Analyzing Impact of Changing Fuel-Mix Composition of Thailand Power Generation

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ชนัยพงศ์ ศรีชัย : การวิเคราะห์ผลกระทบจากการเปลี่ยนแปลงโครงสร้างเชื้อเพลิงการผลิตไฟฟ้า. (Analyzing Impact of Changing Fuel-Mix Composition of Thailand Power Generation) อ.ที่ปรึกษาหลัก : ผศ. ดร.ฐิติศักดิ์ บุญปราโมทย์, อ.ที่ปรึกษาร่วม : ดร.พงษ์สันธ์ บัณฑิตสกุลชัย

การผลิตไฟฟ้าเป็นหนึ่งในธุรกิจพลังงานที่สำคัญต่อการพัฒนาเศรษฐกิจของประเทศ ดังนั้นประเทศไทยจึงได้จัดทำแผนพัฒนากำลังการผลิตไฟฟ้า ระยะเวลา 20 ปีขึ้น โดยจะถูกนำมาใช้เป็นแผนหลักในการเสริมสร้างความมั่นคงทางด้านพลังงานและความมีเสถียรภาพของระบบไฟฟ้า การศึกษานี้จะมุ่งเน้นไปยังภาคธุรกิจการผลิตไฟฟ้าและทำการประเมินถึงผลกระทบที่จะเกิดขึ้นเมื่อเกิดการเปลี่ยนแปลงสัดส่วนของเชื้อเพลิงในการผลิตไฟฟ้าด้วยการเปรียบเทียบระหว่างแผนพัฒนากำลังการผลิตไฟฟ้าปี 2558 และ แผนพัฒนากำลังการผลิตไฟฟ้าปี 2561 โดยจะจำลองสถานการณ์จำลองที่ 1 ให้พลังงานไฟฟ้าทั้งหมดถูกผลิตด้วยเชื้อเพลิงแก๊สธรรมชาติในสัดส่วนร้อยล่ะ 37 เชื้อเพลิงถ่านหินร้อยล่ะ 23 และที่เหลืออีกร้อยล่ะ 50 ถูกผลิตด้วยเชื้อเพลิงอื่นๆ และเปลี่ยนแปลงสัดส่วนการผลิตด้วยการเพิ่มการผลิตไฟฟ้าด้วยเชื้อเพลิงแก๊สธรรมชาติขึ้นเป็นร้อยล่ะ 53 และลดสัดส่วนเชื้อเพลิงถ่านหินลงเหลือร้อยล่ะ 12 ในสถานการณ์จำลองที่ 2 ผลการศึกษาแสดงให้เห็นขนาดเศรษฐกิจที่ขยายตัวมากขึ้นอย่างมีนัยยะสำคัญเมื่อมีการเพิ่มสัดส่วนการผลิตไฟฟ้าจากแก๊สธรรมชาติ

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The energy industry is considered one of the important sectors for national economic development—especially the electricity generation industry then Thailand has developed a power development plan as the nation roadmap to ensure power security and reliability of the electricity system. In this study, we focus on the electricity generation industry and examine the impacts resulting from the changing composition of power generation type compare between Thailand's Power Development Plan year 2015 and the year 2018. The scenario case 1 assuming that the electricity generation is generated from 37% of Natural Gas, 23% of Coal, and 50% other. When the changing fuel proportion by increasing Gas-fired power plant to 53% and decrease Coal-fired power plant and other to 12%, 35% accordingly in scenario case 2. As a result, Power Development Plan year 2018 is increase more the total output of the Thai economy than the Plan year 2015 cause to significantly benefit of the economy.

Field of Study:	Energy Technology and Management	Student's Signature .....
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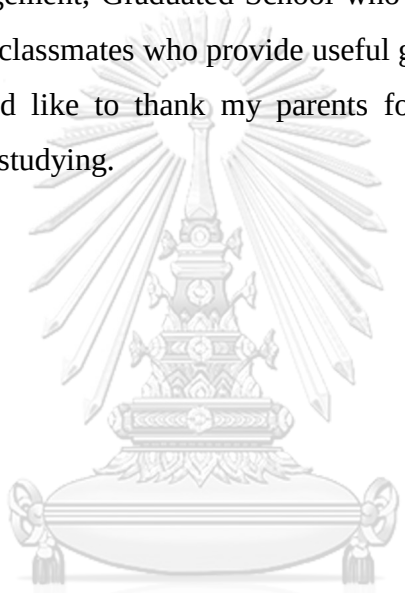

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Chapter 1

Introduction

1.1 Background

Thailand Power Development Plan or PDP which is a master plan for the national electricity supply in the long term for 15-20 years prepared by the Ministry of Energy (Thailand) together with the Electricity Generating Authority of Thailand (EGAT) in order to build a power system reliability and sufficient electricity demand to support the economic and social development of the country, including the quality of life of the people. Also, the power development plan 2015 (PDP2015) of Thailand was emphasized on improving power system reliability with balancing diversification of fuel used by reducing dependence on natural gas power generation, increasing a share of coal power generation via clean coal technology. According to the government policies, the framework of PDP2015 was approved by criteria as the following

1. Energy Security: dealing with an increase in power demand taking into account fuel diversification to lessen the dependency of one particular fuel
2. Economy: maintain an appropriate cost of power generation and implementing energy efficiency
3. Ecology: reducing environmental and social impacts by lessening carbon dioxide intensity of power generation

The estimated fuel requirement for the PDP2015 are shown in the **Table 1**:

Table 1 estimated fuel requirement for the PDP2015

Fuel	Percentage in 2026	Percentage in 2036
Imported hydro power	10 – 15	15 – 20
Clean coal including lignite	20 – 25	20 – 25
Renewable energy including hydro	10 – 20	15 – 20
Natural gas	45 – 50	30 – 40
Nuclear	-	0 – 5
Diesel/Fuel oil	-	-

In 2018, after implemented PDP2015 for a while. The electricity consumption has changed from the prediction of electricity demand. Also, the government has to review and improve the plan to be corporate with the current situation by revised the criteria to

1. Energy Security: covering the reliable to a generation, transmission and distribution in each region, suitably response to electricity demand and prepare the readiness of power system to initiate the competition in electricity generation.

2. Economy: maintain an appropriate cost of power generation, promote the low power generating costs
3. Ecology: reducing environmental by promote the renewable power generating and increase the efficiency of the power system by develop smart grid network.

As the framework of the criteria, the power development plan 2018 (PDP2018) was changed the fuel composition by increase electricity generating from gas-fired power plant by decrease coal power generation and imported power as shown in **Figure 1**

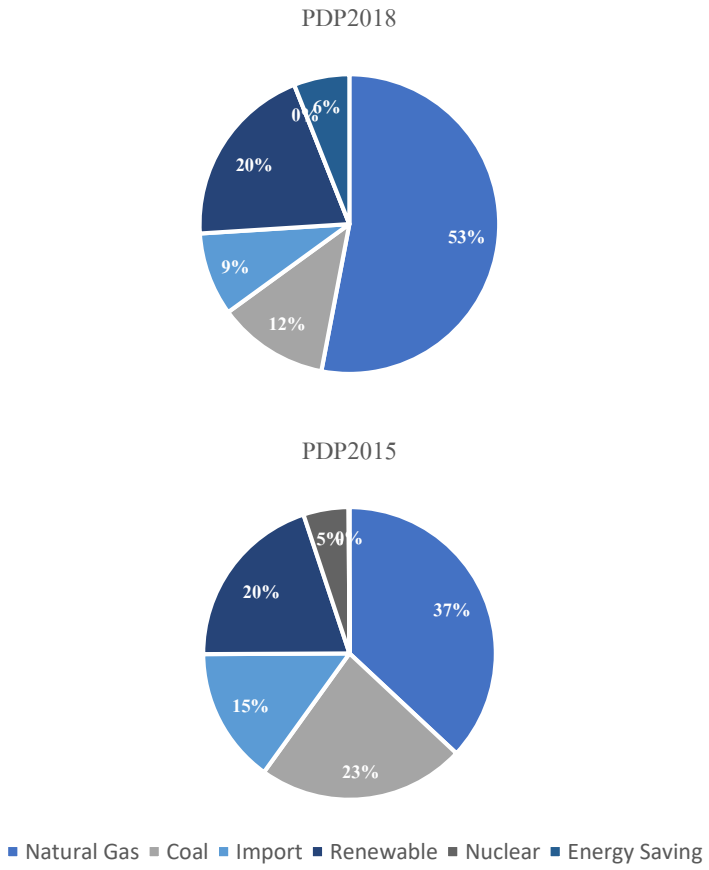

Figure 1 Comparison the fuel composition

Therefore, it leads to the question of research that what is the impact on the economy from the changing fuel-mix composition of Thailand power generation.

1.2 Research Objective

To determine and compare the macro-economic impacts of changes in the composition of electricity power generation as described in PDP2015 and PDP2018

1.3 Hypothesis

Changing the composition of power generation by increasing the electricity generated from gas-fired power plants from 37% to 53% and decreasing the share of coal power generation and imported power make a negative impact on Thailand's economy.

1.4 Scope of work

1. Use GTAP9 data base, GTAP Power data and GTAP CO_2 Emission as base data then adjust the data to Input-output table from.
2. Use Power generation on 2011 as a basis for comparison.
3. Compare the differences in GDP growth, income effect, tax effect, value-added effect and co_2 emission with the changing percentage of power generation between PDP2015 and PDP2018 plan.
4. Assume that all electricity generated is totally sold to the domestic non-generation activities

1.5 Expected Outcome

1. Construct a tool for analyzing the fuel proportion of PDP
2. Evaluate and compare the economic impacts of PDP2015 and PDP2018
3. Propose the policy recommendation to related agencies

1.6 Report components

Chapter 1 Introduction including the introduction, research objective, hypothesis, scope of work and expected outcome

Chapter 2 Literature including the research data and literature review

Chapter 3 Methodology

Chapter 4 Result and Conclusion including the implementation, result and conclusion

Chapter 2

Literature Review

2.1 Research Data

2.1.1 Thailand Development Plan 2015

Thailand Development Plan 2015 or PDP2015 was emphasized on improving power system reliability by reducing dependence on natural gas power generation, increasing a share of coal power
generation with clean coal technology, importing power from neighboring countries, and developing renewable energy. In addition, the plan aims on transmission and distribution system development in order to support for renewable energy development and Association of Southeast Asian Nations (ASEAN) Economic Community. The PDP2015 focuses on

1. Energy Security: dealing with an increase in power demand taking into account fuel diversification to lessen the dependency of one particular fuel
2. Economy: maintaining an appropriate cost of power generation and implementing energy efficiency
3. Ecology: reducing environmental and social impacts by lessening carbon dioxide intensity of power generation

The PDP2015 was formulated in line with social and economic development direction addressed by the office of National Economic and Social Development Board (NESDB). The average growth of projected long-term Thai Gross Domestic Products (GDP) estimated by the NESDB was 3.94 percent. With the integration of the PDP2015 and the Energy Efficiency Development Plan (EEDP) to foster energy efficiency, the expected energy saving would be 89,672 GWh in year 2036. Moreover, renewable energy, for instance, municipal waste, biomass, biogas, wind and solar power generation will be encouraged according to the Alternative Energy Development Plan (AEDP). Investments in transmission and distribution system will accommodate renewable energy and smart-grid development. Consequently, estimated fuel requirements for the PDP2015 are shown in **Table 2**:

Table 2 Estimated fuel requirement for the PDP2015

Fuel	Percentage in 2026	Percentage in 2036
Imported hydro power	10 – 15	15 – 20
Clean coal including lignite	20 – 25	20 – 25
Renewable energy including hydro	10 – 20	15 – 20
Natural gas	45 – 50	30 – 40
Nuclear	-	0 – 5
Diesel/Fuel oil	-	-

Power Demand Forecast was calculated upon the average long-term GDP growth during year 2014-2036 estimated by the NESDB of 3.94 percent and the average population growth of 0.03 percent. In addition, the energy saving target from the EEDP accounts for 89,672 GWh, and the renewable energy development target from the AEDP was set at 19,634.4 MW in year 2036. It would grow 2.67 percent annually from year 2014 to 2036. In year 2036, the expected energy and power demand would be 326,119 GWh and 49,655 MW respectively.

The long-term power demand forecast was developed into 2 cases as the following:

1. BAU (Business as Usual) Case: the statistical data of year 2013 was used in the model where the energy conservation measures were already implemented. Therefore, in 2036, the estimated energy saving would be 27,282 GWh, as a result, the maximum power demand would reach 59,300 MW or grow on the average of 3.5 percent.
2. Base Case: the measures of energy conservation from the EEDP were integrated in the model. Therefore, in year 2036, the energy intensity would be reduced from that of year 2010 by 24 percent accounting for 89,672 GWh of the energy saving. The maximum power demand would reach 49,655 MW or grows on the average of 2.7 percent with the power demand saving of 9,543 MW as shown in **Table 3**

Table 3 comparison of power demand forecast between BAU case and Base case

Year	BAU case (1)		Base case (2)		Difference (2) – (1)	
	MW	GWh	MW	GWh	MW	GWh
2016	30,304	198,439	30,218	197,891	-86	-548
2021	36,993	242,623	35,775	234,654	-1,218	-7,969
2026	43,755	287,748	40,791	267,629	-2,964	-20,119
2031	50,991	336,680	45,438	298,234	-5,554	-38,446
2036	59,300	393,335	49,655	326,119	-9,645	-67,216

2.1.2 Thailand Development Plan 2018

In 2018, Thailand lead by Ministry of Energy together with Electricity Generating Authority of Thailand prepared the Power Development Plan 2018 use for 2018 – 2037 or PDP 2018 that was focused on

1. Security: Give importance to the security of the national electricity system in order to be stable, covering the power generation system, power transmission system, and area's distribution system in order to reach the demand for electricity. To support the national economic and social development plan, which will be in line with the economic, population, urban, and national growth rate at both a national and regional level.
2. Economy: Considering the appropriate electricity production costs for promoting low-cost electricity generation to reduce user's burdens and not

impede long-term national economic and social development, including improving the management of electricity costs efficiently to reflects the actual cost.

3. Ecology: Promoting the Micro Grid systems in remote areas, industrial estates, or special economic zones to be suitable per the electricity demand in each area. To use the area's resources to maximize benefits and reduce the burden of investment in the power transmission system. Also, improving the efficiency of the electrical system in both electricity generation and distribution, including encouraging the Demand Response to increase the potential peak demand that will be useful for managing the electrical energy crisis. Developing a smart grid network system to support the Decentralized Generation (DG) supports the promotion of energy efficiency.

Power Demand Forecast was calculated by NESDB upon the average long-term GDP growth from 2017 - 2037 with 3.8 percent per year, the average population growth rate is -0.02 percent per year. The forecasted peak demand for a total of 3 electricity authorities' system and the net peak power in the year 2037 is approximately 367,458 MWh and 53,997 MW accordingly. The Comparison of the power demand forecast between PDP2015 and PDP2018 shown as **Table 4**

Table 4 Comparison of the power demand forecast between PDP2015 and PDP2018

Year	PDP2015 (1)		PDP2018 (2)		Difference (2) – (1)	
	MW	GWh	MW	GWh	MW	GWh
2018	32,429	212,515	29,969	203,203	-2,460	-9,312
2022	36,776	241,273	35,213	236,488	-1,563	-4,785
2027	41,693	273,440	41,079	277,302	-614	3,862
2032	46,296	303,856	47,303	320,761	1,007	16,905
2037	-	-	53,997	367,458		

2.1.3 Global Trade Analysis Project (GTAP)

GTAP was established in 1992, with the objective of lowering the cost of entry for those seeking to conduct quantitative analyses of international economic issues in an economy-wide framework. The Project consists of several components:

- a fully documented, publicly available, global data base,
- a standard general equilibrium modeling framework,
- software for manipulating the data and implementing the standard model,
- a global network of more than 12,000 researchers in more than 159 countries with a common interest in global economic analysis of trade, resources and the environment,

- a consortium of national and international agencies providing leadership and a base level of support for the Project, and
- a website for dissemination of data, software and project-related information (www.gtap.org).

The central ingredient in GTAP's success has been the global data base. It combines detailed bilateral trade, transport and protection data characterizing economic linkages among regions, together with individual country input-output data bases which account for inter-sectoral linkages within regions.

The GTAP Data Base is the global data base representing the world economy for a given reference year - 2004, 2007 and 2011 for the GTAP 9 Data Base. The files comprising the GTAP Data Base are packaged with two alternative aggregation packages. The GTAP Data Base includes all the data files in the data packages, except for the time series trade data. It comprises four files: sets, parameters, main data, and energy volume data. All the files are header array files (a GEMPACK binary format) (Harrison and Pearson, 1998). GTAP 9 Data Base versions have one additional data file, namely, CO2 emissions data and another meta-data file.

In the standard GTAP 9 Data Base, there are 57 commodities and 134 regions. It comprised of 244 countries formed the set of standard countries such that it omits no significant economies and it captures all significant information from the contributed international data sets. It obtains a GDP estimate for each standard country for use as a scaling factor in aggregating data sets.

GTAP 9 Data Base use GTAP Sectoral Classification (GSC2) to definite the sector as shown in **Tables 5** that define the GTAP agricultural and food processing sectors by reference to the Central Product Classification (CPC) and the other GTAP sectors are defined by reference to the International Standard Industry Classification (ISIC) as shown in **Table 6**

Table 5 GSC2 Sectors defined by Reference to the CPC

GAS2 No.	**Code**	**CPC Code**	**Description**
1	pdr	0113	Rice, not husked
		0114	Husked rice
2	wht	0111	Wheat and meslin
3	gro	0112	Maize (corn)
		0115	Barley
		0116	Rye, oats
		0119	Other cereals
4	v_f	012	Vegetables
		013	Fruit and nuts
5	osd	014	Oil seeds and oleaginous fruit
6	c_b	018	Plants used for sugar manufacturing
7	pfb	0192	Raw vegetable materials used in textiles
8	ocr	015	Live plant; cut flowers and flower buds; flower

GAS2 No.	Code	CPC Code	Description
			seeds and fruit seeds; vegetable Seeds
		016	Beverage and spice crops
		017	Unmanufactured tobacco
		0191	Cereal straw and husks, unprepared, whether or not chopped, ground, pressed, or in the form of pellets; swedes, mangolds, fodder roots, hay, Lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets
		0193	Plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes
		0194	Sugar beet seed and seeds of forage plants
		0199	Other raw vegetable materials
9	ctl	0211	Bovine cattle, sheep and goats, horses, asses, mules, and hinnies, live
		0299	Bovine semen
10	oap	0212	Swine, poultry and other animals, live
		0292	Eggs, in shell, fresh, preserved or cooked
		0293	Natural honey
		0294	Snails, live, fresh, chilled, frozen, dried, salted or in brine, except sea snails; frogs' legs, fresh, chilled or frozen
		0295	Edible products of animal origin n.e.c
		0297	Hides, skins and furskins, raw
		0298	Insect waxes and spermaceti, whether or not refined or colored
11	rmk	0291	Raw milk
12	wol	0296	Raw animal materials used in textile
13	frs	03	Forestry, logging and related service activities
19	cmt	21111	Meat of bovine animals, fresh or chilled
		21112	Meat of bovine animals, frozen
		21115	Meat of sheep, fresh or chilled
		21116	Meat of sheep, frozen
		21117	Meat of goats, fresh, chilled or frozen
		21118	Meat of horses, asses, mules or hinnies, fresh, chilled or frozen
		21119	Edible offal of bovine animals, swine, sheep, goats, horses, asses, mules or hinnies, fresh, chilled or frozen
		2161	Fats of bovine animals, sheep, goats, pigs and poultry, raw or rendered; wool grease
20	omt	21113	Meat of swine, fresh or chilled
		21114	Meat of swine, frozen

GAS2 No.	Code	CPC Code	Description
		2112	Meat and edible offal, fresh, chilled or frozen, n.e.c.
		2113	Preserves and preparations of meat, meat offal or blood
		2114	Flours, meals and pellets of meat or meat offal, inedible; greaves
		2162	Animal oils and fats, crude and refined, except fats of bovine animals, sheep, goats, pigs and poultry
21	vol	2163	Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and mustard oil, crude
		2164	Palm, coconut, palm kernel, babassu and linseed oil, crude
		2165	Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and mustard oil and their fractions, refined but not chemically modified; other oils obtained solely from olives and sesame oil, and their fractions, whether or not refined, but not chemically modified
		2166	Maize (corn) oil and its fractions, not chemically modified
		2167	Palm, coconut, palm kernel, babassu and linseed oil and their fractions, refined but not chemically modified; castor, tung and jojoba oil and fixed vegetable fats and oils (except maize oil) and their fractions n.e.c., whether or not refined, but not chemically modified
		2168	Margarine and similar preparations
		2169	Animal or vegetable fats and oils and their fractions, partly or wholly hydrogenated, inter-esterified, re-esterified or elaidinised, whether or not refined, but not further prepared
		217	Cotton linters
		218	Oil-cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; vegetable waxes, except triglycerides; degras; residues resulting from the treatment of fatty substances or animal or vegetable waxes
22	mil	22	Dairy products
23	pcr	2316	Rice, semi- or wholly milled
24	sgr	235	Sugar
25	ofd	212	Prepared and preserved fish

GAS2 No.	Code	CPC Code	Description
		213	Prepared and preserved vegetables
		214	Fruit juices and vegetable juices
		215	Prepared and preserved fruit and nuts
		2311	Wheat or meslin flour
		2312	Cereal flours other than wheat or meslin
		2313	Groats, meal and pellets of wheat
		2314	Cereal groats, meal and pellets n.e.c.
		2315	Other cereal grain products (including corn flakes)
		2317	Other vegetable flours and meals
		2318	Mixes and doughs for the preparation of bakers' wares
		232	Starches and starch products; sugars and sugar syrups n.e.c.
		233	Preparations used in animal feeding
		234	Bakery products
		236	Cocoa, chocolate and sugar confectionery
		237	Macaroni, noodles, couscous and similar farinaceous products
		239	Food products n.e.c
26	b_t	24	Beverages
		25	Tobacco products

Table 6 GSC2 Sectors defined by Reference to the ISIC

GAS2 No.	Code	ISIC3 Code	Description
14	fsh	015	Hunting, trapping and game propagation including related service
		05	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing
15	coa	101	Mining and agglomeration of hard coal
		102	Mining and agglomeration of lignite
		103	Mining and agglomeration of peat
16	oil	111	Extraction of crude petroleum and natural gas (part)
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
17	gas	111	Extraction of crude petroleum and natural gas (part)
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
18	omn	12	Mining of uranium and thorium ores

GAS2 No.	Code	ISIC3 Code	Description
		13	Mining of metal ores
		14	Other mining and quarrying
27	tex	17	Manufacture of textiles
		243	Manufacture of man-made fibres
28	wap	18	Manufacture of wearing apparel; dressing and dyeing of fur
29	lea	19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
30	lum	20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
31	ppp	21	Manufacture of paper and paper products
		22	Publishing, printing and reproduction of record media
32	p_c	231	Manufacture of coke oven products
		232	Manufacture of refined petroleum products
		233	Processing of nuclear fuel
33	crp	241	Manufacture of basic chemicals
		242	Manufacture of other chemical products
		25	Manufacture of rubber and plastic products
34	nmm	26	Manufacture of other non-metallic mineral products
35	i_s	271	Manufacture of basic iron and steel
		2731	Casting of iron and steel
36	nfm	272	Manufacture of basic precious and non-ferrous metals
		2732	Casting of non-ferrous metals
37	fmp	28	Manufacture of fabricated metal products, except machinery and equipment
38	mvh	34	Manufacture of motor vehicles, trailers and semi-trailers
39	otn	35	Manufacture of other transport equipment
40	ele	30	Manufacture of office, accounting and computing machinery
		32	Manufacture of radio, television and communication equipment and apparatus
41	ome	29	Manufacture of machinery and equipment n.e.c.
		31	Manufacture of electrical machinery and apparatus n.e.c.
		33	Manufacture of medical, precision and optical instruments, watches and clocks
42	omf	36	Manufacturing n.e.c.
		37	Recycling

GAS2 No.	Code	ISIC3 Code	Description
43	ely	401	Production, collection and distribution of electricity
44	gdt	402	Manufacture of gas; distribution of gaseous fuels through mains
		403	Steam and hot water supply
45	wtr	41	Collection, purification and distribution of water
46	cns	45	Construction
47	trd	50	Sales, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
		51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
		521	Non-specialized retail trade in stores
		522	Retail sale of food, beverages and tobacco in specialized stores
		523	Other retail trade of new goods in specialized stores
		524	Retail sale of second-hand goods in stores
		525	Retail trade not in stores
		526	Repair of personal and household goods
		55	Hotels and restaurants
48	otp	60	Land transport; transport via pipelines
		63	Supporting and auxiliary transport activities; activities of travel agencies
49	wtp	61	Water transport
50	atp	62	Air transport
51	cmn	64	Post and telecommunications
52	ofi	65	Financial intermediation, except insurance and pension funding
		67	Activities auxiliary to financial intermediation
53	isr	66	Insurance and pension funding, except compulsory social security
54	obs	70	Real estate activities
		711	Renting of transport equipment
		712	Renting of other machinery and equipment
		713	Renting of personal and household goods n.e.c
		72	Computer and related activities
		73	Research and development
		74	Other business activities
55	ros	92	Recreational, cultural and sporting activities
		93	Other service activities
		95	Private households with employed persons
56	osg	75	Public administration and defense; compulsory social security
		80	Education

GAS2 No.	Code	ISIC3 Code	Description
		85	Health and social work
		90	Sewage and refuse disposal, sanitation and similar activities
		91	Activities of membership organizations n.e.c.
		99	Extra-territorial organizations and bodies
57	dwe	n.a.	n.a

n.a. Not available
n.e.c. Not elsewhere classified

2.2 Literature review on the Economic Impacts Analysis

For the study in economic impact. A selected method was evaluated based on the essential principles or criteria. The good analytical method and study designs with universal features are base on a set of criteria with four principles (Selltiz et al., 1976; Bahr et al., 1984).

- Reliability – the method must provide consistent and stable results when applied it repeatedly to the same case.
- Disaggregate – the method framework must allow the analysis to be performed at disaggregated levels that show impact across sectors in the economy, depending on the sectoral intensity of energy use.
- Transparency – the method must reasonably indicate the relation between the methods, assumptions, and results. Moreover, individuals who out of this field can understand and accessible.
- Data requirement – The method must include publicly accessible information.

2.2.1 Macroeconomic Model Analysis

Most of the studies have attempted to create a linkage between the investment in infrastructure and utilities and economic growth, such as Gross Domestic Product (GDP). The principle of infrastructure capital stock is including roads and railways when the infrastructure systems and utilities were expanded. The result shall relate to the expansion of the overall economy. The most method use the creation of Quasi-production functions or described as Transport infrastructure which is a variable which inject into the economy and measures the impact of capital inflows in other manufacturing sectors.

Aschauer (1989) used the Aggregate Cobb-Douglas Production function to describe the relationship between USA transportation investment and GDP during the years 1949-1985. Graham (2006) used the macroeconomic model to find the Elasticity of Productivity compared with Agglomeration measure in the United Kingdom. While Banister (2007) argued that many studies of the investment in transportation infrastructure were proved, it impact to the benefit of a whole economy but still unclarified about the "level" of the impact.

The weakest of analyzing the impact of changing structural with the macroeconomic analysis model is the method cannot explain the "mechanism" of the effect connected to the economic system. By the way, policymakers have to answer which project produces the highest return to the society. Therefore, they must identify and explain what are economic returns by using these models (Lakshamanan and Anderson, 2002) . However, the macroeconomic model is dominated as a suitable tool for finding the most "Public spending" suitable for infrastructure investment.

2.2.2 Microeconomic Model Analysis

The microeconomics model analysis focuses on the finding of connection between the changing of the sector structure and the increasing productivity of the specify production process. The standard tools of microeconomics are the Cost-Benefit Analysis (CBA) techniques. It is widely use for evaluate the transportation investment projects to ensure efficiently use of the resources (Nash, 1993; Keegan et al., 2007).

CBA was one of the best tools and widely accepted for assessing the economic impact of transportation investment projects. The strengths are "benchmarking" and "ranking" that are the essential options of the considered project (Brent, 1996) . However, the CBA may cause "Exaggerated" assessments on the positive side depending on the intent of the assessors (Belli et al., 2001) because of they do not assess on macroeconomic impact but directly verify only the received benefits of the user. The assessment results are also sensitive to the chosen discount rate that convert the benefits and costs of the project to the present value relate to analyzed period. The CBA trends bias the projects which is provide faster returns projects more than a long-term benefits projects (TCRP, 1998).

From all of the mentioned reasons, the CBA was a tool for ranking and choosing investment projects, but there are not adjustable tools due to strict methodological coherence.

2.2.3 Input-output Analysis

The concept of input-output analysis was first proposed by Russian economist Wassily Leontief (Leontief, 1966) . It is a macroeconomic analysis tool that is exciting and has been applied widely by economists and scientists. It was a base for developing models of studying for the energy consumption of the economics (Chapman 1984 ; Bullard and Herendeen, 1975). then continues to be developed as a model for the study of greenhouse gas emissions from the manufacturing sector (Common and Salma, 1992; Gay and Proops, 1993; Suksuntornsiri and Limmeechokchal, 2005; Limmeechokchai and Suksuntornsiri, 2007; Peter and Herwich, 2008).

The input-output analysis was developed based on the concept that each product or service has to use other goods or services to be the Input of the production process. Simultaneously, the output of each production sector used to respond the

economy's final demand, and there must also be a part that will become an intermediate input to support the process of other production sectors as well

In general, the input-output analysis method uses to describe the impact on the production volume of the entire economy as a result of the increase in demand or consumption in a particular production sector through the links between each other. For example, the investment of the transport facility construction will increase production, consumption, and employment in the production sectors relates to the construction industry, such as steel, soil, sand, glass. The input of the model also includes the spending of other production sectors, which are related to the construction, operation, and maintenance of this new transportation system. The Output of the model is the evaluating result of the direct and indirect effects on all production sectors in the economy.

The strengths of the input-output analysis are simplicity and transparency. In addition, the essential data for analysis was already available in almost all countries in the world. Because the government agencies responsible for statistical data was to create an Input-Output Table periodically. Also, it is a model that gives a detailed of a time-based economy and uses it to analyze the impact at each of the production sector. Moreover, the input-output analysis is a "neutral" analysis tool for political and ideological beliefs (Foran et al., 2005) because there are no behavioral conditions in model all in the case of people, entrepreneurs, or even the government.

However, the input-output analysis also has certain conditions and restrictions. One significant limitation is the "Constantly coefficient" which represents an industrial structure that will not change even if the economic situation changes. Another limitation is the "Supply-side constraint" which includes the limited amount of production factors such as skilled labor, natural resources, land, etc. Usually, "price" is a tool to determine the consumption of both producers and consumers. But in the IOA, the change only occurs in the form of the "Quantity" then Price adjustment is not set to occur in the model (West 1995 and 2005). However, the input-output analysis is an essential statistical analysis tool for cover entirely and easy to understand the complicated economy and used by countries in the world for a long time (Foran et al., 2005).

2.2.4 Summary

According to evaluate the economic impact assessment tools with four assessment criteria as namely reliability, sectorial disaggregation, transparency, and data requirements, each analysis has its strength and weakness as shown in **Table 7.**

Table 7 Economic Impact Methods: Key Features

Criteria	**Cost-benefit Analysis**	**Macro Models**	**I-O Models**
Reliability	Medium/High	Medium	Medium
Disaggregate	No	No	Sectoral

Criteria	Cost-benefit Analysis	Macro Models	I-O Models
Transparency	Medium/High	Low/Medium	Medium/High
Data Requirement	Medium	Medium/High	Medium

Wang and Charles (2010)

Form the **Table 7**, the input-output analysis was passing the 4 criteria with details as follows

- The input-output analysis can use to analyze the impacts of energy sectors both in the macroeconomy and each production sector, such as employment household and value-added. On the other hand, it can use in every country and every required base year due to each country usually collected and publicize the input-output table.
- The input-output analysis is an appropriate tool to analyze the impacts in production sectors and can disaggregate the sector as much as required if it has sufficient data.
- The details of the analysis are not too complicated and interpretation of the results from the model is not difficult.
- The required data are publicized by the government.

Therefore, this study selected the input-output analysis to be the study methodology for study the impact of economy according the changing fuel-mix composition of Thailand power generation

Chapter 3

Methodology

3.1 Input-Output Analysis Principle

The Input-output table is a table showing the relationship between factors of production and use of products despite being in the form of final demand and intermediate consumption. Analysis of economic changes by using the factors will show the connection between the manufacturing industry or various production in the economy together with the value or production level of different industries within a particular economy that meet the overall needs that arise in that economy.

According to the data collection of the System of National Account (SNA) which base data of the input-output table was collected well and always balanced between income and outcome. It can ensure that data of the table is reliable and links other macro data of the economic system.

Input-output Analysis is a tool that show the relationship between production and primary factors, intersectoral flows, and final demand and transfer, which links various production sectors in the entire economy systematically, as shown in **Table 8**.

Table 8 Input-output Analysis

Producers	Producer as Consumers					Final Demand	Total Output
	1	…	*j*	…	*n*		
1	z_{11}	…	z_{1j}	…	z_{1n}	f_1	x_1
2	z_{21}	…	z_{2j}	…	z_{2n}	f_2	x_2
⋮	⋮	⋱	⋮	⋱	⋮	⋮	⋮
n	z_{n1}	…	z_{nj}	…	z_{nn}	f_n	x_n
Value Added	v_1	…	v_j	…	v_n		

Where, z_{ij} represents transactions from sector $i = 1, 2\ldots, n$ use as intermediate input of sector $j = 1, 2\ldots, n$ when n is the total of economic sectors

f_i represents total final demand of sector i

x_i represents total output of sector i

the relationship between total output of each sector, intermediate input and total final demand in the row of the table can describe as formula (3-1) that summation of production in each sector shall equal to summation of final demand

$$x_i = z_{i1} + \cdots + z_{ij} + \cdots + z_{in} + f_i = \sum_{j=1}^{n} z_{ij} + f_i \qquad (3\text{-}1)$$

Where, a bold lowercase letters is a column vector of variable and a bold capital letter is a matrix of variable

$$\mathbf{x} = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}, \mathbf{Z} = \begin{bmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nn} \end{bmatrix} \; and \; \mathbf{f} = \begin{bmatrix} f_1 \\ \vdots \\ f_n \end{bmatrix}$$

Or describe in linear algebra as Formula (3-2)

$$\mathbf{x} = \mathbf{Z}\boldsymbol{i} + \mathbf{f} \tag{3-2}$$

Where, *i* represent column vector of 1's of appropriate n dimension

The final demand consists with a household demand, a private investment, a government investment and an export.

If the assumption of the Input-Output model is as follows

- The used raw materials in the same production sectors are assumed to be the same and assumed to be not similar in different production sectors
- In a short period (not more than 3-5 years), the price of used raw material in each production sector is fixed as assumed a used constant proportion, with have no further economy of scale, non-substitutability and non-unemployment. The employment shall depend on increasing of demand

From the assumption, the intermediate input coefficient can examine by Formula (3-3) which ratio of used raw materials in production per unit is constant.

$$a_{ij} = \frac{z_{ij}}{x_j} \tag{3-3}$$

That Production function of the input-output analysis can explain with Leontief production function as Formula (3-4)

$$x_j = min\left(\frac{z_{1j}}{a_{1j}}, \frac{z_{2j}}{a_{2j}}, \ldots, \frac{z_{nj}}{a_{nj}}\right) \tag{3-4}$$

When take Formula (3-3) into Formula (3-1), It can explain the relation between a Total output (x_i) of each production sector as shown in formula (3-5)

$$x_i = a_{i1}x_1 + \cdots + a_{ii}x_i + \cdots + a_{in}x_n + f_i = \sum_{j=1}^{n} a_{ij}z_{ij} + f_i \tag{3-5}$$

When ^ represent a *n* x *n* diagonal matrix from vector *n* that take into Formula (3-3) and (3-5) in linear algebra then it can describe in Formula (3-6) and (3-7) accordingly.

$$\mathbf{A} = \mathbf{Z}\hat{\boldsymbol{x}}^{-1} \text{ or } \mathbf{Z} = \mathbf{A}\hat{\mathbf{x}} \quad (3\text{-}6)$$

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f} \quad (3\text{-}7)$$

When **I** represent a *n* x *n* identity matrix which value in diagonal is 1. Formula (3-7) can describe in a new formula as Formula (3-8)

$$(\mathbf{I} - \mathbf{A})\mathbf{x} = \mathbf{f} \quad (3\text{-}8)$$

When $\mathbf{L} = \mathbf{I} - \mathbf{A}^{-1}$ represent is inverse matric of **(I – A)** called "Leontief Inverse" then the Total output from final demand can examine as shown as Formula (3-9)

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{L}\mathbf{f} \quad (3\text{-}9)$$

The Formula (3-9) is used to initiate the study by changing the final demand or Production function related to the electricity generation's composition.

3.2 Multiplier Effect

Multiplier is a coefficient which describes the effect on the economy's changing by external factors or Exogenous changes.

- Initial effect is the directly changing by external factor which impact to the economy's system
- Direct effects are the production value factor of each sector, which used in the production of goods or services to respond to the "directly" changing of an external factor. In the case of changing one unit of an external factor, the required factors' production value is an Intermediate input matrix or matrix **A**.
- Indirect effects are the consequent effects that describe the used factors in the production of goods or services as factors of production in the previous cycle or describe to $\mathbf{A}^2 + \mathbf{A}^3 + \ldots$

So that the total effect of the changing one external factor is the summation of initial effect, direct effects and indirect effect as describe as Formula (3-10) that called "Leontief Inverse"

$$(\mathbf{I} - \mathbf{A})^{-1} = \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \cdots \quad (3\text{-}10)$$

Multiplier usually uses for analyzing the several estimations of the effects of exogenous changes such as

1. the total outputs of each production sector.
2. the household's income in each production sector.
3. the increasing of employment in each production sector.

4. Value-added of each production sector e.g. indirect tax, profits.

An output multiplier of the production sector j is defined as the total value of production in all sectors of the economy that is response to the changing of one value unit of final demand. The simple output multiplier for the sector can be describes as

$$m(o)_j = \sum_{i=1}^{n} l_{ij} \tag{3-11}$$

Or rewrite to linear algebra equation as

$$\boldsymbol{m}(o) = \boldsymbol{i}'\boldsymbol{L} \tag{3-12}$$

Where **i**' is a row vector of the matrix **i** or matrix [1,...,1]

However, there are one of multiplier call "Income Multiplier" is commonly used to analyze the impact of final demand, which is calculated by multiplying Leontief Inverse by the vector of the coefficient of Vector (employment coefficient,) as

$$\boldsymbol{\varepsilon}' = \mathbf{e}'\hat{\mathbf{x}}^{-1} \tag{3-13}$$

Where $\boldsymbol{\varepsilon}'$ is the vector of employment in each sector

Income multiplier can examine by the Formula (3-14)

$$m(h)_j = \sum_{i=1}^{n} \varepsilon_i l_{ij} \tag{3-14}$$

Or rewrite to linear algebra formula as Formula (3-15)

$$\boldsymbol{m}(h) = \boldsymbol{\varepsilon}'\boldsymbol{L} \tag{3-15}$$

Chapter 4

Results and Conclusion

4.1 Implementation

Firstly, before the analyzing the impacts of the economy by the Input-Output Analysis. The GTAP9 data table was aggregated sector from 57 commodities into 22 sectors and uses alternative GTAP Power Data Base to disaggregate "Electricity" sector to 9 sub-sectors separate by fuel type.

Figure 2 IO Table aggregation and disaggregation step

Table 9 Sectors Mapping

Original Sectors 57 Sectors	**Aggregated Sectors 22 Sectors**	**Disaggregate Electricity Sector 30 Sectors**
Paddy rice	Agriculture, Forestry and Fishing	Agriculture, Forestry and Fishing
Wheat		
Cereal grains nec		
Vegetables, fruit, nuts		
Oil seeds		
Sugar cane, sugar beet		
Plant-based fibers		
Crops nec		
Cattle,sheep,goats,horses		
Animal products nec		
Raw milk		
Wool, silk-worm cocoons		
Forestry		
Fishing		
Coal	Coal	Coal
Oil	Oil	Oil
Gas	Gas	Gas
Other minings	Other minings	Other minings
Meat: cattle,sheep,goats,horse	Food processing products	Food processing products
Meat products nec		
Vegetable oils and fats		
Dairy products		
Processed rice		
Sugar		
Food products nec		

Original Sectors 57 Sectors	**Aggregated Sectors 22 Sectors**	**Disaggregate Electricity Sector 30 Sectors**
Beverages and tobacco products		
Petroleum, coal products	Petroleum, coal products	Petroleum, coal products
Chemical, rubber, plastic products	Chemical, rubber, plastic products	Chemical, rubber, plastic products
Ferrous metals	Ferrous, non-ferrous and metal products	Ferrous, non-ferrous and metal products
Metals nec		
Textiles	Primary industries (textile, leather, wood, paper)	Primary industries (textile, leather, wood, paper)
Wearing apparel		
Leather products		
Wood products		
Paper products, publishing		
Metal products		
Motor vehicles and parts	Motor vehicles and transport equipment	Motor vehicles and transport equipment
Transport equipment nec		
Electronic equipment	Electronic equipment	Electronic equipment
Machinery and equipment	Machinery and equipment	Machinery and equipment
Other manufactures	Other manufactures	Other manufactures
Electricity	Electricity	Transmission & distribution
		Nuclear power electricity
		Coal power electricity
		Gas power electricity
		Wind power electricity
		Hydroelectric
		Oil power electricity
		Solar power electricity
		Other electricity
Gas manufacture, distribution	Gas manufacture, distribution	Gas manufacture, distribution
Construction	Construction	Construction
Trade	Trade	Trade
Transport nec	Transportation	Transportation
Sea transport		
Air transport		
Communication	Communication	Communication
Financial services nec	Financial services, insurance and business services	Financial services, insurance and business services
Insurance		
Business services nec	Other services	Other services
Recreation and other services		

Original Sectors 57 Sectors	Aggregated Sectors 22 Sectors	Disaggregate Electricity Sector 30 Sectors
PubAdmin/Defence/Health/Educat		
Dwellings		
Water		

Then, the actual generated data on the year 2011 was set as the base data are shown in **Table 10** and uses the forecasted percentage of energy generation in PDP2015 and PDP2018 as the scenarios as shown in **Table 11** and **12** accordingly with the assumption of the following data:

1. Transmission line loss is 9.28% as the proportion of the transmission sector with the overall total output of the energy production sector at year 2011.
2. Both scenarios set the increasing power consumption from the year 2011 to the end of planned year from 164,089.92 GWh to 326,120.00 GWh

Table 10 Energy Generation by Fuel type on 2011

No.	Fuel Type	GWh
1	Natural Gas	108,261.32
2	Coal & Lignite	31,711.73
3	Oil	1,351.56
4	Hydro	7,934.92
5	Imported	10,774.41
	- LA-Hydro	10,643.41
	- MY-Hydro	8.31
	- MY-Gas	57.46
	- MY-Coal	53.92
	- MY-Oil	4.43
	- MY-Diesel	5.27
	- MY-Others	1.62
6	Solar	95.10
7	Wind	4.70
8	Other Renewable	3,956.18
Total		164,089.92
Loss		32,212.35

Table 11 Planned Energy Generation by Fuel type as PDP2015

Sector code	Electricity Sector	GWh	Percentage
tnd	Transmission & distribution	30,277.62	9.28%
nuc	Nuclear power electricity	14,599.80	4.48%
cnl	Coal power electricity	66,911.90	20.52%

Sector code	Electricity Sector	GWh	Percentage
gss	Gas power electricity	109,048.97	33.44%
wnd	Wind power electricity	9,056.65	2.78%
hyd	Hydroelectric	52,165.49	16.00%
oll	Oil power electricity	46.89	0.01%
slr	Solar power electricity	18,101.22	5.55%
xel	Other electricity	25,911.44	7.95%
Total Planned Energy Generation		326,120.00	100.00%

Table 12 Planned Energy Generation by Fuel type as PDP2018

Sector code	Electricity Sector	GWh	Percentage
tnd	Transmission & distribution	32,212.35	9.28%
nuc	Nuclear power electricity	-	0.00%
cnl	Coal power electricity	41,858.01	12.06%
gss	Gas power electricity	177,911.34	51.28%
wnd	Wind power electricity	9,056.65	2.61%
hyd	Hydroelectric	34,758.04	10.02%
oll	Oil power electricity	100.42	0.03%
slr	Solar power electricity	18,101.22	5.22%
xel	Other electricity	32,960.97	9.50%
Total Planned Energy Generation		346,959.00	100.00%

The total Energy Generation separated by fuel type following the PDP2015 and PDP2018 were set into the scenario and converted the percentage of planned energy generation to a differential of energy final demand by multiply with a total final demand of all energy sectors as describe in **Formula (4-1)** and get a result as **Table 13**.

$$\mathbf{\Delta f}_{Scenario} = \%\mathbf{G}_{Planned} \times \mathbf{f}_{Energy} \quad (4\text{-}1)$$

Table 13 Converted Planned Energy Generation to ΔF

Sector code	Electricity Sector	Δf_S1	Δf_S2
Tnd	Transmission & distribution	7,862.53	7,862.53
Nuc	Nuclear power electricity	3,791.29	-
Cnl	Coal power electricity	17,375.76	10,216.88
Gss	Gas power electricity	28,317.96	43,425.35
Wnd	Wind power electricity	2,351.84	2,210.58
Hyd	Hydroelectric	13,546.40	8,483.89

Sector code	Electricity Sector	Δf_S1	Δf_S2
Oil	Oil power electricity	12.18	24.51
Slr	Solar power electricity	4,700.55	4,418.22
Xel	Other electricity	6,728.71	8,045.25

Then the research rewrite final demand variable in the formula (3-9) to **Δ**F and take the data in **Table 13** to calculate the difference total output as the results separate by sector shown in **Table 14**.

$$\mathbf{\Delta x = L\Delta f} \quad (4\text{-}2)$$

Table 14 Differential of sectoral total output

Sector	Scenario I	Scenario II	Diff.
Agriculture, Forestry and Fishing	303.36	346.42	43.06
Coal	15,817.57	9,426.10	-6,391.48
Oil	5,268.28	5,626.66	358.38
Gas	11,589.19	17,067.33	5,478.14
Other minings	244.68	271.09	26.41
Food processing products	290.62	327.62	37.00
Petroleum, coal products	6,566.72	6,990.40	423.69
Chemical, rubber, plastic products	1,393.22	1,572.98	179.77
Ferrous, non-ferrous and metal products	137.11	151.61	14.49
Primary industries (textile, leather, wood, paper)	1,791.36	1,960.97	169.61
Motor vehicles and transport equipment	985.08	1,028.40	43.32
Electronic equipment	368.91	444.12	75.22
Machinery and equipment	3,420.99	3,546.20	125.22
Other manufactures	1,513.36	1,850.27	336.91
Transmission & distribution	8,377.31	8,369.87	-7.43
Nuclear power electricity	3,800.97	9.27	-3,791.70
Coal power electricity	17,695.44	10,531.85	-7,163.59
Gas power electricity	29,823.14	44,909.71	15,086.57
Wind power electricity	2,354.32	2,212.95	-141.36
Hydroelectric	13,575.16	8,511.89	-5,063.27
Oil power electricity	65.89	77.31	11.41
Solar power electricity	4,702.04	4,419.67	-282.37
Other electricity	6,748.15	8,064.34	1,316.19
Gas manufacture, distribution	22,043.47	33,130.02	11,086.54
Construction	123.85	150.83	26.98
Trade	2,155.20	2,338.59	183.39
Transportation	3,742.52	2,688.05	-1,054.47

Sector	Scenario I	Scenario II	Diff.
Communication	728.26	897.19	168.93
Financial services, insurance and business services	3,304.81	4,230.18	925.36
Other services	4,677.41	6,137.52	1,460.11
Total	173,608.39	187,289.40	
Comparison	-	-7.88%	

The coefficient was found by using sectoral income, sectoral value-Added and sectoral tax divide by sectoral total output. The result shown as **Table 15**.

Table 15 Coefficient table

Sector	Income coefficient	Value-Added coefficient	Tax coefficient
Agriculture, Forestry and Fishing	0.2131	0.5658	0.0110
Coal	0.1235	0.7744	0.0041
Oil	0.1186	0.6726	0.0037
Gas	0.1613	0.8138	0.0048
Other mining	0.1626	0.6690	0.0060
Food processing products	0.0709	0.2362	0.0028
Petroleum, coal products	0.0245	0.0907	0.0006
Chemical, rubber, plastic products	0.0868	0.3116	0.0179
Ferrous, non-ferrous and metal products	0.0856	0.3320	0.0161
Primary industries (textile, leather, wood, paper)	0.0811	0.2372	0.0055
Motor vehicles and transport equipment	0.0609	0.2037	0.0016
Electronic equipment	0.0535	0.2029	0.0016
Machinery and equipment	0.0645	0.2363	0.0022
Other manufactures	0.1056	0.3038	0.0033
Transmission & distribution	0.2326	0.5309	0.0258
Nuclear power electricity	0.0000	1.0000	1.0000
Coal power electricity	0.0135	0.0940	0.0417
Gas power electricity	0.0045	0.0882	0.0699
Wind power electricity	0.1721	0.9244	0.0056
Hydroelectric	0.0801	0.9315	0.0042
Oil power electricity	0.0129	0.1194	0.0974
Solar power electricity	0.0790	0.9496	0.0040
Other electricity	0.0981	0.5031	0.0512
Gas manufacture, distribution	0.1149	0.5336	0.0033
Construction	0.0935	0.2377	0.0027
Trade	0.1926	0.7200	0.0057
Transportation	0.1147	0.3072	0.0349

Sector	Income coefficient	Value-Added coefficient	Tax coefficient
Communication	0.1820	0.6237	0.0051
Financial services, insurance and business services	0.2548	0.7095	0.0064
Other services	0.4414	0.6697	0.0097

Rewrite Formula (4-1) to study the multiplier effect of income specifically in following Formula (4-2)

$$\boldsymbol{\varepsilon}'\mathbf{\Delta x} = \boldsymbol{\varepsilon}'\,\mathbf{L\Delta f} \tag{4-3}$$

Where, $\boldsymbol{\varepsilon}'$ represent income coefficient

Also, studying the value-Added and tax by multiplier

$$\boldsymbol{v}'\mathbf{\Delta x} = \boldsymbol{v}'\,\mathbf{L\Delta f} \tag{4-4}$$
$$\tau'\mathbf{\Delta x} = \boldsymbol{\tau}'\,\mathbf{L\Delta f} \tag{4-5}$$

Where, $\boldsymbol{v}'$ represent value-added coefficient
τ' represent tax coefficient

4.2 Linkage result

As shown in the **Figure 3** The Leontief inverse can use for considering the linkage of each electricity sector. The Forward linkage which describes the relationship between one production unit used as inputs for other production units that reflect the effect to downstream industry sector. Normally, the electricity sector is most downstream industry of entire economy but it can be seen that the natural gas power sector is most effect to the downstream sector. It is 1.59 higher than the coal power generation that is 1.12.

However, the backward linkage which describes the relationship between other production units is used as inputs of the considered sector that reflect the effect from upstream sector. It can be seen that the highest value is oil power generation but both gas-fired and coal-fired are most familiar at 2.46 and 2.55 accordingly.

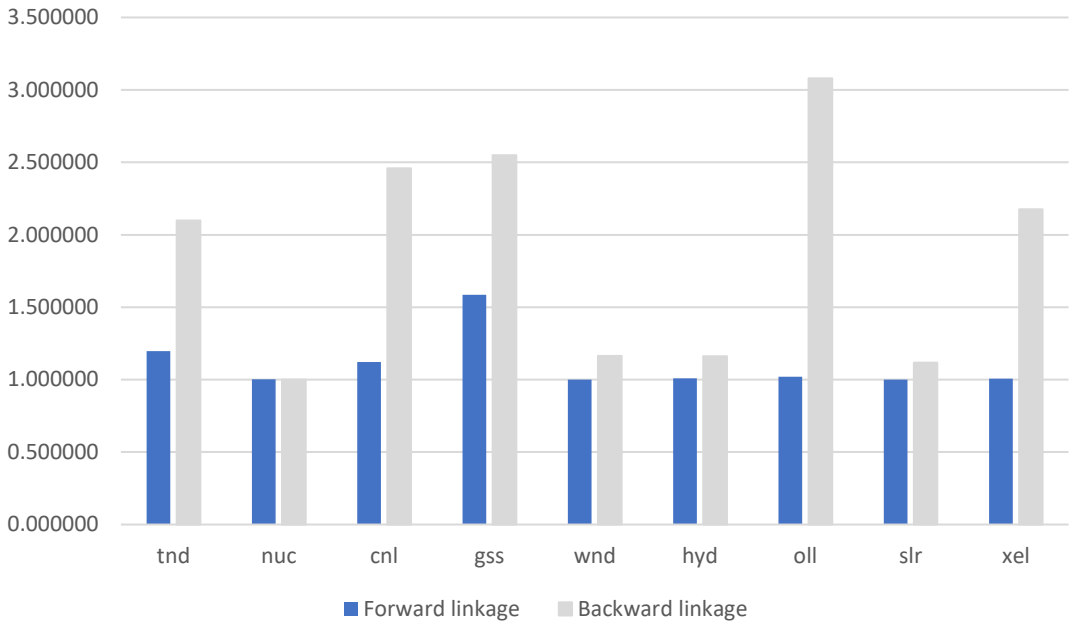

Figure 3 The Linkage's result

Therefore, the comparison linkage's effect between the gas-fired and coal-fired not difference on the upstream industry but gas power generation will be effect more than the coal power on the downstream industry

4.3 Value-added multiplier result

In term of economy value-added which relate to the GDP is shown in **Table 16** and **Figure 4**. The Value-added multiplier result of Scenario I has higher value-added in the sectors relate to Coal industry such as Coal and Coal power electricity and the sectors relate to PDP2015 which are Nuclear and Hydro power electricity but Scenario II has higher value-added in the sectors relate to Gas sector such as Gas, Gas power electricity and Gas distribution. The total value-added between both scenarios are familiar that explain the expansion of the GDP not difference.

***Table 16** The Value-added multiplier's result*

Sector	Scenario I	Scenario II	Diff.
Agriculture, Forestry and Fishing	171.64	196.01	24.37
Coal	12,249.62	7,299.86	-4,949.76
Oil	3,543.30	3,784.34	241.04
Gas	9,430.94	13,888.88	4,457.94
Other minings	163.70	181.37	17.67
Food processing products	68.64	77.38	8.74
Petroleum, coal products	595.45	633.87	38.42
Chemical, rubber, plastic products	434.13	490.15	56.02
Ferrous, non-ferrous and metal products	45.52	50.33	4.81

Sector	Scenario I	Scenario II	Diff.
Primary industries (textile, leather, wood, paper)	424.83	465.06	40.22
Motor vehicles and transport equipment	200.70	209.52	8.83
Electronic equipment	74.84	90.10	15.26
Machinery and equipment	808.47	838.06	29.59
Other manufactures	459.73	562.08	102.35
Transmission & distribution	4,447.20	4,443.25	-3.95
Nuclear power electricity	3,800.97	9.27	-3,791.70
Coal power electricity	1,664.20	990.49	-673.71
Gas power electricity	2,631.71	3,963.00	1,331.30
Wind power electricity	2,176.26	2,045.59	-130.67
Hydroelectric	12,644.90	7,928.60	-4,716.30
Oil power electricity	7.87	9.23	1.36
Solar power electricity	4,465.00	4,196.86	-268.14
Other electricity	3,394.72	4,056.83	662.12
Gas manufacture, distribution	11,761.78	17,677.24	5,915.47
Construction	29.44	35.86	6.42
Trade	1,551.65	1,683.68	132.03
Transportation	1,149.84	825.86	-323.97
Communication	454.24	559.60	105.36
Financial services, insurance and business services	2,344.79	3,001.34	656.55
Other services	3,132.55	4,110.41	977.86
Total	84,328.63	84,304.14	
Comparison	-	-0.03%	

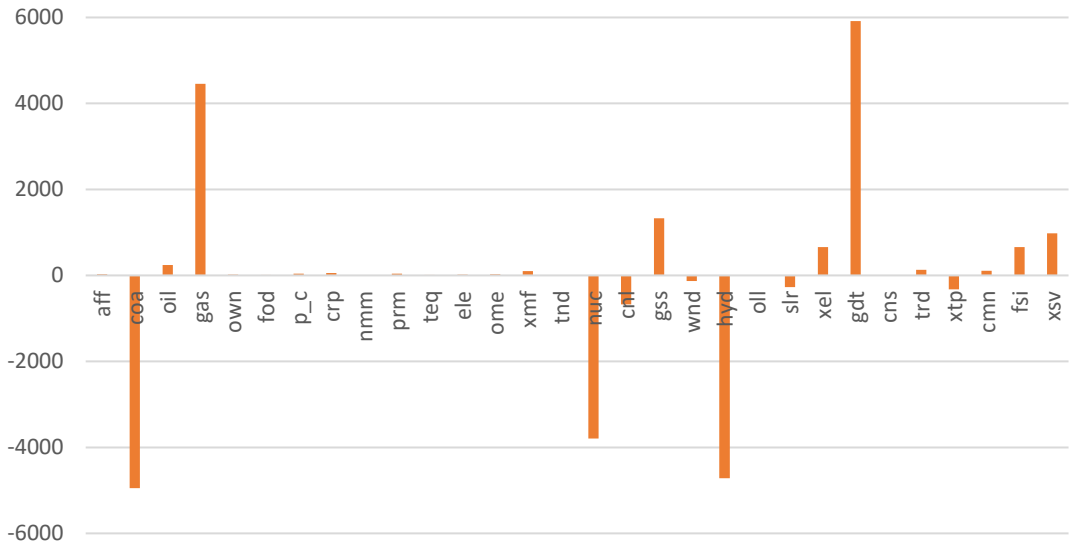

Figure 4 Different of Value-added between both plan

4.4 Income multiplier result

The income multiplier reflects the increasing of household income including both skilled and unskilled labor with the result of backward linkage. The total income from the gas relevant sectors such as gas distribution, gas industry and the other service in scenario II are higher than the coal industry and hydro power electricity. It can explain that the scenario II will make a benefit and increase total income to the household more than scenario I.

Table 17 The Income multiplier's result

Sector	Scenario I	Scenario II	Diff.
Agriculture, Forestry and Fishing	64.64	73.82	9.18
Coal	1,952.72	1,163.68	-789.04
Oil	624.56	667.04	42.49
Gas	1,869.51	2,753.22	883.71
Other minings	39.79	44.08	4.29
Food processing products	20.61	23.23	2.62
Petroleum, coal products	161.14	171.54	10.40
Chemical, rubber, plastic products	120.96	136.57	15.61
Ferrous, non-ferrous and metal products	11.73	12.97	1.24
Primary industries (textile, leather, wood, paper)	145.31	159.07	13.76
Motor vehicles and transport equipment	59.95	62.59	2.64
Electronic equipment	19.75	23.77	4.03
Machinery and equipment	220.70	228.78	8.08
Other manufactures	159.88	195.48	35.59

Sector	Scenario I	Scenario II	Diff.
Transmission & distribution	1,948.78	1,947.05	-1.73
Nuclear power electricity	-	-	0.00
Coal power electricity	238.29	141.82	-96.47
Gas power electricity	135.60	204.20	68.60
Wind power electricity	405.25	380.92	-24.33
Hydroelectric	1,087.63	681.97	-405.67
Oil power electricity	0.85	0.99	0.15
Solar power electricity	371.32	349.02	-22.30
Other electricity	661.74	790.81	129.07
Gas manufacture, distribution	2,533.52	3,807.73	1,274.21
Construction	11.57	14.10	2.52
Trade	415.13	450.45	35.32
Transportation	429.18	308.26	-120.92
Communication	132.56	163.31	30.75
Financial services, insurance and business services	842.20	1,078.02	235.82
Other services	2,064.53	2,709.00	644.47
Total	16,749.42	18,743.49	
Comparison	-	+11.91%	

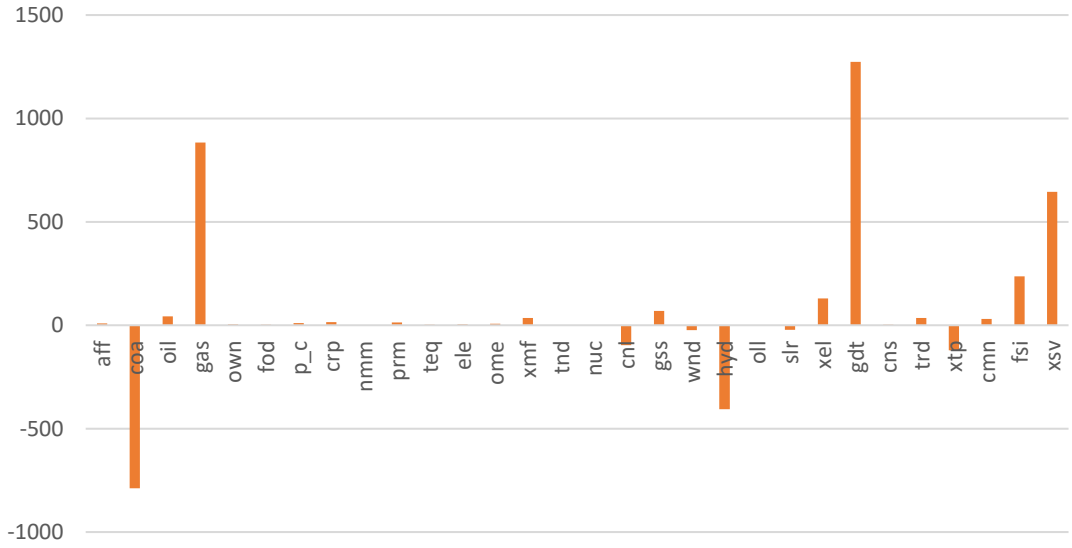

Figure 5 Different of Income between both plan

4.5 Tax multiplier result

The essential government's taxes of this research are in the nuclear electricity, coal electricity and gas electricity sector. Form the result of Tax multiplier shows that the highest tax is nuclear electricity which is not generate in scenario II cause to many tax losses even if there is a compensate tax from gas electricity sector. Therefore, the

government loss profits up to 38.13% if they implement the scenario II instead of scenario I as shown in **Table 18** and **Figure 6**

Table 18 The Tax multiplier's result

Sector	Scenario I	Scenario II	Diff.
Agriculture, Forestry and Fishing	3.34	3.82	0.47
Coal	64.66	38.53	-26.13
Oil	19.66	20.99	1.34
Gas	55.58	81.85	26.27
Other minings	1.48	1.64	0.16
Food processing products	0.81	0.91	0.10
Petroleum, coal products	4.19	4.46	0.27
Chemical, rubber, plastic products	24.90	28.11	3.21
Ferrous, non-ferrous and metal products	2.21	2.44	0.23
Primary industries (textile, leather, wood, paper)	9.83	10.77	0.93
Motor vehicles and transport equipment	1.54	1.60	0.07
Electronic equipment	0.59	0.71	0.12
Machinery and equipment	7.68	7.96	0.28
Other manufactures	4.93	6.03	1.10
Transmission & distribution	215.98	215.79	-0.19
Nuclear power electricity	3,800.97	9.27	-3,791.70
Coal power electricity	737.22	438.78	-298.45
Gas power electricity	2,083.82	3,137.96	1,054.14
Wind power electricity	13.21	12.42	-0.79
Hydroelectric	56.38	35.35	-21.03
Oil power electricity	6.42	7.53	1.11
Solar power electricity	18.70	17.58	-1.12
Other electricity	345.26	412.60	67.34
Gas manufacture, distribution	72.51	108.98	36.47
Construction	0.33	0.40	0.07
Trade	12.22	13.26	1.04
Transportation	130.80	93.95	-36.85
Communication	3.73	4.60	0.87
Financial services, insurance and business services	21.20	27.13	5.94
Other services	45.15	59.24	14.09
Total	7,765.30	4,804.65	
Comparison	-	-38.13 %	

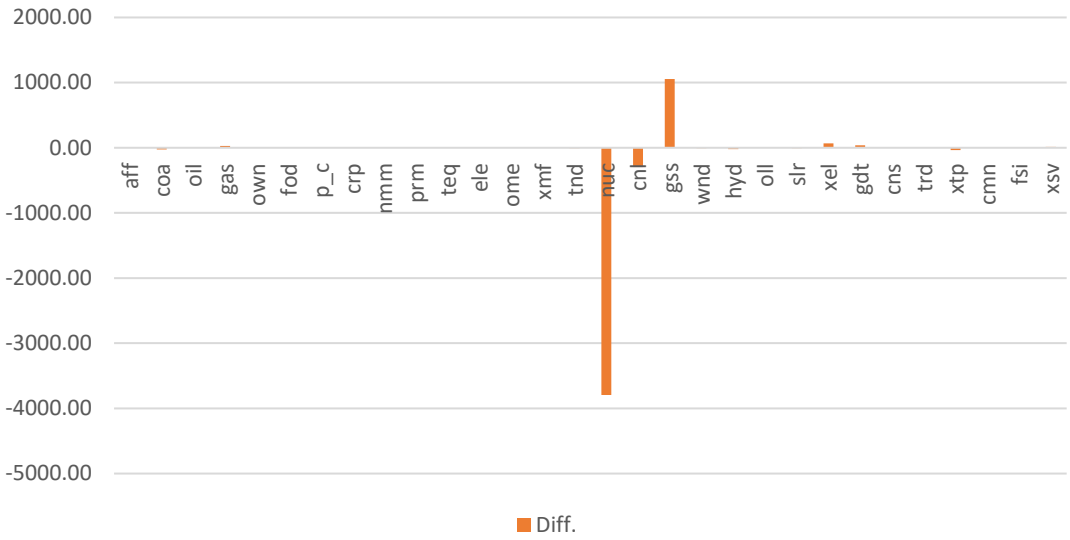

Figure 6 *Different of Income between both plan*

4.6 Carbon Footprint

However, the research uses the carbon emission data in the GTAP data base as shown in **Table 19** to additional analyzing the impact not only in economy but also in environment as well according to changing the fuel-mixed proportions of Thailand power generation.

Table 19 Carbon Footprint in each sector

Sector	Carbon Footprint (Mtoe/MillionUSD)
Agriculture, Forestry and Fishing	0.0074
Coal	0.0005
Oil	0.0015
Gas	0.0007
Other minings	0.0006
Food processing products	0.0052
Petroleum, coal products	0.0014
Chemical, rubber, plastic products	0.0021
Ferrous, non-ferrous and metal products	0.0031
Primary industries (textile, leather, wood, paper)	0.0021
Motor vehicles and transport equipment	0.0013
Electronic equipment	0.0013
Machinery and equipment	0.0007
Other manufactures	0.0056
Transmission & distribution	0.0002
Nuclear power electricity	0.0000
Coal power electricity	0.0114
Gas power electricity	0.0019
Wind power electricity	0.0050

Sector	Carbon Footprint (Mtoe/MillionUSD)
Hydroelectric	0.0001
Oil power electricity	0.0001
Solar power electricity	0.0001
Other electricity	0.0005
Gas manufacture, distribution	0.0111
Construction	0.0013
Trade	0.0003
Transportation	0.0075
Communication	0.0004
Financial services, insurance and business services	0.0005
Other services	0.0035

As the result, the carbon footprint from scenario II release the carbon more 72.53 Mtoe than the scenario I or incrase up to 11.54%. the major sector is gas manufacture, distribution that release up to 369.31 Mtoe. The Government shall carefully consider the increasing the gas-fired powerplant balance with the coal-fired power plant to minimize the country's carbon footprint.

Table 20 The Carbon Footprint's result

Sector	Scenario I	Scenario II	Diff.
Agriculture, Forestry and Fishing	2.25	2.57	0.3197
Coal	8.43	5.03	-3.4074
Oil	8.04	8.59	0.5470
Gas	7.59	11.17	3.5858
Other mining	0.15	0.17	0.0164
Food processing products	1.51	1.70	0.1917
Petroleum, coal products	9.17	9.76	0.5918
Chemical, rubber, plastic products	2.96	3.34	0.3820
Ferrous, non-ferrous and metal products	0.43	0.48	0.0456
Primary industries (textile, leather, wood, paper)	3.81	4.17	0.3604
Motor vehicles and transport equipment	1.27	1.33	0.0560
Electronic equipment	0.48	0.58	0.0977
Machinery and equipment	2.48	2.57	0.0908
Other manufactures	8.47	10.35	1.8850
Transmission & distribution	1.91	1.91	-0.0017
Nuclear power electricity	-	-	0.0000
Coal power electricity	202.05	120.26	-81.7968
Gas power electricity	57.23	86.18	28.9521
Wind power electricity	11.68	10.98	-0.7016

Sector	Scenario I	Scenario II	Diff.
Hydroelectric	1.76	1.11	-0.6580
Oil power electricity	0.01	0.01	0.0015
Solar power electricity	0.44	0.41	-0.0264
Other electricity	3.46	4.14	0.6749
Gas manufacture, distribution	245.72	369.31	123.5845
Construction	0.16	0.20	0.0356
Trade	0.57	0.61	0.0482
Transportation	28.14	20.21	-7.9299
Communication	0.31	0.39	0.0729
Financial services, insurance and business services	1.56	2.00	0.4380
Other services	16.26	21.34	5.0773
Total	628.34	700.87	
Comparison		+11.54	

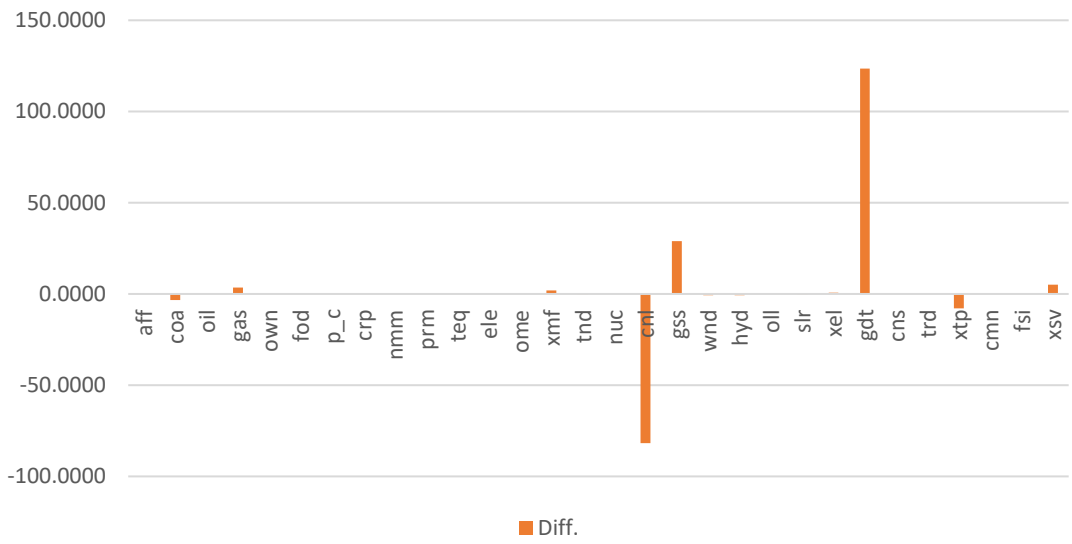

Figure 7 Difference of Carbon footprint between Both Plans

4.7 Conclusion

As shown in **Table 21**, The analysis with the power generation composition as in scenario I and scenario II started by analyzing the result of considering the increase of value-added of the economy of Scenarios II. It is found that there is a slight difference of GDP expansion between the scenarios. When additionally consider in the total income by income multiplier, the increase of scenario II above scenario I up to 11.91% show that the use of a gas fuel generation higher than coal directly more affects the total income of the economy especially in the household sector. However, when compare both scenarios with the tax that the government will receive, it reduces more than 38.13%. And the comparison of the increasing total output between both scenarios which is the essential variable that shows the impact of the entire Thailand

economic system. It is found that the total output of scenario II has a higher value than 7.88 percentage above the scenario II.

Table 21 The result comparison.

	Scenario I	Scenario II	% Comparison
Delta Value-added multiplier	84,328.62	84,304.14	-0.03%
Delta income multiplier	16,749.42	18,743.49	+11.91%
Delta Tax multiplier	7,765.29	4,804.65	-38.13%
Delta Total Output	173,608.39	187,289.40	+7.88%
Delta Carbon Footprint	628.34	700.87	+11.54%

Form the analysis results mentioned above, it can conclude that increasing the composition of Gas fuel, according to the power development plan 2018, will significantly benefit the economy. The relevant government agencies can use the results of this study to be the information and tools to determine the suitable proportion to achieve the highest economic benefits that the study shows the increasing of the composition of gas-fired power plants will benefit the overall economy better than the coal-fired power plants. However, the government has to consider the breakeven point of losing revenue from taxation, the environmental issue and the power security especially the concerns such as the shortage of domestic gas supply or the ineffective implementation of renewable energy promotion.

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