An Analysis of GHG Emissions from Taiwan's Industrial Sector

Sheng-Hsiung Chiu*

Market Intelligence & Consulting Institute (MIC), Institute for Information Industry (III), Taiwan

(**Received** 2 November 2015; **Published on line** 1 December 2015)

*Corresponding author email: linahlli@micmail.iii.org.tw

DOI: 10.5875/ausmt.v5i4.1060

Abstract: To comprehensively elucidate the intelligent automation (IA) demands of Taiwanese companies in Southern China, the researchers administered a structured questionnaire to Taiwanese companies invested in Dongguan region, which was one of the earliest regions to undergo economic reform. A total of 30 valid questionnaires were recovered. Research findings showed that most responders are medium- and large-sized enterprises with production plants in Mainland China. The research also revealed that the higher levels of IA are in the processing, assembly, securing (e.g., tightening screws/fixtures), and quality assurance processes under the category "Manufacturing", and the hardware connection (connecting computer and equipment) and software integration (i.e., MIS, MES, and ERP, among others) processes under "System Integration". The majority of these processes possess corresponding mature solutions. The core issues are maintaining production flexibility and reducing payback periods.

Keywords: Intelligent automation, Taiwanese company in southern China, market analysis

Introduction

Nowadays, the world is at a critical moment making all the efforts to fight against climate change, which poses a serious threat to the environment we live in. The organization, namely Intergovernmental Panel on Climate Change (IPCC), held by the United Nations (UN), is responsible for conducting research regarding topics for climate change and has launched the fifth assessment report (AR5) in 2014. In its fifth assessment report, the results indicated that the world should regulate the cap on GHG emissions of 3,000 gigatons (GT) to gain a 50% chance of limiting the rise in long-term global average temperature to two degrees Celsius and below, relative to pre-industrial levels (IPCC, 2014). Without our full commitment and taking immediate actions, climate change will have severe and irreversible impacts across the world (IEA, 2015).

All parties participating in the United Nations Framework Convention on Climate Change (UNFCCC), another organization that is also established to combat climate change under the UN, are required to submit Intended Nationally Determined Contributions (INDCs). The INDC is a post-2020 climate action which they intend to execute under a new international agreement. The submitted INDCs are expected to be transformed into a legally binding mitigation commitment for replacing the Kyoto Protocol after the twenty-first Conference of Parties (COP 21) held at Paris, France, in December of 2015. Facing the crisis of climate change, substantial and sustained reduction in GHG emissions is a relevant activity involving governments, private entities, households, etc., meaning no matter who you are, the GHG reduction discipline is without a doubt everyone's responsibility.

Due to international policies, Taiwan is not required to submit our INDC proposal for GHG emission mitigation to the UNFCCC. However, to contribute efforts in climate change, our government held four National Energy Conferences between 1998 and 2015 to identify targets and strategies for GHG emission reduction. According to the energy statistics gathered by the Bureau of Energy, GHG emissions from the industrial sector accounted for 49% of the nation's total emissions, so clean energy and GHG emission reduction are both advanced priorities of the energy policy. The Energy Management Act and

Renewable Energy Development Act were passed to provide disciplines to develop clean and sustainable energy resources. The Greenhouse Gas Reduction Act is now enacted to strengthen the regulation of GHG and encourage the clean development mechanism (CDM) introduced to the industrial sector to promote GHG emissions reduction. Identifying the determinant factors is necessary to find effective solutions for reducing industrial GHG emissions . Therefore, this study applies the adjusted Kaya identity with Laspeyers decomposition method to explore the driving forces of GHG emissions, and gain some information for Taiwan's industrial sectors to adopt the correct strategies.

Adjusted Kaya Identity

The cause of massive GHG emissions can be mainly attributed to satisfying the human needs from fossil fuel combustions and economic activities. The Kaya identity is an equation contributed from several factors to determine the level of human impact on climate environment as GHG emissions (Kaya, 1989). The Kaya identity is formed with four affecting variables as shown in Eq. (1) below:

$$GHG_t = P_t \times \frac{GDP_t}{P_t} \times \frac{E_t}{GDP_t} \times \frac{GHG_t}{E_t} \quad (1)$$

Where the subscript t denotes the specific year. GHG is the quantity of GHG emissions; P is the population of the observed nation; GDP is the gross domestic product; E is the final energy consumption; GDP per capita is represented by productivity; Energy intensity is the energy consumption per unit of GDP; GHG emissions coefficient is the GHG emission per unit of energy consumption. Eq. (1) showed that GHG emissions can be further decomposed into a multiplier relationship between population, GDP per capita, energy intensity, and the GHG emissions coefficient.

However, since identifying the driving forces of GHG emissions from Taiwan's industrial sector is the main focus of this paper, Eq. (1) is modified into Eq. (2) as follows.

$$GHG_{it} = L_{it} \times \frac{VA_{it}}{L_{it}} \times \frac{E_{it}}{VA_{it}} \times \frac{GHG_{it}}{E_{it}} = L_{it} \times LP_{it} \times EI_{it} \times GI_{IT} \quad (2)$$

Where another subscript denotes Taiwan's industrial sector. L is the number of labors served in the industrial sector; VA represents the value-added of the industrial sector. In this paper, we use the refined Laspeyers decomposition method (Ang, 2000) to explore how the four driving factors described in Eq. (2), summarized in Table 1, affect GHG emissions from Taiwan's industrial sector.

The purpose of this study is to understand how the relative contributions of the four factors are affecting various GHG emissions. The change in GHG emissions of Taiwan's industrial sector between the specific year (T), and the base year (0), can be decomposed into the contribution of the change of labor served (ΔL_i), the change of labor productivity (ΔLR_i), the change of energy intensity (ΔEI_i), and the change of GHE intensity (ΔGI_i), as expressed in Eq. (3) and (4).

$$\Delta GHG_i = GHG_i(T) - GHG_i(0) = \Delta L_i \times \Delta LP_i \times \Delta EI_i \times \Delta GI_i \quad (3)$$

$$\Delta GHG_i = [L_i(0) + \Delta L_i] \times [LP_i(0) + \Delta LP_i] \times [EI_i(0) + \Delta EI_i] \times [GI_i(0) + \Delta GI_i] - L_i(0) \cdot LP_i(0) \cdot EI_i(0) \cdot GI_i(0) \quad (4)$$

In order to obtain the different contribution of each factors in percentage of change in GHG emissions, we calculated according to Eq. (5) as follows:

$$\frac{\Delta L_i}{\Delta GHG_i} \times 100\% + \frac{\Delta LP_i}{\Delta GHG_i} \times 100\% + \frac{\Delta EI_i}{\Delta GHG_i} \times 100\% + \frac{\Delta GI_i}{\Delta GHG_i} \times 100\% = 100\% \quad (5)$$

Variable	Evaluation	Description
L_{it}	L_{it}	Number of labor
LR_{it}	VA_{it} / L_{it}	Labor productivity
EI_{it}	E_{it} / VA_{it}	Energy intensity
GI_{it}	GHG_{it} / E_{it}	GHG emissions from energy use

Table 1. Variables of GHG emission change in Taiwan's industrial sector.

An Overview of Taiwan's Energy Consumption

GHG emission trend analysis

The interrelationship between economic growth and energy consumption, coupled with energy-related Greenhouse Gas (GHG) emissions, are considered very close; this is true especially for developing countries, and Taiwan is no exception. For example, the real GDP of Taiwan's economy has kept a cumulative annual growth rate (CAGR) of about 3.49% since 2004, at the same time, energy consumption was 1.05%. In addition, the GHG emission per capita was 9.82 to 11.01 tons per year between 2000 and 2012. As demonstrated in Table 2, GHG emissions for 2012 were about 252.0 million tons (MT) of

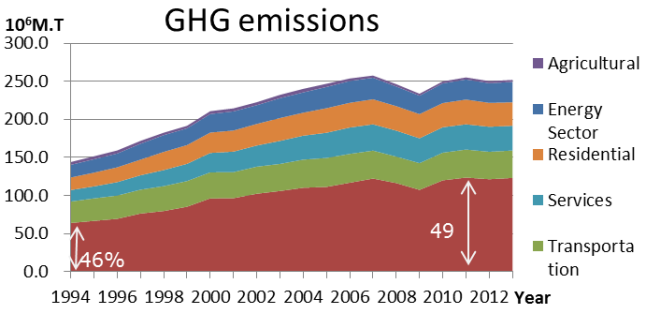
Sheng-Hsiung Chiu is a Postdoctoral Research Fellow working at Market Intelligence & Consulting Institute of Institute for Information Industry and National Cheng Kung University. He received his Ph.D. degree from the Department of Management Science at National Chiao Tung University in Taiwan. He has participated in the project "National Energy Program-Phase II: project for promoting and managing energy strategies", and his main research interests are in the areas of Energy Economics and Performance Evaluation.

CO2e, which included seven different components such as CO2, CH4, N2O, HFCS, PFCS, SF6, and NF3; the number showed an increase of 4.9% in the past decade. More importantly, GHG emissions is an unavoidable problem in Taiwan as we are in the pursuit of economic growth and sustainable development.

Reducing GHG emissions and improving energy efficiency have become common concerns all around the world in the fight against climate change. Following the "Kyoto Protocol", Taiwan also established the "Sustainable Energy Policy Convention" on June 5, 2008, showing that we as a sustainable society are concerned with energy security, economic growth, and environmental protection. To make every effort and fulfill our responsibility, we should put forward an unconditional target to reduce GHG emissions for 2025 to the benchmark level as year 2000.

If we do not adopt advanced procedures to process GHG emissions, it is possible that the continued increasing trends on GDP, energy consumption, and GHG emissions will not change any further. The policies on energysaving and carbon reduction, including changing the energy mix, improving energy efficiency, and increasing energy prices are all effective ways when considering different alternatives for reducing CO2 emissions. However, a gap between the goal and reality still exists, but technological innovations and utilization of energy technologies may be likely to improve energy efficiency and drive the reduction of GHG emissions.

In 2014, both energy efficiency target and GHG emission reduction target were incorporated into the administrative program by the Executive Yuan, which regulated that by 2025, energy intensity will be decreased by 50%, while GHG emissions will also be reduced to the emission level of 2005. Furthermore, the Taiwanese government prompted the Greenhouse Gas Reduction and Management Act in Parliament in June, 2015. For about the next 10 years, GHG emissions will be decreased by 50%, and GHG emissions in 2050 will equal the year 2005. As shown in Figure 1 and Table 2, the industrial sector plays an important role in Taiwan's energy consumption diminution and GHG emissions reduction. According to the Greenhouse Gas Reduction Act, the regulation of industrial GHG emissions is a top priority and industrial sub-sectors such as the commodity industry, chemical material industry, mental industry, and information and electronic industries are of great significance. It can be seen that the achievement of GHG emissions reduction relies on the low-carbon transition of industrial sectors.



Source: BOE (2014), III MIC (2015)

Figure 1. Taiwan's GHG emissions (by sector).

Sector	2004		2009		2013	
	Emission (MT)	Ratio	Emission (MT)	Ratio	Emission (MT)	Ratio
Industrial	110.2	46%	107.4	46%	123.1	49%
Transportation	37.0	15%	35.1	15%	36.0	14%
Service	31.4	13%	32.6	14%	32.5	13%
Residential	30.2	13%	31.8	14%	30.9	12%
Energy	26.8	11%	24.2	10%	26.7	11%
Agricultural	4.6	2%	2.6	1%	2.7	1%
Total	240.2	100%	233.8	100%	252.0	100%

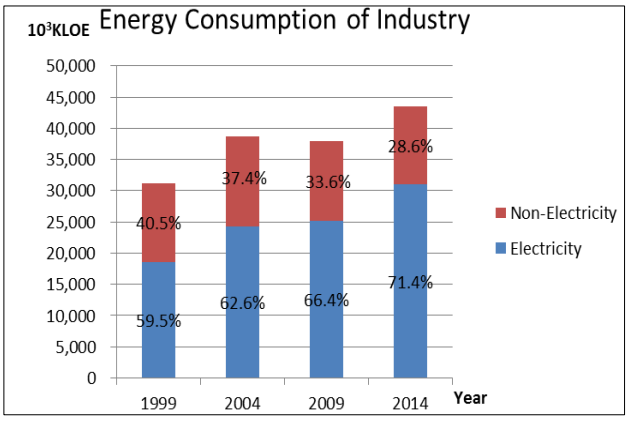
Table 2. Taiwan's GHG emissions (by sector) in the past decade.

Energy consumption trend analysis of the industrial sector

The importance of the industrial sector is highlighted by its role in providing jobs and value-added creations for nearly 36.14 of employed population, and 35.13% of GDP in 2014. In addition, the CAGR of industrial value-added increased 4.15% between 2010 and 2014, and made a contribution of 1.88% to the growth of Taiwan's GDP in 2014. People will benefit from the economic growths produced by the industrial sector, but energy consumption with GHG emissions are also increasing at a remarkable rate, destroying our living environment.

The energy consumption of Taiwan's industrial sector and its six sub-industries with high energy consumptions are summarized in Table 3. These six sub-industries have accounted for about 80% of total energy consumption in the industrial sector, and both the chemical material and electronic machine industries need our close attention. There is no doubt that coal combustion and electricity use within the industrial sector is more considerable. We also simplified the analysis of the relationship between electricity and non-electricity factors affecting the operational model of Taiwan's industry sector during the period of 1999 to 2014. As shown in Fig. 2, data indicated that electricity consumption from the industry sector has increased from 59.5% in 1999 to 71.4% in 2014, largely due to mass deployment of automatic equipment which enhance industrial productivity and efficiency. On the contrary, non-electricity consumption has declined significantly

from 40.5% in 1999 to 28.6% in 2014. It can be estimated that the amount of fossil fuel consumed will be consistently lower than electricity in the future.



Source: BOE (2014), III MIC (2015)

Figure 2. Energy consumption of Taiwan's industrial sector.

GHG emissions analysis of the industrial sector

The Laspeyers decomposition method we used in this studyis to solve the adjusted Kaya identity for quantifying the impacts of four key determinants on the energy-related GHG emissions from Taiwan's industrial sector, such as employed labor, productivity per capita of employed labor, energy intensity, and GHG intensity, which is demonstrated in Table 4.

Decomposition results showed that the changes of GHG emissions in Taiwan's industrial sector have a slight variation between 2007 and 2014 Relative to 2007, it can be seen that changes in GHG emissions for Taiwan's industrial sector has decreased by 0.90%. The volatile rate of GHG emissions was significantly influenced by industrial activity and energy use structure. Specifically, the industrial activity indicator evaluated by productivity per capita of employed labor (LR) is the major driving force to increase change in GHG emissions by about 15.52%. By contrast, the energy intensity indicator has a great effect on the decline of GHG emissions by nearly 18.64%.

Notably, both natural gas and renewable energies are prompted by the government to supply energy during with the transition to low-carbon structure, but GHG emission intensity provides only limited assistance in the reduction of GHG emissions for the industrial sector. Because more and more factories are interested in automation and intelligent production to enhance their productivities, they rely heavily on electricity. Therefore, if GHG emissions intensity improves with energy technology innovations and practice, the country's GHG emissions reduction target will be achievable.

	Energy Consumption (10^3KLOE)									
	Coal		Oil		Natural gas		Electricity		Subtotal	
	2005	2014	2005	2014	2005	2014	2005	2014	2005	2014
Industrial sector	**6,380.0**	**8,163.7**	**6,176.4**	**2,467.1**	**906.8**	**1,841.6**	**25,424.1**	**30,574.5**	**39,169.4**	**43,512.5**
Chemical Material	2,891.1	4,395.4	1,870.6	646.9	144.8	368.4	5,745.5	6,067.8	10,695.6	11,632.5
Electronic Machine	N/A	N/A	134.6	60.6	80.7	94.2	6,259.5	10,015.1	6,474.8	10,215.5
Basic Metal	1,383.8	1,842.8	772.4	308.2	226.4	366.0	3,312.0	3,866.7	5,697.1	6,391.6
Non-Metallic Mineral	1,726.4	1,414.8	501.7	284.7	232.0	225.5	1,156.5	1,307.6	3,616.7	3,232.5
Textile	53.4	69.9	1,162.6	294.5	43.1	33.6	1,718.1	1,252.3	3,013.1	1,696.2
Paper	325.1	440.8	284.9	57.3	6.1	17.5	844.2	788.9	1,586.9	1,444.0
Total	**6,379.8**	**8,163.7**	**4,726.8**	**1,652.2**	**733.1**	**1,105.2**	**19,035.8**	**23,298.4**	**31,084.2**	**34,612.3**
Share	**0.16**	**0.19**	**0.12**	**0.04**	**0.02**	**0.03**	**0.49**	**0.54**	**0.79**	**0.80**

Source: BOE (2014), III MIC (2015)

Table 3. Energy consumption of Taiwanese industrial sector.

Year	GHG emission	Factor			
		L	LR	EI	GI
2007-2010	-1.95%	-0.50%	9.54%	-9.15%	-1.83%
2011-2014	1.07%	6.07%	5.93%	-9.45%	-1.49%
2007-2014	-0.90%	5.55%	15.52%	-18.64%	-3.33%

Table 4. Decomposition of the change of GHG emissions in Taiwan's industrial sector.

Discussion and policy implications

In this study, by using an adjusted Kaya identity, four driving factors reflecting the possible contributions of GHG emissions reduction from Taiwan's industrial sector between 2007 and 2014 are evaluated. In addition, recent trends of labor, labor productivity, energy intensity, and GHG intensity from Taiwan's industrial sector can be surveyed upon to keep the yearly information up to date. Our evaluation showed that GHG emissions from Taiwan's industrial sector was 123.10 million metric tons in 2014 and 122.35 million metric tons in 2007, with a decrease of 1.95% from 2007 to 2010, and a decrease of 1.07% from 2011 to 2014, roughly accounted for 0.90% of GHG emissions during this specific period. GHG emissions were at its peak in 2011.

The evaluation of this study showed that the GHG emissions reduction from Taiwan's industrial sector from 2007 to 2014, were benefited from improved energy intensity as well as GHG intensity. The Executive Yuan should continues to place a high priority in the promotion of improving its energy efficiency and planning establishment of affordable low-carbon energy systems for reducing GHG emissions. Regarding the mitigation potential of GHG emissions, the policy is more likely to achieve a much higher reduction rate in Taiwan's industrial sector compared to other sectors.

Persisting growth of industrial productivity is indispensable to the national economy, but massive GHG emissions from the industrial sector impacts our image as well as environmental sustainability. From the industrial sector's perspective, GHG mitigation practices can be employed in several conceptual directions as follows:

Firstly, a cap and trade mechanism and directed actions are two pillars of Greenhouse Gas Reduction Act which will be carried out on regulated industries that are roughly classified as industrial sector. The industrial sector should take the initiative in GHG emission mitigation. For the offset project implemented by the EPA, the industrial sector has the incentive to acquire credits which can be used to offset future emission allowance or exchange for economic benefits under the cap and trade mechanism.

Secondly, the current trend is moving towards massive automation processes at our factories, which has greatly increased its productivity and decreased energy consumption. In view of this, it will be necessary to introduce advanced processes for electricity transmission instead of relying on traditional ways of fossil fuel. For example, "Production 4.0" planned by the Government will be the practical policy in the coming years, which is more important for the transition of the industrial sector, creating a higher demand for electricity. Besides, the GHG emission coefficient for electricity is relative lower than direct combustion of fossil fuel.

Finally, it is critical to consider energy-saving advancements to reduce energy consumption and improve energy intensity. Energy-saving technologies should be aggressively promoted, especially for the industrial sector, through the applications of internet of things (IOT) systems, machine to machine (M2M) connections of manufacturing equipment, plant energy management system (PEMS), advanced metering infrastructure (AMI), etc., to provide feasible energy-saving solutions. The AMI will be a great benefit to the end-user because it can participate in the electricity transmission and usage; it is composed of a smart meter, communication network, and a central system, which records electricity consumption in time intervals and communicates two-way information with the power system operator to help improve the quality of power. Taiwan Power Company is required to take the responsible for promoting AMI introduction, and the industrial sector has the highest priority in its adoption.

Reference

[1] B. W. Ang and F. Q. Zhang, "A survey of index decomposition analysis in energy and environmental studies," *Energy*, vol. 25, no. 12, pp. 1149-1176, 2000.
doi: 10.1016/S0360-5442(00)00039-6

[2] Bureau of Energy (BOE), Ministry of Economic Affairs, "Energy development convention," Taipei, Taiwan, 2012.

[3] Bureau of Energy (BOE), Ministry of Economic Affairs, "Energy statistic annual report," Taipei, Taiwan, 2014.

[4] Environmental Protection Administration, Executive Yuan, "Greenhouse gas reduction and management act," Taipei, Taiwan, 2015.

[5] International Energy Agency, "Energy and climate change," Paris, France, 2015

[6] Intergovernmental Panel on Climate Change, "AR5 Synthesis Report," Geneva, Switzerland, 2014.

[7] Y. Kaya, "Impact of carbon dioxide emission control on GDP growth: Interpretation of proposed scenarios," in *Presentation to the energy and industry subgroup, response strategies working group,* IPCC, Paris, 1989.

[8] Ministry of Economic Affairs (MOEA), Executive Yuan, "Sustainable Energy Policy Convention," Taipei, Taiwan, 2008.