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Estimation of Taiwan's CO_2 Emissions Related to Fossil Fuel Combustion – A Sectoral Approach

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1. Introduction

In terms of annual carbon dioxide (CO_2) emissions, Taiwan emitted 293.66 million metric tons of CO_2 in 2007 and the volume was down to 279.14 million metric tons in 2009. However, from 2007 to 2009, Taiwan's CO_2 emission ranking rose from the 22nd to the 21st largest emitter in the world. International comparisons of total CO_2 emissions are shown in Table 1. After the Kyoto Protocol entered into force in 2005, the Taiwanese government convened its second National Energy Conference.[3] The Taiwan Environmental Protection Administration (EPA), designated as the leading government agency in greenhouse gas policy, submitted its Greenhouse Gas Reduction Bill to the legislature in 2006. Unfortunately, the Greenhouse Gas Reduction Bill was not passed.

After President Ma Ying-jeou took office in 2008, he announced his target of stabilizing Taiwan's GHG emissions at 2008 levels by 2020. Furthermore, the Committee of Carbon Reduction of the Executive Yuan has proposed a national target for reducing carbon dioxide in fuel emissions, dropping to 2005 levels by 2020 and to 2000 levels by 2025. The EPA resubmitted the Greenhouse Gas Reduction Bill to the legislature in 2008. It is still being considered, but if it passes, the bill would authorize the EPA to regulate GHGs with a cap-and-trade scheme and sectoral emission performance standards. That is, the government of Taiwan is considering setting up a carbon trading exchange.

Accordingly, the understanding of the historical allocation of the carbon dioxide emission across sectors and industries becomes very important. This information will allow the government to evaluate the potential trading volume of a future domestic carbon market. To get a grip on the issue of potential trading volume, we start from estimating Taiwan's CO_2 emission levels. Since the largest source of CO_2 emissions is from the oxidation of carbon

[3] As a response to the Kyoto Protocol, the government convened the first National Energy Conference in 1998.

Units: Million Metric Tons

Ranking	Country	Year 2007	Ranking	Country	Year 2009
1	China	6256.704	1	China	7706.826
2	United States	6018.131	2	United States	5424.53
3	Russia	1627.203	3	India	1591.126
4	India	1368.383	4	Russia	1556.661
5	Japan	1254.438	5	Japan	1097.965
6	Germany	827.2343	6	Germany	765.5618
7	Canada	610.0027	7	Canada	540.9669
8	United Kingdom	569.8945	8	Iran	528.6026
9	Korea, South	503.0997	9	Korea, South	528.1344
10	Iran	489.3254	10	United Kingdom	519.944
11	South Africa	463.7263	11	South Africa	451.2196
12	Italy	459.5288	12	Mexico	443.6122
13	Mexico	444.2595	13	Saudi Arabia	438.2468
14	France	423.0563	14	Brazil	425.1693
15	Australia	410.3513	15	Australia	417.6815
16	Brazil	400.4417	16	Indonesia	414.9409
17	Saudi Arabia	396.4678	17	Italy	407.866
18	Indonesia	390.2196	18	France	396.6518
19	Spain	387.9257	19	Spain	329.8573
20	Ukraine	354.0988	20	Poland	285.7852
21	Poland	295.9488	21	Taiwan	279.1429
22	Taiwan	293.6621	22	Thailand	254.8797
23	Turkey	280.1906	23	Turkey	253.0567
24	Netherlands	258.1038	24	Ukraine	252.4726
25	Thailand	247.3535	25	Netherlands	248.9068

Source: International Energy Statistics, U.S. Energy Information Administration, http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8.

Table 1. Total Carbon Dioxide Emissions from the Consumption of Energy

when fossil fuels are burned,[4] IPCC makes sectoral emissions estimates based on fuel consumption. In Taiwan's recent inventories of greenhouse gas emissions, estimates of CO_2 emissions carried out by the Bureau of Energy were calculated in accordance with IPCC methodology. However, the estimation breaks down the CO_2 emissions by sector (energy

[4] Fossil fuel combustion accounts for 70-90 percent of total anthropogenic CO_2 emissions. (IPCC, 1997a)

sector, industrial sector, transportation sector, agricultural sector, service sector, and residential sector).

Attempting to delineate the CO_2 emissions of Taiwan, we further estimate Taiwan's fossil fuel CO_2 emissions by subsector/industry.

2. Research Methodology

In this section, the methodology for estimating CO_2 emissions from energy is discussed. Following the IPCC Guidelines for National Greenhouse Gas Inventories,[5] we estimate 2005-2010 CO_2 emissions based on fuel consumption data by sub-sectoral activity. Individual subsector's fuel consumption data were obtained from the Energy Balance Sheet compiled by the Bureau of Energy.[6] Table 2 gives a list of subsectors and industries included in the sample.

Therefore, CO_2 emissions from fuel combustion by fuel type j for each subsector (industry) i in year t is calculated as follows:[7]

$$\boldsymbol{CO_2}\textbf{emission}_{i,t} = \sum_{j}[\boldsymbol{carbon\ content\ for\ fuel\ j - carbon\ stored\ for\ fuel\ j}] * \boldsymbol{fraction\ of\ carbon\ oxidized\ for\ fuel\ j} * \frac{\mathbf{44}}{\mathbf{12}} + \boldsymbol{CO_2}\ \textbf{emissions from electricity consumption for each subsector}\ \boldsymbol{i}$$

where

$$\boldsymbol{carbon\ content\ for\ fuel\ j} = \boldsymbol{fuel\ consumption\ expressed\ in\ energy\ units\ (TJ)\ for\ fuel\ j} * \boldsymbol{carbon\ emission\ factor\ for\ fuel\ j}\ ;$$

$$\boldsymbol{carbon\ stored\ for\ fuel\ j} = \boldsymbol{carbon\ content\ for\ fuel\ j} * \boldsymbol{fraction\ of\ carbon\ stored\ for\ fuel\ j}\ ;$$

$$\boldsymbol{CO_2}\ \textbf{emissions from electricity consumption for each subsector}\ \boldsymbol{i} = \textbf{total}\ \boldsymbol{CO_2\ emissions\ from\ electricity} * [\boldsymbol{electricity\ consumption\ for\ subsector\ i} / (\boldsymbol{total\ electricity\ consumption})]$$

[5] The IPCC Guidelines were first accepted in 1994 and published in 1995. UNFCCC COP3 held in 1997 in Kyoto reaffirmed that the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories should be used as "methodologies for estimating anthropogenic emissions by sources and removals by sinks of greenhouse gases" in calculation of legally-binding targets during the first commitment period. http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html.

[6] http://www.moeaboe.gov.tw/English/Statistics/EnStatistics.aspx.

[7] http://www.ixon.com.tw/

Sector	Subsector or industry	
Energy sector	Coal Mines Coke Ovens Blast Furnaces Oil and Gas Extraction Petroleum Refineries	Electricity Plants Electricity to Pump Up Cogeneration Plants Gas Companies
Industrial sector	Mining and Quarrying Food, Beverage and Tobacco Textile, Wearing Apparel and Accessories Leather and Fur Wood, Bamboo and Furniture Pulp, Paper and Paper Product Printing Basic Industrial Chemicals Petrochemical Materials Chemical Fertilizers Artificial Fibers Resin, Plastics and Rubber Other Chemical Materials Chemical Products	Rubber Products Plastic Products Cement and Cement Products Others (Pottery, China, and etc.) Iron and Steel Non-metal Fabricated Metal Products Machinery and Equipments Electrical and Electronic Machinery Transport Equipments Precision Instruments Miscellaneous Industries Water Supply Construction
Transportation sector	Domestic Air Road	Rail Internal Navigation
Agriculture Sector	Agriculture, Animal Husbandry and Forestry Fishing and Aquaculture	
Service Sector	Wholesale and Retail Hotels and Restaurants Transport Services Storage and Warehousing Communication	Finance, Insurance and Real Estate Business Services Social and Personal Services Public Administration Not Specified Services
Residential Sector		

Table 2. Subsectors or Industries included in the sample

That is, using IPCC methodology as the basis, the estimation process can be divided into six steps that lead to figures for CO_2 emissions from fuel combustion.

1) Obtain the amount of each fuel consumed by each sub-sector.
Since heating value data provided by the Bureau of Energy are in 10^7 kilocalories, we multiply the consumption by 0.04184 to give the amounts of all fuels in terajoules (TJ).

2) Estimate total carbon content in fuels.
Carbon content represents the total amount of carbon that could be emitted if 100 percent were released to the atmosphere. To estimate the carbon content in tons of carbon, we multiply fuel consumption in TJ by the appropriate carbon emission factors (more precisely, the specific carbon content, t C/TJ). This calculation should be done for all fuel types in each sector. The carbon emission factors for each fuel type are shown in Table 3.

3) Estimate the amount of carbon stored in products.
After estimating the total carbon contained in the fuels, the next step is to estimate the amount of carbon from those fuels which are used for non-energy purposes. Some of the fuel supplied to an economy is used as a raw material (or feedstock) for the manufacture of products or in a non-energy use (e.g., bitumen for road construction, lubricants). Therefore, in some cases, the carbon from the fuels is oxidized quickly to CO_2, while in other cases the carbon is stored in the product, sometimes for as long as centuries. The amounts of stored carbon should be deducted from the calculation for total carbon emissions.

Fuel	Carbon Emission Factor (t C/TJ)	Fuel	Carbon Emission Factor (t C/TJ)
Solid Fossil		Liquid Fossil	
Anthracite	26.8	Crude Oil	20.0
Coking coal	25.8	Lubricants	20.0
Lignite	27.6	LPG	17.2
Peat	28.9	Natural Gasoline	17.2
Coke Oven Coke	29.5	Naphtha	20.0
Patent Fuel	25.8	Motor Gasoline	18.9
Coke Oven/Gas Coke	29.5	Aviation Gasoline	18.9
Bituminous Coal- Steam Coal	25.8	Jet Fuel- Kerosene	19.5
Sub-bituminous – Coal	26.2	Jet Fuel- Gasoline	19.5
Blast Furnace Gas	66	Kerosene	19.6
Refinery Gas	18.2	Diesel Oil	20.2
Oxygen Steel Furnace Gas	13	Fuel Oil	21.1
Coke Oven Gas	13.0	Asphalts	22.0
Gaseous Fossil		Solvents	20.0
Natural Gas (dry)	15.3	Petroleum Coke	27.5
		White Spirits	20.0
		Other Petroleum	20.0
		Paraffin Waxes	20.0
		Natural Gas Liquids	17.2

Source: IPCC (1997b). Revised 1966 IPCC Guidelines for National Greenhouse Gas Inventories: Workbook (Volume 2),
http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1wb1.pdf.

Table 3. Carbon Emission Factors

The amount of the carbon stored is obtained by multiplying the carbon content and fraction of carbon stored. Table 4 represents the fraction of carbon stored for different types of fuel. Since in Taiwan, lubricants and bitumen are used as raw materials and in non-energy consumption, the Bureau of Energy gives the figures of these two fuel types as 1.0. Naphtha and LPG are used as raw materials in the industry of Petrochemical Materials; consequently, the Bureau of Energy gives the figures of these two fuel types in Petrochemical Materials as 1.0, while in other industries as 0.

4) Account for carbon oxidized during combustion.

When energy is consumed, not all of the carbon in the fuel oxidizes to CO_2. Incomplete oxidation occurs due to inefficiencies in the combustion process that leave some of the carbon unburned or partly oxidized as soot or ash. The Intergovernmental Panel on Climate Change (IPCC) guidelines for calculating emissions inventories require that an oxidation factor be applied to the carbon content to account for the small portion of the fuel that is not oxidized into CO_2. Table 5 shows the fraction of carbon oxidized. For example, for all oil and oil products, the oxidation factor used is 0.99 (i.e., 99 percent of the carbon in the fuel is eventually oxidized, while 1 percent remains un-oxidized).

Fuel Type	IPCC version	Taiwan's version	
		Petrochemical	others
Naphtha	0.75	1.0	0.0
Lubricants	0.5	1.0	1.0
Bitumen	1.0	1.0	1.0
Coal Oils and Tars (from Coking Coal)	0.75		
Natural Gas	0.33		
Gas/Diesel Oil	0.50		
LPG	0.80	1.0	0.0
Ethane	0.80		

Source: Bureau of Energy (2011).

Table 4. Fraction of Carbon Stored

Fuel	Fraction of Carbon Oxidized
Coal	0.98
Oil and Oil Products	0.99
Gas	0.995
Petroleum Coke	0.99

Source: IPCC (1997a). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference manual Volume 3 Chapter 1.
http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ref1.pdf

Table 5. Oxidation Factors as given in the 1996 IPCC Guidelines

5) Convert emissions of carbon to the full molecular weight of CO_2.

Since the ratio of the molecular weight of CO_2 (m.w. 44) to the molecular weight of carbon (m.w. 12) is 44/12, i.e., one ton of carbon is equal to 44/12 tons of CO_2, all final estimates are

multiplied by 44/12 to convert net carbon emissions from energy consumption to total CO_2 emissions.

6) Estimate CO_2 emissions from electricity consumption.
In estimating CO_2 emissions, the Bureau of Energy in Taiwan provides a supplemental method which accounts for all fossil fuel combusted and all electricity consumption. That is, to estimate the CO_2 emissions in a given subsector, the emissions from fossil fuel combustion may be added to the emissions from electricity consumption. Following the approach of the Bureau of Energy, we first sum up electricity consumption from both the energy sector and the non-energy sector, and then distribute the total emissions in kWh across "end-use subsectors," according to the ratio of each sub-sector's electricity consumption to total electricity consumption.

3. Estimation Results

The purpose of this paper is to investigate CO_2 emissions from fossil fuels combustion across Taiwan's 57 subsectors (or industries). The estimates of CO_2 emissions and the related results are presented in the following section.

3.1 Level of Total CO_2 Emissions

Figure 1 shows that between 2005 and 2007, Taiwan's carbon dioxide emissions rose from approximately 250.3 million metric tons to 261.1 million metric tons and the corresponding per capita value rose from 10.99 metric tons to 11.37 metric tons. Thereafter, CO_2 emissions from fossil fuels combustion in 2008 and 2009 show a trend of decrease. Three main reasons contribute to this negative growth. The first may be the economic recession caused by the global financial crisis. The second is that energy consumption went down after the prices of oil and electricity were rationalized. The third is that the government is vigorously conducting related policies and measures on energy saving and carbon reduction. However, the total CO_2 emissions rose again in 2010 from 238.1 million metric tons to 252.9 million metric tons and CO_2 emissions per capita rose from 10.3 metric tons to 10.92 metric tons.

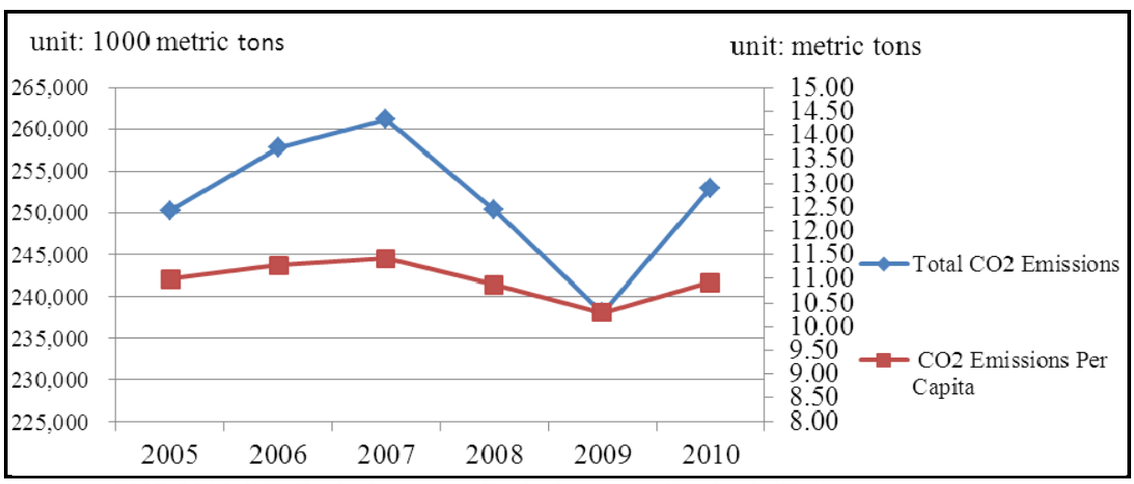


Figure 1. 2005-2010 CO_2 Emissions and Emissions per Capita in Taiwan

3.1.1 CO_2 Emission by Sector

If total CO_2 emissions from fossil fuels combustion are allocated to the economic sector, then the industrial sector emitted 46.4% (116,857,500 metric tons) of subtotal average CO_2 (251,783,300 metric tons) from fuel combustion, the transportation sector 14.1% (35,402,000 metric tons), the service sector14.0% (35,194,170 metric tons), the energy sector11.0% (27,606,330 metric tons), the residential sector12.7% (33,558,590 metric tons), and the agricultural sector 1.3% (3,164,270 metric tons).

Table 6 and Figure 2 show that the industrial sector dominated fossil fuel CO_2 emissions from 2005 to 2010.

Unit: 1000 metric tons

Sector	2005	2006	2007	2008	2009	2010	Average
Energy	28722.5 (11.5%)	29414.79 (11.4%)	29075.4 (11.1%)	26670.48 (10.7%)	25082.73 (10.5%)	26672.05 (10.5%)	27606.33 (11.0%)
Industrial	112628.1 (45.0%)	118306.34 (45.9%)	123527.7 (47.3%)	117509.5 (46.9%)	108637.2 (45.6%)	120536.3 (47.7%)	116857.5 (46.4%)
Transportation	36799.12 (14.7%)	36752.32 (14.3%)	35604.08 (13.6%)	33813.01 (13.5%)	34146.77 (14.3%)	35299.42 (14.0%)	35402.45 (14.1%)
Agricultural	4270.9 (1.7%)	3405.77 (1.3%)	2857.24 (1.1%)	3107.94 (1.2%)	2703.94 (1.1%)	2639.8 (1.0%)	3164.27 (1.3%)
Services	34474.35 (13.8%)	36081.85 (14.0%)	35942.53 (13.8%)	35677.02 (14.2%)	34212.58 (14.4%)	34776.67 (13.7%)	35194.17 (14.0%)
Residential	33447.02 (13.4%)	33851.27 (13.1%)	34133.79 (13.1%)	33592.29 (13.4%)	33305.59 (14.0%)	33021.59 (13.1%)	33558.59 (13.3%)
Total	250342 (100%)	257812.34 (100%)	261140.7 (100%)	250370.3 (100%)	238088.8 (100%)	252945.8 (100%)	251783.3 (100%)

Table 6. Aggregate Fossil Fuel CO2 Emission by Sector, 2005-2010

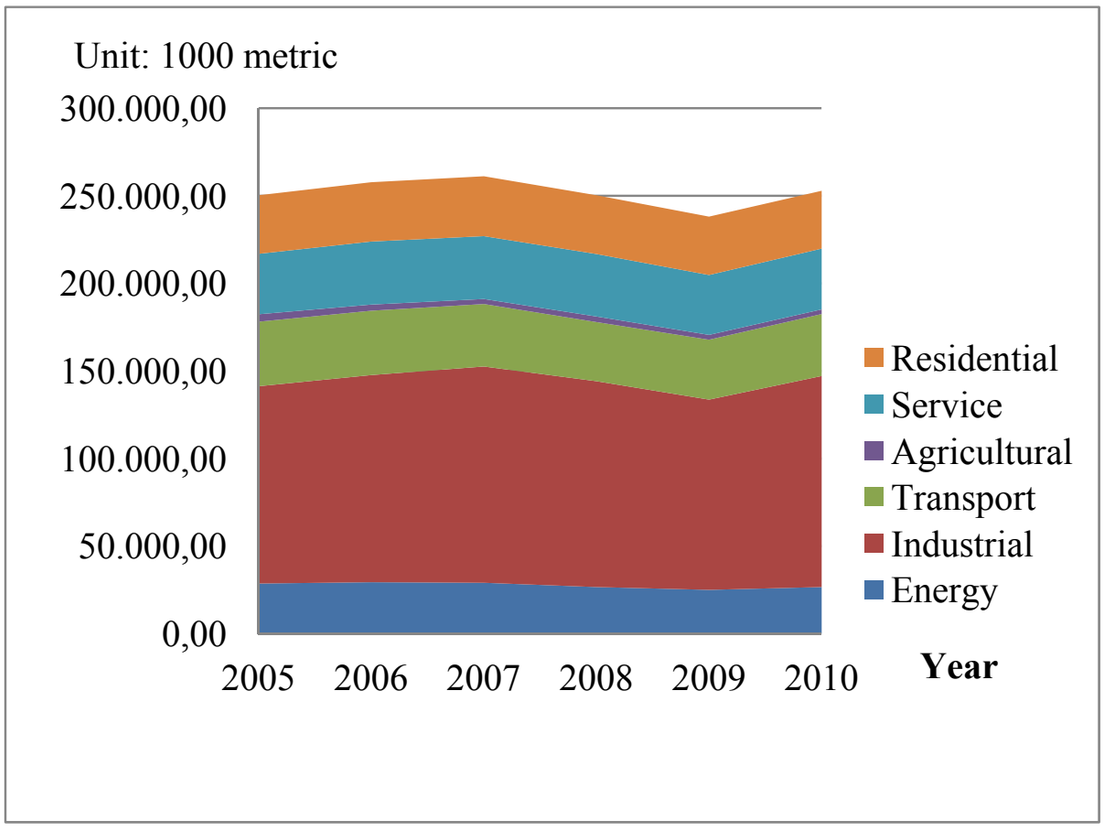


Figure 2. Taiwan's CO2 Emissions from Fuel Combustion, 2005-2010

3.1.2 CO_2 Emissions by Subsector

After further estimating CO_2 emissions from fuel combustion for each subsector, we obtain some important points on the industrial, transport, and energy sectors which need to be addressed.

Industrial sector

Aggregate data from 2005 to 2010 shows that around 46.4% of carbon dioxide emissions are attributable to the industrial sector. Electrical and Electronic Machinery, Petrochemical Materials, Iron and Steel and Artificial Fibers account for around one-half of this amount. CO_2 emissions from the industrial sector are presented in Table 7. The distribution of CO_2 emissions related to the industrial sub-sectors is shown in Figure 3.

Unit: metric tons

Sub-sector	2005	2006	2007	2008	2009	2010	Average
Mining and Quarrying	366,545	366,948	367,046	376,121	381,374	435,224	382,210
Food, Beverage and Tobacco	3,490,823	3,480,565	3,400,271	3,249,925	3,237,041	3,348,114	3,367,790
Textile, Wearing Apparel and Accessories	8,532,973	7,848,310	7,479,042	6,538,729	5,649,643	5,914,709	6,993,901
Leather and Fur	313,297	289,741	275,930	272,655	284,767	257,659	282,341
Wood, Bamboo and Furniture	331,688	338,114	335,333	320,223	283,124	301,477	318,326
Pulp, Paper and Paper Product	4,370,238	4,254,829	4,212,811	3,888,590	3,630,128	3,783,437	4,023,339
Printing	371,902	379,051	385,078	377,819	352,131	364,755	371,789
Basic Industrial Chemicals	3,059,326	3,291,378	3,208,213	2,509,519	2,342,075	2,397,367	2,801,313
Petrochemical Materials	13,716,142	14,952,806	18,630,290	17,503,780	16,994,752	18,591,606	16,731,563
Chemical Fertilizers	1,142,978	1,120,812	1,221,010	1,273,419	1,193,491	1,123,055	1,179,127
Artificial Fibers	7,462,358	7,944,708	8,537,250	7,495,414	7,045,735	7,839,318	7,720,797
Resin, Plastics and Rubber	4,850,328	5,580,850	5,704,723	5,161,846	4,887,555	5,425,261	5,268,427
Other Chemical Materials	1,258,578	1,301,359	1,234,661	922,640	1,034,539	1,153,908	1,150,947
Chemical Products	2,600,729	2,548,404	2,580,231	2,496,558	2,361,979	2,715,784	2,550,614
Rubber Products	934,244	915,705	940,179	930,477	864,426	999,875	930,818

Plastic Products	4,044,185	4,179,991	4,227,114	3,968,155	3,780,430	4,080,562	4,046,739
Cement and Cement Products	7,978,782	7,823,317	7,260,074	6,759,060	5,775,455	5,905,550	6,917,040
Others	3,598,231	3,930,897	3,980,277	3,999,902	3,681,233	4,305,275	3,915,969
Iron and Steel	14,504,718	15,627,904	15,584,547	14,903,393	12,931,939	15,738,728	14,881,871
Non-metal	1,108,608	1,090,043	1,107,395	1,034,513	871,250	988,295	1,033,351
Fabricated Metal Products	4,231,155	4,388,725	4,478,430	4,324,757	3,704,740	4,452,390	4,263,366
Machinery and Equipment	1,148,366	1,217,632	1,255,934	1,243,187	1,049,711	1,292,931	1,201,294
Electrical and Electronic Machinery	18,404,777	20,356,701	21,846,391	22,822,217	21,596,448	24,100,092	21,521,104
Transport Equipment	1,842,836	1,893,038	1,976,473	1,941,264	1,847,092	2,112,642	1,935,557
Precision Instruments	402,450	604,739	723,056	722,500	567,607	584,551	600,817
Miscellaneous Industries	1,048,149	1,058,022	1,043,500	963,693	867,631	896,664	979,610
Water Supply	846,637	897,638	917,484	904,818	862,141	869,290	883,002
Construction	667,115	624,138	614,975	604,369	558,787	557,767	604,525
Total	112,628,153	118,306,364	123,527,720	117,509,541	108,637,223	120,536,284	116,857,547

Table 7. CO_2 Emissions from Industrial Sector, 2005-2010

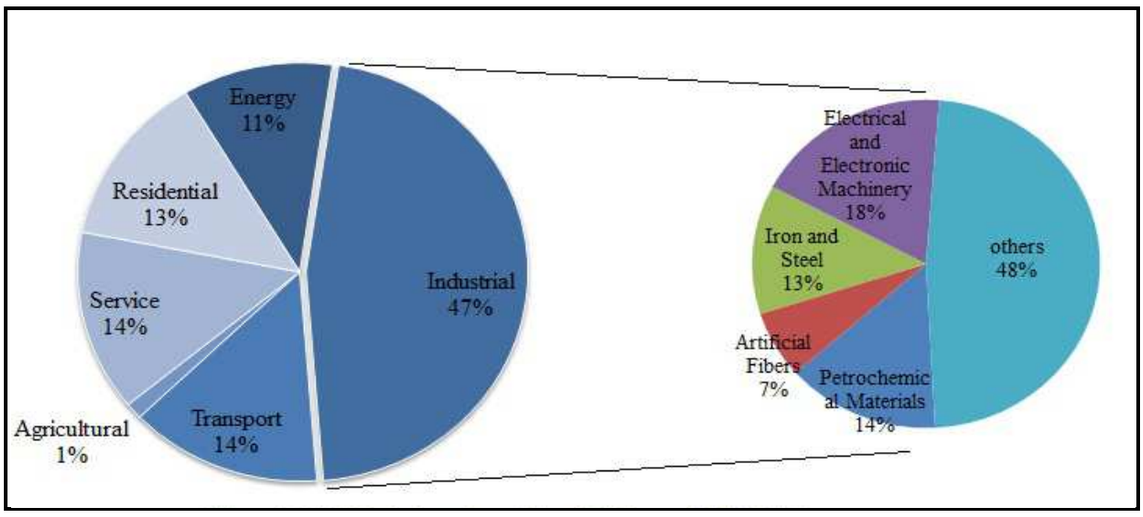


Figure 3. CO_2 Emissions from Industrial Sector, 2005-2010

Transport Sector

The transport sector, the second largest emitting sector, contributes 14.1% of the total CO_2 emissions in Taiwan. CO_2 emissions from the transport sector are shown in Table 8. In the transport sector, road transport is responsible for a significant share of the CO_2 emissions as shown in Figure 4.

Unit: metric tons

Sub-sectors	2005	2006	2007	2008	2009	2010	Average
Domestic Air	586,101.1	510,875.6	386,334.7	256,321.4	225,937.9	228,419.8	365,665.1
Road	34,644,467.5	34,714,511.4	33,612,956.1	31,955,343.2	32,330,742.1	33,375,030.1	33,438,841.7
Rail	446,111.9	469,986.7	654,017.4	831,505.4	807,533.1	839,938.7	674,848.9
Internal Navigation	1,122,435.9	1,056,947.8	950,773.8	769,841.7	782,556.6	856,034.7	923,098.4
Total	36,799,116.4	36,752,321.5	35,604,082.0	33,813,011.7	34,146,769.7	35,299,423.3	35,402,454.1

Table 8. CO_2 Emissions from the Transport Sector, 2005-2010

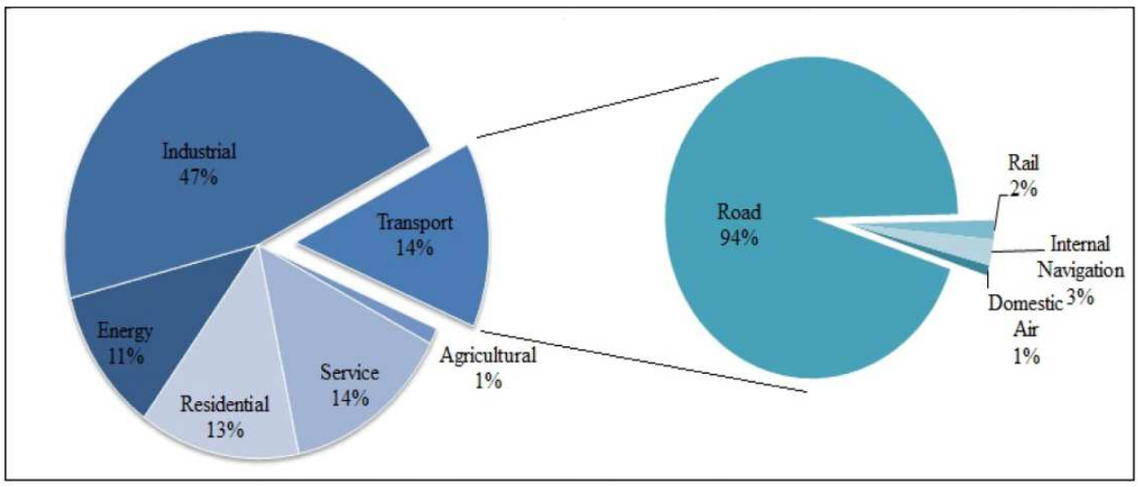
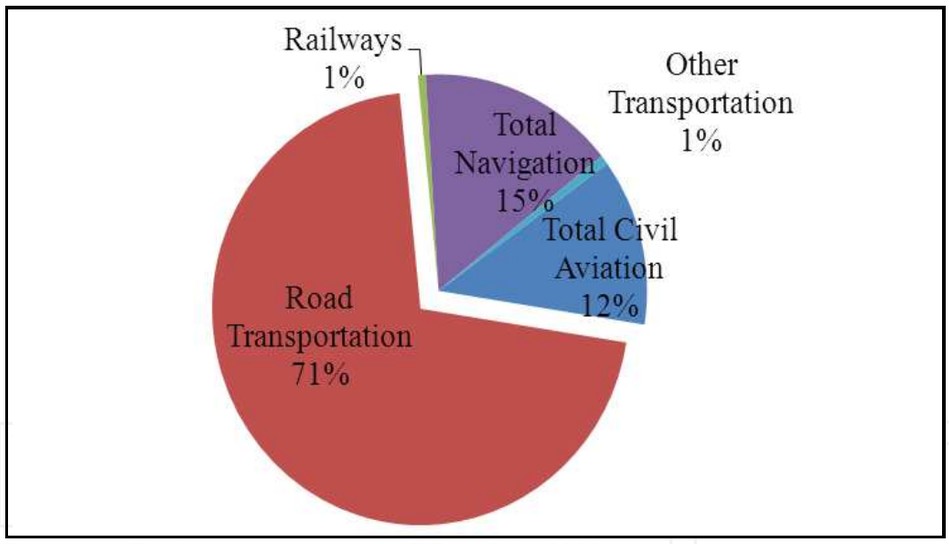


Figure 4. CO_2 Emissions from Transportation Sector, 2005-2010

The fact that road activity generates the most CO_2 emissions means that road vehicles, including motorcycles, passenger cars and trucks, account for approximately 94% of all transport-related CO_2 emissions. This percentage is much higher than that of EU 27, which can be seen from Figure 5.



Source: European Environment Agency (EEA), July 2009

Figure 5. Share by Mode in Total Transport CO_2 Emissions, including International Bunkers : EU27(2007)

Energy Sector

The energy sector, the fifth largest CO_2 emitter, accounts for 11.0% of total CO_2 emissions. From 2005 to 2010, the petroleum refineries industry accounted for the major share (35% on average) of total CO_2 emissions in the energy sector, followed by electricity plants and blast furnaces. CO_2 emissions from the energy sector are presented in Table 9.The distribution of CO_2 emissions related to the energy sector is shown as Figure 6.

Unit: metric tons

Sub-Sectors	2005	2006	2007	2008	2009	2010	Average
Coal Mines	5,897.5	2,583.1	5,688.6	5,038.5	6,022.2	5,082.7	5,052.1
Coke Ovens	3,079,585.4	3,158,183.8	3,134,733.0	2,951,828.4	2,530,175.0	3,388,922.5	3,040,571.4
Blast Furnaces	3,572,462.4	3,866,130.9	4,043,693.0	3,920,091.1	3,385,142.1	4,227,864.3	3,835,897.3
Oil and Gas Extraction	58,481.1	57,234.1	45,683.8	10,857.1	10,705.7	9,505.5	32,077.9
Petroleum Refineries	11,187,078.6	10,776,132.1	10,151,043.1	8,792,185.8	8,690,228.1	8,783,988.3	9,730,109.3
Electricity Plants	6,280,975.6	6,614,605.4	6,740,893.6	6,599,869.4	6,200,770.3	6,320,543.7	6,459,609.7
Pump-Generated Electricity	3,090,802.0	3,201,415.9	3,020,076.4	2,656,614.9	2,663,217.0	2,346,080.3	2,829,701.1
Cogeneration Plants	1,028,417.7	1,257,728.3	1,437,248.7	1,183,130.8	1,313,200.3	1,344,551.6	1,260,712.9
Gas Companies	418,796.7	480,773.4	496,344.1	550,863.7	283,266.0	245,509.4	412,592.2
Total	28,722,497.0	29,414,787.0	29,075,404.3	26,670,479.7	25,082,726.7	26,672,048.3	27,606,323.9

Table 9. CO2 Emissions from the Energy Sector, 2005-2010

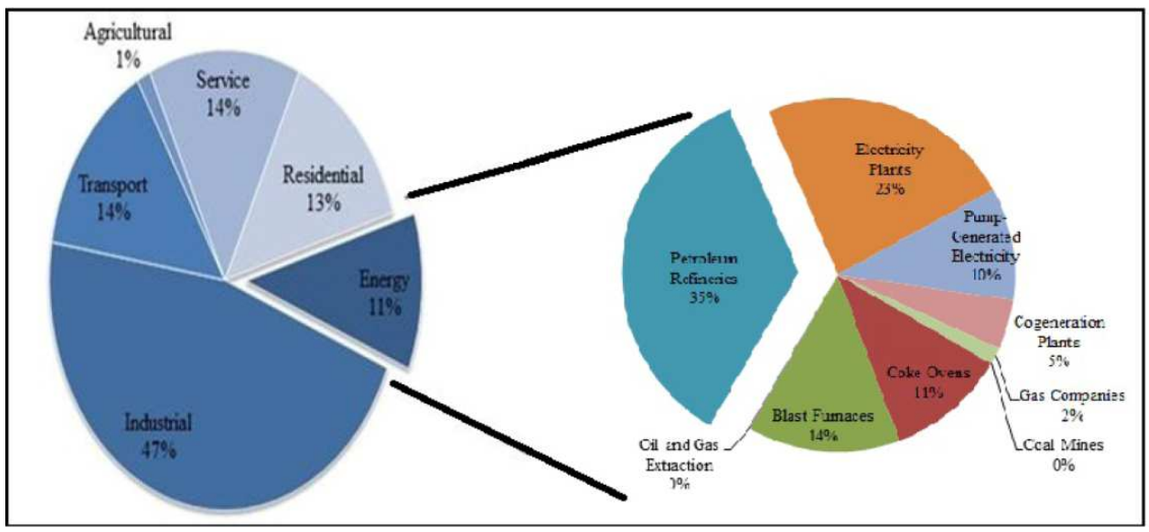


Figure 6. CO_2 Emissions from Energy Sector, 2005-2010

3.2 10 High-Emitting Subsectors in Taiwan

The residential sector in Taiwan is the largest contributor to CO_2 emissions. As discussed earlier, road transport is responsible for a significant share of the CO_2 emissions in the transport sector. It also is ranked second in fossil fuel CO_2 emissions among 57 sub-sectors. Electrical and electronic machinery industry is ranked third.

The top 10 high-emitting subsectors in Taiwan are presented in Table 10 and the time trend of the 10 high-emitting subsectors in Taiwan is shown in Figure 7.

Unit: metric tons

Ranking	Average CO2 Emissions
Residential	33,558,590.7
Road	33,438,841.7
Electrical and Electronic Machinery	21,521,104.3
Petrochemical Materials	16,731,562.8
Iron and Steel	14,881,871.4
Other Services	12,219,482.9
Petroleum Refineries	9,730,109.3
Artificial Fibers	7,720,797.0
Textile, Wearing Apparel and Accessories	6,993,901.0
Cement and Cement Products	6,917,039.71

Table 10. Top 10 High CO_2 Emitters in Taiwan, 2005-2010

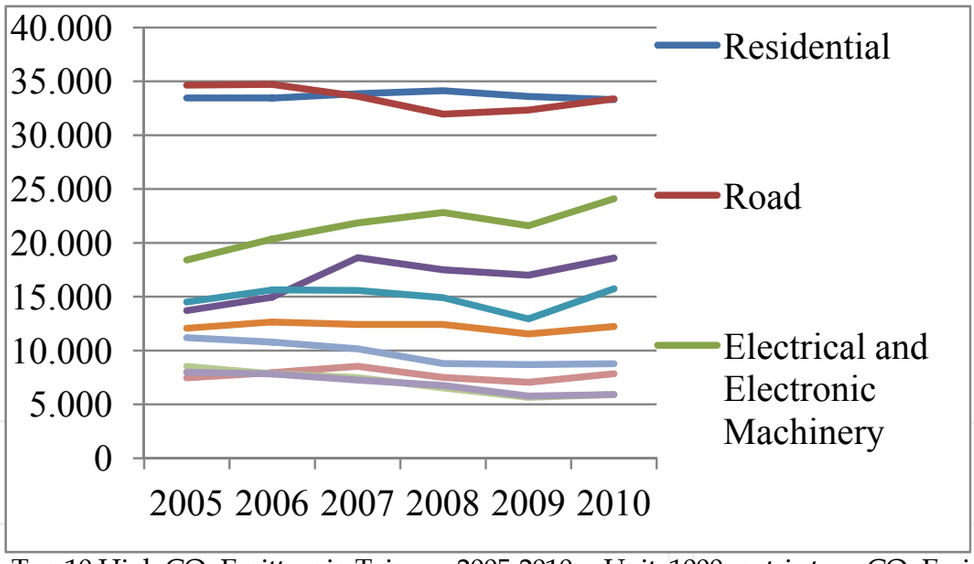


Figure 7. Top 10 High CO_2 Emitters in Taiwan, 2005-2010 Unit: 1000 metric tons CO_2 Emissions

4. Conclusion and Future Research Direction

This paper is part of an ongoing research project designed to investigate the potential size of Taiwan's carbon market. When tackling this big issue on the size of the carbon market, we first use IPCC's sectoral approach to estimate CO_2 emissions from fuel combustion and examine the sectoral and subsectoral distribution of CO_2 emissions in Taiwan. Utilizing the Energy Balance Sheet compiled by the Bureau of Energy, this analysis is based on the fuel consumed in each subsector and the electricity used in the subsector.

With the results obtained in this paper, we are planning to examine the demand and supply structure of Taiwan's carbon market by projecting CO_2 emission data to year 2012 and 2013. Since the cap (emission rights) is given, the quantity of demand for emission rights and the quantity of supply for emission rights could thus be identified.

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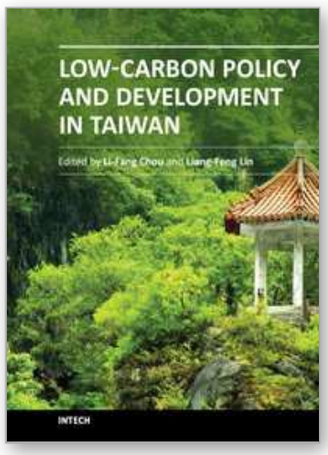

Low Carbon Policy and Development in Taiwan
Edited by Dr. Liang-Feng Lin

ISBN 978-953-51-0156-7
Hard cover, 97 pages
Publisher InTech
Published online 24, February, 2012
Published in print edition February, 2012

Taiwan a typical small Asian country with few energy resources is well known for its high-tech industry in the last 20 years. However as a member of the global village Taiwan feels the responsibility to reduce carbon emissions. The book tells you how Taiwan transforms itself from a high-tech island to become a low carbon island. The book address Taiwan's low-carbon developmental policies of the past 10 years, applies an econometric approach to estimate Taiwan's sector department CO2 emissions, shows how environmental change affects the economic growth of Taiwan, and provides two successful examples of low-carbon pilot regions in Taiwan. Stephen Shen, the Minister of the Environment Protection Agency of Taiwan, believes that the book arrives at the right time, because this is the time to educate the people of Taiwan, about the necessary action for achieving a low carbon society.

How to reference
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Shinemay Chen, Der-Cherng Lo and Huai Hsuan Yu (2012). Estimation of Taiwan’s CO2 Emissions Related to Fossil Fuel Combustion - A Sectoral Approach, Low Carbon Policy and Development in Taiwan, Dr. Liang-Feng Lin (Ed.), ISBN: 978-953-51-0156-7, InTech, Available from: http://www.intechopen.com/books/low-carbon-policy-and-development-in-taiwan/estimation-of-taiwan-s-co2-emissions-related-to-fossil-fuel-combustion-a-sectoral-approach

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