

pathways to
deep decarbonization

2014 report

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Preface

The Deep Decarbonization Pathways Project (DDPP) is a collaborative initiative, convened under the auspices of the Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI), to understand and show how individual countries can transition to a low-carbon economy and how the world can meet the internationally agreed target of limiting the increase in global mean surface temperature to less than 2 degrees Celsius (°C). Achieving the 2°C limit will require that global net emissions of greenhouse gases (GHG) approach zero by the second half of the century. This will require a profound transformation of energy systems by mid-century through steep declines in carbon intensity in all sectors of the economy, a transition we call “deep decarbonization.”

Currently, the DDPP comprises 15 Country Research Partners composed of leading researchers and research institutions from countries representing 70% of global GHG emissions and different stages of development. Each Country Research Partner has developed pathway analysis for deep decarbonization, taking into account national socio-economic conditions, development aspirations, infrastructure stocks, resource endowments, and other relevant factors. The pathways developed by Country Research Partners formed the basis of the DDPP 2014 report: *Pathways to Deep Decarbonization*, which was developed for the UN Secretary-General Ban Ki-moon in support of the Climate Leaders' Summit at the United Nations on September 23, 2014. The report can be viewed at deepdecarbonization.org along with all of the country-specific chapters.

This chapter provides a detailed look at a single Country Research Partner's pathway analysis. The focus of this analysis has been to identify technically feasible pathways that are consistent with the objective of limiting the rise in global temperatures below 2°C. In a second—later—stage the Country Research Partner will refine the analysis of the technical potential, and also take a broader perspective by quantifying costs and benefits, estimating national and international finance requirements, mapping out domestic and global policy frameworks, and considering in more detail how the twin objectives of development and deep decarbonization can be met. This comprehensive analysis will form the basis of a report that will be completed in the first half of 2015 and submitted to the French Government, host of the 21st Conference of the Parties (COP-21) of the United Nations Framework Convention on Climate Change (UNFCCC).

We hope that the analysis outlined in this report chapter, and the ongoing analytical work conducted by the Country Research Team, will support national discussions on how to achieve deep decarbonization. Above all, we hope that the findings will be helpful to the Parties of the UNFCCC as they craft a strong agreement on climate change mitigation at the COP-21 in Paris in December 2015.

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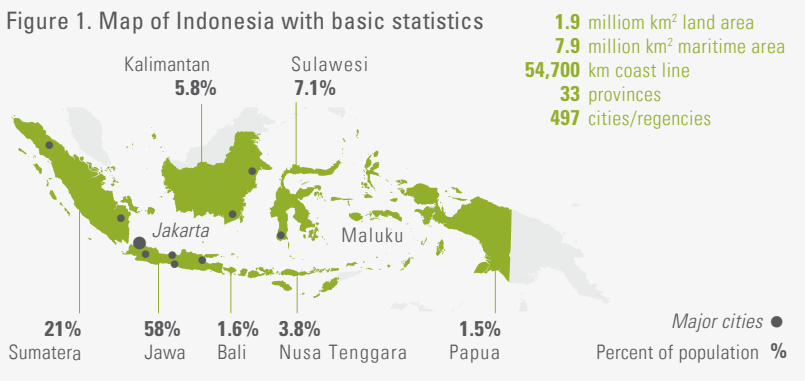
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1 Country profile

1.1 The national context for deep decarbonization and sustainable development

Indonesia is the largest archipelago in the world. Located between the Pacific and the Indian Oceans, it bridges two continents: Asia and Oceania. It consists of approximately 17,000 islands with a population of 234 million. The majority (almost 80%) of Indonesians live in the Western part of Indonesia on the islands of Jawa and Sumatera (see [Figure 1](#)). Fossil fuels have historically been the major source of energy in Indonesia. Out of the 189 Mtoe of primary energy supply in 2011, oil accounts for almost half at 46.3%. The remainder is provided by coal (26.1%), natural gas (20.4%), commercial biomass (3.4%), hydro (2.4%), and geothermal (1.3%). In addition to this commercial energy, traditional biomass is still used for cooking in rural areas. The major energy consumers in Indonesia are industry (46.1%) and transport (35.6%). The remaining 18.3% is shared by residential (11%), commercial (4.2%), and agriculture, mining and construction (3.2%). The majority of final energy consumption is in the form of fuels (oil, coal, gas, and biomass comprise 88%), and the remaining 12% of final energy is provided as electricity. Indonesia's electrification rate (the percent of the population with access to electricity) is around 78%, with a low per capita annual consumption of 660 kWh/capita. Given that the country is an archipelago with many islands and remote rural communities, a

Figure 1. Map of Indonesia with basic statistics



large number of Indonesians do not have access to electricity. Fossil fuels are the dominant source of energy for electricity generation; coal, natural gas, and oil respectively represent 42%, 32%, and 12% of the generation mix. The remaining 13% is provided by hydropower (8%) and geothermal (5%). Indonesia developed with this dependency on fossil fuels in part because of the country's energy resource endowment, which includes 120 billion tons of coal, 8 billion barrels of oil, and 150 Trillion Standard Cubic Feet (TSCF) of natural gas. In addition to fossil energy, Indonesia is also endowed with renewable energy resources, including 75 GW of hydro,¹ 29 GW of geothermal, 50 GW of biomass, and solar energy potential of 4.5 kWh/m²/day.

Indonesia is a developing nation with a GDP of 847 billion US\$ (2012). The per capita GDP in 2012 was 3,592 US\$. Over the past 5 years, the country's annual economic growth fluctuated between 4.3% and 5.9%. The Indonesian economy has shifted from one that was highly dependent on agriculture to one that is more industry and service-based. In 2012, the composition of the economy was: 47% industry, 38% service, and 15% agriculture. It is expected that the Indonesian economy will move further toward a service-based

economy in the future. Despite continuous economic growth, many Indonesians are still poor, with approximately 11% of the population living below the poverty line. In the next three decades, the Indonesian population is expected to grow at approximately 1% each year, and employment for this additional population is critical. To lift the population out of poverty, the government plans to promote economic growth that averages at least 5% per year and has set a goal of reducing the poverty rate to below 4% by 2025.

Historically, energy has not been used efficiently in Indonesia because prices were kept artificially low through government subsidies. These subsidies have helped fuel an increase in energy use; average annual growth of energy consumption has been larger than average annual GDP growth. Through efficiency measures, the government hopes to reverse this trend by 2025. It is also expected that remote, rural communities will be electrified using local renewable resources such as microhydro power and solar photovoltaic (PV) technology. The government has set a goal that all households will have access to electricity by 2025, and plans for energy efficiency and the increased use of renewable energy resources have put Indonesia on a deep decarbonization pathway.

1.2 GHG emissions: current levels, drivers, and past trends

According to the Indonesian Second National Communication (which reports the latest official figures concerning the country's emissions), Indonesian GHG emissions were around 1,800 MtCO₂e in 2005 (see Figure 1). This represents an increase of 400 MtCO₂e compared to 2000. Most emissions (63%) come from land use change and peat fire, and combustion of fossil

¹ This is a resource potential, based on preliminary resource surveys. Assuming this could be converted into technical potentials and with capacity factor of 40%, then this resource will generate 263 TWh per year. As comparison, in 2010 the generation of hydropower was 16 TWh. Many of the hydro resources are located in Eastern Indonesia, far from electric demand center in the West. Transmission from East to West requires construction of undersea cables.

fuels contributes around 19% of the emissions. In the fuel combustion category, coal is the major emission source (see Figure 2). The second major source is oil combustion. Coal is the main fuel in power generation as well as a major energy source for industrial activities. Oil is used in the transport and building sectors. In the end-use sector, one-half of the direct combustion emissions are from fuel burning in industrial activities. Emissions from

power generation come from the building (60%) and industry (40%) sectors.

As shown in Figure 3, the main driver of GHG emissions over the past decade has been economic activity, which increased at a rate of 5% to 6% per year. Increasing energy use per unit of GDP also contributed to the increase in emissions, showing that the economy simultaneously grew more energy-intensive.

Figure 2. Decomposition of GHG and Energy CO₂ Emissions in 2005

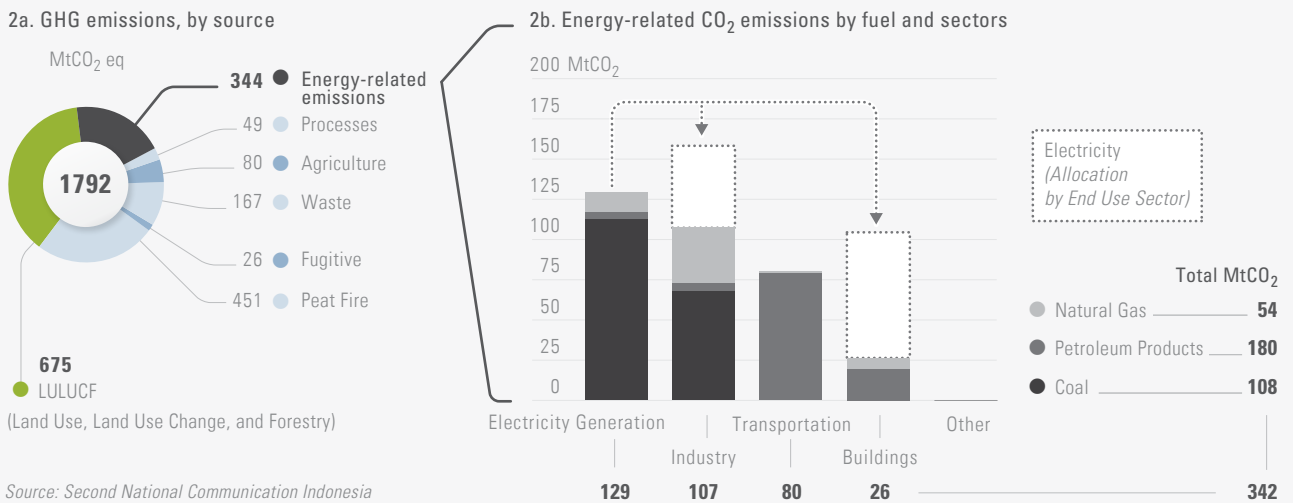
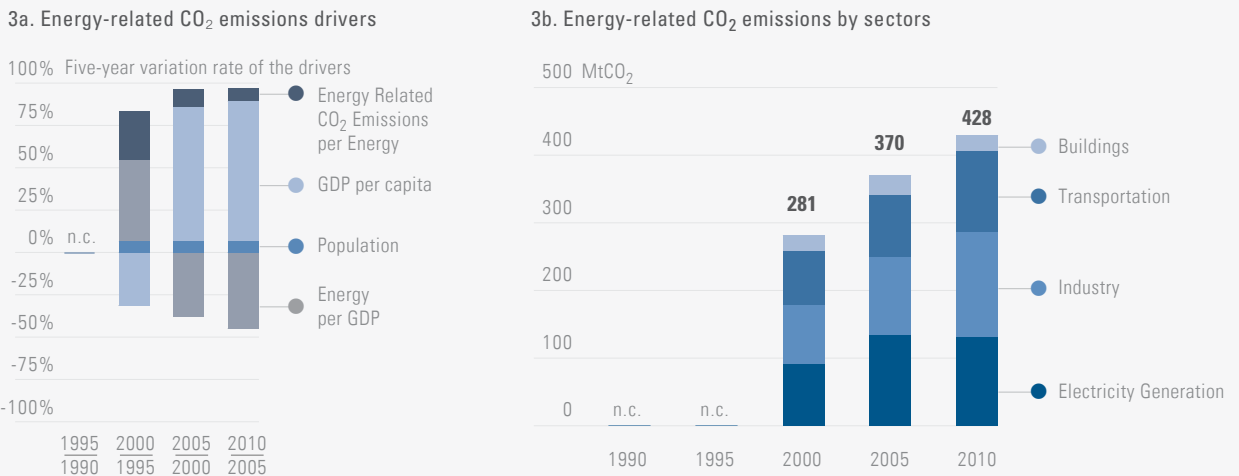


Figure 3. Decomposition of historical energy-related CO₂ Emissions, 1990 to 2010



2 National deep decarbonization pathways

2.1 Illustrative deep decarbonization pathway

2.1.1 High-level characterization

As a developing nation, the Indonesian economy and population are projected to grow significantly in the next four decades. The projections for these energy service demand drivers and other relevant development indicators are shown in **Table 1**.

To achieve significant decarbonization, Indonesia has to drastically change its energy supply and demand mix (see **Figure 4**). The following are the important features of decarbonization in primary energy: reduce oil consumption, reduce coal share and equip most of the remaining coal plants with CCS, increase the share of natural gas and equip a significant fraction of gas plants with CCS, significantly increase the share of renewables, and begin to use nuclear power. The important features of decarbonization in final energy are: significantly

decrease use of coal, increase the share of natural gas, significantly reduce oil consumption, and significantly increase share of electricity.

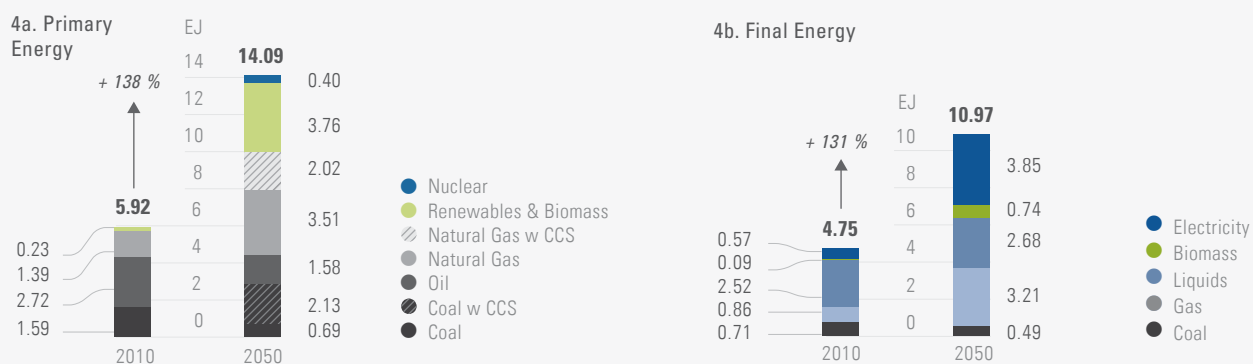
The drastic change of the primary as well as the final energy mix is the result of many measures. As shown in **Figure 5**, the illustrative Indonesian decarbonization pathway is a combination of energy efficiency, low- and zero-carbon emitting technologies, and structural changes in the economy. The key elements of the pathway are as follows:

- Energy efficiency improvements would be deployed in all sectors.
- The deployment of lower-carbon emitting energy sources would be realized in part through fuel switching from coal to gas, oil to gas, and a switch from onsite fuel combustion to use of electricity. The remaining large energy systems that burn fossil fuels would be equipped with CCS technology.
- Further fuel switching to renewable resources is a critical component of the scenario in all

Table 1. Development Indicators and Energy Service Demand Drivers

	2010	2020	2030	2040	2050
Population [Millions]	234	252	271	289	307
GDP per capita [\$/capita]	2,306	3,655	5,823	9,319	14,974
Access to Electricity	70%	85%	99%	99%	99%
Poverty indicator	12%	8%	3%	3%	2%

Figure 4. Energy Pathways, by source



sectors: solar, hydro, and geothermal for power generation, biofuels in transport, and biomass, biofuels, and biogas in industry.

- Structural changes in the economy (i.e. decreased role of industry in the formation of national GDP through service sector substitution) are expected to contribute to the decarbonization of the energy sector.

By implementing these strategies, the energy-related Indonesian CO₂ emissions will change in a sustainable manner by realizing deep decarbonization by 2050. As shown in Figure 6, industry and power generation remain the major sources of emissions in 2050. Significant decarbonization will occur in the power sector, from 130 MtCO₂ in 2010 to 68 MtCO₂ in 2050. Despite decarbonization efforts, emissions from industrial sector will continue to increase, from 155 MtCO₂ in 2010 to 221 MtCO₂ in 2050.

As shown in Figure 2, land use change and forestry are the main sources of GHG emissions, and they will continue to be so without new strategies in these areas. Therefore these sources have been targeted for reduction as part of the national emissions reduction commitment. The emissions from this sector mainly come from deforestation, forest degradation, and peat emissions. A decrease

in emissions can be accomplished through six strategies: (i) the acceleration of establishment of a forest management unit (FMU) in all forest areas to ensure the improvement of forest management, (ii) the introduction of mandatory forest certification systems to reduce illegal logging and increase the application of sustainable management practices, (iii) a reduced dependency on natural forests in meeting wood demands by increasing the use of low-carbon stock lands or degraded lands for the development of timber plantation and enhancement of carbon sequestration by increasing forest regeneration and land rehabilitation, (iv) the reduction of forest conversion in meeting land demand

Figure 6. Energy-related CO₂ Emissions Pathway, by Sector, 2010 to 2050

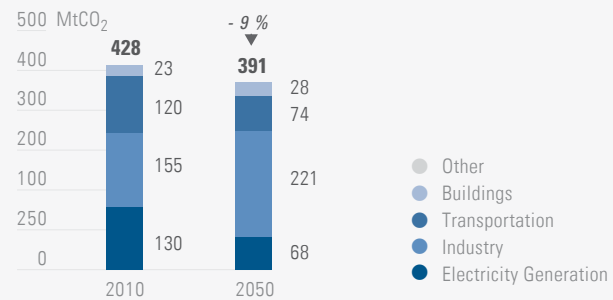
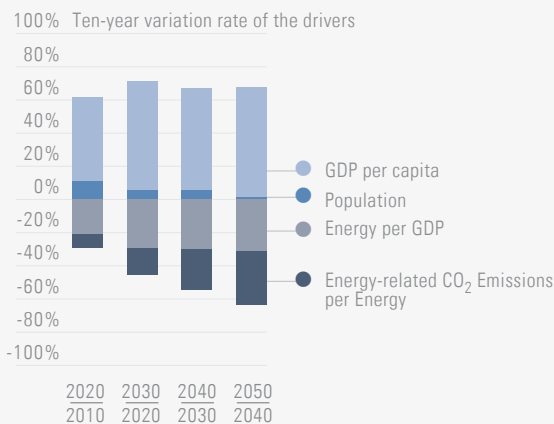
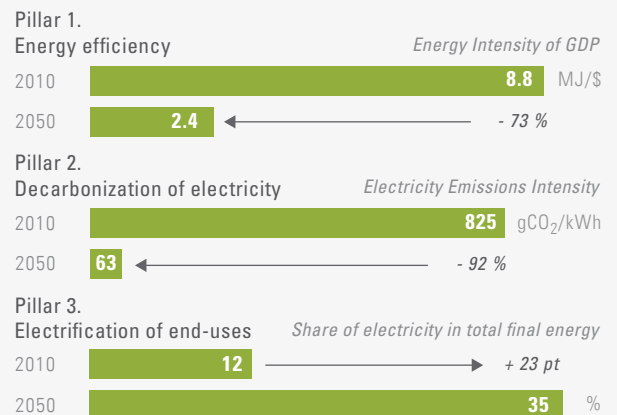


Figure 5. Energy-related CO₂ Emissions Drivers, 2010 to 2050

5a. Energy-related CO₂ emissions drivers



5b. The pillars of decarbonization



for agriculture by increasing the productivity of the existing agricultural land and planting intensity as well as optimizing the cultivation of unproductive lands, (v) a restriction on the use of peat land for agricultural development and the implementation of low-emission technologies in peat land, and (vi) the issuance of financing/incentive policies and the development of a financing system to support the implementation of the first five strategies.

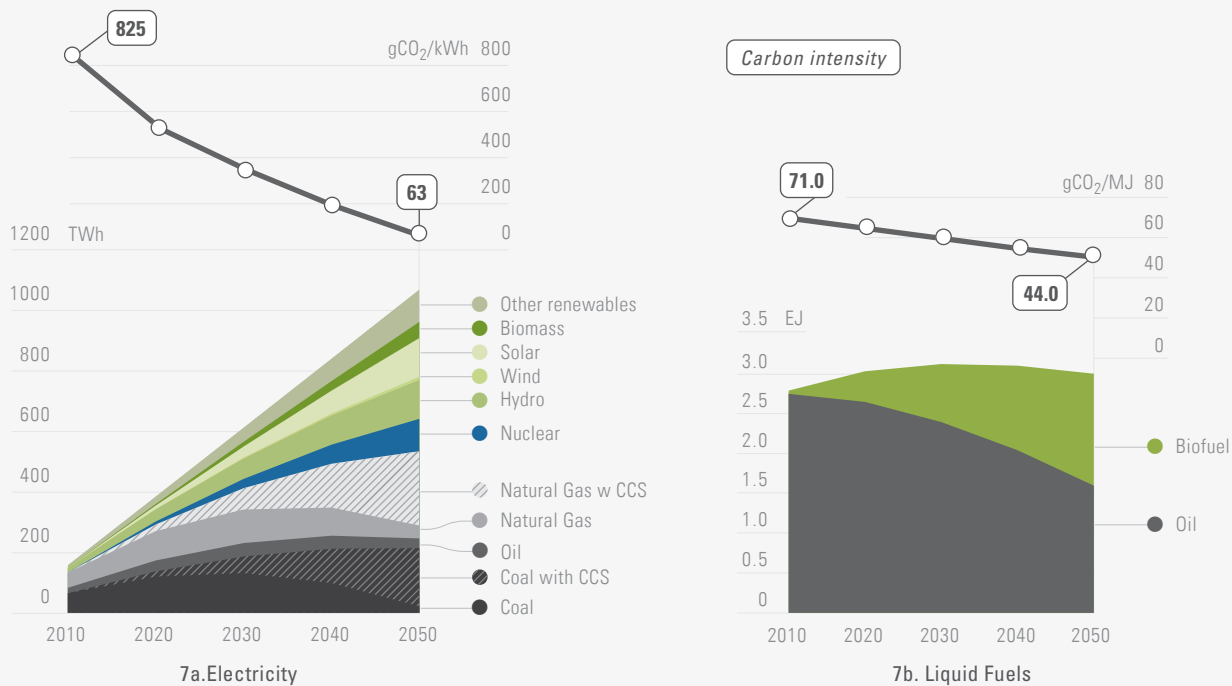
The implementation of the above strategies could significantly reduce GHG emissions in these sectors from about 3.42tCO₂e/capita (about 800 MtCO₂e) in 2010 to about -1.08tCO₂e/cap (about -330 MT-CO₂e) in 2050. These sources could become a net-sink of CO₂ emissions by 2030 at a rate of about -0.29tCO₂e/cap (about 80 MtCO₂e).²

2.1.2 Sectoral characterization

As mentioned above, Indonesia's primary energy mix is currently dominated by fossil fuels. Oil, coal

and gas together account for 93% of the energy supply, and the remaining 7% comes from renewable energy resources (biomass, hydropower, and geothermal). The end users of the energy are the industrial sector (50%), transport (34%), and building (16%). The breakdown of types of energy on the end user side is as follows: liquids (54%), gas (18%), coal (15%), and electricity (11%). To achieve decarbonization, a major transformation will take place in the energy system, including the electrification of transport and industry and deployment of renewables and application of CCS. Another important element of the decarbonization pathway is a significant increase in the share of biofuels in transportation, industry, and power generation. To ensure sustainability, the feedstock of biofuels would be planted in unused land (without disturbing forest stock), and as time progresses and new technology is developed, the feedstock will come from waste biomass.

Figure 7. Energy Supply Pathways, by Resource



Electricity Generation

Electricity demand will increase significantly with economic development and a shift of energy use in residential, industrial, and transport toward electricity. In the power sector, the decarbonization strategy includes fuel switching to lower-carbon emitting fuels (coal to gas, oil to gas), massive deployment of CCS for remaining coal and gas power plants, and extensive deployment of renewables (solar, geothermal, hydropower, and biofuels). Deep decarbonization in power generation will also require deployment of nuclear power plants and efficiency improvements in existing power plants. A summary of this decarbonization pathway is shown in [Figure 7](#). Electricity demand will grow 5% per annum on average, from 158 TWh in 2010 to 1,083 TWh in 2050. Decarbonization in this sector will result in a decrease in the average CO₂ emission factor, from 825 gCO₂/kWh in 2010 to 63 gCO₂/kWh in 2050, and the CO₂ emissions of the electricity generation will decrease from 130 MtCO₂ in 2010 to 68 MtCO₂ in 2050.

Liquid Fuels

To achieve deep decarbonization, it is assumed that there would need to be a significant switch from petroleum fuels to biofuels. [Figure 7b](#) shows the trajectory of the total liquid fuels used in transport, industry, and power generation and their associated carbon intensity.

Industry

Fuel switching to lower-carbon fuels and bioenergy (solid biomass wastes and biofuels) is the dominant strategy for decarbonization in the industrial sector. In addition, CO₂ emission reductions are also realized through industrial efficiency improvement (decreasing energy intensity) and CCS for coal and

gas in heavy industry. These decarbonization measures would reduce the emission intensity of fuels in industry sector from 3.81 tCO₂/toe in 2010 to 1.88 tCO₂/toe in 2050. The trajectory of industrial energy use and the associated emission intensities are shown in [Figure 8a](#). A decreased share of industry and heavy industry in the national economy would also contribute to the emission reductions. It is expected that the share of industry in GDP will decrease from 27.8% in 2010 to 17% in 2050. Improvements in efficiency are expected to reduce industrial energy intensity from 365 toe/M\$ in 2010 to 229 toe/M\$ in 2050.

Transport Sector

The energy demand in the transport sector is expected to increase significantly with economic development and population growth. In the passenger transport sector the decarbonization strategy includes modal shift to mass transport, electrification of vehicles, fuel switching to less-carbon emitting fuels (oil to gas), use of more energy-efficient vehicles, and extensive use of biofuels. Similar strategies are also applied to freight transport. A shift of freight transport from road to railway is expected to decrease CO₂ emissions. As a result of modal shift, it is expected that the share of personal vehicles decreases from 60% in 2010 to 40% in 2050. In 2050, it is expected that 30% of personal cars are electric vehicles. Decarbonization of this sector is expected to reduce the emission intensity from 3.02 tCO₂/toe in 2010 to 1.73 tCO₂/toe in 2050. [Figure 8b](#) shows the trajectory of energy use and the associated emission intensities of transport sector.

Building Sector

Decarbonization in the building sector would result primarily from fuel switching from oil to gas/LPG

2 It is assumed that all government targets on wood, palm oil, and rice production are met. The government target for wood production from natural forest will be stable at about 18.54 million m³/year (starting from 2020-2050), and timber plantation will reach 360 million m³ by 2050. The area for palm oil plantation, which is now about 9.27 million ha, will increase to 15 million ha by 2050, and rice production will meet domestic demand (self sufficiency). The land demand for settlement and commercial building will increase following the population growth.

and from fuels to electricity along with more efficient electric equipment. Switching from on-site fuel combustion to electricity would reduce direct emissions from buildings, and with a decarbonized electricity generation sector, this switch would lead to emission reductions. For the residential sector, increasing per capita income will increase energy consumption, but this will be balanced by more efficient equipment and the expectation that homes will remain relatively small. The trajectory of buildings energy use is shown in [Figure 8c](#).

2.2 Assumptions

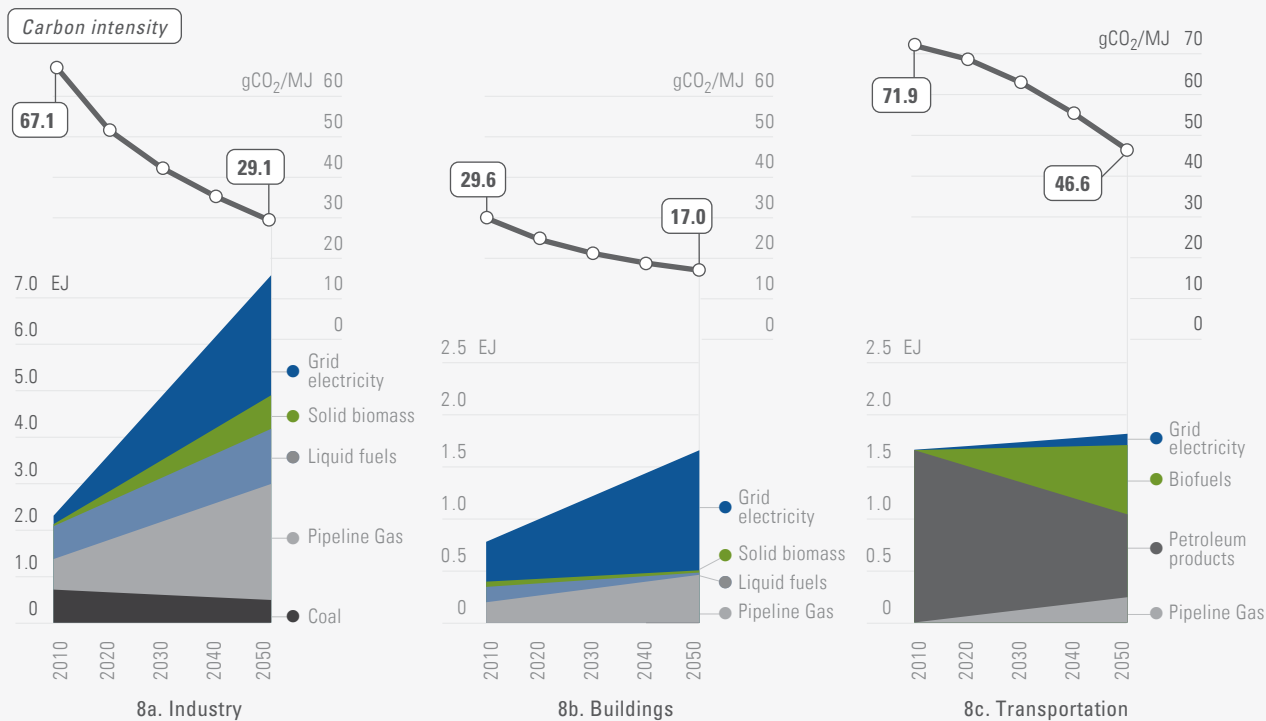
The deep decarbonization of energy activities in Indonesia can only be achieved through a combination of measures: efficiency, fuel switching (including to electricity), deployment of renewable, nuclear, and CCS and structural change of the

economy, especially in the industrial sector. The success of the country's decarbonization pathway is obviously dependent on the realization of many assumptions used in its development.

Indonesian hydropower plants under the illustrative scenario would generate around 37 GW in 2050, which is approximately half of the total hydro resources (75 GW). Indonesian geothermal resources would amount to around 29 GW, which supports the 25 GW of geothermal power assumed in the scenario. As a tropical country with an average radiation of 1.45 kWh/m²/day, it is reasonable for Indonesia to envisage a scenario where 75 GW solar power is used in 2050.

For energy security reasons, Indonesia will most likely continue to use its abundant coal resources for electricity generation. However, most of the plants will be equipped with CCS facilities to

Figure 8. Energy Use Pathways for Each Sector, by Fuel, 2010 – 2050



Note: Carbon intensity for each sector includes only direct end-use emissions and excludes indirect emissions related to electricity or hydrogen production.

capture CO₂ and store it in geological formation. Given the need for deep decarbonization, CCS will also be used to reduce emissions from natural gas power plants. The total CO₂ that would need to be stored by 2050 equals about 3,300 Mton (with an annual value of 286 Mton). The storage is assumed to take place in the abandoned and depleted oil and gas reservoirs in Indonesia. It is estimated that the volume of Indonesian depleted reservoirs could store around 11,000 Mton, which is more than three times the space required by the CCS scenario. Deep decarbonization also includes the massive use of biofuels for transport, industry, and power generation. In 2050, the total biofuel demand would be around 85 Mton per year. Based on current technological standards, to meet this biofuel demand domestically, around 18 million ha of land are needed to grow the biofuel feedstock. Indonesia currently has around 8 million ha of land devoted to crude palm oil (CPO) production, which could be used as biofuel feedstock. The additional 10 million ha of land needed to support biofuel for decarbonization would be available from unused non-forest land, which is estimated to be around 50 million ha.

2.3 Alternative pathways and pathway robustness

Power generation is one of the major contributors of CO₂ emissions. Under the current pathway, the main tool of decarbonization is coal and gas CCS. Therefore, the uncertainty of the pathway lies in the uncertainty of CCS deployment. There is only a limited amount of research into the scale of geological formation for CCS in Indonesia. The suitability of the CCS scenario is based on the assumption that the CO₂ will be injected in depleted gas and oil reservoirs. If all of this storage does not become available, the alternatives to CCS include: more hydropower, biomass, and solar. An increase in the use of hydropower would require the construction of long subsea cables, as the location of large hydro resource is in Eastern Indonesia, while the demand center is in Western Indonesia. If half of the CCS

envisaged in the illustrative scenario could not be realized, hydro would need to be increased from 30 GW to 61 GW, and biomass would need to increase from 15 GW to 20 GW. The increase in solar power would eventually be constrained by concerns for grid reliability associated with resource intermittency. Under the illustrative scenario, the share of intermittent renewables is only around 14%. If the use of hydropower were limited below what is assumed in this scenario, solar could be substantially increased before reaching reliability limits, which are estimated to occur above a 25% threshold.

2.4 Additional measures and deeper pathways

More aggressive efforts to substitute internal combustion engine cars with electric vehicles (EVs) would help further reduce direct emissions in the transportation sector. Under the illustrative pathway, the share of EVs in personal cars is 30% in 2050. It may be further increased to 50% in 2050. Also, more electrification in the light industry will reduce direct emissions. Under the current pathway, the light duty fleet is 35% EVs in 2050. This level of electrification could conceivably be increased to 50%. The feasibility of this increase, however, requires further research. An increase in electrified transportation and industry will create more emissions in the power sector; the low-electric emission factor must therefore be maintained. As mentioned above, additional hydropower and geothermal power could be harnessed to support this increased load. To utilize the remaining large hydropower resource, it would be necessary to construct a subsea electricity transmission line, given that the resource is located far away from the demand center.

2.5 Challenges, opportunities, and enabling conditions

The Indonesian illustrative decarbonization pathway is primarily composed of technological changes that are very different from the current mix of energy technologies. Many of the technol-

ogies are still in their infancy (e.g. CCS, electric vehicles, high efficiency power plants, etc.). The realization of the pathway is highly dependent on the development and maturation of these technologies in the coming years, and the technological approach would require massive development of new infrastructure (e.g. infrastructure for enabling mass public transport, new railways, gas transmission, subsea electrical transmissions, and CCS facilities). As a result, one of the main challenges of the pathway is how to finance the infrastructure investment.

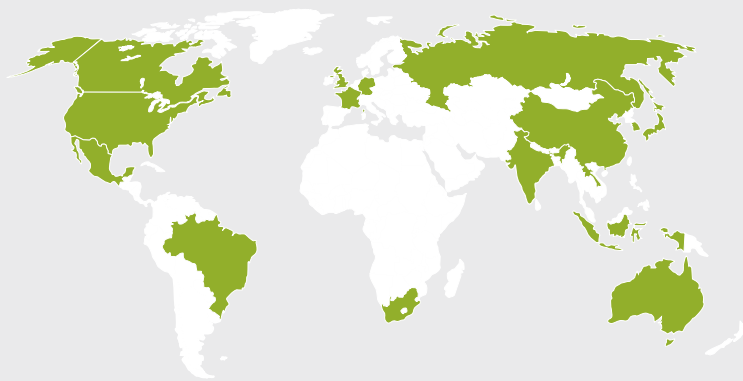
Some of the commercially available technologies, such as solar, biofuel and geothermal power, are currently more expensive than conventional fossil fuel technologies. Wide-scale deployment of these low-carbon resources would therefore require further technology development to lower costs, making them competitive with conventional resources. Deployment of nuclear power also poses a special challenge: social acceptability. It is therefore necessary to explore how to convince Indonesians that nuclear power is a necessary part of the future energy mix.

In 2009, the Indonesian Government announced a non-binding commitment to reduce its emissions 26% by 2020 (compared to business as usual development). However, being a non-Annex I country, concern for climate change is not yet fully internalized in Indonesian development agenda. To embrace a deep decarbonization pathway, the government has to first adopt climate change as a key component of its national development agenda. In summary, significant efforts are necessary for a deep decarbonization pathway to be realized: internalizing climate change into the national agenda, financing for investments in infrastructure, technology development, technology transfer, a social campaign for nuclear, and the right energy pricing policy for renewables. To overcome some of these challenges, international cooperation is needed, especially for infrastructure financing and technology transfer.

2.6 Near-term priorities

Deep decarbonization is a long-term development objective, and the incorporation of climate change in the Indonesian national agenda has just begun. To embrace deep decarbonization, Indonesia must continue to internalize climate change in the political sphere. Nevertheless, there are a number of near-term actions that need to be taken now to begin implementing a decarbonization pathway:

- The modal shift to public transport was initiated decades ago, but the success of these efforts has been limited. One of the barriers is that investment in public transport has been limited. As a result, new efforts to explore financing options for the transportation sector are needed.
- Biofuels were introduced into the Indonesian energy system in 2005. However, the use of this fuel is currently limited. One of the barriers is that biofuels have to compete with subsidized petroleum diesel and gasoline. Though recently the government has subsidized biofuels, increased policies to promote biofuel development are needed. Currently biofuel production uses traditional feedstocks that are also needed for the food sector, i.e. crude palm oil and molasses. Research and development into other biofuel feedstocks must be emphasized.
- Some technologies that are envisaged in the pathway, such as electric vehicles and CCS, are new to Indonesia. Research, development, and demonstration of these technologies needs to be conducted over a number of years in order to make progress.
- The key challenge of deep decarbonization is the financing of low-carbon infrastructure. The government, therefore, has to begin to look for international cooperation and find assistance for infrastructure development. In addition, the government must seek international partners for the technology transfer of technologies necessary for deep decarbonization.



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