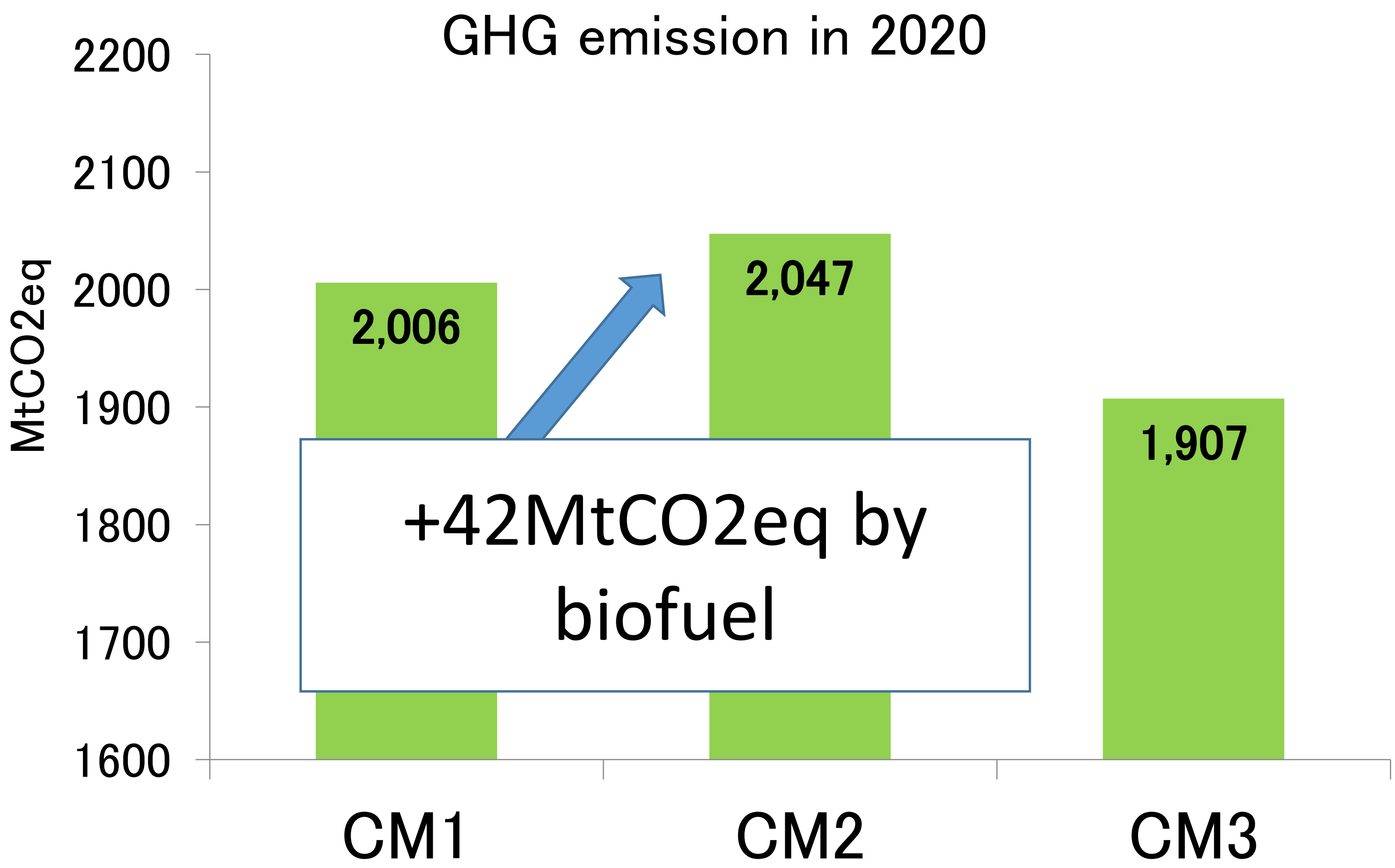


Indonesia Scenarios
GHG emissions

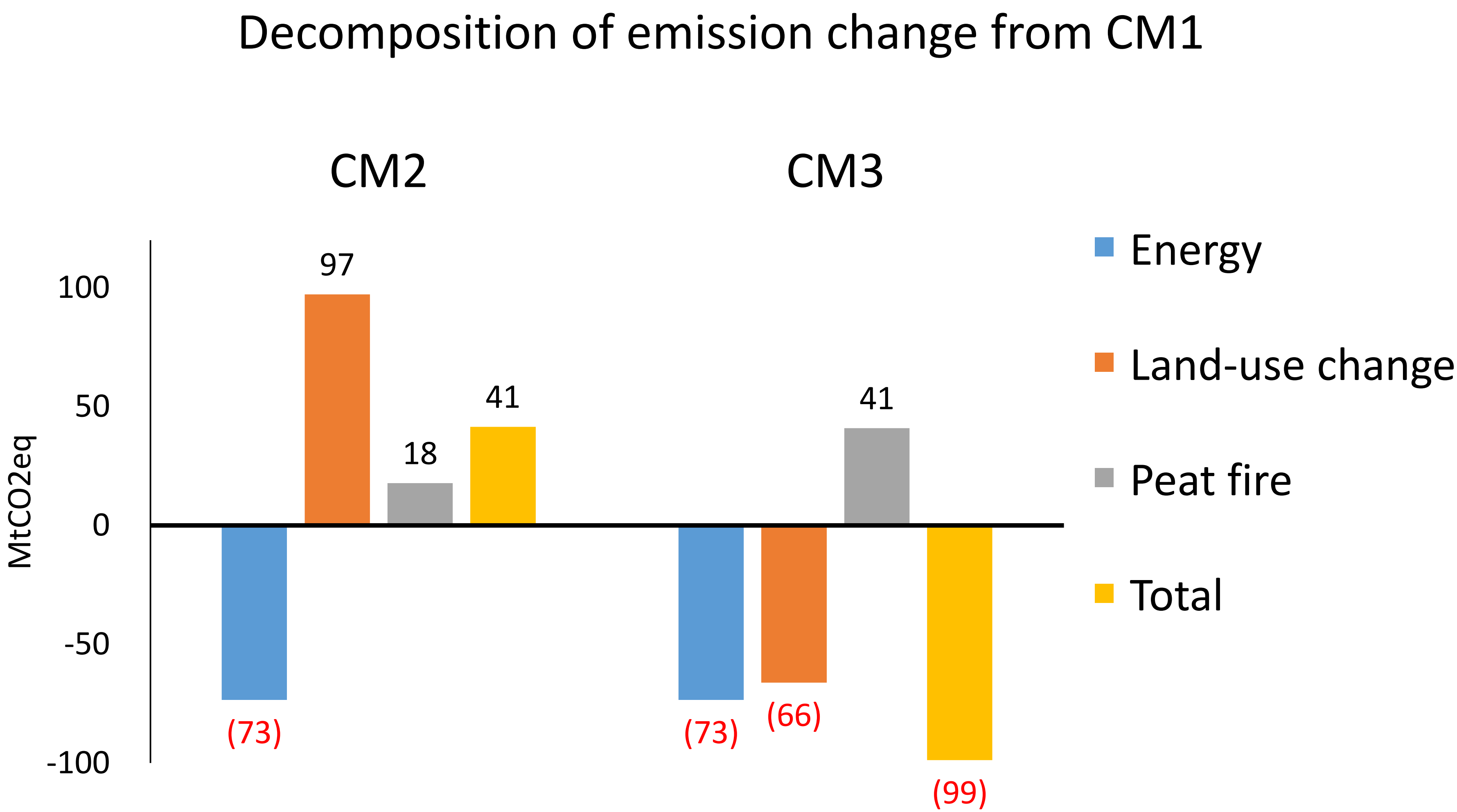
BaU: Business as usual
CM1: Current policy
CM2: Current policy + Biofuel
CM3: CM2 + utilizing abandoned land



Biofuel had adverse impact



Deforestation for biofuel production increase total GHG emissions



Summary

- LCS scenario can support policy making for long-term mitigation goals
- Appropriate mitigation options should be chosen considering cost, effectiveness, co-benefit and risk
- Modeling can compare different options by quantifying there potentials