Energy Economic Impacts of Feed-in Tariff Programs under Thai Renewable Energy Electricity Plan

Energy Input-Output Analysis

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***Abstract*—In order to launch a new policy that could improve higher contribution of private investments on renewable electricity supplied to the grid, Feed-in tariffs (FITs) program is currently aimed to substitute the previous adder program in Thailand. Increasing in renewable electricity supplied from private sector to the grid could induce higher direct and indirect effects to the economy in long run. This study provides a long-term impact assessment of the expected FIT and quantity implemented in the economy by energy input-output model. Annual expected FIT's from each renewable power sector were assessed from financial analysis and forecasted related to future costs trends. The renewable electricity contributions were forecasted as presented in the Alternative Energy Development Plan (AEDP 2012-2021) and in the Power Development Plan (PDP2010). Specific input-output structure in each additional renewable energy power sector was provided based on surveyed data. The reference scenarios were assumed that the grid electricity was performed in business as usual activity (BAU) without renewable electricity supplied. The macro economic impacts from purchasing electricity from private renewable power sector were assessed annually base on Energy Input-Output model in terms of economy-wide output, total primary energy supply (TPES), CO_2 emissions, and value of employment, during the studied period. Result of the study presented a higher TPES, particularly in biomass, but a lower in fossil primary energy supply. There were increasing in significant annual CO_2 emissions reductions. Both of the FITs under two different plans induced reductions in import content with some reductions in local employments due to less employments required in renewable power plants. Better impacts on FITs programs could be found in the PDP case where each renewable energy technology was supplied to the grid prioritized by minimum cost.**

***Index Terms*—Energy planning, CO_2 emissions, Feed-in tariffs, Adders, Economics impact, Input-Output Analysis**

I. Introduction

In Thailand, 4 potential renewable energy sources for electricity generation supplied to the grid are solar PV, wind, small hydro and biomass, but sources their return on investments are not interesting comparing with other power generation. Since 2006, the adder has been announced to subsidize the small power producer (SPP) and the very small power producer (VSPP) programs to motivate a private sector investment in electricity generation from renewable energy i.e. biomass, biogas, waste, hydro, wind, and solar electricity [1]. Under the adder program, only biomass and PV are nominated, but totally under expectation. Many companies requested for delay of the committed company Schedule commercial operation date (SCOD) to the grid [2]. New target has been placed according to the 15-Years Renewable Energy Plan and the AEDP 2012-2021with higher adder price [3].

To provide a better wholesale electricity price that would be fair to producers and customers, the Feed-in tariffs (FIT) program has been announced by the National Energy Policy Board in 2013, according to the AEDP 2012-2021, with higher target of electricity supplied from renewable energy [4]. The FITs will be paid as a fixed wholesale price to a contracted private company who supply electricity from a designated renewable energy in a long term contract period. With higher amount of burden, as a result of subsidizing price and quantity, the higher average retail electricity price should be aware of, comparing to the business-as-usual increasing based price.

This study provides an impact assessment of implementation of renewable energy electricity supplied from the private sector under FITs program in Thailand in 2010-2030. Two FITs programs with different renewable fuel mix programs, i.e. AEDP during 2010-2020 and prioritized under PDP2010 during 2010 to 2030, were assessed. The results were presented in terms of changes in total monetary outputs and employments, TPES and CO_2 from Thai economy.

II. Methodology and Assumptions

According to input-output (I-O) model, annual impact was assessed in order to provide a long term impact. To identify annual impact, assumptions were provided on business-as-usual (BAU) and on two of the studied FITs program cases (Program), as seen in Fig. 1.

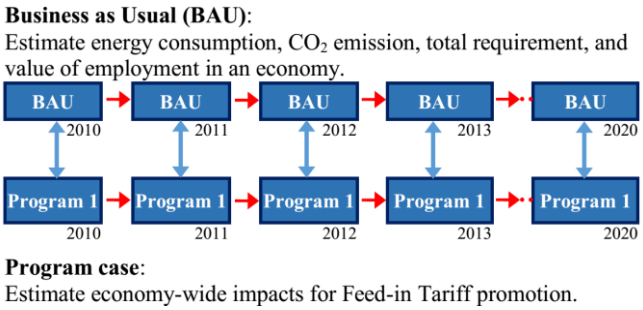

Fig. 1. Annual assumptions between BAU and program cases.

A. Selected Renewable Energy Sources

Four potential renewable energy sources contributed in the FITs program are solar PV, wind, small hydro and biomass. Each renewable power supply was located in 5 new defined power sectors due to common in their cost structures i.e.

- Solar Rooftop power sector
- Solar Farm power sector
- Wind Farm power sector
- Biomass power sector
- Small Hydro power sector

B. Senarios

During the planning period, annual wholesale trades from these power sectors were expected to penetrate into the grid supply into 2 FITs program scenarios and their individual reference business-as-usual (BAU) i.e.

1) AEDP Case

- Share of electricity sold to the grid from each defined renewable power sector were as addressed in the AEDP in 2012-2021 [4]. (see Fig. 2)
- The reference scenario was assumed that the grid electricity was performed in business as usual activity (BAU) without renewable electricity supplied.

2) PDP case

- Share of electricity from these 5 renewable power sectors* were supplied to the grid according to accumulated power installed as addressed in the PDP2010 revision 3 [5], including additional new biomass (see Fig. 3). By the PDP, each renewable energy technology was supplied to the grid prioritized by their costs. Biomass is the first priority, followed by wind, small hydro, and PV. New potential biomass was added into the biomass sector.
- This reference scenario was assumed that the grid electricity was performed in BAU without additional renewable electricity supplied.

*except waste and large hydro power in PDP2010

C. Annual Wholesale and Retail Prices of Electricity

Annual wholesale/retail prices, quantity, cost structure were preliminary assessed prior to provided direct economy-wide impacts.

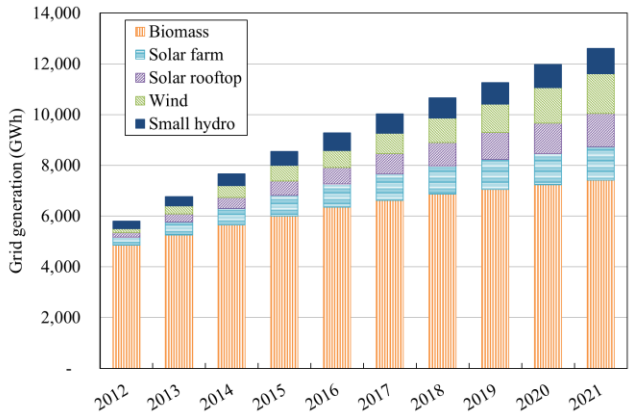

Fig. 2. Penetration of renewable electricity to the grid 2012-2021: AEDP case

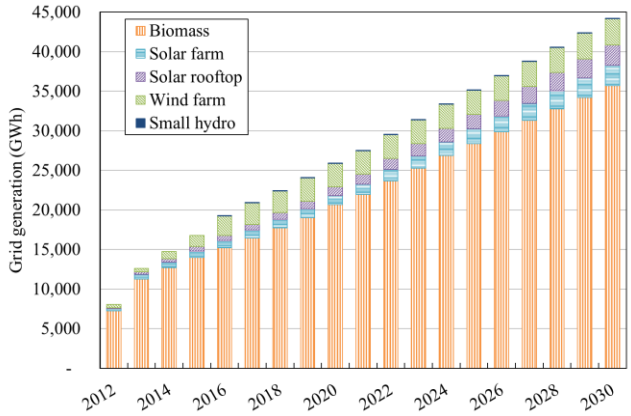

Fig. 3. Penetration of renewable electricity to the grid 2012-2030 based on PDP2010 and new biomass.

- FITs was defined as the expected wholesale electricity price bought from quantity of contracted electricity generation companies entered in each year.
- Annual retail electricity price was defined as a common price that all end users paid to the grid.
- Direct impact from electricity supply from these additional power sector caused different inter-industrial transactions, compared to the business-as-usual economic activity.

1) Projections of wholesale renewable electricity prices bought to the grid

FITs that each power sector would be paid on the commercial operating date (COD) until end of the contract, was represented as FITs on COD year. The FITs on COD year were estimated during 2010-2030 based on expected return-on-investment of each technology and projected escalation of costs, according to IAEA projection [6], in each technology. A specific FIT paid for additional electricity quantity supplied from each power plant was fixed since the COD until the operation reached 20-years of contract period. The annual FIT prices for these five technologies by COD year were derived in the previous author's work [7], and presented in Fig. 4.

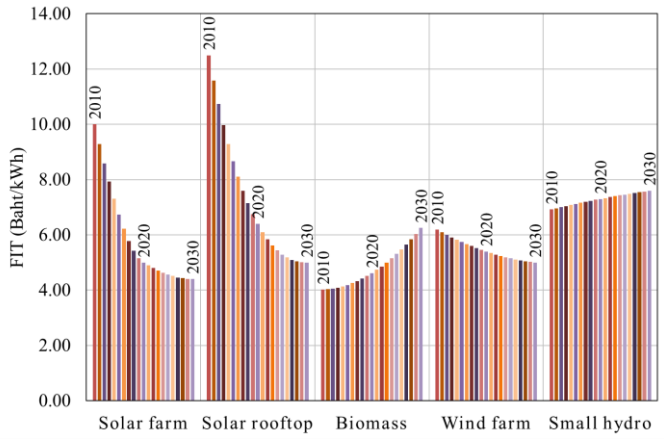

Fig. 4. Long term FIT prices for COD of 5 renewable energy technologies[10]

2) Retail Electricity Price

Average electricity price in Thailand has been increasing related to the future crude oil price. Fig.5 presents historical electricity [7,8] and crude oil price[9], and a result of extrapolation on base retail electricity price until the end of the planning period (2030). The projection was also used in previous analysis in [10].

3) Structural Effects of renewable electricity bought into the grid

A linear indiect effects in upper level of impacts could be explained by the inverse I-O model [11, 12]:

$$X = [I-A+M]^{-1}Y. \quad (1)$$

Where I is identity matrix, A is the coefficient matrix of local transaction, M is the coefficient matrix of import transaction, and Y is the matrix of final consumption in an economy [13]. The Office of the National Economic and Social Development Board (NESDB) has been providing continuous surveys and presents the local transaction coefficient, the import transaction coefficient, and the momentary of final consumption. I-O structures in year 2000 and year 2005 [13, 14] were projected with transaction modifications throughout the studied year in this study.

To represent the combination of direct and indirect effects in an economy, the Neuman series was applied to the inverse matrix $[I-A+M]^{-1}$. As a result, the total requirement in Eq. 1 can be rewritten as:

$$X = Y + (A+M)Y + (A+M)^2Y + \ldots + (A+M)^{\infty}Y. \quad (2)$$

Where Y is the direct effect on a vector of change in final consumptions in an economy in a specific year, and (A+M)Y is the direct effect to local transaction coefficients (A) including the change to import coefficients by a change in final consumptions in an economy in a specific year. The 3rd term is the indirect effect in the 1st round that the direct effects induced changes in all other sectors, and so on in the 4th -∞ terms. Indirect effects by the I-O model in Eq. 2 could be expained in Fig. 6.

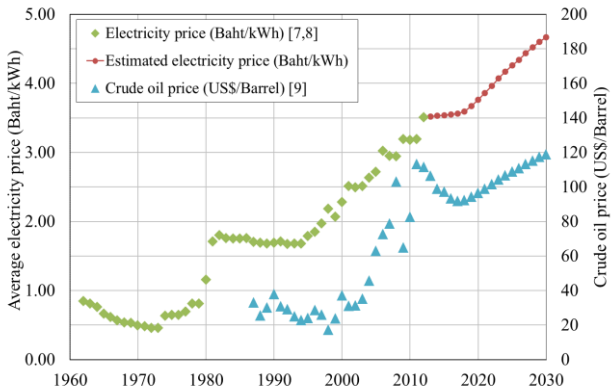

Fig. 5. Projection of annual retail electricity price to 2030.

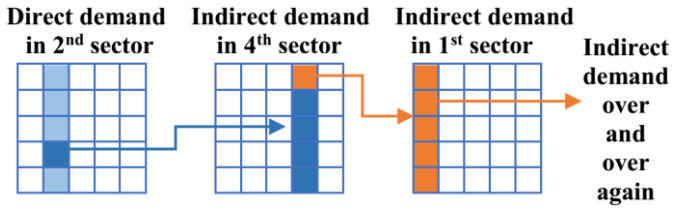

Fig. 6. Indirect effects by I-O model.

With energy input-output analysis, the total requirement X in Eq. 1 can be extended to assess the total economic energy consumption and total economic environmental emission. The total energy consumption EI and total environmental emission EF in an economy can be estimated by Eq. 3 and Eq. 4, respectively.

$$EI = F\,X = F\,[I-A+M]^{-1}Y\,. \quad (3)$$

$$EF = e\,X = e\,[I-A+M]^{-1}Y\,. \quad (4)$$

Where F is the coefficient of fuel consumption of each sector per total momentary production, and *e* is the coefficient of enviromental emissions by fuel consumption in each sector per total monentary production. Recent energy input-output data [15] was projected throughout the studied year for total fuel consumption assessment. Also, CO_2 emission from fossil fuel were evaluated according to IPCC2006 [16].

As described that five potential renewable energy sources contributed in the FITs program are solar rooftop, solar farm, wind farm, small hydro and biomass, direct impact from electricity supply from these 5 additional power sector was not only shifted the sales of the existing power sector to the new sectors, but also caused different inter-industrial transactions, compared to the business-as-usual economic activity. Cost structure of the existing power sector was derived from the recent I-O table [14]. Modified input-output (I-O) structure related to these additional sectors was constructed to enhance the national I-O structure to design the new energy I-O model for this typical study.

Additional vectors and rows of the new I-O sectors were designed based on surveyed data in existing renewable energy power plants. Cost coefficients of the 5 additional sectors,

compared to the existing power sector are presented in Fig.7. Obviously, share of wages (employment costs) of the private renewable power sector is much lower than the share of wage in the existing power sector. Wages coefficient of the existing power sector was 19.09% while those of solar farm, solar rooftop, biomass, wind farm and small hydro sectors were renewable sector were 2.50%, 3.67%, 4.23%, 1.51% and 1.80%, respectively.

Major cost in the biomass power sector is fuel cost mostly supplied from various local agricultural sectors. The fuel prices are also varied. Fig. 8 presents average fuel price from site survey in the current year.

III. Impacts Assessments

Finally, with a specific change in a unit of transaction in an economy, indirect changes could also be found. Macro-economic impacts in terms of monetary output from purchasing electricity from these 5 renewable power sectors were assessed annually during the studied period. Impacts on employment, in terms of monetary output could be addressed by the change on the total output of the household's income.

With I-O model applied to primary energy transactions, CO_2 emission factors related to IPCC guidelines, the macro economic impacts from purchasing electricity from these 5 renewable power sector were assessed annually base on Energy Input-Output model in terms of economy-wide output, total primary energy supply (TPES), and CO_2 emissions, and value of employment, during the studied period.

Therefore, total impacts thoughtout the economy could be found by the rusults of this energy I-O models i.e.

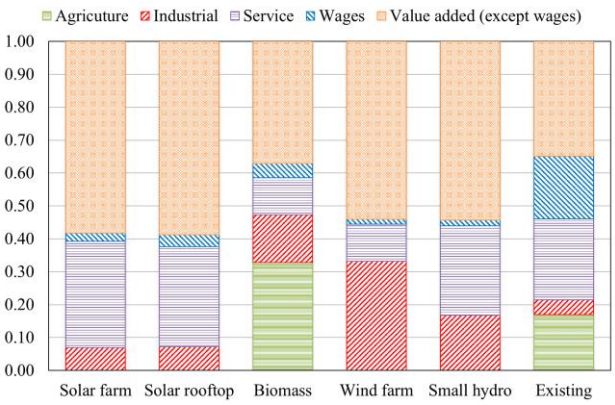

Fig. 7. Cost coefficients of new and existing power sectors.

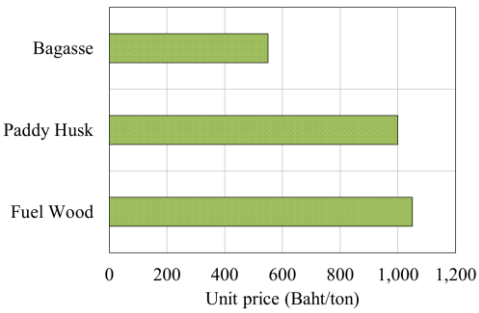

Fig. 8. Unit price of biomass fuel.

A. AEDP case

1) The Country Total Primary Energy Supply (TPES)

Reference scenario for AEDP case was predicted that the TPES would be increased from approximately 110,000 ktoe in 2010 to be 180,000 ktoe in 2021. The TPES includes crude oil, natural gas, condensate, coal, lignite, fuel wood, charcoal, and imported secondary energy.

Implementation of FITs on AEDP program effects the TPES, including fossil and renewable energy. Fig. 9 presented the difference of TPES on the program over BAU since 2010 to 2021. It was found that they were higher in the first year and gradually decreases until 2015 and were lower since 2016. This was because the portion of biomass grid generation would be continuously decreased as presented in Fig. 2. In the other words, this portion presented the reduction in energy consumption by renewable grid generation. Higher the portion of grid generation without energy consumption in some of other renewable energy resources, i.e. solar, wind, and hydro, will lower the TPES. Since 2016 as addressed on AEDP 2012-2021, grid generation by primary renewable energy except biomass will be higher than 1.50% of the country grid generation. The higher the portion of grid generation with less primary energy consumption, the lower in TPES. It could be summarized that the accumulated TPES by the FITs under AEDP was totally less that the BAU, as shown in Fig. 9.

2) CO_2 Emissions Reductions

In reference scenario for AEDP case, CO_2 emissions were expected to be increased from approximately 330 million ton in 2010 to 560 million ton in 2021. Fig.10 presents increasing emission reductions, in direct fossil fuel consumption in the country and in indirect fossil fuel consumptions in the economy, for the whole planning period. Lower in 3 million ton to 9 million ton, directly and indirectly, in 2010 and 2021could be expected by the FITs program.

3) Impacts on Economic Sectors' Outputs

Considering domestic and import, impacts on all economic sectors' monetary outputs were found annually reduced as presented in Fig.11. Most of reductions were in imports. Small increases in domestic outputs were seen in first 3 years, and small reductions were seen in 4-5 last years of the planning period.

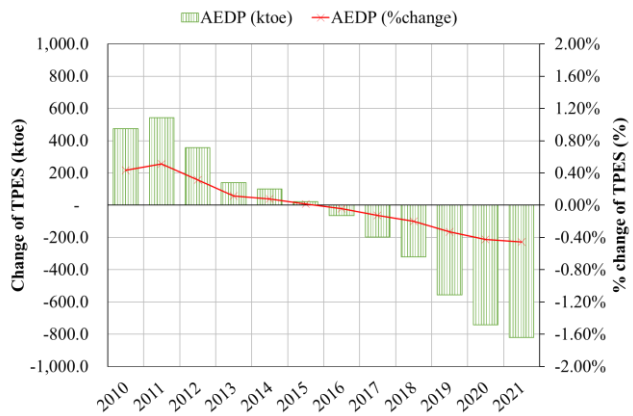

Fig. 9. TPES change by AEDP case.

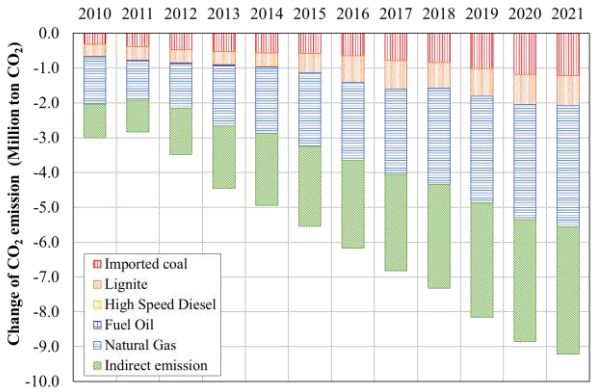

Fig. 10. CO_2 emissions reductions by AEDP case.

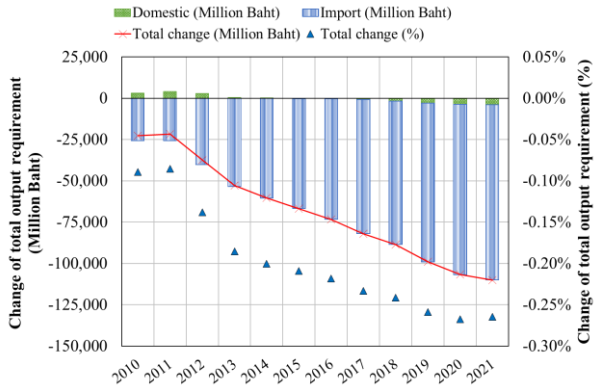

Fig. 11. Reductions of total requirement by AEDP case.

Due to lower cost coefficient in private power sector as shown in Fig 7, the total employments were expected to be reduced under the AEDP program about 7,000-28,000 million Baht/year as seen in Fig.12. However, most of reductions were imported employments embedded in import commodities, particularly in imported dependent technology. Reduction in domestic employments found in a smaller portion i.e. 1,000-7,000 million Baht/year.

B. PDP case

1) The Country Total Primary Energy Supply (TPES)

Reference scenario for PDP case was predicted that the TPES would be increased from approximately 110.000 ktoe in 2010 to be 248,000 ktoe in 2030. Fig. 13 presented the difference of TPES on the PDP case over BAU since 2010 to 2030. It was found that they were higher in the first year and gradually decreases until 2015 and were lower since 2016. This was because the portion of biomass grid generation continuously decreased as shown in Fig. 3. On the other meaning, this portion presented the reduction in energy consumption by renewable grid generation. Higher the portion of grid generation without energy consumption, lower the TPES. Since 2016 as addressed on PDP2010 revision 3, grid generation by renewable energy except biomass will be higher than 1.90% of the country grid generation. As shown in Fig. 13, it could be summarized that the accumulated TPES by the FITs under PDP was totally less that the BAU.

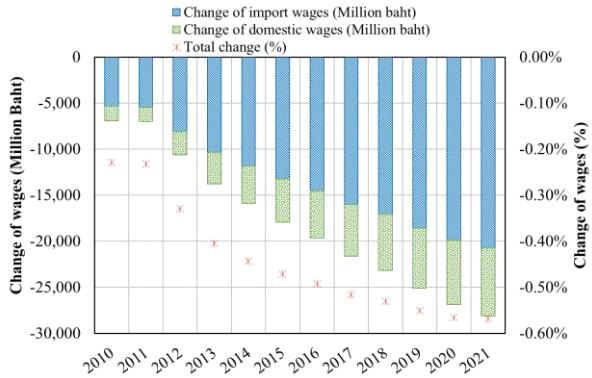

Fig. 12. Wages reductions by AEDP case.

2) CO_2 Emissions Reductions

Reference scenario in the PDP case, CO_2 emissions were expected to be increased from approximately 330 million ton in 2010 to 770 million ton in 2030. Among to total quantity, emissions from the existing power sector were projected to be increased from 88 million ton in 2010 to 182 million ton in 2030.

Significant lower CO_2 emissions, directly and indirectly, were expected by the FITs program under PDP2010 program. Fig.14 presents annual increasing emission reductions, in direct fossil fuel consumption in the country and in indirect fossil fuel consumptions in the economy, for the whole 20-years period. Mitigation of 32 million ton of CO_2 emissions could be expected in 2030 by the FITs program under PDP scheme.

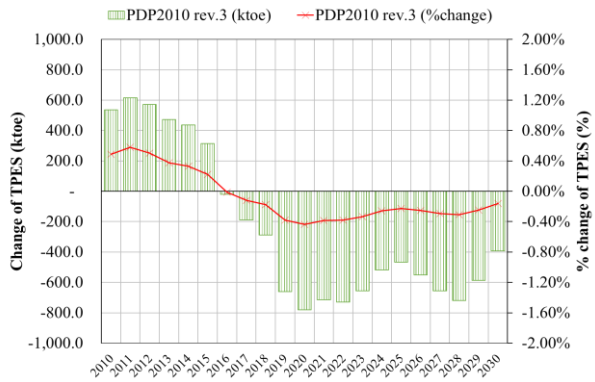

Fig. 13. TPES change by PDP case.

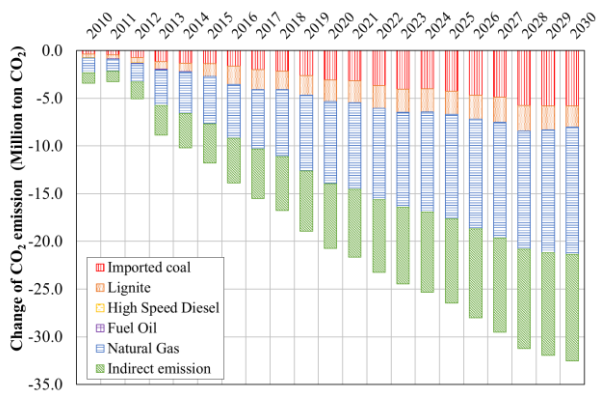

Fig. 14. CO_2 emissions reductions by PDP case.

3) Impacts on Economic Sectors' Outputs

Fig.15. presents that impacts on all economic sectors' monetary outputs, including domestic and import, were annually reduced. Most of the reductions were significantly in imports. Some increases in domestic outputs were seen in last 8 years of the planning period.

In reference scenario, the total employments were expected to be increase from 25 billion Baht in 2010 to 41 billion Baht in 2030. Implementation of FITs under PDP could reduce the employment by 8-75 billion Baht/year as seen in Fig.16. However, most of reductions were imported employments embedded in import commodities. Reduction in domestic employments found approximately 1-14 billion Baht/year.

IV. CONCLUSIONS AND RECOMMENDATIONS

Implementations of FITs on electricity supplied from private renewable power sector could provide reduction fossil primary energy supply. The total output of the economy was expected to be decreased by import content. The higher TPES was induced by higher demand in domestic biomass. In case of high portion of renewable electricity generated without primary energy consumption (or except biomass), TPES under both the program cases were found lower than those of BAUs. CO_2 emissions reductions could be expected for the long term period. Both of the FITs programs induced reductions in import content with some reductions in local employments due to less employments required in renewable power plants. Better impacts could be found could be found in the PDP case where each renewable energy technology was supplied to the grid prioritized by minimum cost.

ACKNOWLEDGMENT

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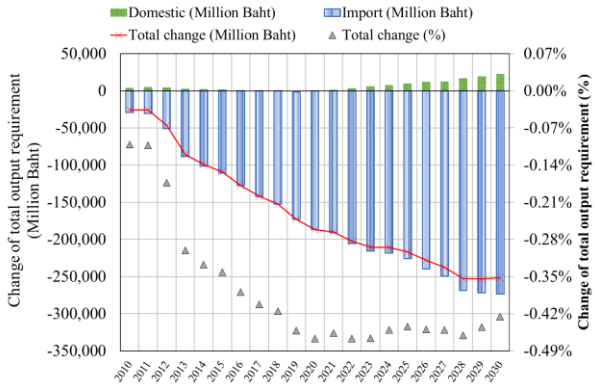

Fig. 15. Reductions of total requirement by PDP case.

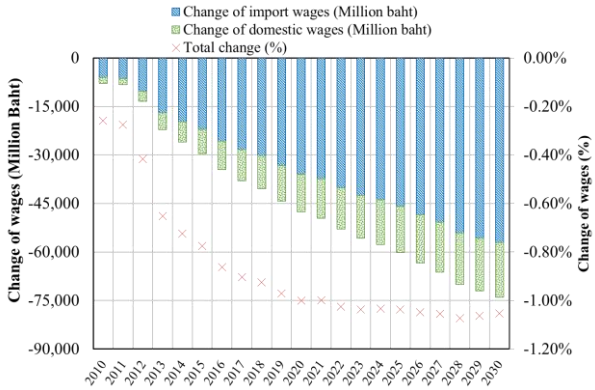

Fig. 16. Reductions of total employment by PDP case.

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