Kementerian PPN/ Bappenas

AFD Agence Française de Développement

Department for International Development

ASSESSING LOW CARBON AND RESILIENT GROWTH IN INDONESIA:

an application of the ThreeME model

FINAL REPORT

CEDS Center for Economics and Development Studies

TNO innovation for life

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AUTHORS LIST

Dr Frédéric Reynès is a senior researcher in energy and environmental economics at the Netherlands Organisation for Applied Scientific Research (TNO) and an affiliated researcher at the French Economic Observatory (OFCE), Sciences Po Paris. He started his economic research by writing a PhD in the field of labour macroeconomics. He worked then as an economist at the Analysis and Forecasting Department of OFCE and at the Institute for Environmental Studies (IVM) where he extended his research interests to the field of energy and environmental economics by publishing regular forecasting and business cycle studies on the oil market and by developing for the ADEME (French Environment and Energy Management Agency) the model THREEME: Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy. Frédéric has a solid research and educational background in the field of macroeconomics, with special emphasis on quantitative and modelling analysis. His main expertise and research interests include energy and environmental issues (in particular the economic impact of energy transition, environmental taxes and the oil market) and labour market issues. At TNO, he is mainly involved in various research and consultancy projects with a strong modelling and data analysis component applied to energy transition and resource use.

Paul Malliet is economist at Analysis and Forecasting Department of the French Economic Observatory (OFCE), Sciences Po Paris since 2011, after having graduated from Toulouse School of Economics where he specialized in environmental and energy economics. His master thesis was dedicated to the study of the impact of climate fiscal instruments on the direction of the technical progress in a endogenous growth model. He has been working at the OFCE on the development of the model THREEME (Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy) and its research is mainly conducted around the question of the energy transition and its economic impacts. He recently extended its research on the energy efficiency economic drivers and its transcription into macroeconomic analysis.

Nizhar Marizi is a planner at the Ministry of National Development Planning/ Bappenas. He graduated BEng in Regional and City Planning from Bandung Institute of Technology in 2001, graduated MSc in Environmental Planning from the University of Indonesia in 2005, and was awarded Ph.D. from The University of Kitakyushu in 2012 for studies in Regional Social System. He has been worked at Bappenas for over thirteen years cooperating with National and Local Government Institutions, International Development and Aid Agencies, and Non-Governmental Organizations covering environmental and energy issues including green growth, renewable energy, and climate change. Currently, he serves as a Deputy Director for Energy Resources and Institutional Affairs who is responsible for renewable energy and energy conservation planning coordination.

ABSTRACT

This report offers an empirical application of the notion of energy transition to the Indonesian economy by simulating the medium- and long-term impacts of proposed investment plan in power generation capacities on the Indonesian economy. The starting point of the analysis comes from ThreeME framework, a Multi-sectoral Macroeconomic Model based on Keynesian theory. It is designed to address dynamics of global economic activity, energy system development and carbon emissions causing climate change. The ThreeME model is well suited for policy assessment purposes in the context of developing economies as it informs the transitional effects of policy intervention. In particular, disequilibrium can arise in the form of involuntary unemployment, inertia of technical systems and rigidity of labor and energy markets, as a result of delayed market-clearing in the goods markets and slow adjustment between prices and quantities over the simulation time path.

Calibrated using sectorial and aggregated national accounts data, an Indonesian version of the ThreeME has been developed and accounts for 37 commodities -including 4 energy sources- and 44 sectors, with an explicit distinction between 11 energy sectors and 4 transport sectors. Electricity production is disaggregated into 8 technologies: hydro, geothermal, wind, solar, nuclear, coal-based, oil-based and gas-based. A disaggregation between 5 regions is also made. The ThreeME-Indonesia model is used to gauge the economic and environmental effects of energy and fiscal policy measures in Indonesia at the national and regional levels. Different policy scenarios are assessed, each reflecting the impact of investments in electricity production capacities.

This document is the result of an 18 months' research collaboration involving the Ministry of National Development Planning (BAPPENAS), the French Agency for Development (AFD), the French Economic Observatory (OFCE), the Netherlands Organization for Applied Scientific Research (TNO) and the Center for Economics and Development Studies from the Padjadjaran University (CEDS).

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The ThreeME model has originally been developed by the OFCE and TNO in collaboration with the French Environment and Energy Management Agency (ADEME). Its adaptation to the Indonesian context has benefited from the important support from the Center for Economic and Development Studies (CEDS), University of Padjadjaran, in particular from Dr. Arief Anshory Yusuf, Heriyaldi and Megananda Suryana. This support is here greatly acknowledged. The authors are also particularly grateful to the Energy Development in Supporting Sustainable Development team (PTSPE) from the Indonesian Agency for Technology Assessment (BPPT) for having shared their data resulting from the *Outlook Energi Indonesia 2015*.

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The authors are finally particularly grateful to Arief A. Yusuf, Megananda and Heriyaldi for having organized the Bandung training workshop on the model in August 2015 and for their strong support in the organization of the restitution seminar *"Toward Energy Transition: From Economic Modeling to National Action Plans"*.

FOREWORD

Indonesia was one of the development success stories in the mid-1990's. It recorded a fourfold increase in income per capita and significant poverty reduction in only 2 decades (1976-1996). This was attributed to the stable economic growth of 7% per year. This high economic growth has contributed to the rising importance of Indonesia in the world economy. However, Indonesia faces a set of challenges. For the last one decade, Indonesia has been experiencing a slowing down of economic growth, a slowing down of poverty reduction, and unprecedented rising income inequality. Those challenges are complemented by another new challenge with regard to the climate change.

It is estimated that Indonesia's total emission contributes around 7% of the global emission. Sectors that contribute the most to Indonesia's emissions are deforestations, forest degradations, and peat fires, which together accounts for as much as 80% of the national emissions. However, emissions from energy through fossil fuel combustion have been increasing quite rapidly, with the majority coming from electricity and transportation. As a result, Indonesia is a major greenhouse gas emitter, ranked fifth in the world according to some recent estimates.

Indeed, energy is very important in Indonesia's development. Compared to other Southeast Asian countries, for example, the country's electrification ratio is still lower, especially in rural area. However, reducing dependence on fossil-fuel energy is not only about commitment toward emissions reduction but also a strategic agenda. Indonesia is rich with renewable energy potentials and its fossil fuels reserves will soon to be depleted.

Indonesia has a progressive plan to increase renewable energy share in the future energy mix. National Energy Policy aims to have 23% renewable energy share in 2025 and 31% in 2050. Meeting these ambitious targets will help Indonesia achieve greater energy security while, at the same time, reducing greenhouse gas emissions and other environmental damage from fossil fuels. There are various options and scenarios to achieve such challenging targets. However, much more needs to be done and will be done.

In 2014, Bappenas and the France Agency for Development (AFD) agreed to work together on program aiming at strengthening the planning capacity of policy-making process related to the promotion of low-carbon growth path in Indonesia. This Final Report of 'Assessing Low Carbon and Resilient Growth in Indonesia: An Application of the ThreeME Model' is the result of the collaboration work which provides the evaluation results of electricity production mix scenarios for greenhouse gas emissions and Indonesian economy impact that analyzed by the model. It is our hope that the report will benefit the various energy sector stakeholder to identify the most favorable energy transition policy for Indonesia to ensure the realization of energy sovereignty.

We would like to express our appreciation and gratitude to AFD, the French Economic Observatory (OFCE), the Netherlands Organization for Applied Scientific Research (TNO), and the Center for Economic and Development (CEDS) of the Universitas Padjajaran for their support and cooperation, and for all stakeholders for their valuable contributions to the development of this Final Report.

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The Paris Agreement, adopted last year during the 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) and entered into force on November 4th 2016, might be the most ambitious international collaboration ever achieved. Indonesia took actively part to the negotiations and markedly provided an ambitious and comprehensive Intended Nationally Determined Contribution (INDC), either on its unconditional or conditional objectives of Greenhouse gases (GHG) emissions. Development Partners are keen on supporting the Indonesian authorities towards achieving such a huge goal.

Hence, this report concludes a two-year long meaningful collaboration between Bappenas, AFD (the French Agency for Development) and the consortium OFCE-TNO. Building on AFD and OFCE successful past experiences in France and Mexico, it was decided with Bappenas to develop macroeconomic modelling capacities to support low carbon growth planning.

OFCE/TNO consortium was tasked to provide and implement an analytical tool (the ThreeME model) capable of simulating the economic and climate impacts of energy transition policies, e.g. changes in the electricity production mix or climate policies such as fiscal policies on energy products. Initially planned to provide inputs for the Indonesian INDC to COP 21, it was intended that the model would assist Bappenas to measure the GHG emissions trajectory of Indonesian policies, as well as their impact on the country's economy. The consortium's work, together with the support of CEDS, from Padjadjaran University, has simulated the outcomes for the Indonesian economy of two electricity mix scenarios: an official one, PLN's ten-year business plan (or RUPTL), and a more ambitious one, Indonesia's version of the Deep Decarbonization Pathways Project. This insightful analysis is compiled in this report.

After the successful adoption of the Paris Agreement, the Three ME model can be a very valuable asset to support the design of policies in line with the Indonesian INDC and to assess their macroeconomic impact. The project has also associated several other institutions involved in energy planning issues like Ministry of Energy and Mineral Resources, Ministry of Finance or BPPT. All of them have shown a great interest in the possibilities offered by the model, increasing the capacities for economic modelling not only in the administration but also in research agencies and universities.

It is my great pleasure to deeply thank Bappenas for its insightful involvement since the inception of this partnership and for being the spearhead of this initiative that may, modestly, be of some use to support the Government of Indonesia in its most valuable efforts to follow a green energy transition way.

Mr. Ghislain de Valon
Indonesia Country Director
Agence Française de Développement (AFD, French Agency for Development)

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GLOSSARY OF ACRONYMS OR ABBREVIATIONS USED

AEC	ASEAN Economic Community
AFD	French Agency for Development
ASEAN	Association of Southeast Asian Nations
BAPPENAS	Ministry of National Development Planning
BAU	Business-As-Usual
BPPT	Agency for the Assessment and Application of Technology
CCS	Capture and Storage
CEDS	Center for Economics and Development Studies from the Padjadjaran University
CREP-ITB	Center for Research on Energy-Policy, Institut Teknologi Bandung
CCROM-BAU	Centre for Climate Risk and Opportunity Management, Bogor Agriculture University
CGEM	Computable General Equilibrium Model
COP 21	2015 United Nations Climate Change Conference
DDPP	Deep Decarbonisation Pathways Project
DEN	National Energy Council
DFID	Department for International Development
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GWe	Gigawatt equivalent
IEA	International Energy Agency
INDC	Intended National Determined Contribution
IRSAM	Inter-Regional Social Accounting Matrix

KEN	National Energy Policy
LULUCF	Land Use, Land Use Change and Forestry
MP3EI	Masterplan Acceleration and Expansion of Indonesia Economic Development 2011-2025
NEP	National Energy Plan
OECD	Organization for Economic Co-operation and Development
OFCE	French Economic Observatory, Sciences po Paris
OPEC	Organization of the Petroleum Exporting Countries
PLN	State Electricity Company (Indonesia)
PPP	Purchasing Power Parity
RAD-GRK	Local Action Plan for GHG Emission Reduction
RAN-GRK	National Action Plan on Reducing GHG Emissions
RES	Renewable Energy Sources
RPJMN	National Medium-Term Development Plan
RPJPN	National Long-Term Development Plan
RUEN	National Energy Plan
RUPTL	Electricity Supply Business Plan PT PLN
SDGs	Sustainable Development Goals
ThreeME	Multi-sectors Macroeconomic Model for the Evaluation of Environmental and Energy policy
TNO	Netherlands Organization for Applied Scientific Research
UNEP	United Nations Environment Programme

EXECUTIVE SUMMARY

This report presents the main outcome of a research collaboration involving the Ministry of National Development Planning (BAPPENAS), the French Agency for Development (AFD), the French Economic Observatory (OFCE), the Netherlands Organization for Applied Scientific Research (TNO) and the Center for Economics and Development Studies from the Padjadjaran University (CEDS), which was financed by the AFD with a delegation of funds from the United Kingdom Department for International Development (DFID).

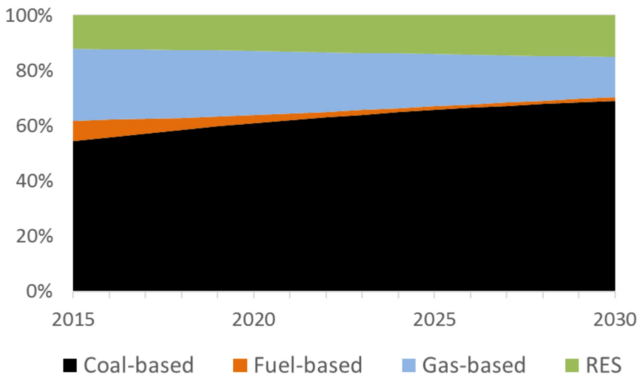
The starting point of this program was the adaptation of the *Multi-sectors Macroeconomic Model for the Evaluation of Environmental and Energy policy* (ThreeME) model to the Indonesian context. Compared to most technical energy models for Indonesia, ThreeME is able to measure the economic and environmental impact both on energy sectors and on the rest of the economy.

The report starts with an overview of the Indonesian context and national policy on energy and climate change (Section 2), in particular of the legislations aiming to tackle the challenges regarding energy supply and the reduction of Greenhouse Gases (GHG) emissions. It then provides a short description of the ThreeME model and how it was adapted to Indonesia (Section 3). Section 4 presents the simulation results of two scenarios regarding the electricity production mix. The first one is based on the assumptions published in the *Rencana Usaha Penyediaan Tenaga Listrik 2016-2025 (RUPTL)*. Largely based on investments in coal power plants until 2020, this scenario shows a clear reorientation toward the development of Renewable Energy Sources (RES) after this date. The second scenario is based on the *Deep Decarbonisation Pathways Project (DDPP)* and is more ambitious in terms of development of RES both regarding the implementation timing and the magnitude. The contribution of each scenario to the unconditional economy-wide mitigation target presented in the Indonesian contribution to the Paris Agreement (reduction by 29% in 2030 of GHG emissions compared to the business as usual scenario) would differ widely. Indeed, the mitigation effort achieved by the DDPP scenario goes beyond this target level, while the mitigation effort achieved by the RUPTL scenario represents only 40% of this target level (and therefore requesting more mitigation efforts on others sectors). Regarding the macroeconomic effect, we find quite similar and rather small impacts for both scenarios compared to the baseline scenario. It appears however that the DDPP scenario has a slightly more positive economic effect compared to the RUPTL scenario. These results advocate for considering the deep decarbonisation of the electricity mix.

Baseline scenario

The impact on the RUPTL and DDPP scenarios is measured in comparison to a baseline or Business-As-Usual (BAU) scenario. The *baseline scenario* is based on the BPPT scenario derived from the *Energi Outlook Indonesia 2015*. In this *baseline scenario*, the Indonesian electricity production until 2030 is expected to remain largely based on fossil energy (more than 80% of the total production over the period 2015-2030, see Figure 1), with coal-based electricity accounting for 69% of the electricity produced in 2030.

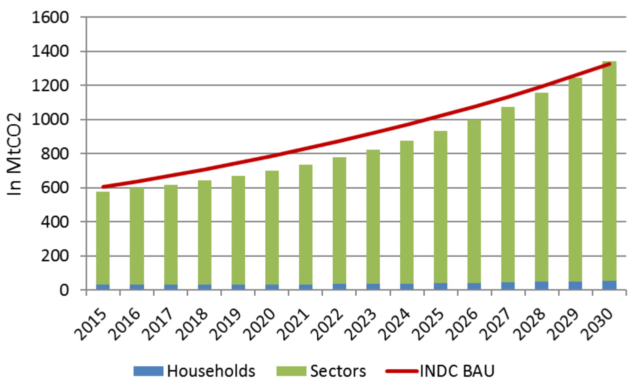
Figure 1. Baseline scenario: Electricity production mix between 2015 and 2030



RUPTL and DDPP scenarios

Accounting for the other sources of direct CO_2 emissions from energy consumption, the baseline scenario follows more or less the trend projected in the BAU of Intended National Determined Contribution (INDC) (see Figure 2).

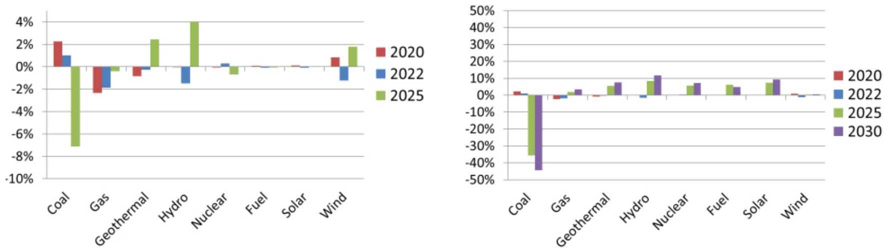
Figure 2. Baseline scenario: Direct CO_2 emissions from energy consumption



In the RUPTL scenario, the share of coal in the mix is 2 percentage points higher in 2020 compared to the baseline, due to the implementation of the first phase of the 35 GW plan that is largely based on coal (see Figure 3.a). The share of fossil-fuel-based power plants is decreasing after 2020 with the reorientation toward the development of RES. But the share of coal-based electricity stays more or less stable between 2015 and 2030 (see Figure 4.a).

Figure 3. Change in electricity production share per technology w.r.t the baseline

(a) RUPTL scenario (b) DDPP scenario

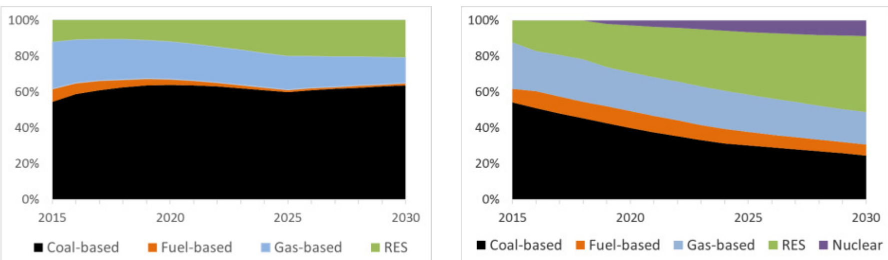


Source: RUPTL (2016-2025), DDPP, Authors' calculations

The Deep Decarbonisation Pathways Project (DDPP) is an international initiative aiming at estimating the full potential of decarbonisation in different economies of the world by 2050. The objectives of the DDPP is to build coherent national low-carbon pathways, based on national circumstances (e.g. resource endowment), interests (e.g. competitiveness) and needs (e.g. development priorities) with the view to reach a national long-term (2050) decarbonisation consistent with the 2°C target. Indonesia is one of the sixteen countries where such an analysis has been conducted by energy research teams. The "Pathways to deep decarbonization in Indonesia" Report was published in 2015 by the Center of Research on Energy Policy (Institut Teknologi Bandung) and the Center for Climate Risk and Opportunity Management (Bogor Agricultural University).

Figure 4. Electricity production mix between 2015 and 2030

(a) RUPTL scenario (b) DDPP scenario



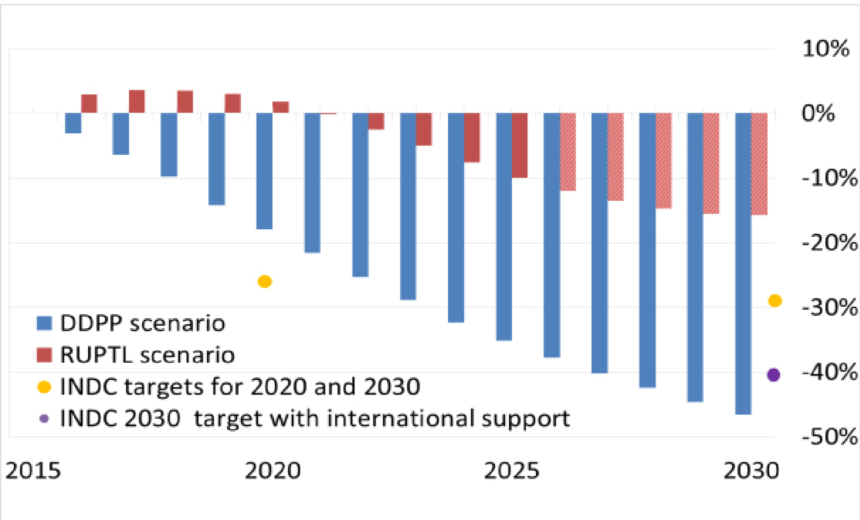
Source: RUPTL 2016-2025, Pathways to deep decarbonisation in Indonesia, Authors' calculations.

The DDPP scenario is clearly more orientated towards low carbon electricity generation than the RUPTL scenario. In the DDPP scenario the share of fossil based technologies decrease from 82.1% to 50.5% between 2015 and 2030 (see Figure 4.b). The share of coal in the mix is 36 percentage points lower by 2025 compared to the baseline whereas this share is only 7 points lower in the RUPTL (see Figure 3, b versus a).

Main Results

In comparison with the baseline, the RUPTL scenario leads to an increase in emissions until 2020, whereas the decrease in emissions in the DDPP scenario is immediate. Moreover, by 2025 and 2030, the magnitude of the mitigation efforts compared to the baseline is three times higher in the DDPP scenario (- 59 $MtCO_2$ in 2030; Figure 5.a) than in the RUPTL scenario (- 20 $MtCO_2$). Figure 5.b shows that the mitigation effort achieved by the DDPP scenario goes beyond the unconditional and conditional economy-wide mitigation targets presented in the Indonesian contribution to the Paris Agreement (reduction by respectively 29% and 41% in 2030 of GHG emissions compared to the business as usual scenario). The mitigation effort achieved by the RUPTL scenario is significantly lower as it represents only 40% of this target level in 2030.

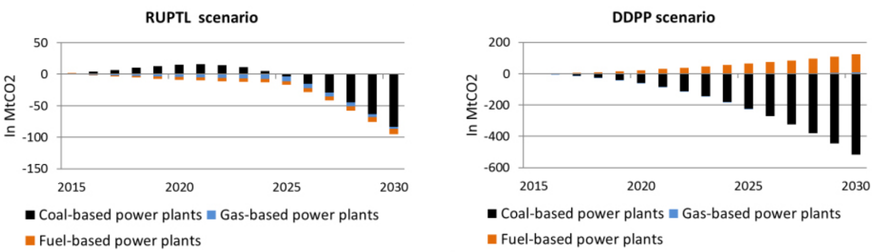
Figure 5. Change in CO_2 emissions related to power generation
for the RUPTL and DDPP scenarios (w.r.t the baseline)



Source: ThreeME, simulation based on the 2016-2025 RUPTL and DDPP scenarios.

This difference between the two scenarios has a significant impact in terms of cumulated emissions or "carbon budget", on the period 2015-2030. In the DDPP scenario, the reduction of the cumulated emissions compared to the baseline is immediate whereas it intervenes only after 2024 in the RUPTL scenario. By 2030, the cumulated reduction in CO_2 emissions compared to the baseline is about 600 $MtCO_2$ in the DDPP scenario against 94 $MtCO_2$ in the RUPTL scenario (see Figure 6).

Figure 6. Cumulated CO_2 emissions (absolute deviation w.r.t the baseline)



Source: ThreeME, simulation based on the 2016-2025 RUPTL and DDPP scenarios.

While the climate change impacts widely differ between the two scenarios, the global economic effect remains quite similar and rather small in both scenarios. This reflects partly the fact that the contributions to the global economy of electricity production based on RES and fossil fuel are not radically different. At the disaggregated level, differences between sectors in terms of investment and employment are clearly visible but they tend to more-or-less compensate each other. The development of the low carbon technologies has however a slightly more positive effect in terms of employment and value added compared to fossil fuel based electricity production. Therefore, the DDPP scenario has a small positive economic effect over the period 2015-2030. To a lesser extent, the same is true for the RUPTL scenario but only after 2020 and the reorientation toward more RES (see macroeconomic results in Table 1).

In addition to its very positive effect on GHG mitigation, these results suggest that the decarbonisation of the electricity mix can have a positive (or at least neutral) impact on the economy at the national level. In the context of the entry into force of the Paris agreement, this gives an additional support for considering ambitious decarbonisation of the electricity mix.

Table 1. Main indicators for the RUPTL and DDPP scenarios

		RUPTL revision Scenario			DDPP Scenario		
Macroeconomic results		**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Real GDP	(a)	-0.01	0.03	0.07	0.27	0.53	0.62
Household consumption	(a)	-0.03	0.04	0.12	0.28	0.76	1.02
Investments	(a)	0.03	-0.02	-0.07	1.10	2.24	2.69
Exports	(a)	0.00	0.02	0.05	-0.04	-0.19	-0.34
Imports	(a)	0.00	-0.06	-0.10	0.34	0.78	1.01
Employment	(d)	-15.61	24.77	61.72	257.33	471.68	456.78
Real wage	(a)	-0.02	0.03	0.08	0.20	0.68	1.05
Price	(a)	-0.01	-0.06	-0.11	0.09	0.32	0.46
CO_2 Emissions	(a)	0.2	-1.1	-1.7	-1.6	-3.0	-4.1
CO_2 emissions index	(b)	121.2	159.5	227.8	119.3	156.7	222.7
Change in emissions index	(e)	-0.1	-2.1	-4.4	-2.0	-4.9	-9.6
Sectoral CO_2 emissions		**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Electricity - Coal	(f)	2.1	-8.7	-19.9	-19.9	-32.4	-72.0
Electricity - Gas	(f)	-1.0	-0.2	1.4	-0.6	0.9	2.8
Electricity - Fuel	(f)	0.1	-0.1	-1.5	7.5	9.2	10.1
Electricity (Total)	**(f)**	**1.3**	**-9.0**	**-20.0**	**-12.9**	**-22.3**	**-59.1**
Industry	(f)	-0.1	0.3	0.3	2.0	4.6	6.9
Other sectors	(f)	0.0	0.0	0.0	0.3	1.1	0.9
Energy (wt Electricity)	(f)	0.0	-1.4	-2.9	-1.0	-11.8	-5.4
Sectoral employment		**2015-2020**	**2020-2025**	**2025-2030**	**2015-2020**	**2020-2025**	**2025-2030**
Electricity - Coal	(g)	3.3	-1.9	-9.7	-11.6	-27.9	-37.2
Electricity - Gas	(g)	-6.4	-5.1	2.3	-6.0	1.2	9.3
Electricity - Fuel	(g)	0.1	0.1	-0.3	4.7	6.9	5.6
Electricity - Hydro	(g)	-3.9	8.9	26.3	12.9	34.0	54.2
Electricity - Geothermal	(g)	-11.3	4.6	34.9	26.1	50.0	65.4
Electricity - Solar	(g)	0.6	0.9	-0.3	29.7	79.1	94.7
Electricity - Wind	(g)	0.9	3.4	4.7	0.3	0.7	1.0
Electricity - Nuclear	(g)	0.0	0.0	-0.1	0.1	3.0	4.8
Total electricity	**(g)**	**-16.8**	**10.8**	**57.9**	**56.3**	**147.1**	**197.8**
Sectoral Investment		**2015-2020**	**2020-2025**	**2025-2030**	**2015-2020**	**2020-2025**	**2025-2030**
Electricity - Coal	(h)	2,050	-1,521	-9,952	-7,014	-20,978	-39,085
Electricity - Gas	(h)	-828	-754	269	-717	175	1,568
Electricity - Fuel	(h)	11	12	-56	988	1,567	1,607
Electricity - Hydro	(h)	-442	1,151	4,287	1,463	4,776	10,900
Electricity - Geothermal	(h)	-701	343	3,506	1,635	4,132	8,265
Electricity - Solar	(h)	470	785	-703	24,168	77,778	143,576
Electricity - Wind	(h)	291	1,430	2,912	94	294	602
Electricity - Nuclear	(h)	2	12	-946	1,016	19,749	48,842
Total electricity	**(h)**	**854**	**1,458**	**-682**	**21,634**	**87,493**	**176,276**

Legend: (a) Relative deviation in % to the baseline, (b) in index 2015=100, (c) in GDP % (deviation to the baseline), (d) in thousands (deviation to the baseline), (e) in index points (deviation to the baseline), (f) annual emissions, in $MtCO_2$, (g) in thousands of jobs on average over the period (deviation to the baseline), (h) in Rp. billions over the period (deviation to the baseline).

RINGKASAN EKSEKUTIF

Pendahuluan

Laporan ini menyajikan hasil utama dari penelitian kolaborasi yang melibatkan Badan Perencanaan Pembangunan Nasional (BAPPENAS), Badan Pembangunan Perancis (AFD), Lembaga Penelitian Perancis (OFCE), Lembaga Penelitian Terapan Belanda (TNO), dan Pusat Studi Ekonomi dan Pembangunan dari Universitas Padjadjaran (CEDS), dengan dibiayai oleh AFD dengan dana delegasi dari Departemen Kerajaan Inggris (UK) untuk Pembangunan Internasional (DFID).

Pada tahap awal dari program ini adalah adaptasi model makro multi-sektor untuk evaluasi kebijakan lingkungan dan energi (*Multi-sectors Macroeconomic Model for the Evaluation of Environmental and Energy Policy*, disingkat ThreeME) untuk konteks Indonesia. Dibandingkan dengan kebanyakan model energi untuk Indonesia, model ThreeMe mampu untuk mengukur dampak ekonomi dan lingkungan di sektor energi dan pada ekonomi secara umum.

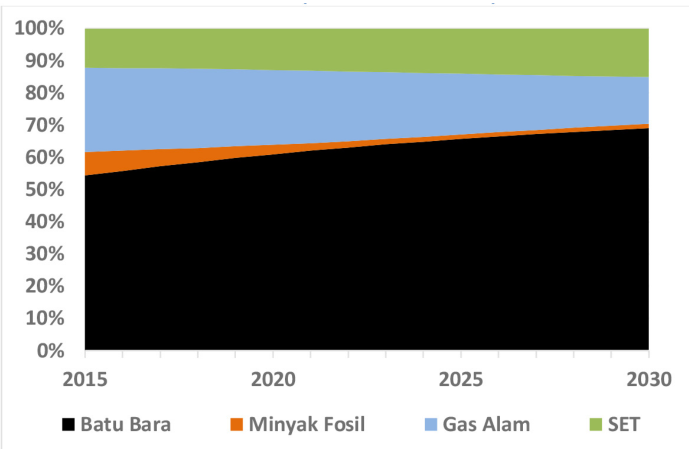
Laporan ini diawali dengan gambaran dari konteks Indonesia dan kebijakan nasional tentang energi dan perubahan iklim (Bagian 2), khususnya dari peraturan perundang-undangan yang bertujuan untuk mengatasi tantangan pasokan energi dan pengurangan emisi gas rumah kaca (*Greenhouse Gases*, disingkat GHG). Kemudian memberikan penjuelasan singkat tentang model ThreeMe dan bagaimana model tersebut diadopsi untuk Indonesia (Bagian 3). Bagian 4 menyajikan hasil simulasi dari dua skenario mengenai komposisi produksi listrik. Skenario yang pertama didasarkan pada asumsi yang diterbitkan dalam Rencana Usaha Penyediaan Tenaga Listrik 2016-2015 (RUPTL). Berdasarkan investasi pada pembangkit listrik tenaga batubara sampai dengan 2020, skenario ini menunjukkan reorientasi terhadap pengembangan Sumber Energi Terbarukan (SET) setelah periode tersebut. Skenario kedua adalah berdasarkan *Deep Decarbonisation Pathway Project* (DDPP) dan ini lebih ambisius dalam hal pengembangan SET bik mengenai waktu pelaksanaan maupun besarnya. Kontribusi masing-masing scenario terhadap target mitigasi yang berdampak ekonomi luas yang dilakukan Indonesia dalam Perjanjian Paris (yakni pengurangan sebesar 29% pada tahun 2030 dari emisi gas rumah kaca dibandingkan skenario business as usual – BAU) jauh berbeda. Ternyata, upaya mitigasi yang dihasilkan melalui skenario DDPP melampau level targetnya, sedangkan upaya mitigasi yang dicapai melalui skenario RUPTL menghasilkan hanya 40% dari level targetnya (sehingga perlu upaya mitigasi dari sektor lainnya). Mengenai efek ekonomi makro, kami menunjukkan hasil yang mirip dan berdampak kecil untuk kedua skenario jika dibandingkan dengan BAU. Walaupun demikian, nampaknya skenario DDPP memiliki dampak positif yang lebih banyak bagi ekonomi dibandingkan dengan skenario RUPTL.

Hasil ini merekomendasikan untuk mempertimbangkan dekarbonisasi pada komposisi produksi listrik.

Skenario Baseline

Dampak dari skenario RUPTL dan DDPP diukur dengan membandingkan dengan kondisi awal atau skenario BAU. Skenario BAU adalah berdasarkan skenario BPPT yang dihasilan dari Energi Outlook Indonesia 2015. Dalam skenario ini, produksi listrik Indonesia hingga 2030 diperkirakan akan tetap sebagian besar didasarkan pada sumber energi fosil (lebih dari 80% dari total produksi selama periode 2015-2030, lihat Gambar 1), dimana pembangkit listrik tenaga batubara menyumbang sekitar 68% untuk produksi listrik pada tahun 2030.

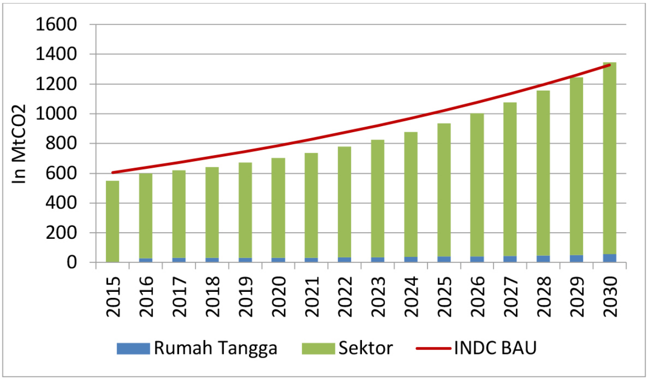
Gambar 1. Skenario BAU: Komposisi Produksi Listrik periode 2015-2030



Sumber: Perhitungan penulis berdasarkan BPPT

Berdasarkan sumber emisi CO_2 langsung lainnya dari konsumsi energi, skenario BAU kurang lebih mengikuti trend proyeksi dari kondisi kontribusi nasional (Intented National Determinied Contribution, disingkat INDC) (lihat Gambar 2).

Gambar 2. Skenario BAU: Emisi CO2 emissions langsung dari konsumsi energi



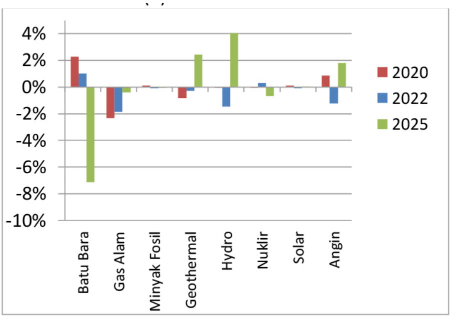
Sumber: Estimasi penulis, Skenario BAU ThreeMe Indonesia

Skenario RUPTL dan DDPP

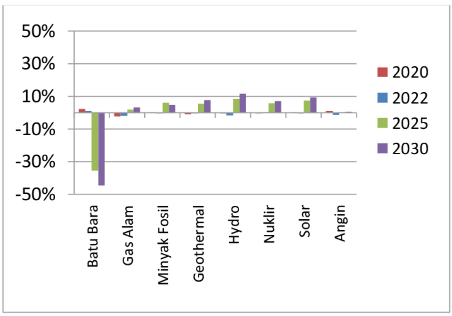
Dalam skenario RUPTL, kontribusi tenaga batu bara dalam komposisi 2 persen lebih tinggi jika dibandingkan dengan BAU pada tahun 2020, disebabkan oleh implementasi tahap pertama rencana 35GQ yang sebagian besar berasal dari batubara (Lihat Gambar 3.a). Kontribusi pembangki listrik tenaga minyak fosil tenyata menurun setelah tahun 2020 dengan reorientasi menuju pengembangan Sumber Energi Terbarukan (SET). Namun, kontribusi dari tenaga batubara kurang lebih tetap antara periode 2015 dan 2030 (lihat Gambar 4.a)

Gambar 3. Perubahan kontribusi komposisi produksi listrik, dibandingkan dengan BAU

(a) Skenario RUPTL



(b) Skenario DDPP

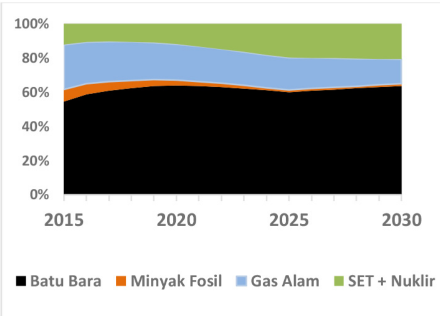


Sumber: RUPTL (2016-2025), DDPP, Perhitungan penulis

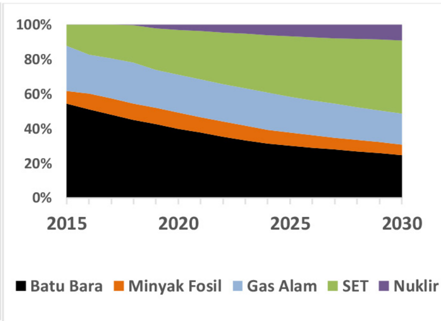
Deep Decarbonisation Pathways Project (DDPP) adalah satu inisiatif internasional yang bertujuan untuk memperkirakan peotensi penuh dari dekarbonisasi di negara-negara pada tahun 2050. Maksud dari DDPP adalah untuk membangun jalur nasional karbon rendah yang koheren, berdasarkan keadaan nasional (misalkan persediaan sumber daya), kepentingan (misalkan daya saing), dan kebutuhan (misalkan prioritas pembangunan), dengan pandangan untuk mencapai target jangka panjang nasional (2050) dekarbonisasi yang konsisten dengan target 2°C. Indonesia merupakan salah satu dari 16 negara yang dianalisis oleh tim peneliti energi. Laporan mengenai *"Pathway to deep decarbonization in Indonesia"* dipublikasikan pada tahun 2015 oleh Pusat Studi Kebijakan Energi (CERP) ITB dan Pusat Studi Resiko dan Manajemen Iklim IPB.

Gambar 4. Komposisi Produksi Listrik pada periode 2015 – 2030

(a) Skenario RUPTL



(b) Skenario DDPP



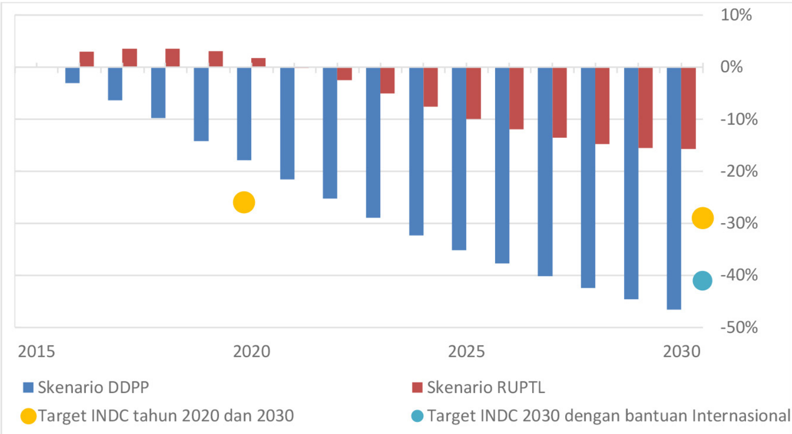
Sumber: RUPTL 2016-2025, Laporan "Pathways to deep decarbonization in Indonesia", Perhitungan penulis

Skenario DDPP lebih berorietasi pada pembangkit listrik dengan karbon rendah jika dibandingkan dengan skenario RUPTL. Dalam skenario DDPP kontribusi teknologi tenaga fosil menurun dari 82.1% menjadi 50.5% antara tahun 2015 dan 2030 (lihat Gambar 4.b). Kontribusi batu bara pada komposisi produksi listrik adalah sebesar 36% lebih rendah pada tahun 2025 dibandingkan dengan BAU, padahal pada skenario RUPTL kontribusinya hanya 7 persen lebih rendah (lihat Gambar 3.b versus a).

Hasil Utama

Dibandingkan dengan BAU, skenario RUPTL menyebabkan peningkatan emisi hingga 2020, sedangkan penurunan emisi pada skenario DDPP terjadi dengan cepat. Selain itu, pada tahun 2025 dan 2030, besaran upaya mitigasi pada skenario DDPP (-73 MtCO_2 pada tahun 2030) adalah empat kali lebih tinggi dibandingkan dengan skenario RUPTL (hanya -21 MtCO_2). Gambar 5 menunjukkan upaya mitigasi yang dicapai dengan skenario DDPP melampaui target mitigasi Indonesia (baik tanpa maupun dengan bantuan) dalam perjanjian Paris (pengurangan oleh masing-masing 29% dan 41% pada tahun 2030 dari emisi gas rumah kaca dibandingkan dengan BAU). Upaya mitigasi yang dicapai melalui skenario RUPTL secara signifikan lebih rendah karena hanya mewakili 40% dari level target pada tahun 2030.

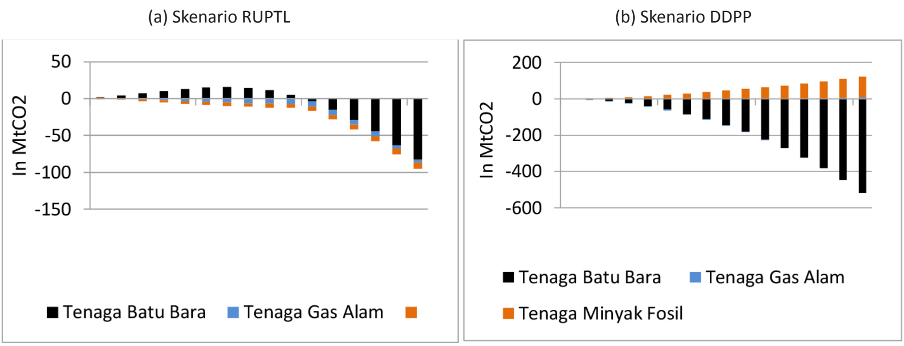
Gambar 5. Perubahan pada emisi CO2 untuk skenario RUPTL dan DDPP, dibandingkan dengan BAU



Sumber: ThreeME, Simulasi berdasarkan skenario RUPTL 2016-2015 dan DDPP

Perbedaan antara dua skenario memiliki dampak yang signifikan dalam emisi kumulatif, pada periode 2015-2030. Dalam skenario DDPP, pengurangan emisi kumulatif terjadi dengan cepat sedangkan pada skenaro RUPTL terjadi setelah tahun 2024. Pada tahun 2030, pengurangan kumulatif emisi CO_2 jika dibandingkan dengan BAU adalah sekitar 600 $MtCO_2$ pada skenario DDPP dan sekitar 94 $MtCO_2$ pada skenario RUPTL (Lihat Gambar 6).

Gambar 6. Emisi Kumulatif CO2 (Deviasi absolut terhadap BAU)



Sumber: ThreeME, simulasi berdasarkan skenario RUPTL 2016-2025 dan DDPP

Walaupun dampak lingkungan terlihat berbeda jauh antara kedua skenario, dampak pada ekonomi ternyata hampir mirip dan kecil pada kedua skenario. Hal ini mencerminkan sebagian fakta bahwa kontribusi ke perekonomian produksi listrik dengan tenaga SET dan fosil tidak berbeda jauh. Pada tingkat yang lebih rendah, perbedaan antara industri dalam hal investasi dan lapangan kerja bisa terlihat lebih jelas, namun mereka kurang lebih saling kompensasi satu sama lain. Perkembangan teknologi karbon rendah memiliki dampak sedikit lebih positif dalam hal tingkat kesempatan kerja dan nilai tambah jika dibandingkan dengan produksi listrik tenaga fosil. Oleh karena itu, skenario DDPP memiliki efek ekonomi yang positif kecil selama periode 2015-2030. Pada tingkat yang lebih rendah, kondisi yang sama berlaku untuk skenario RUPTL tetapi hanya setelah 2020 dan lebih reorientasi pada SET (Lihat hasil Makroekonomi pada Tabel 1)

Selain dampak yang sangat positif pada mitigasi gas rumah kaca, hasil ini menunjukkan bahwa dekarbonisasi pada komposisi produksi listrik dapat memberikan dampak positif (setidaknya netral) terhadap perekonomian di tingkat nasional. Dalam konteks berlakunya perjanjian Paris, ini memberikan dukungan tambahan untuk mempertimbangkan dekarbonisasi yang ambisius pada komposisi produksi listrik.

Tabel 1. Indikator Utama untuk skenario RUPTL dan DDPP

		RUPTL Scenario			DDPP Scenario		
Macroeconomic results		**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
PDB Riil	(a)	-0.01	0.03	0.07	0.27	0.53	0.62
Konsumsi RT	(a)	-0.03	0.04	0.12	0.28	0.76	1.02
Investasi	(a)	0.03	-0.02	-0.07	1.10	2.24	2.69
Ekspor	(a)	0.00	0.02	0.05	-0.04	-0.19	-0.34
Impor	(a)	0.00	-0.06	-0.10	0.34	0.78	1.01
Kesempatan Kerja	(d)	-15.61	24.77	61.72	257.33	471.68	456.78
Upah Riil	(a)	-0.02	0.03	0.08	0.20	0.68	1.05
Harga	(a)	-0.01	-0.06	-0.11	0.09	0.32	0.46
Emisi CO_2	(a)	0.2	-1.1	-1.7	-1.6	-3.0	-4.1
Indeks Emisi CO_2	(b)	121.2	159.5	227.8	119.3	156.7	222.7
Perubahan Indeks Emisi CO_2	(e)	-0.1	-2.1	-4.4	-2.0	-4.9	-9.6
Emisi CO_2 Sektoral		**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Listrik - Batu Bara	(f)	2.1	-8.7	-19.9	-19.9	-32.4	-72.0
Listrik - Gas Alam	(f)	-1.0	-0.2	1.4	-0.6	0.9	2.8
Listrik - Minyak Bumi	(f)	0.1	-0.1	-1.5	7.5	9.2	10.1
Listrik (Total)	**(f)**	**1.3**	**-9.0**	**-20.0**	**-12.9**	**-22.3**	**-59.1**
Industri	(f)	-0.1	0.3	0.3	2.0	4.6	6.9
Sektor lainnya	(f)	0.0	0.0	0.0	0.3	1.1	0.9
Energi (tanpa Listrik)	(f)	0.0	-1.4	-2.9	-1.0	-11.8	-5.4
Kesempatan Kerja		**2015-2020**	**2020-2025**	**2025-2030**	**2015-2020**	**2020-2025**	**2025-2030**
Listrik - Batu Bara	(g)	3.3	-1.9	-9.7	-11.6	-27.9	-37.2
Listrik - Gas Alam	(g)	-6.4	-5.1	2.3	-6.0	1.2	9.3
Listrik - Minyak Bumi	(g)	0.1	0.1	-0.3	4.7	6.9	5.6
Listrik - Hidro	(g)	-3.9	8.9	26.3	12.9	34.0	54.2
Listrik - Geothermal	(g)	-11.3	4.6	34.9	26.1	50.0	65.4
Listrik - Solar	(g)	0.6	0.9	-0.3	29.7	79.1	94.7
Listrik - Angin	(g)	0.9	3.4	4.7	0.3	0.7	1.0
Listrik - Nuklir	(g)	0.0	0.0	-0.1	0.1	3.0	4.8
Listrik Total	**(g)**	**-16.8**	**10.8**	**57.9**	**56.3**	**147.1**	**197.8**
Investasi Sektoral		**2015-2020**	**2020-2025**	**2025-2030**	**2015-2020**	**2020-2025**	**2025-2030**
Listrik - Batu Bara	(h)	2,050	-1,521	-9,952	-7,014	-20,978	-39,085
Listrik - Gas Alam	(h)	-828	-754	269	-717	175	1,568
Listrik - Minyak Bumi	(h)	11	12	-56	988	1,567	1,607
Listrik - Hidro	(h)	-442	1,151	4,287	1,463	4,776	10,900
Listrik - Geothermal	(h)	-701	343	3,506	1,635	4,132	8,265
Listrik - Solar	(h)	470	785	-703	24,168	77,778	143,576
Listrik - Angin	(h)	291	1,430	2,912	94	294	602
Listrik - Nuklir	(h)	2	12	-946	1,016	19,749	48,842
Listrik Total	**(h)**	**854**	**1,458**	**-682**	**21,634**	**87,493**	**176,276**

Keterangan: (a) Deviasi relatif dalam % terhadap BAU, (b) dalam index 2015=100, (c) dalam GDP % (deviasi terhadap BAU), (d) dalam ribuan (deviasi terhadap BAU), (e) dalam satuan indeks (deviasi terhadap BAU), (f) emisi tahunan, dalam MtCO2, (g) dalam ribuan pekerjaan (rata-rata) selama periode (deviasi terhadap BAU), (h) dalam miliar Rupiah selama periode (deviasi terhadap BAU).

1 INTRODUCTION

The Paris Agreement was approved in December 2015 at the unanimity of the representatives of the 196 parties participating to the COP 21 (2015 United Nations Climate Change Conference) and entered into force on the 4th of November 2016. It retains the ambitious target to limit the global temperature increase to 1.5 °C compared to pre-industrial level. According to the United Nations Environment Programme (UNEP), "to stay within the 2 °C limit, global carbon neutrality will need to be achieved sometime between 2055 and 2070" (UNEP, 2014, p. XV). Having already emitted around 1 900 Gt since the 19th century, the Intergovernmental Panel on Climate Change (IPCC) estimated that the world has used more than 65 percent of the carbon dioxide budget allowing to stay within the 2°C limit. Meeting this target will therefore imply a big effort that is likely to have an important impact on the different economies around the world and in particular on their energy sectors.

Indonesia is at the nexus of the climate change problematic being on one hand, one of the most exposed countries to the consequences of global warming and on the other hand, endowed with large natural resources (such as fossil fuels and primary forests) that have an impact on the whole Greenhouse Gases (GHG) emissions balance. LULUCF (Land Use, Land Use Change and Forestry) is currently the highest contributor to the national emission mix (up to 80%) but the energy sector is projected to have the fastest growing emissions. Whereas the Indonesia development is the main driver of emissions increase, the Indonesian government is fully aware of the climate threat. It has adopted a low carbon growth path defined in the National Action Plan on Reducing GHG Emissions known as RAN-GRK (Presiden Republik Indonesia, 2010). This plan aims at stabilizing the carbon intensity of the economy and therefore at reducing GHG emissions with respect to a business-as-usual (BAU) scenario. The Indonesian Intended National Determined Contribution (INDC) which has been submitted to the UNFCCC is based on this National Action Plan and provides targets until 2030. This plan aims at reaching at least a 29% GHG emissions reduction with respect to the BAU by 2020 which amounts to an annual reduction of 1.189 Gt CO_2e by this date. This emissions target reduction could be brought to 41% if Indonesia benefits from international support.

Measuring the impact of energy transition on the economy is a highly challenging task. It requires the assistance of quantitative modelling tools. Substantial modification in the energy production structure does not affect only the production of energy itself. It has also an impact on the overall economy through different channels. One of them is the link between economic sectors. Each economic sector has a specific feature in terms of energy and material use, capital and labor intensity or exposition to international competition. They are therefore likely be affected very differently by the energy transition. Heterogeneity could also be found between regions. This is one important element to take into account when evaluating the economic costs and benefits of energy transition. Another channel is the effects on prices which in return define substitution mechanisms between energy commodities, capital and energy, but also the international competitiveness of the economy.

Economic modelling tools such the ThreeME (Multi-sectors Macroeconomic Model for the Evaluation of Environmental and Energy policy) model can be used as a support to the definition of policies related the energy transition for several reasons:

- It provides a quantitative evaluation of the impact of specific policy measures related to energy transition (such as the development of renewable energy, a reform about the taxation on energy). In particular, it measures the impact in terms of employment, investment, production, value-added, prices at the aggregate, sectorial and regional level.
- ThreeME can help establishing a business-as-usual (baseline) scenario, based on detailed sectoral data and in line with the national development priorities.
- These analyses can serve as a bases for dialogue between the parties involved in the decision making (ministries, provinces, etc.).

As an illustration of a typical application of ThreeME that can be used as policy support, this report provides the simulation results of two scenarios regarding the electricity production mix (see section 4). The first one is based on the assumptions published in the *Rencana Usaha Penyediaan Tenaga Listrik 2016-2025* (RUPTL). Largely based on investments in coal power plants until 2020, this scenario shows a clear reorientation toward the development of Renewable Energy Sources (RES) after this date. The second scenario follows the hypotheses of the Deep Decarbonisation Pathways Project (DDPP) and is more ambitious in terms of development of RES both regarding the implementation timing and the magnitude. While the environmental impact is quite different between the two scenarios, we find that the global economic effect remains quite similar and rather small compared to the baseline scenario. It seems however that the development of the RES has a slightly more positive effect in terms of employment and value added compared to fossil fuel based electricity production. This result advocates for national initiatives aiming to invest in the decarbonization of the economy.

1.1 The technical cooperation between BAPPENAS-AFD-OFCE-TNO

BAPPENAS (Ministry of National Development Planning) is the ministry of the Government of Indonesia in charge is the national development planning matters. With the relevant ministries, BAPPENAS is responsible for translating the mitigation strategies into action plans for individual sectors. BAPPENAS is also working with provinces in developing action plans at the provincial level. BAPPENAS thus faces challenges in the implementation of the RAN-GRK because it is very difficult to anticipate the implications of the various mitigation options in terms of development, socio-economic aspects, natural resources implications such as forestry conservation, etc. and therefore to identify options that contribute both to sustainable development and to the reduction of emissions.

AFD is a public utility company and a specialized financial institution. It is part of France's official public development aid scheme, further to a mission entrusted to it by the French Ministry of Foreign and European Affairs and the French Ministry of the Economy, Finance and Employment. Its mission contributes towards the Sustainable Development Goals (SDGs), financing growth and preserving global public goods. Valuing its competencies and experience in the field of low carbon growth, AFD has implemented fruitful program to support the development of low carbon and resilient growth strategies through macroeconomic modelling work in countries such as Mexico and South Africa, and support here a similar partnership with the Government of Indonesia.

AFD started its operations in Indonesia in 2007 with a mandate focusing on the fight against climate change. Through its first years of activity, AFD extended loans to the Government of Indonesia and to a local bank for a total of 1 000 MUSD to promote the development of renewable energy and energy efficiency projects and support the Government of Indonesia's strategy to fight against climate change. In 2011, AFD and the Department for International Development ("DFID") UK launched a joint initiative to promote investments in low carbon development in Indonesia, which comprised a low carbon growth planning component.

In this context, BAPPENAS, and in particular its Office of Deputy Minister of Maritime and Natural Resources c.q. Directorate for Energy Resources, Mineral, and Mining, and AFD agreed to work together on a program aiming at strengthening the planning capacity of BAPPENAS so as to inform policy-making process related to the promotion of low-carbon growth path in Indonesia. This program has been financed through AFD/DFID joint initiative in Indonesia.

This technical assistance program has four main components:

- Installing within BAPPENAS the Multi-sectors Macroeconomic Model for the Evaluation of Environmental and Energy policy (ThreeME) model adapted to the Indonesian context
- A training program to develop the skills of BAPPENAS in modeling
- A component of international dialogue on energy transition and climate change issues by organizing seminars in France and in Indonesia bringing together high-level international experts and stakeholders.
- A dissemination of the program with the support of the CEDS.

1.2 Structure of the report

The present report is divided in 5 sections. Section 2 describes the Indonesian context and national policy on energy and climate change. It also presents elements to understand the current Indonesian economic context as well as the recently approved reforms, in particular the energy reform. Section 3 provides a short description of the ThreeME model and how it was adapted to Indonesia. Section 4 presents the simulation results of two scenarios regarding the electricity production mix: (1) the 2016-2025 RUPTL scenario is largely based on investments in coal power plant at least until 2020, investments in Renewable Energy Sources (RES) being mainly made after this date; (2) the DDPP scenario is more ambitious regarding the development of RES. Section 5 concludes.

2 INDONESIAN CONTEXT AND NATIONAL POLICY ON ENERGY AND CLIMATE CHANGE

2.1 The Planning of the economic development

Despite having moved from a centrally controlled and planned economy system to a market economy in the end of the eighties, the Indonesian Government still has a central role in the design of the economic development strategy of the country. The BAPPENAS formulates action plans that aims to fulfill development goals and ensures the coordination of the different ministries and administration in the accomplishment of these objectives. This action is based on the publication of national development plans which can differ regarding their length by providing a different set of goals for different dates. The *Rencana Pembangunan Jangka Menengah Nasional* (RPJMN), or National Medium-Term Development Plan is the cornerstone of the planning approach of the economic development strategy for the Republic of Indonesia since it translates the mandate of the executive power (the elected president and its government) into concrete, tangible measures and targets defined for the different sectors of the economy. The last RPJMN, which has been issued in December 2014, expresses the political program of the current president of Indonesia Joko Widodo. The main challenges that constitute this program are the following:

- Fighting against the rising of inequalities and extreme poverty
- Enhancing sustainable natural resource management and increase resilience to climate change consequences
- Ensuring social justice for all citizen
- Spurring public infrastructures

The long-term planning of the economy is relying on the ***Rencana Pembangunan Jangka Panjang Nasional*** (RPJPN), or National Long-Term Development Plan. This document sketches the next twenty years' development. The current RPJPN, which covers the period 2005-2025, sets the objectives that Indonesia is willing to achieve in order to improve its development. This Plan is broadly based on three pillars:

- Seek to be a developed and self-reliant country which guarantees the widest possible equality
- Ensure justice and democracy by promoting rules that are fair, consistent, non-discriminatory and serves the public interest.
- Encourage development which respects all the component of the society and spur peace among all the people as their integrity.

The RPJPN has set numerous goals that would make Indonesia one of the major economies in the world by the end of 2025 with an objective of a GDP between USD 4 and 4.5 trillion. Beside this growth goal, Indonesia seeks to achieve an income per capita equivalent to middle income countries (around USD 15 000 per capita), having an unemployment and a poverty level below 5%.

In articulation with the RPJPN, four national medium-term development plans (RPJMN) are issued every 5 years at the beginning of a new presidential mandate. The RPJMN 2015-2019 takes in the Jokowi administration priorities and focuses on the investment in infrastructures. The government plans to initiate infrastructure projects worth a total of Rp 4.5 quadrillion ($345 billion).

Besides the National Development Planning and through an inter-administration work done under the precedent legislature, the Government has written a special report untitled "Masterplan: Acceleration and expansion of Indonesia Economic Development 2011-2025" (Coordinating Ministry For Economic Affairs, 2011). With respect to the RPJPN, this masterplan emphasizes the articulation between the geographical dimension and the economic activities. It completes the RPJPN by identifying six different regions as economic corridors which can become growth centers specialized in certain activities regarding their comparative local advantages.

The design of long-term development strategies combined with the central and changing role of energy sectors in the economic development of Indonesia call for the use of relevant economic tools. The concerns around the economic specialization by regions as well as the changes in the energy activities are two integrated dimensions that are essential in addressing questions about the economic impacts of public policies.

2.2 Energy and climate change policy

In the recent years, several legislations have been enacted to tackle the challenges regarding energy supply and the Indonesian GHG emissions reduction pledges required as a contribution to the international community in the fight against climate change. This section exposes the main laws and regulation that pave the way toward a more efficient and sustainable energy production system.

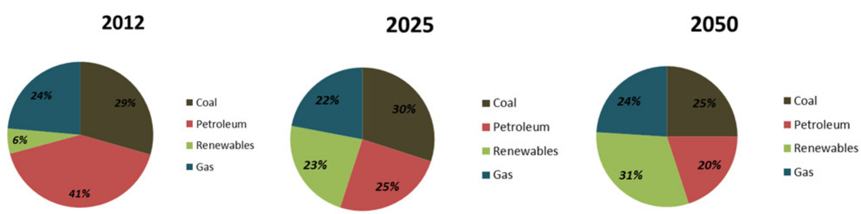
2.2.1 Energy regulation

Besides the RPJMN, which is issued every five years, several legislations have been put in place during the past decade to secure the energy supply and define the structure of the energy system. *The Energy Law No 30/2007* has created the National Energy Council which gathers relevant members of the government, representative of the industries and consumers and experts on environmental and energy issues. Its role is to:

- Formulate the National Energy Policy (KEN)
- Establish the National Energy Plan (RUEN)
- Supervise the implementation of cross sectoral energy policies
- Determine measures in response to conditions of energy crisis and emergency
- Regulate type, amount, time and location of energy buffer stock (strategic reserves)

The National Energy Policy aims to ensure the energy sovereignty and security of Indonesia. Therefore, energy resources are considered as strategic national development assets and not as commodities, as it used to be seen in previous decades. This change of paradigm, associated to a more collegial steering of the energy use aims at a more patrimonial approach in the management of the energy assets. Figure 7 shows the different energy share targets in the total energy mix by 2025 and 2050.

Figure 7. Energy mixes targets from the national energy policy



Source: National Energy Council (DEN)

Indonesia is expected to experience an average annual growth for its domestic electricity demand of 8.4 % per year until 2022. In order to satisfy this demand, Indonesia has launched in 2006 the fast track program[1] for building massive power generation capacity. The first phase was accomplished in 2014 and consisted in the construction of 37 coal fired power plants generating altogether 10 000 MW extra capacity. The second phase of the fast track program has been launched in 2010[2] with the goal to install 93 power plant projects and create around 10 000 MW of additional generating capacity. In 2015, the program has fixed objectives for the composition of

1 Presidential of the Republic of Indonesia Decrees No. 71 of the 5/07/2006.
2 President of Republic of Indonesia No.4/2010.

the energy mix. Whereas in 2010 the composition of the primary energy mix of this program was clearly orientated toward renewable energy with respective shares of 11% for hydropower, 34% for geothermal, 40% for coal and 15% for Gas, amendments[3] have sensibly changed the content and the objectives of the program. The construction of some gas plants has been canceled, many geothermal plants delayed and very large coal plants have been added to the program accounting at the end for almost 18 000 MW of power generation. The completion of the project has been as well delayed with an update of the completion target from 2014 to 2020, if not beyond.

A new National Energy Policy (NEP2014) which replaces the 2007 National Energy Policy was adopted by the parliament and signed on the 17 October 2014 as a Government Regulation[4]. It introduces several changes that reorients the national strategy on the energy issue, notably by reestablishing Indonesia's energy independence as a priority through rebalancing energy resources from export to the domestic market. It slightly updates the targets on the energy mix by 2025 with regards to the previous NEP. This new target on the energy mix is translated into a 30% share for coal, 22% for oil, 23% for the renewable resources and 25% natural gas[5]. Finally, NEP2014 aims at achieving a complete electrification of the country by 2020 with a full access to energy for all Indonesians.

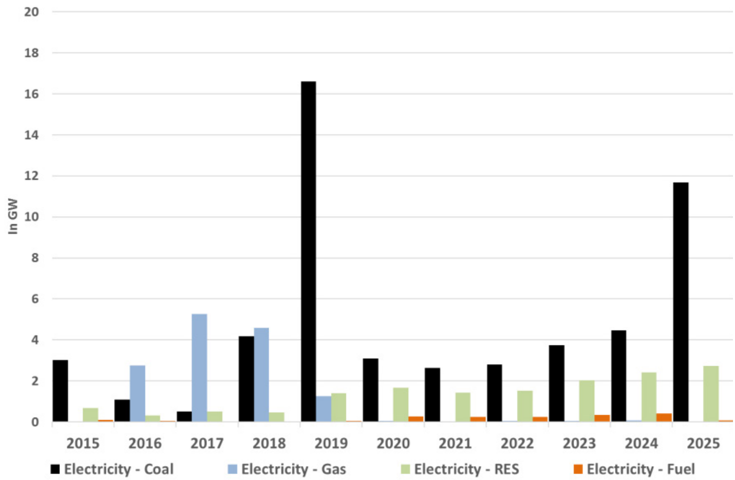
In order to satisfy a rapidly growing demand for electricity, a new program of construction of supplementary power generation capacities has been announced by the president Joko Widodo in April 2015. This ambitious plan aims at building 35 000 MW of supplementary capacities by 2019. About 40% of these new capacities are going to be constructed by private investors, whereas the remaining will come from PLN, the national electricity production company. This plan is the first component of a larger scale ten-years investment plan in power generation capacities (RUPTL), in order to reach the 99,7% of electrification rate by 2020. This 35 000 MW plan was integrated to the 2015-2024 RUPTL power supply business plan, which was forecasting the installment of 70.4 GW additional generation capacities, coal-fired plants being the main technology retained with 42.1 GW (see Figure 8 and Figure 9).

3 President of the Republic of Indonesia Decree No. 48/2011 and revised by MoEMR Instruction No.1/2012.

4 Government Regulation No. 79/2014.

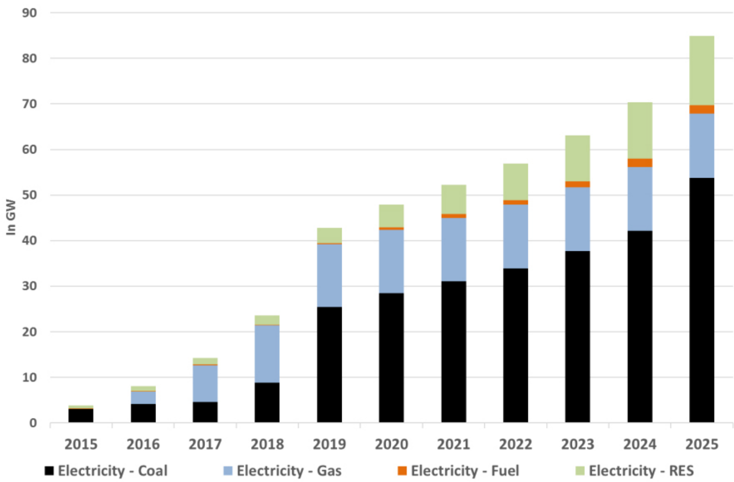
5 To be reminded that the energy mix shares were initially set in the 2007 version at 30% for coal, 22% for gas, 23% for renewables and 25% for oil.

Figure 8. Annually installed electricity generation capacities in the previous RUPTL



Source: PLN, RUPTL (2015-2024), authors' calculations

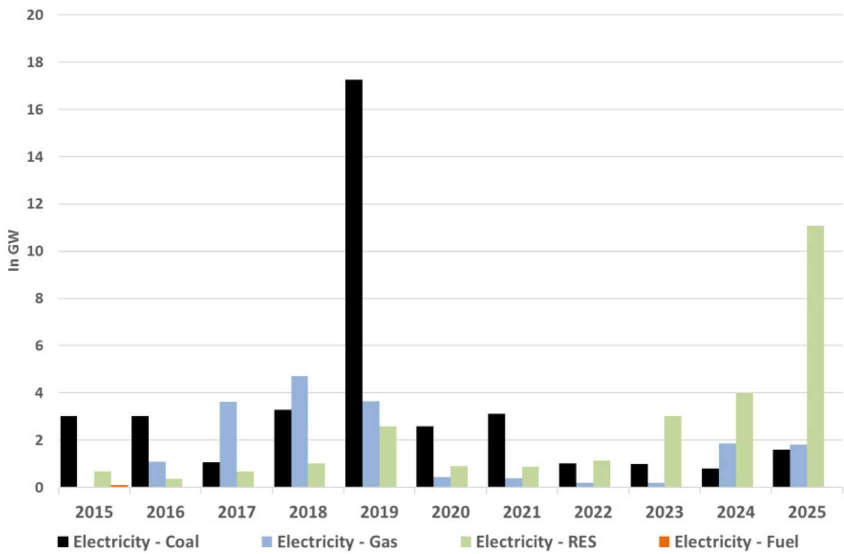
Figure 9. Cumulated capacities installed within the previous RUPTL Plan



Source: PLN, RUPTL (2015-2024), authors' calculations

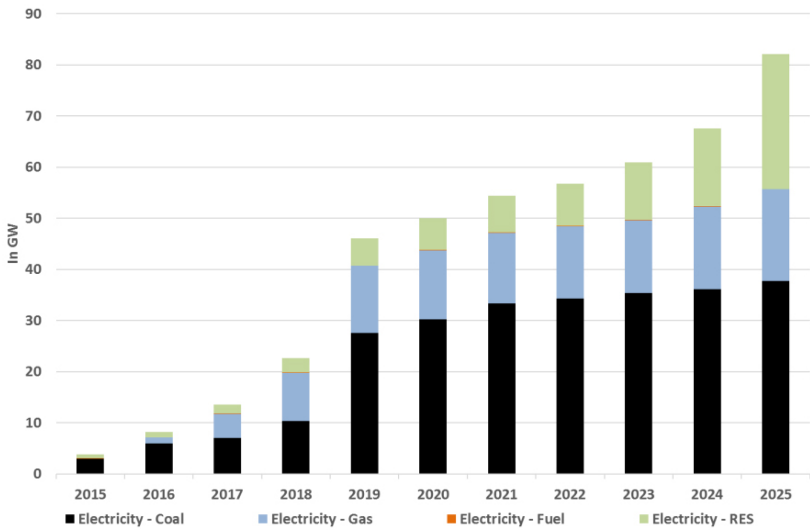
The major role that would play coal-based power plants, and the absence of sufficient RES capacities led the Ministry of Energy to revoke this version of the RUPTL which has been considered incompatible with the NEP2014's energy mix targets. In order to comply with this decision, PLN had to propose a reorientation of its business investment plan which would be compatible with the NEP2014. Hence the RUPTL 2016-2025 published in June 2016 proposes a new investment plan in generating capacities that takes into account the requirement of increasing the RES capacities (see Figure 10 and Figure 11). Whereas the new RUPTL confirms the importance of coal and gas based investments for the phase going until 2020, a reorientation toward more RES is clearly observed from 2023, bringing the 2025's share in the cumulated new capacities of RES from 17.9% in RUPTL 2015-2024 to 32.1% in RUPTL 2016-2025.

Figure 10. Annually installed electricity generation capacities in the revised RUPTL



Source: PLN, RUPTL (2016-2025), authors' calculations

Figure 11. Cumulated capacities installed within the revised RUPTL Plan



Source: PLN, RUPTL (2016-2025), authors' calculations

2.2.2 Climate regulation

The National Action Plan for Greenhouse Gas Reduction (RAN-GRK)[6] translates into legal terms the pledge of Indonesia made during the 2009 G20 in Pittsburgh to cut off its GHG emissions from 26% in 2020 compared to the BAU level[7]. With international support, this pledge would be increased to 41% (BAPPENAS, 2013). These objectives have been translated into emission reduction targets for different sectors, forestry and peatland being the main contributors to the global effort with 80 to 84% of the total emission reduction (see Table 2).

The *Rencana Aksi Daerah penurunan emisi Gas Rumah Kaca (RAD-GRK)* or Local Action Plan for GHG Emission Reduction constitutes the translation of the roadmaps at Provinces level. As requested in the September 2011 Presidential Decree, the RAN-GRK has been translated into an integrated, concrete, measurable and practical action plan for the period between 2010 and 2020, both at national and provincial levels. The RAN-GRK, which have been requested to all 33 provinces, is made according to the following steps:

6 Presidential Regulation No°61/2011.
7 The BAU scenario starting in 2010 is based on the historical trend of emissions (2000-2010), projected increases in energy sectors and the absence of mitigations actions.

- Calculation of GHG inventory and of a provincial multi-sectoral BAU baseline
- Identification and selection of mitigation actions
- Development of mitigation scenarios according to selected and prioritized GHG mitigation actions in line with their local development priorities and plans
- Identify the key stakeholders/institutions and financial resources
- Local governments can also encourage the involvement of public and private companies by raising awareness of the climate change impacts and facilitating Private Public Partnerships (PPPs) (among other options)

Table 2. Possible distribution and target of emission reduction

Sector	Emission Reduction (Giga ton CO2e)		Action Plan	Institution
	26%	+15%		
Forestry and Peatland	0.672	0.367	Forest and land fire control, water and hydrologi management on peatland, forest and land rehabilitation, illegal logging control, avoiding deforestation, community development	MoFr, MoPW, MoA, MoE
Waste	0.048	0.030	Sanitary landfill development, 3 R and sewerage system in urban areas	MoPW, Moe
Agriculture	0.008	0.003	Introduction of low methane rice variety, irrigation efficiency, organic fertillizer utilization	MoA, MoPW, Moe
Industry	0.001	0.004	Energy efficiency, renewable energy development	MoI
Energy and Transportation	0.038	0.018	Fuel efficiency improvement, mass transportation, demand side management, renewable energy, energy efficiency	MoT, MoEnergy, MoPW, MoF
	0.767	0.422		

Source: Indonesia's National Mitigation Actions: Paving the Way towards NAMAs (discussion document), BAPPENAS 2011.

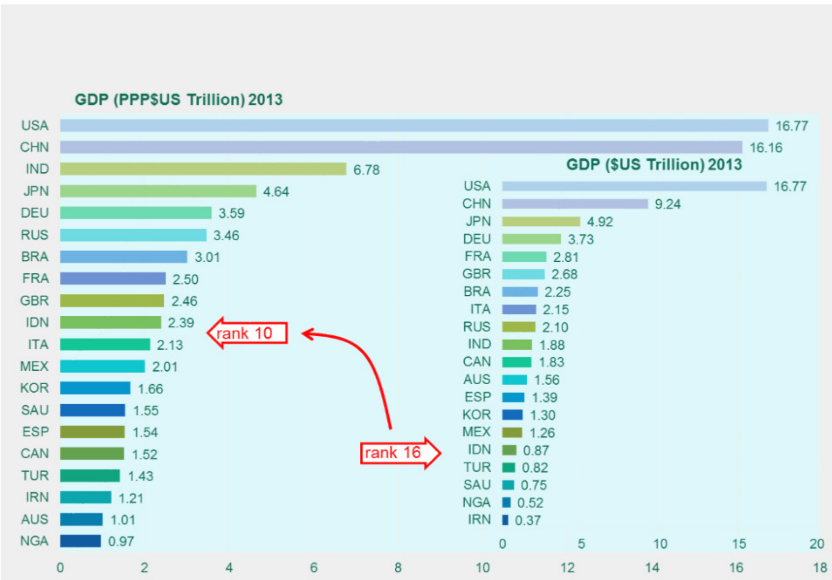
The Indonesian INDC has been submitted the 3 September 2015 and provides the same targets from the RAN-GRK for 2020 and 29% GHG emissions reduction by 2030. Since this contribution has mainly been built on the RAN-GRK, it is not surprising that there are no substantial changes.

2.3 Macroeconomic context

Indonesia is at a turning point of its economic development. After having experienced a growth strategy based on the exports of the natural resources which have led to increase the GDP per capita from 79 US$ in 1968 to 3475 constant US$ in 2013, the 4th largest country in the world in terms of population, with 240 million inhabitants has to find new growth drivers in order to solve several key issues: the middle-income trap (The World Bank Office Jakarta, 2014), the oil's exhaustion (which has been at the core of its development so far), the fight against the poverty and last but not least, the decarbonization of its economy and the reduction of environmental damages. To overcome certain of these challenges, Indonesia benefits from an important potential in renewable energies especially regarding the geothermic and its biomass valorization. Despite favoring the coal exploitation as main energy source in the recent years, the environmental pressure and the strong increase in the related CO_2 emissions may change the long-term policy regarding the coal's place in the economy.

Although some of these challenges may be seen as antagonist, there is a strong potential in Indonesia and sufficient policy leeway for the government to reorient the growth toward a more sustainable and inclusive development. Indonesia is a planned economy that has a strong administration and control on the key sectors of the economy. The public administration has issued several reports as the MP3EI (Coordinating Ministry For Economic Affairs, 2011) indicating the ambition and the development strategy for the next decades. In particular, they give insights on the path that Indonesia is willing to undertake in order to escape from the middle-income trap, and even to reach an ambitious GDP per capita target of 12 000 US$ in 2025.

Figure 12. World biggest economies



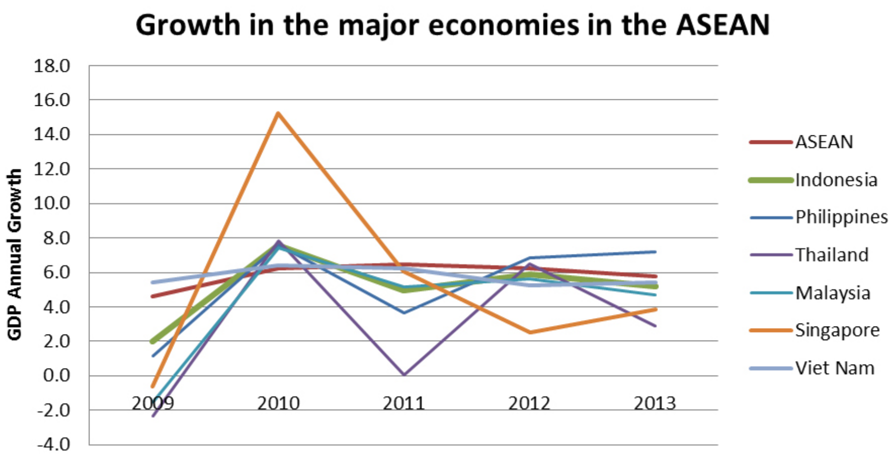
Source: World Bank

Figure 12 above shows that Indonesia is part of the biggest economies in the world. Member of the G20, Indonesia was ranked 13th in 2013 regarding its level of GDP. Evaluated in purchasing power parity (PPP), this rank is even higher: 10th.

2.3.1 Indonesia economy: a pillar of the Southeast Asia region

South-East Asia is one of the most dynamic regions in the world. Over the last decade, the growth trend in the region kept rising around 6% and has quickly recovered from the 2007 financial crisis (see Figure 13 below).

Figure 13. Growth rates in the ASEAN major economies (in %)



Source: ASEAN

Indonesia is also a founder member of the Association of Southeast Asian Nations (ASEAN) which has been with other countries such that Thailand, Malaysia, the Philippines, Singapore formed in 1967 and includes today 10 countries. Being a free trade area since 1992, the ASEAN members seek to move towards more integration by establishing a unified common market. This has been concretized by the introduction of the ASEAN Economic Community (AEC) the first January 2016. This process is expected to spur the market opportunities but some observers points out some difficulties, notably the strong economic heterogeneity remaining between the member countries. This could prevent the ASEAN members to really take benefit from this unification.

The evolutions on the South-East Asian regional energy market push the different ASEAN member countries to shift their supply in energy goods. Since 1990, the region's energy demand has expanded two-and-half-times. The International Energy Agency (IEA) forecasts that energy demand in these countries will increase by over 80% by

2035 (OECD & Secretariat, 2013) which would require massive investment in energy production capacities. Due to its affordability and its abundance, coal is seen as the pivot fuel for electricity generation for the development of South-East Asia regions. Due to its endowment in natural resources, Indonesia is going to be at the nexus of the Southeast Asia Energy market.

The Indonesian economic recovery after the Indonesian financial crisis has been spectacular. Between 2001 and 2012, GDP has almost doubled from US$ 580 billion to US$ 1.1 trillion (thanks to an annual growth rate of 5.5% on average) while Indonesia succeeds in establishing political and economic stability after the Suharto's era.

The 2000's economic slowdown compared to the years before the 1998 financial crisis (on average a 10 % annual growth rate of GDP) indicates more a change in the determinants of this growth than a decline of the economic development. Before the crisis, investments were the main growth drivers but the uprising of a new middle-income class in Indonesia triggered the activity by strengthening the domestic final demand. However, this growth has not been as labor-intensive as it used to be in the 1980's and it is more about a labor transfer from agriculture to services sectors that comes along with the evolution of the structure of the economy in the past decade.

Despite having one of the highest rates of investment in the region (mainly driven by the construction sector), the lack of infrastructures prevents the economic growth to reach its full potential and it has been estimated that this underinvestment costs up to 0.5 point of GDP growth each year (World Bank, 2013).

2.4 Energy outlook

2.4.1 Energy resources

Fossil fuel resources have been at the center of the economic development of Indonesia which used to be a member of OPEC until 2008. Indonesia witnessed its peak in oil production in 1981 with 1.7 million of barrels per day but has then experienced a constant decline to finally reach a production of less than one million barrels per day in 2013. On the other hand, the domestic consumption has constantly increased from 455 000 barrels per day in 1981 to more than 1.6 million in 2013 which has led Indonesia to become a net oil importer since 2008. This situation seems to be irreversible and according to the data of Energy Information Agency (EIA), the country faces only 12 years of oil consumption at the current level before exhausting all of its proven reserves. According to the EIA, Indonesia was the 11th world producer in 2012 and the 7th gas exporting country with 1.365 Billion cubic feet[8]. With proven reserves of 104 trillion

8 Indonesia is currently the 4th world exporter of LNG gas after accounting for more than one third of global LGN exports throughout the 1990's when Indonesia used to be 1st world LNG exporter (Source: U.S Energy Information Administration)

cubic feet (20% percent of the Asia and Oceania's reserves), it can become a key player in the gas supply for the next decades.

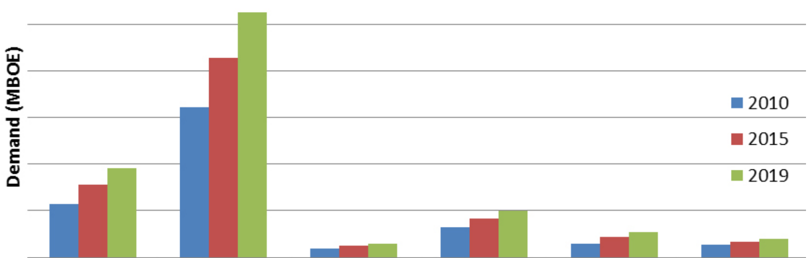
Nonetheless, the abundance of coal in Indonesia can also curb the gas development as a source of energy for domestic uses. Being in 2012 the 5th World producer and the 1st exporter in the world, Indonesia is more and more reorienting its growing production toward the domestic market, especially for the purpose of electricity generation.

Besides being favorably endowed with large fossil fuels reserves, Indonesia also benefits from an important potential for renewable energies resources which remains underused. For instance, in 2010, only 5.5% of the hydropower and 4.3% of geothermal potentials were exploited. Solar, Wind and Biomass for their part are quasi-inexistent in the energy production despite a huge potential of thousands of Gigawatt equivalent (GWe)[9].

2.4.2 Energy demand

Indonesia's energy sector is complex, with widely varying energy demands throughout an archipelago of 17 000 islands, of which about 6 000 are inhabited at different levels of population density and feature diverse economic activities. Indonesia's energy demand is projected to grow by 7-8% per year, higher than the country's projected economic growth of 4.6-6.5%. Appropriate energy policy and infrastructure delivery will be required to ensure the extensive expansion of reliable energy to support consistent economic growth.

Figure 14. Energy Demand by Region (MBOE)



	Sumatera	Jawa	Bali & Nusa Tenggara	Kalimantan	Sulawesi	Maluku & Papua
2010	115.14671	321.64338	18.55490	65.14398	29.99191	27.75440
2015	154.90890	427.57305	24.88109	82.90750	43.94124	33.99968
2019	191.03500	526.13638	29.96261	98.89302	54.35670	39.86858

9 For instance, the potential for solar power is estimated to reach 1.200 GWe whereas the generator capacity of PLN was 34.5 GW in 2011 (source: National Energy Council).

Based on BAPPENAS study in 201410, the national final energy demand is projected at 768 211.46 MBOE in 2015 and 940 252.29 MBOE in 2019. The largest demand would be in Java which amount to 427°573.05 MBOE in 2015 and 526 136.38 MBOE in 2019, while smallest demand would be in Bali and Nusa Tenggara, reaching 24 881.09 MBOE in 2015 and 29 962.61 MBOE in 2019 (see Figure 14). In average, the energy demand is expected to increase by 27% in five years. The highest growth would be in Sulawesi at 35% and lowest in Kalimantan with 17%. This projection uses the LEAP model and uses 2011 as base year and projects energy demand and supply up to 2025. The total demand consists of six sectors, namely household, commercial, industry, transportation, other, and non-energy.

2.4.3 Reorientation of Energy Management

As an energy exporter, Indonesia has long benefited from its abundant energy resources. Though no longer a net oil exporter, Indonesia is now the biggest coal exporter in the world even though it only hold 2.4% of the world's reserves. The country has also become a gas exporting country, beginning with the first LNG shipment in 1979, with exports now reaching 45% of total national gas production.

However, since the economy continues to grow, increasing domestic demand for energy requires a paradigm change in the country's national energy management. There is a need to shift from the previous view, of energy as a commodity to sell for foreign exchange, to a new view of energy resources as natural capital to be used primarily for its own economic development. This means, instead of exporting the bulk of energy resources, Indonesia is going to use them as raw materials for national industry, services, and homes in ways that will add to the nation's productive capacity and help ensure energy security. One important policy to realize that purpose is by setting a domestic market obligation (DMO) for coal and natural gas production. The RPJMN 2015-2019 has set DMO by 60% for coal and 64% for natural gas.

Until now, Indonesia's dependence on oil, and therefore on energy imports, is still very high. On the other hand, there is a huge, untapped renewable energy potential of 300-800 gigawatts. However, the utilization of these renewable energy resources is still relatively low. Over the course of more than 50 years of energy development, the utilization of renewables has only reached 6 to 7% of the total energy supply. Some impediments that still hamper the rapid development and an expanded utilization of renewable energy resources are land use conflicts, burdensome permit processes, and difficulties in land acquisition. Realizing the importance of tapping renewable energy resources and resolving the problems, the Government of Indonesia has established a separate Directorate General of Renewable Energy and Energy Conservation under

10 LEAP Model Development: The Projections of National and Provincial Energy Supply and Demand, BAPPENAS 2014

MEMR in 2010, which has provided a major thrust for renewable energy development, although the unit's current capacity is limited.

3 ThreeME FOR INDONESIA

3.1 Main characteristics of ThreeME

ThreeME (Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy) is a country-generic and open source model developed since 2008 by the ADEME (French Environment and Energy Management Agency), the OFCE (French Economic Observatory) and TNO (Netherlands Organization for Applied Scientific Research). Initially developed to support the energy/environment/climate debate in France, ThreeME is now been applied to other national contexts such as Mexico and the Netherlands. This section provides a short non-technical description of ThreeME. A more technical presentation is given in APPENDIX B: Main equations of ThreeME[11].

The model is specially designed to evaluate the medium and long term impact of environmental and energy policies at the macroeconomic and sector levels. For this, ThreeME combines several important features:

- Its **sectorial disaggregation** allows analysis of the effect of transfer of activities from one sector to another in particular in terms of employment, investment, energy consumption or trade balance.
- The **energy disaggregation** allows analysis of the energy behavior of economic agents. Sectors can arbitrate between different energy investments: substitution between capital and energy when the relative energy price increases; substitution between energy sources. Consumers can substitute between energy sources, between transports or between goods.
- ThreeME is a **CGEM** (Computable General Equilibrium Model). It therefore takes into account the interaction and feedbacks between supply and demand (see Figure 15). The demand (consumption, investment) defines the supply (production). The supply defines in return the demand through the incomes generated by the production factors (labor, capital, etc.). Compared to bottom-up energy models such as MARKAL or LEAP, ThreeME goes beyond the mere description of the sectoral/technological dimension by linking those with the global economic system.
- ThreeME is a **neo-Keynesian model**. Compared to standard Walrasian-type CGEM, prices do not clear instantaneously supply and demand. Instead the model is dynamic and prices and quantities adjust slowly. This has the advantage to allow for situations of disequilibrium between supply and demand (in particular the presence of involuntary unemployment). This framework is better suited for

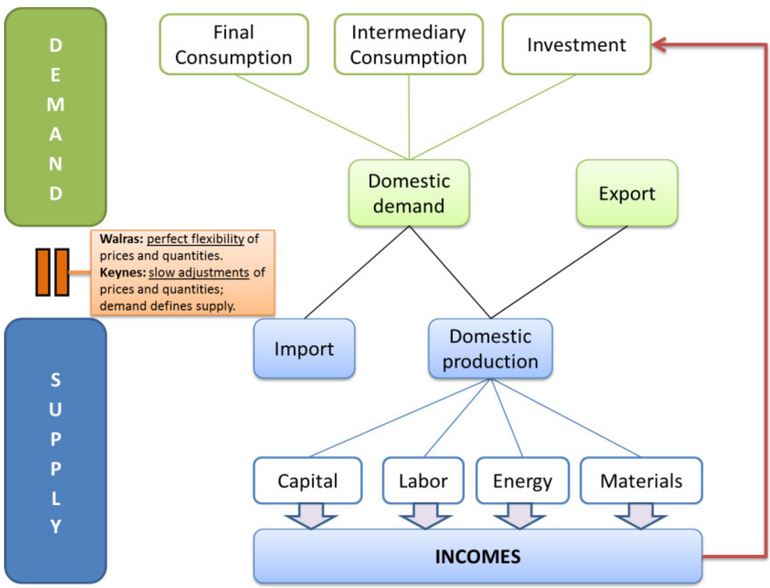
11 For full description of ThreeME see Callonnec, Landa, Malliet, Reynès, & Tamsamani (2013).

policy purposes because it provides information regarding the transition phase of a particular policy (not only about the long term).

Being a neo-keynesian CGEM, ThreeME takes into account:

- *General equilibrium effects:* supply influences demand and vice versa
- *Direct and indirect effects of the energy transition:* the direct effects are the impacts for the energy, building, transport sectors whereas the indirect effects (or rebound effects) are the impacts for the rest of the economy (in particular the other sectors, the government, households).
- *A double dividend (environmental and economic) is possible* through the improvement of the trade balance, the reduction of fiscal distortion (e.g. reduction of the taxation of labor and capital financed by a tax on carbon) and the positive macroeconomic effects due to the demand increase (positive multiplier).

Figure 15. Architecture of a CGEM



ThreeME can be used to simulate the economic impact of various policies. Examples of scenario simulations related to energy and climate policies include:

- A carbon tax
- A phasing out of energy subsidies
- A tax credit in favor of energy renovation in the building sector
- Subsidies in favor of green investments in the buildings, automotive and public transport sectors
- The impact of transitions in the energy sectors (such as an increase of renewables).

3.2 Main characteristics of the Indonesian version of ThreeME

The Indonesian version of the ThreeME model follows the generic architecture also used for other country versions. However, in the Indonesian version, the model can be run at the national level but also at the regional level. The database is disaggregated into five regions: Sumatra, Java, Kalimantan, Sulawesi and East-Indonesia (see Figure 16 below)

Figure 16. Regional disaggregation of Indonesia

To get a regional and sectorial disaggregation of national account data, we used the IRSAM database (Resosudarmo, Nurdianto, & Hartono, 2009) developed within the *"Analysing Pathways to Sustainability in Indonesia"* project[12] by CEDS (Center for Economics and Development Studies, University of Padjadjaran). This database, which considers 35 sectors and 5 regions, has been further disaggregated in order to explicitly represent each energy production activity individually. Indeed, in the original IRSAM database, the electricity sector is grouped with the water and gas sectors. Moreover, the electricity sector is not disaggregated by technology. Several steps consisting in disaggregating and re-aggregating data was necessary to reach the final database used in ThreeME. At the end the model has 37 commodities (including 4 energy sources: Coal, Refined Oil, Gas & Electricity) and 44 sectors (see Table 3 below). The energy activities are divided into 11 sectors: Coal Fuel, Oil Fuel, Gas fuel and 8 electricity sectors.

Table 3. Sectoral disaggregation in the ThreeME model

Number	Activity	Abreviation	Number	Activity	Abreviation
1	Paddy	APAD	23	Other Industries	ADW
2	Other Foodcrops	AOF	24	Construction	ACON
3	Estatecrops	AEC	25	Trade	ATR
4	Livestock	ALS	26	Hotel and Restaurant	AHR
5	Forestry	AFOR	27	Land Transportation	ALTR
6	Fishery	AFIS	28	Water Transportation	AWTR
7	Oil Palm	AMIN	29	Air Transportation	AATR
8	Non-Energy Mining	AOP	30	Communications	ACOM
9	Fish Processing	AFIP	31	Finance	AFIN
10	Food and Drink Processing	AFDP	32	Public Services	APS
11	Drinking water	ATEX	33	Other Services	AOS
12	Textiles	AFL	34	Petroleum fuel	APFU
13	Foot and Leather	AWP	35	Natural Gas (fuel)	ANG
14	Wood Processing	APP	36	Coal (fuel)	ACO
15	Pulp and Paper	ARP	37	Electricity - Coal	AECO
16	Rubber Processing	APECH	38	Electricity - Gas	AEGA
17	Petrochemical	ACEM	39	Electricity - Fuel	AEP
18	Cement	ABMET	40	Electricity - Hydro	AEH
19	Basic Metal	AMETP	41	Electricity - Geothermal	AEGE
20	Metal Processing	AEM	42	Electricity - Solar	AES
21	Electricity Machinery	ATE	43	Electricity - Wind	AEW
22	Transport Equipment	AOI	44	Electricity - Nuclear	AENU

Source: ThreeME-Indonesia

12 The Inter-Regional Social Accounting Matrix (IRSAM) database was built by Budy P. Resosudarmo, Djoni Hartono and Arief A. Yusuf for the "Analysing Pathways to Sustainability in Indonesia" collaborative project between Bappenas, USAID, CSIRO and the World Bank.

Electricity sector is disaggregated into 8 technologies: Coal-based power plant, fuel-based power plant, Gas-power plant, Hydrology, Geothermal, Wind, Solar and Nuclear. The evolution of the share of each technology is determined exogenously. This assumption is realistic for the electricity production sector, since the government delivers the authorization for installing power plants. Hence, the investment choices in electricity technologies sectors do not obey to the same market rules as the others economic activities. They are almost entirely determined by public policy. The parametrization of the electricity mix in the base year uses data from the Handbook of energy & economics statistics of Indonesia & the Outlook Energi Indonesia 2015 to determine the level of production in GWh in 2005 and 2013 by type of technology.

The modelling of the energy demand is detailed by type of economic agent and by type of energy (oil, coal, gas and electricity). This allows for a precise estimation of the variation in the domestic CO_2 emissions. In ThreeME, we consider only CO_2 emissions from the combustion of fossil fuels. The calculation of emission levels consists in multiplying the fossil energy demand by the corresponding emission coefficient. These coefficients are specific for each economic actor, each sector and each energy source depending on their carbon intensity. CO_2 emissions from the combustion of fossil fuels by sector and households are proportional to the quantity of energy consumed.

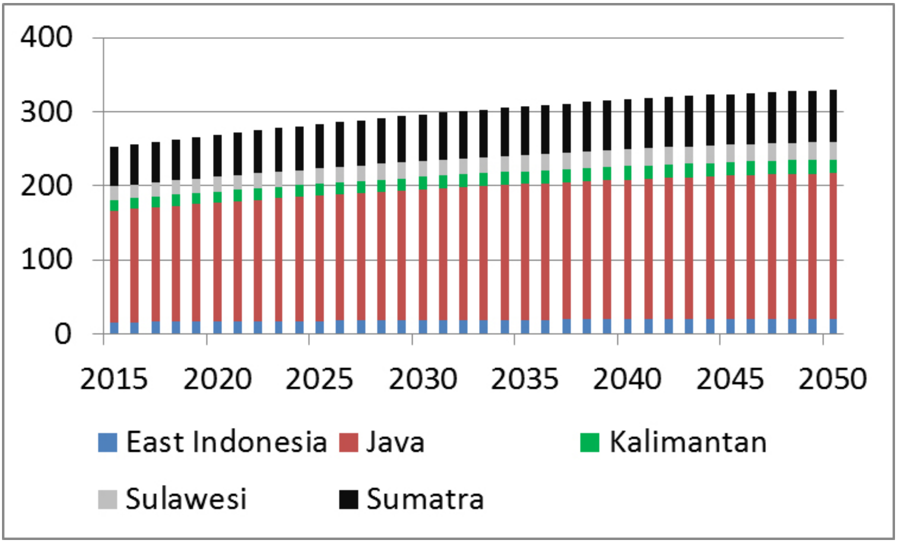
4 SIMULATION RESULTS

4.1 Baseline scenario

The baseline (reference or business-as-usual) scenario is the path the model predicts when all exogenous variables follow their "business-as-usual" (BAU) trend. The baseline scenario is meant to be a consistent vision of the future rather than a real forecast. It is the virtual scenario predicted by the model for a given trajectory of the exogenous variables. Although it excludes cyclical fluctuations, the idea is to reflect as much as possible the expected changes regarding key exogenous variables such as population, productivity gains, tax rates, elasticities, external demand. By definition, the baseline scenario always excludes the impact of any policy being studied since this can be seen as a shock compared to the reference scenario and is simulated as an alternative scenario (see section 4.2).

The impact of a new policy is measured as a difference from the baseline expressed as a percentage, the choice of the baseline scenario thus affects the results of the scenario simulated. Therefore, it is important to define a coherent vision of the future but this may prove a difficult task in terms of calibration. To achieve the construction of a realistic baseline scenario, we focus on obtaining projections for a few key macroeconomic variables, such as the real gross domestic product (GDP), population, the evolution of labor productivity, and the evolution of international energy prices.

Figure 17. Population projection in millions (2015-2050)



Source: Projection from UNEP (medium scenario).

Table 4. Macroeconomic indicator for RPJMN (2015-2019)

Indicators	2014	2015	2016	2017	2018	2019
GDP growth rate	5.1%	5.8%	6.6%	7.1%	7.5%	8.0%
Household consumption	5.2%	5.3%	5.5%	5.7%	5.8%	6.1%
Government consumption	2.4%	1.3%	1.6%	2.0%	2.3%	2.5%
Investments	4.9%	8.1%	9.3%	10.4%	11.2%	12.1%
Exports of Goods and Services	-0.7%	2.1%	7.6%	8.8%	11.0%	12.2%
Of wich Non-oil export	-1.0%	8.0%	9.9%	1.2%	1.4%	1.4%
Imports of Goods and Services	-3.6%	1.5%	6.8%	9.8%	12.5%	14.0%
Of which Non-oil import	-1.0%	6.1%	7.1%	1.0%	1.2%	1.2%
GDP share						
Primary sector	13.3%	13.2%	13.0%	12.8%	12.6%	12.3%
Secondary sector	20.7%	20.8%	21.0%	21.1%	21.3%	21.6%
Tertiary sector	66.0%	66.0%	66.0%	66.1%	66.1%	66.1%
Inflation	8.4%	5.0%	4.0%	4.0%	3.5%	3.5%
Primary balance of budget	-0.7%	-0.6%	-0.5%	-0.4%	-0.3%	0.0%
Surplus/deficit of the state budget	-2.0%	-1.9%	-1.8%	-1.6%	-1.4%	-1.0%
Tax revenue/GDP	11.5%	13.2%	14.2%	14.6%	15.2%	16.0%
Unemployment rate	5.9%	5.7%	5.4%	5.2%	4.9%	4.3%

Source: RPJMN from Table 4.2 (Main Targets Development) and Table 4.3 (Targets of growth and economic structure)

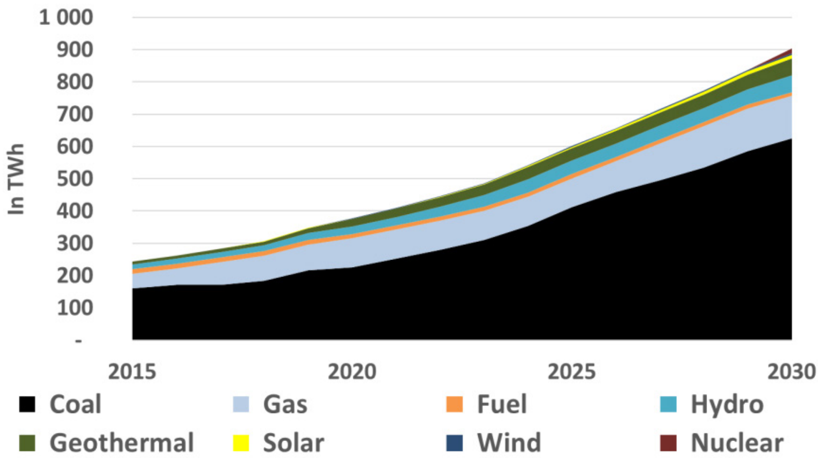
The baseline scenario is characterized by certain key underlying assumptions summarized below:

- Population projections by 2050 are taken from the United Nations, Department of Economics and Social Affairs, Population Division (see Figure 17).
- Macroeconomic indicators such as GDP growth, inflation, tax revenues follows the forecast of the RPJMN report (see Table 4).
- For the long-term trend of GDP, we make the assumption that the Indonesian labor productivity is converging to the one of the US. According to World Bank data for 2014, the Indonesian GDP per capital is 6.4 % of the one of the US. With the growth hypothesis of the RPJMN report, it reaches 8.2% in 2020; we assume then that it reaches 13.5% in 2030 and 29% in 2050.
- The electricity production mix is calibrated according to the BPPT (Agency for the Assessment and Application of Technology) scenario (see Figure 18 below). The BPPT scenario is derived from the *Energi Outlook Indonesia* 2015 and integrates the impact of the previous release of the RUPTL (2015-2024) on electricity production until 2024. Therefore, this scenario shows that the Indonesian electricity production until 2030 is expected to remain largely based on fossil energy[13]. The production through coal, gas and fuel plants represents nearly 88% of the total production in 2015. This share, which is expected to decrease to 84% by 2030 because of the decrease of gas and fuel plants, is mainly compensated by the increase of geothermal and nuclear (see Figure 19 and Table 5). The share of coal electricity is expected to increase from 52% to 64% between 2015 and 2030.
- It is known that elasticities of substitution between input are difficult to estimate. Therefore, we have used conservative values for these elasticities of substitution. ThreeME assumes a production structure that can be decomposed into three levels (see Figure 20). The level of elasticity used in each level is presented in Table 6. The first level assumes a technology with four production factors (capital, labor, energy and material), using a Variable Output Elasticities Cobb-Douglas function. This function is a generalization of the constant elasticity of substitution function that allows integrating different values of elasticity between each couple of production factors (Callonnec, Landa, Malliet, Reynès, & Yeddir-Tamsamani, 2013; Reynès, 2011b). At the second level, the investment, energy, material and margins aggregates are further decomposed. The elasticities of substitution between energies (oil-coal refining, gas and electricity) are assumed equal to 0.6. At the third level, the demand for each factor is either imported or produced domestically for each type of uses (such intermediary consumption, investment, final consumption and public investment). In all cases, we assume an Armington elasticity of substitution of 0.8.

13 As shown in Figure 9, the 2015-2024 RUPTL was mainly relying on the addition of coal-based capacities.

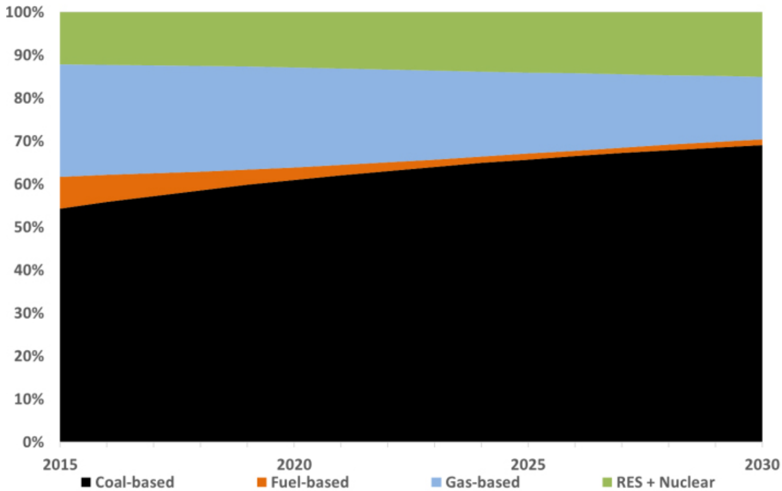
- Energy efficiency increases exogenously by 1% on average per year for production sectors. No exogenous trend for the price of energy technology is considered.

Figure 18. Baseline electricity production mix (BPPT scenario)



Source: BPPT, Authors' calculations

Figure 19. Evolution of the electricity production mix between 2015 and 2030 in the baseline



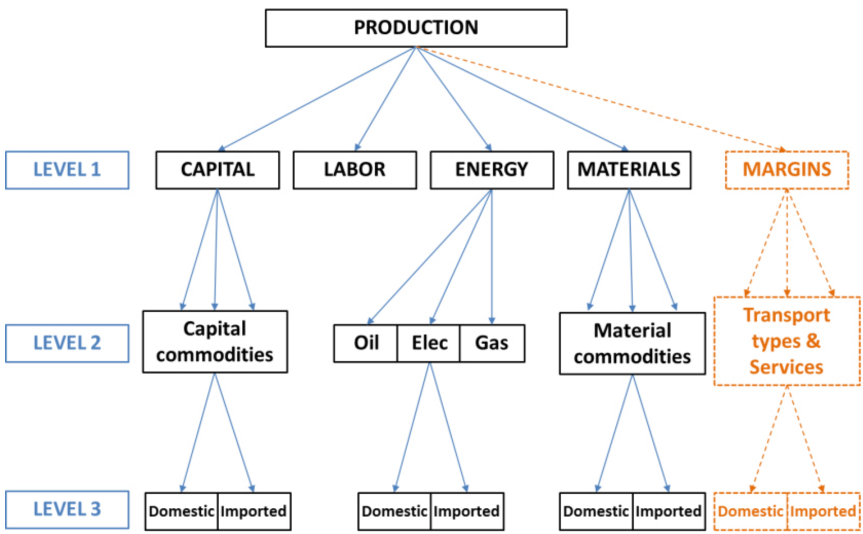
Source: BPPT, Authors' calculations

Table 5. Electricity production share per technology (BPPT scenario)

	2015	2020	2025	2030
Coal	54.3%	61.0%	65.7%	69.1%
Gas	26.1%	23.2%	18.9%	14.5%
Fuel	7.4%	2.9%	1.4%	1.3%
Geothermal	4.7%	6.1%	6.3%	5.7%
Hydro	7.3%	5.9%	5.6%	5.8%
Nuclear	0.0%	0.1%	0.8%	1.6%
Solar	0.1%	0.4%	0.9%	1.3%
Wind	0.1%	0.3%	0.5%	0.6%

Source: BPPT, PLN, Authors' calculations.

Figure 20. Production structure



Source: ThreeME-Indonesia

Table 6. Value of elasticity of substitution *

Description	Value
Level 1: KLEM Elasticity Between Capital and labor in all sectors Between Capital and Energy Between Labor and Energy in non-energy sectors Between Labor and Energy in energy sectors Between Capital and materials, Labor and materials and Energy and materials in all sectors	 0.5 0.6 0.3 0 0
Level 2 Between energy intermediate input in all sectors Between investment goods and between material goods	 0.6 0
Level 3 Armington elasticity of substitution between domestic and foreign goods	0.8
Between final consumption goods	1
Elasticity of exports	0.8

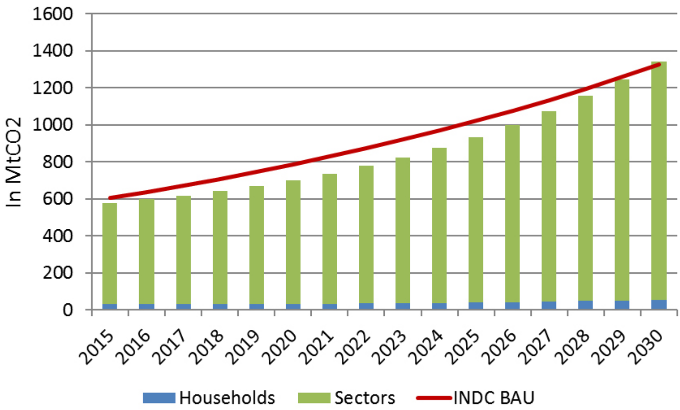
** An elasticity of substitution between two inputs (i.e. labor and capital) of 0.5 means that the ratio between the quantities of the two inputs (Labor/Capital) decreases by 0.5% if the relative price of labor with respect to capital increases by 1%.*

All the assumptions listed above lead to a total CO_2 emission from energy uses of 1 732 millions of tons by 2030. There are two main emitting segments in the economy[14]: households and productive sectors. These segments respectively contribute by 55 (4.1%) and 1 288 (95.9%) $MtCO_2$ (see Figure 21) by 2030. For the sake of comparison, we also estimate the baseline on which the Indonesian INDC relies, taking the historical trend of emissions between 2000 and 2010 (a 5.37% annual growth rate). Households include transport for domestic use only (private light-duty fleet) and residential emissions[15]. Transport, services, agriculture, energy and industry represent respectively 13.6%, 5.1%, 2%, 43.9% and 35.4% of the total emissions of economic sectors by 2030. (see Figure 22). The evolution of GDP is provided in Figure 23.

14 Unless specified otherwise, we always refer to direct CO_2 emissions related to energy use. ThreeME does not take into account for emissions related to land use.

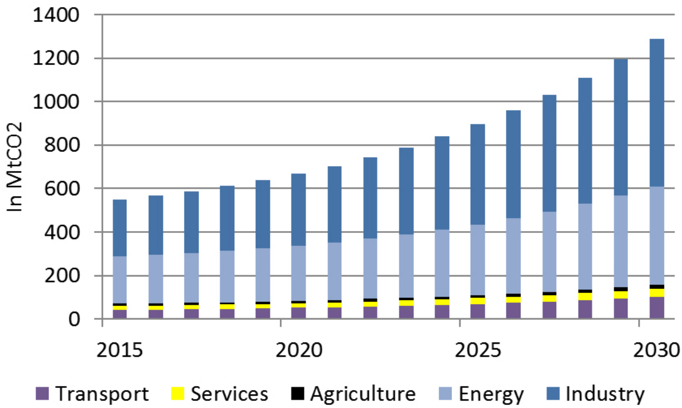
15 Emissions from electricity generation are accounted as issued by the electricity sectors, fossil fuels being an intermediate consumption in the electricity production process.

Figure 21. Direct CO_2 emissions from energy consumption



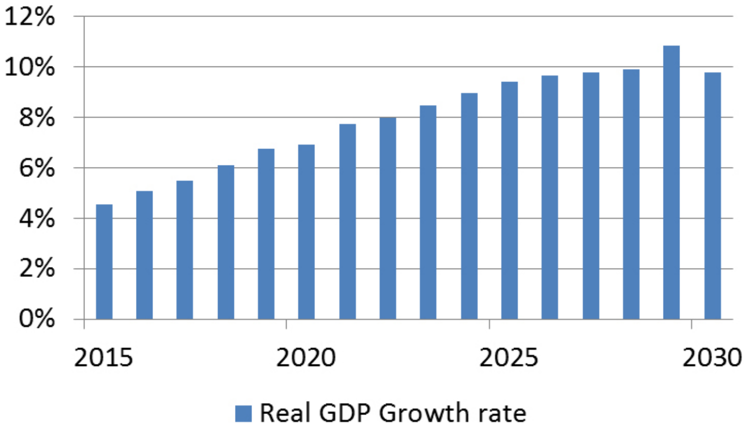
Source: own estimation, ThreeME Indonesia baseline scenario.

Figure 22. Direct CO_2 emissions from energy consumption of sectors



Source: own estimation, ThreeME Indonesia baseline scenario.

Figure 23. GDP growth rate (baseline scenario)



Source: own estimation, ThreeME Indonesia baseline scenario.

4.2 Alternative scenario 1: the 2016-2025 RUPTL

Due to the strong increase in demand, the risk of power outage is rising in Indonesia. This may lead to major power crises in the coming years. The decoupling observed over the past 10 years between the growth of demand and the one of production capacity raises great concern about the sustainability of the current development. In addition, the electricity demand is expected to grow further because of the stringent need for electrification where about 15% of the population does not have access to electricity, and because ensuring access to the electricity network for all Indonesian citizens is the number one energy policy priority of the President Joko Widodo's administration.

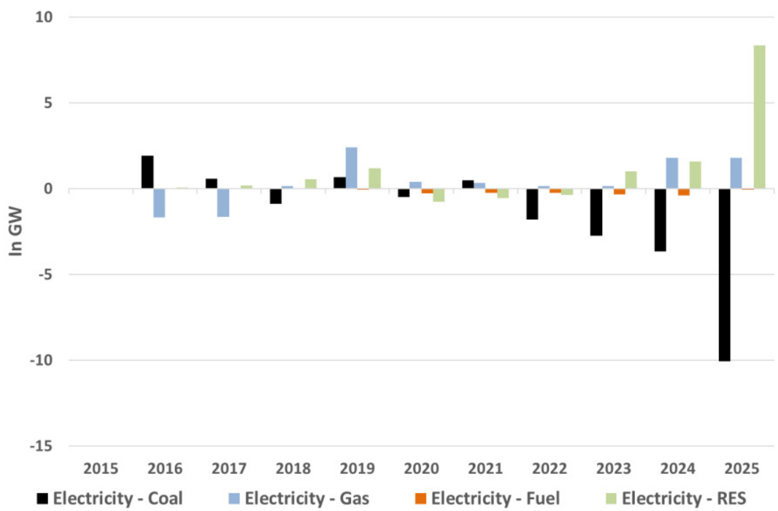
4.2.1 Main hypotheses of the RUPTL scenario

This urgent need to develop power generation capacities is a strong incentive for the development of fossil fuel based power plants and in particular coal power plants. This was reflected in the previous release of the RUPTL (2015-2024) that was rejected by the Minister of Energy for its lack of ambition in terms of RES (see Section 2.2.1). The publication of the 2016-2025 RUPTL shows a clear reorientation of the energy policy toward RES which is more in line with the RUEN and the Indonesian INDC. The 2016-2025 RUPTL scenario is structured into two phases:

- The first phase corresponds to the implementation of the 35GW investment plan until 2019. Figure 24 shows that there is no major changes compared to the previous version of the RUPTL: less gas power plant capacities installed are compensated by more coal power plants in 2015 and 2016 and more RES in 2018 and 2019.

- The second period, 2020-2025, shows a clear strategic reorientation toward the development of renewable energies compared to the previous RUPTL release. As shown in Figure 24, less construction of coal power plants is planned especially after 2022. By 2025, the 28.4 GW of coal-based new capacity originally planned are replaced by gas (4.9 GW) and RES (20.1GW) based power plants whereas 3.4GW capacities are removed.

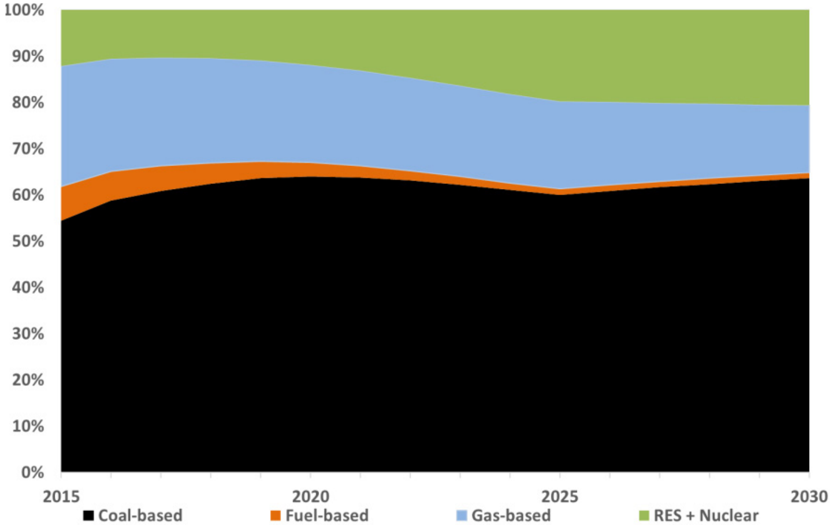
Figure 24. Difference between the RUPTL 2016-2025 and the RUPTL 2015-2024 regarding the annually installed power generation capacities per technology



Source: PLN, authors' calculations

The power generation investment plan defined in the 2016-2025 RUPTL leads to a significant shift in the structure of the new electricity production capacities compared to the 2015-2024 release. The impact in terms of total capacity and therefore production is relatively smaller than on the new capacity but still visible (compare Figure 25 and Figure 19). Table 7 shows the electricity production mix induced by the 2016-2025 RUPTL investment plan. The shares of all fossil-fuel-based power plants are decreasing after 2020. Before this date only coal-fired plants are increasing, benefiting from the first phase of the 35 GW plan. Except for hydro-power, the share of all RES is increasing from 2015 on, but the expansion becomes faster in the second phase of the plan, that is after 2020. In order to compare with the DDPP and to cover the whole period on which the Indonesian INDC applies, we measure the effect of the new RUPTL after 2025, we assume that the gap share with the baseline scenario stays constant beyond that date. Therefore, the coal share increase in the baseline and in the RUPTL 2016-2025 scenarios is the same between 2025 and 2030. The change in electricity technology production shares between the 2016-2025 RUPTL and the baseline BPPT scenario (obtained by subtracting Table 7 to Table 5) is given in Figure 26.

Figure 25. Evolution of the electricity production mix between 2015 and 2030 in the revised RUPTL scenario



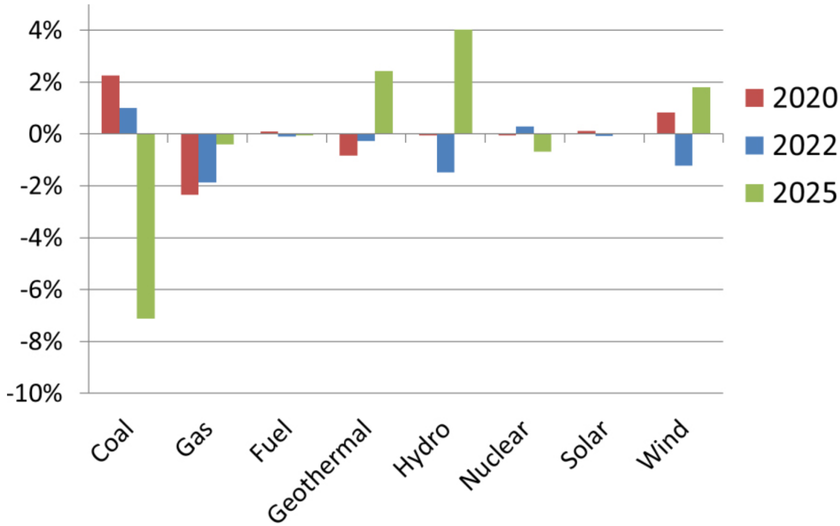
Source: BPPT, PLN, Authors' calculations

Table 7. Electricity production share per technology (Revised RUPTL scenario)

	2015	2020	2025	2030
Coal	54.3%	63.2%	58.6%	62.1%
Gas	26.1%	20.9%	18.5%	14.1%
Fuel	7.4%	3.0%	1.3%	1.3%
Geothermal	4.7%	5.3%	8.7%	8.2%
Hydro	7.3%	5.9%	9.7%	9.9%
Nuclear	0.0%	0.0%	0.1%	0.8%
Solar	0.1%	0.5%	0.9%	1.3%
Wind	0.1%	1.2%	2.3%	2.4%

Source: BPPT, PLN, Authors' calculations

Figure 26. Absolute deviation in the electricity production share per technology between 2015 and 2030 in the RUPTL scenario w.r.t the baseline



Source: RUPTL (2016-2025), Authors' calculations

4.2.2 Macroeconomic and sectorial impact of the RUPTL scenario

The shares presented in Table 7 are used to simulate the RUPTL scenario with ThreeME. This simulation is compared to the simulation of the baseline scenario that uses the share of Table 5. All other exogenous variables are common across both scenarios. The macroeconomic impact of the modification of the RUPTL with respect to the baseline is limited (see Table 8). Whereas the first phase of the RUPTL is based on the increase of fossil fuels capacities, it has only a (very) slightly negative impact in terms of GDP until 2020 (-0.01%), the second phase based on more RES has a small positive impact (+0.02% in 2025 and +0.07% in 2030). Employment figures provide a similar story with a lower level of employment with nearly -20 thousand jobs in 2018 and a reverse dynamic observed afterwards (+nearly 62 thousand jobs in 2030). Such figures are very small in relative terms since they correspond to an increase of the unemployment rate of 0.01 percentage point in 2018 and to a decrease of this same rate of 0.03 point in 2030.

Only CO_2 emissions show a limited but significant change. Whereas they reach their highest point in 2018 (+0.4%), they become lower than the baseline scenario after 2020 to reach - 1.7 % in 2030. The "2015 = 100" emission index is lower by 4.2 point compared to the baseline.

Table 8. Macroeconomic results (RUPTL scenario), in relative deviation to the baseline

		2015	2016	2017	2018	2019	2020	2025	2030
Real GDP	(a)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	0.03	0.07
Household consumption	(a)	-0.01	-0.01	-0.02	-0.03	-0.03	-0.03	0.04	0.12
Investments	(a)	0.00	0.00	0.01	0.02	0.02	0.03	-0.02	-0.07
Exports	(a)	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05
Imports	(a)	0.01	0.01	0.01	0.01	0.01	0.00	-0.06	-0.10
Unemployment rate	(a)	0.01	0.01	0.01	0.01	0.01	0.01	-0.02	-0.03
Employment	(d)	-7.24	-12.59	-17.33	-19.81	-19.19	-15.61	24.77	61.72
Real wage	(a)	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	0.03	0.08
Price	(a)	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.06	-0.11
Debt	(c)	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03
Public deficit	(c)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Expenditures	(a)	0.00	-0.01	-0.01	-0.02	-0.03	-0.04	-0.11	-0.29
Revenues	(a)	0.00	0.00	-0.01	-0.02	-0.03	-0.03	-0.08	-0.12
Emissions	(a)	0.23	0.34	0.41	0.39	0.32	0.17	-1.07	-1.68
Emissions index	(b)	100.00	103.34	107.06	111.20	115.95	121.21	159.54	227.85
Change in emissions index	(e)	0.00	0.12	0.19	0.17	0.10	-0.07	-2.09	-4.42

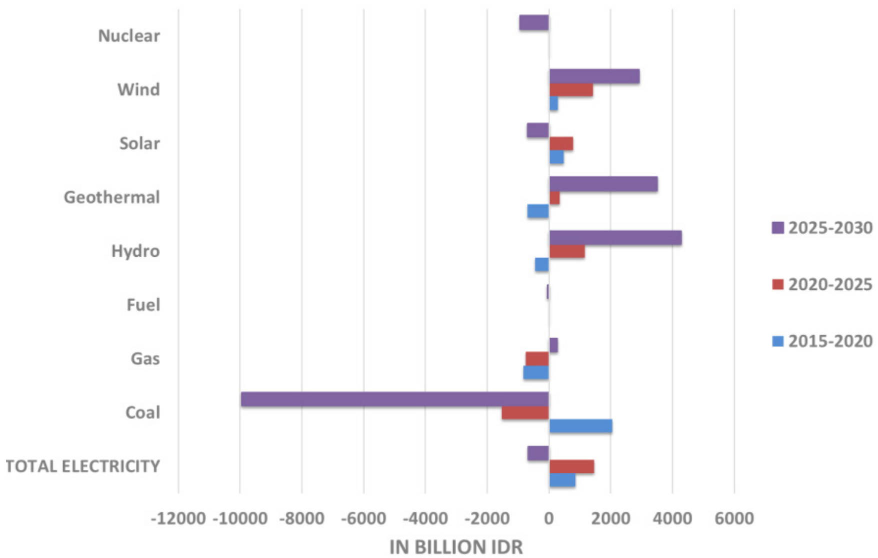
Legend: (a) Relative deviation in % to the baseline, (b) in index 2015=100, (c) in GDP % (deviation to the baseline), (d) in thousands (deviation to the baseline), (e) in index points (deviation to the baseline).
Source: ThreeME, simulation based on the 2016-2025 RUPTL

Based on the above results, we can conclude that the modification of the electricity mix structure announced in the RUPTL 2016-2025 is quite neutral at the macroeconomic level compared the BPPT baseline scenario and therefore comparable to the previous release of the RUPTL. And whereas the investment plan toward more RES is not an economic burden compared to less clean alternative (it even has a slight positive effect), the reduction of the GHG emissions is significant with a 1.7% decrease by 2030. As said previously, we can identify two periods that differs in growth drivers. Whereas until 2020, the investment variation remains slightly positive, it becomes negative with respect to the baseline after this date (see Table 8). Inversely, the employment variation evolves in the opposite direction, the impact of the RUPTL being relatively negative and becomes positive only after 2022. These effects come from the economic features of the electricity generation technologies (labor intensity, cost of investment of the generation capacities, load factors, etc). It appears that the renewables technologies require relatively more labor and less capital than the coal-based one. Therefore, substituting the generation capacities of one technology by another modifies the production structure of the electricity sectors in terms of labor, capital and intermediate consumption[16]. The following of this section will therefore focus on the impacts of the electricity generation activity on the investment, labor, and CO_2 emissions.

At the sectoral level, the difference induced by the RUPTL reorientation is more striking than at the macroeconomic level. As shown in Figure 27, the electricity sectors' investments differ radically from one scenario to the other. Whereas the investments in gas-based power plants are lower of 828 Rp. billions by 2020 and 754 Rp. billions between 2020 and 2025 w.r.t the baseline, they become positive afterward to reach 269 Rp. billions between 2025 and 2030. The investments in coal-based power plants are higher until 2020 than in the previous version of the RUPTL with an extra investment of 2050 Rp. Billions but they sharply decrease for the following periods: -1521 Rp Billions between 2020 and 2025 and close to - 10 Rp. Trillions between 2025 and 2030. On the whole period of the RUPTL 2016-2025, this still represents an extra investment of 529 Rp. Billions (40.6 Million US$).

The investments dedicated to renewables also reflect this two-phases RUPTL plan (see Figure 27) since there is relatively less investment by 2020 (-383 Rp. Billions w.r.t to the baseline) and relatively more after (3709 Rp. Billions between 2020 and 2025 and 10 Rp. Trillions between 2025 and 2030). Hydrology, Geothermal, Wind and Solar investments represent for the period 2015-2020 respectively 41.7%, 29.6%, 4.3% and 24.4%.

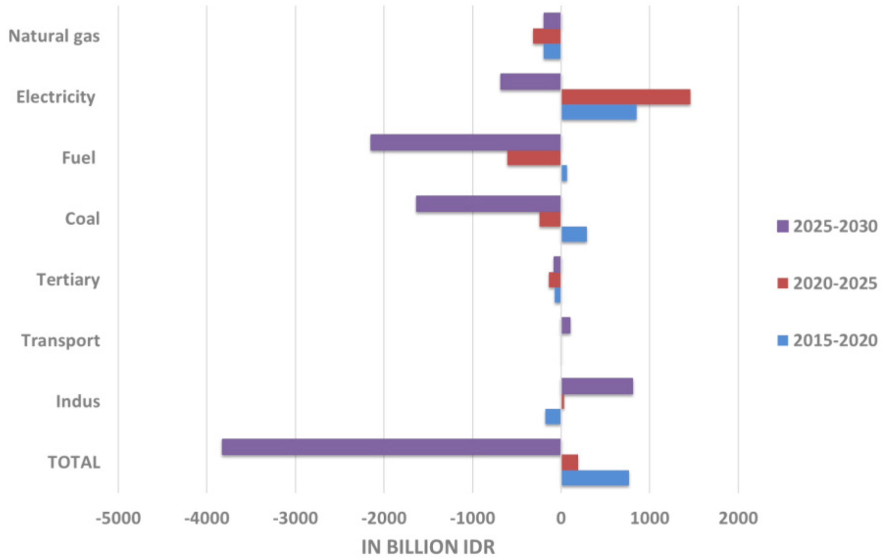
Figure 27. Investments in electricity sectors (absolute difference w.r.t the baseline)



Source: ThreeME, simulation based on the 2016-2025 RUPTL

16 For more details, refer to APPENDIX A: Methodology for the disaggregation of the electricity sector.

Figure 28. Investments in economic sectors (absolute difference w.r.t the baseline)

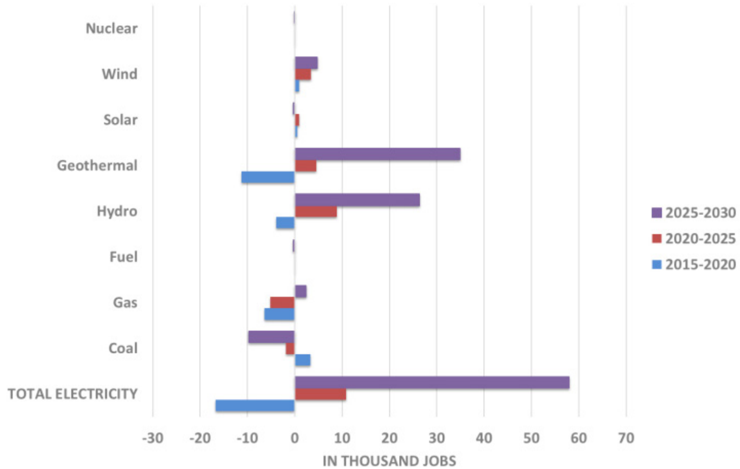


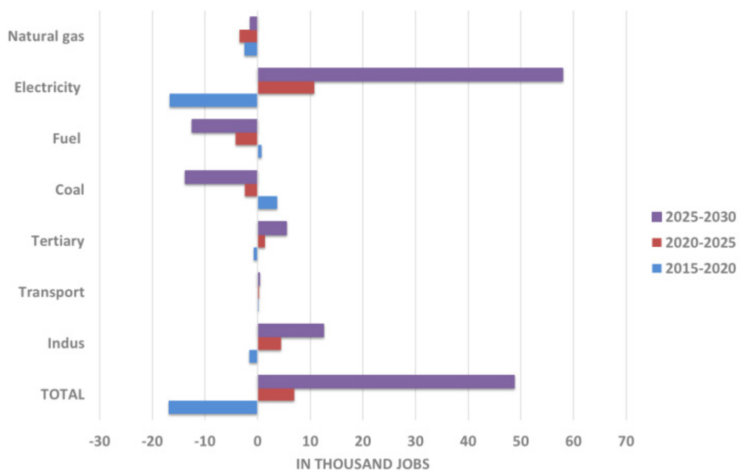
Source: ThreeME, simulation based on the 2016-2025 RUPTL

These changes induced by the RUPTL revision show rather clearly this new dynamic, which is mainly characterized in its first period (2015-2021) by an acceleration of coal-based power plants installation. It appears also that the adjustments made to comply with the National Energy Policy targets for RES by 2025, concern the reduction of gas-based power plants instead of coal-based power plants. As a whole, we estimate an increase of investments in electricity sectors of 854 Rp. Billions by 2020 and of 1458 Rp. Billions for the 2020-2025 period, and a decrease of 682 Rp. Billions afterwards (compared to the baseline scenario).

The change in the electricity mix will also impact the other sectors of the economy through the demand addressed to them, i.e. through the purchases of electricity sectors to other sectors (investments or intermediate consumptions from the electricity sectors). Figure 28 clearly shows the decline in the demand addressed to the fossil fuels sectors (oil and gas producing sectors) and to the coal extraction sector after 2020. Before this date only natural gas has less investment (201 Rp. Billions) whereas coal extraction and oil producing sectors have more investments (respectively of 288 and 69 Billions Rp.). After 2020, the trend is not ambiguous anymore and all these sectors see their investments shrinking to 1167 Rp Billions (and even 3970 Rp. Billions between 2025 and 2030). The impact on transportation and services remains minor on the whole period (until 2030) but the industry, after experiencing a decline of its investments between 2015 and 2025 witnesses an increase in its investments of 808 Rp. Billions by 2030. However as a whole, and due to the electricity generation activities, the net effect on the total amount of investment remains positive by 2025 mainly driven by those in electricity generation, and we estimate around 953 Rp. Billions supplementary investment by 2025. The fossil fuels and coal extraction sectors however induce a relative negative impact on investment (electricity generation as well to a lesser extent) afterwards. The industry on the contrary has more investment after 2025.

Figure 29. Average job creation (absolute difference w.r.t to the baseline)





Source: ThreeME, simulation based on the 2016-2025 RUPTL

The general impact on employment appears in the simulation to be firstly negative until 2020 and positive afterwards (see Figure 29). In the electricity generation sectors, the loss of activities in gas-based and geothermal power-plants lead to these results for the first period considered. The creation of jobs in coal-based power plants sectors does not offset the negative effects. This comes from the fact that this technology is relatively less intense in labor than gas or geothermal power plants. In the second period (2020-2025), the impact on employment becomes positive, thanks to RES which create 18 000 additional jobs. The gas power plants sector still represents 5 000 less jobs with respect to the baseline, leading to an overall effect of 11 000 net jobs created in the electricity generation activity. The 2025-2030 period amplifies this trend[17].

The impact on the other sectors of the economy depends on their link with electricity sectors. Sectors highly dependent on fossil-fuels based power plants lose jobs whereas the other sectors tend to gain jobs. Whereas employment decreases by 7 000 (resp. 26 000) jobs in fossil-fuel sectors by 2025 (resp. 2030), it increases by more than 4 000 (resp. 12 000) jobs in industrial sectors. By accounting for these indirect effects, the global impact in terms of net job creations is 7 000 (resp. 49000) jobs w.r.t the baseline between 2020-25 (resp. 2025-30).

The impact on CO_2 emissions appear to be quite significant since the electricity generation sector emissions decrease by 10% in 2025 (after having increased by 2% in 2020). In terms of total emissions avoided over the whole period, Figure 30 above shows the variation for each sector. Unsurprisingly, emission reductions related to coal-based power plants explain nearly 90% of the total decrease by 2025. Whereas 2 $MtCO_2$ are avoided w.r.t to the baseline over the period 2015-2025, 69 supplementary $MtCO_2$ are avoided over the period 2025-2030. Notice that these figures refer to flows of emissions and not to stocks. Because of the emission increase between 2015 and 2020 due to the construction of coal-based power plants, the stock of cumulated emissions decreases only after 2023 w.r.t the baseline scenario (see Section 4.4 for more detail).

4.3 Alternative scenario 2: the DDPP for Indonesia

The Deep Decarbonisation Pathways Project (DDPP) is an international initiative that has been launched by the IDDRI[18] and the SDSN[19] to estimate the full potential of decarbonisation in different economies of the world by 2050. Indonesia is one of the sixteen countries where such an analysis has been conducted. The Center for Research on Energy Policy of the Institut Teknologi Bandung (CREP-ITB[20]) and the Centre for

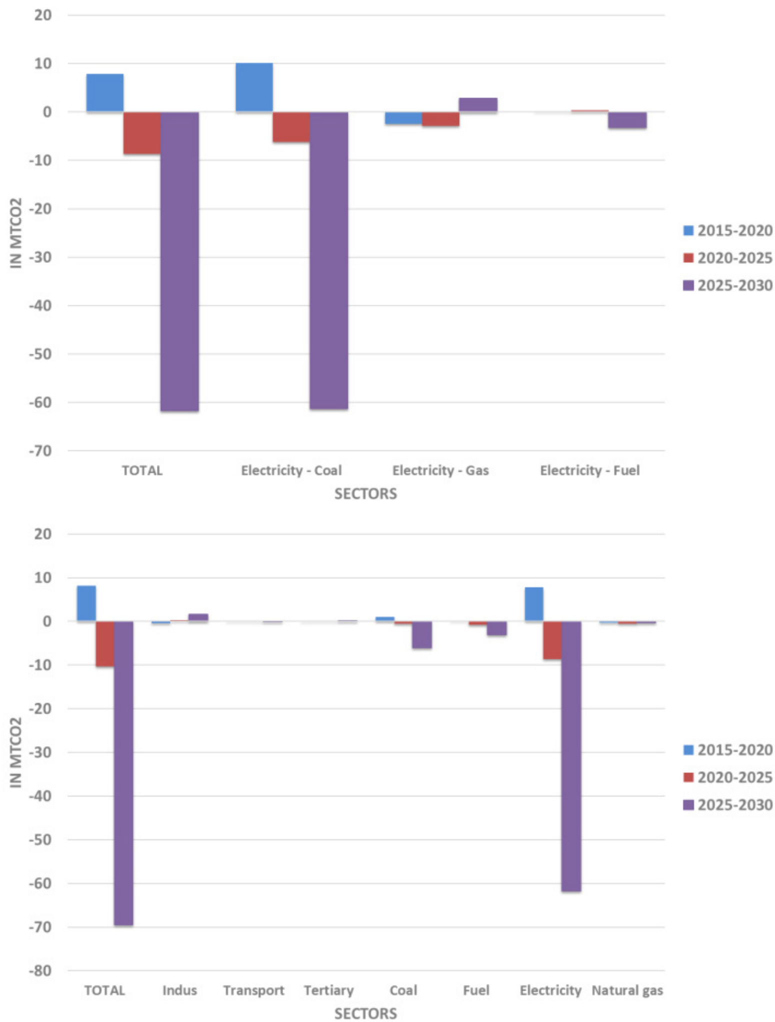
17 Due to slow adjustments notably on the labor market, the effect of the economy still appears in the periods after the shock.

18 Institute for Sustainable Development and International Relations: http://www.iddri.org/

19 Sustainable Development Solutions Network: http://unsdsn.org/

20 http://crep.itb.ac.id/

Figure 30. Absolute variation in GHG emissions per sector in the RUPTL scenario w.r.t to the baseline



Source: ThreeME, simulation based on the 2016-2025 RUPTL

Climate Risk and Opportunity Management in Southeast Asia Pacific (CCROM-SEAP[21]) are the Indonesian Research Centers involved in this study[22]. The associated released report ***Pathways to Deep Decarbonization in Indonesia*** (Ucok, 2015) gives a thorough analysis of an energy transition scenario compatible with limiting global temperature increases to less than 2°C compared to pre-industrial time and aims to provide answers to two crucial issues:

- The technical feasibility of such a structural change for the Indonesian economy
- The amount of required investments

Three scenarios have been defined in this study in order to cover a wide scope of potential alternatives in the process of decarbonization:

- "Renewable": large-scale development of renewable-based power generation complemented by Nuclear Energy
- "Renewable+CSS" (Carbon Capture & Storage): More balanced scenario with carbon capture.
- "Economic Structural Change": Consider structural changes in the economy, on energy-demand side.

The energy and GHG emissions scenarios were calculated using the calculator tool developed by the DDPP secretariat, and which is standard to the other countries studies. The different decarbonization scenario analysis conducted in Indonesia rely on four pillars:

- Energy Efficiency: through the deployment of efficient technologies, both on supply and demand side
- Fuel switching: through the deployment of low and zero-emitting technologies for final end-uses
- Decarbonization of the power sector: through the deployment of low-carbon emitting power generation options (Renewables, CCS, Nuclear)
- Structural change in the economy: through the substitution activities such as fossil fuel extraction and industry to less-emitting activities, such as services

However, for the sake of comparison with the RUPTL revision scenario, our analysis does not conduct a complete economic analysis of all the pillars of the DDPP scenario but only considers the direct effects of the transformation of the energy system (third pillar). The main indirect effects are omitted. Because the interdependence between economic sectors is not taken into account explicitly, the effect on the activity of

21 http://ccromseap.ipb.ac.id/

22 The chapter on Indonesia is available at http://deepdecarbonization.org/wp-content/uploads/2015/11/DDPP_IDN.pdf.

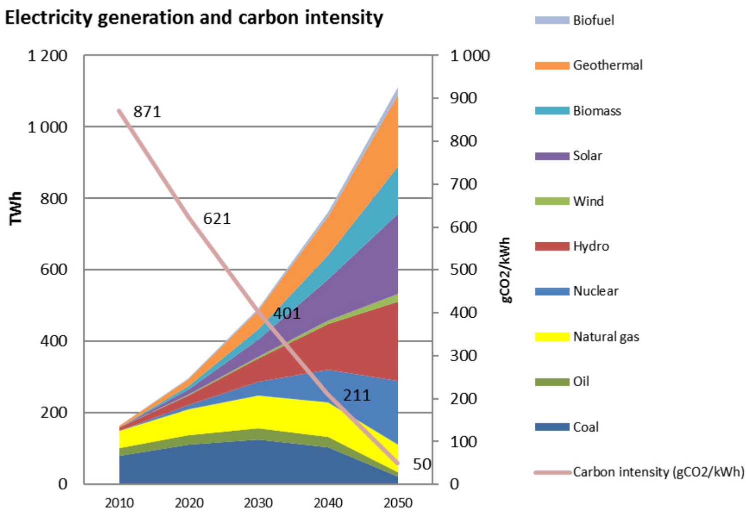
non-energy sectors is not measured. This may change the global outcome in terms of investment and employment. The effects that the changes in prices may have on the economy are also not considered. The same is true for the effects on household consumption that result from changes in prices and employment.

In order to account for these indirect effects, we propose to estimate the economic impact of the modification of the power generation as defined in the DDPP "Renewable" scenario with ThreeME. For the sake of comparison with the new RUPTL scenario simulated in Section 4.2, we only focus on the effect of a change in the electricity production mix as defined in the DDPP scenario.

4.3.1 Main hypotheses of the DDPP scenario

Figure 31 shows the evolution of the electricity production by technology until 2050 according to "renewable" scenario of DDPP[23]. It assumes a progressive decarbonisation of the electricity production mix from 871 to 50 gCO_2/kWh between 2010 and 2050 through the replacement of fossil fuel based electricity technologies by RES and nuclear technologies.

Figure 31. Electricity generation and carbon intensity-Renewable Scenario

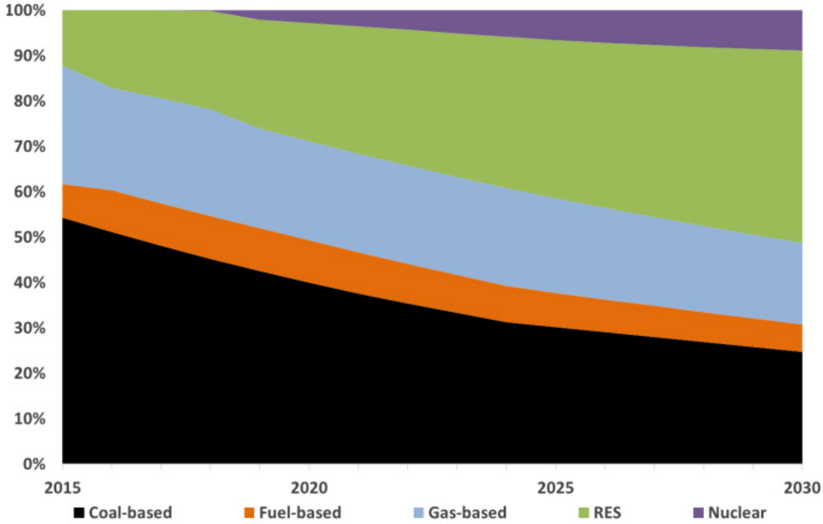


Source: Pathways to deep decarbonisation in Indonesia.

23 DDPP defines two other scenarios. The "renewable+CCS" assumes that the development of Carbon Capture and Storage (CCS) requires the development of less RES. The scenario "economic structural change" make further hypothesis on the reduction of the energy demand through behavioral changes. We reserve the analysis of these scenarios for further research.

Figure 32 and Table 9 rescale Figure 31 (between 2015 and 2030). The change in the electricity production mix is quite significant with almost a doubling of the share of RES during the whole period (15.4% in 2015 against 28.3% in 2030). The share of nuclear increases from nearly zero to 8% and the coal-based power plants share is nearly divided by two (54.3% in 2015 and 24.7% in 2030).

Figure 32. Electricity Mix 2015-2030 for the DDPP Scenario



Source: Pathways to deep decarbonisation in Indonesia.

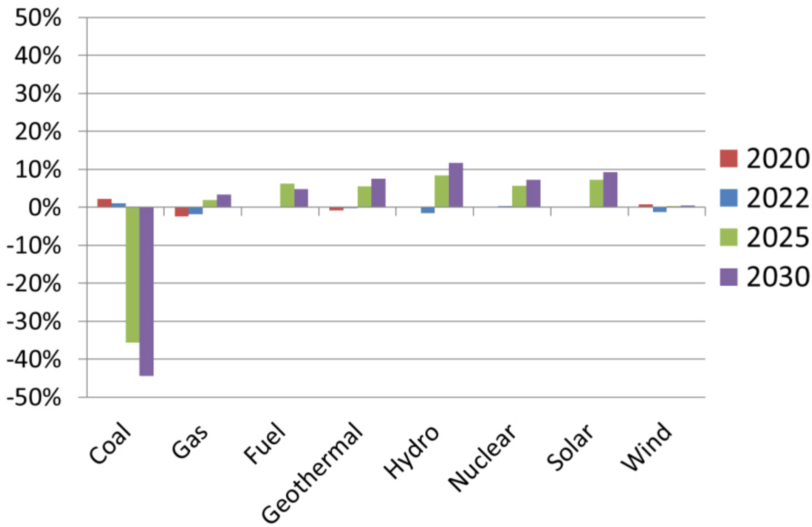
Table 9. Electricity production share per technology (DDPP scenario)

	2015	2020	2025	2030
Coal	54.3%	40.0%	30.1%	24.6%
Gas	26.1%	21.8%	20.8%	17.9%
Fuel	7.4%	9.3%	7.6%	6.1%
Geothermal	4.7%	10.2%	11.8%	13.3%
Hydro	7.3%	10.1%	14.1%	17.5%
Nuclear	0.0%	2.8%	6.5%	8.9%
Solar	0.1%	5.3%	8.2%	10.6%
Wind	0.1%	0.5%	0.8%	1.1%

Source: Pathways to deep decarbonisation in Indonesia

The changes in electricity technology production shares between the 2016-2025 RUPTL and the baseline BPPT scenario (obtained by subtracting Table 9 to Table 5) is given in Figure 33.

Figure 33. Absolute deviation in the electricity production share per technology between 2015 and 2030 in the DDPP scenario w.r.t the baseline



Source: Pathways to deep decarbonisation in Indonesia, authors' calculations

4.3.2 Macroeconomic and sectorial impact of the DDPP scenario

As we did for the simulation of the RUPTL scenario (in Section 4.2), the shares presented in Table 9 are used to simulate the DDPP scenario with ThreeME. This simulation is compared to the simulation of the baseline scenario that uses the shares of Table 5. All other exogenous variables are common across both scenarios. The impact of the DDPP scenario at the macroeconomic level is limited but larger than the RUPTL scenario (see Table 10 versus Table 8). Compared to the RUPTL scenario, there appears to be only one phase and the impact on GDP and employment compared to the baseline scenario is positive over the all period. Moreover, this positive impact is increasing over time to reach +0.6% for GDP and + 456.8 thousand jobs by 2030. This positive dynamic is partly driven by investments required by a larger share of RES and nuclear electricity production, these being on average more expensive than fossil technologies. It is also driven by the increase in household consumption (+1% in 2030) that follows the increase in employment.

On the other hand, this positive dynamic has a positive effect on inflation: the reduction of unemployment has a positive effect on wages which are passed to prices;

the general increase of the activity provides also an incentive for firms to increase their prices. This has a negative impact on trade with a slight drop in exports which are less competitive because of the conservative assumption that the rest of the world does not take similar measures. The global impact on GDP is summarized in Figure 34 where the GDP increase compared to the baseline scenario is decomposed between the contribution of households' consumption, investment and the trade balance.

Table 10. Macroeconomic results (DDPP scenario), in relative deviation to the baseline

		2015	2016	2017	2018	2019	2020	2025	2030
Real GDP	(a)	0.00	0.02	0.07	0.13	0.20	0.27	0.53	0.62
Household consumption	(a)	0.00	0.01	0.04	0.10	0.18	0.28	0.76	1.02
Investments	(a)	0.00	0.07	0.30	0.56	0.81	1.10	2.24	2.69
Exports	(a)	0.00	0.00	0.00	-0.01	-0.02	-0.04	-0.19	-0.34
Imports	(a)	0.00	0.02	0.08	0.17	0.24	0.34	0.78	1.01
Unemployment rate	(a)	0.00	-0.01	-0.04	-0.08	-0.12	-0.16	-0.27	-0.24
Employment	(d)	0.00	15.48	59.55	125.16	189.40	257.33	471.68	456.78
Real wage	(a)	0.00	0.01	0.03	0.07	0.13	0.20	0.68	1.05
Price	(a)	0.00	0.00	0.01	0.03	0.05	0.09	0.32	0.46
Debt	(c)	0.00	0.00	0.00	0.00	-0.01	0.00	0.16	0.44
Public deficit	(c)	0.00	0.00	0.01	0.00	-0.01	0.00	0.02	0.07
Expenditures	(a)	0.00	0.03	0.09	0.16	0.20	0.26	0.55	0.59
Revenues	(a)	0.00	0.01	0.06	0.16	0.26	0.32	0.70	0.82
Emissions	(a)	0.00	-0.36	-0.67	-0.95	-1.35	-1.64	-3.03	-4.14
Emissions index	(b)	100.00	102.85	106.15	109.98	114.28	119.29	156.74	222.66
Change in emissions index	(e)	0.00	-0.37	-0.72	-1.05	-1.56	-1.99	-4.90	-9.61

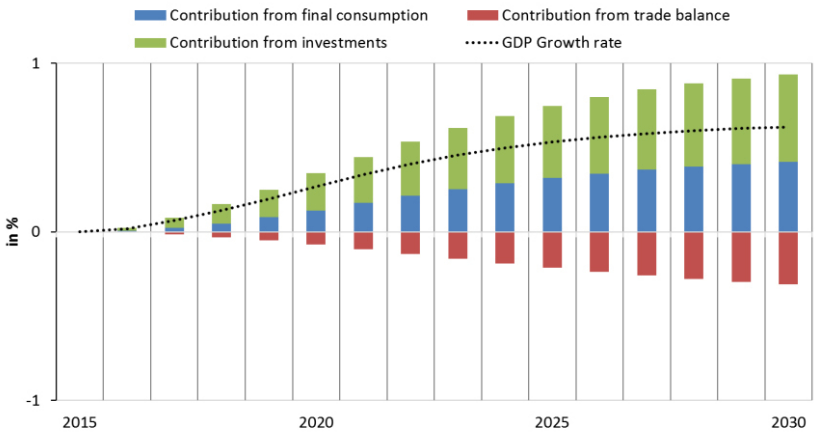
Legend: (a) Relative deviation in % to the baseline, (b) in index 2015=100, (c) in GDP % (deviation to the baseline), (d) in thousands (deviation to the baseline), (e) in index points (deviation to the baseline).

Source: ThreeME, simulation based on the DDPP scenario.

With respect to the previous RUPTL scenario, the impact on GHG emissions is also higher since we observe a decrease of 4.1% with respect to the baseline in 2030. The "2015 = 100" index is lower by 9.6 points compared to the baseline. The emissions reduction in the electricity generation sectors (as previously shown in Figure 5) is of 46.6%. The other sectors of the economy also experience a variation of their emissions, with less emissions coming from coal extraction activity (-5.3 $MtCO_2$ in 2030) but more coming from industry and services sectors (+ 6 $MtCO_2$ in 2030). However, taken as a whole, the impact of the other economic sectors is rather small compared to electricity sectors. DDPP finds a very close result with a carbon intensity reduction in electricity sectors of 46.2%[24]. It may also come from the integration in our analysis of the effect on the overall activities. In general, the taking into account of a rebound effect in general equilibrium analysis leads to lower reduction in CO_2 emissions compare to a partial equilibrium analysis. A deeper analysis is given in Section 4.4.

24 This result is calculated from Figure 31 where the carbon intensity of the electricity mix drops from 746 in 2015 to 401 gCO_2/kWh in 2030.

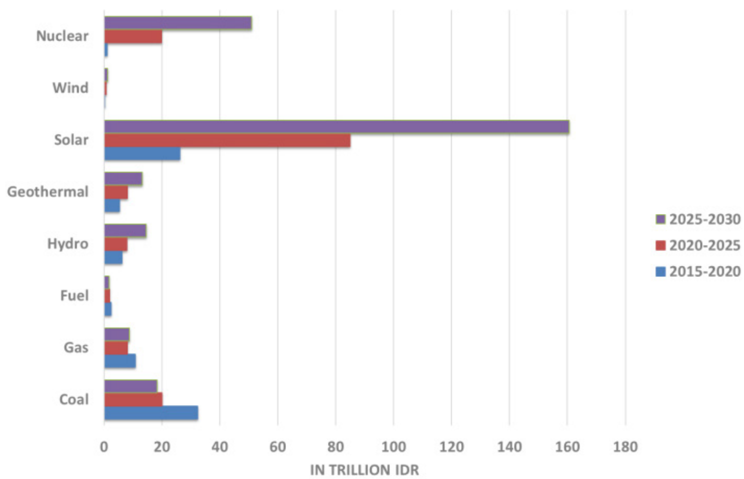
Figure 34. Decomposition of the GDP deviation in its different contributions



Source: ThreeME simulation based on DDPP.

Total investments are expected to reach more than 236 Rp. Trillions by 2025 in the electricity generations sectors (see Figure 35). This is mainly due to Solar plants which represents an investment of 111 Rp. Trillions in the next ten years. Even if the share of coal-fired power plants in the electricity mix radically shrinks, the total investment remains still important with a total estimated to 57 Rp. Trillions before 2025. Nuclear development after 2025 represents also a 40 Rp. Trillions investment.

Figure 35. Total amount of investments per electricity sectors



Source: ThreeME, simulation based on DDPP.

For the 2015-2020 period, we estimate that 20 Rp. trillions of supplementary investments are required compared to the baseline scenario. For the RES, this represents 6.4 Rp. trillions by 2020 and 13.7 Rp. trillions between 2020 and 2025. Over the whole period, this corresponds respectively to 5.7 Rp. trillions for hydrology, 4.3 Rp. trillions for Geothermal, 1.8 Rp. trillions for solar and 8.2 Rp. trillions for Wind power. On the contrary, coal-based investment sharply declines over the whole period by 25.6 Rp. trillions compared to the baseline scenario.

The Deep Decarbonization scenario has a strong incidence on investment since it would require more than 38 Rp. Trillion to be implemented. The Nuclear Power plants construction represents the major share of this total amount with almost 40 Rp. Trillion of investments, the renewables being less costly and needing relatively less capital than the coal-based power plants that they are partly replacing.

Figure 36. Absolute difference in economic sectors investments w.r.t the baseline

Source: ThreeME simulation based on DDPP.

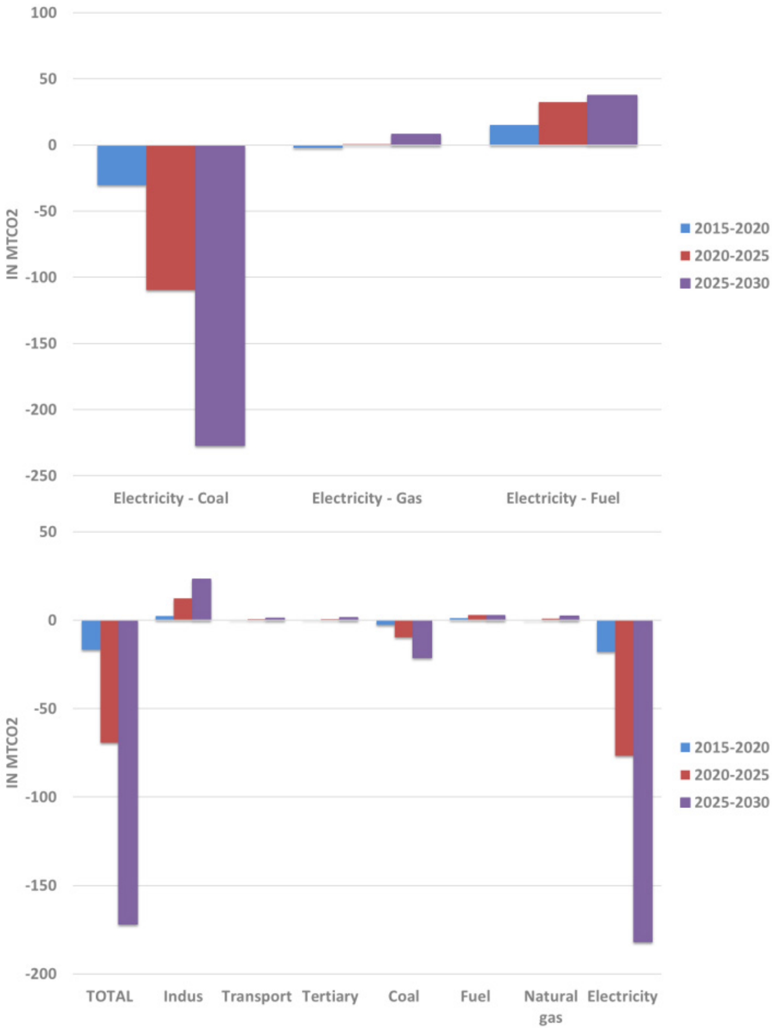
The total investment in electricity power generation sectors represents almost 6 Rp. Trillion by 2020 and more than the double in 2025 with 15.6 Rp Trillions (see Figure 36). Nuclear power plants and coal-based capacities represent the major shares of these investments due to their capital intensity and the weight they have in the electricity generation mix.

The impact on employment is quite important and contrary to the RUPTL scenario which induces in the first years a negative impact, in the DDPP scenario, all the sectors (except coal-based power plants) witness a positive, immediate and progressive impact on employment (see Figure 37) following the deployment of their associated power generation capacities. Almost all the other sectors in the economy also benefit from jobs creation, especially in the industry and to a lesser extent in tertiary sectors. However, the coal extraction sector experiences a decrease of employment. The total positive impact on the electricity sector comes from the substitution of a less labor-intensive (coal-based power plants), to more labor-intensive technologies (for more details, see Table 15 in APPENDIX A: Methodology for the disaggregation of the electricity sector)

Figure 37. Absolute Job variation in the DDPP scenario w.r.t to the baseline

Source: ThreeME simulation based on DDPP.

Figure 38. CO_2 emissions difference on five-years periods in the DDPP scenario w.r.t to the baseline



Source: ThreeME simulation based on DDPP.

The decrease in CO_2 emissions is more important in the DDPP scenario than in the RUPTL scenario since it represents 36.8% less emissions compared to the baseline. Figure 38 represents this decrease in absolute terms. As in the RUPTL revision scenario, the emissions reduction almost come integrally from the shut-down of coal-based power plants with a total reduction of about 220 $MtCO_2$ between 2025 and 2030.

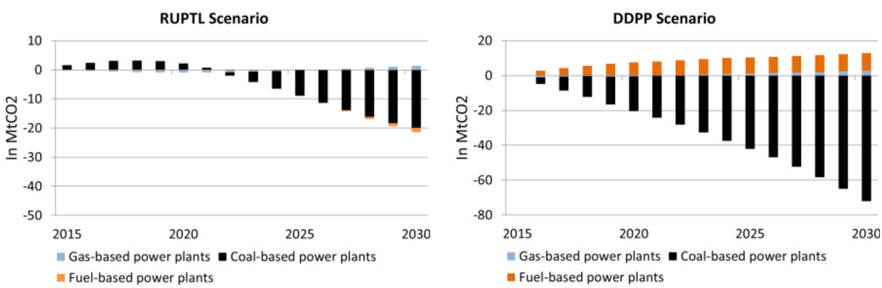
However, the emissions from the other fuel-based power plants is increasing w.r.t to the baseline, especially fuel-based power plants which are responsible for increasing emissions by almost 40 $MtCO_2$ between 2025 and 2030. We can also notice the existence of a rebound effect in the DDPP scenario, since the other sectors of the economy witness an increase of their CO_2 emissions of about 10 $MtCO_2$. The Industry sectors account for 23 supplementary $MtCO_2$ emissions, whereas the coal extraction sector diminishes its emissions by 21 $MtCO_2$. The emissions from the other sectors increase moderately, representing 8 supplementary $MtCO_2$.

4.4 Comparative approach for emissions

This section focuses on the respective impact of the two scenarios presented above in terms CO_2 emissions. Unsurprisingly the level of emissions from the electricity generation sectors is heavily correlated to the coal use, which exhibits a higher carbon intensity ratio in comparison to gas and fuel. The revision of the RUPTL leads to a decrease in emissions of 1.7% compared to the baseline in 2030 (see Table 8).

The overall impact on emissions with respect to the baseline scenario is shown in Figure 39. As already explained regarding the RUPTL scenario, we clearly observe an increase of CO_2 emissions between 2015 and 2020 that results from the increase of coal-based power plants before 2021. In the case of the DDPP, it highlights two salient facts: firstly, the significant reduction of emissions from coal-based generating capacities which reaches 80 $MtCO_2$ in 2030 and secondly, the increase of emissions from fuel-based power plants (which represents 7.18 $MtCO_2$ in 2030).

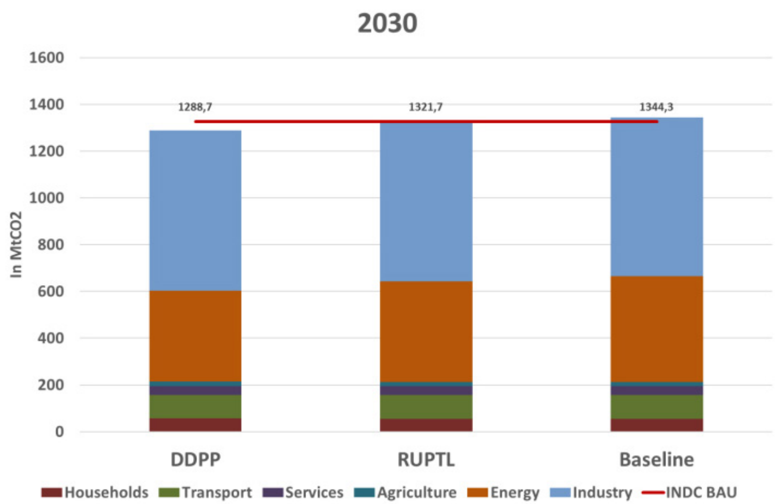
Figure 39. Change in emissions for the RUPTL and DDPP scenarios (w.r.t the baseline)



Source: ThreeME, simulation based on the 2016-2025 RUPTL and DDPP scenarios.

With respect to the baseline scenario, we also observe in 2025 a decrease of 3.2% in the CO_2 emissions from energy activities in the RUPTL revision scenario (see Figure 40), and 10.5% in the case of the DDPP scenario (resp. 5.1% for the RUPTL scenario and 14.2% for the DDPP scenario in 2030). In terms of absolute emissions, the reduction accounts for 22.55 $MtCO_2$ in the RUPTL scenario and 55.61 $MtCO_2$ in the DDPP scenario. However, this results do not radically change the total emissions from fossil fuel combustion, the power sector being responsible of about 9.6% of them. Recall that the emissions reduction in the DDPP scenario is only coming from the power sector and thus does not reflect the whole potential covered in the original study, which is much more ambitious and would be of about 60%, with respect to our baseline.

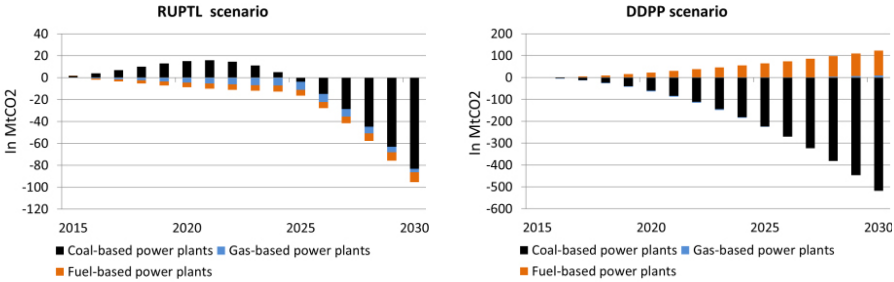
Figure 40. Comparison of the total energy related annual CO_2 emissions between the different scenarios in 2025 and 2030



Source: ThreeME, simulation based on the DDPP and the 2016-2025 RUPTL

Considering the cumulated emissions, we clearly see that the RUPTL has eventually a positive climate impact after 2024 where cumulated emissions start to decrease compared to the baseline scenario (Figure 41). The relatively higher investment in coal-based capacities between 2015 and 2021 induces an increase in the stock of carbon emitted over the whole period which has consequences even after the reorientation toward RES capacities. In the end, by 2030 the avoided emissions are only 95 $MtCO_2$. In comparison, the Deep Decarbonization scenario, which operates an immediate reorientation in the choice of electricity generation capacities leads to an instant reduction of emissions. If we consider the cumulated annual emissions, the effect on the cumulated stock is by the end of the period almost six times higher with about 600 $MtCO_2$ of avoided emissions.

Figure 41. Cumulated stock of CO_2 emissions absolute deviation w.r.t the baseline in the two scenarios



Source: ThreeME, simulation based on the 2016-2025 RUPTL and DDPP scenarios.

This difference in terms of impact on emissions between the two scenarios highlights the importance of the time-profile in the choice of generation capacities installment. Postponing the decarbonization of the electricity generation mix leads to significant long-term consequences. In the case of the RUPTL revision, even if the electricity mix RES share is higher by 5.4 percentage points compared to the previous version by 2025, the favorable impact on the cumulated CO_2 emissions appears only in 2028, three years after the completion of this plan. This exhibits the strong inertia in the decarbonization process of the energy system compared to a more ambitious DDPP scenario: by 2030, the cumulated reduction in CO_2 emission is about 600 $MtCO_2$ in the DDPP scenario against 30 $MtCO_2$ in the RUPTL scenario.

4.5 Decomposing volume and price effects

4.5.1 Approach

The analysis of scenario results may be difficult due to the amount of simultaneous effects. With the large sectorial disaggregation, the model has more than 20 000 endogenous variables which may leads to complex interactions between effects. Broadly speaking, the model embodies two types of effects. We define the first type as ***volume*** effects. They correspond to the effects on the real economy that is to the quantities of production, consumption, investment, imports, exports, labor, etc. In ThreeME, all these variables are linked because by definition the supply of a product (national production plus imports) is equal to the demand which is constituted from intermediary consumption (the consumption of goods by economic sectors), final (public and private) consumption, investment of sectors and exports. For instance, when the production of electricity increases, the production of other sectors increases because of the increase of intermediary consumption of the electricity sectors. This increase in the production of the other sectors generates in return additional intermediary consumption and therefore production. This is called the ***multiplier of intermediaries***. This multiplier is generally calculated by using standard Input-Output (IO) analysis consisting in the inversion of the Leontief matrix (see e.g. Miller & Blair, 1985). This type of analysis is often applied to analyze energy consumption patterns of economic activities (e.g. Ferreira Neto, Perobelli, & Bastos, 2014).

Since ThreeME is based on IO data, it can also be used to perform IO analysis. Compared to the standard approach, ThreeME has the advantage to easily allow for dynamics in the Leontief coefficients such as the change over time in the production mix of electricity due to the implementation of the New RUPTL plan. A second advantage is that ThreeME can derive other multiplier effects than the multiplier of intermediaries. A second multiplier is the ***multiplier of investment***: a higher production requires a higher level of capital and therefore additional investments. Finally, a third multiplier is the ***multiplier of consumption***: a higher production requires a higher level of labor which generates additional incomes that are partly spent in additional consumption. Using standard IO analysis to derive these multipliers is generally not possible because of the dynamics of capital accumulation and consumption. These cannot be derived through a simple matrix inversion but can only be dynamically simulated.

A third advantage of ThreeME is that it can go beyond the analysis of volume effects because it embodies also ***price*** effects. As a CGEM, ThreeME can therefore make the bridge between the IO analysis and the general equilibrium framework. Price effects are mainly defined through the interaction of two main economic behaviors, the wage and the price setting:

- Wages increase with prices and decrease with unemployment (Phillips curve hypothesis): see Section 8.4 for more detail.
- Prices are defined as a mark-up over the costs of production which means they increase with wages: See Section 8.6 for more detail.

This dynamic between prices and wages creates the inflation dynamic of the model. This dynamic has in return effects on volumes through substitutions mechanisms between production factors, between energy types, between commodities, between national and foreign productions.

Because price and volume effects interact between each other, it is sometimes difficult to analyze the results of a simulation. Therefore, it can be useful to define a procedure that allows for the decomposition of these effects. Here we apply one that consists in the five following steps:

- ***Step 1: Direct effect (without multipliers)***

  This simulation accounts only for the effects on the electricity producing sectors and assumes that the production of the other sectors, investment of all sectors and final consumption remain unchanged compared to the baseline scenario.

- ***Step 2: Effects Step 1 + Multiplier of intermediaries***

  In addition to the direct effects from Step 1, this simulation accounts also for indirect effects by taking into account the change in the production of the other sectors induced by the change in the electricity mix production. Investment of all sectors and final consumption remain unchanged compared to the baseline scenario.

- ***Step 3: Effects Step 2 + Multiplier of investment***

  In addition to the effects from Step 2, this simulation includes the effects related to the change in investments. Consumption remains unchanged compared to the baseline scenario. Change in the composition of sectors from Step 1 and changed demand for intermediate inputs from Step 2 creates an impulse for change in the amount of investment needed.

- ***Step 4: Effects Step 3 + Multiplier of consumption***

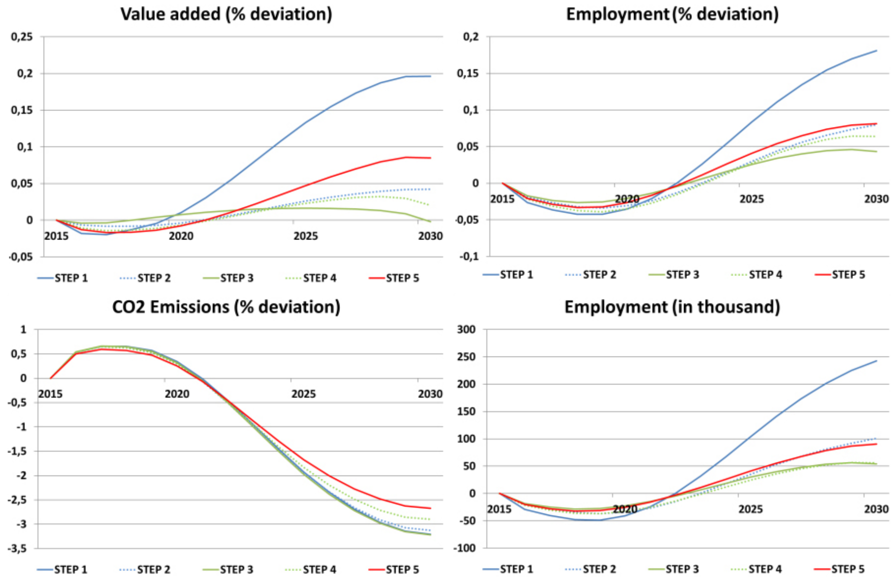
  In addition to the effects from Step 3, this simulation includes the effects related to the change in final consumption. Employment change induced by Steps 1-3 changes the disposable income for households and therefore changes the volume of consumption.

- ***Step 5: Effects Step 4 + Price effects***

  In addition to all the volume effects of Step 1 to 4, Step 5 includes the price effects by assuming prices as endogenous. This means that the equations defining prices are activated and that ThreeME is used as a CGEM. This allows for measuring the impact of the shock on inflation and the subsequent substitution mechanisms.

Each step corresponds to two simulations of ThreeME: simulation of the baseline and simulation of the RUPTL scenario. This scenario is suitable for this exercise because it is a shock affecting the volumes. Other type of scenario suitable would be a change in production or an increase in demand. But this decomposition is not possible for scenario involving the effect of a price signal (such as the implementation of a carbon tax or a reduction of subsidies).

Figure 42. Decomposition of effects (Revised RUPTL scenario)



Source: ThreeME, simulation based on the 2016-2025 RUPTL

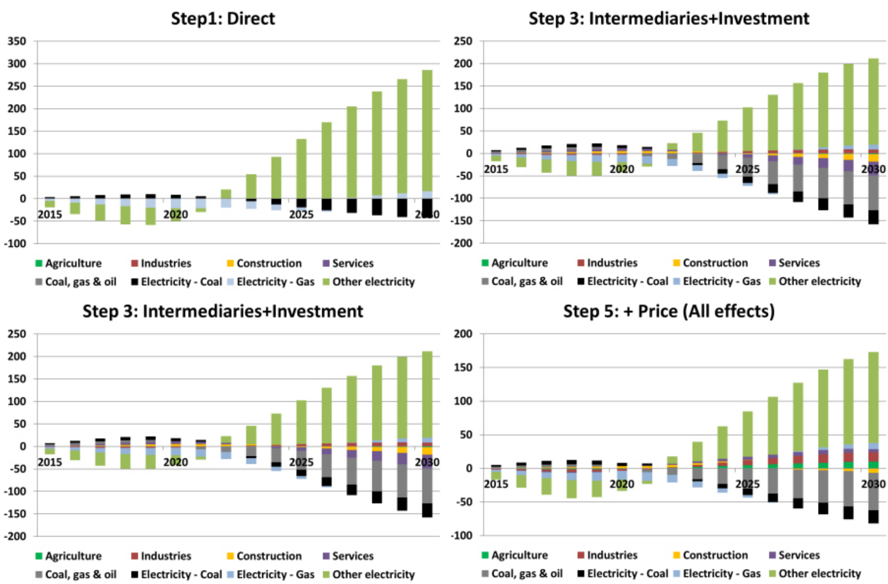
4.5.2 Results

Figure 42 above shows the results of the decomposition procedure presented in section 4.5.1 for certain indicators: value-added, employment and GHG emissions at the national level. According to this simulation, the RUPTL scenario has a positive impact on value-added and employment. The direct effects (step 1) leads to an increase of the value-added and employment of respectively 0.2 and 0.18 percent compared to the baseline scenario in 2030. This positive effect is however attenuated when the multiplier of intermediaries, of investment and of consumption are taken into account (see Step 2, 3, 4). This is due in this case to the relative lower demand addressed to the over fossil fuel sectors, labeled Coal, Gas and Oil which experienced a decrease of 78 000 employments by 2030 (See Figure 43). When all multipliers are taken into account (step 4), the evolution of value-added and of employment is respectively of -0.02 and 0.04 percent in 2030. The introduction of the prices effects does not change much the results (compare step 4 and step 5) because the aggregate economic effect of the RUPTL scenario is relatively small.

The decomposition of effects shows a similar pattern for GHG emissions for all steps. In general higher economic activity leads to higher CO_2 emissions because of the so-called rebound effect. But the effect is small. This is an illustration that the increase in GHG emissions is more related to the increase of the share of coal and gas plants than of the economic activity.

Figure 43 shows the decomposition of effects on sectorial employment. Unsurprisingly the direct positive impact on employment (Step 1) concerns the sectors of electricity production by Other Electricity (e.g. Hydrology, Geothermal, Wind Power & Solar Power) since the highest capacities are constructed in these technologies, w.r.t to the baseline. In step 3, the effect of the multiplier of intermediaries and investment is also taken into account. The sectors supplying the sectors of electricity production by coal and gas are the main losers: these are the coal, gas, oil and to a lower extent the services and construction sectors.

Figure 43. Direct and indirect employment per sectors



Source: ThreeME, simulation based on the 2016-2025 RUPTL

5 CONCLUSIONS

5.1 Simulation results

This report presented the simulation results of electricity scenarios using the ThreeME model. Compared to most technical energy models for Indonesia, ThreeME is able to measure the economic and environmental impact both on energy sectors and on the rest of the economy. We have focused the analysis on the simulation of three electricity scenarios. (1) The *baseline scenario* is based on the BPPT scenario derived from the *Energi Outlook Indonesia 2015*. It integrates the impact of the previous release of the RUPTL (2015-2024) on electricity production until 2024. In this scenario, the Indonesian electricity production until 2030 is expected to remain largely based on fossil energy. (2) The *2016-2025 RUPTL scenario* is still largely based on investments in coal power plants with more investments compared to the baseline until 2020. Compared to the previous release of the RUPTL, this scenario shows a clear reorientation toward the development of Renewable Energy Sources (RES) after 2020. (3) The *Deep Decarbonisation Pathways Project (DDPP) scenario* is more ambitious regarding the development of RES both regarding the implementation timing and the magnitude.

The main objective was to compare the economic and environmental impact of the 2016-2025 RUPTL and DDPP scenarios using the ThreeME model. The impact is measured relatively to the BPPT baseline scenario. Whereas the RUPTL scenario leads to an increase in emissions until 2020, the decrease in emissions in the DDPP scenario is immediate. Moreover, by 2025 and 2030, the magnitude of the effort is four times higher in the DDPP scenario compared to the RUPTL scenario (see Figure 39). This difference has a significant impact in terms of cumulated emissions, that is on the use of the "carbon budget". In the DDPP scenario, the reduction of cumulated emissions compared to baseline is immediate whereas it intervenes only after 2028 in the RUPTL scenario. By 2030, the cumulated reduction in CO_2 emissions is about 600 $MtCO_2$ in the DDPP scenario against 30 $MtCO_2$ in the RUPTL scenario (see Figure 41).

While the environmental impact is quite different between the two scenarios, we find that the global economic effect remains quite similar and rather small compared to the baseline scenario (see Table 11). This reflects partly the fact that the contributions to the global economy of electricity production based on RES and fossil fuel are not radically different. At the disaggregated level, differences between sectors in terms of investment, employment production are clearly visible but they tend to more-or-less compensate each other. It seems however that the development of the RES has a slightly more positive effect in terms of employment and value added compared to fossil fuel based electricity production. Therefore, the DDPP scenario has a small positive economic effect over the all simulation period compared to the baseline. The same is true for the RUPTL scenario but only after 2020 and the reorientation toward more RES.

These results suggest that actions against climate change can have a positive impact on the economy or at least neutral compared to certain fossil fuel based alternatives whereas the environmental impact is radically different. In the context of the COP21 Paris's agreement, this gives an additional support to national initiatives willing to invest in the decarbonization of the economy sooner rather than later.

Table 11. Main indicators for the RUPTL and DDPP scenarios

		RUPTL Scenario			DDPP Scenario		
Macroeconomic results		**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Real GDP	(a)	-0.01	0.03	0.07	0.27	0.53	0.62
Household consumption	(a)	-0.03	0.04	0.12	0.28	0.76	1.02
Investments	(a)	0.03	-0.02	-0.07	1.10	2.24	2.69
Exports	(a)	0.00	0.02	0.05	-0.04	-0.19	-0.34
Imports	(a)	0.00	-0.06	-0.10	0.34	0.78	1.01
Employment	(d)	-15.61	24.77	61.72	257.33	471.68	456.78
Real wage	(a)	-0.02	0.03	0.08	0.20	0.68	1.05
Price	(a)	-0.01	-0.06	-0.11	0.09	0.32	0.46
CO_2 Emissions	(a)	0.2	-1.1	-1.7	-1.6	-3.0	-4.1
CO_2 emissions index	(b)	121.2	159.5	227.8	119.3	156.7	222.7
Change in emissions index	(e)	-0.1	-2.1	-4.4	-2.0	-4.9	-9.6
Sectoral CO_2 emissions		**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Electricity - Coal	(f)	2.1	-8.7	-19.9	-19.9	-32.4	-72.0
Electricity - Gas	(f)	-1.0	-0.2	1.4	-0.6	0.9	2.8
Electricity - Fuel	(f)	0.1	-0.1	-1.5	7.5	9.2	10.1
Electricity (Total)	**(f)**	**1.3**	**-9.0**	**-20.0**	**-12.9**	**-22.3**	**-59.1**
Industry	(f)	-0.1	0.3	0.3	2.0	4.6	6.9
Other sectors	(f)	0.0	0.0	0.0	0.3	1.1	0.9
Energy (wt Electricity)	(f)	0.0	-1.4	-2.9	-1.0	-11.8	-5.4
Sectoral employment		**2015-2020**	**2020-2025**	**2025-2030**	**2015-2020**	**2020-2025**	**2025-2030**
Electricity - Coal	(g)	3.3	-1.9	-9.7	-11.6	-27.9	-37.2
Electricity - Gas	(g)	-6.4	-5.1	2.3	-6.0	1.2	9.3
Electricity - Fuel	(g)	0.1	0.1	-0.3	4.7	6.9	5.6
Electricity - Hydro	(g)	-3.9	8.9	26.3	12.9	34.0	54.2
Electricity - Geothermal	(g)	-11.3	4.6	34.9	26.1	50.0	65.4
Electricity - Solar	(g)	0.6	0.9	-0.3	29.7	79.1	94.7
Electricity - Wind	(g)	0.9	3.4	4.7	0.3	0.7	1.0
Electricity - Nuclear	(g)	0.0	0.0	-0.1	0.1	3.0	4.8
Total electricity	**(g)**	**-16.8**	**10.8**	**57.9**	**56.3**	**147.1**	**197.8**
Sectoral Investment		**2015-2020**	**2020-2025**	**2025-2030**	**2015-2020**	**2020-2025**	**2025-2030**
Electricity - Coal	(h)	2,050	-1,521	-9,952	-7,014	-20,978	-39,085
Electricity - Gas	(h)	-828	-754	269	-717	175	1,568
Electricity - Fuel	(h)	11	12	-56	988	1,567	1,607
Electricity - Hydro	(h)	-442	1,151	4,287	1,463	4,776	10,900
Electricity - Geothermal	(h)	-701	343	3,506	1,635	4,132	8,265
Electricity - Solar	(h)	470	785	-703	24,168	77,778	143,576
Electricity - Wind	(h)	291	1,430	2,912	94	294	602
Electricity - Nuclear	(h)	2	12	-946	1,016	19,749	48,842
Total electricity	**(h)**	**854**	**1,458**	**-682**	**21,634**	**87,493**	**176,276**

Legend: (a) Relative deviation in % to the baseline, (b) in index 2015=100, (c) in GDP % (deviation to the baseline), (d) in thousands (deviation to the baseline), (e) in index points (deviation to the baseline), (f) in $MtCO_2$, (g) in thousands in average on the period (deviation to the baseline), (h) in Rp. billions on the period (deviation to the baseline).

5.2 Next steps

The simulations conducted here only focused on scenarios for electricity production for two main reasons. First, the development of electricity infrastructures is a crucial issue for Indonesia both from a climate and development perspective. Second, this analysis has the advantage to put forward certain key characteristics of the ThreeME model, namely the link between economic activities and CO_2 emissions but also the link between economic sectors themselves. Compared to most energy models, ThreeME takes into account the impact of energy policies on all the sectors of the economy and not only on the targeted energy sectors. This way ThreeME can account for the effects of transfers of economic activities from one sector to another which is one of the main implication of energy transition policies. This allows for decomposing between the “winners” and the “looser” in terms of employment for instance and to derive the net impact.

Although the supply of electricity is potentially an important contributor to the decarbonisation of the economy, it only represents one part of the story. For this reason, the DDPP scenario, which was the most ambitious scenario with a 36.8 % emissions reduction between 2015 and 2030 in the electricity power generation, led to a global reduction of only 4.1%. Other important aspect for the decarbonisation of the economy are the demand for fossil fuel by sectors and households and the possibilities of substitution with other energy sources. These can be influenced by price incentives such as tax and subsidies. The recent reforms led by the Jokowi government to phase-out fuel subsidies can be seen as a first step on the pathway of a sustainable low-carbon economy and call for pursuing in this direction. As a general equilibrium model, ThreeME can investigate the impact of such incentives on the economy. As already done for Mexico for instance (Landa Rivera, Reynès, Islas Cortes, Bellocq, & Grazi, 2016), an extension of the current analysis would consist in measuring the impact of a reduction of fossil fuel subsidies and/or the implementation of a carbon tax. This could be done through measuring the level of carbon tax required to meet all the targets of the complete DDPP scenario under various hypotheses regarding the possibilities of substitutions and the recycling of tax revenues.

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7 APPENDIX A: METHODOLOGY FOR THE DISAGGREGATION OF THE ELECTRICITY SECTOR

7.1 Technologies for the electric sector

The data disaggregation of the electricity sector is divided into three major categories of energy: four renewable energy technologies, nuclear and three technologies based on fossil fuel. The main source of information is the *Handbook of Energy & Economic Statistics of Indonesia 2014*. Table 12 shows the final disaggregation.

Table 12. Installed capacities and generation by type of technology

	Capacity (MW)	Generation (MWh)	Generation (%)	Fuel
Hydro	5165.61	16930	7.83%	
Geothermal	1345.4	9414	4.36%	
Wind	0.63	1.4	0%	
Solar	9.02	5.59	0%	
Nuclear	0	0	0%	
Coal-based	22243.92	110452	51.10%	Coal
Fuel-based	6216.47	20333.8	9.41%	Petroleum products
Gas-based	15982.59	59009	27.30%	Natural gas
Total	50962	216145.8		

Source: ESDM, Handbook of Energy & Economic Statistics of Indonesia 2014

7.2 Employment

Due to a lack of data sources regarding the job content per technology for Indonesia, we used the methodology published by the Institute of Sustainable Future in its report *Calculating Global Energy Sector Jobs: 2012 methodology* (Rutovitz & Harris, 2012). Table 13 shows the data by technology type obtained in ThreeME.

Table 13. Employment by technology (in thousand)

Technologies	Fixed Jobs	Variable Jobs	Total Jobs	Total (%)
Coal	111219.62	111097.28	222316.90	54.72%
Gas	31965.18	45030.94	76996.12	18.95%
Fuel	12432.85	17514.78	29947.64	7.37%
Hydro	10331.22	48563.19	58894.41	14.49%
Geothermal	2690.80	15126.67	17817.47	4.39%
Solar	9.02	330.96	339.98	0.08%
Wind	1.26	3.39	4.65	0.00%
Nuclear	0.00	0.00	0.00	0.00%
Total	168649.95	237667.21	406317.17	100%

Source: ThreeME Indonesia based on Rutovitz, J. and Harris, S. 2012. Calculating global energy sector jobs: 2012 methodology. Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney

The methodology consists in using a series of indicators developed by Greenpeace International and the Institute for Sustainable Futures of the University of Technology Sydney, taking into account specific characteristics of different countries, including the analysis of the creation of permanent and variable jobs per installed capacity within the different electricity generation technologies.

Because the study does not contain specific information about Indonesia, it is considered that the conditions for the country are the value for "non-OECD Asia" for taking into account of local specificities (See Table 14).

The total percentage of total employment is given by:

$$ET = EF + EV$$

Where:

ET: Total jobs
EF: Fixed Jobs
EV: Variable jobs

a) ***Fixed jobs:*** permanent jobs generated by the operation and maintenance of existing capacity by technology type in the base year, which are referenced to the values published by the Organization for Economic Cooperation and Development (OECD)

$$EF = CER * fOM$$

Where:

EF : Permanent jobs generated by the operation and maintenance in the base year (Jobs)
CER : Installed capacity (MW)
fOM : Value of jobs per installed capacity (Jobs/MW)

b) ***Variable jobs:*** Those that are generated by the development of new projects considering the factors of jobs created by technology in line with the values reported by the OECD and regionalization factors specific for non-OECD Asia.

$$EV = \left(\frac{CER * fC * fRC}{ft} \right) + \left(\frac{CER * fM}{ft} \right)$$

Where:

EV : Temporary jobs created by the development of new projects (Jobs)
CER : Installed capacities (MW)
fC : Factor of jobs generated by the construction/installation (Jobs year/MW)
fM : Factor of jobs generated from the Manufacture (Jobs year/MW)
ft : Construction time (years)
fRC : Regional Adjustment Factor for manufacturing (years)

The regional adjustment values were calculated considering that the values for Indonesia are somewhere between "China" and "India", and that they grow linearly in the period 2015 - 2035, see Table 14.

Table 14. Regional adjustment factors for construction/installation indicators-

Reference	2015	2020	2035
Non-OECD Asia	3	2.3	1.4

Source: Rutovitz, J. and Harris, S. 2012. Calculating global energy sector jobs: 2012 methodology. Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney.
Key: in 2015, the number of job year per MW is 3 times higher than the one of OECD.

Table 15. OECD Factor of employment used in the global analysis 2012

Technologies	Construction	Construction/ Installation	Manufacture	O&M
	ft (years)	fC (Jobs year/ MW)	fM (Jobs year/MW)	fOM (Jobs / MW)
Coal	5	7.7	3.5	0.1
Gas	2	1.7	1	0.08
Fuel	2	1.7	1	0.08
Hydro	2	6	1.5	0.3
Geothermal	2	6.8	3.9	0.4
Solar	1	11	6.9	0.3
Wind	2	2.5	6.1	0.2
Nuclear	10	14	1.3	0.3

Source: Rutovitz, J. and Harris, S. 2012. Calculating global energy sector jobs: 2012 methodology. Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney

7.3 Capital stock

To obtain the distribution of the capital stock, we used the total installed capacity multiplied by the investment cost of each technology.

Table 16. Capital Stock in 2013

Technologies	Investment Costs ($US/MW)	Costs* MW ($US billion)	Stock (%)
Coal	1788000	14.84	40.39%
Gas	900000	9.14	24.88%
Fuel	1300000	5.87	15.98%
Hydro	1565000	5.34	14.53%
Geothermal	1808500	1.54	4.18%
Solar	2352000	0.01	0.04%
Wind	1590000	0	0.00%
Nuclear	4026000	0	0.00%
Total		**36.75**	**100.00%**

Source: ThreeME Indonesia based on COPAL 2013.

The stock of the electric sector is given by:

$$Sk = Ci * MW$$

Where:

Sk = Stock
Ci = Investment cost in terms of $US/MW
MW = Installed capacity in terms of MW in 2013

8 APPENDIX B: MAIN EQUATIONS OF THREEME

8.1 Specification of adjustment mechanisms

Unlike Walrasian models that assume that equality between supply and demand is achieved through a perfect flexibility of prices and quantities, ThreeME represents more realistically the functioning of the economy by taking into account explicitly the slow adjustment of prices and quantities (factors of production, consumption). In this Keynesian framework, permanent or transitory underemployment equilibria are possible and supply is determined by demand.

ThreeME assumes that the actual levels of prices and quantities gradually adjust to their notional level. The notional level corresponds to the optimal (desired or target) level that the economic agent in question (the company for prices and the demand for production factors, the household for consumption, the Central bank for the interest rate, etc.) would choose in the absence of adjustment constraints. These constraints mainly come from adjustment costs, physical or temporal boundaries and uncertainties. Formally, we assume that the adjustment process and expectations for prices and quantities are represented by the following equations:

$$\ln\left(X_t\right) = \lambda_0^X * \ln\left(X_t^n\right) + \left(1-\lambda_0^X\right) * \left(\ln\left(X_{t-1}\right) + \Delta\ln\left(X_t^e\right)\right) \quad (1)$$

$$\Delta\ln\left(X_t^e\right) = \lambda_1^X * \Delta\ln(X_{t-1}^e) + \lambda_2^X * \Delta\ln\left(X_{t-1}\right) + \lambda_3^X * \Delta\ln\left(X_t^n\right) \quad (2)$$

Where X_t is the actual value of a given variable (e.g. the production price, labor, capital, etc.), X_t^n is its notional level, X_t^e its anticipated value at period t and λ_1^X are the adjustments parameters (with $\lambda_1^X + \lambda_2^X + \lambda_3^X = 1$).

Equation (1) assumes a geometric adjustment process. Taking into account the anticipations guaranties that the actual variables converge to their notional levels in the long run. Equation (2) assumes that the anticipations are adaptive (« backward-looking »). One can see that Equations (1) and (2) can be reformulated into an Error Correction Model used in the econometric estimations to take into account the non-stationary propriety of some variables:

$$\Delta\ln\left(X_t\right) = \alpha_1 * \Delta\ln\left(X_{t-1}\right) + \alpha_2 * \Delta\ln\left(X_t^n\right) - \alpha_3 * \ln\left(\frac{X_{t-1}}{X_{t-1}^n}\right)$$

For this, the following constraints must hold:

$$\lambda_0^X = \alpha_3, \lambda_1^X = 0, \lambda_2^X = \alpha_1 / (1-\alpha_3), \lambda_3^X = (\alpha_2 - \alpha_3) / (1-\alpha_3)$$

We also assume that the substitution effects *(SUBST_X)* adjust slowly to the notional substitution effects *(SUBST_X^n)*:

$$SUBST\_X_t = \lambda_4^X * SUBST\_X_t^n + \left(1-\lambda_4^X\right) * SUBST\_X_{t-1} \quad (3)$$

The three equations above allow a rich set of adjustment as they integrate different types of rigidity (on prices and quantities, on expectations and on substitution mechanisms). For illustrative purposes, we present the full specification of the demand for labor *(L)*. For simplicity, the sector index is omitted. The notional labor demand *(L^n)* is derived by minimizing production costs (see Section 8.2). It depends positively on the level of the output *(Y)*, negatively on the labor productivity *(PROG_L)* and on an element gathering all the substitution phenomena with the other production factors *(SUBST_L):*

$$\Delta \ln\left(L_t^n\right) = \Delta \ln\left(Y_t\right) - \Delta \ln\left(PROG\_L_t\right) + \Delta SUBST\_L_t \quad (4)$$

We introduce a distinction between the actual and notional substitution effects to account for the fact that labor demand generally responds more quickly to changes in the level of production than to substitution phenomena: while it is "physically" necessary to increase employment to meet rising production, substitutions involve changes to the structure of production whose implementation takes longer. The actual substitution therefore adjusts gradually to the notional substitution *(SUBST_L^n)* which depends on the relative prices between the production factors:

$$\Delta SUBST\_L_t^n = -\eta^{LK} \varphi_{t-1}^K \Delta ln(C_t^L / C_t^K) - \eta^{LE} \varphi_{t-1}^E \Delta ln(C_t^L / C_t^E) \quad (5)$$

Where η^{LK}, η^{LE}, η^{LMat} are the elasticity of substitution between labor and the other production factors respectively capital, energy, material (i.e. non-energy intermediate consumption). φ^K, φ^E, φ^{Mat} are respectively the capital, energy and materials shares in the production costs. C^K, C^L, C^E, C^{Mat} are respectively the unitary costs of production of capital, labor, energy and material. The next section provides more information on the derivation of factors demands.

Finally, the adjustment mechanisms being defined according to the equations (1), (2) and (3), the three following relationships are used:

$$
\begin{aligned}
ln(L_t) &= \lambda_0^L * ln(L_t^n) + (1-\lambda_0^L) * (ln(L_{(t-1)}) + \Delta ln(L_t^e)) \\
\Delta \ln\left(L_t^e\right) &= \lambda_1^L * \Delta \ln\left(L_{t-1}^e\right) + \lambda_2^L * \Delta \ln\left(L_{t-1}\right) + \lambda_3^L * \Delta \ln\left(L_t^n\right) \\
SUBST\_L_t &= \lambda_4^L * SUBST\_L_t^n + \left(1-\lambda_4^L\right) * SUBST\_L_{t-1}
\end{aligned} \quad (6)
$$

8.2 The production function and the production factors demand

The production structure is decomposed into three levels (see Figure 20). The first one assumes a production function with 4 inputs (or production factors), often referred as KLEM (capital, labor, energy and materials). The first level has a fifth element: the transport and commercial margins. Stricto sensu, they cannot be considered as production factors since they intervene after the production process. Thus they are not substitutable with the production factors. But they are closely related to the level of production since once a good has been processed, it has to be transported and commercialized. At the second level, the investment, energy, material and margins aggregates are further decomposed by type of commodities (e.g. energy sources). At the third level, the demand for each factor or margin is either imported or produced domestically.

The demands for production factors are derived from the minimization of the firm's production costs. We assume a production function with constant returns-to-scale more general than the CES (Constant Elasticity of Substitution) insofar as substitution elasticities may differ between different inputs pair (Reynès, 2011). The production costs minimization program leads to the following equations for the notional factors demand. This holds for every economic activity, but for algebraic simplicity the sector index is omitted here:

$$\Delta \ln\left(FP_{j,t}^n\right) = \Delta \ln\left(Y_t\right) - \Delta \ln\left(PROG\_FP_{j,t}\right) + \Delta SUBST\_FP_{j,t} \quad (7)$$

$$\Delta SUBST\_FP_{j,t}^n = -\sum_{\substack{j'=1 \\ J'\neq j}}^{J} \eta_{j,j'} \varphi_{j',t-1} \Delta \ln\left(C_{j',t}^{FP} / C_{j,t}^{FP}\right)) \quad (8)$$

$$\text{with} \quad \varphi_{j,t-1} = \frac{C_{j,t}^{FP} * FP_{j,t-1}}{\sum_j C_{j,t}^{FP} * FP_{j,t-1}} \quad and \quad j = \left\{K, L, E, M\right\} \quad (9)$$

Where FP_j^n is the notional demand of input j (KLEM), $\eta_{j,j'}$ the elasticity of substitution between the pairs of inputs j and j', $PROG\_FP_{j,t}$ the technical progress related to input j, $C_{(j)}^{(FP)}$ the cost/price of input j and Y the level of production of the sector under consideration.

According to national accounts data, THREEME assumes that each commodity may be produced by more than one sector. For instance, electricity can be produced by several sectors such as nuclear or wind power. The production of each sector is defined by the following equations:

$$Y_{c,a} = \varphi_{c,a} YQ_c \qquad (10)$$

$$Y_a = \sum_c Y_{a,c} \qquad (11)$$

Where YQ_c is the aggregated domestic production of commodity c. It is determined by the demand (intermediate & final consumption, investment, public spending, exports and stock variation). $\varphi_{c,a}$ is then the share of commodity c produced by the sector a (with $\sum_a \varphi_{c,a} = 1$) and Y_a is the aggregated production of sector a.

8.3 Equations for investment & capital

Investment in ThreeME depends on the anticipated production, on its past dynamic, on substitution phenomena and on a correction mechanism, which guaranties that companies reach their level of long-term notional capital stock. The stock of capital is deducted from the investment according to the standard capital accumulation equation:

$$\Delta ln(IA_t) = \theta_1^I A * \Delta ln(IA_{(t-1)}) + \theta_2^I A * \Delta ln(Y_t^e)$$
$$+\theta_3^{IA}(\ln\left(K_{t-1}^n\right) - ln(K_{t-1})) + \Delta SUBST\_K_t \qquad (12)$$

$$K_t = \left(1-\delta^K\right) K_{t-1} + IA_t$$

Where *IA* is the investment, Y^e the anticipated production, *K* and K^n the actual and notional stocks of capital, *SUBST_K* a variable gathering substitution phenomena between capital and the other inputs, and δ^K the depreciation rate of capital. Moreover, we impose the constraint $\theta_1^{IA} + \theta_2^{IA} = 1$ in order to guaranty the existence of the stationary equilibrium path.

This specification is a compromise between the short-term dynamics empirically observed and the consistency of the model in the long run. Like the E-MOD or

MESANGE econometric models (Chauvin Valérie;Dupont, 2002; Klein & Simon, 2010), it is common to estimate an investment equation rather than capital stock equation for serval reasons. Firstly, time series capital stock data are often unreliable. Secondly, this approach better represents the short-term dynamics of investment. In particular, it avoids capital destruction phenomena (negative investment) that are in practice unusual, since companies generally prefer to wait for the technical depreciation of their installed capital. Unlike E-MOD or MESANGE, we assume in addition that investment depends on the difference between the actual and notional capital stock. This element ensures that the effective capital stock converges over time towards its notional level. In the long-term, the model is then consistent with the production function theory that establishes a relationship between the levels of production and capital stock (and not with the flow).

8.4 Wage equation

Several studies have shown that the theoretical arguments and empirical estimates difficultly allow choosing between the two specifications. However, this difference of specification has important implications on the definition of the equilibrium unemployment rate (NAIRU) and thus on the inflationary dynamic and the long-term proprieties of a macroeconomic model (e.g. L'Horty & Thibault, 1998 ; Chagny, Reynès, & Sterdyniak, 2002). In ThreeME, we choose a general specification that includes the Phillips and WS curves. It assumes that the notional nominal wage (W_t^n) positively depends on the anticipated consumption price (P_t^e) and on the labor productivity ($PROG\_L_t$), and negatively on the unemployment rate (U_t):

$$\Delta \ln(W_t^n) = \rho_1^W + \rho_2^W * \Delta \ln\left(P_t^e\right) + \rho_3^W * \Delta \ln\left(PROG\_L_t\right) - \rho_4^W U_t - \rho_5^W \Delta U_t \quad (13)$$

This relation can alternatively be identical, either to the Phillips curve, or to the WS curve depending on the value of the selected parameters (Heyer, Reynés, & Sterdyniak, 2007; Reynès, 2010). The Phillips curve corresponds to the case where $\rho_4^W > 0$ whereas the WS curve assumes $\rho_4^W = 0$. For the model to have a consistent steady-state in the long-run, the WS curve must also impose the constraints identified by Layard et al. (2005) : a unit indexation of wages on prices and productivity: ($\rho_2^W = \rho_3^W = 1$) and $\rho_1^W = 0$.

8.5 Equation of households' consumption

In the standard version of the model, consumption decisions are modeled through a ***Linear Expenditure System*** (LES) utility function generalized to the case of a non-unitary elasticity of substitution between the commodities Brown & Heien (1972). Households' expenditures for each commodity evolve (more or less) proportionally to their income:

$$\left(EXP_c^n - NEXP_c\right).PEXP_c = \beta_c^{EXP}\left[\left(1-MPS\right).DISPINC\_VAL - \sum_c PEXP_c * NEXP_c\right] \quad (14)$$

With $\sum_c \beta_c^{EXP} = 1$

Where $EXP_{c,h}^n$ corresponds to the volume of notional consumption (expenditures) in commodity c and $PEXP_c$ to its price $NEXP_c$ is the incompressible volume of expenditures in commodity c, $DISPINC\_VAL$ is the households' disposable income and MPS their marginal propensity to save.

In the case of no incompressible expenditures ($NEXP_c = 0$), households aim at allocating a share β_c^{EXP} of their total expenditure (in value), $\left(1-MPS\right).DISPINC\_VAL$, to commodity c. This share is constant if the elasticity of substitution between the commodities is equal to one (Cobb-Douglas assumption). In this case (Cobb-Douglas utility function without incompressible expenditures), commodity c expenditures stay exactly proportional to income. In the case of a CES function where the elasticity of substitution is $\eta^{(LES\_CES)}$, the marginal propensity to spend varies depending on the relative prices according to the following specification:

$$\Delta\beta_{c,t}^{EXP} = \left(1-\eta^{LES\_CES}\right) * \Delta\frac{PEXP_{c,t}}{PEXP_t^{CES}} \quad (15)$$

$$PEXP_t^{CES} = \left(\sum_c \beta_{c,0}^{EXP} * PEXP_{c,t}^{\left(1-\eta^{LES\_CES}\right)}\right)^{\frac{1}{1-\eta^{LES\_CES}}} \quad (16)$$

8.6 Equations of prices and of the mark-up rate

The production price for each sector is set at the lowest level by applying a mark-up over the unit cost of production (which includes labor, capital, energy and other intermediate consumption costs) :

$$PY_t^n = CU_t * \left(1+TMD_t\right) \quad (17)$$

$$\Delta\ln\left(1+TM_t^n\right) = \sigma^{TM} * \left(\Delta\ln\left(Y_t\right) - \Delta\ln\left(Y_{t-1}\right)\right) \quad (18)$$

$$TMD_t = \lambda^{TM} * TM_t^n + \left(1-\lambda^{TM}\right) * TMD_{t-1} \quad (19)$$

Where PY_t^n is the notional price CU_t, the unitary cost of production and Y_t the level of production. TMD_t and TM_t^n are respectively the desired and notional mark-up.

The equation of notional price is a behavioral equation: by assuming that the addressed demand to a firm is a negative function of its price, one can easily demonstrate that the optimal price corresponds to a mark-up over the marginal cost of production. The mark-up equation reflects the fact that the returns-to-scale are decreasing in the short-term. Therefore, a non-expected increase in production results into a higher marginal cost of production and therefore into a higher notional price.

The other prices are calculated according to their accounting definition and are therefore (directly or indirectly) a function of the producer price. The price of the domestically produced commodity c is a weighted average of the production prices of activities (indexed by a) producing that commodity. For example, the price of electricity is a weighted average of the production prices of the sectors producing electricity. The price paid by the final user (consumer, government, sector, rest of the world) integrates in addition the commercial and transportation margins, and the taxes net from subsidies. Combined with the price of imports, we get the average price for each commodity paid by each end user.

8.7 Equations of foreign trade

Exports are determined by the external demand addressed to domestic products and the ratio between the export and world prices:

$$\Delta \ln\left(X_{c,t}\right) = \Delta \ln\left(WD_{c,t}\right) + \Delta SUBST\_X_{c,t}$$
$$\Delta SUBST\_X_{c,t}^n = -\eta^X * \Delta \ln\left(P_{c,t}^X / P_{c,t}^W / TC_t\right) \qquad (20)$$

Where $WD_{c,t}$ is the world demand, $P_{c,t}^W$ its price. $P_{c,t}^X$ is the export price that depends on the production costs and which reflects the price-competitiveness of the domestic products. TC_t is the exchange rate; η^X is the price-elasticity (assumed constant).

We assume imperfect substitution between domestic and imported goods (Armington, 1969). The demand for domestic and imported products is :

$$\Delta \ln\left(A_{c,t}^D\right) = \Delta \ln\left(A_{c,t}\right) + \Delta SUBST\_AD_{c,t} \qquad (21)$$
$$\Delta SUBST\_AD_{c,t}^n = \eta_c^A * \Delta \ln\left(P_{c,t}^{AD} / P_{c,t}^{AM}\right) * \frac{P_{c,t-1}^{AM} * A_{c,t-1}^M}{P_{c,t-1}^A * A_{c,t-1}}$$
$$A_{c,t}^M = A_{c,t} - A_{c,t}^D$$

Where $A_{c,t}$ represents the demand for each type of use (intermediary consumption, investment, consumption, public spending, exports, etc.), $P^{A}_{(c,t)}$ is its price. $A^{M}_{c,t}$ and $A^{D}_{c,t}$ are the imports and the domestic products demanded for each type of use A, $P^{AM}_{c,t}$ and $P^{AD}_{c,t}$ are their respective prices. The elasticity of substitution η^{A}_{c} by type of use A of a given commodity c can potentially be different, which allows a high degree of flexibility.

9 APPENDIX C: CONSTRUCTION OF THE DATABASE

The IRSAM macroeconomic database has 35 economic sectors and corresponding goods at the regional level. Unfortunately, the energy sectors have insufficient detail for the analysis we want to conduct for several reasons:

(a) Certain energy sectors are grouped with other sectors (e.g. electricity and Gas are with Drinking Water) and should therefore be separated

(b) Other energy sectors are scattered in different sectors (e.g. oil and gas are both in mining and refinery) and should therefore be regrouped

(c) The electricity sector is not disaggregated by technology

The original segmentation is exposed in the table below. Sectors from primaries activities are in green, from secondary sector in yellow and tertiary are in blue. The activities that we are looking for more disaggregation are colored in grey and are all including the energy production activities.

Table 17. Original Sectoral segmentation from the IRSAM database

1	Paddy	13	Textiles	25	Electricity, Gas and Drinking Water
2	Other Foodcrops	14	Foot and Leather	26	Construction
3	Estatecrops	15	Wood Processing	27	Trade
4	Livestock	16	Pulp and Paper	28	Hotel and Restaurant
5	Forestry	17	Rubber Processing	29	Land Transportation
6	Fishery	18	Petrochemical	30	Water Transportation
7	Oil, Gas and Geothermal Mining	19	Cement	31	Air Transportation
8	Coal and Other Mining	20	Basic Metal	32	Communications
9	Refinery	21	Metal Processing	33	Finance
10	Oil Palm	22	Electricity Machinery	34	Public Services
11	Fish Processing	23	Transport Equipment	35	Other Services
12	Food and Drink Processing	24	Other Industries		

Source: IRSAM database

This segmentation choice is not compatible with the outcome we are looking for, which is to identify the macroeconomic impacts and spillover effects of a low carbon growth strategy. For the disaggregation we used a database which has been produced for assessing the different energy mixes at the provincial level using the LEAP25 software. This database has been produced in the scheme of the USAID ICED project (Indonesian Clean Energy Development). This is a complete database on the energy systems defined for each of the 32 Indonesian provinces, which provides the required information on the bottom-up part of the model.

9.1 The determination of the ponderation values

The assignment of values to the ponderation shares is not resulting from calculations but is resulting to an estimation work that has been mainly conducted by the CEDS based on other Social Accounting Matrices databases for Indonesia.

For the decomposition of the energy sectors, we used the energy data (see the Appendix A for more details)

9.2 Data source

The database construction for ThreeME is partly based on existing databases. The **IRSAM macroeconomic database** has been originally published in the context of the IRSA-5 model project, on which CEDS has been playing a key role. This database has the particularity to combine a regional segmentation into 5 regions with a sectorial segmentation into 35 sectors of the national accounting tables which is the only one in the Indonesian statistics to provide such features.

The second main data source comes from the technical-economic study that has been conducted within the frame of the **ICED project** funded by USAID. This database gives extensive information for the 35 Indonesian provinces on their energy supply as the determinants of the energy demand. The electricity production is disaggregated per technology of production. It has the advantage that it can be used to calibrate the base year but also the baseline and alternative scenarios. An example of the evolution of the electricity mix is given below:

The calibration of the energy block is relying on different statistical sources:

- The calibration at the base year is based on the statistics from the Handbook of Energy and Economics Statistics of Indonesia 2006 which allows us to calibrate the electricity production mix and their related capacities of production at the base year.

25 The Long-Range Energy Alternative Planning System is a built-in tool that allows creating projections of energy systems.

- We also use the energy production calibration at the year 2013 (the most recent available information) in order to assess the evolution of the energy production between 2005 and 2013 and on which we can construct the realist baseline scenario up to this date.
- We also use the prospective work that BPPT conducted in the realization of the Outlook Energi Indonesia 2015 which gives insights on the structure of the electricity production baseline and its evolution by 2050.
- In order to have regional energy production scenarios, we match the national electricity mix with the regional LEAP database. We took from this database the regional share for each type of energy production technology and as control variable the national electricity mix BPPT.

The determination of the production factor intensity per technology rests upon three set of parameters

- The capital intensity depends on two variables; the depreciation rate for each technology[26] and the investment cost. The first parameter's set yields on usual observed depreciation rates observed for the considered electricity production technology. The second parameter, the cost of investment per MW is derived from international studies that has been used to the ThreeME Mexico project because of lack of information relative to this question which can be assumed to be relatively comparable to Indonesia to some extent.
- The labor intensity is constructed according to the methodology developed by Rutovitz & Harris (2012) that takes into account specific characteristics of different countries, including the analysis of the creation of permanent and variable jobs within the different electricity generation technologies 27
- The intermediate consumption intensity per technology has been determined by CEDS. Following national accounting database on the energy sectors.

9.3 Calibration steps

The construction of the database for the ThreeME Indonesian version from the raw data requires several steps in order to be useable by the model. A **first step** consists in decomposing the Inter-Regional Social Matrix (which is a 325 x 325 matrix) into 5 distinct regions and a matrix of regional transfers for all the variables (final consumption, intermediate consumption, stock variation and monetary transfers). In this step, the database should be adapted in order to fit the template used by the ThreeME model. In particular, we have to take care about some definition issues related to taxes,

26 The depreciation rate is also the inverse of the supposed life expectancy of a power plant
27 We have chosen to use these data, because of lack of available information to the Indonesian country.

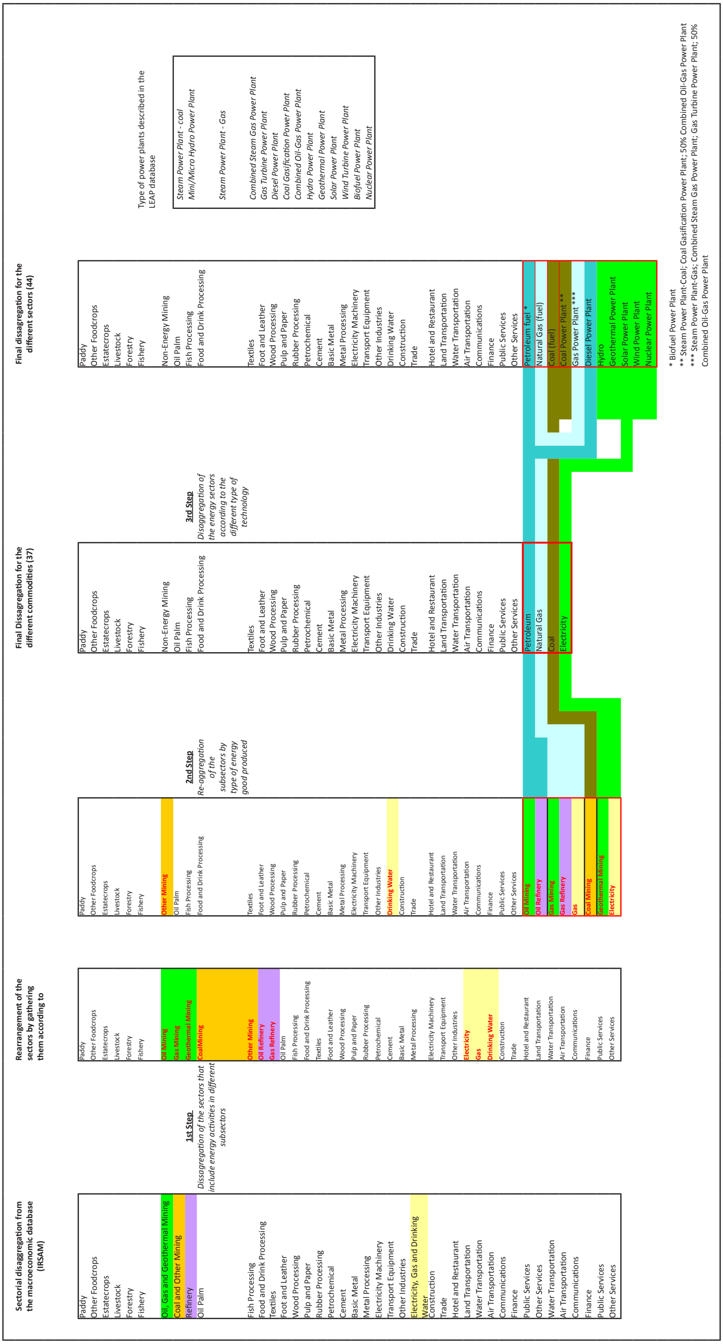
commercial and transport margins and transfers between agents. After this first step the model can technically run for each region considered as separate countries with the sectorial segmentation of the IRSAM database. But since this database does not identify properly energy sectors, further data treatment is required for the model to conduct meaningful analysis.

Therefore, the **second step** consists in disaggregating further the energy sectors. It consists in the matching of the IRSAM and LEAP databases in order to have a final disaggregation that encompasses the different energy production technologies as independent sectors. Beyond the constraint to keep the macroeconomic consistency with the decomposition of some of the sectors of the economy, this task requires confronting other data sources to calibrate more precisely the economic features of the energy sectors (in particular regarding the disaggregation by sectors of intermediary consumption, capital stock, labor, etc.).

As an illustration, Figure 44 shows the different **sub-steps** followed to go from the 35 sectors of IRSAM to the 44 sectors finally retained in ThreeME:

1. Disaggregation into subsectors of the IRSAM sectors that include (partly or totally) activities related to energy production (i.e. resources extraction, refining, distribution).
2. Re-aggregation of the previous created subsectors on the base of the type of the energy commodity produced (natural gas, fuel, coal or electricity).
3. Disaggregation of the electricity sector into 8 type of production technology. Compared to the LEAP database, we have regrouped the technologies using the same primary sources. For instance, Electricity - Gas regroup different type of gas power plant identified in LEAP: (Combined) Steam, Turbine, Combined Oil-Gas.

Figure 44: Steps followed for the construction of the ThreeME database



Source: ThreeME database

10 APPENDIX D. CALIBRATION OF THE CO_2 EMISSIONS

10.1 The CO_2 Emissions calibration

The calibration of the CO_2 emissions in the model is the result of a combination between different sources. This disaggregation has been made onto several dimensions which are, at the sectoral level and the regional level. In order to avoid perimeter issues and miscounting in the total amount of $C0_2$ emissions resulting from the combustion of fossil fuels, we control the total volume of $C0_2$ emissions communicated in the *Second National Communication to the UNFCCC* and derived relative shares parameters from the LEAP database to affect the emissions per source and geographical origin. The present Appendix presents the methodology we have followed to calibrate emissions for the ThreeME model.

We have taken as main reference regarding the total volume of the emissions resulting from the energy use the second national communication to the UNFCCC issued in 2011 and inventorying the Indonesian GHG emissions for the date 2005 (which is also the base year in the model).

Since fossil fuels emissions are resulting from their combustion, we only consider CO_2 emissions and do not take other type of GHG gases in the considered emissions in ThreeME. The following table indicates the total volume per year and by type of gases the GHG emissions from energy sectors.

Table 18: Energy sectors emissions from 2000 to 2005 by gas ($GgCO_2e$)

Type of Gases	2000	2001	2002	2003	2004	2005
CO_2	247.522	274.145	296.08	303.086	341.536	339.426
CH_4	30.175	29.263	28.366	27.315	26.662	26.711
N_2O	3.241	3.367	3.464	3.549	3.924	3.663
Total ($GgCO_2e$)	280.938	306.774	327.911	333.95	372.123	369.8

Source: Indonesia Second National Communication under the UNFCCC, Ministry of Environment, 2011

However, we do not have the disaggregation by source neither by region which has led us therefore to use the LEAP database to determine the relative share in CO_2 emissions. To be noted that in the LEAP database, there is a distinction between emissions from *"demand side"* and "supply-side" which is not same concept as in economics. To our understanding, *"demand side"* refers to emissions resulting from private agents (households and government) and non-energy sectors, whereas "supply side" yields to the different producing energy sectors. The emissions shares, per region and per source is given in the Table 19.

Table 19: Regional shares of direct CO_2 emissions from combustion

	Java-Bali	Sumatra	Kalimantan	Sulawesi	East Indonesia	TOTAL
Gas	12,02%	2,03%	0,31%	0,67%	0,01%	**15,04%**
Fuel	31,13%	3,25%	12,02%	4,33%	6,77%	**57,49%**
Coal	8,54%	17,15%	0,16%	0,80%	0,83%	**27,47%**
TOTAL	**51,68%**	**22,42%**	**12,49%**	**5,80%**	**7,61%**	**100%**

Source: LEAP database, ICED project

$$EMS_{ems,a} = \varphi_{ems,a}^{ENER\_CONS} . \varphi_{ems,a}^{ENER\_CONS} . EMS^{TOT}$$

$EMS_{ems,reg}^{LEAP\_D}$: Total amount of emissions from the source ***ems*** resulting from non-energy producing sectors in the region ***reg***.

$EMS_{ems,reg}^{LEAP\_S}$: Total amount of emissions from the source ***ems*** resulting from energy producing sectors in the region ***reg***.

EMS^{UNFCCC} : Total amount of CO_2 emissions from energy use given in the official document "***Second national communication to the UNFCCC***"

$EMS_{a,ems}^{REG}$ *:* Emissions for each region from economic activities a and per source *ems*

$$\varphi_{ems,reg}^{LEAP\_S} = \frac{EMS_{ems,reg}^{LEAP\_S}}{EMS^{LEAP\_S}}$$

$$\varphi_{ems,reg}^{LEAP\_D} = \frac{EMS_{ems,reg}^{LEAP\_D}}{EMS^{LEAP\_D}}$$

Table 20: CO_2 emissions per region and source for 2005

	Java-Bali	Sumatra	Kalimantan	Sulawesi	East Indonesia	TOTAL
Gas	40,782.07	6,885.79	1,053.48	2,278.76	42.52	51,042.62
Fuel	105,649.39	11,021.84	40,786.22	14,707.59	22,966.70	195,131.74
Coal	28,980.57	58,200.79	543.89	2,706.34	2,820.05	93,251.64
TOTAL	175,412.03	76,108.43	42,383.59	19,692.69	25,829.27	339,426.00

Source: LEAP databased from ICED project, 2nd national communication and authors' calculations

$\varphi_{ems,a}^{ENER\_CONS\_D}$: Relative share of the energy consumption per sector (including Households and the Government) in the total

$$EMS_{a,ems,reg}^{D} = \varphi_{ems,a}^{ENER\_CONS\_D} . \varphi_{ems,reg}^{LEAP\_D} . EMS^{UNFCCC}$$

$$EMS_{a,ems,reg}^{S} = \varphi_{ems,a}^{ENER\_CONS\_S} . \varphi_{ems,reg}^{LEAP\_S} . EMS^{UNFCCC}$$

We verify that identity holds in the calibration

$$EMS^{UNFCCC} = \sum_{reg}\sum_{ems}\sum_{a}\left(EMS_{a,ems,reg}^{S} + EMS_{a,ems,reg}^{SD}\right)$$

10.2 Carbon intensity of the Indonesian economy

We provide in this section the estimated carbon intensity of the Indonesian economy through two tables. The first one exhibits the added value created per sector for one ton of carbon emitted, the second presents the production created for one ton of carbon. We find an average production of 1280 $ per ton of $C0_2$ emitted which is line with estimations from International Energy Agency (find source).

The analysis through an emissions intensity index is quite useful to compare some activities with others. We propose an index of dispersion that inform on the relative carbon efficiency with the overall economy. The Carbon Intensity Dispersion Index (CIDI) is defined as follow:

$$CIDI_a = \frac{VA_a}{VA} \Big/ \frac{EMS_a}{EMS} = \frac{\varphi_a^{VA}}{\varphi_a^{EMS}}$$

The total economy CIDI is equal to one and sectors which are particularly carbon intensive are below 1 whereas the relative less carbon intense sectors are above 1. The tables below provide the index values for the added value and the production.

	Added Value	Added value created per ton of CO2 emitted (in M IDR/ton)	Added value created per ton of CO2 emitted (in $/ton)
Paddy	78,562,123	41,043	3,420,260
Other Foodcrops	105,985,939	2,822	235,144
Estatecrops	91,067,577	134	11,192
Livestock	47,136,818	878	73,163
Forestry	25,422,173	20	1,673
Fishery	49,699,589	32	2,632
Oil Palm	18,243,902	743	61,914
Non-Energy Mining	72,461,949	13	1,124
Fish Processing	14,720,443	311	25,926
Food and Drink Processing	137,854,005	74	6,178
Drinking water	6,465,606	5	401
Textiles	51,240,119	22	1,809
Foot and Leather	13,888,851	152	12,662
Wood Processing	34,537,340	11	943
Pulp and Paper	48,859,653	18	1,512
Rubber Processing	23,125,744	6	511
Petrochemical	42,434,915	2	193
Cement	8,992,381	0	16
Basic Metal	12,938,995	1	94
Metal Processing	8,461,112	2	139
Electricity Machinery	40,940,722	40	3,351
Transport Equipment	47,290,485	85	7,071
Other Industries	15,016,103	1	105
Construction	121,824,153	6	509
Trade	375,325,648	64	5,326
Hotel and Restaurant	81,310,744	184	15,351
Land Transportation	67,510,227	7	561
Water Transportation	21,097,702	3	266
Air Transportation	13,102,728	2	184
Communications	60,009,518	37	3,059
Finance	212,257,477	225	18,780
Public Services	117,698,787	117,698,787	9,808,232,253
Other Services	115,281,338	83	6,888
Petroleum fuel	220,768,234	4	338
Natural Gas (fuel)	42,146,444	2	152
Coal (fuel)	15,799,077	1	104
Electricity - Coal	17,459,268	1	43
Electricity - Gas	14,381,457	1	107
Electricity - Fuel	- 4,186,924	- 0	- 25
Electricity - Hydro	8,060,552	8,060,552	671,712,697
Electricity - Geothermal	2,748,517	38	3,183
Electricity - Solar	2,586	2,586	215,490
Electricity - Wind	652	652	54,335
Electricity - Nuclear	0	0	27
Total	2,497,944,729	7	613

	Production	Production created per ton of CO2 emitted (in IDR/Ton)	Production created per ton of CO2 emitted (in $/Ton)
Paddy	89,381,671	46,696	3,891,297
Other Foodcrops	116,618,727	3,105	258,734
Estatecrops	120,826,190	178	14,850
Livestock	91,165,668	1,698	141,503
Forestry	32,574,090	26	2,143
Fishery	64,138,620	41	3,397
Oil Palm	97,900,791	3,987	332,244
Non-Energy Mining	93,953,348	17	1,457
Fish Processing	49,474,838	1,046	87,136
Food and Drink Processing	496,267,421	267	22,241
Drinking water	13,435,852	10	834
Textiles	181,184,783	77	6,396
Foot and Leather	31,047,684	340	28,305
Wood Processing	106,894,835	35	2,919
Pulp and Paper	120,925,964	45	3,743
Rubber Processing	99,845,087	26	2,205
Petrochemical	116,093,475	6	527
Cement	27,220,081	1	48
Basic Metal	44,106,690	4	320
Metal Processing	31,280,761	6	512
Electricity Machinery	185,937,178	183	15,221
Transport Equipment	152,256,759	273	22,765
Other Industries	75,871,022	6	531
Construction	380,429,950	19	1,589
Trade	583,847,298	99	8,285
Hotel and Restaurant	208,039,503	471	39,276
Land Transportation	162,604,847	16	1,352
Water Transportation	64,722,747	10	817
Air Transportation	74,911,841	13	1,053
Communications	84,298,439	52	4,297
Finance	282,878,316	300	25,028
Public Services	117,698,787	117,698,787	9,808,232,253
Other Services	203,505,465	146	12,160
Petroleum fuel	349,029,481	6	534
Natural Gas (fuel)	110,464,789	5	400
Coal (fuel)	36,423,740	3	240
Electricity - Coal	48,646,968	1	120
Electricity - Gas	38,586,740	3	287
Electricity - Fuel	16,235,695	1	98
Electricity - Hydro	10,063,379	10,063,379	838,614,894
Electricity - Geothermal	6,204,948	86	7,186
Electricity - Solar	3,211	3,211	267,587
Electricity - Wind	804	804	67,028
Electricity - Nuclear	0	0	34
Total	5,216,998,484	15	1,281

Source: ThreeME calibration

	Share of activities Added Value	Share of activities CO2 emitted	Indice of intensity carbon
Paddy	3.15%	0.00%	5,577.03
Other Foodcrops	4.24%	0.01%	383.42
Estatecrops	3.65%	0.20%	18.25
Livestock	1.89%	0.02%	119.30
Forestry	1.02%	0.37%	2.73
Fishery	1.99%	0.46%	4.29
Oil Palm	0.73%	0.01%	100.96
Non-Energy Mining	2.90%	1.58%	1.83
Fish Processing	0.59%	0.01%	42.27
Food and Drink Processing	5.52%	0.55%	10.07
Drinking water	0.26%	0.40%	0.65
Textiles	2.05%	0.70%	2.95
Foot and Leather	0.56%	0.03%	20.65
Wood Processing	1.38%	0.90%	1.54
Pulp and Paper	1.96%	0.79%	2.47
Rubber Processing	0.93%	1.11%	0.83
Petrochemical	1.70%	5.41%	0.31
Cement	0.36%	14.04%	0.03
Basic Metal	0.52%	3.38%	0.15
Metal Processing	0.34%	1.50%	0.23
Electricity Machinery	1.64%	0.30%	5.46
Transport Equipment	1.89%	0.16%	11.53
Other Industries	0.60%	3.51%	0.17
Construction	4.88%	5.88%	0.83
Trade	15.03%	1.73%	8.68
Hotel and Restaurant	3.26%	0.13%	25.03
Land Transportation	2.70%	2.95%	0.92
Water Transportation	0.84%	1.94%	0.43
Air Transportation	0.52%	1.75%	0.30
Communications	2.40%	0.48%	4.99
Finance	8.50%	0.28%	30.62
Public Services	4.71%	0.00%	NO CO2
Other Services	4.62%	0.41%	11.23
Petroleum fuel	8.84%	16.05%	0.55
Natural Gas (fuel)	1.69%	6.79%	0.25
Coal (fuel)	0.63%	3.73%	0.17
Electricity - Coal	0.70%	9.95%	0.07
Electricity - Gas	0.58%	3.30%	0.17
Electricity - Fuel	-0.17%	4.07%	- 0.04
Electricity - Hydro	0.32%	0.00%	NO CO2
Electricity - Geothermal	0.11%	0.02%	5.19
Electricity - Solar	0.00%	0.00%	NO CO2
Electricity - Wind	0.00%	0.00%	NO CO2
Electricity - Nuclear	0.00%	0.00%	NO CO2
Total	100%	100.00%	1.00

	Share of activities production	Share of activities CO2 emitted	Indice of intensity carbon
Paddy	1.71%	0.00%	3,038.09
Other Foodcrops	2.24%	0.01%	202.00
Estatecrops	2.32%	0.20%	11.59
Livestock	1.75%	0.02%	110.48
Forestry	0.62%	0.37%	1.67
Fishery	1.23%	0.46%	2.65
Oil Palm	1.88%	0.01%	259.40
Non-Energy Mining	1.80%	1.58%	1.14
Fish Processing	0.95%	0.01%	68.03
Food and Drink Processing	9.51%	0.55%	17.36
Drinking water	0.26%	0.40%	0.65
Textiles	3.47%	0.70%	4.99
Foot and Leather	0.60%	0.03%	22.10
Wood Processing	2.05%	0.90%	2.28
Pulp and Paper	2.32%	0.79%	2.92
Rubber Processing	1.91%	1.11%	1.72
Petrochemical	2.23%	5.41%	0.41
Cement	0.52%	14.04%	0.04
Basic Metal	0.85%	3.38%	0.25
Metal Processing	0.60%	1.50%	0.40
Electricity Machinery	3.56%	0.30%	11.88
Transport Equipment	2.92%	0.16%	17.77
Other Industries	1.45%	3.51%	0.41
Construction	7.29%	5.88%	1.24
Trade	11.19%	1.73%	6.47
Hotel and Restaurant	3.99%	0.13%	30.66
Land Transportation	3.12%	2.95%	1.06
Water Transportation	1.24%	1.94%	0.64
Air Transportation	1.44%	1.75%	0.82
Communications	1.62%	0.48%	3.36
Finance	5.42%	0.28%	19.54
Public Services	2.26%	0.00%	NO CO2
Other Services	3.90%	0.41%	9.49
Petroleum fuel	6.69%	16.05%	0.42
Natural Gas (fuel)	2.12%	6.79%	0.31
Coal (fuel)	0.70%	3.73%	0.19
Electricity - Coal	0.93%	9.95%	0.09
Electricity - Gas	0.74%	3.30%	0.22
Electricity - Fuel	0.31%	4.07%	0.08
Electricity - Hydro	0.19%	0.00%	NO CO2
Electricity - Geothermal	0.12%	0.02%	5.61
Electricity - Solar	0.00%	0.00%	NO CO2
Electricity - Wind	0.00%	0.00%	NO CO2
Electricity - Nuclear	0.00%	0.00%	NO CO2
Total	100%	100.00%	1.00

Source: ThreeME calibration