IME609: Project 1
Final Presentation

Japan

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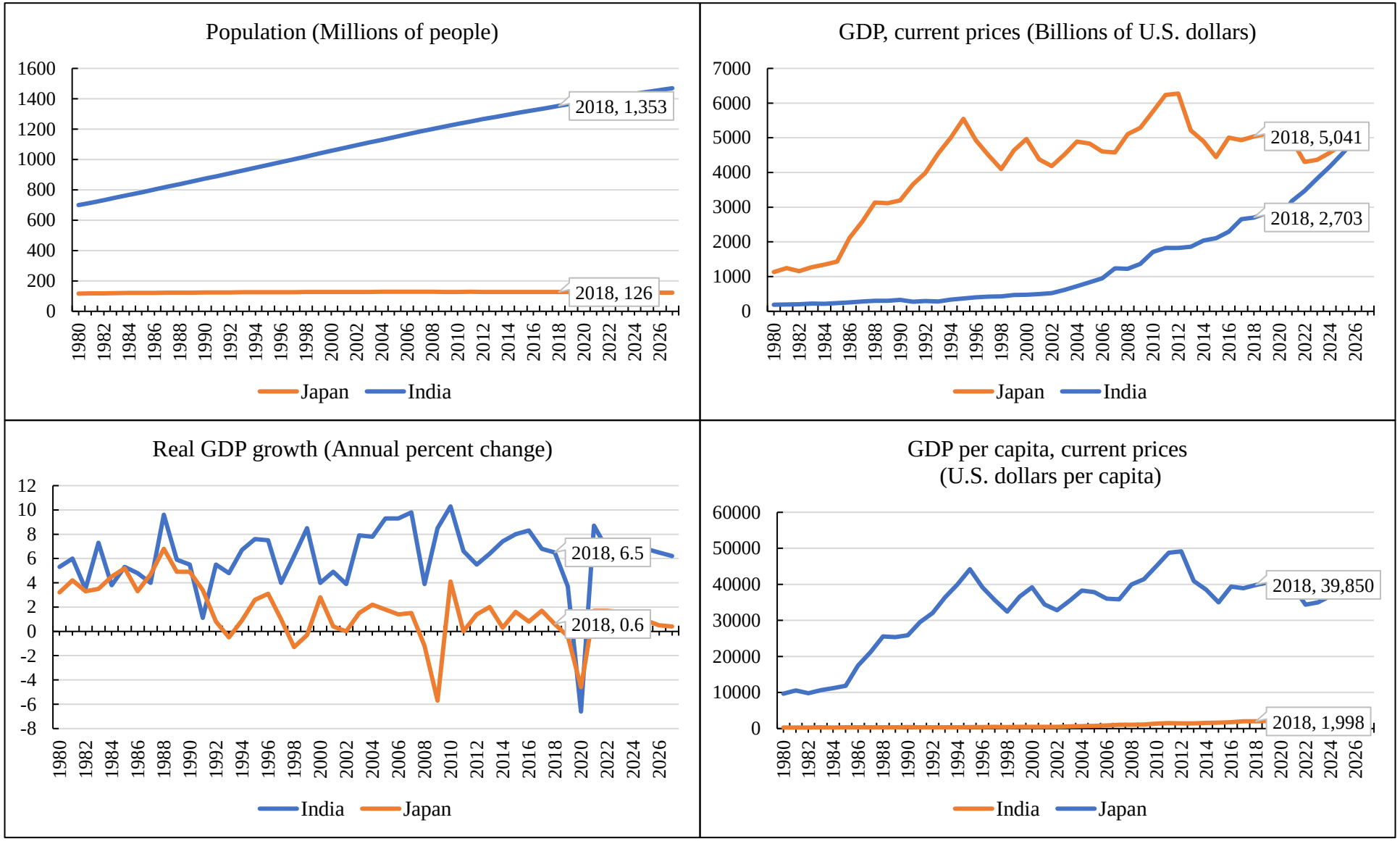
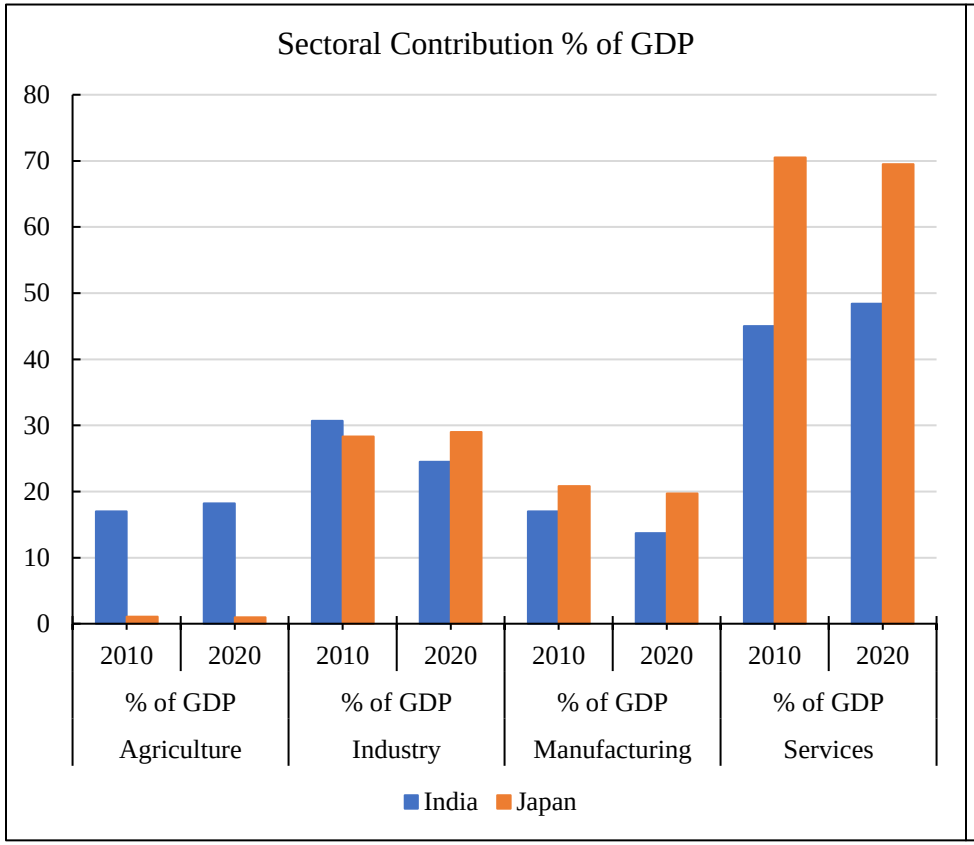
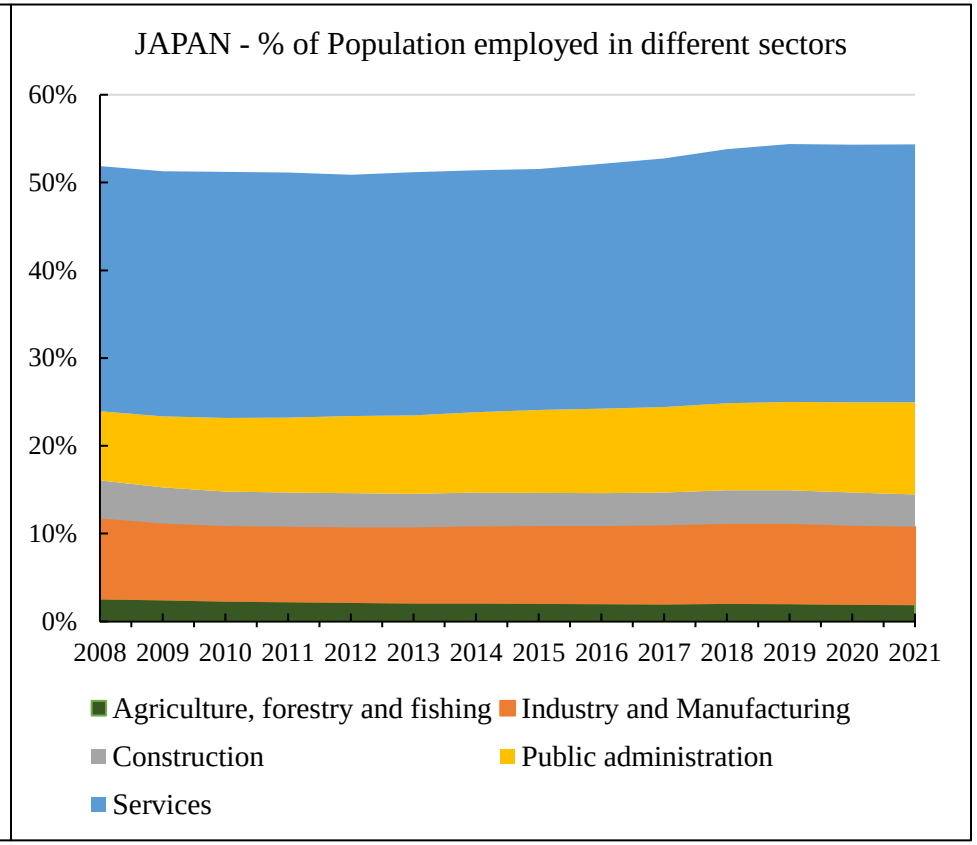
Country Profile – Key Indicators



Data Source: IMF Data Mapper (2022) Link: https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC/ADVEC/WEOWORLD

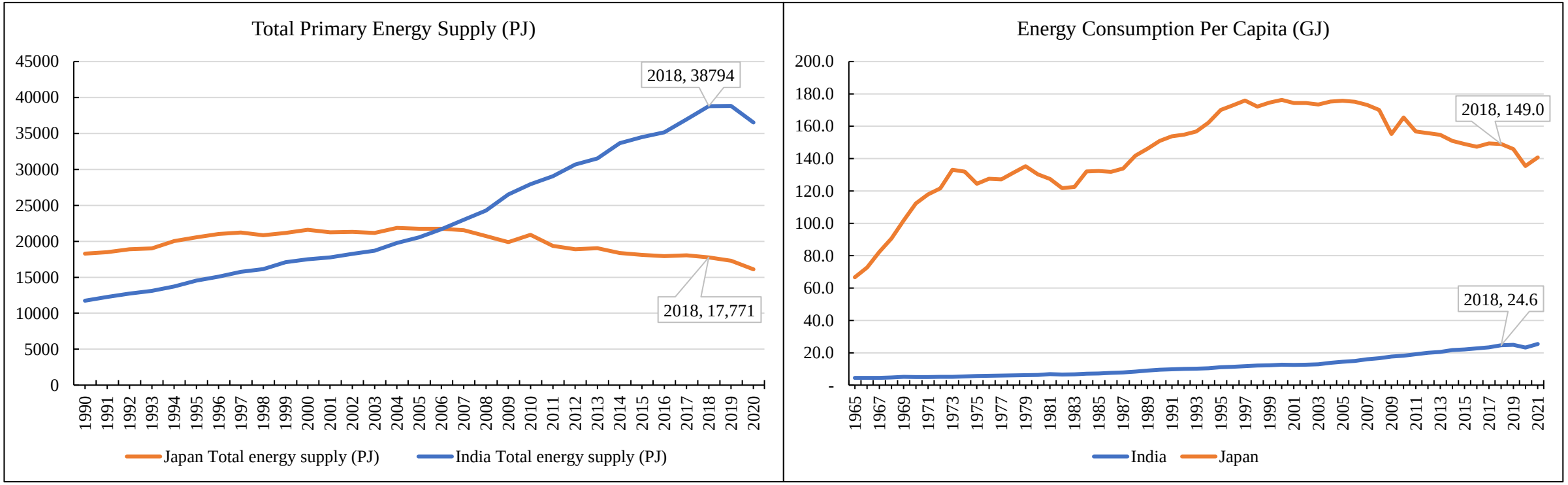
Sectoral Contribution in GDP & % of Population employed sector-wise





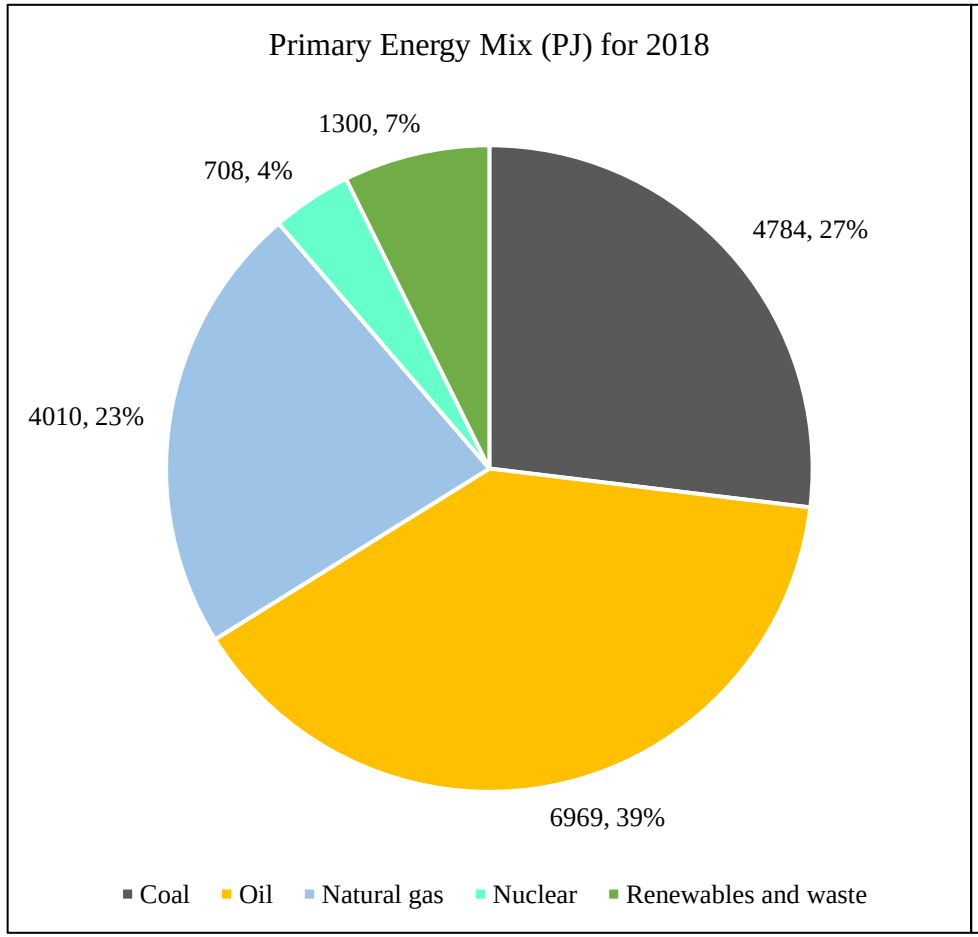
Source: World Development Indicators, World Bank (2022) Link: http://wdi.worldbank.org/table/

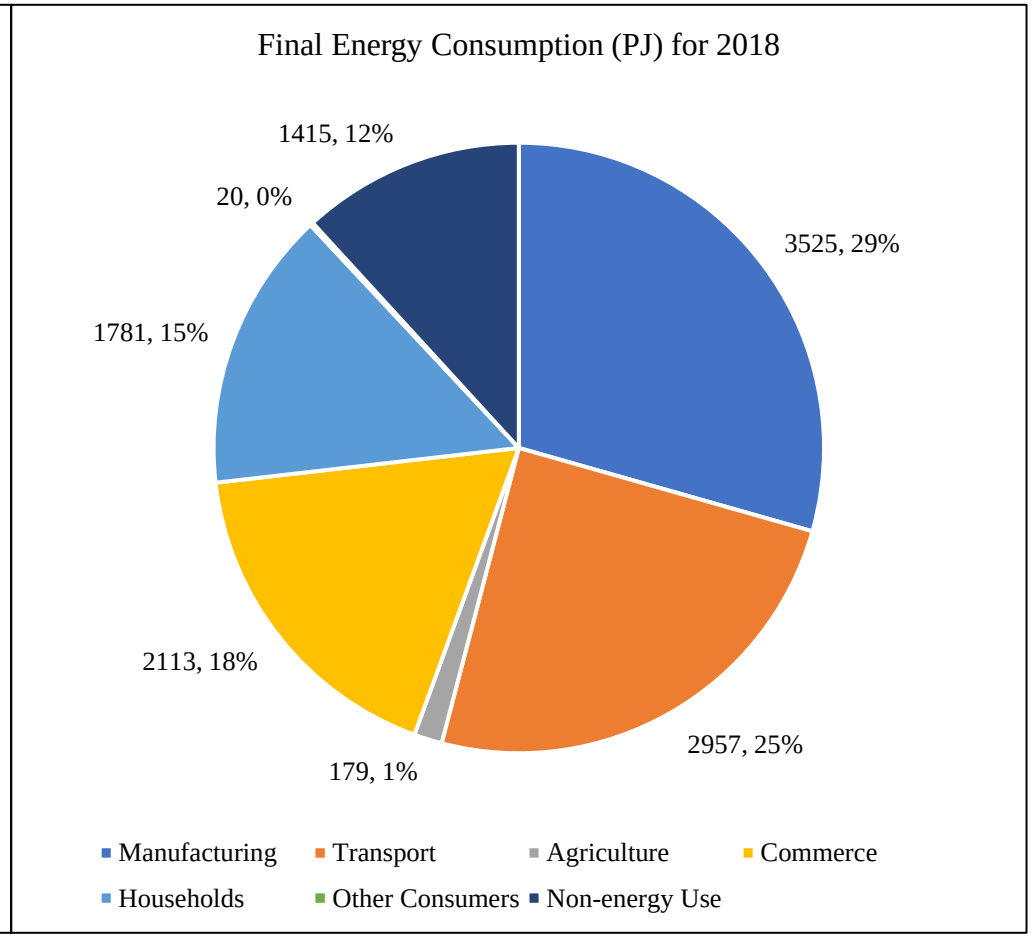
Primary Energy Supply



Source:
IEA Energy Balance, IEA (2022) Link: https://www.iea.org/data-and-statistics/data-product/world-energy-balances
BP Statistical Review of World Energy (2022) Link: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

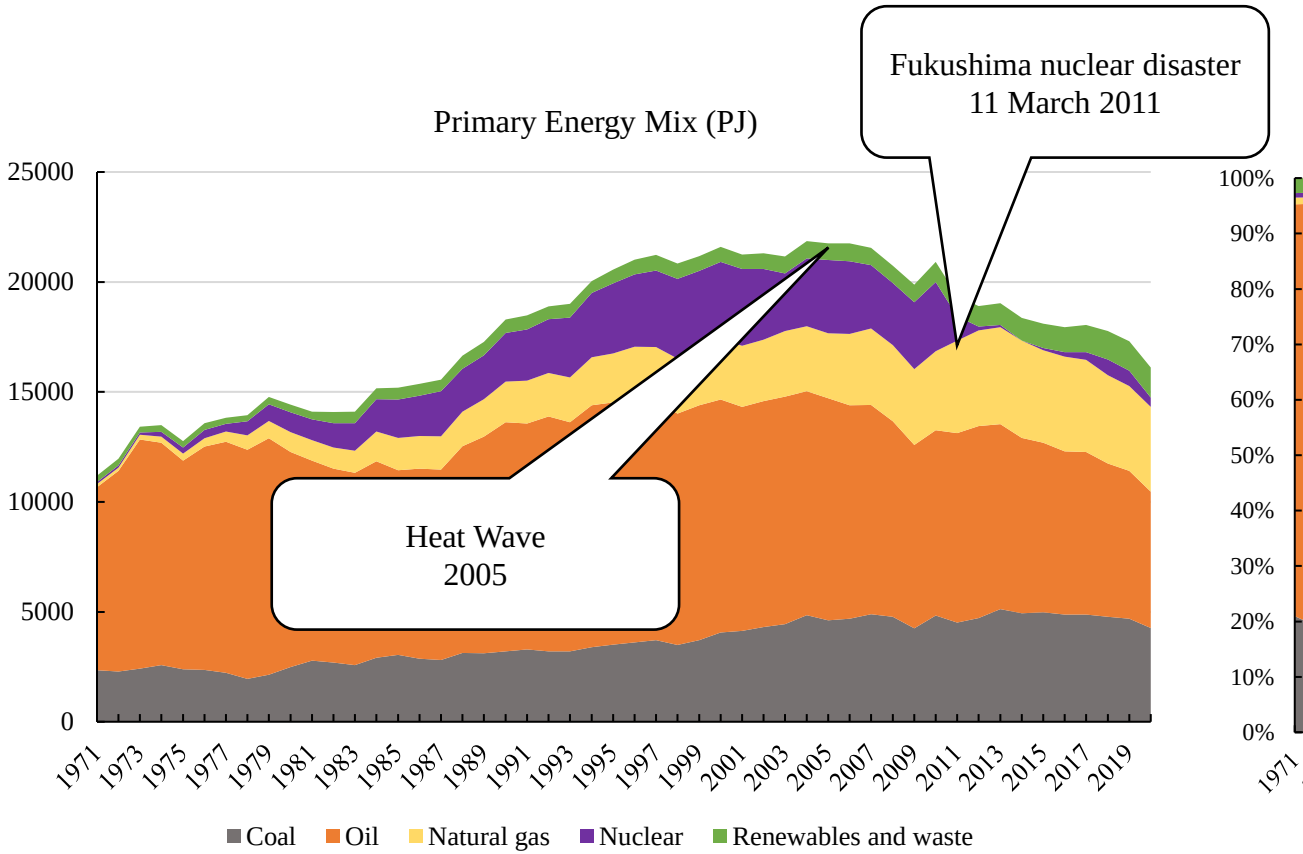
Primary Energy Mix and Final Energy Consumption

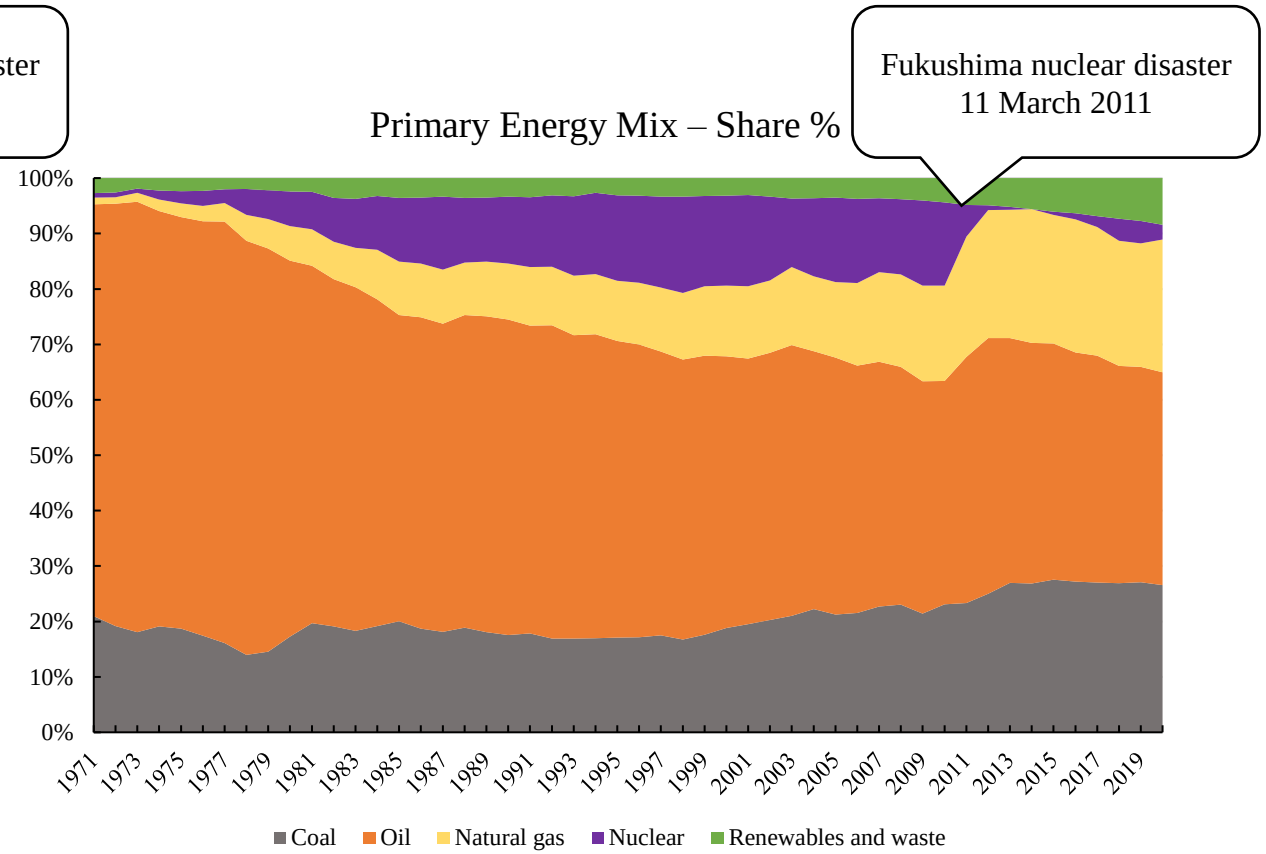




Source:
IEA Energy Balance, IEA (2022) Link: https://www.iea.org/data-and-statistics/data-product/world-energy-balances
The 2020 Energy Balances (2020), UN Statistics Division Link: https://unstats.un.org/unsd/energystats/dataPortal/
BP Statistical Review of World Energy (2022) Link: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

Japan's Primary Energy Mix



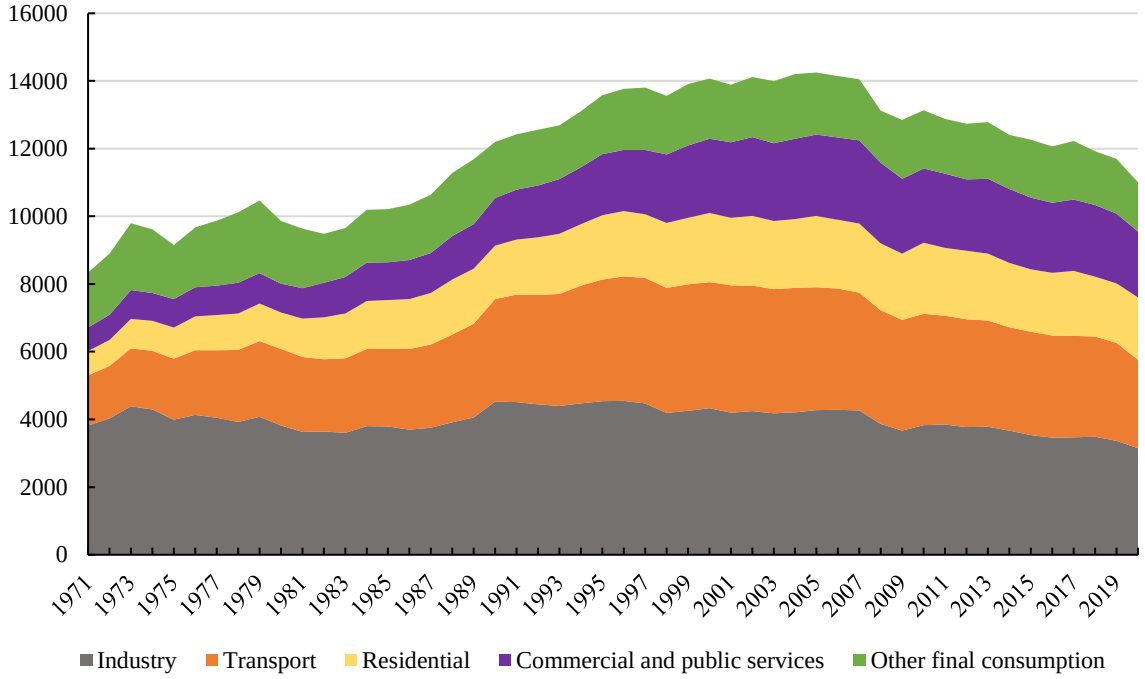


Source: IEA Energy Balance (1971-2019)

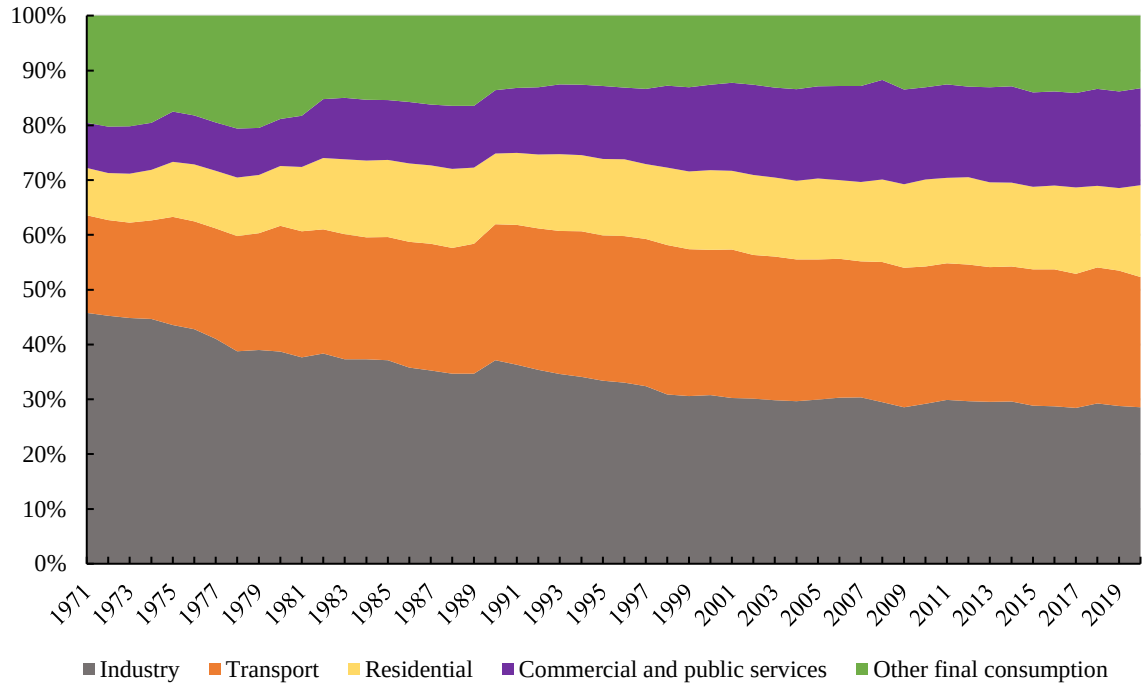
	% of World Energy Consumption	Change from 2011-2021
Japan	9.3%	2.9%
India	4.2%	-1.1%

Japan’s Final Energy Consumption

Sector-wise Final Energy Consumption (PJ)



Sector-wise Final Energy Consumption - % Share



Source: IEA Energy Balance (1971-2019)

IOT

Most inputs are utilized in the sector itself

Chemical Products is useful for all the sectors

Air and Water Transport Dominated by Petroleum Products

Service Sector goes as input in almost all the sectors

Basic metals are often used in construction activities

Basic metals are used in equipment manufacturing

Electricity is mostly used in appliances and water supply

Land based transportation is prominent in all sectors

	Agriculture & Fishing	Mining	Services	Food	Textile	Wood	Paper	Coke and petroleum products	Chemical and chemical products	Other non-metallic mineral products	Basic metals Fabricated metal products	Electronics	Electrical equipment	Transport equipment	Electricity, gas, steam and air conditioning supply	Water supply	Construction	Land transport and transport via pipelines	Water & Air transport	Public administration
Agriculture & Fishing	0.13	0.00		0.16	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
Mining	0.00	0.09	0.00	0.00	0.00	0.00	0.01	0.08	0.02	0.22	0.16	0.01	0.01	0.00	0.00	0.00	0.0	0.00	0.00	0.00
Services	0.17	0.2	0.21	0.20	0.25	0.16	0.17	0.26	0.18	0.09	0.08	0.2					0.16	0.16	0.28	0.18
Food	0.07		0.01	0.12	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.0					0.00	0.00	0.00	0.00
Textile	0.01	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.0					0.00	0.0	0.01	0.00
Wood	0.00	0.00	0.00	0.00	0.00	0.17	0.02	0.00	0.00	0.00	0.00	0.0					0.02	0.00	0.00	0.00
Paper	0.0	0.00	0.01	0.02	0.01	0.01	0.25	0.00	0.01	0.01	0.00	0.0					0.00	0.01	0.01	0.01
Coke and petroleum products	0.02	0.03	0.00	0.00	0.01	0.00	0.00	0.22	0.04	0.01	0.00	0.0					0.01	0.03	0.18	0.01
Chemical and chemical products	0.04	0.02	0.02	0.02	0.04	0.03	0.05	0.10	0.24	0.01	0.00	0.02	0.03	0.03	0.0	.01	0.02	0.01	0.01	0.01
Other non-metallic mineral products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.00	0.01	0.02	0.01	0.00	0.0	0.05	0.00	0.00	0.00
Basic metals Fabricated metal products	0.00	0.02	0.00	0.02	0.01	0.02	0.00	0.02	0.02	0.02	0.34	0.10	0.12	0.11	0.01	0.00	0.14	0.00	0.01	0.01
Electronics	0.02	0.04	0.03	0.01	0.03	0.02	0.01	0.02	0.02	0.01	0.01	0.15	0.05	0.03	0.05	0.02	0.05	0.02	0.02	0.04
Electrical equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.15	0.03	0.00	0.00	0.01	0.00	0.00	0.01
Transport equipment	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.38	0.00	0.00	0.00	0.01	0.07	0.01
Electricity, gas, steam and air conditioning supply	0.01	0.03	0.01	0.01	0.02	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.19	0.02				0.01
Water supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.0				0.02
Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00				0.00
Land transport and transport via pipelines	0.03	0.02	0.01	0.03	0.02	0.03	0.03	0.05	0.02	0.03	0.02	0.01	0.02	0.01	0.03	0.01				0.01
Water & Air transport	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.01	0.01	0.00		0.00	0.01	0.00	0.00	0.00	0.11	0.00
Public administration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						0.00	0.00	0.00	0.00	0.00	0.00

Energy Balance of Japan (PJ) - 2018

Transactions(down)/Commodity(right)	Primary Coal and Peat	Coal and Peat Products	Primary Oil	Oil Products	Natural Gas	Biofuels and Waste	Nuclear	Electricity	Heat	Total Energy	Of which Renewables
Primary production	22	---	17	---	94	593	701	544	105	2076	978
Imports	4883	46	6375	1851	3966	*57943	---	---	---	17179	*57943
Exports	-1	-42	---	-735	---	*-24	---	---	---	-778	*-24
International marine bunkers	---	---	---	-178	---	---	---	---	---	-178	---
International aviation bunkers	---	---	---	-302	---	---	---	---	---	-302	---
Stock changes	---	-2	-20	2	-50	0	---	---	---	-70	0
Total energy supply	**4904**	**3**	**6371**	**638**	**4010**	**651**	**701**	**544**	**105**	**17928**	**1036**
Statistical differences	9	47	-13	89	-12	0	0	30	0	149	554
Transfers and recycled products	---	---	129	-129	---	---	---	---	---	1	---
Transformation	**-4462**	**653**	**-6510**	**6018**	**-2758**	**-377**	**-701**	**3272**	**-68**	**-4933**	***-271926**
Electricity CHP & Heat Plants	-2867	-260	-21	-444	-2827	-372	-701	3272	-68	-4289	*-271308
Electricity Plants	-2867	-260	-21	-444	-2814	-372	-701	3276	-91	-4295	*-271308
CHP plants	---	---	---	---	---	---	---	---	---	---	---
Heat plants	---	---	---	0	-13	---	---	-4	23	6	---
Coke ovens	-1243	1258	---	-18	---	-4	---	---	---	-8	---
Briquetting plants	---	---	---	---	---	---	---	---	---	---	---
Liquefaction plants	---	---	---	---	---	---	---	---	---	---	---
Gas works	---	---	---	---	---	---	---	---	---	---	---
Blast furnaces	-352	-419	---	---	---	---	---	---	---	-771	---
NGL & gas blending	---	---	---	-73	69	0	---	---	---	-3	0
Oil refineries	---	---	-6489	6565	---	---	---	---	---	76	---
Other transformation	---	75	---	-12	---	*-508	---	---	---	62	*-508
Energy industries own use	-12	-120	0	-290	-47	-6	---	-220	0	-695	-6
Losses	---	---	---	---	---	---	---	-162	---	-162	---
Final consumption	**422**	**489**	**4**	**6149**	**1218**	***266937**	**---**	**3404**	**37**	**11989**	***202943**
Final Energy Consumption	**422**	**459**	**1**	**4776**	**1208**	***266937**	**---**	**3404**	**37**	**10574**	***202943**
Manufacturing const. and mining	421	455	1	763	477	*157942	---	1250	0	3525	*113815
Iron and steel	99	399	---	53	108	2	---	251	---	912	*181
Chemical and petrochemical	113	34	1	362	86	7	---	200	---	803	*963
Non-ferrous metals	1	7	---	18	21	1	---	44	---	92	---
Non-metallic minerals	134	13	---	87	33	29	---	65	---	360	*5557
Transport equipment	0	2	---	17	27	*4	---	100	---	147	*4
Machinery	0	0	---	37	61	*17	---	242	---	340	*17
Mining and quarrying	---	0	---	8	---	---	---	4	---	12	---
Food and tobacco	0	---	---	59	79	*1029	---	92	0	232	*1033
Paper pulp and printing	75	---	---	31	31	*112474	---	130	---	380	*100747
Wood and wood products	---	---	---	5	1	*1490	---	10	---	17	*1490
Textile and leather	---	0	---	9	9	*104	---	14	---	33	*104
Construction	---	---	---	62	2	---	---	21	---	85	---
Industry n.e.s	0	0	0	14	19	*3695	---	77	0	113	*3719
Transport	0	---	---	2875	2	18	---	62	---	2957	18
Road	---	---	---	2594	2	18	---	---	---	2614	18
Rail	0	---	---	7	---	---	---	62	---	69	---
Domestic aviation	---	---	---	147	---	---	---	---	---	147	---
Domestic navigation	---	---	---	128	---	---	---	---	---	128	---
Pipeline transport	---	---	---	---	---	---	---	---	---	---	---
Transport n.e.s	---	---	---	---	---	---	---	---	---	---	---
Other Consumption	1	4	---	1138	730	*91042	---	2092	37	4092	*71175
Agriculture forestry and fishing	0	0	---	166	0	*20	---	12	0	179	0
Commerce and public services	1	4	---	506	369	*70977	---	1138	25	2113	*59513
Households	---	---	---	466	361	0	---	943	11	1781	10
Other consumption n.e.s	---	---	---	---	---	20	---	---	0	20	*701
Non-energy use	0	30	3	1373	9	---	---	---	---	1415	---

Source: UN Stat Division Energy Balance (2018)

Models for emission estimation using input-output table

Model Name	Short Description	Tool Used	Methodology	Emission Estimated
Model 1	Basic Total Output Estimation	GAMS	Total demand of USD 100 million was given as input to each sector	No
Model 2	Basic sectoral emission using **energy intensity**	Excel	**Total Emission (million tCO_2e)** = Production(Million USD) * Wt. Avg. Emission Factor (gCO2e/MJ) * Energy Intensity(MJ/USD)	Yes
Model 3	Sectoral emission **using prices and calorific values** (as per class discussion)	Excel	**Total Emission (million tCO_2)** = [Production(Million USD) / Prices (USD/tonnes)] * Calorific Value(MJ/tonnes) * Emission Factor (gCO_2/MJ)	Yes
Model 4	Sectoral emission using **energy balance table** (using actual energy consumption data)	Excel	**Total Emission (million tCO_2)** = Final Energy Consumption(MJ) * Emission Factor (gCO_2/MJ)	Yes
Model 5	**Environmental extended IO model JAPAN**	GAMS	**Total Emission (million tCO_2)** = Output to meet total demand(Million USD) * Emission Intensity(tCO_2/USD) **T(Emission tCO_2)** = Emission intensity(tCO_2/USD) * $(I-A)^{-1}$ *Demand(USD)	Yes
Model 6	Environmental extended IO model JAPAN with **constraint**	GAMS	**Total Emission (million tCO_2)** = Output to meet total demand(Million USD) * Emission Intensity(tCO_2/USD) **T(Emission tCO_2)** = Emission intensity(tCO_2/USD) * $(I-A)^{-1}$ *Demand(USD) Constraint of Total Emission less than 700 million tons of CO_2	Yes
Model 7	Environmental extended IO model JAPAN with **Carbon Tax**	GAMS	Japan's National Policy imposed Carbon Tax of 2.16 USD/tCO2. **Total Revenue from Carbon Tax (million USD)** = Emission (Million tCO_2) * Carbon Tax(USD/tCO_2)	Yes
Model 8	Environmental extended IO model JAPAN with **Abatement Measures for Net Zero** by 2030 in Japan	GAMS	Total Sectoral Emission is being equated with four different **abatement measures** viz. afforestation, bioenergy based CCUS, direct air capture CCUS and others. Abatement cost were added for each measure. Then constraints were added to find total cost.	Yes

Model 1 – Basic Total Output Estimation

Total demand of USD 100 million was given as input to each sector

```
1  set i 'sector' /S1*S20/;
2
3  alias (i,j);
4
5  parameter t(i,*);
6  $CALL GDXXRW JAPANINPUT_V2.xlsx par=t rng=COEFFOUT_INPUT!A1:U21
7  $GDXIN JAPANINPUT_V2.gdx
8  $LOAD t
9  $GDXIN
10
11 parameter d(i) /S1*S20 = 100/ ;
12
13 Variable x(i), totaloutput;
14
15 equation e1, etot;
16 e1(i).. x(i) - sum(j, t(i,j)*x(j)) =e= d(i);
17 etot.. totaloutput =e= 0;
18
19 model m /all/;
20
21 solve m using lp minimizing totaloutput;
22
23 display x.l;
24
```

	Total Production required to meet demand
Agriculture & Fishing	164.57
Mining	231.19
Services	868.20
Food	145.16
Textile	132.70
Wood	132.01
Paper	176.24
Coke and petroleum products	225.30
Chemical and chemical products	268.94
Other non-metallic mineral products	123.02
Basic metalsFabricated metal products	323.10
Electronics	236.60
Electrical equipment	151.75
Transport equipment	211.15
Electricity, gas, steam and air conditioning supp	195.74
Water supply	118.07
Construction	107.89
Land transport and transport via pipelines	177.84
Water & Air transport	135.26
Public administration	102.42

Model Results

Model 2 – Sectoral emission using energy intensity

Total Emission (million tCO_2e) = Production(Million USD) * Energy Intensity(MJ/USD) * Wt. Avg. Emission Factor(gCO_2e/MJ)

Assumptions :

1. Energy Intensity for Japan = 3 MJ/USD (Source: World Bank)
2. Weighted Average Emission Factor (Table 1) (Source: IPCC and IEA Sankey Diagram)

	Domestic Demand	COAL_EF	OIL_EF	GAS_EF	ELEC_EF	WT_COAL	WT_OIL	WT_GAS	WT_ELEC	Weighted Average Emission Factor
Unit	(USD Million)	(gCO2e/MJ)	(gCO2e/MJ)	(gCO2e/MJ)	(gCO2e/MJ)	%	%	%	%	(gCO_2e/MJ)
Agriculture & Fishing	44,349	90.3	68.6	50	136	0.00	0.94	0.00	0.06	72.64
Mining	4,102	90.3	68.6	50	136	0.00	0.67	0.00	0.33	90.84
Services	26,99,454	90.3	68.6	50	136	0.06	0.23	0.15	0.56	104.86
Food	2,40,195	90.3	68.6	50	136	0.00	0.25	0.35	0.40	89.05
Textile	36,864	90.3	68.6	50	136	0.00	0.37	0.20	0.43	93.86
Wood	1,130	90.3	68.6	50	136	0.00	0.25	0.00	0.75	119.15
Paper	5,546	90.3	68.6	50	136	0.47	0.09	0.09	0.35	100.72
Coke and petroleum products	56,054	90.3	68.6	50	136	0.00	0.00	0.00	0.00	0.00
Chemical and chemical products	92,786	90.3	68.6	50	136	0.10	0.45	0.22	0.23	82.18
Other non-metallic mineral products	2,492	90.3	68.6	50	136	0.40	0.23	0.19	0.18	85.88
Basic metals Fabricated metal products	15,547	90.3	68.6	50	136	0.55	0.06	0.11	0.28	97.36
Electronics	2,90,460	90.3	68.6	50	136	0.00	0.12	0.19	0.69	111.57
Electrical equipment	45,198	90.3	68.6	50	136	0.00	0.11	0.17	0.72	113.97
Transport equipment	1,20,388	90.3	68.6	50	136	0.03	0.12	0.18	0.67	111.06
Electricity, gas, steam and air conditioning supply	1,00,360	90.3	68.6	50	136	0.00	0.00	0.00	0.00	0.00
Water supply	49,330	90.3	68.6	50	136	0.00	0.00	0.00	1.00	136.00
Construction	5,46,138	90.3	68.6	50	136	0.00	0.72	0.06	0.22	82.31
Land transport and transport via pipelines	1,00,950	90.3	68.6	50	136	0.00	0.97	0.01	0.02	69.76
Water & Air transport	23,360	90.3	68.6	50	136	0.00	1.00	0.00	0.00	68.60
Public administration	3,39,319	90.3	68.6	50	136	0.06	0.23	0.15	0.56	104.86

Model Assumptions

Model 2 - Basic sectoral emission using energy intensity (contd.)

```
set i 'sector' /S1*S20/;

alias (i,j);

parameter t(i,*);
$CALL GDXXRW JAPANINPUT_V2.xlsx par=t rng=COEFFOUT_INPUT!A1:U21
$GDXIN JAPANINPUT_V2.gdx
$LOAD t
$GDXIN

parameter d(i,*) ;
$CALL GDXXRW JAPANINPUT_V2.xlsx par=d rng=DOMDEMAND_INPUT!A1:B21
$GDXIN JAPANINPUT_V2.gdx
$LOAD d
$GDXIN

parameter ef(i,*) ;
$CALL GDXXRW JAPANINPUT_V2.xlsx par=ef rng=EMISSION_INPUT!A1:B21
$GDXIN JAPANINPUT_V2.gdx
$LOAD ef
$GDXIN

scalar ERG_INT /3/;

Variable x(i), dummy, sectemiss(i);

equation e1, edum, e2;
e1(i).. x(i) - sum(j, t(i,j)*x(j)) =e= d(i,'Domestic Demand');
edum.. dummy =e= 0;
e2(i).. x(i)*ef(i,'EF')*ERG_INT =e= sectemiss(i);

model m /all/;

solve m using lp minimizing dummy;

display x.l;
display d;
display sectemiss.l;
```

Unit (million tCO2e)	Emission considering domestic demand	Emission considering demand with net export
Agriculture & Fishing	30.58	24.01
Mining	38.07	1.25
Food	93.85	81.14
Textile	19.07	9.05
Wood	10.43	7.38
Paper	32.96	32.23
Coke and petroleum products	0.00	0.00
Chemical and chemical products	91.68	97.00
Other non-metallic mineral products	13.58	14.29
Basic metalsFabricated metal products	112.08	131.86
Electronics	206.97	227.21
Electrical equipment	48.06	55.33
Transport equipment	100.27	174.39
Electricity, gas, steam and air conditioning supply	0.00	0.00
Water supply	35.91	35.46
Construction	138.66	138.32
Land transport and transport via pipelines	46.79	45.14
Water & Air transport	12.39	14.17
Public administration	108.04	107.21
Services	1378.27	1360.99
Total	**2517.66**	**2556.41**

Model Results

Model 3 – Sectoral emission using prices and GCV

Total Emission = [Production(Million USD) / Prices (USD/tonnes)] * Calorific Value(MJ/tonnes) * Emission Factor (gCO_2/MJ) ($million\ tCO_2$)

Assumptions :

1. Using only two sectors at supply side:
    1. Mining and Quarrying
    2. Coke and Petroleum Products
2. Distribution of Mining and Quarrying activities into Coal and Natural Gas Extraction
3. Distribution of Coke and Petroleum Products into Crude Oil and Oil Products (Source: UNSTAT Energy Balance)
4. Prices (Source: IEA)
5. Calorific Value and Emission Factors (Source: IPCC)

	Weights %	Agriculture & Fishing	Mining	Services	Food	Textile	Wood	Paper	Coke and petroleum products	Chemical and chemical products	Other non-metallic mineral products	Basic metals Fabricated metal products	Electronics	Electrical equipment	Transport equipment	Electricity, gas, steam and air conditioning supply	Water supply	Construction	Land transport and transport via pipelines	Water & Air transport	Public administration
Mining	Coal	0.02	1.00	0.01	0.01	0.01	0.00	0.70	1.00	0.63	0.81	0.82	0.00	0.00	0.09	0.52	0.00	0.64	0.00	0.00	0.01
	Natural Gas	0.98	0.00	0.99	0.99	0.99	1.00	0.30	0.00	0.37	0.19	0.18	1.00	1.00	0.91	0.48	1.00	0.36	1.00	1.00	0.99
Coke and petroleum products	Crude Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.00
	Oil Products	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	0.99	1.00	1.00	1.00

Model Assumptions

Model 3 – Sectoral emission using prices and GCV

Total Emission = [Production(Million USD) / Prices (USD/tonnes)] * Calorific Value(MJ/tonnes) * Emission Factor (gCO_2/MJ) ($million\ tCO_2$)

Price Assumptions (Source: IEA)	Prices (USD/tonnes or barrel)
Coal (USD/tonnes) 2019	121.00
Natural Gas (USD/Mbtu) 2018	9.30
Crude Oil (USD/barrel) 2018	49.50
Oil Products (USD/barrel) 2018	61.50

Gross Calorific Value (Source: IPCC)	GCV (MJ/kg)
Coal (MJ/kg)	25.75
Natural Gas (J)	1.00
Crude Oil (MJ/L)	36.84
Oil Products (MJ/L)	39.21

Emission Factor (Source: IPCC)	Emission Factor (gCO_2/MJ)
Coal (gCO2/MJ)	90.30
Natural Gas (gCO2/MJ)	50.00
Crude Oil (gCO2/MJ)	0.00
Oil Products (gCO2/MJ)	68.60

Model Assumptions

Source:
https://www.iea.org/reports/key-world-energy-statistics-2021/prices
https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_annex1-1.pdf

Model 3 – Emission Matrix

Total Emission = [Production(Million USD) / Prices (USD/tonnes)] * Calorific Value(MJ/tonnes) * Emission Factor (gCO_2/MJ) ($million\ tCO_2$)

	Total Emission	Agriculture & Fishing	Mining	Services	Food	Textile	Wood	Paper	Coke and petroleum products	Chemical and chemical products	Other non-metallic mineral products	Basic metals Fabricated metal products	Electronics	Electrical equipment	Transport equipment	Electricity, gas, steam and air conditioning supply	Water supply	Construction	Land transport and transport via pipelines	Water & Air transport	Public administration
	Agriculture & Fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	Coal (million ton CO2)	0.01	9.75	1.08	0.02	0.01	0.00	14.00	248.15	81.81	190.39	1124.78	0.00	0.00	0.53	5.09	0.00	218.67	0.00	0.00	0.01
	Natural Gas (million ton CO2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Wood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Paper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coke and petroleum products	Crude Oil (million ton CO2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil Products (million ton CO2)	13.01	1.32	140.31	6.30	1.53	0.66	2.99	252.27	106.65	2.15	10.82	6.12	1.64	1.78	89.36	2.84	34.38	52.14	89.33	22.90
	Chemical and chemical products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other non-metallic mineral products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Basic metals Fabricated metal products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Electronics	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Electrical equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Transport equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Electricity, gas, steam and air conditioning supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Water supply	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Land transport and transport via pipelines	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Water & Air transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Public administration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Total Emission (million tCO2) = 2732

Model Results

Model 4 – Sectoral emission using energy balance table

Total Emission (million tCO_2)
= Final Energy Consumed (MJ) * Emission Factor (gCO_2/MJ)

Assumptions :

1. Using actual energy balance table from (Source:UNSTAT)
2. Emission Factors (Source: IPCC)

Emission Factor (Source: IPCC)	Emission Factor (gCO2/MJ)
Coal (gCO2/MJ)	90.30
Natural Gas (gCO2/MJ)	50.00
Crude Oil (gCO2/MJ)	0.00
Oil Products (gCO2/MJ)	68.60

Model Assumptions

Source: UN Stat Division Energy Balance (2018)

Transactions(down)/Commodity(right)	Primary Coal and Peat	Coal and Peat Products	Primary Oil	Oil Products	Natural Gas	Biofuels and Waste	Nuclear	Electricity	Heat	Total Energy	Of which Renewables
Primary production	22	---	17	---	94	593	701	544	105	2076	978
Imports	4883	46	6375	1851	3966	*57943	---	---	---	17179	*57943
Exports	-1	-42	---	-735	---	*-24	---	---	---	-778	*-24
International marine bunkers	---	---	---	-178	---	---	---	---	---	-178	---
International aviation bunkers	---	---	---	-302	---	---	---	---	---	-302	---
Stock changes	---	-2	-20	2	-50	0	---	---	---	-70	0
Total energy supply	**4904**	**3**	**6371**	**638**	**4010**	**651**	**701**	**544**	**105**	**17928**	**1036**
Statistical differences	9	47	-13	89	-12	0	0	30	0	149	554
Transfers and recycled products	---	---	129	-129	---	---	---	---	---	1	---
Transformation	**-4462**	**653**	**-6510**	**6018**	**-2758**	**-377**	**-701**	**3272**	**-68**	**-4933**	***-271926**
Electricity CHP & Heat Plants	-2867	-260	-21	-444	-2827	-372	-701	3272	-68	-4289	*-271308
Electricity Plants	-2867	-260	-21	-444	-2814	-372	-701	3276	-91	-4295	*-271308
CHP plants	---	---	---	---	---	---	---	---	---	---	---
Heat plants	---	---	---	0	-13	---	---	-4	23	6	---
Coke ovens	-1243	1258	---	-18	---	-4	---	---	---	-8	---
Briquetting plants	---	---	---	---	---	---	---	---	---	---	---
Liquefaction plants	---	---	---	---	---	---	---	---	---	---	---
Gas works	---	---	---	---	---	---	---	---	---	---	---
Blast furnaces	-352	-419	---	---	---	---	---	---	---	-771	---
NGL & gas blending	---	---	---	-73	69	0	---	---	---	-3	0
Oil refineries	---	---	-6489	6565	---	---	---	---	---	76	---
Other transformation	---	75	---	-12	---	*-508	---	---	---	62	*-508
Energy industries own use	-12	-120	0	-290	-47	-6	---	-220	0	-695	-6
Losses	---	---	---	---	---	---	---	-162	---	-162	---
Final consumption	**422**	**489**	**4**	**6149**	**1218**	***266937**	**---**	**3404**	**37**	**11989**	***202943**
Final Energy Consumption	**422**	**459**	**1**	**4776**	**1208**	***266937**	**---**	**3404**	**37**	**10574**	***202943**
Manufacturing const. and mining	421	455	1	763	477	*157942	---	1250	0	3525	*113815
Iron and steel	99	399	---	53	108	2	---	251	---	912	*181
Chemical and petrochemical	113	34	1	362	86	7	---	200	---	803	*963
Non-ferrous metals	1	7	---	18	21	1	---	44	---	92	---
Non-metallic minerals	134	13	---	87	33	29	---	65	---	360	*5557
Transport equipment	0	2	---	17	27	*4	---	100	---	147	*4
Machinery	0	0	---	37	61	*17	---	242	---	340	*17
Mining and quarrying	---	0	---	8	---	---	---	4	---	12	---
Food and tobacco	0	---	---	59	79	*1029	---	92	0	232	*1033
Paper pulp and printing	75	---	---	31	31	*112474	---	130	---	380	*100747
Wood and wood products	---	---	---	5	1	*1490	---	10	---	17	*1490
Textile and leather	---	0	---	9	9	*104	---	14	---	33	*104
Construction	---	---	---	62	2	---	---	21	---	85	---
Industry n.e.s	0	0	0	14	19	*3695	---	77	0	113	*3719
Transport	0	---	---	2875	2	18	---	62	---	2957	18
Road	---	---	---	2594	2	18	---	---	---	2614	18
Rail	0	---	---	7	---	---	---	62	---	69	---
Domestic aviation	---	---	---	147	---	---	---	---	---	147	---
Domestic navigation	---	---	---	128	---	---	---	---	---	128	---
Pipeline transport	---	---	---	---	---	---	---	---	---	---	---
Transport n.e.s	---	---	---	---	---	---	---	---	---	---	---
Other Consumption	1	4	---	1138	730	*91042	---	2092	37	4092	*71175
Agriculture forestry and fishing	0	0	---	166	0	*20	---	12	0	179	0
Commerce and public services	1	4	---	506	369	*70977	---	1138	25	2113	*59513
Households	---	---	---	466	361	0	---	943	11	1781	10
Other consumption n.e.s	---	---	---	---	---	20	---	---	0	20	*701
Non-energy use	0	30	3	1373	9	---	---	---	---	1415	---

Model 4 – Sectoral emission using energy balance table

Total Emission = Final Energy Consumption (MJ) * Emission Factor (gCO_2/MJ)

Total Emission	Iron and steel	Chemical and petrochemical	Non-ferrous metals	Non-metallic minerals	Transport equipment	Machinery	Mining and quarrying	Food and tobacco	Paper pulp and printing	Wood and wood products	Textile and leather	Construction	Road	Rail	Domestic aviation	Domestic navigation	Other Consumption	Agriculture forestry and fishing	Commerce and public services
Coal (million tons)	36.06	3.05	0.59	1.17	0.22	0.00	0.01				0.00						0.37	0.00	0.37
Natural Gas (million tons)	3.65	24.85	1.21	5.97	1.19	2.52	0.55	4.08	2.14	0.31	0.65	4.25	177.97	0.46	10.06	8.75	78.06	11.42	34.69
Oil Products (million tons)	5.38	4.28	1.04	1.63	1.37	3.04		3.97	1.55	0.05	0.47	0.12	0.09				36.48	0.00	18.44

Model Results

Total Emission (million tCO2) = 492

Model 5 – Sectoral emission using emission intensity (ton CO_2 /USD)

Total Emission (million tCO_2) = Output to meet total demand(Million USD) * Emission Intensity(tCO2/USD)

Assumptions :

1. Using actual CO_2 emission data to calculate emission intensity (Source: OECD)
2. Emission Intensity = CO_2 emission (tonnes) / Output at base price
3. Multiplication of Output (X_i) generated to meet total demand with emission intensity

$$\mathbf{T} = \mathbf{B}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}$$

Source:

Yang, Y. and Suh, S., 2011. Environmental impacts of products in China. Environmental science & technology, 45(9), pp.4102-4109.

Yang, Y., Ingwersen, W.W., Hawkins, T.R., Srocka, M. and Meyer, D.E., 2017. USEEIO: A new and transparent United States environmentally-extended input-output model. Journal of cleaner production, 158, pp.308-318.

Yang, Y., Park, Y., Smith, T.M., Kim, T. and Park, H.S., 2022. High-Resolution Environmentally Extended Input–Output Model to Assess the Greenhouse Gas Impact of Electronics in South Korea. Environmental Science & Technology, 56(4), pp.2107-2114. file:///C:/Users/snmal/OneDrive/Desktop/energies-15-06104-v2.pdf

	Agriculture & Fishing	Mining	Services	Food	Textile	Wood	Paper	Coke and petroleum products	Chemical and chemical products	Other non-metallic mineral products	Basic metals Fabricated metal products	Electronics	Electrical equipment	Transport equipment	Electricity, gas, steam and air conditioning supply	Water supply	Construction	Land transport and transport via pipelines	Water & Air transport	Public administration
tCO2 (million)	11.99	2.68	70.84	9.33	1.08	0.44	10.61	31.01	34.48	19.33	70.90	6.67	0.74	1.34	437.25	1.54	11.29	11.70	57.30	8.54
OUTPUT (USD million)	111408	5491	4383036	307157	34152	21113	107965	162736	397721	55687	453762	684955	162791	525041	233616	87333	560316	223002	71054	340931
EMISSION INTENSITY (tCO2/USD)	1.1E-04	4.9E-04	1.6E-05	3.0E-05	3.2E-05	2.1E-05	9.8E-05	1.9E-04	8.7E-05	3.5E-04	1.6E-04	9.7E-06	4.5E-06	2.6E-06	1.9E-03	1.8E-05	2.0E-05	5.2E-05	8.1E-04	2.5E-05

Model Assumptions

Model 5 – Sectoral emission using emission intensity (tonnes CO_2 /USD)

$$\mathbf{T} = \mathbf{B}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}$$

```
set i 'sector' /S1*S20/;

alias (i,j);

parameter t(i,*);
$CALL GDXXRW JAPANINPUT_V2.xlsx par=t rng=COEFFOUT_INPUT!A1:U21
$GDXIN JAPANINPUT_V2.gdx
$LOAD t
$GDXIN

parameter td(i,*) ;
$CALL GDXXRW JAPANINPUT_V2.xlsx par=td rng=TOTDEMAND_INPUT!A1:B21
$GDXIN JAPANINPUT_V2.gdx
$LOAD td
$GDXIN

parameter ei(i,*) ;
$CALL GDXXRW JAPANINPUT_V2.xlsx par=ei rng=EMISSIONINTUSD_INPUT!A1:B21
$GDXIN JAPANINPUT_V2.gdx
$LOAD ei
$GDXIN

Variable x(i), sectemiss(i), dummy;

equation e1, edum, e2;
e1(i).. x(i) - sum(j, t(i,j)*x(j)) =e= td(i,'Total Demand');
e2(i).. x(i)*ei(i,'EI') =e= sectemiss(i);
edum.. dummy =e= 0;

model m /all/;

solve m using lp minimizing dummy;

display x.l;
display td;
display sectemiss.l;
```

	Emission Intensity (tCO2/USD)	X(i) Output to meet domestic demand (USD million) (From GAMS model)	X(i) Output to meet total demand (USD million) (From GAMS model)	Total Emission considering domestic demand (million tCO2)	Total Emission considering total demand (million tCO2)
Agriculture & Fishing	1.08E-04	140303.1035	110188.00	15.10	11.86
Mining	4.87E-04	139706.1333	4589.87	68.06	2.24
Services	1.62E-05	4381455	4326535	70.82	69.93
Food	3.04E-05	351296	303722	10.67	9.23
Textile	3.15E-05	67730	32124	2.14	1.01
Wood	2.10E-05	29173	20635	0.61	0.43
Paper	9.83E-05	109090	106654	10.72	10.48
Coke and petroleum products	1.91E-04	185535	160460	35.35	30.57
Chemical and chemical products	8.67E-05	371884	393433	32.24	34.11
Other non-metallic mineral products	3.47E-04	52714	55467	18.29	19.25
Basic metals & Fabricated metal products	1.56E-04	383727	451433	59.96	70.54
Electronics	9.73E-06	618346	678817	6.02	6.61
Electrical equipment	4.54E-06	140556	161818	0.64	0.73
Transport equipment	2.56E-06	300946	523405	0.77	1.34
Electricity, gas, steam and air conditioning supply	1.87E-03	238452	232249	446.31	434.69
Water supply	1.76E-05	88014	86921	1.55	1.53
Construction	2.02E-05	561534	560146	11.32	11.29
Land transport and transport via pipelines	5.24E-05	223561	215665	11.73	11.31
Water & Air transport	8.06E-04	60185	68872	48.54	55.54
Public administration	2.51E-05	343462	340803	8.60	8.54
			TOTAL	**859.43**	**791.24**

Model Results

Model 6 – Sectoral emission using emission intensity (tonnes CO_2 /USD) with constraint

```
set i 'sector' /S1*S20/;

alias (i,j);

parameter t(i,*);
$CALL GDXXRW JAPANINPUT_V2.xlsx par=t rng=COEFFOUT_INPUT!A1:U21
$GDXIN JAPANINPUT_V2.gdx
$LOAD t
$GDXIN

parameter td(i,*) ;
$CALL GDXXRW JAPANINPUT_V2.xlsx par=td rng=TOTDEMAND_INPUT!A1:B21
$GDXIN JAPANINPUT_V2.gdx
$LOAD td
$GDXIN

parameter ei(i,*) ;
$CALL GDXXRW JAPANINPUT_V2.xlsx par=ei rng=EMISSIONINTUSD_INPUT!A1:B21
$GDXIN JAPANINPUT_V2.gdx
$LOAD ei
$GDXIN

Variable x(i), sectemiss(i), dummy, alpha;

equation e1, edum, e2,e3;
e1(i).. x(i) - sum(j, t(i,j)*x(j)) =e= alpha*td(i,'Total Demand');
e2(i).. x(i)*ei(i,'EI') =e= sectemiss(i);
e3.. sum(i,sectemiss(i)) =l= 700;
edum.. dummy =e= 0;

model m /all/;

solve m using lp maximizing alpha;

display x.l;
display td;
display sectemiss.l;
```

To reduce total CO_2 emission from 791 million tonnes to 700 million tonnes, Japan need to reduce demand by 12% in all the sectors.

	Total Emission considering total demand with constraints (million tCO2)
Agriculture & Fishing	10.43
Mining	1.97
Services	61.54
Food	8.12
Textile	0.89
Wood	0.38
Paper	9.23
Coke and petroleum products	26.90
Chemical and chemical products	30.01
Other non-metallic mineral products	16.94
Basic metals & Fabricated metal products	62.08
Electronics	5.81
Electrical equipment	0.65
Transport equipment	1.18
Electricity, gas, steam and air conditioning supply	382.53
Water supply	1.35
Construction	9.94
Land transport and transport via pipelines	9.95
Water & Air transport	48.88
Public administration	7.51
	696.29

Model Results

Model 7a – Carbon Tax Revenue from each sector (million USD)

The Carbon Tax is calculated ex-post analysis.

```
1  set i 'sector' /S1*S20/;
2
3  alias (i,j);
4
5  parameter t(i,*);
6  $CALL GDXXRW JAPANINPUT_V2.xlsx par=t rng=COEFFOUT_INPUT!A1:U21
7  $GDXIN JAPANINPUT_V2.gdx
8  $LOAD t
9  $GDXIN
10
11 parameter td(i,*) ;
12 $CALL GDXXRW JAPANINPUT_V2.xlsx par=td rng=TOTDEMAND_INPUTV!A1:B21
13 $GDXIN JAPANINPUT_V2.gdx
14 $LOAD td
15 $GDXIN
16
17 parameter ei(i,*) ;
18 $CALL GDXXRW JAPANINPUT_V2.xlsx par=ei rng=EMISSIONINTUSD_INPUT!A1:B21
19 $GDXIN JAPANINPUT_V2.gdx
20 $LOAD ei
21 $GDXIN
22
23 Variable x(i), sectemiss(i), dummy, cbtaxsect(i);
24
25 equation e1, edum, e2,e3;
26 e1(i).. x(i) - sum(j, t(i,j)*x(j)) =e= td(i,'Total Demand');
27 e2(i).. x(i)*ei(i,'EI') =e= sectemiss(i);
28 e3(i).. sectemiss(i)*2.16 =e= cbtaxsect(i);
29 edum.. dummy =e= 0;
30
31 model m /all/;
32
33 solve m using lp minimizing dummy;
34
35 display x.l;
36 display td;
37 display sectemiss.l;
```

Assumption	USD/t CO2
Carbon Tax	2.16

Model Assumption

	Revenue from Carbon Tax (million USD)
Agriculture & Fishing	22.54
Mining	4.25
Services	132.92
Food	17.54
Textile	1.93
Wood	0.82
Paper	19.93
Coke and petroleum products	58.11
Chemical and chemical products	64.83
Other non-metallic mineral products	36.59
Basic metals & Fabricated metal products	134.08
Electronics	12.56
Electrical equipment	1.40
Transport equipment	2.54
Electricity, gas, steam and air conditioning supp	826.27
Water supply	2.91
Construction	21.46
Land transport and transport via pipelines	21.50
Water & Air transport	105.58
Public administration	16.23

Model Results

Japan would collect a total of **USD 1.5 billions** in **carbon taxes** alone on **700 million tonnes of CO_2 emissions**.

Model 7b – Carbon Tax impact on output

The Carbon Tax is subtracted from total demand to find impact of carbon tax on output of each sector.

```
set i 'sector' /1*20/
alias (i,j);

parameter t(i,*);
$CALL GDXXRW JAPANINPUT_V2.xlsx par=t rng=COEFFOUT_INPUT!A1:U21
$GDXIN JAPANINPUT_V2.gdx
$LOAD t
$GDXIN

parameter td(i,*) ;
$CALL GDXXRW JAPANINPUT_V2.xlsx par=td rng=TOTDEMAND_INPUTV!A1:B21
$GDXIN JAPANINPUT_V2.gdx
$LOAD td
$GDXIN

parameter ei(i,*) ;
$CALL GDXXRW JAPANINPUT_V2.xlsx par=ei rng=EMISSIONINTUSD_INPUT!A1:B21
$GDXIN JAPANINPUT_V2.gdx
$LOAD ei
$GDXIN

Variable x(i), sectemiss(i), dummy, cbtaxsect(i);

equation e1, edum, e2,e3;
e1(i).. x(i) - sum(j, t(i,j)*x(j)) =e= td(i,'Total Demand')-cbtaxsect(i);
e2(i).. x(i)*ei(i,'EI') =e= sectemiss(i);
e3(i).. sectemiss(i)*2.16 =e= cbtaxsect(i);

edum.. dummy =e= 0;

model m /all/;

solve m using lp minimizing dummy;

display x.l;
display td;
display sectemiss.l;
```

	Revenue from Carbon Tax (million USD) - Ex-post analysis	Revenue from Carbon Tax (million USD) - Impact of output	Total output produced after without considering impact of carbon tax	Total output produced after considering impact of carbon tax
Agriculture & Fishing	22.54	22.53	96965.47	96925.40
Mining	4.25	4.15	4039.08	3944.58
Services	132.92	132.89	3807350.85	3806445.64
Food	17.54	17.54	267275.60	267234.35
Textile	1.93	1.92	28269.37	28257.55
Wood	0.82	0.82	18159.08	18148.66
Paper	19.93	19.91	93855.78	93793.56
Coke and petroleum products	58.11	58.03	141204.52	140990.78
Chemical and chemical products	64.83	64.79	346221.26	346037.28
Other non-metallic mineral products	36.59	36.55	48811.07	48763.20
Basic metals & Fabricated metal products	134.08	133.99	397261.03	396976.89
Electronics	12.56	12.55	597358.71	597221.80
Electrical equipment	1.40	1.40	142400.23	142376.02
Transport equipment	2.54	2.54	460596.29	460547.37
Electricity, gas, steam and air conditioning supply	826.27	821.98	204379.00	203318.38
Water supply	2.91	2.91	76490.27	76464.37
Construction	21.46	21.46	492928.28	492890.68
Land transport and transport via pipelines	21.50	21.49	189785.56	189690.91
Water & Air transport	105.58	105.34	60607.52	60467.43
Public administration	16.23	16.23	299906.82	299888.49
Total	**1503.99**	**1499.02**	**7773865.78**	**7770383.38**

Japan would produce a total of **USD 3.4 billions worth of product less after carbon taxes** on **700 million tonnes of CO_2 emissions**.

Model 8 – Abatement Measure for Net Zero by 2030 in Japan

Price Assumptions	Prices (USD/tCO_2)
Afforestation & Reforestation	24.5
Bio-energy based CCUS	152
Direct Air Carbon Capture	512
Others ex- RE, Efficiency improvement	-

Constraints	In million tCO_2
Afforestation & Reforestation	51
Bio-energy based CCUS	173
Direct Air Carbon Capture	
Others ex- RE, Efficiency improvement	-

Model Assumptions

Source:
https://repositorio.cepal.org/bitstream/handle/11362/48691/1/S2201263_en.pdf
https://www.oecd.org/regional/regional-policy/land-use-Japan.pdf
https://www.mckinsey.com/capabilities/sustainability/our-insights/how-japan-could-reach-carbon-neutrality-by-2050

Model 8 – Abatement Measure for Net Zero by 2030 (contd.)

```
set i 'sector' /S1*S20/;

alias (i,j);

parameter t(i,*);
$CALL GDXXRW JAPANINPUT_V2.xlsx par=t rng=COEFFOUT_INPUT!A1:U21
$GDXIN JAPANINPUT_V2.gdx
$LOAD t
$GDXIN

parameter td(i,*) ;
$CALL GDXXRW JAPANINPUT_V2.xlsx par=td rng=TOTDEMAND_INPUT!A1:B21
$GDXIN JAPANINPUT_V2.gdx
$LOAD td
$GDXIN

parameter ei(i,*) ;
$CALL GDXXRW JAPANINPUT_V2.xlsx par=ei rng=EMISSIONINTUSD_INPUT!A1:B21
$GDXIN JAPANINPUT_V2.gdx
$LOAD ei
$GDXIN

scalar aff_abt /24.5/
       beccus_abt /152/
       daccus_abt /512/
       ocfer_abt /229/;

Variable x(i), sectemiss(i), Z, cbtaxsect(i), Y;
Variable A, B, D, Oth;

equation e1, edum, e2,e3, cost,afflimit, ccuslimit;
e1(i).. x(i) - sum(j, t(i,j)*x(j)) =e= td(i,'Total Demand');
e2(i).. x(i)*ei(i,'EI') =e= sectemiss(i);
e3.. sum(i,sectemiss(i)) =e= Z;
edum.. Z - (A + B + D + Oth) =e= 0;
cost.. Y =e= A*aff_abt + B*beccus_abt + D*daccus_abt;
afflimit.. A =l= 51;
ccuslimit.. B + D =l= 173;

model m /all/;

solve m using lp minimizing Y;

display x.l;
display td;
```

Model Results

	LOWER	LEVEL
VAR Z	-INF	791.2385
VAR Y	-INF	27545.5000
VAR A	-INF	51.0000
VAR B	-INF	173.0000
VAR D	-INF	.
VAR Oth	-INF	567.2385

Total Emission

CO2 Abatement Cost

Afforestation Abatement (MtCO2)

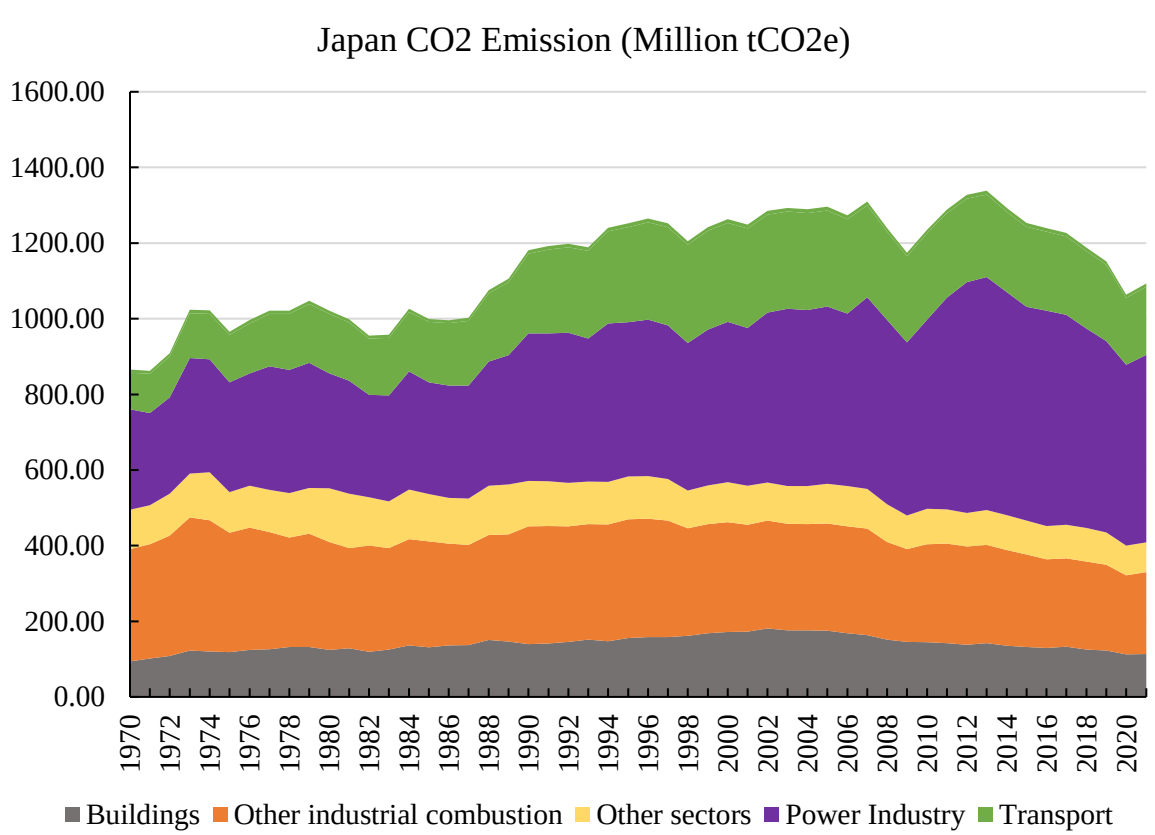
CCUS Abatement (MtCO2)

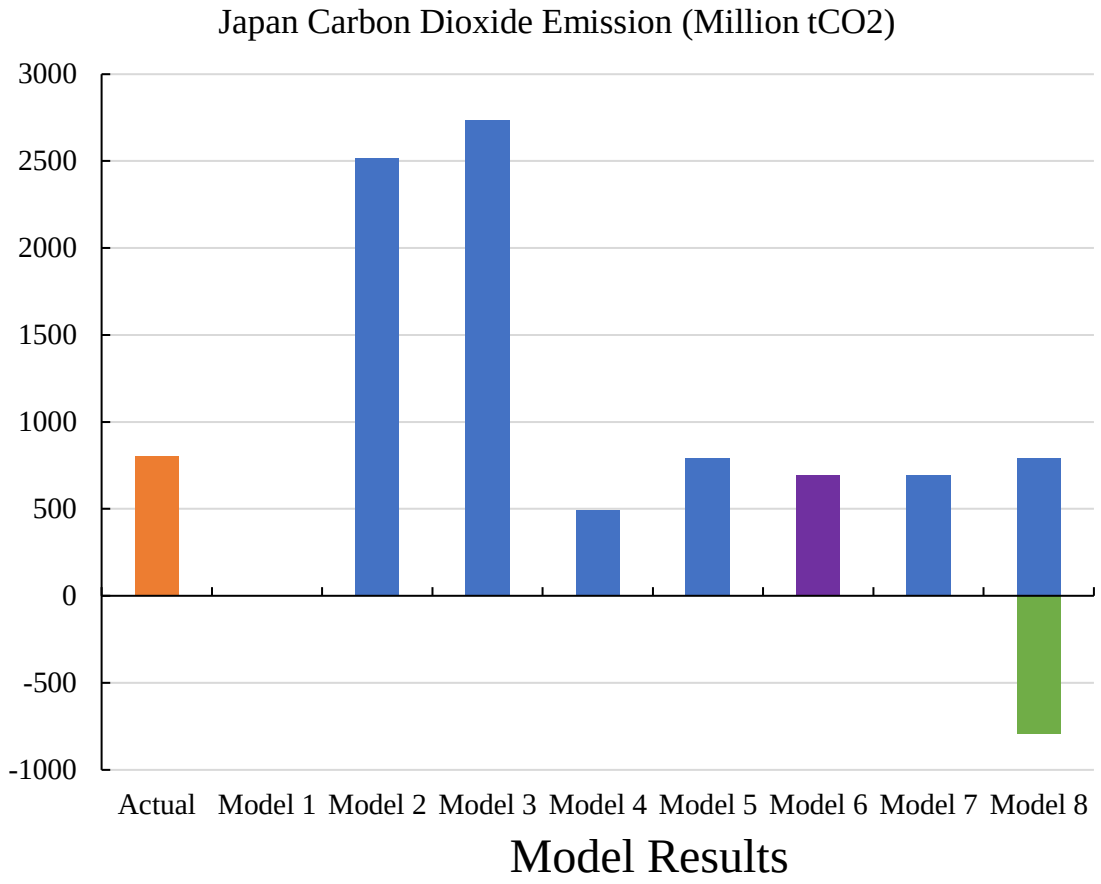
Other Abatement (MtCO2)

It would cost Japan **USD 27.5 billions** in **afforestation** and **CCUS technologies** alone to reduce **224 million tonnes** of CO_2 from the atmosphere by 2030.

Rest **567 million tonnes** of CO_2 could be reduced by other methods like RE transition, energy efficiency, green hydrogen transition, EV, etc.

Comparison of models





Source: Crippa, M., Guizzardi, D., Banja, M., Solazzo, E., Muntean, M., Schaaf, E., Pagani, F., Monforti-Ferrario, F., Olivier, J., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Grassi, G., Rossi, S., Jacome Felix Oom, D., Branco, A., San-Miguel-Ayanz, J. and Vignati, E., CO2 emissions of all world countries - 2022 Report, EUR 31182 EN, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/730164, JRC130363

Comparison of Model Results with actual emission

Thank you