Domestic expenditure and employment impacts of power sector development in Thailand

Scenario analysis using the EIM-ES model

November 2019

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Executive summary

The Economic Impact Model for Electricity Supply (EIM-ES) (Chapter 2)

- The A2A project has developed a transparent model that can be used to estimate the expenditure and employment impacts of different potential electricity sector pathways
- The model calculates total and local expenditure and employment impacts for new and existing electricity supply capacity based on a variety of input data and economic statistics
- This briefing note presents the project's findings on these impacts (which have also been shared with stakeholders from the Government of Thailand in various meetings during 2019)

Modelling three scenarios for Thailand (Chapter 3)

- The EIM-ES for Thailand has been populated with three scenarios to explore different possible power sector pathways – the Power Development Plan (PDP) 2015, the PDP 2018, and a high ambition renewable energy scenario based on WWF's Thailand Power Sector Vision 2050
- The PDPs are compared to understand the economic impact of the rebalancing towards solar and gas and reduced role of coal and biomass in the PDP 2018
- The High RES scenario is included to explore the impact of a much greater level of renewable energy deployment
- The cost and local value share of expenditure varies between technologies, so different combinations of technologies will lead to different levels of economic impact
- The cost and local share inputs are kept constant between the scenarios. An important assumption is that the local share of natural gas supply reduces from more than 60% down to around 20% by 2035, reflecting forecasts of Thailand's increasing requirement for imported gas

Estimated expenditure and investment (Chapter 4)

- Total expenditure over the period 2018 to 2036 is estimated to range from 220 billion USD to almost 250 billion USD, depending on the scenario
- Total expenditure is highest in the High RES scenario due to the higher capex costs of renewables and the need for greater total capacity additions
- Operational costs dominate total expenditure in the PDP scenarios, with fuel costs making up 61-65% of total expenditure
- The High RES scenario features twice as much capex investment in Thailand as the PDP scenarios
- Expenditure on capital investments is more likely to support development of a knowledge economy with increased local industrial capability in modern technologies; scenarios with greater expenditure on fuels (especially fossil fuels) seem less likely to support sustainable growth
- The overall local share is similar between the scenarios with 40-42% of total expenditure retained in Thailand

Estimated employment impacts (Chapter 5)

- Employment impacts are determined by the level of local expenditure spent on labour, and the average salaries in the sectors where expenditure occurs
- The two PDP scenarios show similar levels of total employment (2.9m job years over the period 2018 to 2036) which suggests Thailand can reduce power sector emissions without incurring job losses
- Higher total employment is estimated for the High RES scenario (3.3m job years); although opex related employment is similar to the two PDP scenarios, more than double the amount of capex related jobs are supported due to the much higher investment levels in new (renewable) capacity
- The spread of jobs across sectors and technologies largely follows the pattern for local expenditure, with a relatively higher number of job years from biomass supply due to lower average salaries in the agriculture sector
- Renewable technologies lead to more employment per MW of new plant than conventional technologies, largely due to their higher costs (local shares are similar across technologies); during operation, renewables and conventional technologies create similar employment levels per MWh (biomass is an exception due to entirely domestic fuel production and low agricultural sector salaries)

Broader impacts across the economy (Chapter 6)

- The model calculates broader impacts across the economy using economic statistics from an Input-Output for Thailand, to estimate the indirect and induced effects of expenditure and consumption in related sectors
- In all three scenarios, indirect and induced effects lead to an additional 85-90% expenditure across the Thai economy and additional 90-92% employment

Contents

1. Introduction

The Advancing from Mitigation Ambition to Action (A2A) project, a project financed by the German Government's International Climate Initiative (IKI), aims to support the Government of Thailand with the continued development and implementation of its Nationally Determined Contribution (NDC), with a focus on the energy sector. A key focus of the project is the development of evidence on the economic impacts (often referred to as 'co-benefits') of different power generation scenarios in Thailand, with the aim to support increased climate ambition and accelerated implementation of the NDC.

Under the NDC, Thailand aims to achieve a 20-25% reduction in greenhouse gas emissions by 2030 relative to its business-as-usual (BAU) projections, through measures such as increased energy efficiency and an increase in the use of renewable energy. The expansion and transformation of the power sector required to achieve the NDC will lead to significant investment in the Thai power sector over the next decades. The economic impact of this expenditure, for example the degree of local industrial development and supply chain and job creation, depends on many factors, including technology mix, rate of deployment, and the capacity of local supply chains. To estimate the impact of this expenditure, in terms of investment retained in Thailand, and local job creation, an economic impact assessment model developed by the A2A project has been used to study three different power sector pathways and to examine the resulting differences in economic impact.

This briefing note presents the project's findings on these economic impacts (which have also been shared with stakeholders from the Government of Thailand in various meetings during 2019).

The model and its methodology are described in Chapter 2. The power sector development pathways and additional inputs for the model are discussed in Chapter 3. Insights from the expenditure and employment analysis are discussed in Chapters 4-6. Finally, Chapter 7 contains some suggestions for possible next steps to develop and refine the economic impact analysis of power sector development in Thailand. The Appendices contain additional detail on various important inputs and results.

2. Economic Impact Model for Electricity Supply (EIM-ES)

- **The A2A project has developed a transparent model that can be used to estimate the expenditure and employment impacts of different potential electricity sector pathways**
- **The model calculates total and local expenditure and employment impacts for new and existing electricity supply capacity based on a variety of input data and economic statistics**

2.1. Model background

Expenditure and investment in the electricity sector present an opportunity for economic growth and employment. The impact of expenditures are, however, dependent on country features, choice of technology, and the capacity of local supply chains, among many other factors. To provide insights on the expenditure and employment impacts of different future pathways for the electricity sector, the A2A project has developed the Economic Impact Model for Electricity Supply (EIM-ES). The EIM-ES is a spreadsheet-based model that is transparent and can be tailored to specific scenarios, country features, and the level of data available.

One of the major workstreams of the A2A project's work in Thailand has been data gathering and analysis to populate a country specific version of the EIM-ES model for Thailand, in order to provide evidence to the Thai government about the potential economic impacts of different power sector scenarios. The results of this work are the focus of this document.

Further information on the EIM-ES background and methodology can be found in the EIM-ES methodology paper and user guide, available on the Ambition to Action project website[1].

2.2. Methodology

The EIM-ES estimates the required capital investment and operating expenditure in new and existing electricity generation capacity across different technologies over time, based on specific deployment and generation scenarios that are entered by the user. It then estimates the number of jobs that this expenditure and investment can support.

Figure 1 shows the key calculation steps and inputs used in the EIM-ES to estimate the total required expenditure and subsequently the domestic investment and employment impact.

The first step is to input the deployment and generation scenario, detailing annual capacity additions and retirements (in MW) and annual generation in (MWh) for each technology. The model allows multiple different scenarios to be compared.

Cost inputs are then used to estimate the total required expenditure for a specific deployment and generation scenario. Various costs are included: capital expenditure ('capex') investment costs per MW of new capacity; operations and maintenance costs ('opex'; including both fixed yearly costs per MW and

[1] *http://ambitiontoaction.net/outputs/*

variable costs per MWh), and fuel costs. The capex costs for each technology are entered at a component level (e.g. solar PV cost inputs are entered for the PV module, inverter, balance of system, as well as costs for construction, project development, financing, etc) and these costs are allocated to specific sectors of the economy (e.g. investment on PV modules and inverters is allocated to the electrical equipment manufacturing sector, and plant construction expenditure to the construction sector) so that the economic results can be shown at a sector level (as well as by technology). Examples of cost breakdowns and sector allocations for capital investments in solar PV and natural gas can be found in Appendix 1.

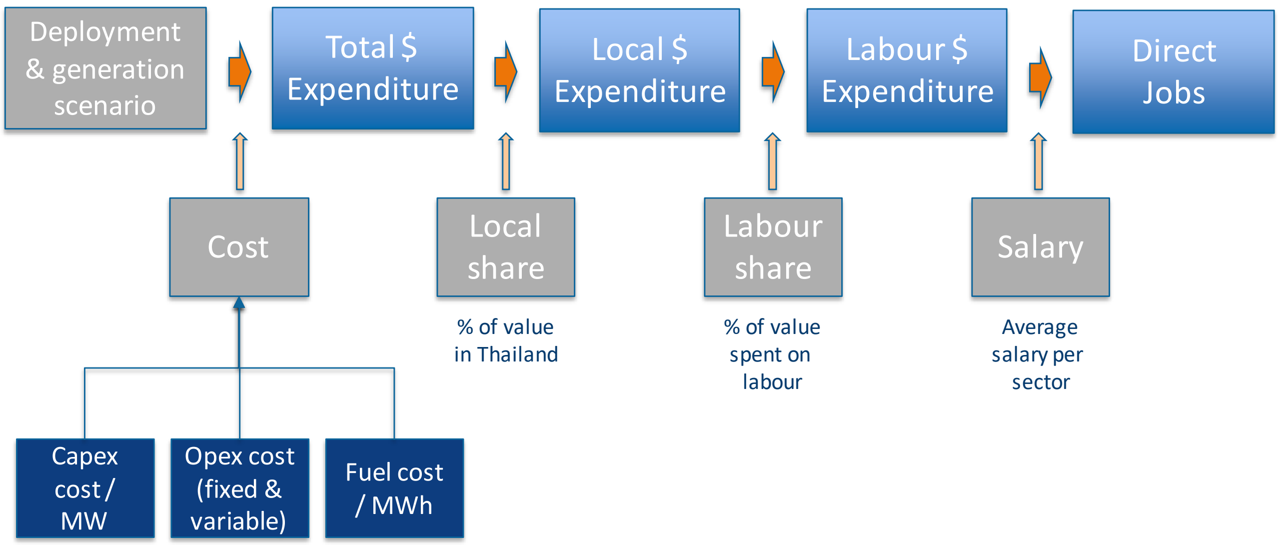

Figure 1: Schematic overview of key inputs (grey boxes) and calculation steps in the EIM-ES

The next step is to work out what proportion of the total required expenditure is retained in the country (rather than being spent on imports of equipment, fuel or services). The key input is estimates of the 'local share', which represent how much expenditure is spent domestically and what portion is spent on imports. By default the EIM-ES determines local share values for each component of a technology based on a country-specific Input-Output (IO) table, for the sector the component is allocated to. While the IO tables provide estimates of the percentage of imports used at a sector level, these are unlikely to be accurate for specific power generation technologies and components. For example while the IO table may show that the electrical equipment sector has a local share of 60%, specific components such as PV modules may be mainly imported, so a much lower local share would be more accurate. Where more detailed local share data is available for a component, the user can override the default IO average sectoral local shares. For the Thailand version of the EIM-ES, considerable effort has been spent by the A2A project to make the local share estimates more accurate, based on primary and desk research. More information on the local share inputs used is provided in Section 3.2.

The third calculation step in the EIM-ES is estimating how much of the domestic expenditure is spent on labour, based on economic statistics on the portion of expenditure spent on labour (and not on e.g. land, materials, etc.). As with local shares, by default sector average labour shares are estimated from the country-specific IO table but the user can specify other labour shares if better data is available.

In the last calculation step the EIM-ES uses average yearly salary data to estimate how many full-time equivalent jobs can be supported, based on the expenditure on labour in that year. Average salary data is entered at a sector level and the estimated employment impacts can be shown at both a sector and technology level. As average salaries can vary greatly per economic sector, the amount of jobs that can be supported by an equal level of expenditure varies per sector.

Total labour impacts are summarised as 'job years' in the EIM-ES, which represent the amount of total full time employment years supported over a period of time, and do not specify how the jobs are spread out over the period, or the number of individual jobs that would be supported (10 job years can represent 10 fulltime equivalent jobs for 1 year, 5 fulltime jobs for 2 years, or other similar configurations).

The methodology described above estimates the *direct* impacts of expenditure and investment in the power sector in Thailand (i.e. impacts in sectors directly related to the manufacturing and installation of new capacity and the operation and maintenance of all capacity (including fuel supply)). However, expenditures in the power sector also lead to impacts across the entire economy (e.g. through expenditure in upstream supply chains to provide raw materials, or by people in newly created jobs spending their wages in other sectors), which results in additional economic impact (and employment), often referred to as the *indirect* and *induced* effects. These economy-wide impacts are also estimated in the EIM-ES, and are discussed in Chapter 6.

3. Scenarios and input data

- **The EIM-ES for Thailand has been populated with three scenarios to explore different possible power sector pathways – the Power Development Plan (PDP) 2015, the PDP 2018, and a high ambition renewable energy scenario based on WWF's Thailand Power Sector Vision 2050**
- **The PDPs are compared to understand the economic impact of the rebalancing towards solar and gas and reduced role of coal and biomass in the PDP 2018**
- **The High RES scenario is included to explore the impact of a much greater level of renewable energy deployment**
- **The cost and local share inputs are kept constant between the scenarios. An important assumption is that the local share of natural gas supply reduces from more than 60% down to around 20% by 2035, reflecting forecasts of Thailand's increasing requirement for imported gas**
- **The cost and local share of expenditure varies between technologies, so different combinations of technologies will lead to different levels of economic impact**

3.1. Scenarios

This chapter describes the three capacity and generation scenarios that have been created in the Thailand version of the EIM-ES developed by the A2A project; the estimated economic impacts of these three scenarios are discussed in the following two chapters. The purpose of comparing different scenarios with the EIM-ES is to explore the economic impacts of different possible combinations of technologies, in particular different levels of ambition for renewable energy deployment.

As the A2A team was not able to develop its own power sector scenarios (because the project did not have the resources to undertake the required electricity system modelling), two scenarios are based on official Thai power sector planning documents (the Power Development Plans) and the third is based on a scenario from a report from WWF considering much higher levels of renewable electricity deployment for Thailand.

The first scenario is based on the PDP 2015, and the second scenario is based on the PDP 2018. The third scenario ('High RES') is based on the Sustainable Energy Scenario from WWF's 2016 report Thailand Power Sector Vision 2050 (WWF, 2016)[2]. As the main objective of the modelling exercise is to explore the economic impacts of different target levels of renewable and conventional power generation capacity and generation, the scenarios have been adjusted to increase comparability, for example current renewable energy deployment levels from the PDP 2018 have been used as the starting position in all scenarios, as this is the most recent source. Table 1 summarises the key adjustments that have been made for the scenarios. All three scenarios are analysed for the same timespan: from 2018 up to 2036, the starting date of the PDP 2018 up to the end date of the PDP 2015.

[2] While the scenarios in the WWF report are not officially endorsed, they are based on power system modelling commissioned by WWF, and the report provides sufficient information to populate a scenario in the EIM-ES model

Table 1: Sources used for installed capacity and generation inputs

Scenario	Technology category	Installed capacity (MW)	Generation (GWh)
PDP 2015	Conventional[3]	PDP 2015	PDP 2015
	Renewables	PDP 2018 starting capacity. 2036 targets from AEDP 2015. Timing of growth equal to PDP 2018	Calculated using same adjusted load factors as in the PDP 2018 scenario
PDP 2018	Conventional	PDP 2018	PDP 2018
	Renewables	PDP 2018	Calculated using RE load factors from Table 4.3 in the PDP 2015, adjusted to match total RE generation in the PDP 2018
High RES	Conventional	PDP 2018 starting capacity. Targets based on WWF (2016) Sustainable Energy Scenario (SES). Timing of capacity changes based on PDP 2018	Starts with PDP 2018 load factors to match starting capacity; adjusted yearly to match WWF load factors for 2037
	Renewables		

The following two sub-sections describe the different capacity additions and electricity generation in the three scenarios.

3.1.1. Capacity additions

Capacity additions cover all newly constructed capacity, including capacity that is installed to replace power stations being retired. The construction of new power stations leads to capital investment and job creation in a range of sectors including construction, manufacturing and related professional services. In both the PDP 2015 and the PDP 2018 there are several gigawatts of lignite, coal, and natural gas retirements, a large fraction of which are replaced by new capacity. There is also a small amount of biomass capacity retired in the PDP 2018 scenario. In the High RES scenario the retirements are assumed to be the same as in the PDP 2018. Yet since the total installed capacity of lignite, coal and natural gas decreases in the High RES scenario, not all retired capacity is replaced.

[3] *Conventional technologies here refers to all fossil fuel technologies and nuclear power*

Figure 2 shows capacity additions in the three scenarios. Fossil and nuclear energy account for 67% of capacity additions in the PDP 2015 scenario. In the PDP 2018 scenario fossil energy accounts for 55% of additional capacity, while the addition of 12.7 GW of solar PV (including floating PV) accounts for 30% of total additions. 11% more capacity is added in the PDP 2018 scenario than in the PDP 2015 scenario, in part due to the large addition of solar PV capacity. Solar PV and wind energy capacity grow most in the High RES scenario, with an addition of 33.7 GW of solar PV and 13.3 GW of wind energy capacity. Fossil capacity accounts for only 15% of new capacity in the High RES scenario. The large additions of solar PV and wind energy in the High RES scenario result in 62% more capacity being installed compared to the PDP 2018 scenario. This is required because of the lower load factors of variable renewables and the resulting need for greater total capacity to meet the electricity demand.

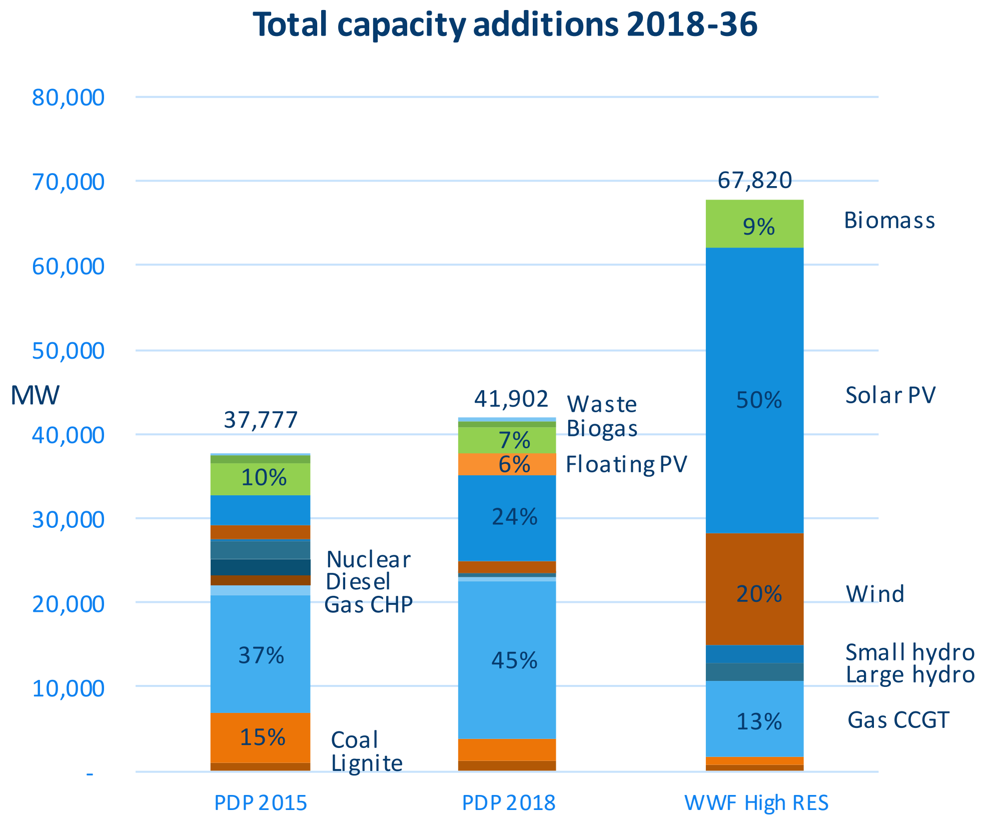

Figure 2: Total capacity additions for the three scenarios

Figure 2 shows the total capacity additions over the whole of the forecast period from 2018 to 2036, however the EIM-ES details capacity additions on an annual basis. The timing of capacity additions influences when investments occur in manufacturing, construction, and installation, as well as annual power generation levels and related expenditure on operations, maintenance, and fuels. In order to make a fair comparison between the scenarios the timing of capacity changes has been aligned with the PDP 2018 where possible. The only exception is for fossil fuels and large hydro in the PDP 2015 scenario, as the PDP 2015 contains detailed yearly data on the changes in installed capacity and generation for these technologies. Appendix 2 shows the annual capacity additions profile for the PDP 2018, and the resulting annual profile for capital investment and operational expenditure.

3.1.2. Generation

Annual electricity generation is used by the EIM-ES to determine the expenditure (and employment) on variable operations and maintenance, as well as the annual fuel requirements. For technologies that consume fuel (conventional fossil thermal and biomass), the total expenditure on fuel over the whole operating lifetime of the powerplant is the single largest expenditure item. Both the PDP 2015 and the PDP 2018 contain annual generation projections for each conventional technology, but only include a total annual figure for all renewable energy generation technologies. For the PDP 2018 scenario, renewable energy generation per technology has been calculated using load factors from the PDP 2015[4], with a number of adjustments in order to match the total renewable generation given in the PDP 2018. The same adjusted load factors are used in the PDP 2015 scenario. The WWF report provides generation data for the different scenarios in the report; however in order to align with the 2018 capacities which are based on the PDP 2018, load factors from the PDP 2018 scenario are used for 2018 in the High RES scenario, and these are then adjusted on an annual basis until they match the WWF load factors in 2036 (so that ultimately they reflect the role envisaged for different technologies in the WWF scenario). An overview of the load factors used can be found in Appendix 1.

Total generation in the PDP 2015 scenario amounts to 4,191 TWh, with 59% from natural gas (see Figure 3). Natural gas accounts for an even larger share (69%) in the PDP 2018 scenario. In the PDP 2018 scenario the contribution from biomass grows from 4% in 2018 to 11% 2036, while generation from solar PV (including floating PV) grows from 2% in 2018 to 8% in 2036. In the High RES scenario natural gas accounts for 50% of total generation, reflecting the continued importance of gas based generation even in an ambitious renewables scenario. Generation from biomass in the scenario grows from 4% in 2018 to 21% in 2036. Growth in generation from solar PV is even larger: growing from 2% in 2018 to 23% in 2036. Despite more additional capacity being installed in the High RES scenario, total generation is 14% lower than in the PDP 2018 scenario.

[4] *Table 4.3 in the PDP 2015*

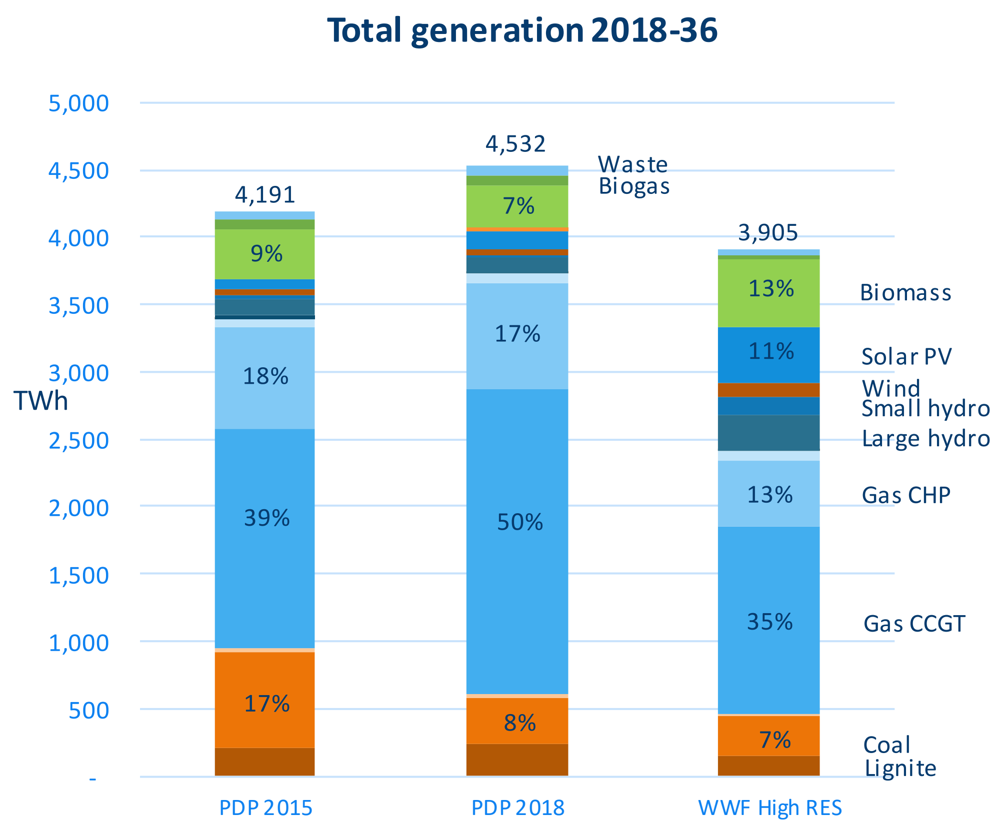

Figure 3: Total generation in the three scenarios

3.2. Costs, local shares, and labour inputs

As outlined in the previous chapter, the EIM-ES model combines the capacity addition and generation projections with cost information to estimate total expenditure requirements, and then uses estimates of the local value share, proportion of expenditure spent on labour, and average salaries, in order to estimate the expenditure retained within Thailand, and the number of jobs supported. This applies to capital expenditures when building new plants, operating expenses from operating them, and also the required expenditure on fuel supply. This sub-section provides information on these important inputs.

The cost inputs are primarily based on research commissioned by the A2A project in Thailand. This includes renewable energy cost data provided by the Department of Alternative Energy Development and Efficiency (DEDE). Where insufficient data was available from primary research, additional literature has been used. As well as a total capex cost per MW for each technology, the model also contains a cost breakdown across the main cost item for each technology, which is used to allocate expenditure to different sectors, and to allow different local share inputs to be entered for different components within a specific technology.

In the current version of the Thailand model the same cost inputs are used for all three scenarios, and all costs are kept constant over time in all the scenarios. Thus all the results detailed in the main text of this paper are based on technology and fuel costs that stay constant over time. However it is possible in EIM-ES to both change the costs over time and to have different costs per scenario. In order to explore the sensitivity of the results to future reductions in the cost of technologies, the scenarios were also run with some assumptions about cost reductions; the results (and the assumptions) are summarized in Appendix 3.

Figure 4 shows that fossil fuel technologies have lower capital expenditure costs than renewables, and that solar PV has the lowest capex cost among the renewable technologies. More detailed information on all cost inputs, including operating expenditure (opex) costs and fuel costs, can be found in Appendix 1.

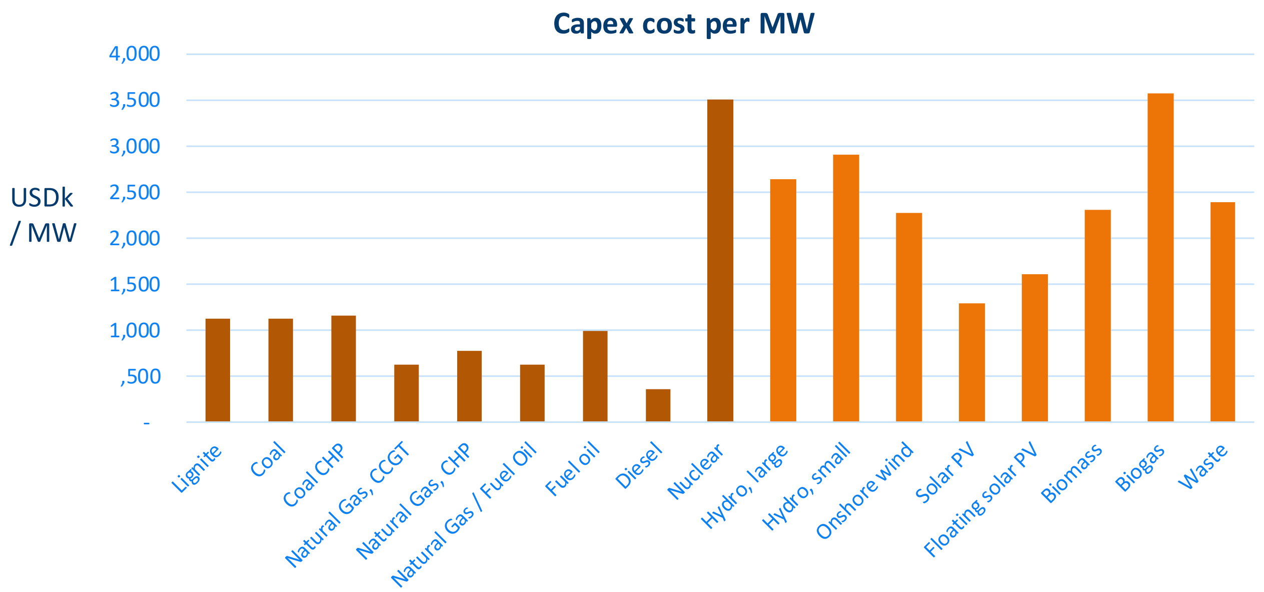

Figure 4: Capex costs per technology

The local share estimates are based on a combination of sources, primarily Input-Output (IO) tables for Thailand from the OECD (data for 2015 from the 2018 edition) and the NESDB (2010), which provide sector level estimates of the proportion of expenditure that is spent on imports. These economic statistics have been supplemented by desk research, interviews, and workshops conducted by the project. The local shares are estimated at the component level for each technology (e.g. for solar PV, there are different local share estimates for the PV module, inverters, balance of system, construction activity, professional services, etc). Examples of the technology cost breakdown to component level, and the corresponding local shares can be found for solar PV and natural gas in Appendix 1.

Because the local share is a critical input for the modelling of expenditure retained within Thailand, and because the IO tables do not provide specific estimates for renewable energy components, the A2A project has invested considerable effort to improve the robustness of these estimates in the EIM-ES model for Thailand. With support from local consultants from South Pole and the Creagy, the project has sought to get a better understanding of the local supply chain capability through desk research, a survey and interviews with both the private and public sector. This was complemented with a workshop with private sector participants from different renewable energy sectors, held in Bangkok in September 2019. These different inputs have been used to refine the local share estimates at the component level for the key technologies (solar PV, biomass, wind, and natural gas).

Figure 5 shows the estimated local share inputs for capex (these figures are the weighted average of the component level local share estimates). In general, the local share is lowest for technologies where local manufacturing and installation capacity is low, such as for nuclear energy and wind energy. For technologies with higher local manufacturing and installation capacity, such as coal, hydropower, and bioenergy, the local shares are higher. However these average level figures hide a wide variation in the local shares at the component level; for example while the local share of PV modules may be very low (around 10%, as most are imported from China), the local share of other components may be more than 50%, and for cost items such as project development and financing, can be as high as 90%, with most work being undertaken within Thailand (see Appendix 1 for detailed examples).

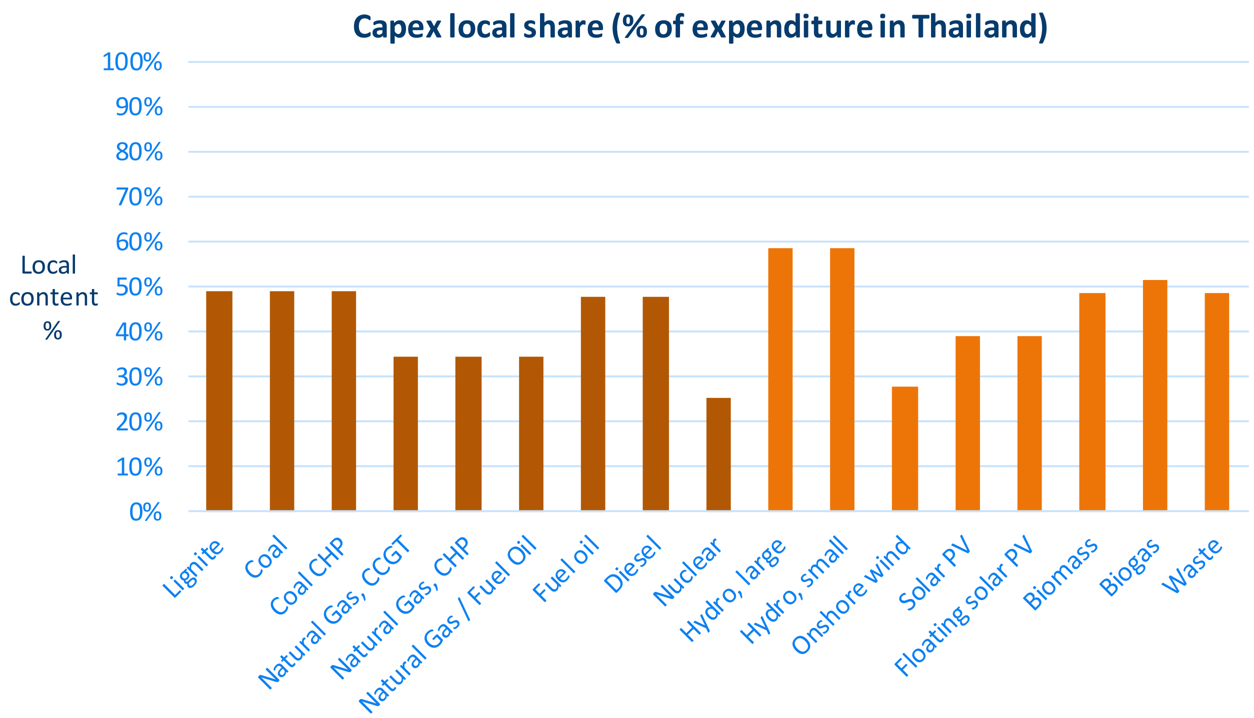

Figure 5: Capex local shares per technology

Local share estimates are also used to calculate the proportion of expenditure on operations and maintenance (O&M) that stays in Thailand, and similarly for expenditure on fuels. For O&M the local value share is between 50% and 60% for all technologies (see Appendix 1), while for fuels it varies widely, as some fuels are sourced domestically (e.g. natural gas, lignite and biomass) and some are mainly imported (e.g. coal and uranium). Figure 6 shows the local shares for the main fuels.

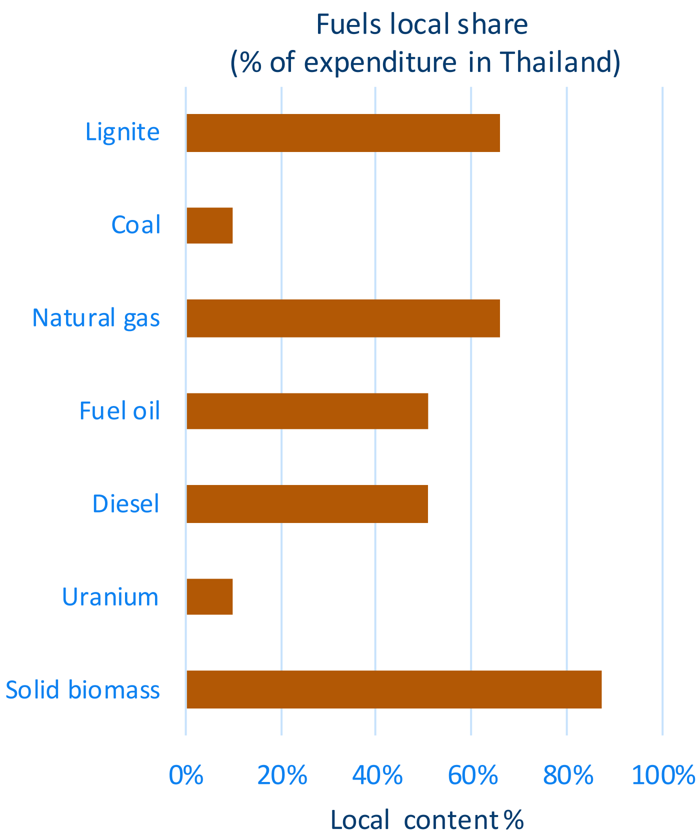

Figure 6: Local share estimates for fuel supply[5]

The local shares for capex, opex and fuels are kept constant over time in the current model setup for Thailand, with the exception of the local share input for natural gas fuel supply. Although the majority of natural gas is currently supplied from domestic sources, gas production in Thailand is projected to decrease sharply over the next few decades (see Figure 7). Because of the heavy reliance on gas powered generation – in all scenarios – expenditure on gas supply is the single largest type of expenditure projected, and the proportion that is sourced locally is thus a major determinant of the domestic expenditure levels and job creation within Thailand. In order to reflect this fairly in the EIM-ES, the local share input for natural gas fuel supply has been adjusted, declining from 66% in 2018 to 18% in 2036. The impact of this reducing local share can clearly be seen in the results for local opex expenditure and job creation, as shown in following chapters.

[5] *Biogas (from wastewater) and waste are considered zero-cost fuels. No expenditure or employment is thus attributed to the supply of these fuels.*

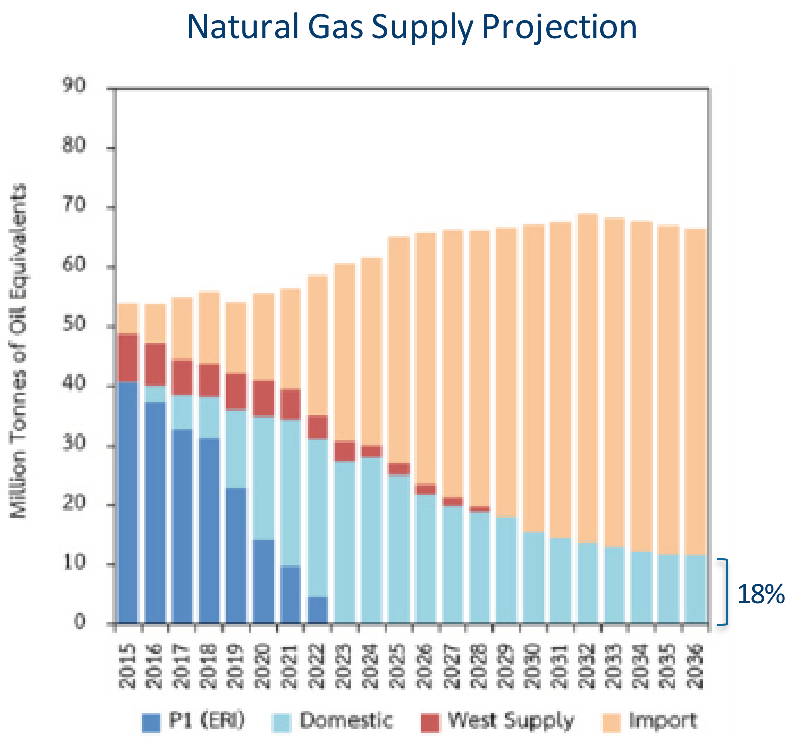

Figure 7: Projection of natural gas supply in Thailand (Thailand Integrated Energy Blueprint 2016)

The final set of inputs relate to the proportion of expenditure that is spent on labour, and the average salaries. Local capex and opex expenditure is allocated to specific sectors (e.g. expenditure on project development is allocated to the business services sector), and sector level estimates for labour shares and average salary levels are used to estimate the employment impact in jobs and job years.

The majority of the labour shares used are based on the 2015 OECD IO table for Thailand. Where the NESDB Input-Output table (2010) provides more relevant sector-level information these have been used instead of the OECD values. Figures for average salaries by sector are taken from the International Labour Organisation (ILO) statistics for Thailand from 2015[6]. The average labour shares per technology (weighted averages of the relevant sectors) all sit in a range between 8 and 14%, and average salaries can also differ substantially, with much higher salaries in for example the utilities and financial sectors compared to the agriculture sector. This has an impact on the relative job creation: for a given level of labour expenditure, more jobs can be supported in sectors with lower average salaries. An overview of the labour shares and average salaries can be found in Appendix 1.

[6] *ILO salary statistics for Thailand (accessed 10 October 2018)*

4. Results: Expenditure and investment

- **Total expenditure over the period 2018 to 2036 is estimated to range from 220 billion USD to almost 250 billion USD, depending on the scenario**
- **Total expenditure is highest in the High RES scenario due to the higher capex costs of renewables and the need for greater total capacity additions**
- **Operational costs dominate total expenditure in the PDP scenarios, with fuel costs making up 61-65% of total expenditure**
- **The High RES scenario features twice as much capex investment in Thailand as the PDP scenarios**
- **Expenditure on capital investments is more likely to support development of a knowledge economy with increased local industrial capability in modern technologies; scenarios with greater expenditure on fuels (especially fossil fuels) seem less likely to support sustainable growth**
- **The overall local share is similar between the scenarios with 40-42% of total expenditure retained in Thailand**

This chapter presents the estimated expenditure and investment results for the three scenarios currently set up in EIM-ES for Thailand. Following the calculation flow in the model, results for total expenditure are presented first (including expenditure on imports), followed by the expenditure that occurs within Thailand ('local expenditure'). In the model, expenditure results are reported on an annual basis, and can be shown by technology, or by sector, as well as split into capex and opex. In this chapter, aggregate results are shown for the period 2018 to 2036.

4.1.1. Total expenditure and investment[7]

Figure 8 below shows total expenditure over the period 2018 to 2036, including both capex and opex, and including imports. Total expenditure is lowest in the PDP 2015 scenario at 220.7 billion USD. Total expenditure is higher in the PDP 2018 scenario at 236.7 billion USD, and the High RES scenario is the most expensive scenario with a total cost of 248.4 billion USD over the period. While the two PDP scenarios look broadly similar in terms of the spread of expenditure across technologies – with 78% of the total expenditure being on conventional technologies in both cases – the High RES scenario looks quite different, with much greater investment in solar and wind in particular, such that expenditure on conventional technologies only accounts for 47% of the total. In all three scenarios, gas makes up the vast majority of the expenditure on conventional technologies.

Expenditure on renewables adds up to 48.3 billion USD in the PDP 2015 scenario and to 52.8 billion USD in the PDP 2018 scenario, and unsurprisingly expenditure on renewables is by far the largest in the High RES scenario, at 131.0 billion USD, accounting for 53% of total expenditure in that scenario. These large expenditures on renewable energy technologies – whether in the PDP or High RES scenarios – indicate the

[7] *All the results in chapter 4 and 5 are 'direct', that is they are expenditure and employment impacts that occur in the power sector and directly related sectors (such as equipment manufacturing and fuel supply). Indirect (from upstream sectors supplying e.g. raw materials) and induced (from e.g. workers spending their wages on leisure, food and healthcare) expenditure and employment impacts are not included. These broader impacts are discussed in Chapter 6.*

potential scale of the opportunity for the development of renewable energy supply chains in Thailand. As a complement to the modelling work described in this paper, the existing industrial capacity in Thailand in renewable energy sectors, and the potential for further development of the renewable energy industry in Thailand have been explored in other workstreams of the A2A project[8].

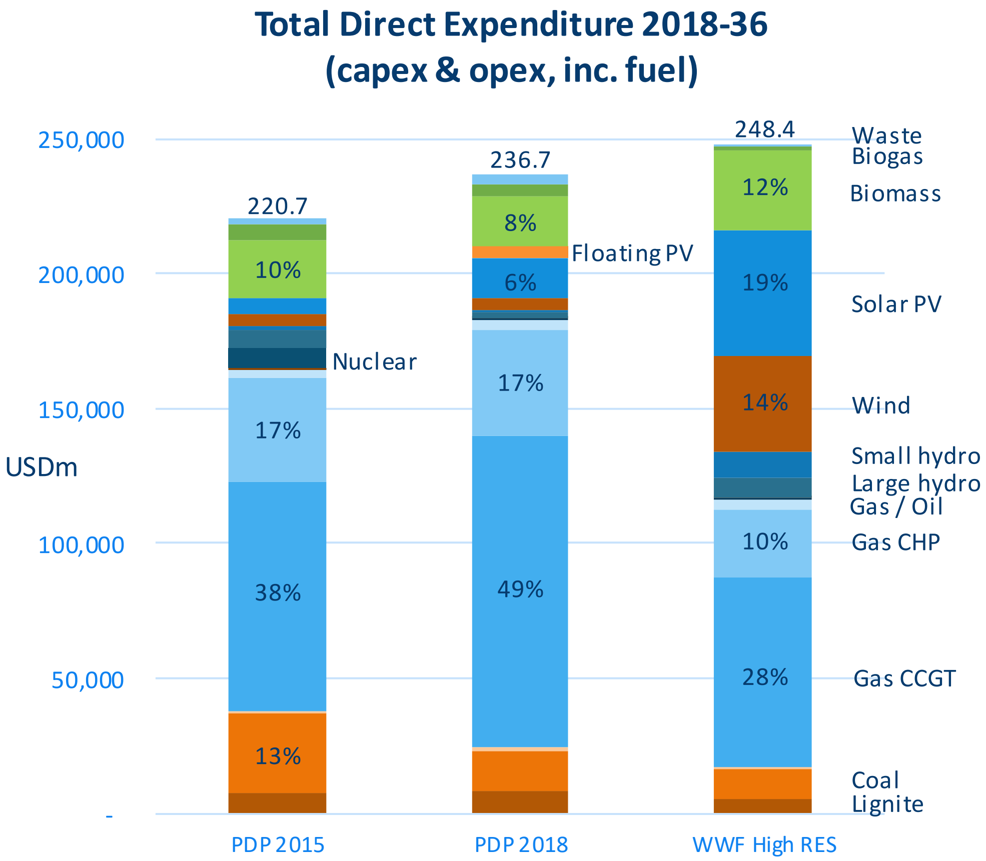

Figure 8: Total investment (domestic expenditure and imports)

The type of expenditure also varies considerably between the PDP scenarios and the High RES scenario. Figure 9 shows the total expenditure split into three expenditure categories of capex, O&M (expenditure to operate and maintain the plants), and fuel costs. In both the PDP scenarios, fuel costs are the largest category, with a share of 61-65% of the total, with capex investment making up 20-21%. However in the High RES scenario, the proportion spent on capex is double that of the PDP scenarios, at 43%, with a significantly lower percentage of total expenditure being spent on fuel, at 42%. These differences are driven by the higher capital costs of renewables, and the much lower requirement for fuel (though as noted above, gas still accounts for around 50% of total generation in the High RES scenario, hence there is still considerable expenditure on fuels).

The much larger share of capital investment in the High RES scenario suggests that power sector development pathways featuring greater deployment of renewables offer greater potential for development of domestic technology industries, as capital investments are more likely to support local

[8] *For more information see the report on Industrial Development in Thailand: Renewable Energy Sector (forthcoming).* http://ambitiontoaction.net/outputs/

industrial development than expenditure on fuel supply (which in the case of fossil fuels, can not be a sustainable industry in the long term).

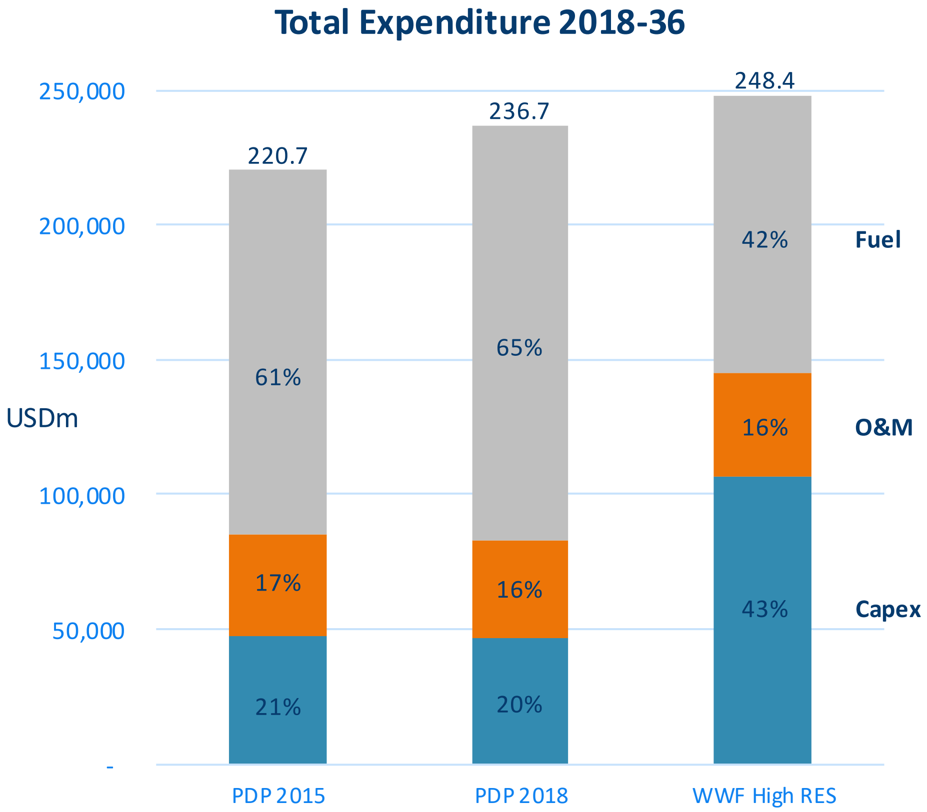

Figure 9: Total expenditure by category

4.1.2. Local expenditure and investment

Of particular interest to policymakers is the proportion of power sector expenditure that is retained within the domestic economy, as only the portion spent domestically can support economic growth, industrial development, and job creation.

Of the total expenditure in the PDP 2015 scenario, 89.6 billion USD remains in Thailand (see Figure 10), corresponding to an overall local share of 41%. Total local expenditure is slightly higher in the PDP 2018 scenario (94.2 USD billion), though the local proportion is actually slightly lower, at 40%. In the High RES scenario the total local expenditure is the highest of the three scenarios, at 105.4 USD billion, and the overall local share in the High RES scenario is marginally higher at 42%. These differences in the overall local share result are driven by the relative balance of expenditure (capex and opex) across the different technologies; a scenario which spends relatively more on technologies (and fuels) with a higher local value share will have a higher overall local share result.

Natural gas accounts for a large share of local expenditure in all three scenarios: 53% in the PDP 2015 scenario, 61% in the PDP 2018 scenario, and 38% in the High RES scenario. The share of local expenditure on lignite and coal is largest in the PDP 2015 scenario at 15%, compared to 10% in the PDP 2018 scenario and 6% in the High RES Scenario, which unsurprisingly has little role for these high carbon fuels. Due to the increased renewable energy targets in the PDP 2018 scenario compared to the PDP 2015 scenario, the local expenditure on wind energy, solar energy, and biomass energy increases from 19% of total local expenditure in the PDP 2015 scenario to 22% in the PDP 2018 scenario. In the High RES scenario solar PV, wind, and biomass account for 45% of the total local expenditure, due to the even more ambitious levels of deployment of renewable energy in this scenario.

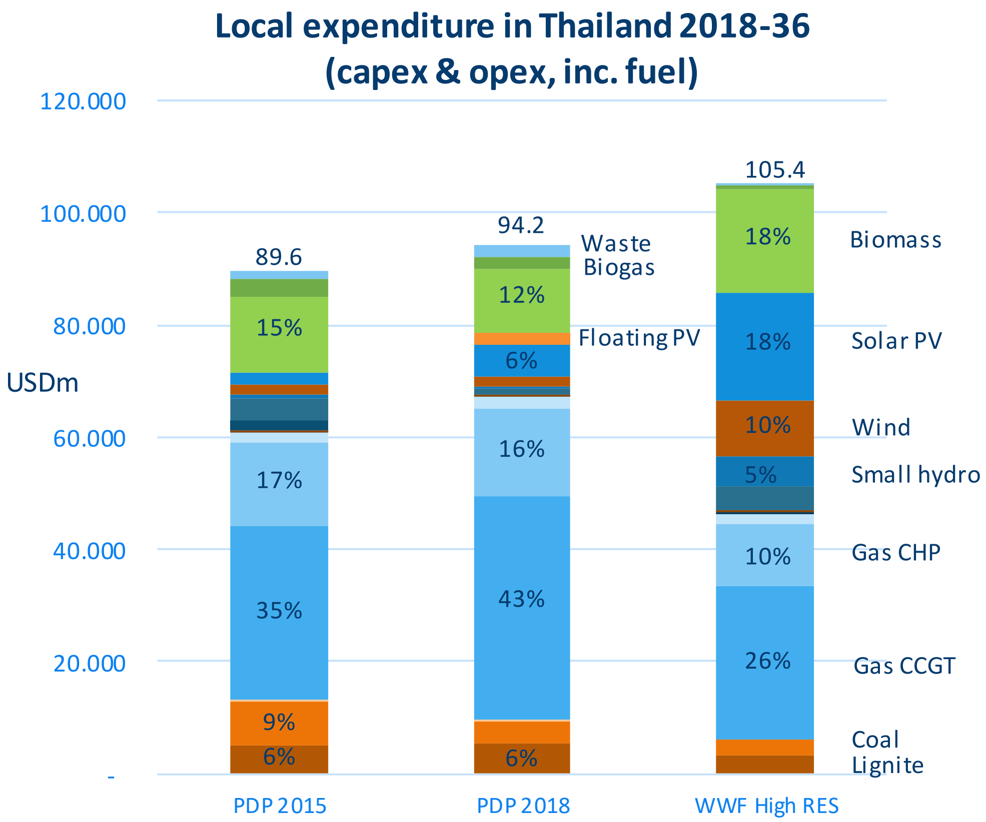

Figure 10: Local expenditure in Thailand by technology

Figure 11 shows the breakdown of local expenditure by category, which mirrors the breakdown of total expenditure, with local capital investment in the High RES scenario more than double the amount in the PDP scenarios. As the industrial development opportunities related to capex investment are likely to be more interesting (in terms of developing supply chains and capabilities and development of a knowledge based economy) than those from operating expenditure, the much higher capex share of local expenditure in the High RES scenario is worth noting.

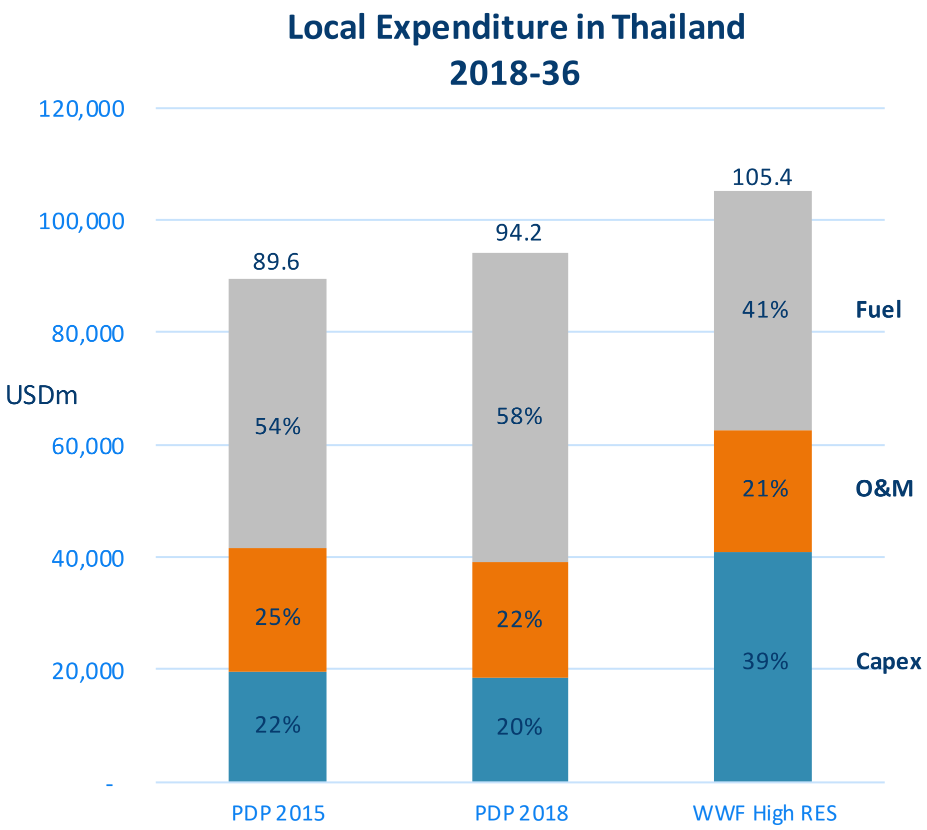

Figure 11: Local expenditure by category

Figure 12 shows how local expenditure is spread across the different sectors of the Thai economy. The much greater role for renewable energy in the High RES scenario also leads to more expenditure in the construction, manufacturing and professional services sectors than in the PDP scenarios, and correspondingly lower expenditure in the extractive sector (i.e. extraction and processing of fossil fuels); from the point of view of economic sustainability this may be a safer bet that continued heavy investment in the fossil fuel extraction sector, given that meeting the Paris Agreement will require a substantial global transition away from fossil fuel use in the future.

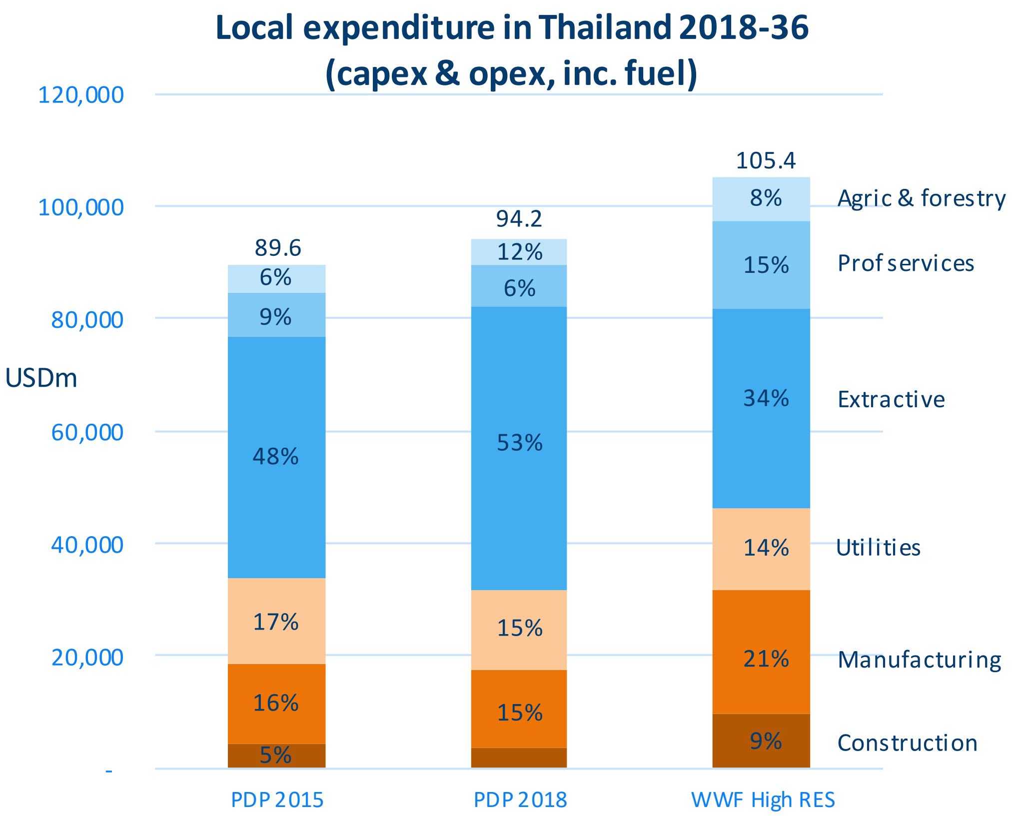

Figure 12: Local expenditure by sector

Figure 13 shows only the local capex investments that take place in Thailand, further highlighting the much greater level of capex investment required in Thailand in the High RES scenario (more than double the amount than in either of the PDP scenarios), of which 94% is in renewables. In both the two PDP scenarios, however, the majority of the local capex investment is also in renewable technologies (60% in the PDP 2015 and 69% in the PDP 2018), showing the clear intention from the Thai government to increase the share of renewable electricity in the coming decades.

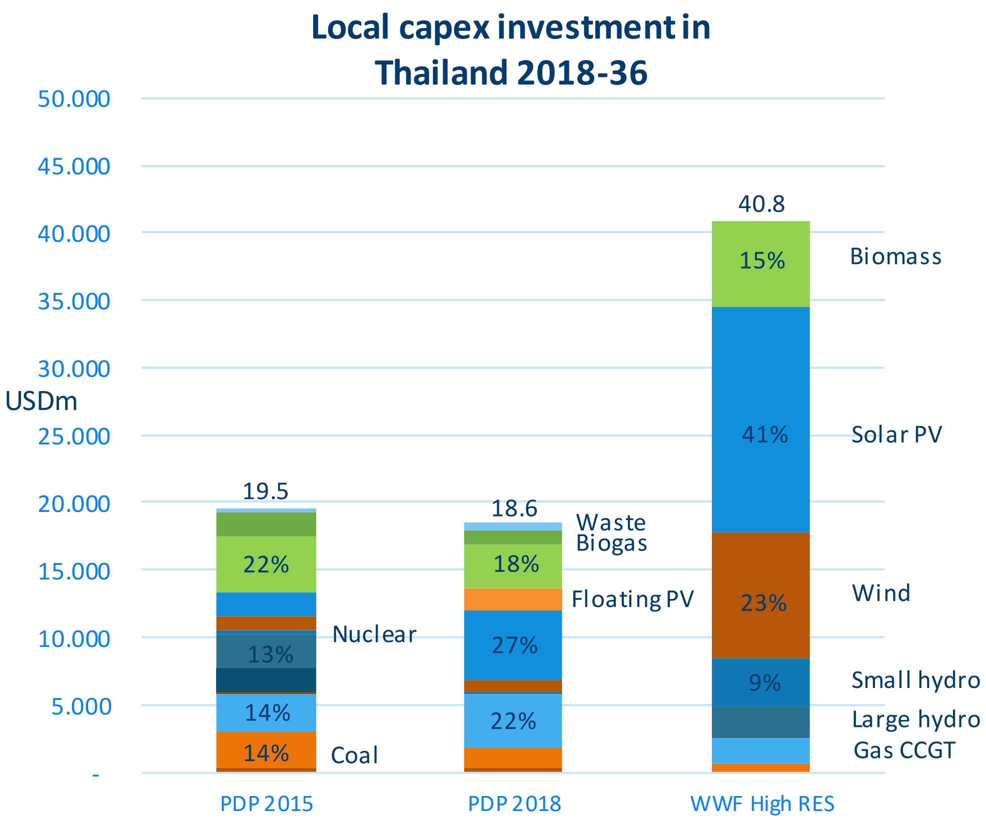

Figure 13: Local capex investment in Thailand by technology

Local opex expenditures are dominated by fossil fuels in all three scenarios, even with the decreasing local share of natural gas supply, and the increased role of renewables in the PDP 2018 and High RES scenarios (which in the case of solar and wind have very low operating costs). Figure 14 shows that local opex expenditure is dominated by technologies that require fuels. With a smaller role for natural gas in the High RES scenario the relative share of opex and fuel supply expenditure on natural gas is smaller, though still high at 59%. On the other hand, local expenditure on biomass opex and fuel supply is larger in the High RES scenario.

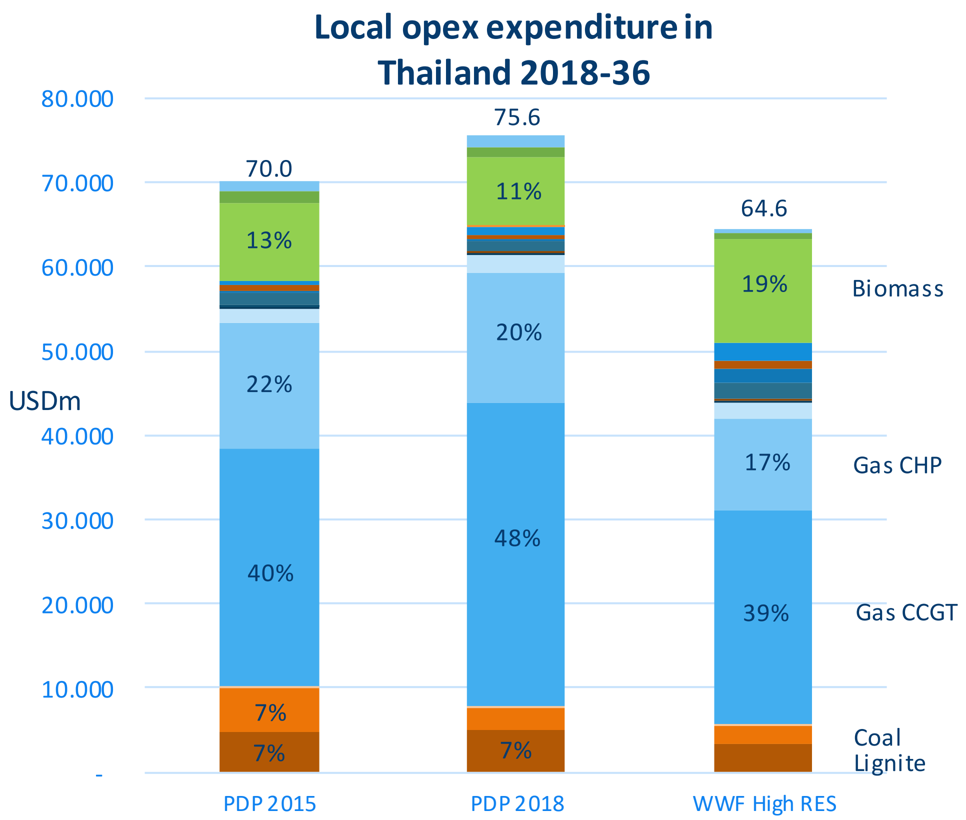

Figure 14: Local opex expenditure (including fuels) by technology

5. Results: Employment impacts

- **Employment impacts are determined by the level of local expenditure on labour and the average salaries in the sectors where expenditure occurs**
- **The two PDP scenarios show similar levels of total employment (2.9m job years over the period 2018 to 2036) which suggests Thailand can reduce power sector emissions without incurring job losses**
- **Higher total employment is estimated for the High RES scenario (3.3m job years); although opex related employment is similar to the two PDP scenarios, more than double the amount of capex related jobs are supported due to the much higher investment levels in new (renewable) capacity**
- **The spread of jobs across sectors and technologies largely follows the pattern for local expenditure, with a relatively higher number of job years from biomass supply due to lower average salaries in the agriculture sector**
- **Renewable technologies lead to more employment per MW of new plant than conventional technologies, largely due to their higher costs (local shares are similar across technologies); during operation, renewables and conventional technologies create similar employment levels per MWh (biomass is an exception due to entirely domestic fuel production and low agricultural sector salaries)**

This chapter presents the estimated employment impacts for the three scenarios. The employment impacts are estimated from the local expenditure results and are calculated at a technology and sector level, using the labour share of expenditure, and average salary inputs. As noted in Chapter 2, when presenting aggregate results for the period 2018-2036, employment impacts are presented in 'job years', where 1 'job year' reflects a full time job that is required for 1 year; were the same job to be required for 10 years it would contribute 10 job years to the total. In particular with the jobs resulting from capex investment on new capacity additions, some of the jobs would only last for a few years while a power plant is being developed and constructed.

5.1.1. Total employment impacts[9]

A similar amount of total direct jobs are created in Thailand in the PDP 2015 scenario and the PDP 2018 scenario, with 2.9m job years estimated for both scenarios over the period 2018 to 2036, as shown in Figure 15. This is a potentially important finding, as it shows that Thailand can reduce the GHG emissions associated with the power sector through increased use of renewable energy without causing job losses in the power sector or sectors directly supplying it. Fears about potential job losses have understandably been a concern for countries when considering their NDC ambition, and in many cases such fears have been exploited by the fossil fuel industry to advocate against ambitions GHG reduction targets and measures.

[9] *All the results in chapter 4 and 5 are 'direct', that is they are expenditure and employment impacts that occur in the power sector and directly related sectors (such as equipment manufacturing and fuel supply). Indirect (from upstream sectors supplying e.g. raw materials) and induced (from e.g. workers spending their wages on leisure, food and healthcare) expenditure and employment impacts are not included. These broader impacts are discussed in Chapter 6.*

The High RES scenario creates more total employment than both PDP scenarios, due to the additional employment contribution from greater deployment of renewable energy technologies, which are more employment intensive per MW during construction and (with the exception of solar PV) equally or more job intensive as conventional technologies during operation (see Figures 19 and 21 for job intensities per technology). In all three scenarios total job creation is dominated by O&M and fuel supply, because these occur over the whole lifetime of the power plants, rather than just for a short period while plants are constructed. In the High RES scenario a larger share of jobs created are from capex investments, because of the additional investment in capital intensive renewable energy technologies in this scenario, as noted in the previous chapter.

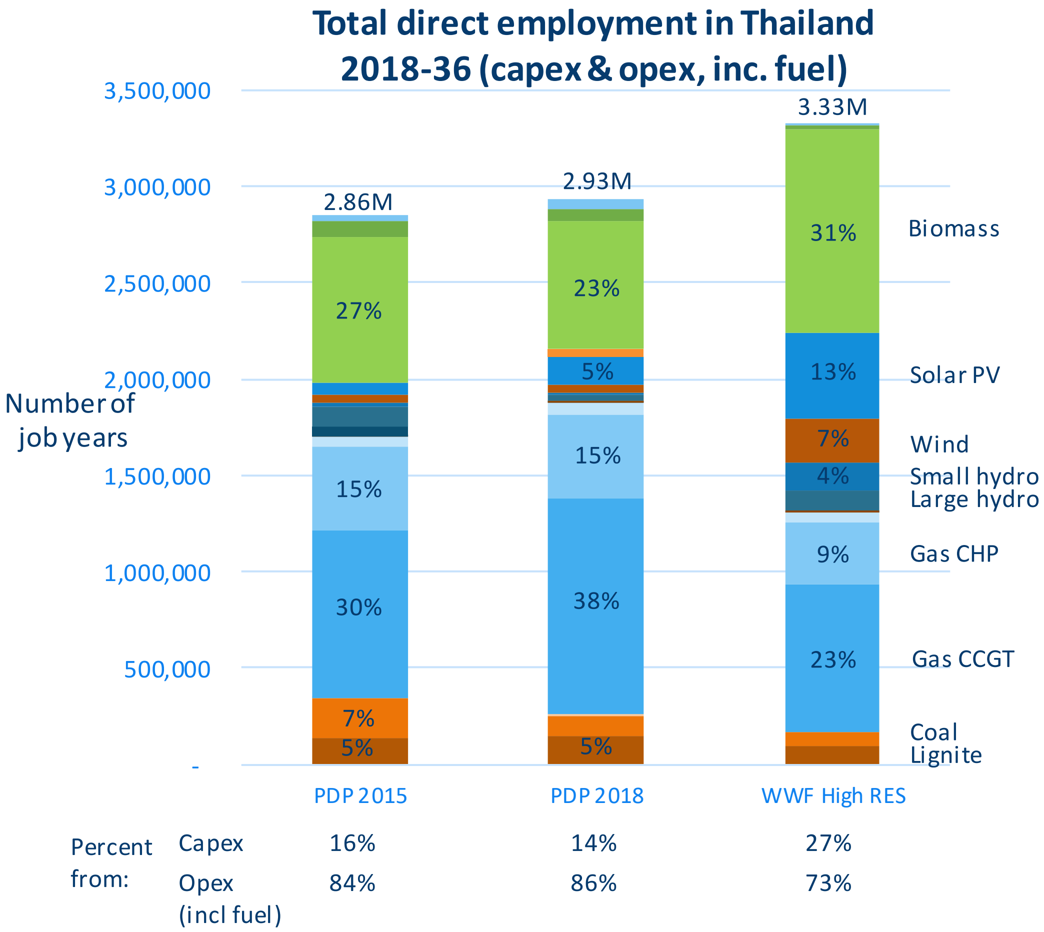

Figure 15: Total direct employment in Thailand by technology

Figure 15 also shows the balance of job creation between technologies. Between the PDP 2015 and 2018, the split of total job years between conventional technologies and renewables is similar, with about two thirds of job years coming from conventional technologies in both scenarios. In the High RES scenario this situation is reversed, with a little over 60% coming from renewable energy. Biomass has a relatively larger share of employment than it does for local expenditure, because average salaries in the agriculture sector (in the biomass supply chain) are considerably lower than in most other sectors, thus more jobs are supported per USDm of expenditure.

There are significant differences in the type of jobs resulting from deployment and operation of different technologies, as illustrated by the example technologies shown in Figure 16, in terms of which sectors they occur in, and whether they relate to short term capital expenditures or ongoing operating expenditures. For natural gas and biomass the majority of jobs are related to operations, maintenance, and particularly fuel supply. For solar PV on the other hand most jobs relate to component manufacturing, project development, and construction, and occur in those sectors rather than in the extractive or agriculture sectors as is the case with gas and biomass.

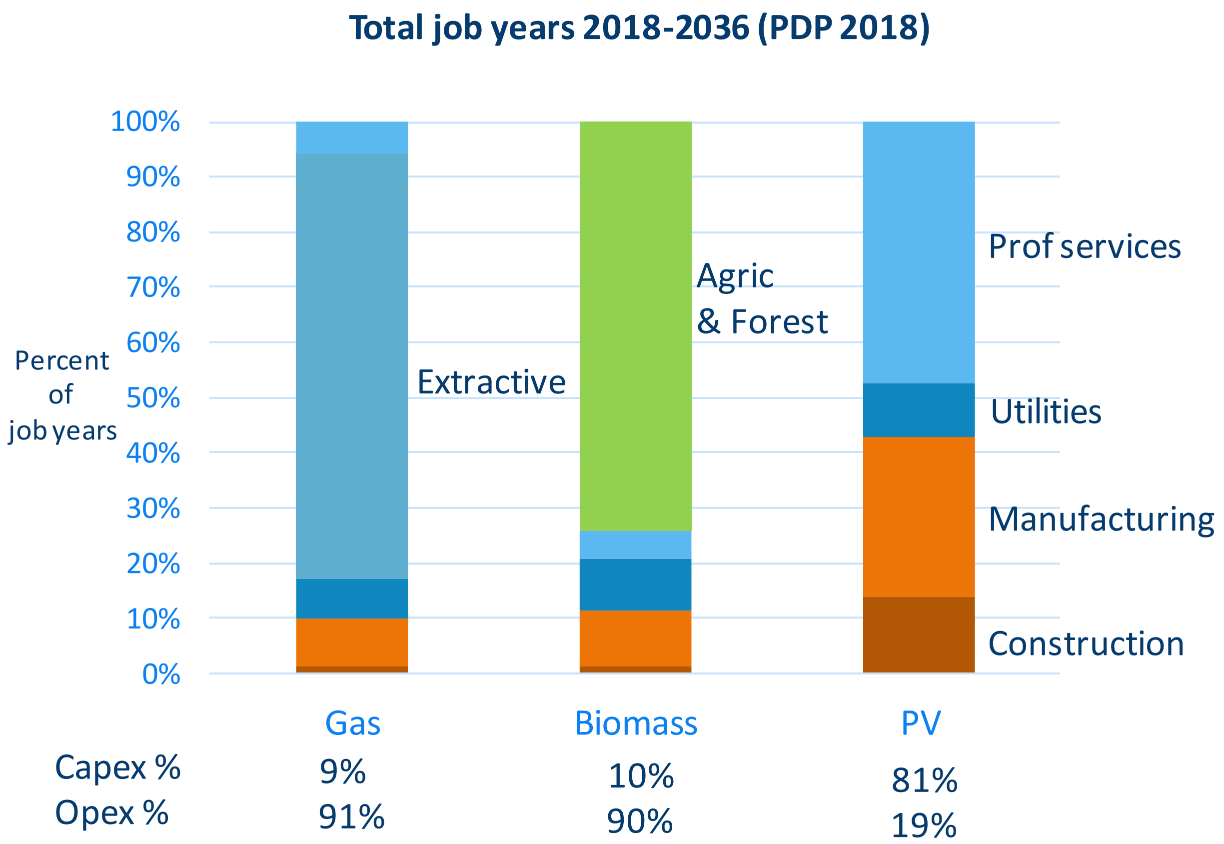

Figure 16: Comparison of employment by sector and type for three technologies

These trends can be seen at the overall level in Figure 17, which shows total employment by sector for all technologies. In the PDP scenarios a large proportion (42-48%) of the total jobs created are in the extractive sector, whereas this is greatly reduced in the High RES scenario, with 30% of total job years occurring in the extractive sector and correspondingly higher shares in other sectors. Figure 17 also highlights the large number of jobs supported in the agriculture and forestry sector, which is caused by high demand for biomass (and relatively low salaries in the sector).

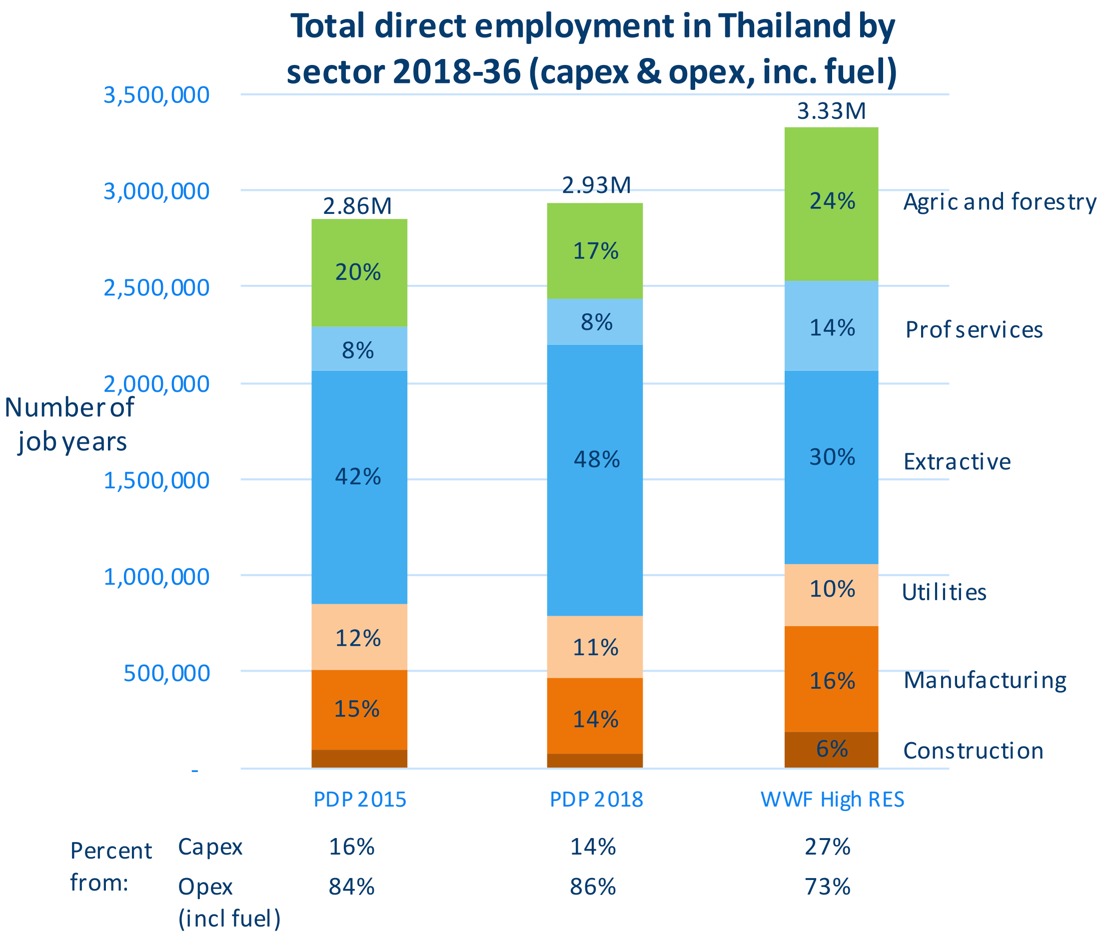

Figure 17: Total direct employment by sector

5.1.2. Capex employment impacts

Looking only at employment from capital expenditure, Figure 18 shows that solar PV is the largest source of jobs in the PDP 2018 scenario and the High RES scenario (including floating solar in the PDP 2018), accounting for 37% and 42% of total capex job years respectively. The greater total investment in capital intensive renewable energy leads to capex-related job creation in the High RES scenario that is more than double the capex employment in the PDP scenarios.

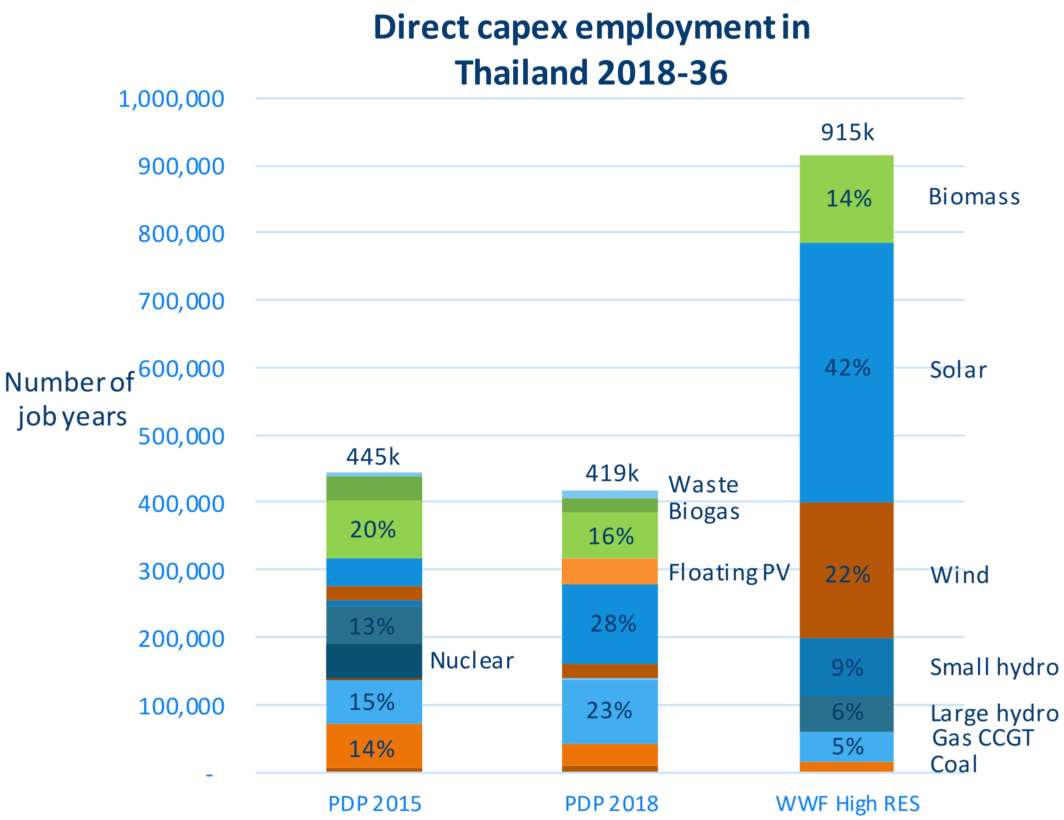

Figure 18: Comparison direct capex employment in Thailand

Figure 19 shows the capex employment impacts, in terms of job years per MW of new capacity, for the main technologies featured in the three scenarios (as cost and local share assumptions are the same in all three scenarios, the employment impacts per MW of new capacity are the same for all scenarios). The shows that capex employment per MW is higher for technologies that have higher capex costs per MW and relatively high local shares, such as hydropower, biomass, and biogas (see Figures 4 and 5). Technologies with low capex cost and low local shares, such as natural gas (average local share of 34%), support lower amounts of capex job years per MW of new capacity. Solar PV and wind, while having relatively high capex costs, have relatively low overall local shares (39% and 28% respectively), reducing the number of local jobs per MW.

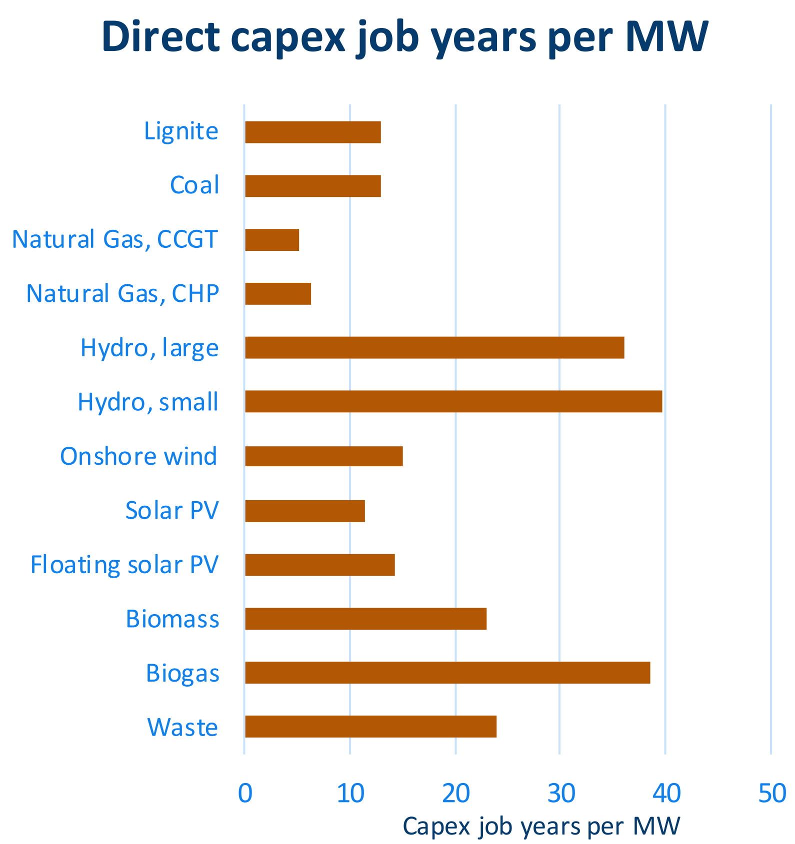

Figure 19: Capex job years per MW (from addition of new capacity)

5.1.3. Opex employment impacts

Jobs related to operation, maintenance, and fuel supply are dominated by technologies with large fuel supply needs such as natural gas, coal, and biomass (see Figure 20). As mentioned in Section 5.1.1 investments in biomass support relatively more jobs due to low salaries in the agriculture and forestry sectors. Renewable energy technologies such as solar PV and wind do require some operations and maintenance jobs, but at a much lower level. The total number of opex jobs does not vary greatly between the three scenarios, and is highest in the PDP 2018, which has the highest total generation (8% more TWh than the PDP 2015).

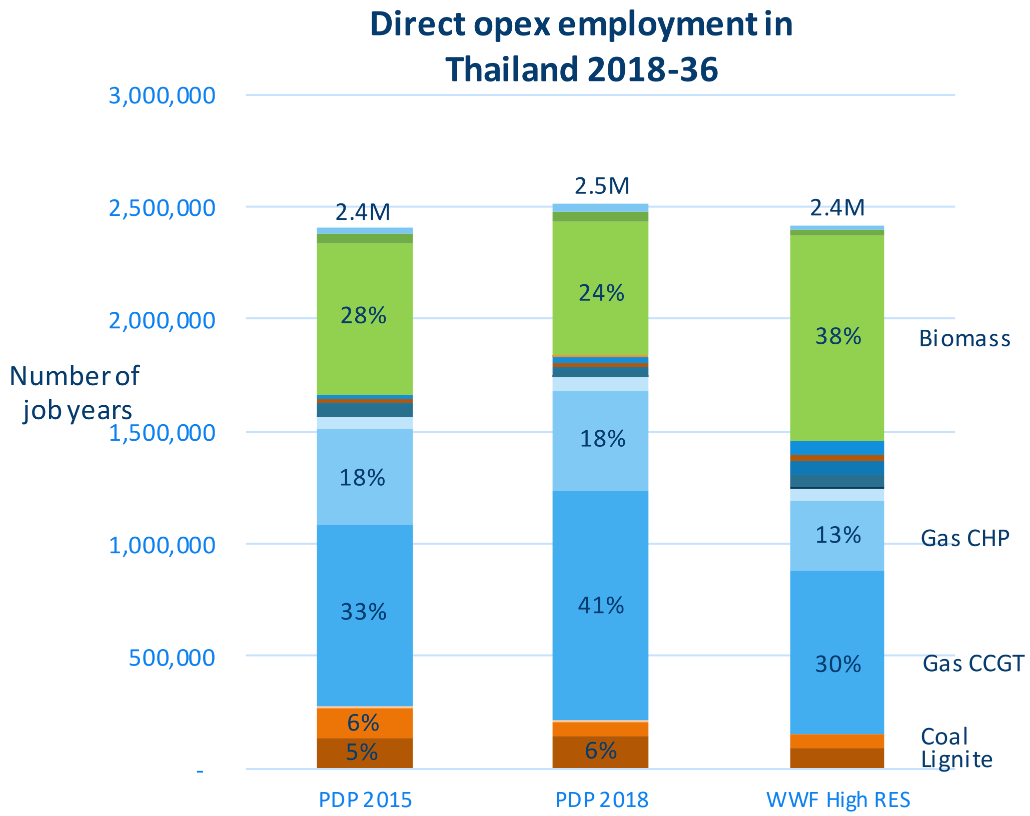

Figure 20: Opex employment (including fuel) by technology

Figure 21 shows a comparison of opex employment impacts per MWh of generation in the PDP 2018 for the main technologies featured in the three scenarios. Since opex expenditure and employment impacts are directly related to the generation scenarios and load factors (which vary per technology), there are slight differences in opex employment impact per MWh in the PDP 2015 and High RES scenarios. Similar trends as seen in Figure 21, however, can be seen in all three scenarios.

The figure shows that opex employment per MWh is influenced by the domestic supply of fuels: domestically sourced lignite creates more employment per MWh than imported coal; the declining local share of natural gas supply reduces the employment per MWh from natural gas; and there is high employment per MWh in biomass as the feedstocks are likely entirely sourced in Thailand. Employment per MWh from biomass is additionally boosted due to relatively low salaries in the agriculture and forestry sectors, which means more jobs can be supported per mUSD spent. Technologies that do not require fuels (PV, wind and hydro) generally have lower employment per MWh although operations and maintenance costs and low load factors increase the impact per MWh (NB biogas feedstock and waste are treated as zero cost fuels in EIM-ES for Thailand and thus no employment is attributed to their fuel supply).

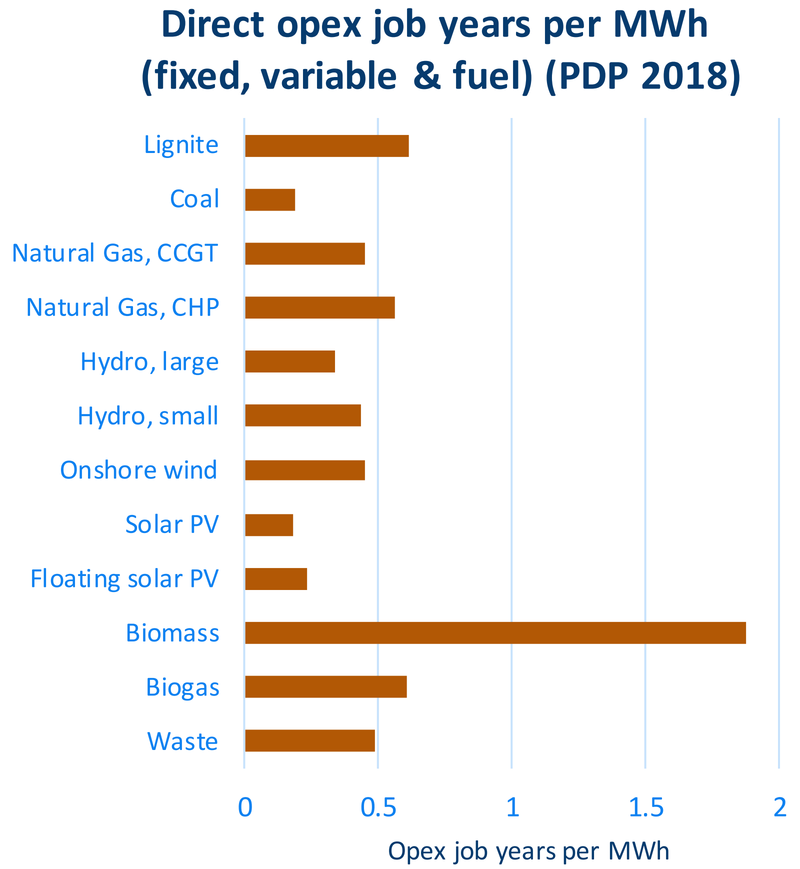

Figure 21: Opex job years per MWh for the PDP 2018[10]

[10] *Opex jobs depend on generation and therefore on load factors, which are different in each scenario. Opex jobs per MWh are therefore slightly different in the PDP 2015 and High RES scenarios*

6. Results: Broader impacts across the economy

- **The model calculates broader impacts across the economy using economic statistics from an Input-Output for Thailand, to estimate the indirect and induced effects of expenditure and consumption in related sectors**
- **In all three scenarios, indirect and induced effects lead to an additional 85-90% expenditure across the Thai economy and additional 90-92% employment**

6.1. Methodology and inputs

The EIM-ES also estimates how expenditure in the power sector leads to economic impacts across the whole economy. Both expenditure in sectors upstream in the supply chain ('indirect') and expenditures from the beneficiaries of direct and indirect economic activity in the power sector ('induced') can be estimated, as well as the job creation that results from those indirect and induced expenditures.

The EIM-ES uses a country specific IO table – which maps how goods and services flow between different sectors of the economy – to estimate the indirect and induced expenditure and employment impacts of the scenarios. The local direct expenditure calculated by the model (and described / presented in Chapter 4) is aggregated to sector level and the IO table is used to estimate how the expenditure in a specific sector (for example construction) would then result in expenditure in sectors which supply the construction sector. The labour shares in the IO table, and the average salaries per sector, are then used to estimate the number of jobs that would be supported by this expenditure. Figure 22 below shows the main steps in the calculation.

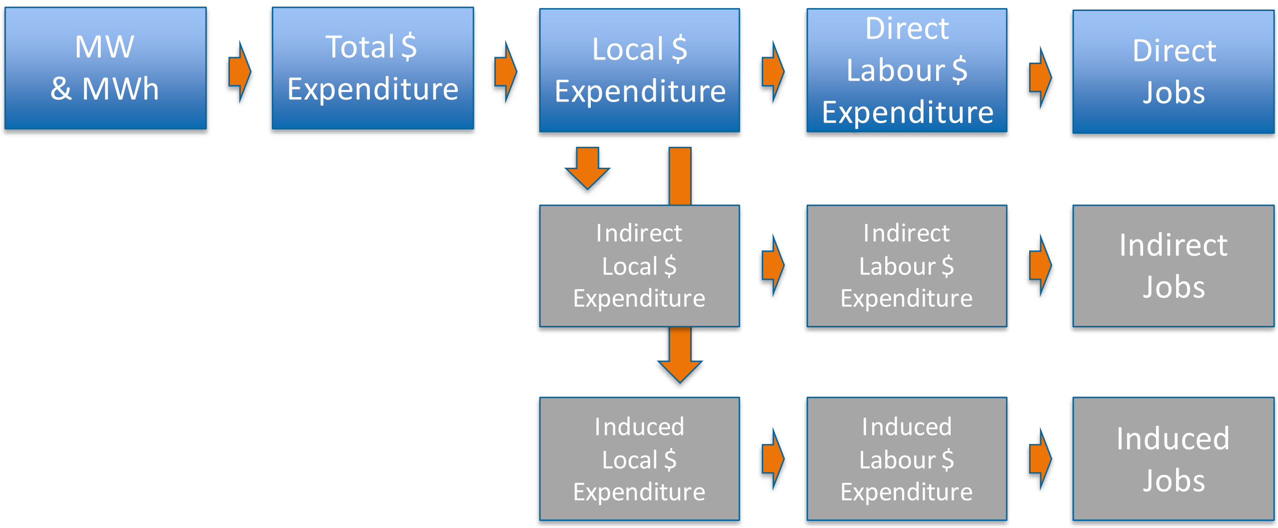

Figure 22: Schematic overview of methodology EIM-ES for broader impacts calculations

6.2. Economy-wide impacts

Total expenditure in Thailand almost doubles for all scenarios when indirect and induced effects are taken into account (see Figure 23). Because all the inputs used to estimate the indirect and induced impacts (i.e., the IO table and average salary data) are consistent across the scenarios, the only driver of different ratios from direct to indirect/induced impacts between the scenarios is the balance of expenditure between sectors. Thus, higher direct expenditure in the PDP 2018 and High RES scenarios, compared to the PDP 2015, result in higher indirect and induced expenditure. Total economy wide expenditures are 4% higher in the PDP 2018 scenario compared to the PDP 2015 scenario. In the High RES scenario the total economy wide expenditure is 15% higher than in the PDP 2018 scenario.

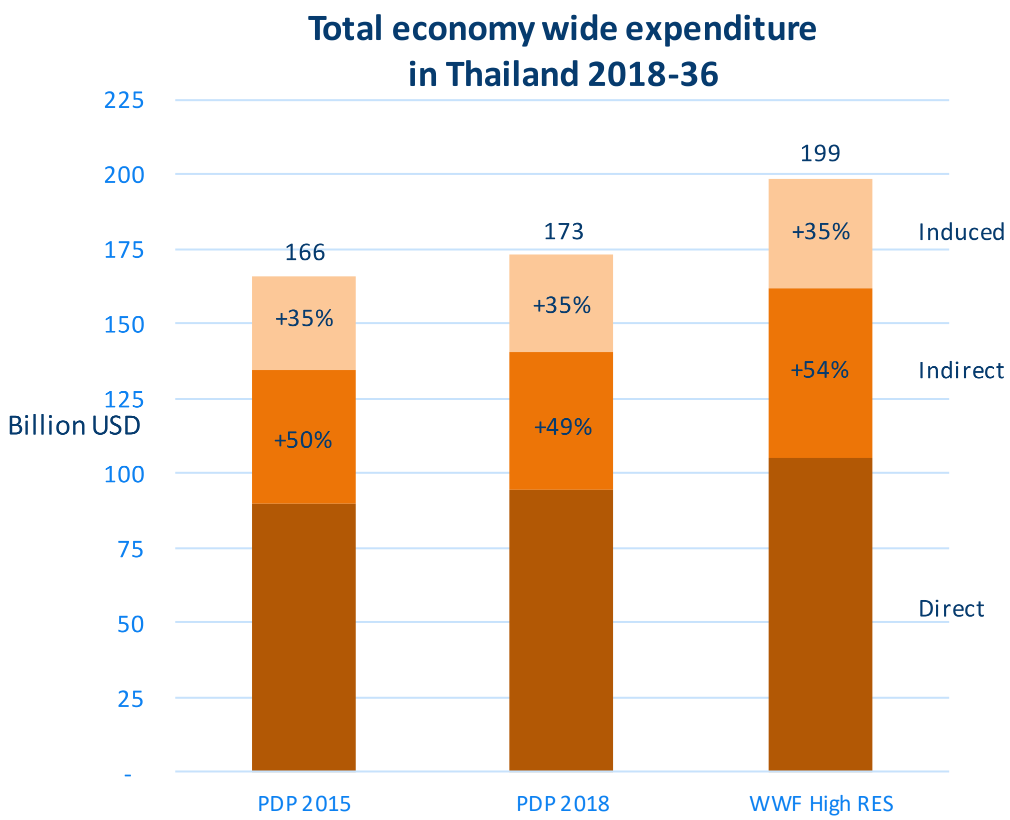

Figure 23: Total economy wide expenditure in Thailand

Figure 24 shows that the extractive sector still accounts for a large share of total expenditure when the broader economic impacts are taken into account, however the overall spread of expenditure across the economy is much more balanced with significant shares for manufacturing and 'other' sectors such as retail, accommodation and food services, education, and agriculture.

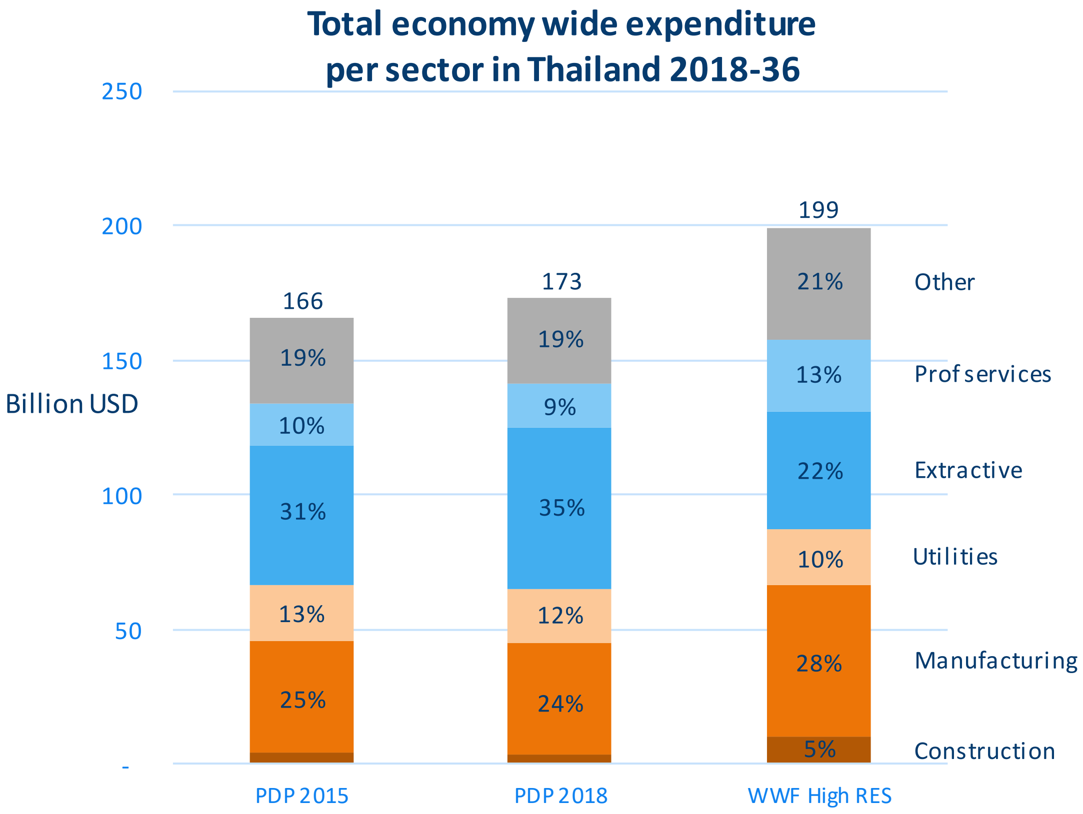

Figure 24: Total economy wide expenditure per sector

As is the case with local expenditure, the majority of economy wide jobs created are directly related to the power sector, but indirect and induced effects each contribute a 40-50% increase in total employment levels relative to direct employment (see Figure 25). Higher expenditure in the PDP 2018 and High RES scenarios result in higher employment numbers in these scenarios as well. Increased expenditure in "other" sectors such as retail, accommodation and food services, education, and agriculture result in a more prominent role for these sectors in total economy employment impacts (see Figure 26). Lower average salaries in sectors such as agriculture contribute to higher employment numbers, as these sectors can support more jobs per USD spent on labour.

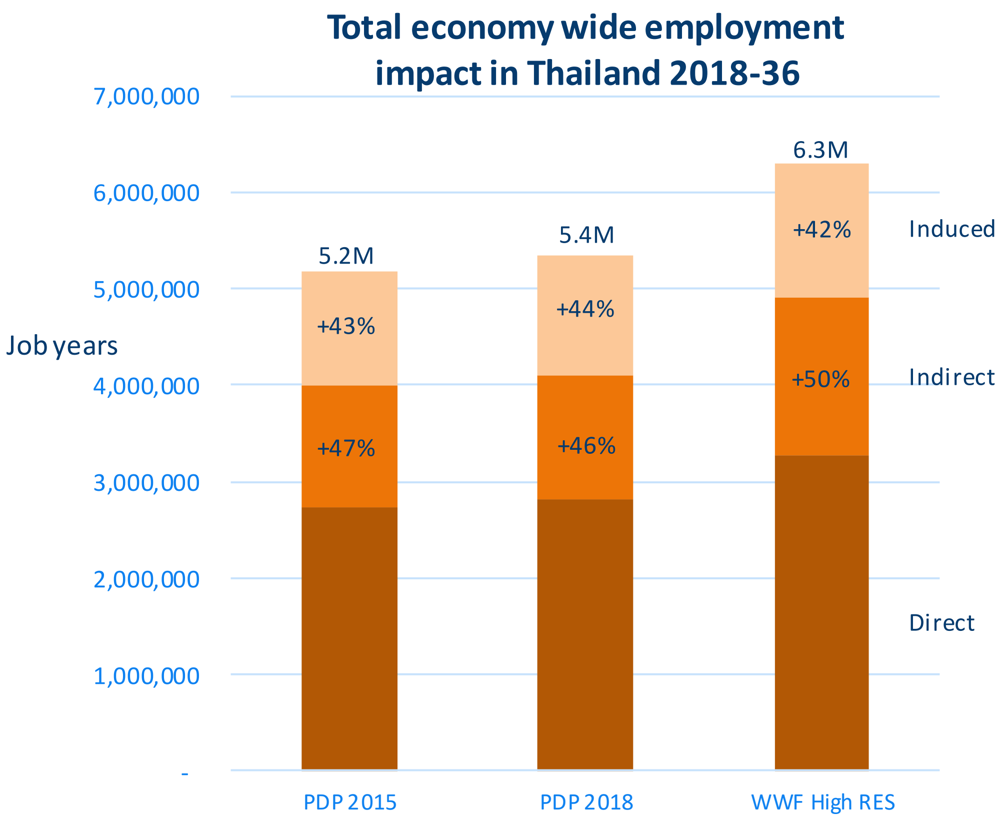

Figure 25: Total economy wide employment impacts

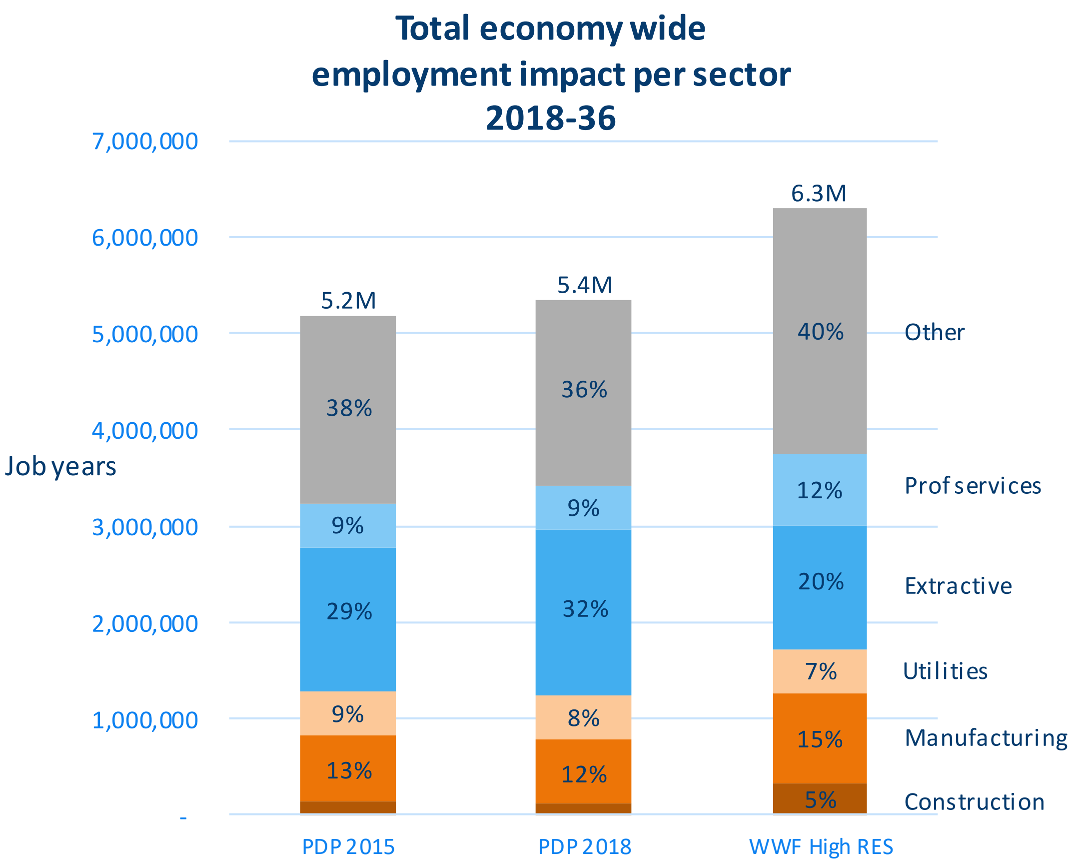

Figure 26: Total economy wide employment impacts per sector

7. Potential next steps

This paper provides an overview of the modelling work undertaken for Thailand during 2019 under the A2A project, using the EIM-ES model.

While the project team has expended considerable time and resources to ensure the inputs to the model and analysis of results is as robust as possible, it is always possible to continue to refine a model such as the EIM-ES, and this final chapter presents some suggestions for areas of further work.

It is also worth noting that for the local share inputs – a key input for the EIM-ES – there was no available information about this for Thailand for specific energy technologies, so the work undertaken by the A2A project to develop assumptions for the local share inputs (for example gathering of information from desk research, interviews, and a private sector workshop) was we believe the first attempt to create an evidence base on this topic.

We identify the following as potential next steps or additional analyses that could be undertaken to strengthen the assessment of economic impacts:

- **Inclusion of additional power sector development scenarios** to explore the economic impacts of different technology mixes;
- **Refinement of technology and fuel costs** based on further research with government agencies and the private sector;
- **Consideration of cost reduction potential** in particular in capex costs (for both renewables and conventional technologies);
- **Further refinement of local share assumptions** based on further research with the private sector; a version of the model could also be created with higher local share assumptions to understand the potential increases in local expenditure and scale of capital investment that could be retained in Thailand in different power sector scenarios;
- **Inclusion of forecasts for fuel prices**, especially the likely evolution of gas prices as the proportion of imports grows over the next 20 years;
- **Updating the Input-Output table information** with more up to date IO tables based on the current exercise being undertaken by the NESDC (n.b. the IO tables need to be in the OECD format in order for the model to use them correctly).

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NESDB Input-Output table for Thailand 2010

Sources for capex and opex costs

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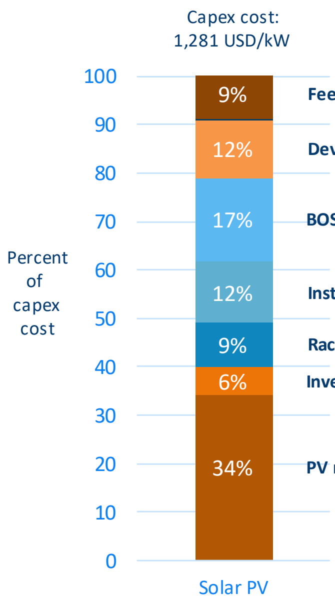
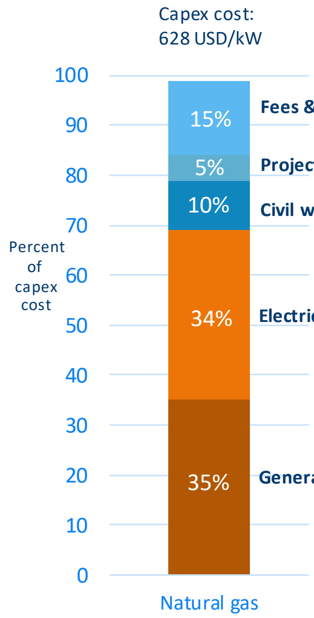
Appendix 1. Detailed inputs

Example component level cost and local share inputs



Component	Sector	Local share	Comment
Fees & contingencies	Financial & insurance	89%	From IO table
Developers costs	Other business services	76%	From IO table
BOS & grid	Electrical equipment	32%	Local share from NESDB electrical machinery subsector
Installation	Construction	63%	Local share from NESDB construction of electrical plants subsector
Racking	Fabricated metal products	47%	Local share from NESDB structural metal products subsector
Inverter	Electrical equipment	10%	Research shows mostly imported
PV module	Electrical equipment	10%	Research shows mostly imported
	Total weighted average	**39%**	

Figure 27: Component level cost and local share inputs for solar PV



Component	Sector	Local share	Comment
Fees & contingencies	Financial & insurance	89%	
Project management	Other business services	76%	
Civil works	Construction	63%	Local share from NESDB construction of electrical plants subsector
Electrical system	Electrical equipment	20%	Research shows large equipment is mostly imported (10% local share). Assumed that ~50% is smaller equipment with a local share of 32% (NESDB electrical machinery subsector)
Generating unit	Electrical equipment	10%	Research shows mostly imported
	Total weighted average	**34%**	

Figure 28: Component level cost and local share inputs for natural gas

Load factors

Table A1 shows the load factors used to estimate renewable energy generation in the PDP 2015 and PDP 2018 scenarios, which have been adjusted from the load factors in Table 4.3 of the PDP 2015. With the adjusted load factors in Table A1 the yearly generation for renewable technologies (excluding large hydro) matches the yearly generation data as mentioned in Appendix 8 of the PDP 2018.

Generation data from the PDPs was used for fossil power, nuclear energy, and large hydropower and therefore no load factors were used. Load factors for these technologies were calculated for the year 2018 of the PDP 2018 in order to be used in the High RES scenario, where the 2018 capacity factors are the same as the PDP 2018, both for conventional technologies as for renewable technologies. These load factors are then adjusted on an annual basis to meet the WWF load factors in 2036, thus reflecting the role of the different technologies as envisaged in that scenario. Table A2 shows the load factors used for the calculation of generation in the High RES scenario.

Table A1: Load factors used to calculate renewable energy generation in the PDP scenarios (selected years)

Technology	2018	2020	2025	2030	2036
Small hydro	41%	42%	40%	42%	44%
Onshore wind	15%	16%	14%	16%	18%
Solar PV	13%	14%	12%	14%	16%
Floating solar PV	13%	14%	12%	14%	16%
Biomass	45%	50%	65%	68%	70%
Biogas	67%	68%	66%	68%	70%
Waste	67%	68%	66%	68%	70%

Table A2: Load factors used to calculate generation in the High RES scenario

Technology	2018	2020	2025	2030	2036
Lignite	85%	86%	87%	89%	90%
Coal thermal	89%	89%	90%	90%	90%
Coal CHP	64%	67%	74%	82%	90%
Natual gas CCGT	42%	42%	44%	45%	47%
Natural gas CHP	73%	70%	63%	56%	47%
Nautral gas / fuel oil	42%	40%	57%	0%	0%
Fuel oil	8%	2%	1%	1%	0%
Diesel	28%	26%	23%	20%	16%
Large hydro	17%	20%	27%	34%	42%
Small hydro	41%	42%	43%	43%	44%
Onshore wind	15%	17%	20%	22%	26%
Solar PV	13%	14%	16%	18%	20%
Biomass	45%	50%	61%	73%	87%

Costs

In the scenarios modelled by the A2A project and reported in this paper, technology costs are the same in all three scenarios and are kept constant over time. The EIM-ES model allows for technology costs to reduce over time to incorporate learning effects, and also for costs to differ between scenarios.

The capex and opex costs are mostly based on research conducted by the project in late 2018 and early 2019. Where gaps remained they have been supplemented from the following sources: Pattapongchai and Limmeechokchai (2011), NEA and IEA (2015), JRC (2014), IRENA (2014), IEA CCC (2015), and IEA (2018a). Fuel cost estimates were based on a mix of sources such as IEA (2018a), IEA (2018b), DEDE (2016), Bank of Thailand (2019), World Nuclear Association (2019), GIZ (2012), and IRENA (2017).

Table A3: Cost inputs used in the EIM-ES for Thailand

Technology	CAPEX (US$/kW)	Fixed OPEX (US$/MW/year)	Variable OPEX (US$/MWh)	Fuel costs (US$/MWth)
Lignite	1,124	27.00	3.56	12
Coal thermal	1,124	27.00	3.56	12
Coal CHP	1,150	30.00	5.00	12
Natural gas	628	17.00	0.80	25
Natural gas CHP	776	36.00	1.00	25
Natural gas / fuel oil	628	17.00	0.80	25
Fuel oil	991	27.72	4.10	61
Diesel	350	12.00	28.69	71
Nuclear	3,500	73.50	2.50	1.3
Large hydro	2,647	25.00	3.49	-
Small hydro	2,980	90.00	0.50	-
Onshore wind	2,277	37.00	-	-
Solar PV[11]	1,281	13.92	-	-
Floating solar PV	1,601	18.51	-	-
Biomass	2,304	83.45	5.00	5.5
Biogas[12]	3,575	171.00	7.58	-
Waste	2,391	136.00	6.90	-

[11] *Cost estimates for large rooftop PV (10 kW – 1 MW)*

[12] *Assumed to be anaerobic digestion of industrial wastewater. Fuel cost is assumed to be zero*

Local shares

Fixed opex costs are broken down into operations and maintenance categories in the EIM-ES (with an additional category of land lease for wind energy). Operations is classified as utilities sector and has a local share of 70%. Maintenance is classified in either the electrical equipment manufacturing sector (local share of 40%) or machinery or the equipment manufacturing sector (local share of 48%). The split of fixed opex costs to operations and maintenance categories differs per technology and therefore determines the average opex local share, which is shown per technology in Figure 29 below. Variable opex costs are assigned to the utilities sector, with a local share of 70% for all variable opex.

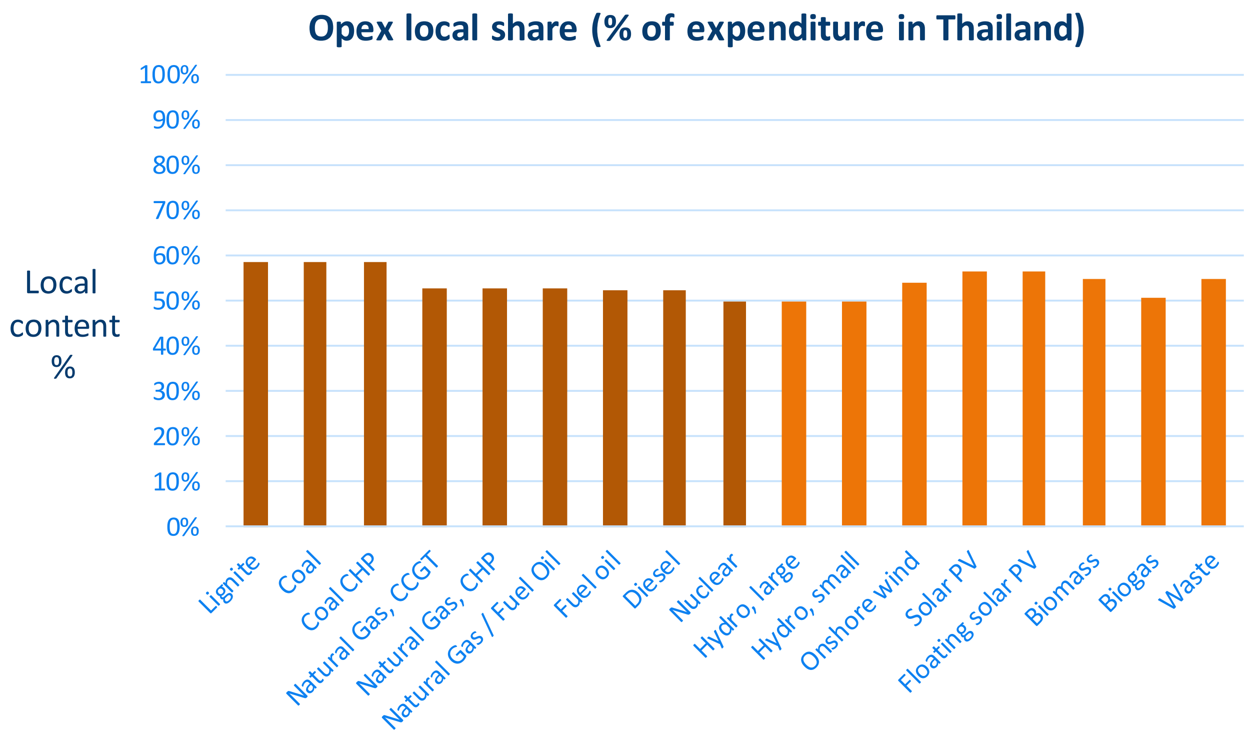


Figure 29: Overview weighted average fixed opex local shares

Labour shares

Capex labour share inputs are determined by the technology capex breakdown to a component level and the sectors the components are assigned to. As the capex breakdowns are unique for each technology (see examples for solar PV and natural gas above), this results in different average capex labour shares for each technology, ranging from 8% up to 14% (see Figure 30).

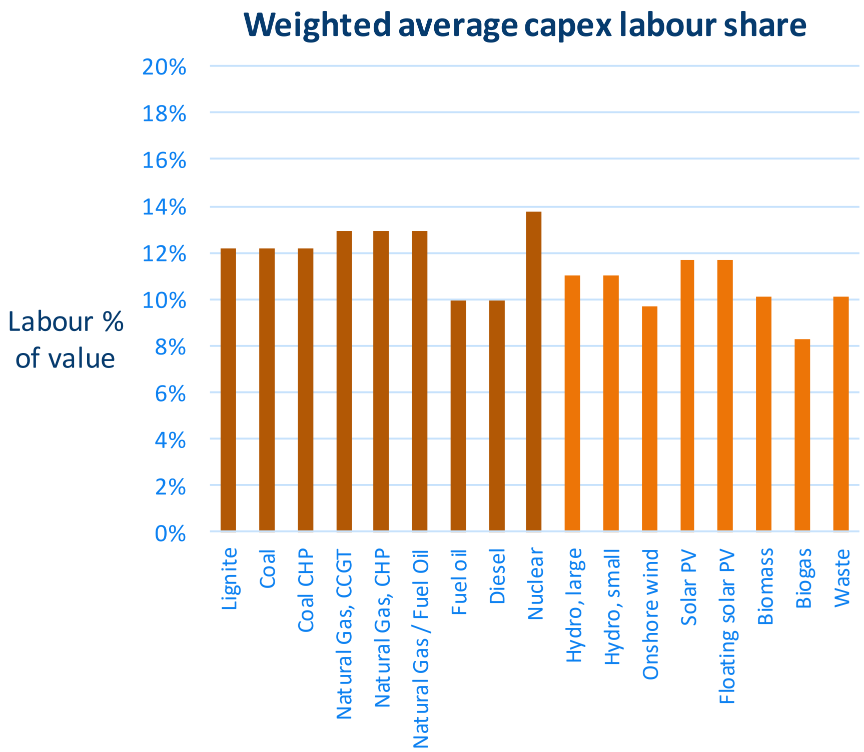


Figure 30: Overview weighted average capex labour shares

Fixed opex is made up of two cost items (operations, and maintenance), and these have the same labour share, so all technologies have the same labour share, apart from wind (which has a third O&M cost category (land lease costs) with a different labour share) (see Figure 31). Variable opex costs are assigned to the utilities sector and therefore have the same labour share for all technologies (17%).

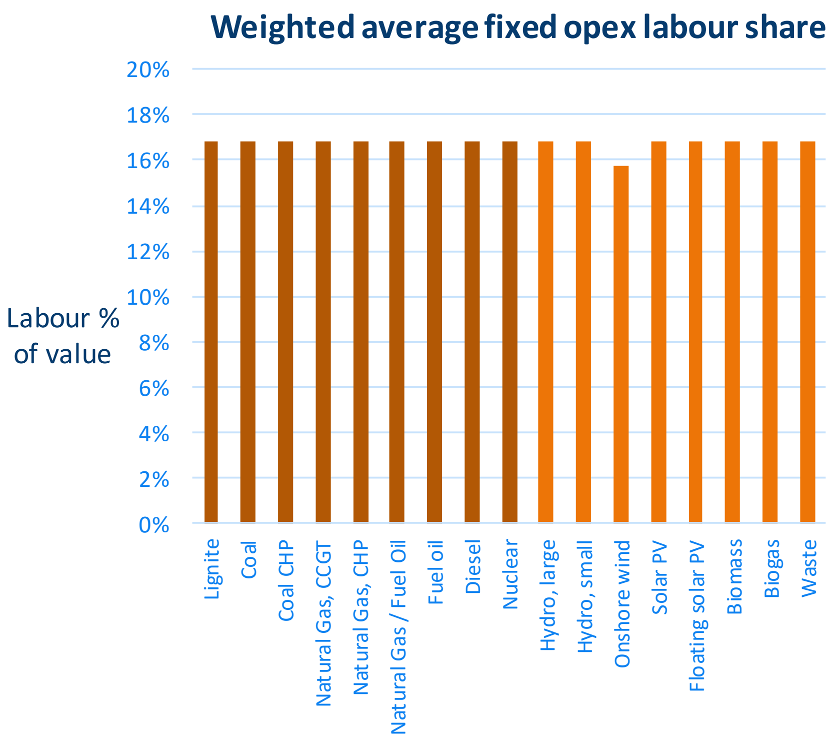


Figure 31: Overview weighted average fixed opex labour shares

Salaries

Average yearly salaries vary widely per sector (see Figure 32). Employment impacts are calculated based on sectoral expenditure levels per technology and therefore employment impacts for a technology are influenced by a mix of sector salaries.

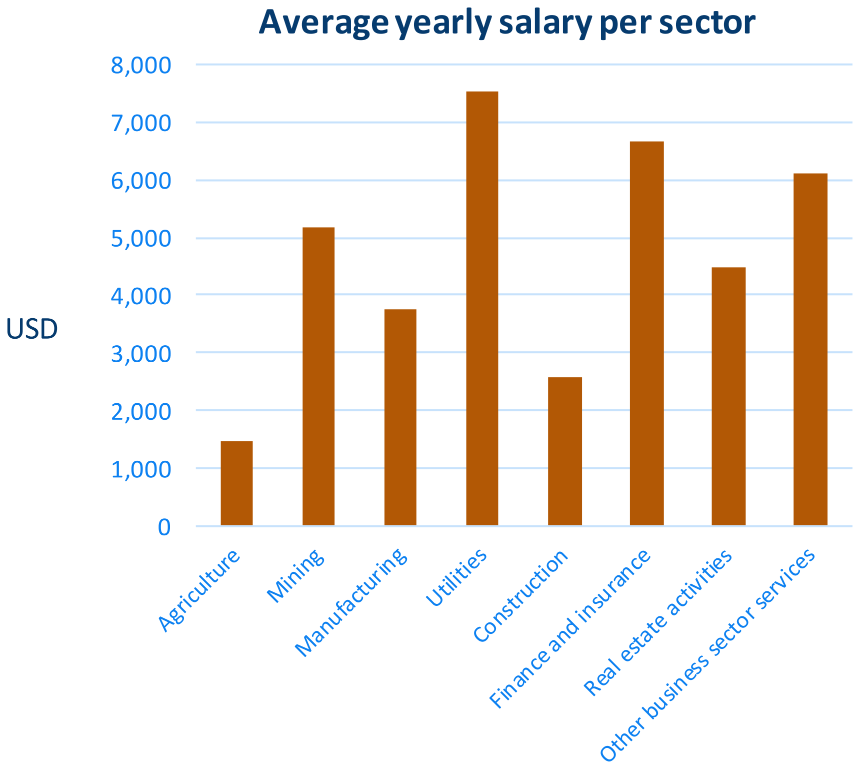


Figure 32: Average yearly salaries for selected sectors (ILO statistics)

Appendix 2. Example yearly results – PDP 2018

The inputs for capacity deployment and generation, and results for expenditure, and employment presented in Chapters 2-6 were aggregated for the whole period 2018-2036, for simplicity and to save space. However as noted, these are all detailed on an annual basis in EIM-ES. The timing of capacity additions influences when investments occur in manufacturing, construction, and installation, as well as annual power generation levels, which themselves affect expenditure on operations, maintenance, and fuels. In this Appendix the timing of capacity additions in the PDP 2018 scenario and the impacts on local direct capex and opex expenditure are shown. The difference in timing of capacity additions in the PDP 2015 and High RES scenarios and the influence on expenditure and employment impacts are briefly discussed as well.

Figure 33 shows that new capacity deployment in the PDP 2018 fluctuates on a yearly basis. Natural gas and biomass capacity are added almost every year, while for some technologies additions are more intermittent (such as lignite and coal). The deployment of solar PV and wind energy capacity occurs mostly in the second half of the scenario, resulting in an increase in investment in the second half of the period. With increasing PV and wind installed capacity in the second half of the scenario, generation and related expenditure on O&M from these technologies also increases in this period.

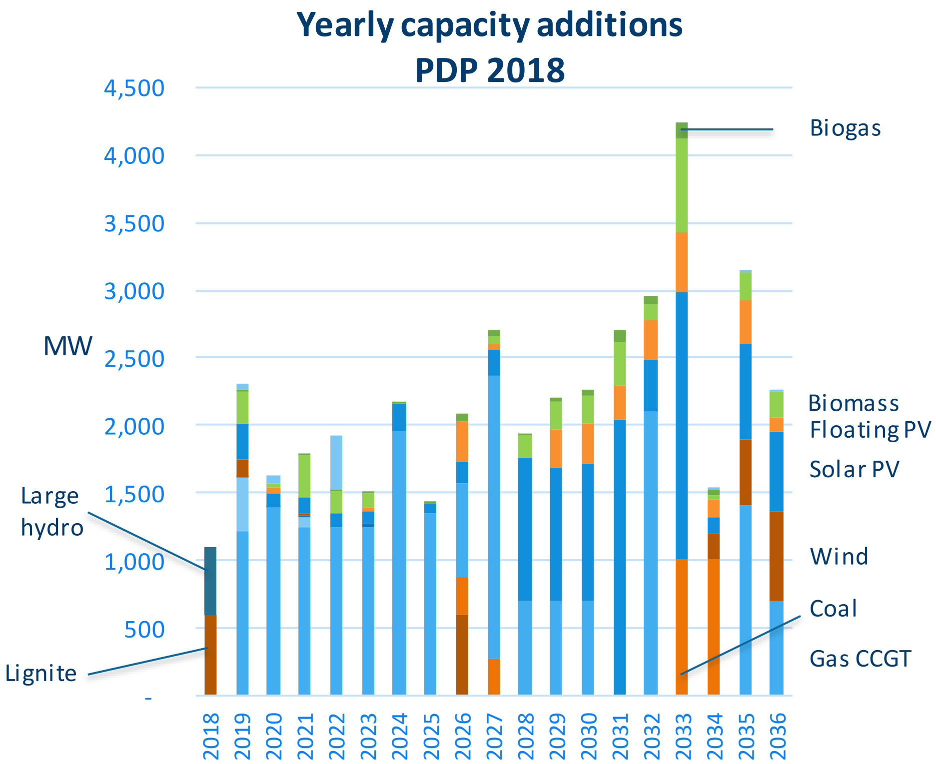


Figure 33: Yearly capacity additions in the PDP 2018 scenario

The timing of capacity additions naturally impacts when capex expenditure occurs. The EIM-ES spreads capex expenditure over the construction period for each technology and assumes all expenditure takes place in the years before capacity comes online. The timing of capex expenditure is therefore both shifted forward and spread out over a number of years, depending on the length of the construction period for each technology. Figure 34 shows that yearly direct local capex expenditure in the PDP 2018 is spread over multiple years for technologies with a longer construction period (e.g. 4 years for coal and lignite) and is less spread out for technologies with short construction periods (e.g. 1 year for solar PV).

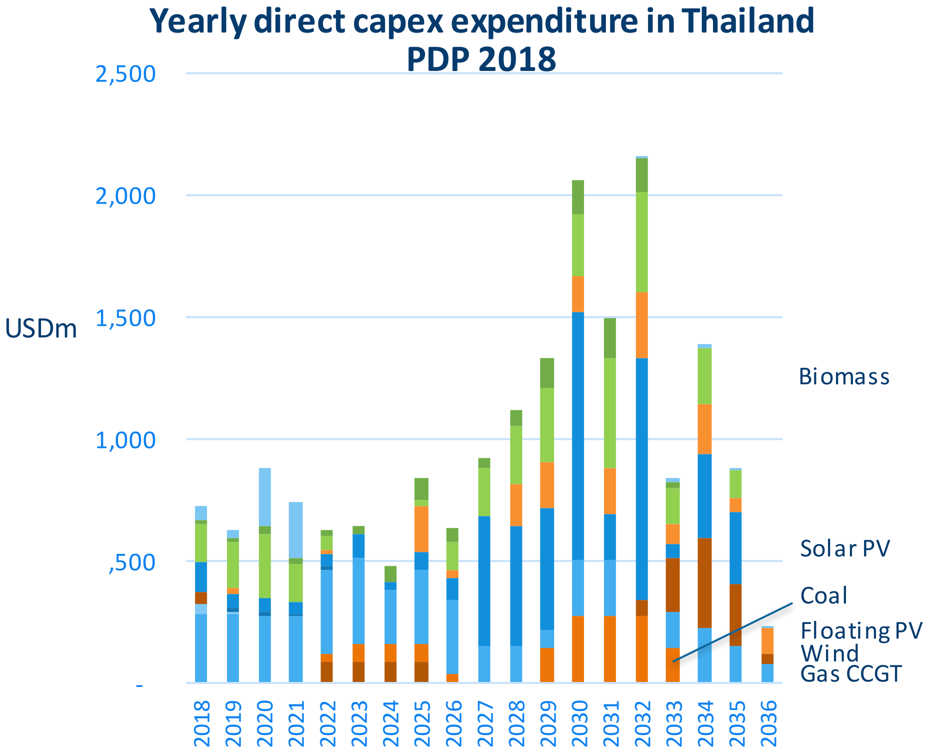


Figure 34: Yearly direct capex expenditure in Thailand in the PDP 2018 scenario

The timing of capacity additions also influences the annual generation and the related expenditure on O&M and fuels. Figure 35 shows the yearly direct local opex and fuels expenditure in the PDP 2018 scenario. Since opex expenditure depends on generation by the total installed capacity (and not just new capacity), the effect of capacity additions is more subtle. The figure does show an increase in opex expenditure on biomass as the installed capacity (and therefore generation) increases over time. The total local opex expenditure is also heavily influenced by the decreasing local share of natural gas supply over time.

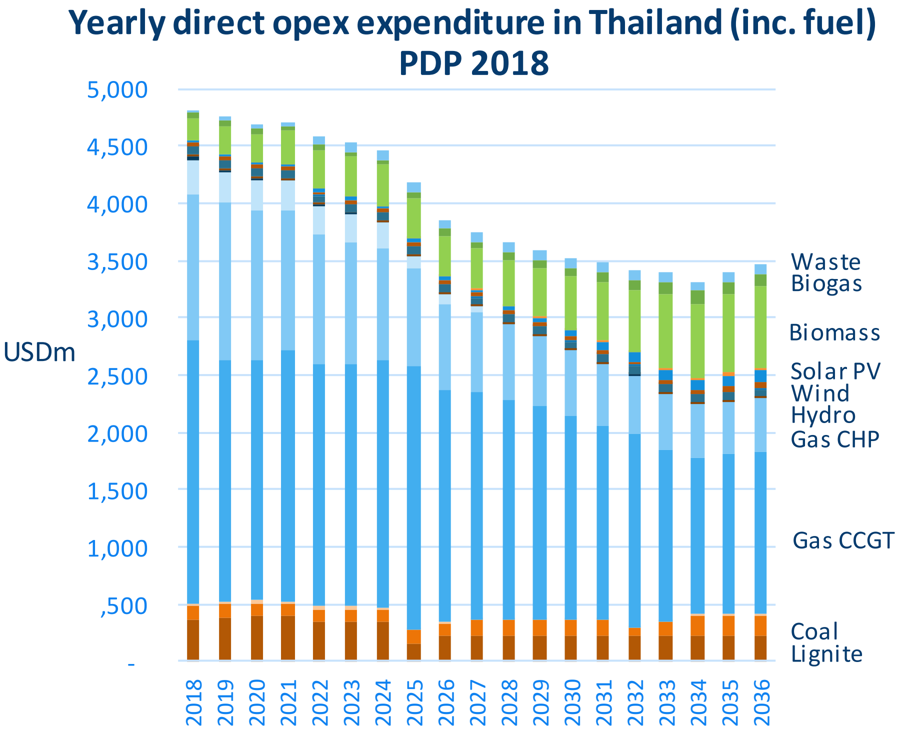


Figure 35: Yearly direct opex expenditure in Thailand (including fuel) in the PDP 2018 scenario

The timing and scale of capacity additions in the PDP 2015 and High RES scenarios differ from the timing of the PDP 2018 scenario. In the PDP 2015 scenario the direct capex expenditure is higher in the first half of the scenario due to investment in coal and large hydro, but the opex expenditure decreases more rapidly than in the PDP 2018 scenario. In the High RES scenario a large amount of new solar PV and wind capacity is installed in the later part of the scenario, shifting capex expenditure to this part of the scenario. Opex expenditure in the High RES scenario decreases in the first half of the scenario, after which opex expenditure increases due to increased biomass generation.

Employment impacts generally follow the timing of investments. As the change in opex expenditure over time is gradual (see Figure 35), the estimated changes in employment in O&M also change gradually. Capex investments show greater changes from one year to the next (see Figure 34), so the level of employment in capex related activities also varies from year to year. The timing of capacity additions is therefore important to take into account when considering employment in manufacturing, construction, and installation of the new capacity. To support sustainable jobs in the manufacturing, construction, and installation sectors a steady investment needs to flow to these sectors.

Appendix 3. Sensitivity to technology cost reductions

As noted in Chapters 2 and 3, technology costs are kept constant over time in the version of the EIM-ES created for Thailand by the A2A project, though it is possible in EIM-ES to vary technology costs in future years, for example to reflect likely cost reductions in renewable energy technologies.

Technology costs have been kept constant in the current model partly because of the complicated relationship between the cost of a technology (or fuel) and the amount of employment supported by that expenditure. In the model, employment is calculated by applying a constant labour share to the local expenditure. If a cost reduction assumption is included in the model, this will reduce the estimated employment results by the same proportion that the technology or fuel cost is reduced (for example if the total local expenditure on a component (e.g. the PV module) is reduced by 25%, this will pass directly through to a 25% reduction in employment attributed to that component), however in the real economy, this relationship is unlikely to be linear, as the cost of technologies or fuels may reduce for various reasons and not all of these cost reductions will be related to, or lead to, reductions in the number of people involved. Unlike more complicated (e.g. econometric) models, EIM-ES is not able to reflect structural changes in the economy over time nor adjust the labour share over time.

As the initial focus of the A2A project in Thailand was on the employment impact co-benefit, the decision was taken to keep costs constant to avoid reducing the employment results in a way that would not reflect the actual situation in the economy. Furthermore, forecasting cost reductions (especially for fuel prices) is highly uncertain and introduces an additional source of complexity into interpretation of the results.

However recently the project's focus in Thailand has shifted more towards the expenditure and investment results; so to understand the sensitivity of the expenditure results to technology cost reductions, a version of the model was created with technology cost reductions included for all scenarios.

Cost reduction forecasts were taken from NREL's Annual Technology Baseline 2017 (for fossil fuels) and the JRC's 2017 report on 'Cost development of low carbon energy sources'. The cost reductions included in the model were as shown in Table A4 below. The impacts of the cost reductions on the key results follow in Table A5.

Table A4: Cost reductions included in sensitivity analysis

Technology	Annual cost reduction	Total cost reduction 2018 to 2036
Lignite	-0.27%	-4.8%
Coal	-0.27%	-4.8%
Coal CHP	-0.27%	-4.8%
Natural Gas, CCGT	-0.35%	-6.2%
Natural Gas, CHP	-0.35%	-6.2%
Natural Gas / Fuel Oil	-0.35%	-6.2%
Fuel oil	-	-
Diesel	-	-
Nuclear	-	-
Hydro, large	-0.03%	-0.5%
Hydro, small	-0.03%	-0.5%
Onshore wind	-0.55%	-9.5%
Solar PV	-2.63%	-38.1%
Floating solar PV	-2.67%	-38.6%
Biomass	-0.55%	-9.5%
Biogas	-0.54%	-9.3%
Waste	-0.74%	-12.5%

The effect on the headline results for expenditure and employment are shown in Table A5 below.

Table A5: Comparison of results with and without cost reductions

Scenario	With constant costs	With cost reduction	Difference
Total expenditure 2018-36 (USD bn)			
PDP 2015	220.7	214.8	-2.7%
PDP 2018	236.7	225.6	-4.7%
High RES	248.4	223.4	-10.1%
Local expenditure 2018-36 (USD bn)			
PDP 2015	89.6	86.8	-3.1%
PDP2018	94.2	89.5	-5.0%
High RES	105.4	95.5	-9.4%
Local capex expenditure 2018-36 (USD bn)			
PDP 2015	19.5	17.9	-8.4%
PDP2018	18.6	15.1	-18.7%
High RES	40.8	32.6	-20.3%
Total direct employment 2018-36 (million job years)			
PDP 2015	2.86	2.79	-2.4%
PDP2018	2.93	2.82	-3.8%
High RES	3.33	3.09	-7.2%

For the two PDP scenarios, the impact of including the cost reductions is relatively limited, at the high level: a 3-5% reduction in total and local expenditure, and a 3-4% reduction in total direct employment. The impact is more pronounced in the High RES scenario, because it has a much higher deployment of renewable energy, which, except for hydro, all feature higher cost reductions than the conventional technologies. In particular solar PV has a cost reduction potential of almost 40% over the period 2018 to 2036, compared to 5-6% for conventional technologies and 9-12% for wind and bioenergy technologies. Total expenditure is reduced by 10% in the High RES scenario, local expenditure by 9% and total employment is reduced by 7%. Looking only at capex expenditure, naturally this shows the larger reductions in all scenarios (because only capex costs rather than opex costs have been reduced in this sensitivity analysis). Local capex expenditure in the PDP scenarios reduces 8.4% in the PDP 2015, and by 19% and 20% in the PDP 2018 and High RES scenarios, which both feature much larger deployment of renewables, especially solar PV (30% of new capacity in the PDP 2018 is solar PV, and 50% in the High RES scenario).