WORLD RESOURCES INSTITUTE

ENERGY INNOVATION POLICY & TECHNOLOGY LLC

TECHNICAL NOTE

A TOOL FOR DESIGNING A POLICY PACKAGE TO ACHIEVE INDONESIA'S CLIMATE TARGETS:

Summary of Methods and Data used in the Indonesia Energy Policy Simulator

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EXECUTIVE SUMMARY

Indonesia, one of the world's major greenhouse gas emitters, has outlined a plan to unconditionally reduce its emissions by 29 percent relative to a business-as-usual (BAU) case in 2030 and up to 41 percent conditioned on international assistance. Policymakers need to design supporting policy packages to meet these climate targets while at the same time meeting the demands of the nation's increasing population. Indonesia's Energy Policy Simulator (EPS), a System Dynamics computer model, can estimate the impacts of various policy packages and offer objective, quantitative analysis to help Indonesia develop smart packages of policies that can work in concert to deliver Indonesia's climate goals. The tool was developed by Energy Innovation LLC, World Resources Institute Indonesia, Open Climate Network, and Indonesia's Institute for Essential Services Reform, following the success of the Energy Policy Simulator's model adaptation in other countries.[1] This technical note describes the structure, the input data sources, and the limitations and assumptions of Indonesia's EPS.

INTRODUCTION

In advance of the 22nd Conference of the Parties (COP22), Indonesia ratified the Paris Agreement and submitted its first nationally determined contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC), which sets out Indonesia's approach to reducing emissions and adapting to a changing climate. In it, Indonesia reiterates its commitment to an unconditional emissions reduction of 29 percent by 2030 relative to its business-as-usual (BAU) case and up to a 41 percent reduction with international assistance.

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Technical notes document the research or analytical methodology underpinning a publication, interactive application, or tool.

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With these climate targets established, Indonesia needs to create a road map to implement the NDC. In recent years, Indonesia has developed and implemented some policy changes to deliver key mitigation actions. For example, a forestry moratorium policy based on Presidential Instruction No. 10 Year 2011 was developed to prohibit clearing primary forests and peatlands inside forest estates and certain other areas. In the energy sector, the Ministry of Energy and Mineral Resources issued Ministerial Regulation No. 41 Year 2015 tightening the competency standards of energy managers in buildings and industry.

Now, the challenge is to estimate mitigation policies' effectiveness at reducing emissions—both to understand how far they will advance Indonesia toward its targets and to understand what combinations of strengthened or new policies may be needed to achieve the targets. As a developing country, Indonesia is projected to experience economic growth and must meet the needs of the growing population.

How can Indonesia identify policy options for each sector, taking into account development and mitigation targets that will be compelling to each ministry? What are some unexplored mitigation activities and their abatement potential and implementation costs or savings? How can supporting policies create an enabling environment for each mitigation action? These are some of the questions asked by policymakers when designing climate policies. When policies are not well planned, they can waste taxpayers' money, slow technology development, or reward incumbent technologies. Only well-designed policies minimize transaction costs and spur innovation. Sorting through which policies work, why, and in what circumstances is therefore of paramount importance. Before this project, no Indonesia-specific, publicly available tools were capable of assessing how varying policies interact to affect emissions and financial metrics.

Background on the Energy Policy Simulator

Indonesia's Energy Policy Simulator is a version of the Energy Policy Simulator, a System Dynamics computer model that estimates the effects of various policies[2] on emissions, financial metrics, electricity system structure, and other outputs.[3] The EPS model is designed to be able to represent different countries by incorporating input data specific to the country in question. This technical note discusses the purpose, structure, function, and input data specific to the Indonesia EPS. More detail on the technical workings of the EPS is available in the EPS online documentation at https://us.energypolicy.solutions/docs/.

Indonesia's Energy Policy Simulator aims to help Indonesian policymakers evaluate a wide array of climate-related policies. The tool allows users to explore unlimited policy combinations and to adjust policy levers to any setting, allowing them to create their own policy scenarios. It simulates years 2016–2050 using annual timesteps and offers hundreds of outputs. Some of the most important are emissions of 12 pollutants; cash flow (costs and savings) for government, industry, and consumers;[4] capacity and generation of electricity by different types of power plants; land use changes and associated emissions or sequestration; and premature deaths avoided by reductions in particulate emissions. These outputs can help policymakers anticipate long-term impacts and costs of implementing new policies. Many of the policies included in the EPS have not yet been explored in Indonesia, thus offering new options to policymakers. The tool may not only help inform a roadmap for Indonesia to implement its Paris Agreement climate goals, but it may also show how Indonesia could potentially set new goals and increase its ambitions.

The model is free and open source. It can be used via an interactive web interface at https://indonesia.energypolicy.solutions or can be downloaded from the same site.

Why Use a Computer Model to Assist in Policy Selection?

Before considering the structure and uses of Indonesia's Energy Policy Simulator, it is worthwhile to ask, "Why use a computer model at all?"

A policymaker seeking to reduce emissions faces a dizzying array of policy options that might advance this goal. Policies may be specific to one sector or type of technology (for instance, light-duty vehicle fuel economy standards) or might be economy-wide (such as a carbon tax). Sometimes a market-driven approach, a direct regulatory approach, or a combination of the two can be used to advance the same goal. For instance, to improve the efficiency of home appliances, a government might offer rebates to buyers of efficient models, mandate that appliance manufacturers meet specific energy efficiency standards, or both. To navigate this field of options, policymakers require an objective, quantitative mechanism to determine which policies will meet their goals and at what cost or savings.

Many studies have examined particular energy policies in isolation. However, it is of greater value if policymakers understand the effects of a package of different policies because the policies may interact. This interaction can produce results different from the sum of the effects of the individual policies.

Thanks to the strength of computer models at simulating complex systems, a customized computer model is a crucial tool to help Indonesian policymakers evaluate multiple policies. To understand how to hit national NDC targets that involve emissions reductions from every sector, a satisfactory model must be able to represent the entire economy and energy system with an appropriate level of disaggregation, be easy to adapt to represent Indonesia, be capable of representing a wide array of relevant policy options, and offer results that include a variety of policy-relevant outputs. Additionally, the model must capture the interactions of policies and other forces in a system whose parameters change dramatically over the course of the model run, reflecting changes as Indonesia continues to grow and develop.

About System Dynamics Modeling

A variety of approaches exist for representing the economy and the energy system in a computer simulation. The Energy Policy Simulator is based on a theoretical framework called "system dynamics." As the name suggests, this approach views the processes of energy use and the economy as an open, ever-changing, nonequilibrium system. This may be contrasted with approaches such as computable general equilibrium models, which regard the economy as an equilibrium system subject to exogenous shocks, or disaggregated technology-based models, which focus on the potential efficiency gains or emissions reductions that could be achieved by upgrading specific types of equipment.[5]

System Dynamics models often include "stocks," or variables whose value is remembered from modeled year to modeled year, and which are affected by "flows" into and out of these variables. For example, a stock might be the total installed capacity of coal power plants, which can only grow or shrink gradually, due to construction of coal plants (an inflow) and retirement of old plants (an outflow). In contrast, the amount of energy generated by coal plants in a given year is calculated afresh every year and is therefore not a stock variable.

System Dynamics models often use the output of the previous annual timestep's calculations as input for the following timestep. The Energy Policy Simulator follows this convention, with stocks such as the electricity generation fleet or the types and efficiencies of building components remembered from one year to the next. Therefore, an efficiency improvement in an early year will result in fuel savings in all subsequent years, until the improved vehicle, building component, or other investment is retired from service.

The industry sector is handled differently. Because the available input data come in the form of BAU levels of fuel use and potential reductions in fuel use and process-related emissions by policy, we implemented these reductions gradually (with corresponding implementation costs), rather than recursively tracking a fleet-wide efficiency. (Because of the diverse forms of input data in the modeled sectors, one approach rarely works for all sectors. Accordingly, Indonesia's Energy Policy Simulator attempts to use whichever approach makes the most sense in the context of a specific sector.)[6]

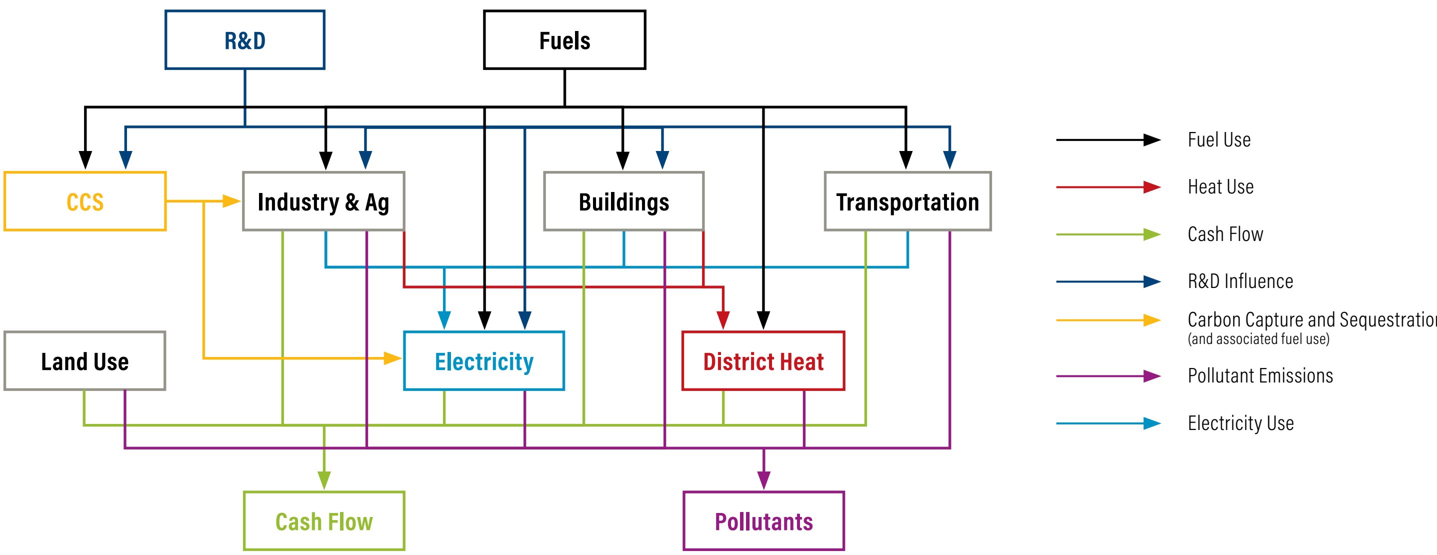
STRUCTURE OF INDONESIA'S ENERGY POLICY SIMULATOR

Indonesia's EPS structure can be envisioned along two dimensions: the visible structure that pertains to the equations that define relationships between variables (viewable as a flowchart) and a behind-the-scenes structure that consists of arrays (matrices) and their elements, which contain data and are acted on by the equations. For example, the transportation sector's visible structure consists of policies (such as a fuel economy standard), input data (such as the kilometers traveled by a passenger or a ton of freight, or the elasticity of travel demand with respect to cost), and calculated values, such as the quantity of fuel used by the vehicle fleet. The arrays in the transportation sector consist of vehicle categories (light-duty vehicles [LDVs], heavy-duty vehicles [HDVs], aircraft, rail, ships, and motorbikes), cargo types (passengers or freight), and fuel types (petroleum gasoline, petroleum diesel, electricity, etc.). The model generally performs a separate set of calculations, based on each set of input data, for every combination of array elements. For example, the model will calculate different fuel economies for passenger HDVs, freight HDVs, passenger aircraft, freight aircraft, and so forth.

The model has five main sectors (industry and agriculture, buildings, transportation, electricity, and land use), plus a few supporting modules handling other functions, as depicted in **Figure 1**.[7]

The model's calculation logic begins with the fuels section, where basic properties of all fuels are set and policies that affect the price of fuels are applied. Information about the fuels is used in the three "demand sectors": transportation, buildings, and industry and agriculture.

Figure 1 | **Diagram of Indonesia's EPS Model Structure**



These sectors calculate their own emissions from direct fuel use (e.g., fossil fuels burned in vehicles, buildings, and industrial facilities). These sectors also specify a quantity of electricity or heat (energy carriers supplied by other parts of the model) required each year. The electricity sector and the district heat module consume fuel to supply the energy needs of the three demand sectors, accounting for transmission and distribution losses. The fifth sector, land use, does not consume fuel or electricity.

All five sectors and the district heat module produce emissions of each pollutant, which are summed in the pollutants box at the bottom right of Figure 1. The same is true for cash flow impacts, which are calculated separately for particular actors (government, industry, consumers, and several specific industries). Calculation of changes in spending (e.g., on capital equipment, fuel, and operations and maintenance), as well as monetized social benefits from avoided public health impacts and climate damages, are also carried out at this stage.

Two model components affect the operation of various sectors. A set of R&D levers allows the user to specify improvements in fuel economy and decreases in capital cost for technologies in each of the four sectors and in the carbon capture and sequestration (CCS) module. The CCS module alters the industry and electricity sectors by reducing their CO_2 emissions (representing sequestration), increasing their fuel usage (to power the energy-intensive CCS process) and affecting their cash flows.

INPUT DATA SOURCES

The model has significant input data requirements, necessitating the use of a variety of data sources. Indonesia's Energy Policy Simulator is adapted from the international, open-source release of Energy Innovation's Energy Policy Simulator. To adapt the model to Indonesia, input data were sourced via the following approaches, in order of priority:

- Indonesian data located in published sources, produced as outputs from other models, or provided by the Indonesian government, were used as input data.
- When Indonesian data were not available, input data from other countries[8] were scaled to represent Indonesia. Scaling factors differ by variable and are selected on the basis of which scaling factor most closely correlates with the variable in question. For example, a variable pertaining to economic output or production might be scaled by GDP, while a variable related to wastewater treatment might be scaled by population.
- When Indonesian data were unavailable and scaling other countries' data would be irrelevant or inappropriate, other countries' input data were used unchanged. For example, scaling data would be irrelevant if the data are not actually country-specific (for example, the global warming potentials of various gases). It may also be inappropriate when, for example, the expected lifetime of a building component (such as an air conditioner) in another country may be the best available estimate of the lifetime of that same type of building component in Indonesia. Scaling the lifetime of a foreign air conditioner by any available factor (e.g., population, GDP) would be nonsensical.

In general, the model uses only publicly available data and sources that do not cost money to access. Table 1 indicates the data source used for each variable and notes when the values are specific to Indonesia (in the source document), are scaled for Indonesia (that is, Indonesia-specific values were generated by us), or are not specific to Indonesia. Many variables have more than one data source, so full source information can sometimes be extensive. Full source information is available in each variable's associated spreadsheet file, which can be downloaded as part of the Indonesia Energy Policy Simulator package (free and open source) from https://indonesia.energypolicy.solutions.

Input variables that exist in the model structure but are not used in the Indonesia version of the simulator, as well as variables that define policy effects and are intended to be set by model users rather than the model creators, are omitted from the table.

Table 1 | **Data Sources for Variables in Indonesia EPS**

SECTION FOLDER	ACRONYM	MEANING	INDONESIA-SPECIFIC VALUES?	MAIN SOURCES
additional outputs	BGRC	Business-as-usual (BAU) GDP-related calculations	yes	OECD, World Bank
additional outputs	SCoC	Social cost of carbon	no	EPA
additional outputs	SCoHIbP	Social cost of health impacts by pollutant	scaled	EPA
additional outputs	VoaSL	Value of a statistical life	scaled	EPA
buildings & appliances	BASoBC	BAU amount spent on building components	scaled	EIA, MEMR
buildings & appliances	BCEU	BAU components energy use	yes	MEMR
buildings & appliances	BDEQ	BAU distributed electricity quantities	yes	MEMR
buildings & appliances	CL	Component lifetime	no	DOE, HUD, State of California

Table 1 | **Data Sources for Variables in Indonesia EPS (continued)**

buildings & appliances	CpUDSC	Cost per unit distributed solar capacity	no	LBNL, Black and Veatch, EnerNex
buildings & appliances	DSCF	Distributed solar capacity factor	yes	MEMR
buildings & appliances	ECiCpCU	Embedded carbon in components per currency unit	no	RFF
buildings & appliances	EoBSDwEC	Elasticity of building service demand with regard to energy cost	no	EIA
buildings & appliances	EoCEDwEC	Elasticity of component energy demand with regard to energy cost	no	EIA
buildings & appliances	EoCPwEU	Elasticity of component price with regard to energy use	no	EERE
buildings & appliances	EoDSDwSP	Elasticity of distributed solar deployment with regard to subsidy percent	no	BNEF
buildings & appliances	FoBObE	Fraction of buildings owned by entity	no	DOE
buildings & appliances	FoLRfCTbRP	Fraction of lifetime remaining for components targeted by retrofitting policy	no	KEMA, Inc.
buildings & appliances	PCFURfE	Percentage components fuel use reduction for electricity	no	DOE
buildings & appliances	PEURfRC	Percent energy use reduction for retrofit components	yes	IESR
buildings & appliances	PPEIdtICEaT	Potential percentage of efficiency improvement due to improved contractor education and training	no	Energy Center of Wisconsin
buildings & appliances	PPEIdtIL	Potential percentage of efficiency improvement due to improved labeling	no	ACEEE
Carbon Capture and Sequestration (CCS)	CC	Carbon capture and sequestration (CCS) costs	yes	World Bank
CCS	CCEL	CCS capital equipment lifetime	no	European Zero Emissions Platform
CCS	CPbE	CCS percentages by entity	yes	CATO-CO2
CCS	CSA	Carbon sequestration amounts	yes	CATO-CO2
CCS	PDiCECpDOC	Percent decline in CCS equipment cost per doubling of capacity	no	CRS

Table 1 | **Data Sources for Variables in Indonesia EPS (continued)**

Cost Outputs	DR	Discount rate	no	EPA
Electricity Supply	ARpUIiRC	Annual retirement per unit increase in relative cost	yes	na
Electricity Supply	BBSC	BAU battery storage capacity	yes	na
Electricity Supply	BCpUC	Battery cost per unit capacity	no	RMI, SNL
Electricity Supply	BCR	BAU capacity retirements	yes	MEMR
Electricity Supply	BDSBaPCF	Boolean: Do suppliers bid at peak capacity factors	no	na
Electricity Supply	BECF	BAU expected capacity factors	yes	MEMR
Electricity Supply	BGCL	BAU generation capacity lifetime	no	NREL, EIA
Electricity Supply	BGDPbES	BAU guaranteed dispatch percentage by electricity source	yes	na
Electricity Supply	BHRbEF	BAU heat rate by electricity fuel	yes	MEMR
Electricity Supply	BITPTaP	Boolean: is this plant type a peaker?	no	na
Electricity Supply	BPHC	BAU pumped hydro capacity	yes	World Bank, Euromoney
Electricity Supply	BRPSPTY	BAU Renewable Portfolio Standard (RPS) percentage this year	yes	Indonesian government
Electricity Supply	BTaDLP	BAU transmission and distribution loss percentage	yes	MEMR
Electricity Supply	BTC	BAU transmission capacity	yes	EKON
Electricity Supply	CCaMC	Capacity construction and maintenance costs	some	EIA, Strich et al., Baith and Sorapipatana, World Energy Council, IRENA, Australian Bureau of Resources and Energy Economics, Black & Veatch
Electricity Supply	DRC	Demand response capacities	scaled	Navigant Research
Electricity Supply	EIaE	Electricity imports and exports	yes	MEMR
Electricity Supply	EStCwCMC	Electricity sources to consider when calculating mean cost	yes	na
Electricity Supply	FoOMCtiL	Fraction of operations and maintenance (O&M) costs that is labor	yes	PLN

Table 1 | **Data Sources for Variables in Indonesia EPS (continued)**

Electricity Supply	FPC	Flexibility point calculations	no	PNNL, NREL, E3, Western Electricity Coordinating Council
Electricity Supply	MCGLT	Max capacity growth lockup table	no	EIA, NREL, DOE
Electricity Supply	MPCbS	Max potential capacity by source	yes	MEMR, World Bank, Indonesian Wind Energy Association
Electricity Supply	MPCFR	Maximum possible capacity factor reduction	no	na
Electricity Supply	MPPC	Minimum power plant capacity	no	EIA
Electricity Supply	NGEpUO	Nonfuel greenhouse gas (GHG) emissions per unit output	no	NREL, Warner & Heath, Dolan & Heath, Hsu et al.
Electricity Supply	NSDoDC	Normalized standard deviation of dispatch costs	no	EIA, IEA
Electricity Supply	NSDoNCC	Normalized standard deviation of new capital costs	no	CRS, NREL, E3
Electricity Supply	PDiBCpDoC	Percent decline in battery cost per doubling of capacity	no	BNEF
Electricity Supply	PDiCCpDoC	Percent decline in capacity cost per doubling of capacity	no	BNEF
Electricity Supply	PTCF	Peak time capacity factors	yes	na
Electricity Supply	RM	Reserve margin	yes	The Lantau Group
Electricity Supply	RQSD	RPS-qualifying source definitions	yes	MEMR
Electricity Supply	SLF	System load factor	yes	MEMR
Electricity Supply	SYC	Start year capacities	yes	MEMR
Electricity Supply	TCAMRB	Transmission capacity across modeled region border	yes	Detik Finance
Electricity Supply	TCCpUCD	Transmission construction cost per unit capacity distance	yes	Asia Development Bank
Fuels	BFCpUEbS	BAU fuel cost per unit energy by sector	yes	MEMR, Anshar et al., GIZ, OTODriver, EIA, Oxford University, DBS Research
Fuels	BFTRbF	BAU fuel tax rate by fuel	yes	Indonesia-Investments, MF

Table 1 | **Data Sources for Variables in Indonesia EPS (continued)**

Fuels	BS	BAU subsidies	yes	MEMR, IEA, Global Subsidies Initiative, ASEAN Center for Energy, F+L Daily, PVTech, IRENA, World Energy Council
Fuels	GbPbT	Global warming potential (GWP) by pollutant by timeframe	no	IPCC
Fuels	PEI	Pollutant emissions intensities	yes	MEF, ANL, Kurokawa et al., Sukarno et al.
Industry	BIFUbC	BAU industrial fuel use before ccs	yes	MEMR, MI, UN Stat
Industry	BPEiC	BAU process emissions in CO_2e	yes (some scaled)	EPA, MEF
Industry	BPoIFUfE	BAU proportion of industrial fuel used for energy	yes	MEMR
Industry	CESTR	Capital equipment sales tax rate	yes	Trading Economics
Industry	CtIEPpUESoS	Cost to implement efficiency policy per unit energy saved or shifted	no	RMI, MacCurdy et al., Babcock and Wilcox, E3
Industry	EoP	Elasticities of production	no	RFF, Aswath Damodaran
Industry	FLRbI	Foreign leakage rate by industry	no	RFF
Industry	MHV	Methane heating value	no	Engineering Toolbox
Industry	PERAC	Process emissions reductions and costs	yes	EPA
Industry	PIFURfE	Percentage industry fuel use reduction for electricity	no	EPA, DOE
Industry	PPRiEYFUfERoIF	Potential percent reduction in end year fuel use from early retirement of inefficient facilities	no	EIA
Industry	PPRiEYFUfICaWHR	Potential percent reduction in end year fuel use from increased cogeneration and waste heat recovery	no	RMI
Industry	PPRiEYFUfIIaIoE	Potential percent reduction in end year fuel use from improved installation and integration of equipment	no	RMI
Industry	RIFF	Recipient industrial fuel fractions	no	RMI
Industry	WMITR	Worker marginal income tax rate	yes	Indonesia Investments

Table 1 | **Data Sources for Variables in Indonesia EPS (continued)**

Land Use & Forestry	AOCoLUPpUA	Annual ongoing cost of land use policies per unit area	yes	Meizlish et al.
Land Use & Forestry	BLACE	BAU land use and land use change and forestry (LULUCF) anthropogenic CO_2 emissions	yes	MEF, National Coordinating Agency for REDD+
Land Use & Forestry	CiLVpUAAbP	Change in land value per unit area affected by policy	yes	Graham et al.
Land Use & Forestry	CSpULApYbP	CO_2 sequestered per unit land area per year by policy	yes	Bonnera et al., National Coordinating Agency for REDD+, WRI Indonesia, MEF
Land Use & Forestry	FoFEtiL	Fraction of forestry expenses that is labor	no	na
Land Use & Forestry	FoFObE	Fraction of forests owned by entity	yes	na
Land Use & Forestry	ICoLUPpUA	Implementation cost of land use policies per unit area	yes	Graham et al., Antara News
Land Use & Forestry	PLANAbPiaSY	Potential land area newly affected by policy in a single year	yes	Ministry of Development and Planning, MEF, WRI Indonesia
Land Use & Forestry	RPEpUACE	Rebound pollutant emissions per unit avoided CO_2 emissions	no	EPA
Transport	AADTbVT	Average annual distance traveled by vehicle type	some	MEMR, MT, ORNL, BTS
Transport	AVL	Average vehicle lifetime	no	NHTSA, BTS, ORNL, Boeing, California State Controller's Office
Transport	AVLo	Average vehicle loading	most	ICCT, MEMR, MT, Antara News, DOT, BTS
Transport	BFFU	BAU fleet fuel use	yes	ICCT, MT, MEMR
Transport	BFoEToFU	BAU fraction of each type of fuel used	yes	ICCT, MEMR
Transport	EoDfVUwFC	Elasticity of demand for vehicle use with regard to fuel cost	yes	MT
Transport	EoFoNVFE	Effect of feebate on new vehicle fuel economy	no	Greene et al.
Transport	EoNVFEwFC	Elasticity of new vehicle fuel economy with regard to fuel cost	yes	MT
Transport	EoVPwFE	Elasticity of vehicle price with regard to fuel economy	no	EPA, Center for Automotive Research

Table 1 | **Data Sources for Variables in Indonesia EPS (continued)**

Transport	FoVObE	Fraction of vehicles owned by entity	some	MT, BTS, General Services Administration, National Fire Protection Administration, Bureau of Justice Statistics, BLS
Transport	FoVSwMB	Fraction of vehicles sold within model boundary	yes	na
Transport	ICpEV	Incremental cost per electric vehicle	no	ICCT, American Public Transportation Association
Transport	PCiCDTdtTDM	Percent change in cargo distance transported due to transport demand management (TDM)	no	IEA
Transport	PTFURfE	Percentage transportation fuel use reduction for electricity	no	EPA, M. J. Bradley & Associates
Transport	VFP	Various fleet properties	yes	ICCT, MEMR, Antara News, MT, BTS, EIA
Transport	VPaEC	Vehicle prices and embedded carbon	some	KompasOtomotif, IOTOMOTIV, Harga Motor, Center for Automotive Research, TruckerToTrucker, *Wall Street Journal*, PE International
Web Application Support	BCF	BTU conversion factors	no	EIA
Web Application Support	DpOCU	Dollars per output currency unit	yes	U.S. Department of the Treasury
Web Application Support	DpOCUfCC	Dollars per output currency unit for cost curve	yes	U.S. Department of the Treasury

Note:

a. Full source information is available in each variable's associated spreadsheet file, which can be downloaded as part of the Indonesia Energy Policy Simulator package (free and open source) from https://indonesia.energypolicy.solutions.

b. Abbreviations of sources are spelled out in the list below.

Main Sources Abbreviation	Name
ACEEE	American Council for an Energy-Efficient Economy
ANL	Argonne National Laboratory
BNEF	Bloomberg New Energy Finance
BLS	U.S. Bureau of Labor Statistics
BTS	U.S. Bureau of Transportation Statistics
CRS	U.S. Congressional Research Service
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
E3	Energy + Environmental Economics
EERE	U.S. Office of Energy Efficiency and Renewable Energy
EIA	U.S. Energy Information Administration
EKON	Indonesia's Coordinating Ministry for Economic Affairs
EPA	U.S. Environmental Protection Agency
HUD	U.S. Department of Housing and Urban Development
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IESR	Indonesia's Institute for Essential Services Reform
IPCC	United Nation's Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LBNL	Lawrence Berkeley National Laboratory
MEF	Indonesia's Ministry of Environment and Forestry
MEMR	Indonesia's Ministry of Energy and Mineral Resources
MF	Indonesia's Ministry of Finance
MI	Indonesia's Ministry of Industry
MT	Indonesia's Ministry of Transportation
NREL	U.S. National Renewable Energy Laboratory
NHTSA	U.S. National Highway Traffic Safety Administration
OECD	Organisation for Economic Co-operation and Development
ORNL	Oak Ridge National Laboratory
PLN	Indonesian government-owned electricity distribution utility
PNNL	Pacific Northwest National Laboratory
RFF	Resources for the Future
RMI	Rocky Mountain Institute
SNL	Sandia National Laboratory

COMPARISONS TO OTHER BASELINE SCENARIOS

In this section, we compare outputs from Indonesia's Energy Policy Simulator's BAU case to similar outputs from other sources' projections. Depending on the quality of the documentation of assumptions and calculations used in other projections, it is sometimes possible for us to identify why our own projection is lower or higher than that other projection. In these cases, we include notes explaining reasons for differences.

Different sources offered different outputs; no source offered all of the outputs that are available from the Energy Policy Simulator. As a result, each figure will show a subset of the external sources alongside the EPS.

Sources to which the EPS BAU case is compared (with associated abbreviations) are:

- **APEC**
  Asia Pacific Economic Cooperation
  2013
  APEC Energy Demand and Supply Outlook, 5th Edition
  http://aperc.ieej.or.jp/publications/reports/outlook/5th/bau.html

- **BAPPENAS**
  Indonesia's Ministry of Development and Planning
  2015
  Developing Indonesian Climate Mitigation Policy 2020–2030 through RAN-GRK Review
  http://www.sekretariat-rangrk.org/images/documents/Background_Doc_INDC-RAN-GRK_Review_2015.pdf

- **BPPT**
  Badan Pengkajian dan Penerapan Teknologi (Indonesia's Agency for the Assessment and Application of Technology)
  2016
  Indonesia Energy Outlook 2016
  http://www.bppt.go.id/unduh/outlook-energi

- **ICCT**
  International Council on Clean Transportation
  2012
  Global Transportation Roadmap Model
  http://www.theicct.org/global-transportation-roadmap-model

- **IRENA**
  International Renewable Energy Association
  2016
  Renewable Energy Outlook for ASEAN, Indonesia Country Profile
  http://www.irena.org/DocumentDownloads/Publications/IRENA_REmap_ASEAN_2016_report.pdf

- **MEF**
  Indonesia's Ministry of Environment and Forestry
  2010
  Indonesia Second National Communication under UNFCCC
  http://unfccc.int/files/national_reports/non-annex_i_natcom/submitted_natcom/application/pdf/indonesia_snc.pdf

- **MEMR**
  Indonesia's Ministry of Energy and Mineral Resources
  2014
  Indonesia Calculator 2050
  http://calculator2050.esdm.go.id/model.xlsx

- **WRI**
  World Resources Institute
  2015
  CAIT Projections
  http://cait2.wri.org/projections

Total Carbon Dioxide Equivalent Emissions, Including Land Use and Forestry

Figure 2 | **Comparison of Total CO_2 Emissions under EPS and Other Projections**

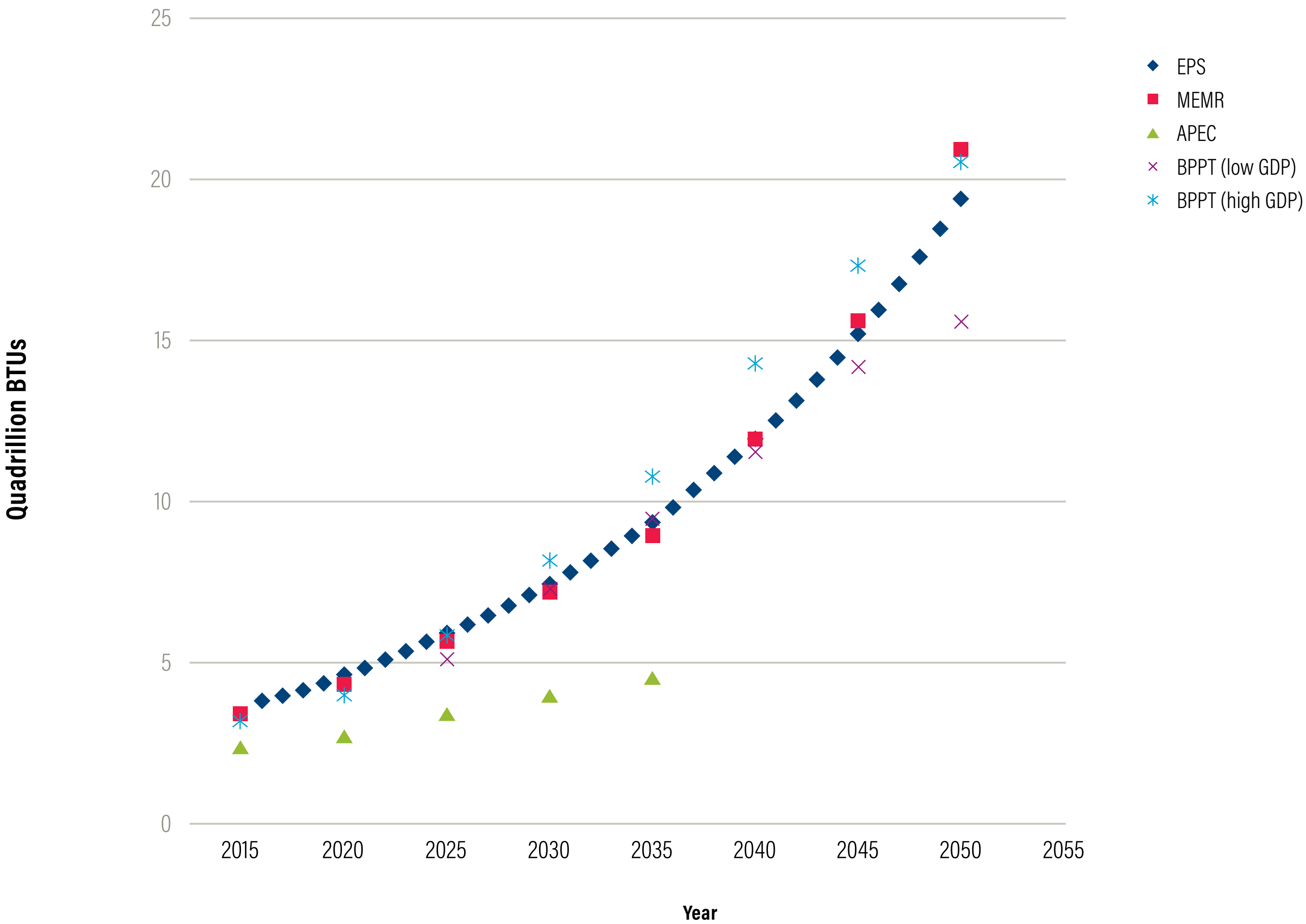
Source:
EPS, Energy Policy Simulator's business-as-usual case. MEMR, Indonesia's Ministry of Energy and Mineral Resources. MEF, Indonesia's Ministry of Environment and Forestry. BPPT, Indonesia's Agency for the Assessment and Application of Technology. WRI, World Resources Institute. BAPPENAS, Indonesia's Ministry of Development and Planning.

Notes:

- BPPT projections do not contain land use and forestry emissions. To allow BPPT's projections to be shown on the same graph as the other models, we added the land use and forestry emissions from the EPS model to BPPT's total, so that land use and forestry emissions do not contribute to any difference between the EPS and BPPT results.
- MEMR, and likely BAPPENAS and BPPT, omit biomass usage in the buildings sector, which is substantial in early years and declines to zero in later years. This causes their emissions to be artificially low in early years of the model run.
- Based on our examination of MEMR's work, MEMR's model appears to contain inaccuracies that substantially increase emissions from the transportation, buildings, and land use sectors in future years, so caution should be taken when comparing MEMR's overall emissions results to those from other models. BAPPENAS uses data from MEMR but does not project so far into the future, so it is unclear if BAPPENAS is similarly affected.
- WRI data in this graph are based on MEF data. WRI's data point does not represent a separate modeling effort.

Energy Demand by Industry

Figure 3 | Comparison of Energy Demand by Industry under EPS and Other Projections



Source:
EPS, Energy Policy Simulator's business-as-usual case. MEMR, Indonesia's Ministry of Energy and Mineral Resources. APEC, Asia Pacific Economic Cooperation. BPPT, Indonesia's Agency for the Assessment and Application of Technology.

Notes:

- MEMR and APEC exclude biomass usage.
- MEMR is the primary source for industrial energy demand in the EPS. However, the EPS adjusts the GDP growth rate down to 5 percent per year and adds biomass usage.

Energy Demand by Buildings and Appliances

Figure 4 | **Comparison of Energy Demand by Buildings and Appliances under EPS and Other Projections**

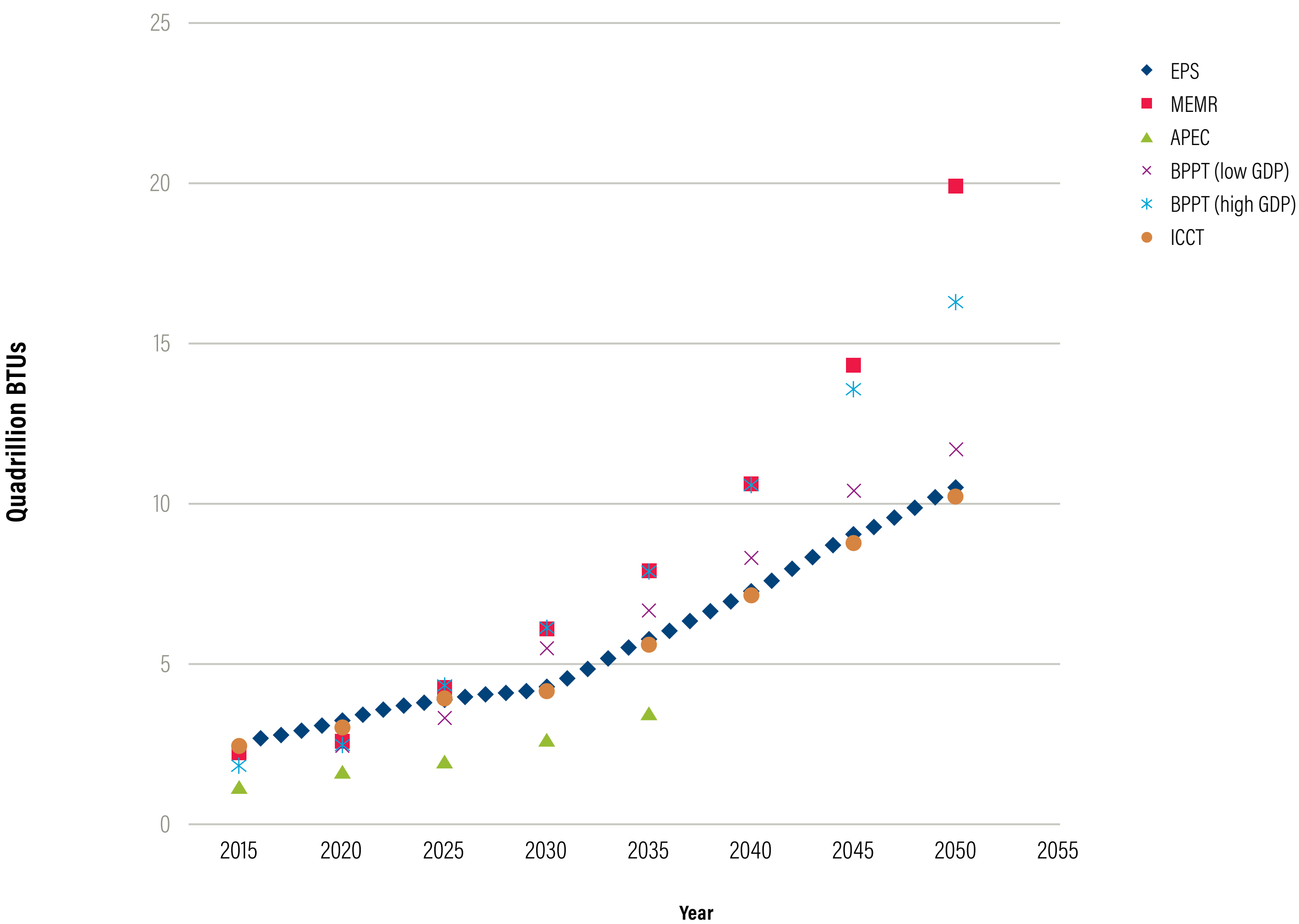
Source:
EPS, Energy Policy Simulator's business-as-usual case. MEMR, Indonesia's Ministry of Energy and Mineral Resources. APEC, Asia Pacific Economic Cooperation. BPPT, Indonesia's Agency for the Assessment and Application of Technology.

Notes:

- MEMR's model appears to contain a decimal point error that causes MEMR's cooking energy use to be 10 times too high.
- MEMR and APEC exclude biomass usage. BPPT excludes biomass usage in residential buildings, which account for the vast majority of biomass usage in the buildings sector.
- MEMR is the primary source for buildings sector energy demand in the EPS. However, the EPS corrects the error in MEMR cooking energy use and adds biomass usage. The effects of these corrections canceled each other out in 2015, but not in later years. (Biomass usage declines to zero by 2050 in the EPS model, which accounts for the slower-than-MEMR growth rate.)

Energy Demand by Transportation

Figure 5 | Comparison of Energy Demand by Transportation under EPS and Other Projections



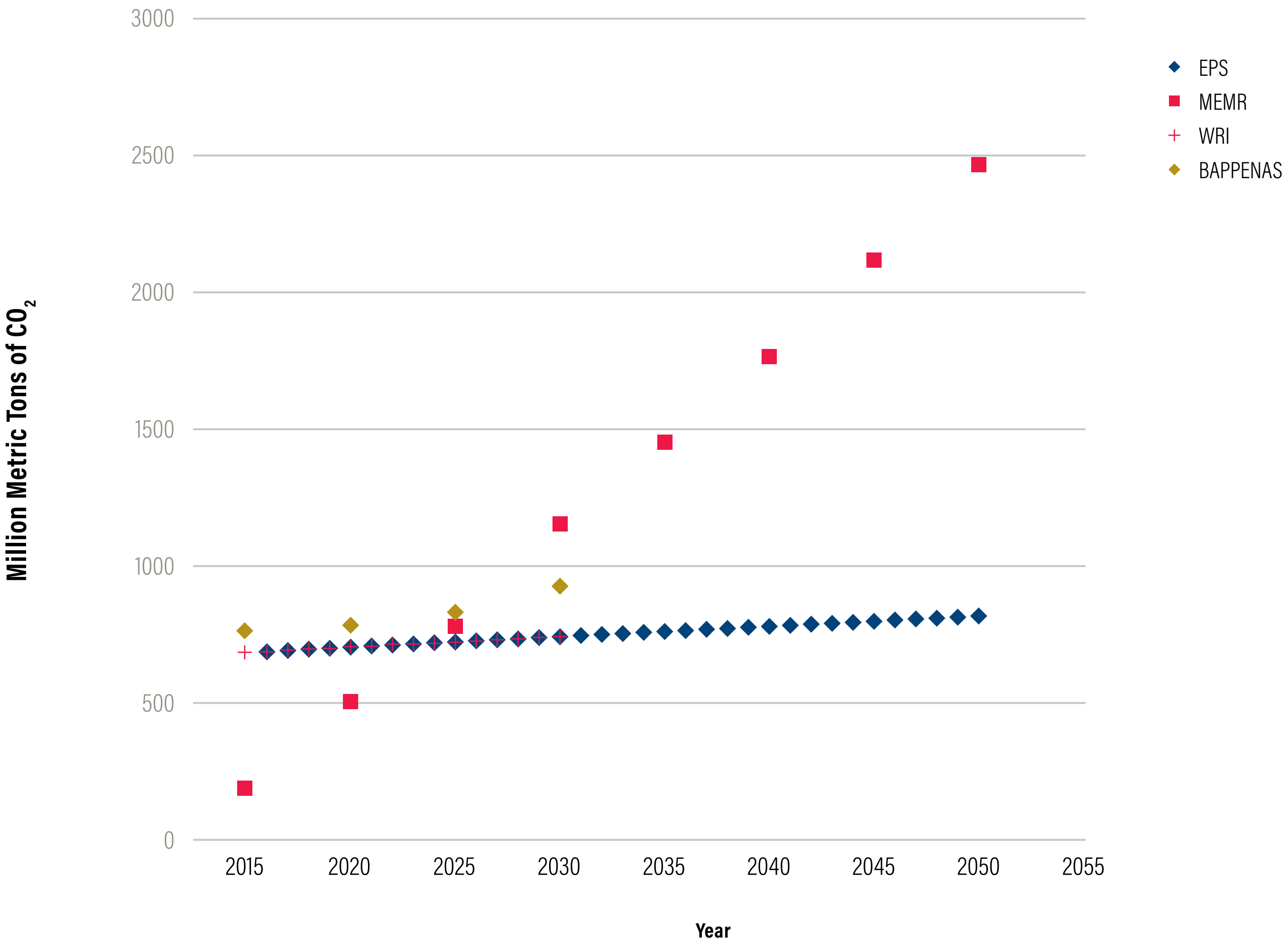
Source:
EPS, Energy Policy Simulator's business-as-usual case. MEMR, Indonesia's Ministry of Energy and Mineral Resources. APEC, Asia Pacific Economic Cooperation. BPPT, Indonesia's Agency for the Assessment and Application of Technology. ICCT, International Council on Clean Transportation.

Notes:

- MEMR's transportation modeling appears to contain inaccuracies that result in overestimation of transportation energy demand, particularly in years further in the future.
- ICCT excludes ships.
- ICCT is the primary source for transportation sector energy demand in the EPS. However, the EPS model adds ship energy usage based on MEMR.
- BPPT uses higher GDP growth projections than the EPS, resulting in BPPT's higher growth rate of transportation energy use.

CO_2 Emissions from Land Use and Forestry

Figure 6 | **Comparison of CO_2 Emissions from Land Use and Forestry under EPS and Other Projections**



Source:
EPS, Energy Policy Simulator's business-as-usual case. MEMR, Indonesia's Ministry of Energy and Mineral Resources. BAPPENAS, Indonesia's Ministry of Development and Planning. WRI, World Resources Institute.

Notes:

- WRI is the primary source for land use and forestry emissions data in the EPS. No modifications to WRI data were made, resulting in precise agreement between WRI and EPS.
- EPS/WRI and BAPPENAS are similar in magnitude and trend.
- MEMR's values appear to be too low in the present and grow at too fast a rate to be realistic.

Electricity Capacity Composition

Different modeling efforts considered different subsets of plant types and different timeframes, making comparison of multiple sources on one graph difficult. Multiple graphs, one per source, are presented instead in Figures 7–11, showing the fuel mix used and the years of data.

The EPS model (Figure 7) projects a total capacity of 97 gigawatts (GW) in 2030 and 489 GW in 2050. This tends to be lower than other projections in 2030 but higher in 2050, most likely due to differences in economic growth assumptions. Also, the EPS model projects a larger share of wind and solar than other models, and the lower capacity factors of wind and solar cause there to be a need for more capacity to supply the same quantity of energy. A tiny amount of nuclear comes online around 2050.

The non-EPS sources vary widely in their projections for the future of Indonesia's electricity grid composition and overall capacity, making it hard to compare EPS results to any sort of consensus or baseline.

MEF projects extremely high total capacities (around 230 GW by 2030), dominated by fossil fuels (Figure 8). BPPT's base scenario projects a total of 169 GW in 2030 and 307 GW in 2050 (Figure 9). BPPT shows a small but significant contribution from renewables. Nuclear begins to play a role in 2035. MEMR shows capacities of 153 GW in 2030 and 273 GW in 2050 (Figure 10). MEMR projects coal to peak by 2025 and all fossil fuels to peak by 2035, with very large contributions from renewables. Nuclear capacity comes online by 2020. IRENA has only one future data point, a total of 120 GW in 2025 (Figure 11). IRENA projects a significant share of capacity to be from renewables, but very little of this is from solar and wind.

Figure 7 | **Indonesia's Energy Policy Simulator Model, Electricity Capacity**

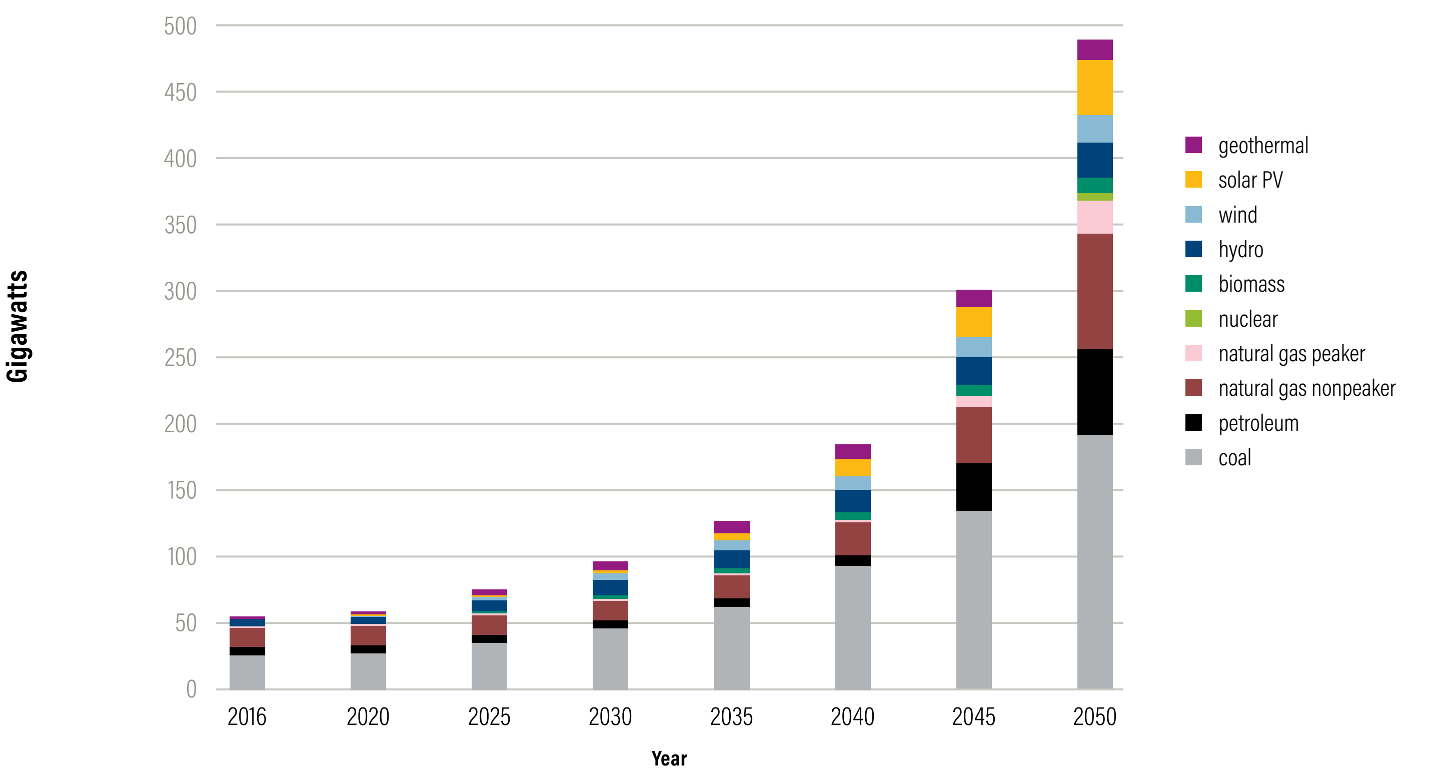


Figure 8 | **Indonesia's Ministry of Environment and Forestry (MEF), Electricity Capacity**

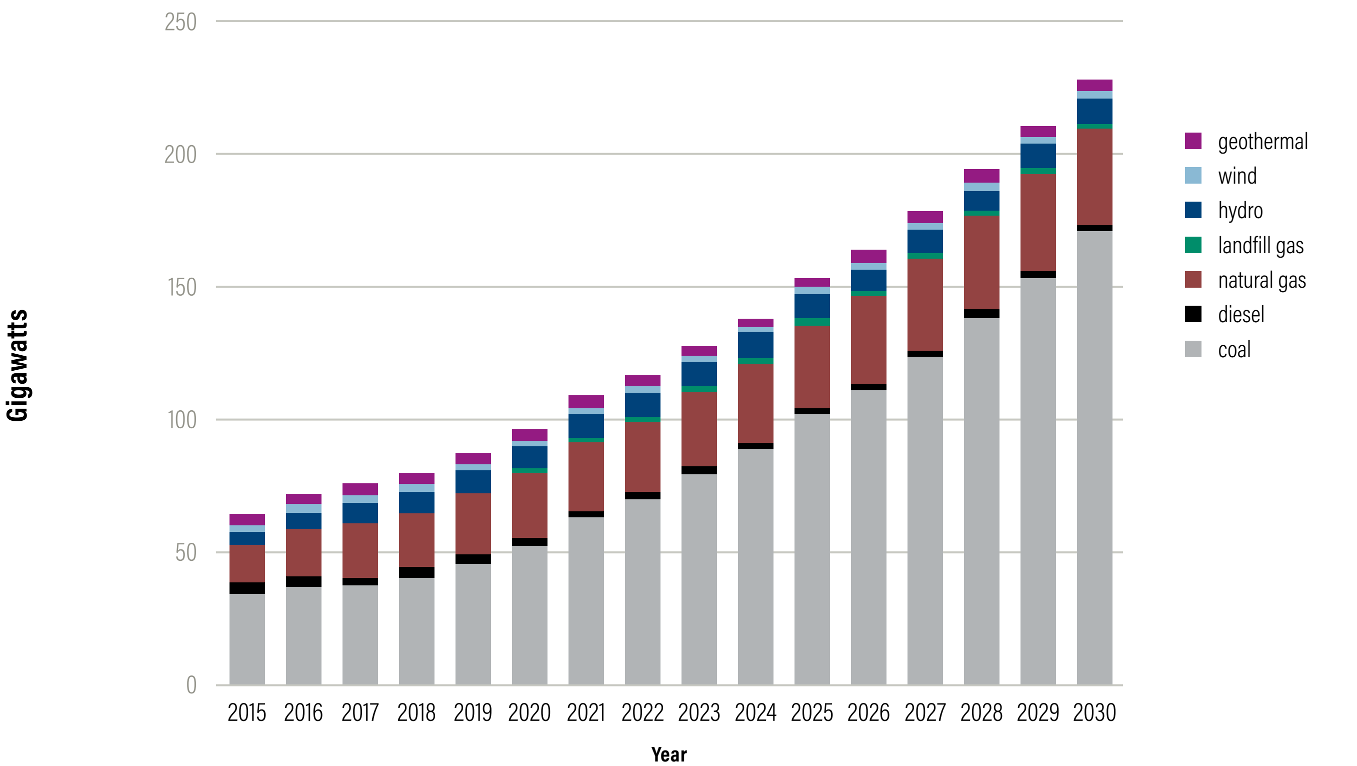


Figure 9 | **Indonesia's Agency for the Assessment and Application of Technology (BPPT), Electricity Capacity**

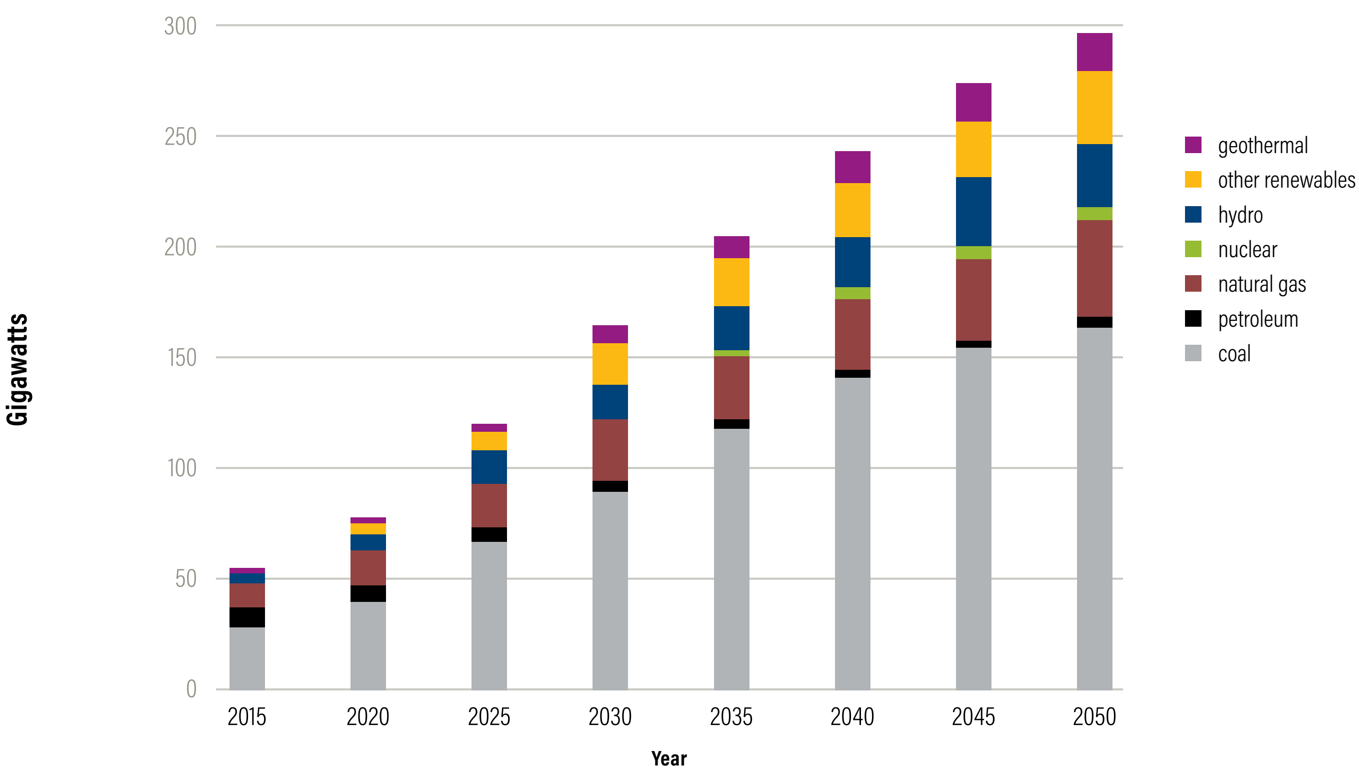


Figure 10 | **Indonesia's Ministry of Energy and Mineral Resources (MEMR), Electricity Capacity**

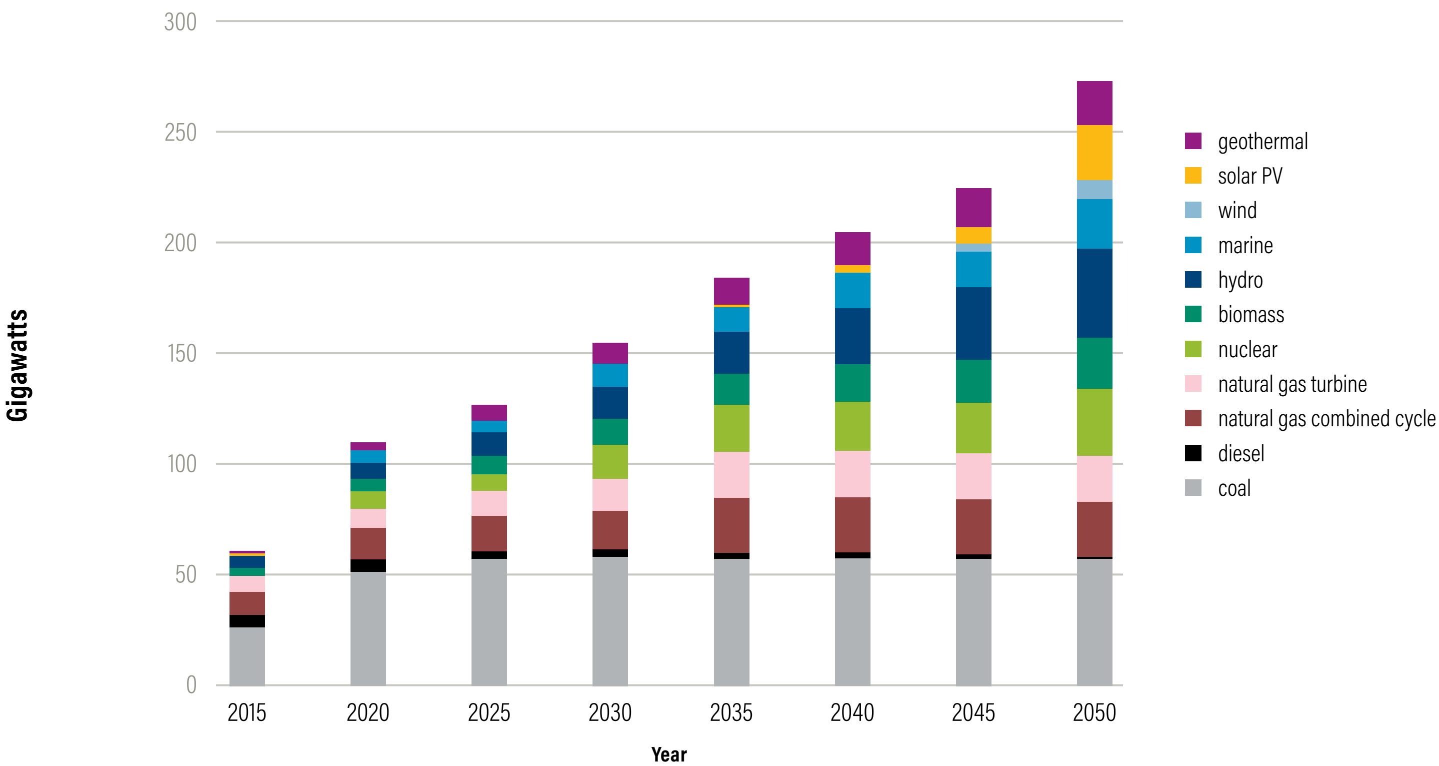
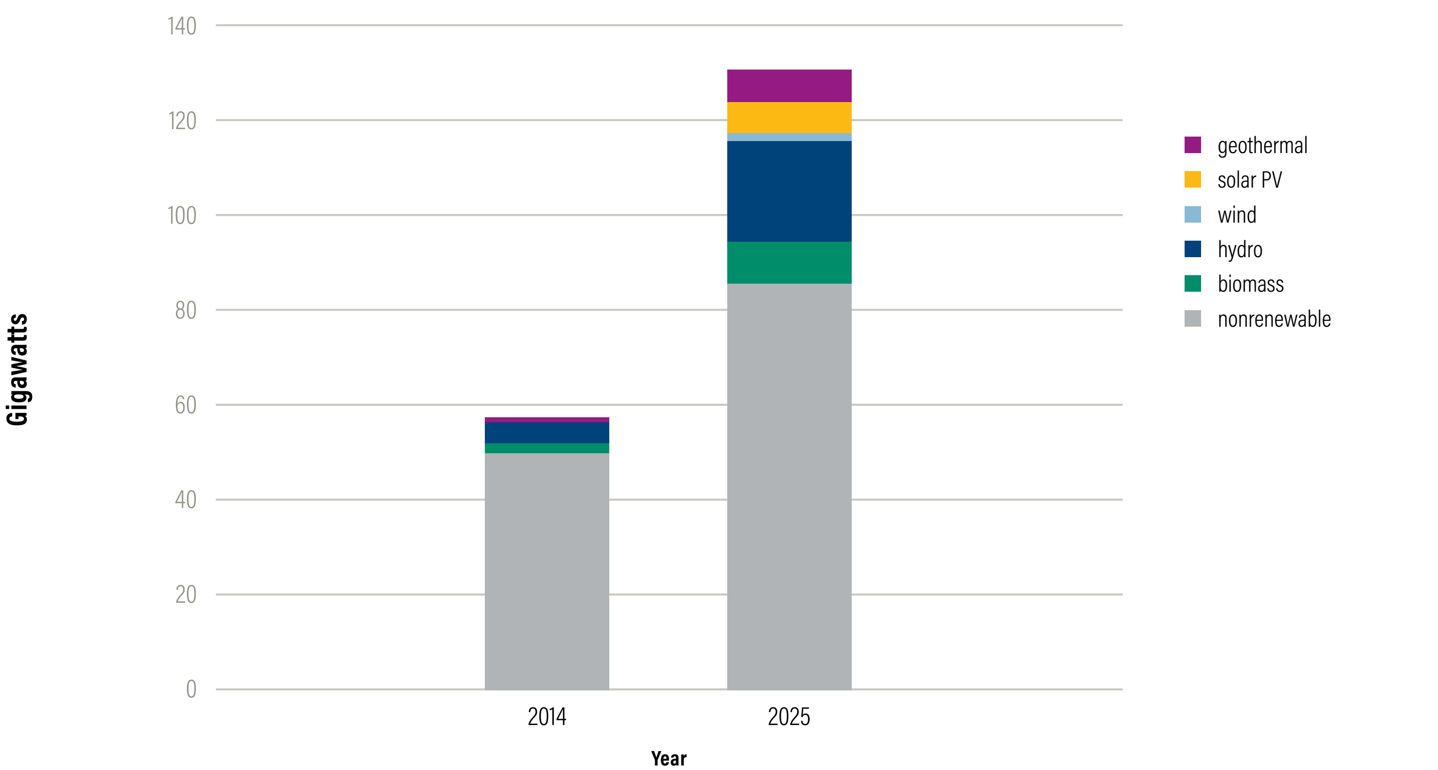


Figure 11 | **International Renewable Energy Association (IRENA), Electricity Capacity**



LIMITATIONS AND ASSUMPTIONS

To create a computer model that is less complex than the real world, it is necessary to make a number of assumptions and simplifications. Similarly, model capabilities and results may be affected by limitations in the available data.

Two types of assumptions underlie Indonesia's EPS: structural assumptions common to all versions of the Energy Policy Simulator and Indonesia-specific assumptions that relate to input data. Structural assumptions are described in detail in the Energy Policy Simulator's online documentation at https://us.energypolicy.solutions/docs/assumptions.html and a summary of some major assumptions is included here:

- **Uncertainty is greater with more or stronger policies.** Input values in the EPS must be studied, measured, or simulated under a particular set of conditions or assumptions. These conditions cannot reflect all possible combinations of policy settings that a user might select in the EPS. Generally, the model's BAU case is likely to be closest to the conditions reflected by the input data. Therefore, the uncertainty of policy effects is likely smallest when few policies are used and enabled policies are set at low values. Uncertainty increases as the policy package includes a greater number of policies and the settings of those policies become more extreme.
- **Characterizing uncertainty numerically is not possible.** Uncertainty bounds were not available for input data, so no uncertainty bounds are available on output data. As an alternative, the Energy Policy Simulator model supports Monte Carlo analysis, which can highlight the sensitivity of the model results to changes in any particular input or set of inputs.
- **EPS policies imply actions, not targets.** The EPS is generally a forward-simulating, not goal-seeking, model, and so policies generally imply specific actions or things that influence actions (such as changing the price of something), rather than specifying targets to be met via unknown actions.
- **Avoidance of double-counting results in limited compliance options for pricing policies.** Pricing policies (and other price effects) alter demand for goods/services and alter the decisions of purchasers looking to buy new equipment, but they cannot holistically account for all possible responses individuals and businesses may have without duplicating certain responses already governed by other policy levers.

Assumptions and challenges related to Indonesian input data are as follows:

- In Indonesia, not all of the data needed are easily available—for example, certain elasticities of demand for services with respect to price, or the value of a statistical life, have not been studied in Indonesia. Additionally, the EPS simulates policies at the national level, while some data are collected at the district level and are not available for all districts in Indonesia. When Indonesian data for a variable are completely unavailable, foreign data may be scaled or adapted to fit Indonesia, introducing uncertainty.
- When input data are available from multiple Indonesian sources, there are discrepancies in the data. We attempted to use the best available combination of data. To understand how the EPS Indonesia data compare to other data sources, see section above outlining the comparison of baselines, along with an explanation of the major differences.
- In developing the Indonesia EPS, attempts were made to customize the model to Indonesia. For example, the district heating policy lever in the original model is not used in the Indonesian adaptation, because district heating of buildings is not applicable to Indonesia. Additionally, unlike many countries in which the energy sector is the dominant source of emissions, a large share of Indonesian emissions come from the land use sector. Thus, the land use sector was enhanced with new capabilities to better reflect the situation in Indonesia, such as representation of peatland restoration. Nonetheless, the scope of changes that could be made to customize model structure for Indonesia is not unlimited. For example, Indonesia consists of many different islands, and a policy may have different impacts in different islands, which have different environmental and economic conditions. The Indonesia EPS does not separately track policy effects on different islands.

FUTURE DEVELOPMENT

At present, Indonesia's EPS contains only one scenario: a business-as-usual scenario.[9] It also allows users to design their own scenarios. To help users design scenarios, guidance is provided on the web interface. These scenarios may be saved or shared with others, and outputs may be downloaded.

In a future stage of this project, the tool may be enhanced to present additional policy scenarios—for example, scenarios for achieving Indonesia's NDC targets. The tool could potentially be used to analyze the implications of different policy pathways for achieving Indonesia's NDC targets and for contributing to the Paris Agreement goals.

ENDNOTES

1. Versions of the EPS have been released for China (https://china.energypolicy.solutions/), the United States (https://us.energypolicy.solutions/), and Mexico (https://mexico.energypolicy.solutions/).
2. The Energy Policy Simulator includes nonenergy policies, such as those affecting land use and industrial processes, as well as energy policies.
3. The Energy Policy Simulator was developed by Energy Innovation LLC with help from the Massachusetts Institute of Technology and Stanford University. The model has been peer reviewed by individuals associated with Argonne National Laboratory, the National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, Stanford University, China's National Center for Climate Change Strategy and International Cooperation, China's Energy Research Institute, and Climate Interactive. The adaptation of the model to Indonesia was carried out jointly by Energy Innovation LLC, Open Climate Network, World Resources Institute Indonesia, and Indonesia's Institute for Essential Services Reform.
4. The Energy Policy Simulator calculates first-order costs and savings (which entities pay which other entities more or less money relative to the BAU case). It does not include a full macroeconomic simulation of the economy, which would consider questions, such as how government spends increased tax revenues (or what government cuts in response to reduced tax revenues), because these decisions are beyond the scope of the energy and nonenergy policies that the computer model seeks to evaluate.
5. Macroeconomic models may be particularly useful for creating a projected BAU case, since their strength is in understanding economic interactions, but they may have trouble representing certain policies—particularly those that save money by causing actions that aren't undertaken in the absence of policy, because of market failures, irrational behavior by economic actors, nonmarket barriers, and so on. Technology-based models may be very useful for understanding the maximum potential abatement that could be derived from different sectors or different activities, which is helpful when deciding which sectors or activities to target with policies. However, they may not provide insight into what policies would induce those technical changes. A System Dynamics model is strong at estimating how policies would affect emissions, cash flows, etc., relative to the BAU case, without needing to rely on many of the underlying assumptions used by macroeconomic models.
6. For more information on how each sector functions, see the model's online documentation at https://us.energypolicy.solutions/docs/.
7. Agriculture is included with other industries because of similarities in how their emissions can be handled within the model structure. For example, agricultural equipment burns fuel, just as fuel is burned by machinery in manufacturing industries. Similarly, just as other industries have "process emissions" unrelated to fuel combustion, agriculture has such emissions (for example, methane from rice fields or ruminant animals). Aspects of agriculture related to land use change, such as cutting down a forest to create a plantation, are handled in the "Land Use" section of the model, not the "Industry and Agriculture" section.
8. Most commonly, scaled data originated from the United States. The types of data missing in Indonesia are often the same types of data missing in other developing countries, while U.S. data availability is relatively good.
9. The BAU scenario is based entirely on the input data (described in the previous sections); that is, no policy levers are enabled inside the EPS for this scenario. Accordingly, the BAU scenario inherits assumptions from the original data sources, most of which were data provided by the Indonesian government. These sources do not always clearly document their assumptions, such as what policies were included. Further, the assumptions may not precisely match between different government data sources. In general, we assume the BAU represents the continuation of existing policies but no implementation of new policies.

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World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

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We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

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We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

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We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

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This working paper is part of an OCN initiative to inform the post-2020 GHG mitigation goals in Nationally Determined Contributions under the United Nations Framework Convention on Climate Change. The OCN Secretariat, based at the World Resources Institute, is managing this multicountry effort. For more information regarding this initiative, contact openclimate@wri.org.