

NET ZERO WORLD

COP28 Outcomes Report

NET ZERO WORLD

Initiative Report—Indonesia

Bruce Hamilton¹, Daniel Vega², Dadan Kusdiana³,
Tony Susandy³, Carolyn Szum⁴, Ronnen Levinson⁴,
Bethany Speer⁵, Ralph Muehleisen¹

1. Argonne National Laboratory

2. U.S. Department of Energy's Office of International Affairs

3. Indonesia's Ministry of Energy and Mineral Resources

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5. National Renewable Energy Laboratory



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List of Abbreviations

AC	air conditioning
ANL	Argonne National Laboratory
DOE	U.S. Department of Energy
ECM	energy conservation measure
EV	electric vehicle
HVAC	heating, ventilating, and air conditioning
IA	Office of International Affairs
IESR	Institute for Essential Services Reform
JETP	Just Energy Transition Partnership
LBNL	Lawrence Berkeley National Laboratory
LEAP	Low Emissions Analysis Platform
LMI	low-to-moderate income
MASKEEI	Indonesian Energy Efficiency Society
MEMR	Ministry of Energy and Mineral Resources
NREL	National Renewable Energy Laboratory
PLN	Perusahaan Listrik Negara
PT	Perseroan Terbatas
SWG	sub-working group
TIMES	The Integrated MARKAL-EFOM System
USAID	U.S. Agency for International Development
USTDA	U.S. Trade and Development Agency

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1 Overview

In alignment with global climate objectives, the Republic of Indonesia, home to the world's fourth-largest population and a diverse archipelago comprising over 17,000 islands, has embraced a federated structure that informs its approach to climate governance. With the submission of its Nationally Determined Contribution to the United Nations Framework Convention on Climate Change on July 22, 2021, Indonesia has set an ambitious baseline target of a 29% reduction in greenhouse gas emissions from its projected business-as-usual state by 2030, with a conditional increase to a 41% reduction contingent upon international support. The Indonesian government recognizes the need for substantial climate finance, estimating the requirement at \$323 billion to realize these targets. Furthering its commitment, Indonesia enhanced its Nationally Determined Contribution in September 2022, increasing its emission reduction goals to 31.9% unconditionally and 43.2% conditionally.

At the COP26 summit, Indonesia underscored its commitment by endorsing the Global Coal to Clean Power Transition Statement, signaling a resolve to phase out unabated coal power by the 2040s, subject to international financial and technical support. Given the significant role of extractable resources in its economy, Indonesia is carefully considering the socioeconomic ramifications of this transition to ensure a just and equitable shift toward a net-zero energy economy.

During its G20 Presidency in 2022, Indonesia highlighted a sustainable energy transition as a cornerstone, demonstrating its leadership in advocating for sustainable, resilient, and inclusive economic advancement. Indonesia's strategic framework, as delineated in its Long-Term Strategy for Low Carbon and Climate Resilience 2050, articulates a vision for national development that harmonizes emission reductions with economic growth, social justice, and climate resilience.

In their November 2023 Joint Statement from the Leaders of the United States and the Republic of Indonesia: Elevating Relations to a Comprehensive Strategic Partnership, President Biden and President Joko Widodo reaffirmed that the two countries will pursue urgent actions in efforts to limit the planet's temperature increase to 1.5 degrees Celsius above preindustrial levels. They resolved to expand collaboration on clean and renewable energy production to accelerate the clean energy transition while working to ensure the affordable, accessible, and transparent provision of clean energy for their citizens. Leaders of the two countries also acknowledged the value of the Net Zero World Initiative in supporting the transformation of Indonesia's energy economy.

The Net Zero World Initiative is a collaborative effort of eight countries, nine U.S. government agencies, 10 U.S. Department of Energy (DOE) national laboratories, and partnering philanthropies and nongovernmental organizations. Its goal is to elevate and enact climate ambition pledges and accelerate the transition to net-zero, resilient, and inclusive energy systems globally. With dedicated cross-lab and interagency teams, the initiative works hand in hand with partner countries to outline country-specific pathways to net zero, guiding both implementation actions and investment strategies.

This chapter details the collaborative endeavors, the partnerships formed, and the strategic initiatives propelling Indonesia toward its laudable climate objectives, with particular emphasis on a Net Zero World Initiative program of joint work built around a theory of change for "Achieving Just Net Zero Energy Transitions Together."

The Net Zero World team, the Government of Indonesia's Ministry of Energy and Mineral Resources (MEMR), and other stakeholders jointly identified and are advancing action in the four priority focus areas shown in Figure 1 to help achieve the country's ambitious climate targets:

The White House. 2023. "Joint Statement from the Leaders of the United States and the Republic of Indonesia: Elevating Relations to a Comprehensive Strategic Partnership." November 13, 2023. <https://www.whitehouse.gov/briefing-room/statements-releases/2023/11/13/joint-statement-from-the-leaders-of-the-united-states-and-the-republic-of-indonesia-elevating-relations-to-a-comprehensive-strategic-partnership/>.

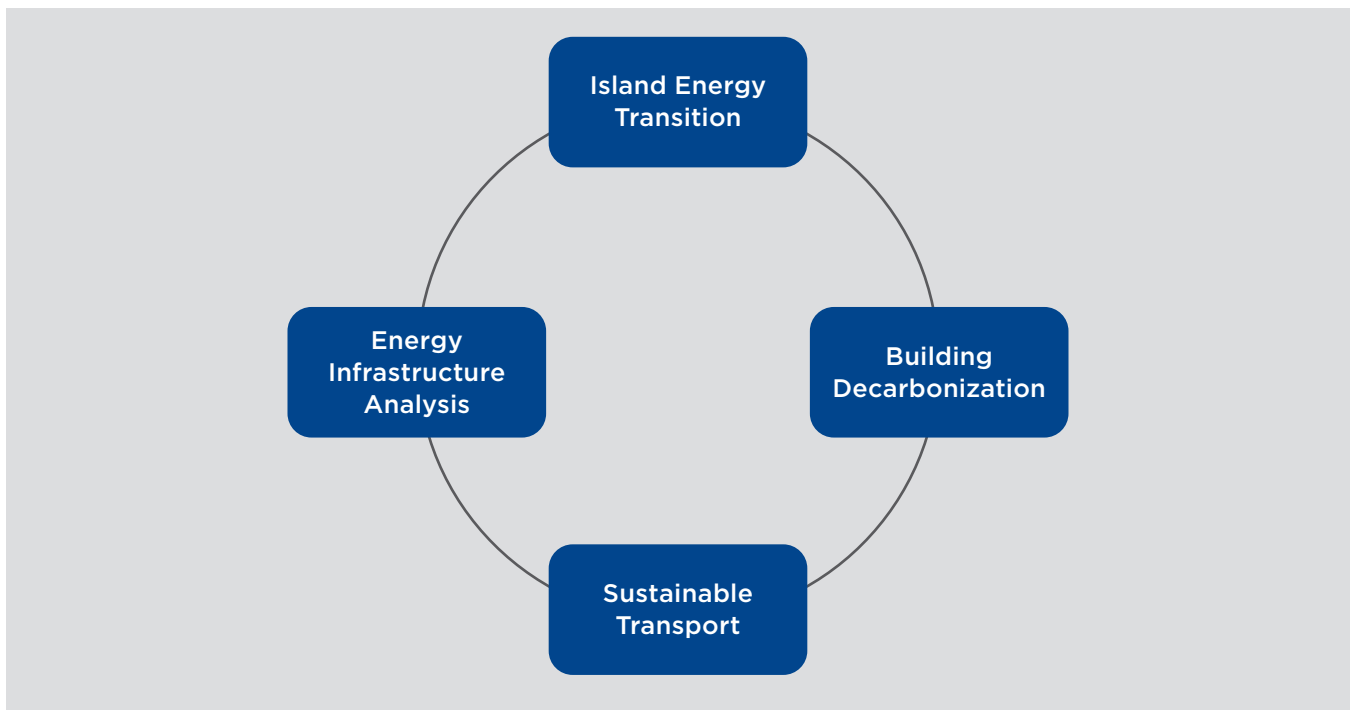


Figure 1. Priority focus areas

The Net Zero World Initiative activities described in the following sections are designed to achieve inclusivity, energy justice, and sustainability by working nationally as well as directly with provinces, diverse stakeholders, and educational institutions, to address local development needs and build enduring institutional and human capacity.

2 Pathway Modeling Tools and Outcomes

Net Zero World modeling experts collaborate with MEMR, the National Development Planning Agency (Bappenas), U.S. Agency for International Development (USAID), and other stakeholders to strengthen clean energy transition planning with modeling tools, analyses, and capacity-building assistance. This effort is pivotal for advancing comprehensive decarbonization and investment assessments.

Primary objectives of this modeling effort are to:

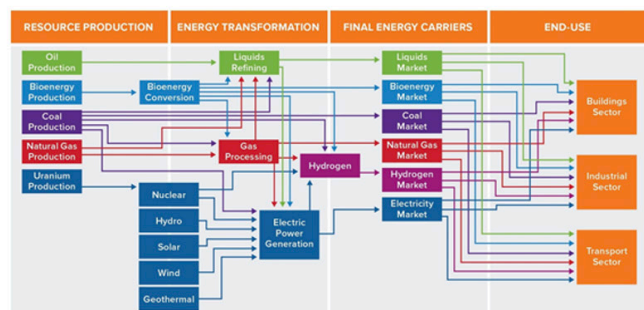
- Develop an energy system analysis modeling framework with a regional breakout of supply and demand, multisector optimization capability, and ability to guide and inform subnational implementation and investment actions that support national energy transition and development goals
- Coordinate modeling assumptions with the International Energy Agency, MEMR, and Bappenas, then apply modeling tools to support decision-making for accelerated coal phase-out, renewable energy deployment, transport electrification, energy efficiency, and inter-island transmission
- Strengthen local capacity of MEMR, provincial planning agencies, and other stakeholders in energy system modeling, policy evaluation, and demand-side investment analysis.

NET ZERO ENERGY TECHNICAL AND INVESTMENT PLANS

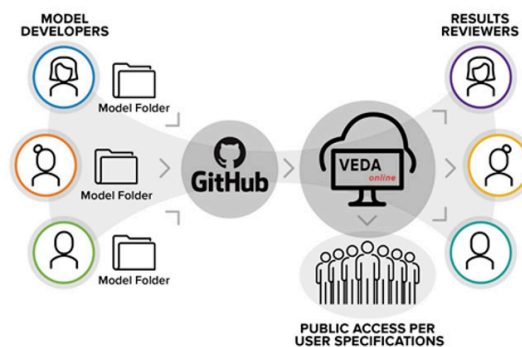
Powerful tools support remote collaboration and analysis of energy system-wide decarbonization pathways.

Local modelers, NZW cross-lab teams, and additional stakeholders work together on country-driven analyses at city- to national-level.

Strengthen local capacity and inform decision making on priority sectors and initiatives on which to focus decarbonization actions, enabling policies, and investment.



Apply NZW cross-lab deep knowledge and expertise with system modeling (LEAP and TIMES), supply- and demand-side technologies, policy options, business models, and just transition planning.



Collaborate remotely among teams of modelers, country energy system experts, and additional stakeholders and reviewers.

Figure 2. Net-zero energy technical and investment planning tools applied in Indonesia

To achieve these objectives, pathway modeling assistance is designed to complement and elevate Indonesia's existing modeling endeavors. Using strategic targets outlined in the Indonesian government's latest road map to net-zero emissions in the energy sector, the advanced analysis framework illustrated in Figure 2 is applied to evaluate supply- and demand-side actions and identify robust technology and investment strategies. This platform supports detailed, country-driven analyses across different scales, from provincial to national, providing crucial insights for decision-making on key decarbonization actions and formulation of suitable policies and financial mechanisms.

Three primary tools are being utilized:

- **Low Emissions Analysis Platform (LEAP):** LEAP is employed for demand-side analysis of Indonesia's energy sector. It focuses on understanding energy consumption patterns and demand-related aspects, providing insights into energy efficiency and demand-side strategies.

- **The Integrated MARKAL-EFOM System**

(TIMES): TIMES is a full energy economy model that integrates assumptions about fuel markets, technologies, demands, and policies. It analyzes supply-demand and cross-sector impacts and uses a least-cost solution logic to identify a cost-effective energy system development pathway.

- **VEDA-Online:** TIMES models are developed, managed, and run within the VEDA-Online model management platform, which facilitates remote collaboration. Analysis participants and reviewers can construct a shared understanding of system data, collaboratively develop scenarios, and share views of analysis results.

Key pathway modeling activities performed include:

- **Developed an Indonesia Regional LEAP model** building on the national LEAP model developed in the first year of the NZW collaboration. The disaggregation was based on physical drivers collected at the regional level in collaboration with IESR and base-year results were validated with

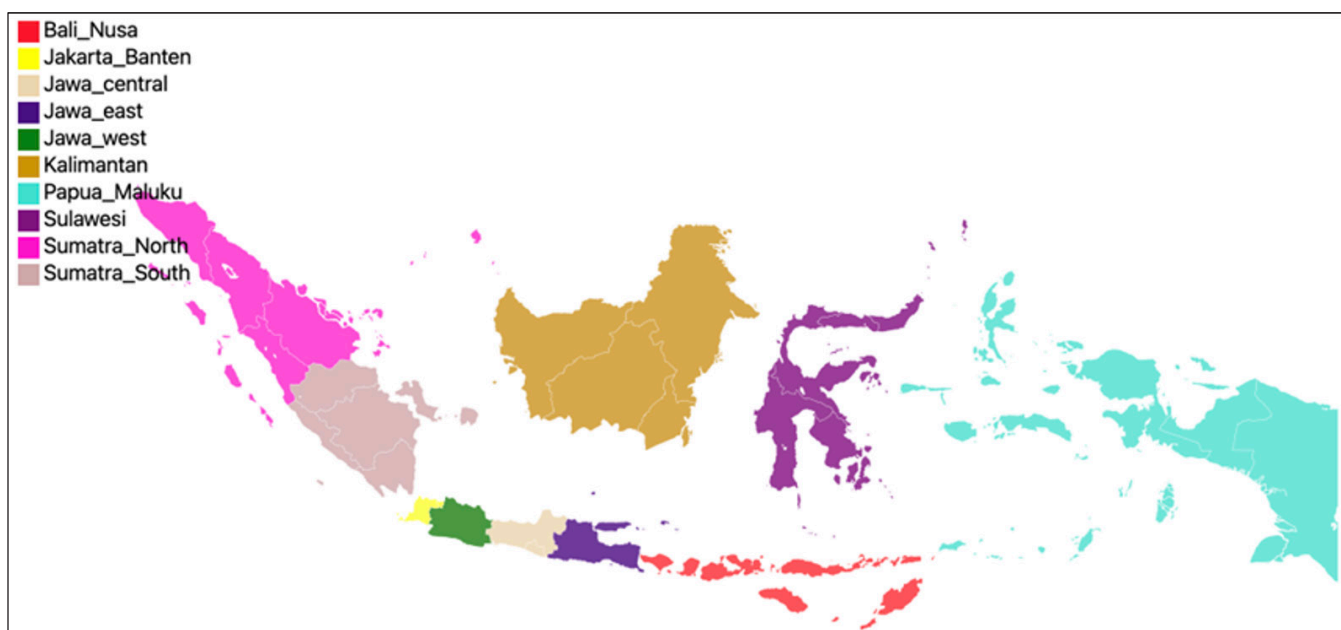


Figure 3. Ten regions represented in the Indonesia Regional TIMES model

electricity sales data from Indonesian state-owned electricity company Perusahaan Listrik Negara (PLN). LEAP model results in the business-as-usual and net-zero scenarios were provided as input to the TIMES model with a breakdown of demand forecast to 2060 by region, sector, end use, and fuel.

- **Developed an Indonesia Regional TIMES model** consisting of 10 model regions (highlighted in Figure 3) with power sector data provided for individual existing generating units of 50 MW or greater and regional values specified for solar and wind resource potential. The model was further updated with demand projection data from LEAP and assumptions on power plant costs, coal plan retrofit options, and regional hydro and geothermal potential from MEMR National Electricity Master Plan scenarios and Indonesia Just Energy Transition Partnership (JETP) analyses.
- **Presented modeling results** to demonstrate how this analysis framework can be used to gain insights into the impact of electric vehicle (EV)

charging, explore multivariable uncertainty in decarbonization pathway analyses, and apply a mark-to-model approach for evaluating investments in environment-improving technologies. For example, preliminary analyses found that EV charging in Indonesia can either exacerbate evening peak challenges or help manage excess daytime solar capacity (Kintner-Meyer et al. 2022). As illustrated in Figure 4, depending on charge timing, grid-responsive “smart” EV charging results in 50 GW less grid battery storage required by 2050.

- **Collaborated with USAID, MEMR, Bappenas, and the German Development Corporation (GIZ)** to enhance and apply modeling capabilities to accelerate integrating new, renewable energy sources and supporting policy reforms under the JETP Comprehensive Investment and Policy Plan and support Bappenas’s results-oriented infrastructure development planning.

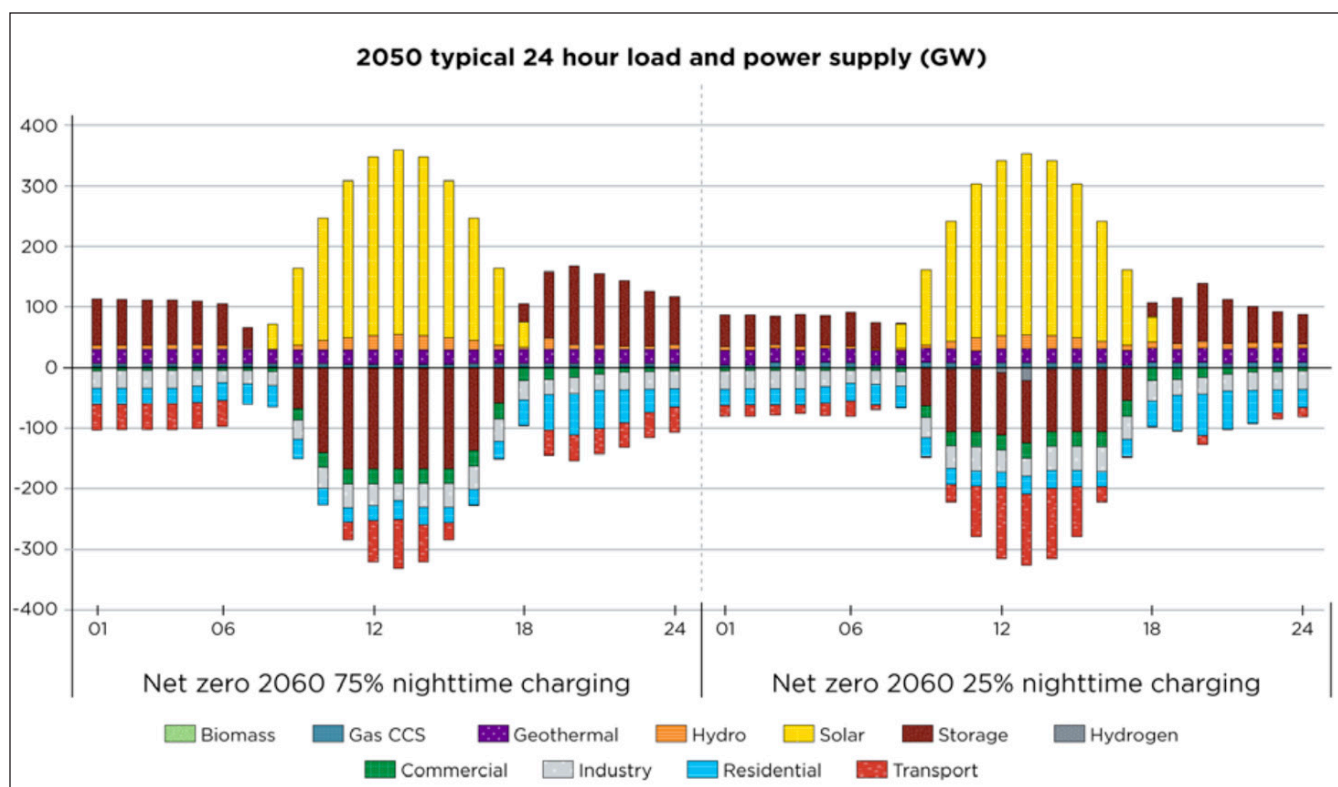


Figure 4. Indonesia's 2050 load profiles (negative) and power supply (positive) for Net Zero 2060 scenarios with fixed 75% nighttime charging (left) and flexible daytime charging (right)

Advanced Analytics for Balancing Risk and Return on Investments in Environment-Improving Technologies

Current investment in environment-improving technologies and net-zero carbon transition has a significant value, part of which cannot be captured by the common mark-to-market method of valuing investment based on current market conditions. Investors who recognize the urgency of decarbonizing the global economy need advanced analytics and methods for balancing risk and return on investments in environment-improving technologies.

In Annex A, we describe the importance of mark-to-model valuation in navigating investment decisions during an active period of global and regional climate policy formation. The proposed mark-to-model valuation methodology accommodates knowledge and anticipations about the future state of the economy, environmental regulation, and other factors. It is a necessary valuation instrument in nonstationary situations when extrapolation of historical data misleads investors. By using this methodology, policymakers can make informed decisions about where to allocate public funds to achieve the greatest economic and environmental benefits.

To demonstrate the mark-to-model method, using the Indonesia TIMES model, the Net Zero World modeling team forced a 500-MW investment in five power plants—solar photovoltaics, pulverized coal, natural gas combined cycle, coal with carbon capture and storage, and natural gas combined cycle with carbon capture and storage—in 2027 and calculated their return on investment over a range of carbon price scenarios. The net present value of each project's capital, operation and maintenance, fuel, and carbon price costs minus its electricity revenue was calculated, normalized by the project's upfront investment cost. Electricity revenue was calculated as the endogenous modeled electricity price multiplied by generation (based on modeled endogenous dispatch) of each technology. The rest of the system evolved according to least cost.

The analysis demonstrated the mark-to-model valuation approach, as well as the ways in which this approach differs from more conventional valuation methods. As modeled in this study, solar has a consistent, moderate return across the carbon price distribution; gas profitability falls with increasing carbon price; and coal with carbon capture and storage is slightly profitable for a small portion of the analyzed carbon price scenarios.

Source: Anda et al. 2023

Key outcomes from this pathway modeling include:

- Local agencies have improved tools for planning, accelerating, and scaling just energy transitions using regionalized models for system-wide analysis with multisector optimization capability and deeper focus on evaluating eMobility, energy efficiency, and inter-island transmission.
- Coordinated energy-planning assistance from Net Zero World, USAID, and GIZ facilitates alignment of modeling assumptions with MEMR and Bappenas, confidence in modeling results, impactful analyses of shorter-term interventions (including EV technology adoption pathways and charging strategies up to 2035), and increased decision support for preparation of the Mid-Term Development Plan.

Next steps in pathway modeling include:

- Advance clean energy transition planning in coordination with USAID to accelerate integrating new, renewable energy sources and supporting policy reforms under the JETP Comprehensive Investment and Policy Plan.
- Continue collaborating with MEMR, Bappenas, USAID, and GIZ on model calibration (e.g., updating model data with regional load growth projections and reviewing sustainable biomass supply curves), conducting analyses to support Bappenas infrastructure development planning, and training local planners on the use of advanced modeling tools.
- Collaborate with MEMR to accelerate geothermal deployment and prepare for the planned March 2024 Workshop on Enhanced Geothermal Systems.
- Launch technical assistance to accelerate action on cost-effective and resilient renewable energy grid integration and strategic transmission investments. This initiative could include analysis of renewable energy enabling transmission investment, regulator-to-regulator knowledge exchange, leveraging of effective capacity-building approaches in Hawaii, and peer-to-peer learning between PLN and other leading international power system operators.

3. Implementation Action Progress and Outcomes

Net Zero World has developed support activities for decarbonization actions designed to accelerate the clean energy transition, strengthen local capacity, and inform decision-making for priority sectors and initiatives. These actions focus on providing regulatory, technical, and financial support to create an enabling environment for accelerating net-zero pathways at the national and subnational scale, together with Indonesian partners.

3.1 Energy Infrastructure Analysis: Captive Coal

The United States, Indonesia, and likeminded countries known as the International Partners Group continue to collaborate on Indonesia's JETP, announced at the 2022 Group of 20 (G20) Summit in Bali, which will reduce emissions and accelerate the deployment of renewable energy in Indonesia. MEMR is a key player in the Indonesia JETP, hosting the JETP Secretariat.

Both Net Zero World and JETP provide excellent opportunities for Indonesia to accelerate its clean energy transition—JETP mobilizes \$20 billion in public and private financing in support of Indonesia's ambitious climate commitments under the agreement, while the Net Zero World Initiative provides technical expertise (e.g., DOE/lab capabilities to technically de-risk projects) and investment mobilization support in association with U.S. government agencies (U.S. Trade and Development Agency [USTDA], U.S. International Development Finance Corporation, Export-Import Bank of the United States, and Millennium Challenge Corporation) and philanthropic partners.

Indonesia, the world's largest producer of nickel, saw foreign direct investment skyrocket in recent years, with a focus on critical mineral development that involves refining low-grade ore to battery-grade material. Nickel refining is done near the mine and is powered by off-grid captive coal-fired power plants. Currently, the refined products are primarily exported to EV battery manufacturers abroad, depriving Indonesians of potential economic, environmental, and other benefits from the clean energy transition, as well as limiting the opportunity

for Indonesia to be viewed as a source for high quality clean mobility manufacturing outputs that meet international standards for environmental, social, and governance requirements.

Initial Net Zero World assistance for energy infrastructure analysis includes technical assistance and decision support focused on identifying viable clean energy alternatives to captive coal. This work leverages the expertise of DOE national laboratories to quantify the energy use and emissions of industrial activities in the battery and EV supply chain and identify clean energy processes that can serve as alternatives to current carbon-intensive methods.

Key captive coal activities performed include:

- A DOE cross-lab team, including an energy management specialist from Lawrence Berkeley National Laboratory (LBNL), a power system analyst from [National Renewable Energy Laboratory](#) (NREL), and an energy finance specialist from Argonne National Laboratory (ANL), was selected to assist with clean energy alternatives to captive coal. The team presented an overview of available Net Zero World technical assistance and investment mobilization support at a facilitated group discussion on engaging captive power generators for decarbonization organized by the MEMR Directorate General of Electricity and USAID's Sustainable Energy for Indonesia's Advancing Resilience Program. See the full presentation in Annex B.
- The cross-lab team also conducted desk research and analysis related to battery-grade nickel refining in Indonesia, identified opportunities for captive power assistance, and reported on the following analyses:
 - Study exploring the current status and expected future developments in the supply and demand for Class I nickel, and the implications for efforts to generate Class I nickel from laterite ores in Indonesia (report provided in Annex C).
 - Life cycle analysis of nickel refining in Indonesia using high-pressure acid leaching to produce battery-grade Class I nickel.

As described in the report provided in Annex D, this study examined a hypothetical high-pressure acid leaching-based nickel operation in Indonesia and evaluated the resulting environmental burdens associated with viable energy input pathways from solar photovoltaic, geothermal, and hydropower as alternatives to the current method of providing electricity via a captive-coal facility.

Key outcomes from this analysis of clean energy alternatives to captive coal include:

- JETP and captive power system stakeholders have improved the understanding of viable clean energy alternatives to captive coal and have become trusted partners with expertise to provide targeted technical assistance and science-based decision support. They are collaborating with Indonesian and international partners on research, analyses, and development assistance that reinforces activities and makes these activities defensible and actionable.
- During a meeting of country leaders, the U.S. government and the Government of Indonesia committed to working toward a low-greenhouse gas emissions mineral supply chain, including efforts to promote clean and low-emission power for mineral processing. The two countries also acknowledged the value of the Net Zero World Initiative to support the transformation of Indonesia's energy economy, including cooperation on low-carbon battery supply chains.

Next steps in energy infrastructure analysis include:

- Develop a nickel-to-battery-to-EV road map that identifies viable clean energy alternatives to captive coal-powered industrial growth—encouraging the creation of clean, high-value battery supply chains, fostering low-carbon technology adoption, supporting the transition to electrified transportation, and meeting world-class environmental and labor standards, in line with JETP goals.
- Expand captive power system support to include development and implementation of low-carbon pilot projects and measures with Net Zero World assistance and joint work focused on

- Engineering analyses to understand electricity and thermal energy requirements and consider process improvements, energy-efficiency potential, and other industrial production process constraints.
- Techno-economic assessments to compare clean energy alternatives to coal at the site over several criteria (e.g., capital costs, operational costs, levelized cost of electricity and heat, efficiency, and emissions).
- Project financial analyses high-level implementation road map development assistance linked to potential JETP financing.

3.2 Island Energy Transitions

At the request of the MEMR Directorate General of New, Renewable Energy and Energy Conservation in April 2022, Net Zero World initiated island energy transition assistance in Indonesia as an early decarbonization action. This joint work supports the national De-Dieselization Program with energy

transition assistance for small island communities in the outermost and least-developed regions of the country—often referred to as 3T (terdepan, terluar, tertinggal) regions.

As illustrated in Figure 5, Net Zero World Island energy transition assistance supports decarbonization actions from candidate site identification, through techno-economic assessment, project feasibility study and design, investment mobilization, deployment, replication, and scale-up.

Key island energy transition activities performed include:

- Completed a techno-economic assessment using NREL's REopt® tool to understand cost implications of pathways to replace diesel installations with renewable energy plus energy storage hybrid minigrids in 12 small island communities.

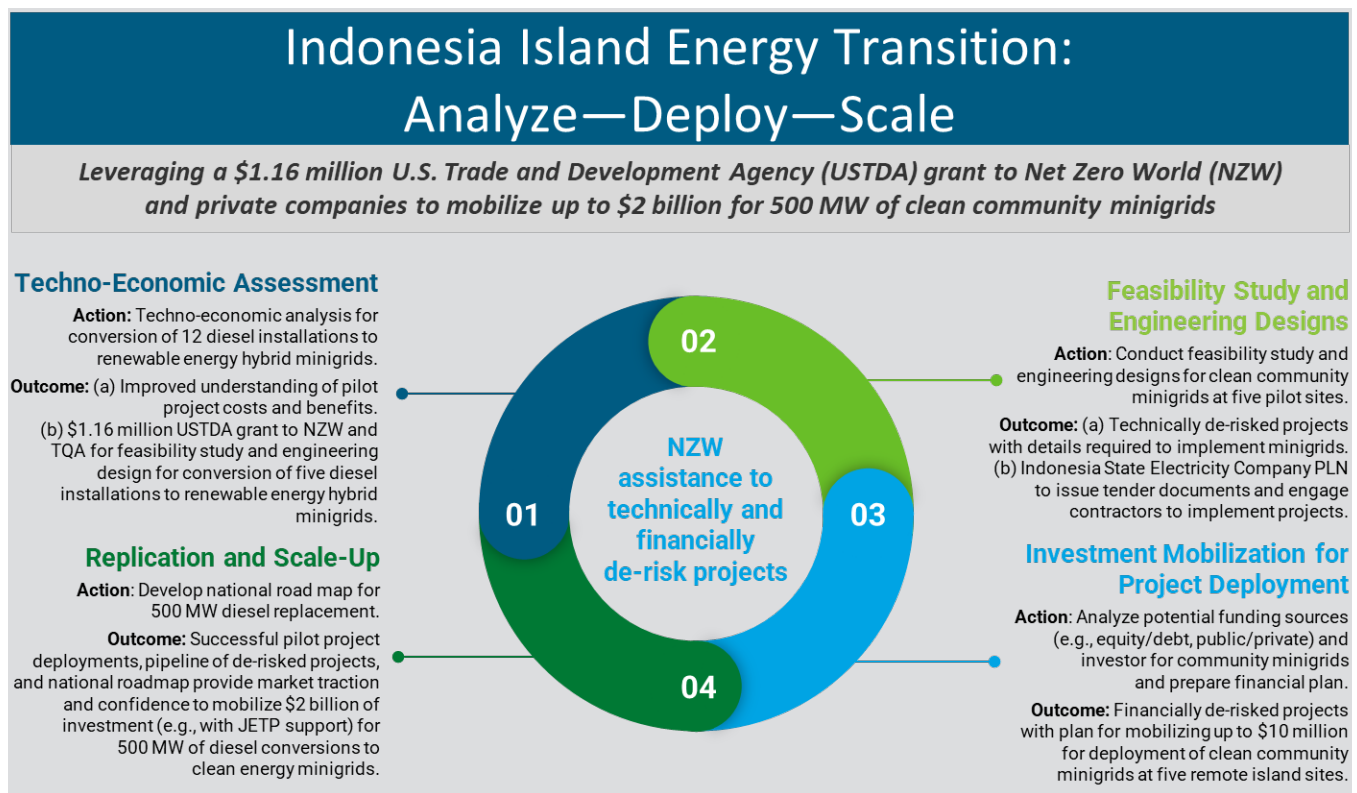


Figure 5. Net Zero World's approach to analyzing, deploying, and scaling clean community minigrids in Indonesia.

- Initiated joint work with industry partner TQ Automation on a feasibility study and engineering designs for implementation of renewable energy hybrid minigrids at 3T islands in Indonesia. This project, conducted for PLN with grant funding from USTDA, focuses on five remote island communities in eastern Indonesia. It delivers detailed engineering designs for minigrid solutions; evaluates associated economic, environmental, and other impacts; and conducts a financial and implementation analysis to help PLN and potential contractors prepare for future deployment of the renewable energy minigrids.
- Began development of a national replication and scale-up road map that recommends regulatory, institutional, technical, and financial pathways for transition of 500 MW of diesel installations in small island communities in the 3T region of Indonesia.
- Key outcomes from this island energy transition assistance include:
 - **Mobilized 1.16 million USD to support renewable energy minigrids.** USTDA agreed to partner with PLN on a feasibility study for renewable energy minigrids in five remote sites in eastern Indonesia. This project is intended to develop a replication strategy for wider renewable minigrid implementation across the region and will be conducted by TQ Automation in a public-private partnership with DOE's national labs under the Net Zero World Initiative.
 - **Increased confidence in deployment of clean energy solutions for remote island communities.** PLN recently confirmed its intent to issue tender documents in Q2 of 2024 to implement clean community minigrid solutions at the previously mentioned five sites, and a philanthropic organization expressed interest in applying a similar approach to support a feasibility study and designs at over 60 additional sites.
 - **Built a pipeline of technically and financially de-risked projects** to replace diesel gensets with renewable energy hybrid systems, which facilitates mobilization of \$1.3 billion in investment for 500 MW of diesel replacement.

- **Supported a just energy transition** that improves the quality of life among people in 3T areas. The Electricity Supply Business Plan 2021–2030 reports that converting 500 MW of diesel to new renewable energy could create over 24,000 new jobs and also help to reduce emissions, decrease fuel consumption and provide other benefits.

Next steps in the island energy transition include:

- Complete ongoing feasibility studies, mobilize investment needed to deploy the five minigrids, collaborate with local and international stakeholders to develop the national replication and scaleup road map, and initiate joint work on implementing the road map.

3.3 Buildings

Indonesia is well positioned to lead Southeast Asia with net-zero energy buildings demonstrations and gain the benefits of cost-effective planning, optimized supply chains, energy efficiency, flexible load management, reduced peak electricity demand, energy cost reduction, and revenue generation. Indonesia is also positioned well to become a leader in critical economic, job creation, environmental, and energy equity gains for underserved communities. This buildings implementation action is designed to accelerate a net-zero and resilient built environment in Indonesia.

Key buildings activities performed include:

- **Building decarbonization workshop.** In its first foray into Indonesia, the Net Zero World Initiative hosted a U.S.–Indonesia Joint Workshop on Decarbonizing the Building Sector, held near Jakarta in Tangerang on February 22–24, 2023 (Annex A: Workshop Summary). Supported by DOE, MEMR, and MASKEEI, the event attracted over 150 buildings industry participants from many parts of the region and the world to discuss collaboration toward a net-zero energy buildings sector in Indonesia. Participants included U.S. and global companies that presented solutions for pursuing a low-carbon future and encouraged policy adoption to support greater investment in Indonesia. The workshop noted Indonesia's

commitment to achieving rapid decarbonization across its entire economy, and organizers outlined the many initiatives already underway to boost building energy efficiency, encourage use of low-carbon materials, and improve construction approval processes by local authorities. Researchers, practitioners, industry, and other experts from a range of countries highlighted the many areas in which the United States and Indonesia might productively collaborate in pursuit of zero-carbon buildings across policy, technology, and capacity building. The program also provided a study tour of some leading green buildings in the BSD City complex in South Tangerang.

The workshop concluded by prioritizing areas for collaboration. These included training and capacity building; pilot projects for low-income housing; support for rating and certification schemes; and the possibility of establishing a building research center for knowledge exchange, information databases, and product testing, all bolstered by access to the expertise of the U.S. national laboratories.

- **Building Decarbonization Working Group.**

To execute this vision, LBNL, MASKEEI, and MEMR launched the Net Zero World Indonesia Building Decarbonization Working Group in May 2023, with four sub-working groups (SWGs). As in other emerging economies, the building sector in Indonesia is dominated by homes—the number of which has been growing rapidly to meet population-driven demand. However, most buildings built over the past four to five decades lack adequate natural ventilation and other passive cooling measures suited to tropical climates, and rely at least partly on air conditioning (AC). The SWGs must address cooling in both new and existing buildings to save energy and reduce carbon as components of the net-zero building strategy.

- Over their first six months, SWG-A (National Center) and SWG-C (Analysis and Financing) have focused on techno-economic analysis of passive and low-energy “whole-building” cooling solutions for Indonesia’s tropical climate. Meanwhile, SWG-B (Capacity Building) has initiated teacher training

(“train-the-trainer”) programs to support career-track workforce development for competencies to develop net-zero buildings, and SWG-D (Pilot Projects) has identified affordable housing pilot projects that incorporate passive, low-cost, and resilient strategies for low-to-moderate income (LMI) communities (Annex F: Working Group Overview).

- **Whole-building cooling simulations.** To save energy, reduce carbon emissions, improve thermal comfort, and reduce reliance on mechanical cooling in LMI homes, SWG-A researchers from the University of Indonesia, Universitas Multimedia Nusantara, PT DEX Solusi Project Consultants, MASKEEI, and LBNL simulated the benefits of 12 passive or low-energy cooling solutions: solar-reflective “cool” roofs, cool walls, insulated roofs, insulated walls, low thermal-emissivity (“low-E”) windows, solar-control window films, ceiling fans with and without temperature setback, exterior and interior window shades, natural ventilation based on schedule and outside air temperature, and natural ventilation based only on outside air temperature. The team used the DOE building simulation software platform EnergyPlus® to model the annual hourly energy use and internal temperatures of a 36 m² floor area, single-story LMI rowhouse (living room, kitchen, bathroom, two bedrooms, attic) in four locations: Balikpapan, Jakarta, Padang, and Waingapu. The home was modeled in two orientations (fronting south or west) and under four AC configurations: (1) bedroom-only AC, 9 p.m.–5:30 a.m. daily, cooling setpoint 25° C; (2) no AC; (3) whole-house AC, 24 hours daily, cooling setpoint 25° C; and (4) whole-house AC, 6 p.m.–6 a.m. daily, cooling setpoint 25° C.

The team evaluated annual heating, ventilating, and air conditioning (HVAC) energy savings and thermal comfort improvements. Operating ceiling fans with thermostat setback control—that is, raising the AC cooling setpoint to account for the cooling effects of air motion—yielded the highest annual HVAC electricity savings (up to 90% with bedroom-only AC). Insulated roofs and walls, cool roofs and walls, and low-E windows were the top envelope measures, each yielding 15%–45% annual HVAC

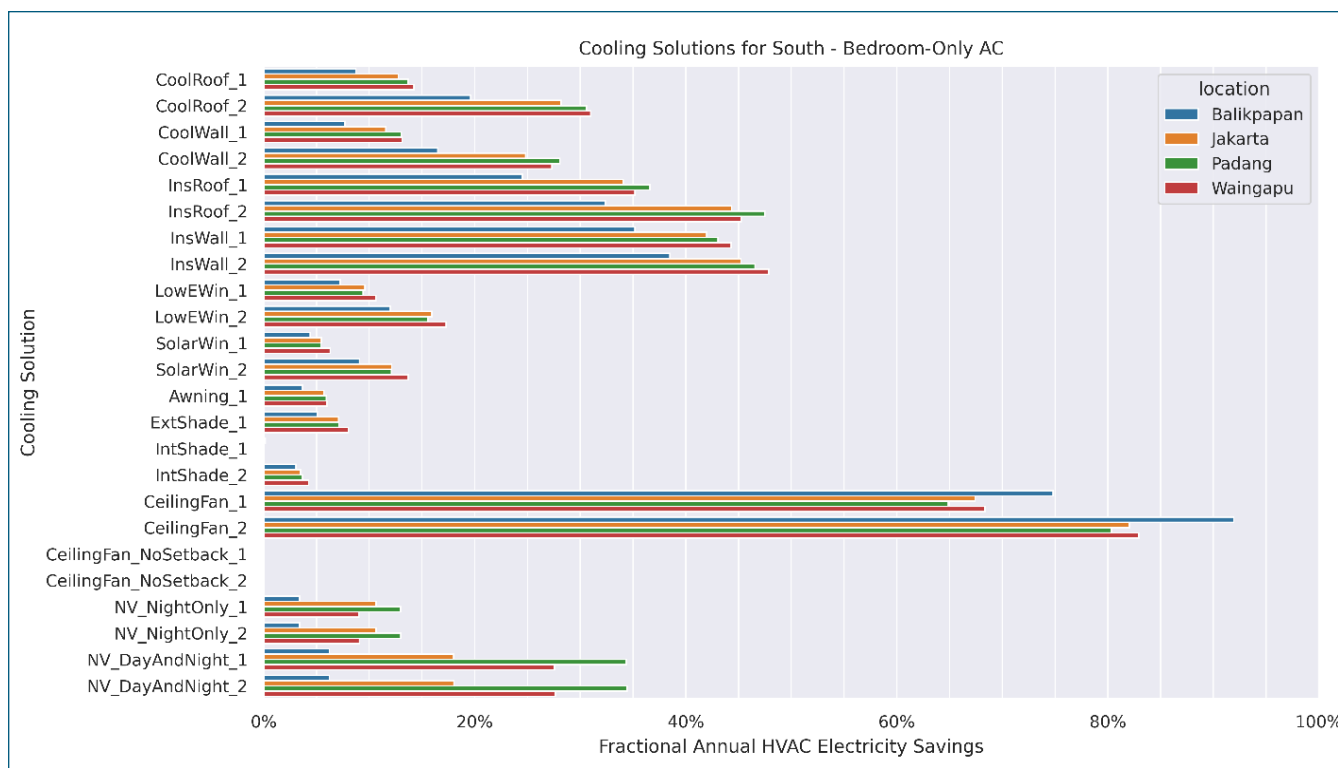


Figure 6. Fractional annual HVAC electricity savings of cooling solutions in four Indonesian cities, reported for a south-facing LMI house with bedroom-only AC

electricity savings with bedroom-only AC. Natural ventilation (opening windows whenever the outside air is sufficiently cool) offered savings of about 5%–35% and was twice as effective when applied 24 hours/day rather than only overnight (1–6 a.m.). All energy savings and comfort improvements are detailed in Annex G: Cooling Simulations.

- **Whole-building cooling cost-benefit analysis.**

Leveraging the results from SWG-A, SWG-C researchers from MASKEEI, MEMR, ANL, LBNL, and Asia Clean Energy Partners Ltd. are estimating the consumer and national costs and impacts associated with the 12 whole-building cooling solutions. This analysis will inform investments in policies and programs to advance research, development, deployment, and commercial adoption of low-energy building sector cooling technologies in Indonesia under the Indonesia JETP Comprehensive Investment and Policy Plan.

SWG-C has completed a cost-benefit analysis framework (Annex H: Cooling Cost-Benefit Analysis

Framework) and initiated data collection and analysis to estimate the national investment against electricity savings for all 12 solutions. For several passive and low-energy cooling solutions that yielded high electricity savings at low cost, SWG-C is evaluating (a) life-cycle cost (USD), payback period (years), and net present value (USD); (b) annual electricity burden change (%) for LMI stakeholders; (c) reduction in annual power-sector generation need by 2030, 2040, 2050, and 2060 (terawatt hours [TWh]); and (d) reduction in annual household electricity consumption by 2030, 2040, 2050, and 2060 (kWh).

SWG-C found that the energy conservation measure (ECM) of a ceiling fan with thermostat setback (raising the cooling setpoint to 28.1° C from 25° C while maintaining constant thermal sensation) provided both the highest nationwide electricity savings and the highest net present value for households, followed by insulated walls, insulated roofs, and cool walls (Annex I: Cooling Cost-Benefit Analysis Results).

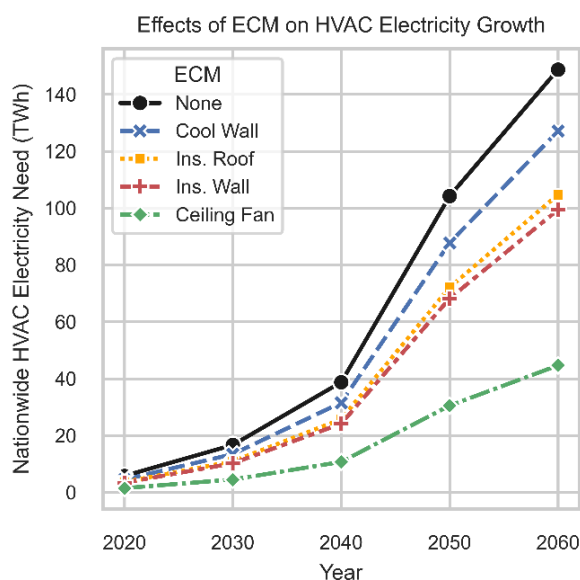


Figure 7. Effects of top four passive/low-energy cooling ECMs on growth of HVAC electricity demand, 2020–2060

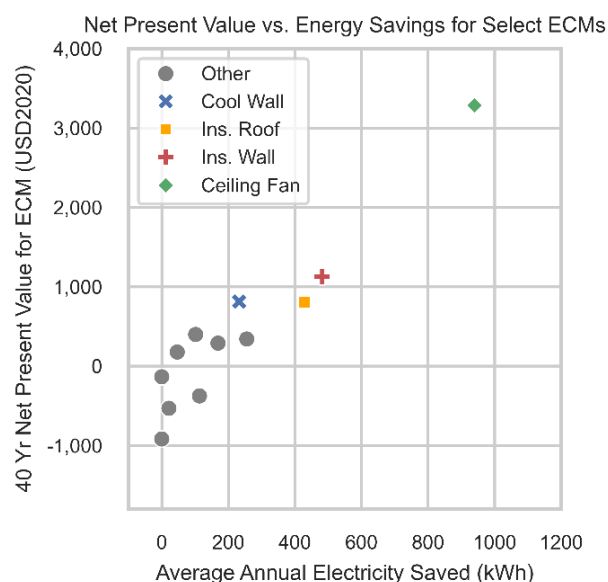


Figure 8. Forty-year net present value of passive/low-energy cooling ECMs vs. average national household electricity savings over the same period

Figure 7 shows baseline (i.e., no ECM) growth in annual national HVAC electricity needs between 2020 and 2060 as compared to annual national HVAC electricity needs when HVAC is combined with the four most-effective ECMs. Figure 8 shows the 40-year net present value (2020–2060) in 2020 USD versus the average annual household HVAC electricity savings for the four ECMs over the same 40-year period. The analysis assumes a rising HVAC minimum equipment performance standard as described in Annex I: Cooling Cost-Benefit Analysis Results

- **Capacity building.** SWG-B members from Green Building Council Indonesia, MEMR, the Ministry of Public Works Housing (MPWH), Trisakti University, MASKEEI and the Indonesia Energy Evaluation Institute, Indonesian Property Management Association, Perseroan Terbatas (PT) Pembangunan Perumahan, and LBNL have initiated a capacity-building program to provide specific knowledge and skills related to designing, constructing, and retrofitting buildings to make them net zero. The program includes improving or expanding currently available training programs, adding new essential skills to meet the specific challenges of retrofitting existing buildings, and providing the capability to conduct monitoring and evaluation of project

implementation. As of October 15, 2023, the SWG-B team proposed six training courses, each consisting of a training-of-trainers component and three modules (elementary, intermediate, and advanced). These six courses—(1) Energy Management, (2) Energy Audit, (3) Building Carbon Footprint Calculation, (4) Integrated Design Approach, (5) Energy Efficiency Projects Monitoring and Verification, and (6) Net Zero Buildings Development Program Monitoring and Evaluation for National Scale—are currently being examined and reviewed by a team formed by MASKEEI. Courses (1) and (2) are currently officially endorsed by the government using the Indonesian National Work Competency Standards. The NZWI’s proposed program will enhance existing courses by including skills needed to develop and manage Net Zero Buildings. Review of three courses and the Training of Trainers will be completed by December 31, 2023; the rest will be completed in the first semester of 2024 (Annex J: Capacity Building).

- **Pilot projects.** The main task of SWG-D is to prepare the development of selected Net Zero Building pilot projects in Indonesia. Its members from Green Building Council Indonesia, MPWH, PT Siemens Indonesia Group, PT Wijaya Karya (state-owned enterprise), PT PLN (state-

owned enterprise), PT Pertamina (state-owned enterprise), and LBNL will identify many available projects across Indonesia and propose those that are ready to be developed as part of the Net Zero Building initiatives in the country. The initiatives will apply and use internationally recognized net-zero rating systems, prioritize the use of local expertise and products, and support Indonesian society and culture. The pilot projects will focus on new and existing LMI homes and apply the following strategies:

1. Develop and apply technologies and methods that are best suited to Indonesia's tropical climate zones, by using low- or no-carbon building materials, and by addressing individual buildings' cooling needs and urban cooling issues suited to unique Indonesian circumstances.
2. Promote and develop the most effective and affordable solutions to reduce carbon emissions while maintaining building occupant health and comfort.
3. Improve the adaptive capacity of buildings and settlements, especially those at the bottom of the social economic pyramid, to make them more resilient to global climate change.
4. Develop, facilitate, and encourage net-zero building innovations in mitigating carbon emissions, an adaptive built environment, and restoration of the natural environment, responding to varied contextual challenges in the Indonesian archipelago.
5. Strive to achieve the highest-possible growth in the value creation of net-zero development initiatives in Indonesia, leading to as many green job opportunities as possible for Indonesia's skilled green working force.

By October 2023, SWG-D identified seven candidate projects: (1) Mother & Child Building of Persahabatan Hospital in Jakarta (new building); (2) Net-Zero Public Schools Owned by the Education Agency of Jakarta (new building); (3) Civil Servant Echelon 3 Housing in the Nusantara, the new capital city (new building); (4) Net-Zero Certified Housing Designed for a Typical Affordable Small House in Jakarta (new building design manual); (5) Existing

Office Buildings Owned by Major State-Owned Enterprises in Indonesia (retrofit existing buildings); (6) Net-Zero Healthy Village in Bandung, West Java (redevelopment and improvement); and (7) Net-Zero Office Buildings (new/retrofit buildings). These projects are detailed in Annex K: Pilot Projects.

Key **outcomes** from this building assistance include:

- Achieved broad consensus on priority areas of collaboration through dialogue with 100+ private sector industry, policymakers, academia and research, and other built environment professionals participating in the Building Decarbonization Working Group.
- Launched Net Zero World Buildings Working Group with the Government of Indonesia (MEMR and MPWH) and related industries.
- Identified viable net-zero and passive design pilot projects for LMI buildings, evaluated project costs and benefits, and received concurrence from JETP Secretariate that this information will be helpful input to JETP in its investment decision making (CIPP).

Next steps in buildings include:

- Advance whole-building cooling recommendations for JETP investments (SWG-A and SWG-C).
- Propose the detailed development model (including the suggested legal entity, ownership, finance, and operation) of the National Center for NZB Development (SWG-A).
- Implement "train-the-trainer" programs for trainings in building energy efficiency and other features for Net Zero Buildings in selected provinces and deliver the approved courses starting in the second semester of 2024 (SWG-B).
- Extend CBA works to cover projects proposed by SWG-A and SWG-D, including high-rise and low-rise LMI housing (SWG-C).
- Establish the steps and structure needed to develop the NZB pilot projects in selected provinces of Indonesia, in partnership with the building developers/project owners (SWG-D).

3.4 Sustainable Transport

Sustainable transport collaboration began in June 2023. Initial work focused on establishing a sustainable transport working group with Indonesian experts and stakeholders, identifying near-term high-impact targeted projects for decarbonizing transport at the subnational level, and developing low-carbon transport strategies for provinces.

Key sustainable transport activities performed include:

- Engaged various national and city agencies to explore potential partnerships and understand priority issues to include as sub-areas of work. Four key focus areas were identified: (a) Electric Two- and Four-Wheelers; (b) Electrification of Public Transport; (c) Charging Infrastructure; and (d) Capacity Building.
- Met with city representatives from Bogor, Makassar, and Depok and colleagues from the Jababeka industrial estate to discuss potential opportunities for joint eMobility work.
- Met with JETP Secretariate, Millennium Challenge Corporation, USAID, U.S. International Development Finance Corporation, USTDA, philanthropic partners, and other international development assistance organizations to present early-stage projects and investment opportunities and explore opportunities to collaborate and amplify the impact of ongoing and planned initiatives.

Key outcomes from this sustainable transport assistance include:

- City representatives from Bogor and Makassar expressed interest in collaborating more deeply in advancing eMobility projects and are taking internal steps to formalize this interest with a partnership agreement.

Next steps in sustainable transport include:

- Make formal working group announcement, with member presentations expected in March 2024.
- Meet more cities/regions to understand cooperation areas and identify opportunities to collaborate on development of low-carbon transport strategies for target provinces focused on: (1) EV charger deployment, and (2) scale-up of biofuels production.

4 Conclusion

4.1 Lessons Learned

To date, our collaborative journey with our country partners has revealed key lessons regarding the effective methods and technical aspects of achieving net-zero pathways. The following insights will inform our approach to continued collaboration with our partners in Indonesia and in other Net Zero World countries:

- Replicate the approach applied in Net Zero World island energy transition assistance to implement projects that demonstrate early wins and tangible value, while developing road maps to guide broader sector decarbonization at scale.
- Seek opportunities to quantify, articulate, and deliver multiple benefits from energy transition actions like the recently initiated joint work on developing a clean energy for battery to EV road map that advances the country's energy transition and economic development goals—encouraging creation of clean, high-value battery supply chains.
- Support Indonesia's goals for accelerating transitions to just and resilient net-zero energy systems, with Net Zero World assistance focused on hard-to-decarbonize areas not already addressed by other national and international programs. For example, while the JETP Comprehensive Investment and Policy Plan focuses on decarbonization actions in the power sector, a Net Zero World Buildings Working Group was launched with the Government of Indonesia and industry to identify net-zero design pilot projects, conduct cost-benefit analyses, and report findings to inform future JETP investment decisions.
- Leverage resources and capabilities available across Net Zero World U.S. government agencies and DOE laboratories, while seeking opportunities to build upon, strengthen, and collaborate with existing assistance programs (e.g., JETP and Millennium Challenge Corporation Second Compact for Indonesia) to foster cross-functional engagement and effective problem-solving that amplifies the impact of assistance programs.

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Mark-to-model valuation of investment in the energy sector

Jon Anda^{a)}, Alexander Golub,^{*)} Amit Kanudia^{c)}, Anil Markandya^{d)}, Evelyn Wright^{e)}

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- a.** Climate Equity Research (jonaanda@gmail.com)
 - b.** American University (agolub@american.edu)
 - c.** KanORS-EMR (amit@kanors.com)
 - d.** BC3 (anil.markandya@bc3research.org)
 - e.** Argonne National Laboratory and Sustainable Energy Economics (Evelyn.L.Wright@gmail.com)
- *)** Corresponding author

1. Introduction

Transitioning to a net-zero carbon emission economy is neither a linear nor a deterministic process. There is a significant gap between emissions under current policies and the net-zero trajectory, known in the literature as the emission gap. However, radical policy adjustments in the foreseeable future are inevitable under the pressure of public demand for stricter environmental policy on the one hand and disruptive technological innovations on the other. The dynamics are characterized by positive feedback, tipping points, phase transition, and bifurcation. A combination of such processes constitutes a major transition event known in the literature as dragon king. In contrast to the black swan, some predictability is possible. However, it requires the application of new instruments for financial analysis.

In our view, such a transition results in an abatement shorts squeeze (Golub et al. (2018) and Golub, Lubowski, and Piris-Cabezas,[2020]), multiple shocks on the global and regional economies, and stranded assets¹. But as noted, this destruction of the capital stock creates new investment opportunities for capital formation in sectors with a high return on investment, increased labor productivity, etc.

For corporations, it is unclear when climate policy may be modified, how radical the strengthening of climate policy would be and how many adjustments will be made over the coming decades during a lifetime of new investment. Business has to make significant investment decisions that would determine committed carbon emissions for the lifetime of deployed capital in the context of great climate policy uncertainty.

In response to climate policy uncertainty, business is likely to exercise a “tween deferral strategy” (see: Golub, Lubowski, and Piris-Cabezas,[2020]), that combines two components:

- Deferring investment into carbon-intensive assets (new construction or major modernization of existing ones);

- Delaying investment into low carbon and energy efficient technology unless this investment yields an immediate return competitive with other investment opportunities

Peszko, G., Van Der Mensbrugghe, D., Golub, A., Ward, J., Marijs, C., Schopp, A., Rogers, J. and Midgley, A., 2020. Diversification and cooperation in a decarbonizing world: climate strategies for fossil fuel-dependent countries. World Bank Publications.

The first strategic response to climate policy uncertainty reflects stranded assets. Business does not discount the possibility of climate policy in the nearest future that may significantly reduce the return on carbon-intensive capital. Fossil fuel-based technologies are mature, and there is not much headroom for some efficiency improvements to compensate for the losses associated with the cost of carbon.

Many corporations that are participants in the Carbon Disclosure Project (CDP) operate an internal carbon pricing. It helps them to avoid some risky investments in carbon-intensive technologies.

The second strategic response is driven by concern that a long delay in climate policy implementation may reduce the return on low-carbon technologies below a “comfortable level” and reduce the equity value of a corporation beyond an acceptable level. As a result, some corporations are inclined to wait until at least some climate policy uncertainty is resolved, and so they exercise a deferral option on low- carbon technologies. Even participants in CDP that use an internal carbon price to justify rejection of a carbon-intensive project do not use the carbon price to decide on accepting a low-carbon project.

In both cases, corporations preserve as much flexibility as possible and wait for new information that may reduce a deferral value on either option.

All corporations are exposed to climate policy uncertainty in a more or less similar way. Therefore, most of them de facto are building up short positions on carbon abatement. Even a partial resolution of climate policy uncertainty may

¹World Bank. The Changing Wealth of Nations 2021: Managing Assets for the Future.

Peszko, G., Van Der Mensbrugghe, D., Golub, A., Ward, J., Marijs, C., Schopp, A., Rogers, J. and Midgley, A., 2020. *Diversification and cooperation in a decarbonizing world: climate strategies for fossil fuel-dependent countries*. World Bank Publications.

spark a synchronized surge of demand on carbon allowances or carbon abatement technologies. Since most corporations are short on abatement, there is no way to close the gap quickly.

Some corporations have plans for how to deploy low-carbon technology and reduce exposure to climate policy when the policy is introduced. R&D creates a call option on new technology. However, the deployment of new technologies requires time and in any case corporations would be exposed to some transition costs.

The introduction of even a relatively modest price on carbon (\$20-50/tCO₂) will trigger a massive capital adjustment across the global economy in all sectors directly or indirectly exposed to the new climate policy environment.

In this paper, we demonstrate the importance of mark-to-model valuation in navigating investment decisions during an active period of global and regional climate policy formation. The mark-to-model valuation accommodates knowledge and anticipations about the future state of the economy, environmental regulation, etc. It is a necessary valuation instrument in nonstationary situations when extrapolation of historical data misleads investors. In the next section, we describe the valuation methodology. Section 3 describes the results, and the last section discusses the conclusions.

2. Methodology

For an individual investor, the future transformation of the regulatory environment and market transformations, including various shocks, appear as an exogenous process characterized by a great deal of uncertainty. The natural reaction is to delay investment decisions and wait until some critical uncertainties are resolved. Yet inaction as well as action may have some irreversible implications.

Delaying any decision, an investor may lose market share, while making a premature decision, this investor may get stuck with the wrong technology. The solution is the mark-to-model valuation of investment alternatives. Advanced modeling allows explicit representation of the uncertainties and investors' benefits from learning. In this section,

we demonstrate the investment processes using as an example five different power production technologies.

2.1 Valuation: the curse of terminal value

Risks related to climate change and emerging climate policy have come to the attention of corporations and investors only in the last decade. ²Cevik and Miryugin (2022)³ conducted an extensive literature review and original econometric analysis providing solid evidence that climate change and extreme weather events have significant negative macroeconomic consequences. Extending this analysis to a corporate level, the authors show that exposure and vulnerability to climate change is strongly associated with a higher cost of capital (cost of borrowing) and lower levels of productivity and return on investment. Fernando, Liu, and McKibbin (2021) examined the sensitivity of stock indices to the global macroeconomic consequences of chronic climate change and extreme climate shocks, as well as the economic effects of transition risk of exposure to climate policies. The authors confirmed the results of other studies regarding the economic costs of climate change and the transition risk of climate policy. However, most of the studies were focused on historical data, and only some took into account future transitions. Forward-looking analysis usually focuses on stranded assets and the future risk of climate change itself on the present market value of global financial assets — Dietz, Bowen, Dixon, and Gradwell (2016). The forward-looking analysis of the positive effect of climate policy and asset diversification on long-term economic growth was established in a World Bank Group study⁴. But this study focused on countrywide positive effects and not on corporations. Climate and climate policy shocks have long-term consequences for the economy and for individual corporations. Over time countries and corporations adapt to climate shocks and shocks of climate policy, but the transition period may take time. During a significant period, some countries and corporations will be winners and some losers.

In a deterministic case, the value of an asset could be obtained by calculating cash flows attributed to the underlying asset and its time distribution and discounting this cash flow with an appropriate cost of capital rate (Copeland et al. 2007; Massari et al.

2016 p.5) or the weighted average cost of capital. Asset valuation plays a vital role in finance for investment analysis of a corporation, IPO, merger, and acquisition, to support the decision to buy or sell a particular stock, etc. There are two dominating approaches for asset valuation:

- Discounted cash flow (DCF) and
- Multiples valuation method

Application of discounted cash flow requires forecasting of future revenues and cost. At the same time, the multiples valuation method relies on currently observed indicators like the enterprise value per earnings, the price per earnings ratio, the price per book value, etc. The multiples valuation method derives the value of the underlying asset from the value of similar assets. This method is popular in quantitative finance since it allows the application of well-established technical instruments like regression analysis (Taylor 2011), factor models (Chincarini 2006), etc. However, the multiples valuation relies on two critical assumptions: (i) the company's value is proportional to selected indicators; and (ii) the growth rate of cash flow and the risk level are constant.

These assumptions are excessively restrictive when we account for structural transformations of the global and national economies that may significantly change the value of underlying assets.

On the contrary, DCF focuses on future cash flows and the opportunity cost of capital. According to Massari et al. (2016), "...financial valuation methods produce reliable estimates if and only if the specific in-depth business analysis is performed" (p.228). The major problem for company valuation is a relatively short time horizon of a business plan. A standard plan horizon is usually 2-5 years. Valuations based on this horizon "...only explain a small portion of total firm's value. In fact, the bulk of the value is a

function of the longer-term results obtained beyond the standard plan horizon" (Massari et al. 2016 p.228). Copeland et al. (2000) also underscore the importance of a longer-term planning horizon for proper assets valuation. Stress-testing a company's future value requires consideration of several external and internal factors that would determine net cash flow during the lifetime of corresponding assets. For example, in preparing an IPO or assessing M&A, an investment bank would use several quantitative tools to predict future returns and quantify risks.

Commonly used Wall Street valuation techniques are based on stationarity assumptions. Under these assumptions the so-called multiples method or price per earnings extrapolates current revenues to perpetuity. The price-to-earnings-growth valuation method extrapolates the observed trend and could be even more misleading than a method based on capitalizing current revenues. When dealing with a nonstationary process, the most valuable information is hidden in the terminal value. Figure 1 illustrates the change in the valuation of carbon-dependent assets. A naive interpretation of the terminal value may seriously mislead the valuation.

Consider three divergent investment options: first take an asset with a relatively low current return on investment but positively exposed to future climate policy —any tightening of the climate policy results in a significant ROI increase. In Figure 1, its current and future returns are presented with "ROI positive alpha" (gray line). The current return is even below the weighted average cost of capital (WACC), marked with a dashed line. Without considering the future changes in ROI, this investment option will be rejected. On the contrary, carbon-intensive investments yield a current return (orange line in Figure 1 called "ROI negative alpha") above WACC and above the return on investment not exposed to climate policy (red line called "ROI climate neutral").

²Faccini, R., Matin, R. and Skiadopoulos, G., 2021. *Are climate change risks priced in the us stock market?* (No. 169). Danmarks Nationalbank Working Papers. See also: Pástor, L., Stambaugh, R.F. and Taylor, L.A., 2021.

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³Cevik, Serhan and Miryugin, Fedor, *Rogue Waves: Climate Change and Firm Performance* (May 2022). IMF Working Paper No. 2022/102, Available at SSRN: <https://ssrn.com/abstract=4129567>.

⁴Peszko, G., Van Der Mensbrugghe, D., Golub, A., Ward, J., Marijs, C., Schopp, A., Rogers, J. and Midgley, A., 2020, op. cit.

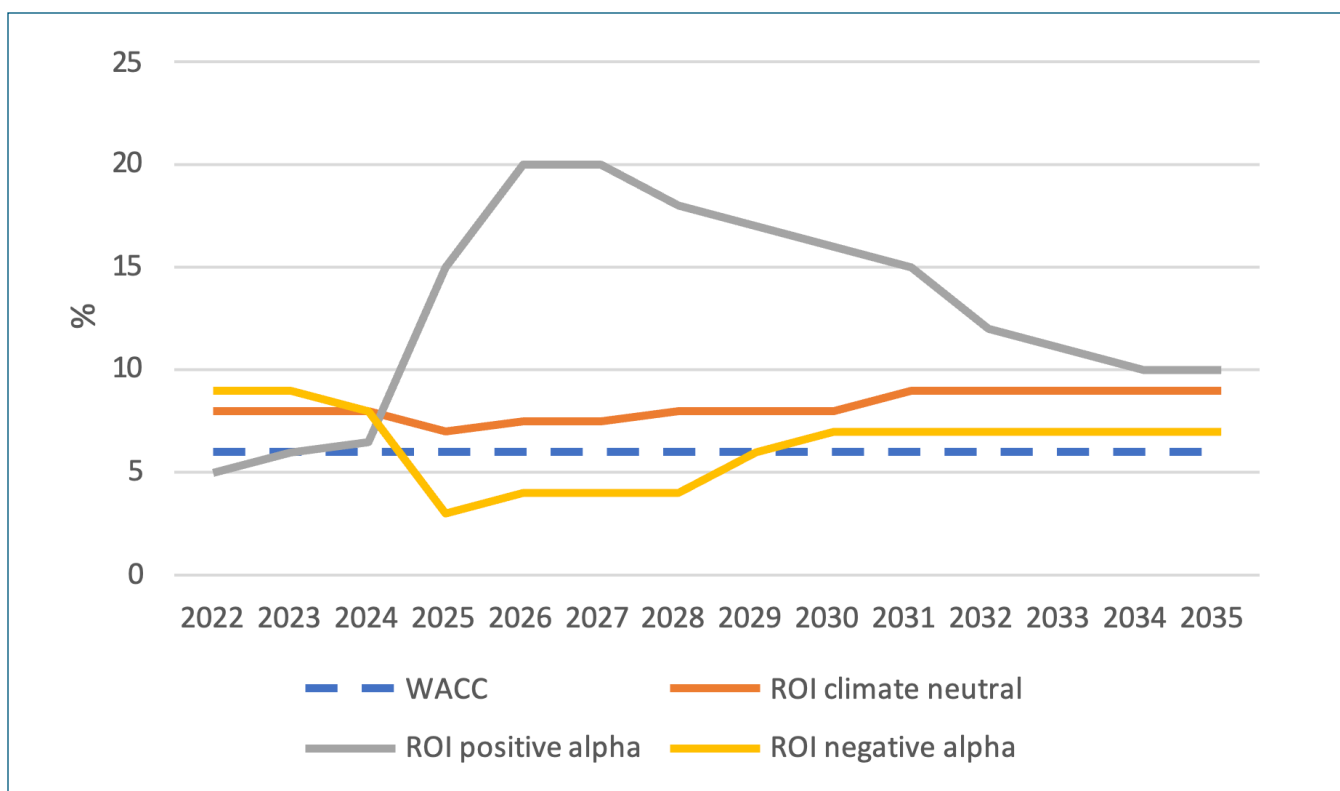


Figure 1. Return on investment differently affected by emerging climate policy.

2.2. Model description and scenario design

Model runs were conducted in the TIAM-framework Indonesia TIMES model. TIMES is a technology-rich, partial equilibrium multi-sector energy system modeling framework. TIMES integrates assumptions across fuel, technology, and policy uncertainties to understand how the entire energy system responds to different incentives, explore the technology and market risks facing policies, and develop strategies to mitigate these risks. TIMES determines least-cost investment pathways and energy system operation to meet exogenously projected energy service demands, subject to various energy system and user-specified policy constraints (Loulou et al. 2016).

In 2022, researchers at Argonne National Laboratory demonstrated the capability to quickly stand-up analysis entry points for country-level energy system-wide decarbonization assessments using re-aggregation of a flexible, global knowledge-based modeling framework (Daniels et al, 2018). The global TIAM-World TIMES model

framework (Labriet et al. 2012) is based on high-quality country-level data sources (e.g., IEA, EIA, NREL), which are flexibly aggregated into user-specified model regions. By re-aggregating model regions to pull out individual countries of interest, an Indonesia TIMES model was extracted as a single country model and then updated using additional country-specific sources. The model contains domestic supply, transformation, and end use sectors in industry, transport, and residential and commercial buildings. Indonesia is modeled as a price taker for imports and exports of coal, oil and oil products and gas, with prices coming from runs of TIAM-World, using supply curves tuned to the IEA Announced Pledges scenario (IEA 2021). The Indonesia TIMES model was most recently used for an analysis of pathways to net zero energy (Kintner-Meyer et al 2022).

The Indonesian energy system is rapidly growing, with demand for electricity projected to increase as much as fourfold between 2020 and 2050 and the light duty vehicle fleet to expand as much as fivefold

(IEA 2022). Decarbonization of the system in the face of this rapid expansion provides a different set of opportunities and challenges than in a more stationary system. In particular, the demand for investment in new electricity generating capacity will be strong over the coming decade, and capacity built will need to be robust in the face of potentially rapidly evolving climate policy at the national and international levels. To demonstrate the mark to model method, 500 MW investment in each of five technologies is forced in either 2023 or 2027: solar PV, pulverized coal, natural gas combined cycle (NGCC), coal with carbon capture and storage (CCS) and NGCC with CCS. The net present value of each project's capital, operation and maintenance, fuel, and carbon price costs minus its electricity revenue is calculated, normalized by the project's upfront investment cost. Electricity revenue calculated as the endogenous modeled electricity price multiplied by generation (based on modeled endogenous dispatch) of each technology. The rest of the system evolves according to least cost.

Two sets of carbon prices ranging in one-percentile steps from the 5th to 95th percentile of the low and high carbon price trajectories were tested against the 2023 and 2027 investment decisions for a total 364 scenarios (see Figure 2). The carbon price was imposed on all energy-related emissions

from all sectors of the Indonesia energy economy. The method for obtaining these scenarios is discussed next.

2.3 Global carbon price scenarios

The latest Emissions gap report called “The Closing Window”⁵ says that current climate policy commitments are insufficient to close the emissions gap and “...only an urgent system-wide transformation can deliver the enormous cuts needed to limit greenhouse gas emissions by 2030.”

According to the World Bank report “State and Trends of Carbon Pricing 2022,”⁶ carbon pricing instruments cover about 23% of global climate emissions. Carbon prices are rising, and the free allocation of carbon allowances is reducing. Worldwide, 68 countries and jurisdictions use carbon pricing instruments, and three more are in the latest implementation stage. The emerging global carbon pricing system is on the rise. As part of that, the carbon border adjustment mechanism is emerging as an important instrument for the transition to harmonized climate policies.

For this study, we use the category “shadow price of carbon.” It could be a volatile carbon price of emission trading systems (ETS) or an unambiguous carbon tax, or an uncertain shadow price of

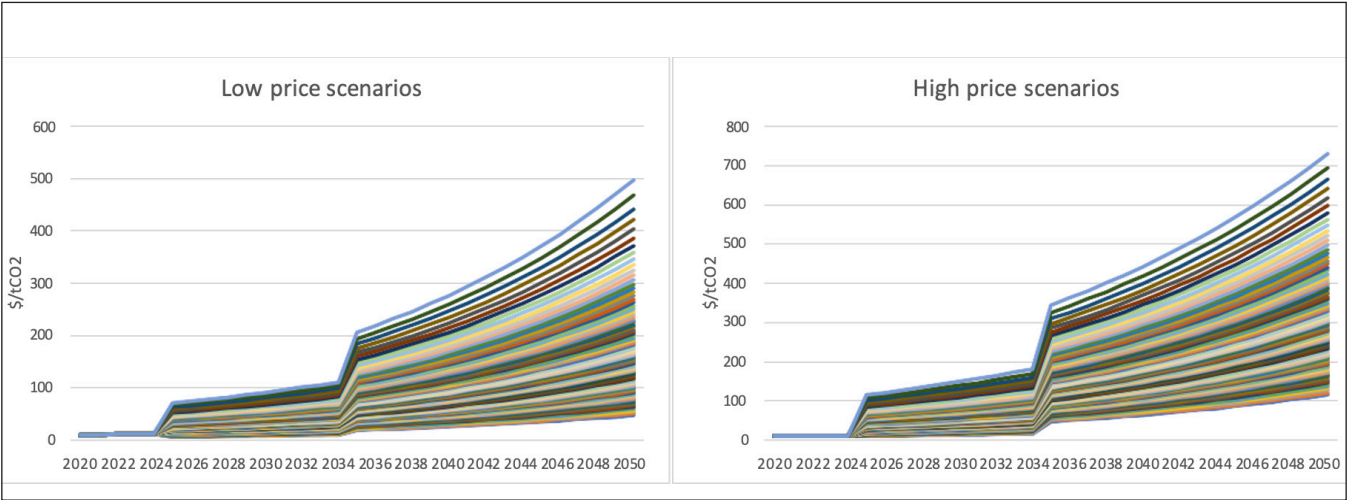


Figure 2. Carbon price scenarios modeled.

⁵ <https://www.unep.org/resources/emissions-gap-report-2022>

environmental impacts. In other words, we do not specify a particular instrument representing carbon price. However, when climate policy uncertainty is resolved, there is a difference between a carbon tax and a carbon price that is a product of cap and trade. The carbon price in cap and trade exhibits residual volatility, while carbon tax has a known value (unless another adjustment of climate policy is expected in the future).

Growing negative climate change impacts across the globe are key in triggering an acceleration of the transition to harmonized global climate policy that balances the benefits and cost of interventions to reduce GHG emissions. In this context, the social cost of carbon (SCC) is a proxy for the shadow price of carbon. An alternative is an uncertain marginal abatement cost. The cost is uncertain due to climate policy uncertainty (uncertain emission target), uncertainty in the cost of abatement technologies, and unknown quality of offset available and allowable on the carbon market (e.g., REDD+ supply) etc. The second approach could be realized in the second phase of the experiments. In the first stage, the main focus is to study business responses to climate policy uncertainty that, for each business, appear exogenous, and each component that constitutes uncertainty is not so important. An exception is an uncertainty in abatement technology specific to the business that would be modeled explicitly. This uncertainty is not correlated with SCC. As a result, we minimize inconsistency in our analysis keeping uncertainty separate.

2.3.1. The carbon price model

The model is a modification of the carbon price model used by Golub et al. 2020 and Fuss et al. 2021⁷. However, in this model, the proxy for the carbon price is SCC. In Golub et al. 2020 and Fuss et al. 2021, the proxy for the global price of carbon is the marginal abatement cost that corresponds to a given climate policy (constrained on emissions stock).

The price model computes the probability distribution for a carbon price. It simulates convergence to the “equilibrium carbon price in 2050.” As that, however, is uncertain, it is represented as a probability distribution of the carbon price in 2050.

Another uncertainty relates to the unknown pattern of climate policy shocks. In the current version, we have two policy shocks: one in 2025 and another in 2035. After 2025 shock, the mean value of the price increases by 5% a year. After the second shock the annual growth rate of the mean value is determined by the formula (1):

$$g = \ln \left(\frac{\mu_{2050}}{\mu_{2035}} \right) / 15$$

Formula 1

Where g is an annual growth rate of carbon price between 2035 and 2050; μ_{2050} denotes mean value of carbon price in 2050 and μ_{2035} stands for the mean value in 2035.

2.3.1.1. Price in 2050

The carbon price in 2050 equals SCC.

To calculate the mean value and fit the probability distribution, we use Resources for the Future (RFF) calculations from Rennert et al. 2022⁸ (Table 1 below)

For the low value, we use \$80/tCO₂, and for the high value, we use \$185/tCO₂, representing SCC in 2020. Since we needed SCC in 2020, we recalculated these initial values with 3% growth rate for the low value of SCC and a 2% annual growth rate for the high value.

The mean value and value in the 95th percentile are summarized in table 1.

⁶<https://openknowledge.worldbank.org/handle/10986/37455>

⁷Golub, A.A., Lubowski, R.N. and Piris-Cabezas, P., 2020. Business responses to climate policy uncertainty: Theoretical analysis of a twin deferral strategy and the risk-adjusted price of carbon. *Energy*, 205, p.117996. Fuss, S., Golub, A. and Lubowski, R., 2021. The economic value of tropical forests in meeting global climate stabilization goals. *Global Sustainability*, 4.

	Mean \$/tCO ₂	95th percentile \$/tCO ₂
Low	200	500
High	340	730

Table 1: Mean value and value in 95th percentile

Based on previous studies, we approximate SCC with lognormal distributions (see Figure 3, carbon price (SCC) in 2050 for high and low scenario).

2.3.1.2. Modeling shocks

Despite additional national determined contribution (NDC) commitments and the return of the United States to the Paris agreement, the emissions gap

continues to increase⁹. The size of the emissions gap and the intensity of damaging climate events determines the magnitude of shocks.

In this version of the model, we use climate sensitivity as a proxy for speed of the convergence of the current price of carbon with SCC.

The carbon price in 2020 is assumed to be \$10/tCO₂. The first shock is in 2025, the second shock is in 2035.

An example of convergence is presented in Figure 4. At the first shock, the rate of catchup is 0.15, and at the second shock, the rate is 0.5.

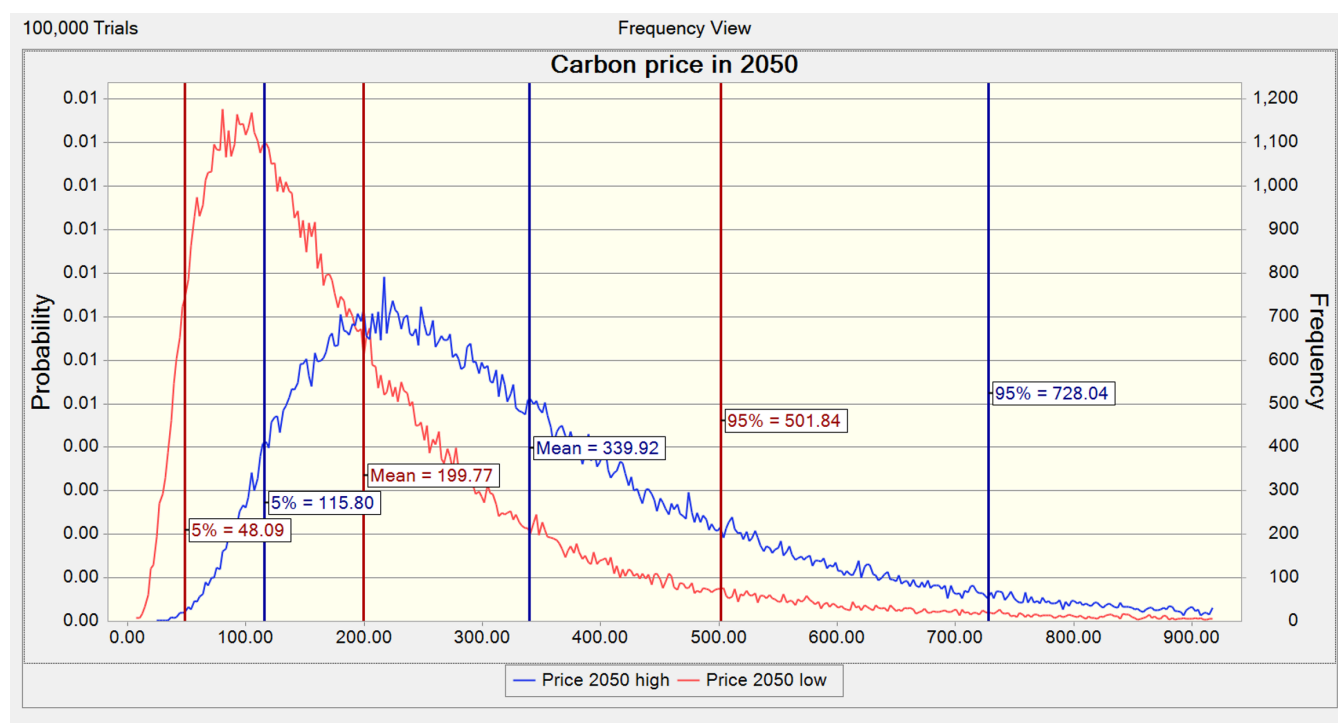


Figure 3. Carbon price probability distributions

⁸Rennert, K., Errickson, F., Prest, B.C., Rennels, L., Newell, R.G., Pizer, W., Kingdon, C., Wingenroth, J., Cooke, R., Parthum, B. and Smith, D., 2022. Comprehensive evidence implies a higher social cost of CO₂. *Nature*, 610(7933), pp.687-692.

⁹ <https://www.unep.org/resources/emissions-gap-report-2021>

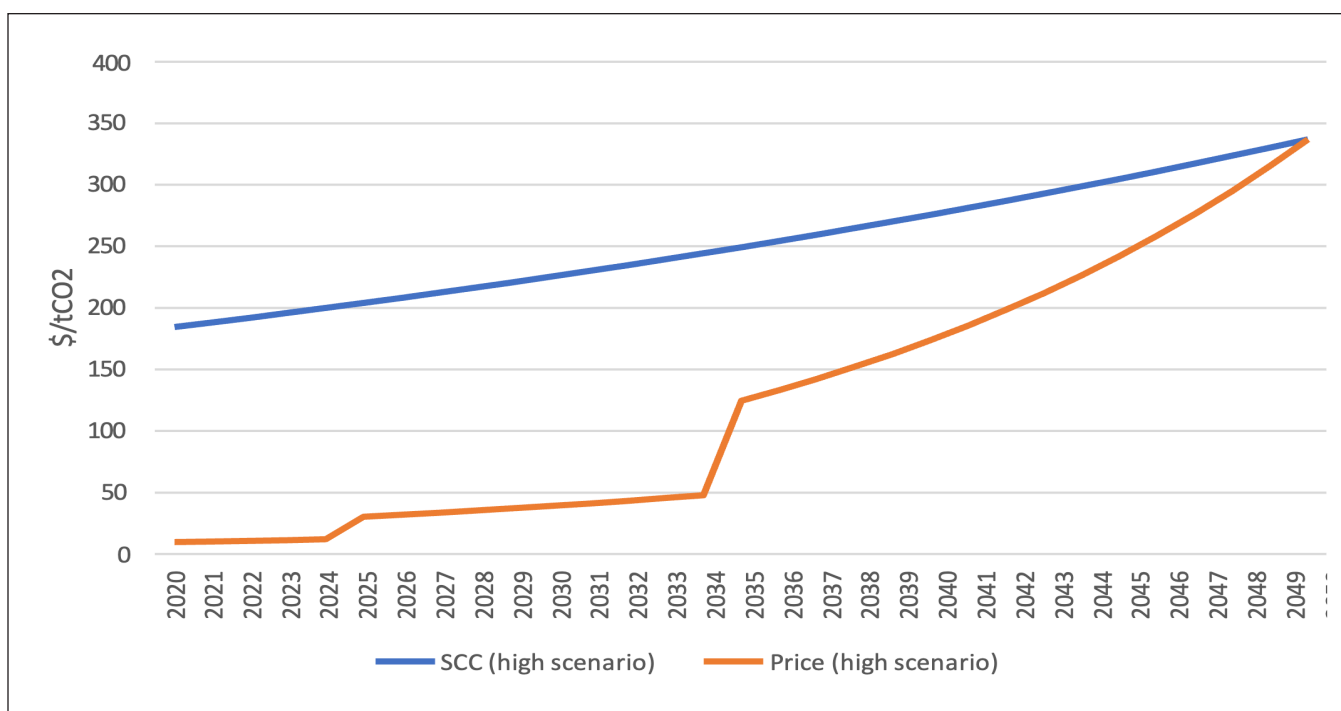


Figure 4. SCC and carbon price.

The results of Monte-Carlo simulations are summarized in Table 2.

Statistics	Price High 2025	Price high 2035	Price high 2050	Price low 2025	Price low 2035	Price low 2050
Trials	100000	100000	100000	100000	100000	100000
Base Case	26	126	340	17	82	200
Mean	45	153	339	47	82	200
Median	35	128	291	36	64	156
Volatility	0.82	0.65	0.61	0.83	0.82	0.81
Standard						
Deviation	37	99	205	39	68	161
Skewness	2.87	2.29	2.12	2.96	2.95	2.89
Kurtosis	20.17	15.61	13.31	20.31	20.56	20.84
Percentiles 2025	Price High 2035	Price High 2050	Price High 2025	Price low 2035	Price low 2050	Price low 2025
5%	11	48	116	11	19	48
95%	115	340	724	119	208	499

Table 2: Results of Monte-Carlo simulations for the carbon price

3. Results

3.1 Model System Results

This section describes the response of the modeled system to the carbon prices tested, providing an overview of the whole system response as well as the results that directly impact the net present value of the test project investments within each scenario. For simplicity, only results for the 2027 investment

scenarios are shown. Because they differ from the 2023 investment scenarios only in the timing of 2.5 GW of investment in a system of >100 GW, the whole-economy results will be very similar.

Figure 5 shows total energy-related CO2 emissions across the Indonesia energy economy in response to the suites of carbon prices. Each line reports one scenario, labeled by its percentile in the carbon price distribution.

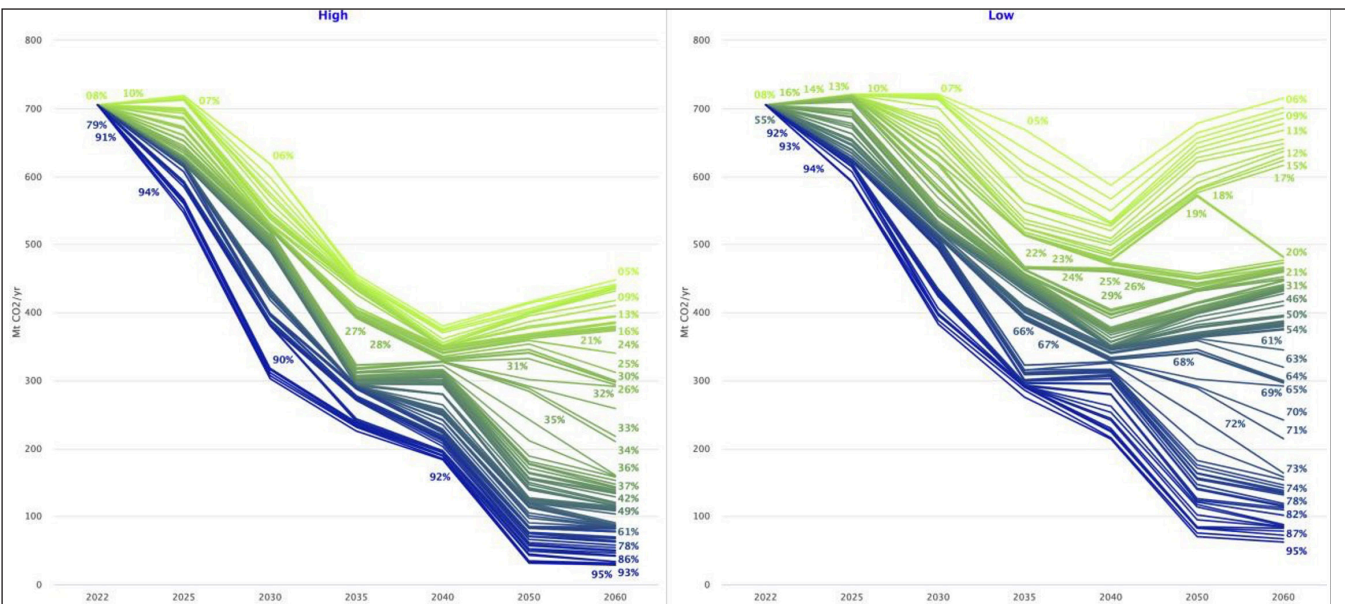


Figure 5. Whole economy energy-related CO2 emissions – High carbon price suite (left) and Low carbon price suite (right).

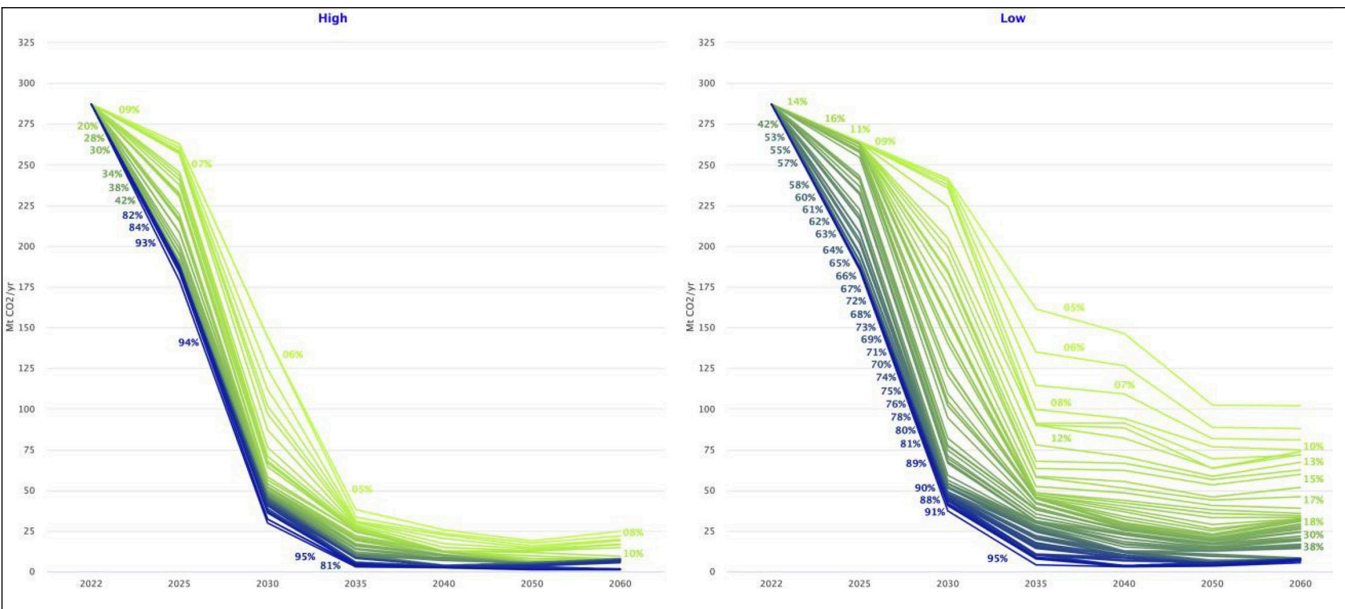


Figure 6. Power sector CO2 emissions – High carbon price suite (left) and Low carbon price suite (right).

Higher prices lead to steeper and more sustained reductions, while lower prices yield more delayed and gradual reductions, and the lowest price scenarios show some emissions rebound after 2040. However, the emissions response to carbon price is not smooth and linear. We see bifurcations of emissions trajectories into bands of scenarios with gaps in between, indicating tipping points where additional sources of emission reductions become cost effective in portions of the energy system.

Figure 6 shows modeled CO2 emissions within the utility power sector in response to the suites of carbon prices. Each line reports one scenario, labeled by its percentile in the carbon price distribution.

As in many other modeling studies, we find that the power sector reduces its emissions earlier and more steeply than other sectors in response to a whole-economy carbon policy. Emissions reductions by 2035 range from 50 to 99 percent below 2022 levels in the Low price scenarios and

85 to 99 percent in the High price scenarios. After these initial steep cuts, reductions begin to level off, leading to 2050 emissions that are 65 to 99 percent below 2022 levels in the Low price cases and 93 to 99 percent below 2022 levels in the High price cases. The emissions response to increasing price is smoother than in the whole-economy results, although here too we see some bifurcations in trajectories in the early years of the carbon price, as cost effective technology options hit tipping points as carbon prices increase. The cost effectiveness of gas-fired technologies in particular displays complex dynamics with changing carbon price.

Figure 7 shows generation by technology type. For simplicity, only the Low carbon price scenarios are shown. A more detailed look at the response of gas-fired technologies to the full range of prices is provided below.

Most technologies show a monotonic response to carbon price, but coal and gas with CCS are the exception. Uncontrolled coal and lignite generation

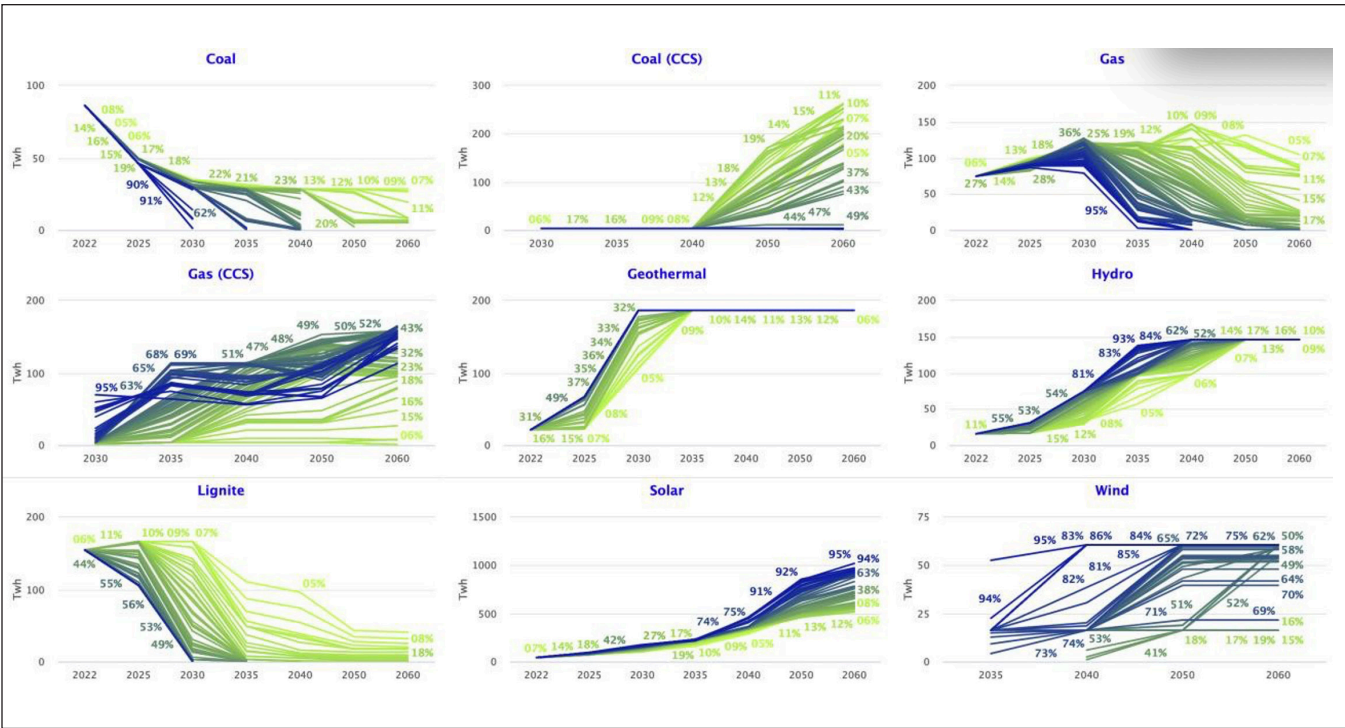


Figure 7 Electricity generation by technology type - Low carbon price scenarios.

fall off rapidly with increasing price, with generation going to zero by 2060 for all scenarios above the 22nd percentile of the Low distribution. Endogenous coal with CCS investment is initially induced by a low carbon price, beginning in 2040. However, investment peaks at the 15th percentile price and falls rapidly thereafter. No endogenous investment beyond our forced test investment technology is made beyond the 50th percentile of the distribution.

Geothermal and hydro investments are made earlier with higher carbon prices, plateauing at modeled potential. Indonesian wind potential is limited and primarily at low wind speeds that are not currently cost effective (Langer et al. 2022). However, higher carbon prices do induce some investment. Solar is the major cost effective renewable energy source. Solar investments are initially similar across carbon prices but are driven up by higher carbon prices after 2035.

Uncontrolled gas generation initially increases similarly across scenarios, but peaks earlier and falls more steeply in response to higher prices. Gas with CCS is stimulated by higher prices, with endogenous investments beginning as early as

2030 for prices above the 80th percentile. However, generation begins to fall off with higher prices, even with continued investment, as the residual emissions become increasingly costly, and the units are used increasingly for load following rather than baseload. Figure 8 and Figure 9 further explore the dynamics underlying the response of gas-fired technologies to carbon price.

Figure 8 provides additional details on the performance of the uncontrolled natural gas combined cycle (NGCC) fleet, with fewer scenarios shown to provide additional clarity. Uncontrolled NGCC sees limited capacity additions in all scenarios after 2022. Changes in generation are primarily driven by capacity factors of the existing fleet and endogenous economic retirement. While capacity factors initially rise in most scenarios, they peak earlier and lower with increasing carbon prices. In the highest priced scenarios, capacity factors immediately begin to decline in 2022.

The modeled minimum capacity factor is 25%. Units unprofitable at even this level of generation economically retire. In the highest carbon price scenarios, they begin to do so as early as 2035,



Figure 8. Capacity factor (left panel), capacity (middle), and electricity production (right) for uncontrolled gas combined cycle fleet.

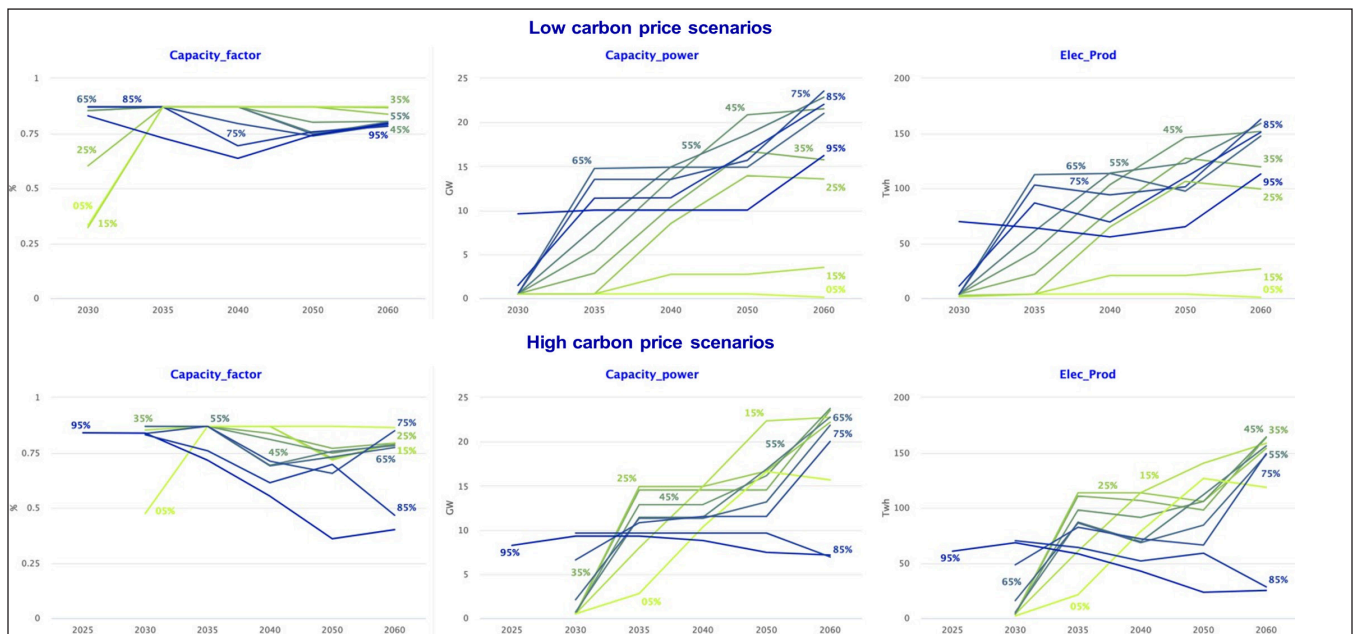


Figure 9. Capacity factor (left panel), capacity (middle), and electricity production (right) for gas combined cycle with CCS fleet.

while in the lowest price scenarios, most of the fleet remains in service as capacity factors remain above 50%.

Figure 9 provides additional details on the performance of the NGCC with CCS fleet, with fewer scenarios shown to provide additional clarity. In the lowest carbon price scenario, the 5th percentile of the Low distribution, the 500 MW test investment is the only NGCC with CCS capacity built during the entire model horizon. Its capacity factor is initially below maximum levels in the lower priced scenarios, but it reaches full dispatch in model year 2030 by the 35th percentile of the Low distribution and all but the lowest prices in the High distribution.

Additional endogenous NGCC with CCS is built as early as 2025 in the highest carbon price scenarios, and by 2040 in most scenarios. Investment occurs later but continues longer and reaches a higher cumulative capacity in more moderately priced scenarios, while the highest carbon prices inhibit later investment. The higher price scenarios also exhibit decreasing capacity factors for NGCC with CCS, as the residual emissions become too costly as carbon prices continue to rise, and the capacity

begins being used for load following rather than baseload. These dynamics lead to a “twist” in the electricity production time series, where production initially rises with increasing carbon price, but eventually falls for the highest price scenarios.

Figure 10 and Figure 11 explore the carbon price response of two additional model outputs that impact the calculations of net present value for our test investment projects — input fuel price and electricity price.

Figure 10 shows the natural gas price and whole economy gas consumption in response to carbon price for the High and Low price scenarios. Gas prices (not including carbon payment) rise substantially with increasing carbon price, reaching as much as 50% higher by 2040 in the 95th percentile Low case than in the 5th percentile, before converging again late in the projection horizon.

Prices are driven up by increasing consumption with higher carbon price, as gas use for hydrogen production more than compensates for decreased use in the power generation and industry sectors.

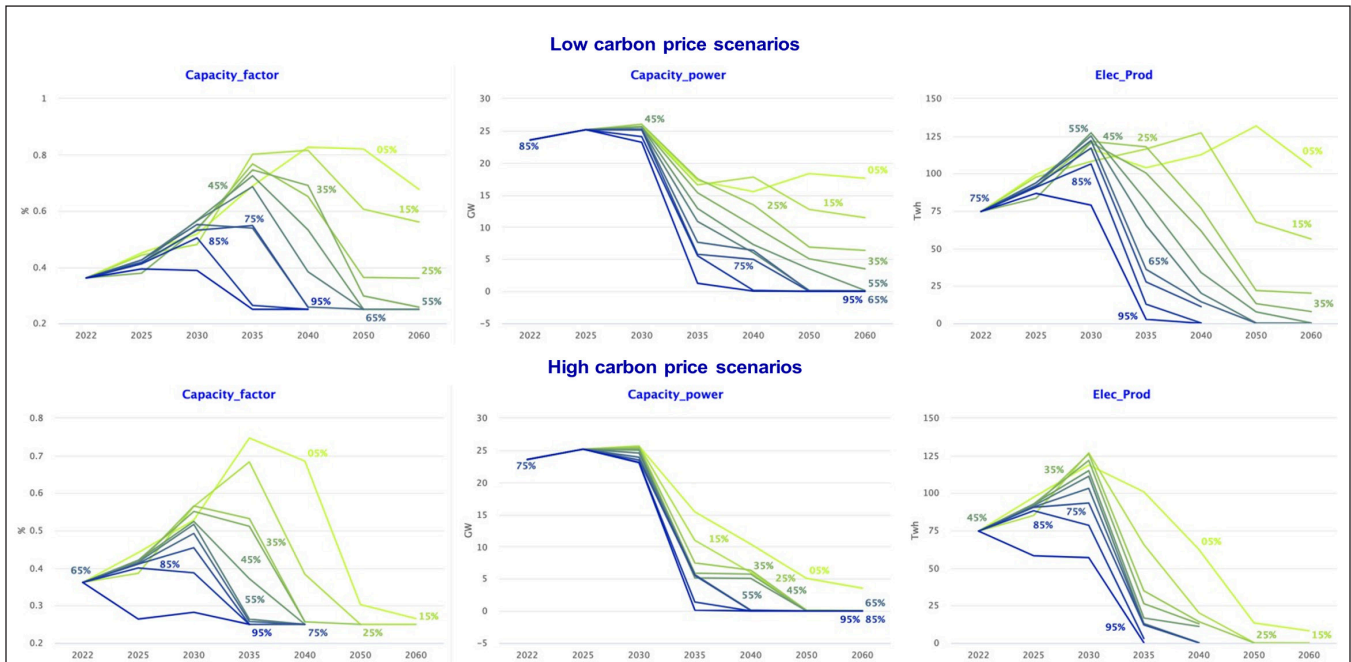


Figure 10. Natural gas price (top) and whole economy gas consumption (bottom) across carbon price scenarios.

(The hydrogen is mostly consumed for heat production in the industrial sector and for heavy vehicle and nonroad transport. Some hydrogen is produced via electrolysis from otherwise curtailed renewable electricity, but thermal production from natural gas with CCS is the predominant source.) By 2050, Indonesia becomes a net gas importer at higher carbon price levels, limiting the upward pressure on gas prices to the global market price.

Unlike gas prices, coal prices are largely consistent across carbon prices, tightly coupled with the global market price.

Figure 11 shows electricity prices by year as a function of carbon price in the High and Low scenarios. These values are used to calculate the revenue that our test investment projects earn. Electricity prices rise sharply with carbon prices in the early years of the projection, with the greatest

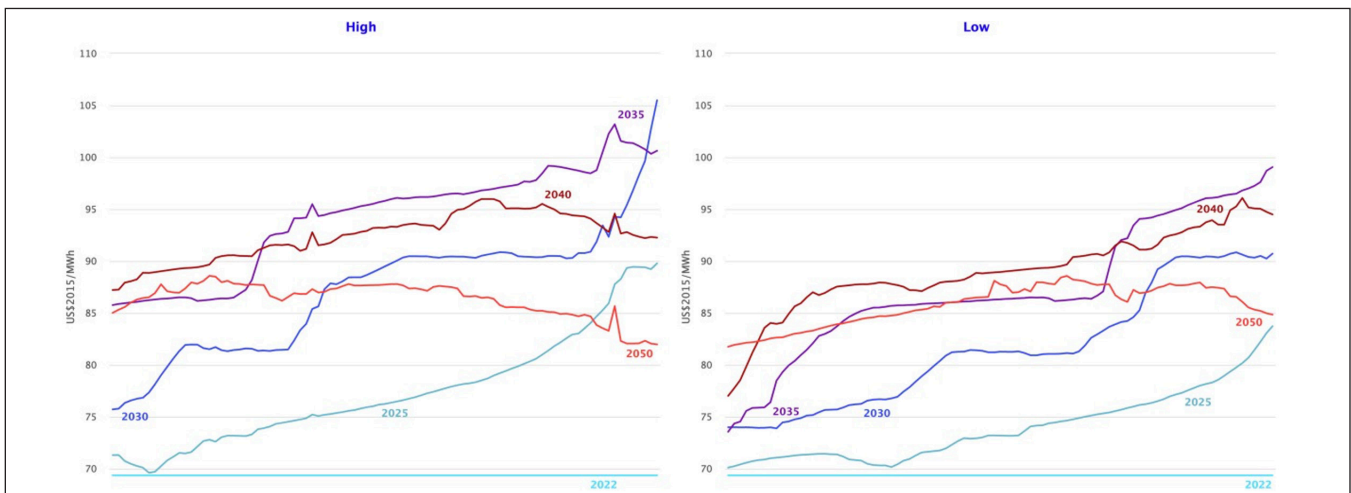


Figure 11. Modeled wholesale electricity price by year in High (left) and Low (right) carbon price scenarios.

total increase occurring in 2030, at 40% over the range of the High scenarios. But the sensitivity of electricity price to carbon price is not uniform over the carbon price distributions. There are ranges of steeper and shallower electricity price increases, and even short ranges of decreases, reflecting the marginal cost of increased generation as the capacity mix changes and different technologies are brought online. By 2040, the sensitivity has decreased, with only shallow increases across all but the lowest parts of the carbon price range. And by 2050, the electricity price has fallen in absolute terms and is no longer increasing with carbon price across most of the range.

The sharp increase of electricity price with carbon price in the early years of the carbon price suggests that policy response to mitigate the impact on ratepayers will be an essential component of a carbon pricing policy package. Options include direct rebates of carbon revenues to ratepayers and investment of revenues in energy efficiency improvement that lower ratepayer bills.

3.2 Mark to model valuation results

Figure 12 A-D summarizes characteristics of return on investment (mean and in 90CI) and option value for different price scenarios and timing for investment decisions. A preliminary analysis of the model output suggests that investment in PV solar is a robust solution relative to different price scenarios.

Applying a robust decision-making approach (see: Hansen, and Sargent [2008]) rules out investment in coal.

Also, gas CC and gas CCS seem less attractive than PV solar; application of real options analysis indicates the benefits of flexibility. Keeping open an option to invest in gas power generation seems rational, given a relatively high option value of an investment in gas CCS and even gas CC. Investment delay till 2027 provides benefits of learning. Presumably, by this time, some policy uncertainty will be resolved.

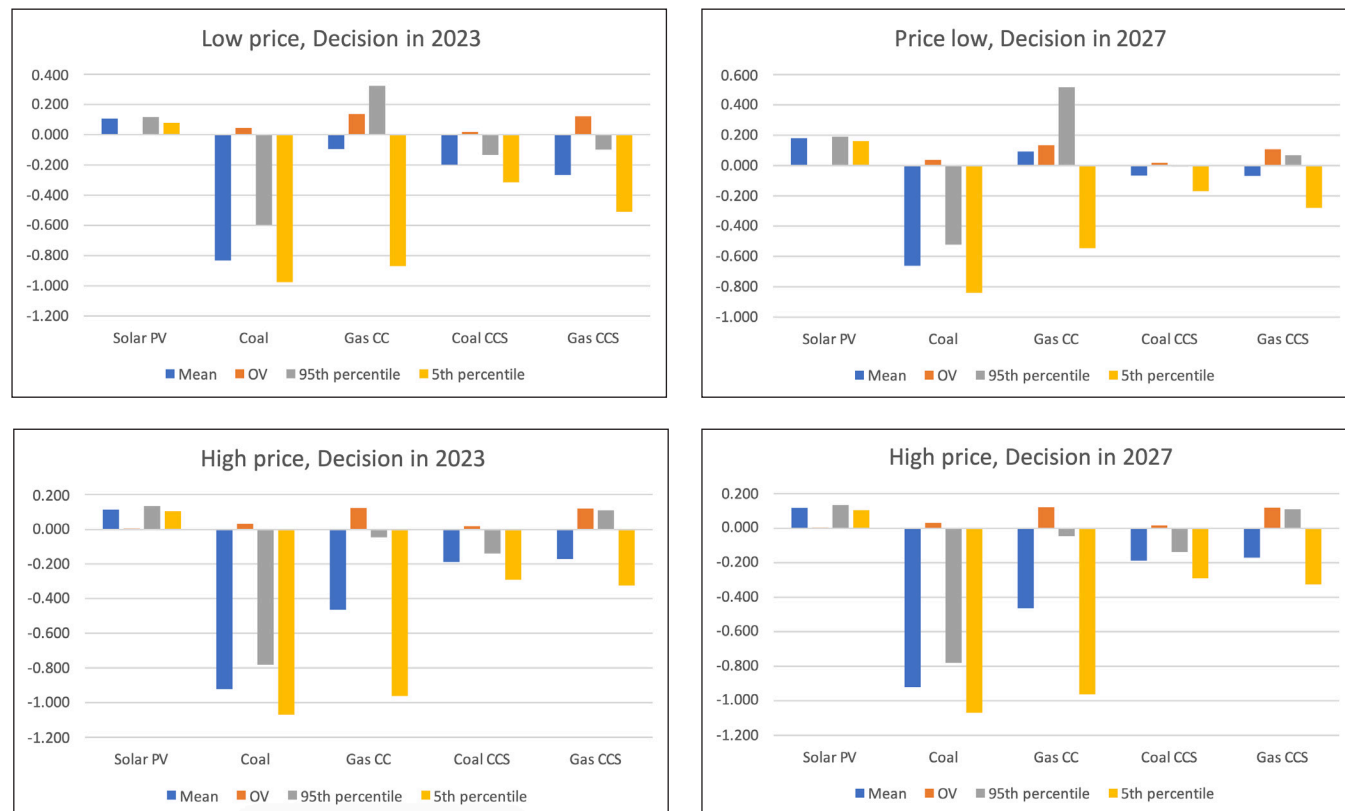


Figure 12 A-D. Return on investment (mean and in 90CI) and option value for different price scenarios and timing for investment decisions.

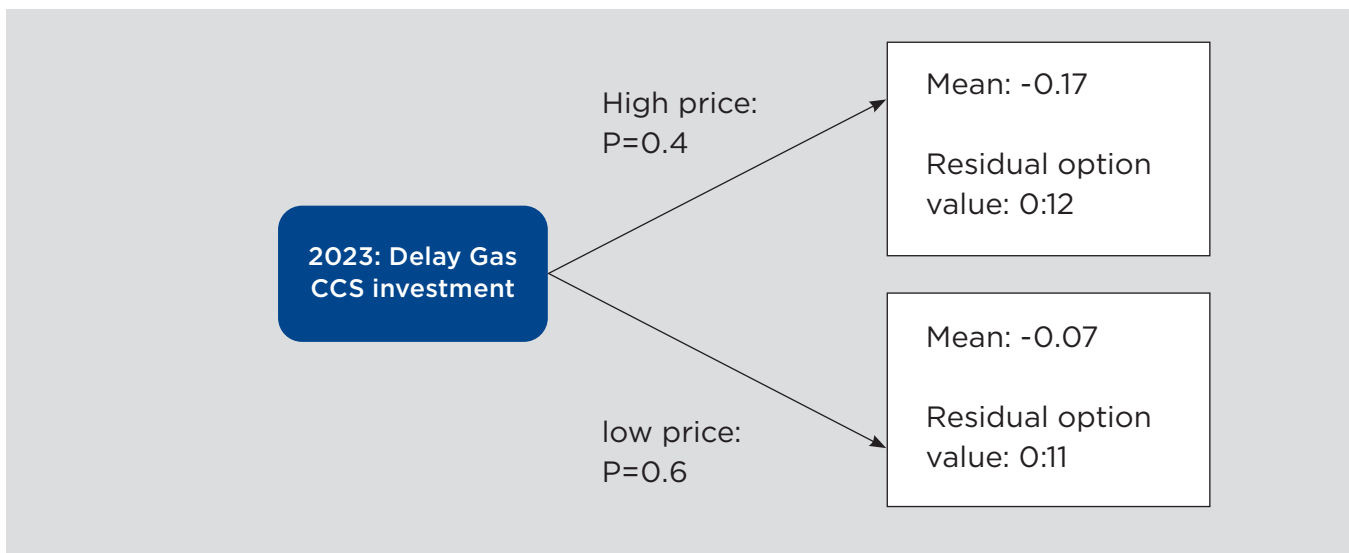


Figure 13 A. Value of Gas CCS with flexibility.

Figures 13 A and B demonstrate the benefits of learning. A stylized decision tree helps to understand how climate alpha is calculated for gas CCS and gas CC.

Considering flexibility, the value of Gas CCS with the option to invest in 2027 is $0.6 \times (0.11 - 0.07) = 0.024$. Without flexibility, the value of this technology is $0.4 \times (0.12 - 0.17) + 0.6 \times (0.11 - 0.07) = 0.004$. Thus, the value of flexibility is 0.02. That much could be spent to secure call options on Gas CCS technology, for example, reserving land to deploy CCS. In this example, the climate alpha is not less than 0.004

and not higher than 0.024. If the actual cost of the land reservation is below 0.02 (which is a breakeven price of land), say 0.01, then the option value is 0.014, while the net value of the call option on the deployment of Gas CCS technology in 2027 is 0.01.

Residual option value could be analyzed further, but it will require additional assumptions for learning processes.

Investment in Gas CC technology has a high value if delayed. The value with flexibility is 0.138.

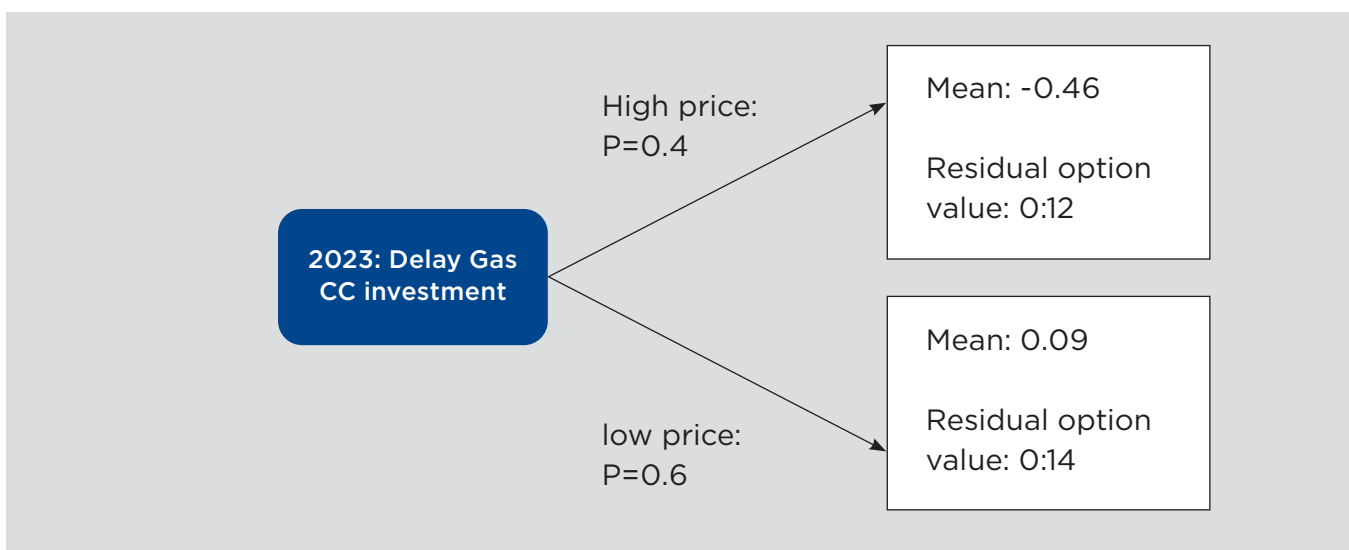


Figure 13 B. Value of Gas CC with flexibility.

4. Discussion and conclusions

The analysis has demonstrated the mark to model valuation approach, as well as the ways this approach differs from more conventional valuation methods. As modeled here, the return on investment for power sector investments depends on model inputs — including plant capital and operating costs and carbon prices — as well as model outputs, including plant dispatch, fuel prices, and electricity prices. As we have seen, these outputs depend on carbon price in sensitive, system-dependent ways that are often not at all regularly-varying or even monotonic with carbon price.

A spreadsheet valuation model that makes assumptions for these parameters — even one that does a good job of incorporating uncertainty analysis — will miss the system interactions that generate their complex relationships with carbon price. A system model is necessary to see these impacts — and to test their dependency on other uncertain parameters such as consumer demand, competing and complementary technologies, and additional policies.

Our analysis focused on investment opportunities in the power sector, but review of the full sector modeling results reveal similar considerations across the energy economy.

Figure 14 shows modeled final energy consumption by fuel across carbon prices in 2030, 2040, and 2050 for the High price scenarios, with 2022 pre-carbon pricing values for comparison. In 2030, we can see the substitution with increasing carbon price of biofuels for oil products, largely in transport, and of gas for coal, largely in industry. In 2040, gas use continues to increase with carbon price until prices reach around the midpoint of the price probability distribution, after which it begins to fall with continued price increases, as hydrogen begins to substitute for gas. We also see some increased electrification of end uses with high price levels. (Much electrification of end uses, including of light duty transportation, is cost effective in the model without a carbon price by the 2030s.) By 2050, the peaking and decline of gas use with rising carbon price is more pronounced. The 2050 peak of gas final energy use occurs at the 31st percentile of the High price distribution and the 70th percentile of the Low price distribution.

Because carbon pricing-induced decarbonization drives transformation across the entire energy economy, we would expect to see similar tipping points in all sectors, suggesting that the mark to model valuation approach has relevance for energy-intensive projects across the economy. Additionally, changes in the technology suites available and cost effective in other sectors of the economy and

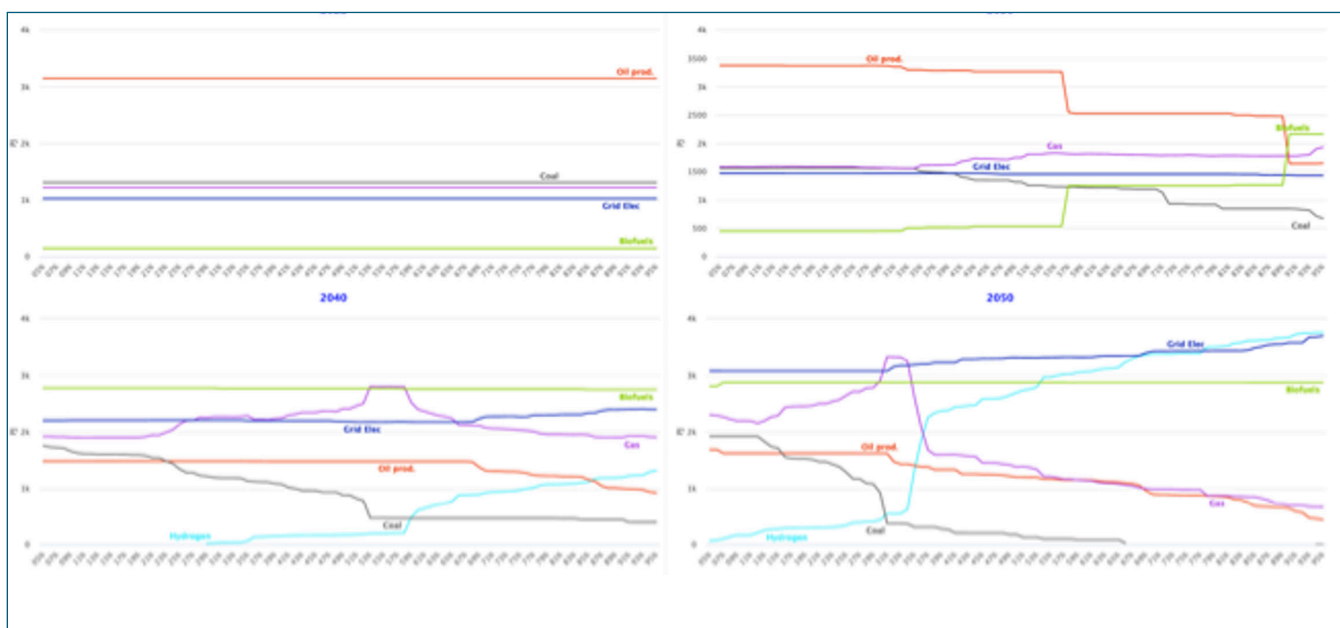


Figure 14. Final (end-use) energy consumption by fuel across carbon prices in 2022, 2030, 2040, and 2050.y.

complementary policies that change incentives in these sectors will also affect the profitability of investments in the power sector by impacting the prices of fuel inputs and electricity outputs as well as the value of carbon reductions across sectors. For example, faster than expected technological progress in bringing down the cost of hydrogen electrolysis technology could shift the competitive landscape for the use of natural gas in hydrogen production, bringing natural gas prices down and potentially further increasing upward pressure on electricity prices. Both impacts would tend to increase the profitability of NGCC with CCS at higher carbon prices.

Some limitations on the analysis are worth noting. First and foremost, this analysis focused on demonstrating the mark to model valuation method within a concrete energy system context. We used current, publicly available data, but did not attempt to reflect current and potential future Indonesian policies that may substantially affect analysis results, including pricing policies for coal, gas, and electricity, as well as environmental policy initiatives. Any real world valuation analysis should reflect these policies and explore the impact of potential policy changes in a detailed way.

Similarly, although the system analysis surfaced some potential broader policy implications of a carbon pricing-driven decarbonization transition — most notably the strong impacts of carbon price on electricity prices — it is beyond the scope of this analysis to assess policy options to support the transition and mitigate impacts on ratepayers and industries. Nor did we assess barriers to pricing-driven transformation. A suite of complementary policies is a necessary accompaniment to any carbon pricing strategy for system transformation.

Finally, in this analysis we modeled only combustion energy-related emissions. Upstream emissions from fossil fuel production, transformation, and transportation are highly uncertain and context-specific. Measurement methodologies and protocols for incorporating these emissions into carbon pricing policies are still under development (Stern 2022). To the extent that these factors are included in a future carbon pricing scheme, this will further impact the future profitability of fossil fuel-fired investments.

Thus presented above, stylized analysis that combined real options analysis and robust decision-making demonstrates the benefits of flexibility and the benefits of delaying investment in gas power generation until some policy uncertainty is resolved. The coal-based technologies should be ruled out, while the expansion of power generation for the next few years should presumably rely on PV solar.

Future research may include consideration of multi-step decision-making processes. At each node in the decision tree, a potential investor gets additional information that reduces uncertainty. The option value declines, and at some point, the investor abandons the deferral option and exercises the call option on the technology in question or drops the call option as well if this technology turns out to be less productive than anticipated. Endogenization of the cost of capital could be another direction to extend the research. Calculation of a deferral option value allows the application of Dixit transformation of cost of capital (the example of the application seen in Golub et al. 2019). In this case, the forward-looking analysis of the energy system would include the behavioral response of investors to climate policy uncertainty and other uncertainty imminent to the green transition.

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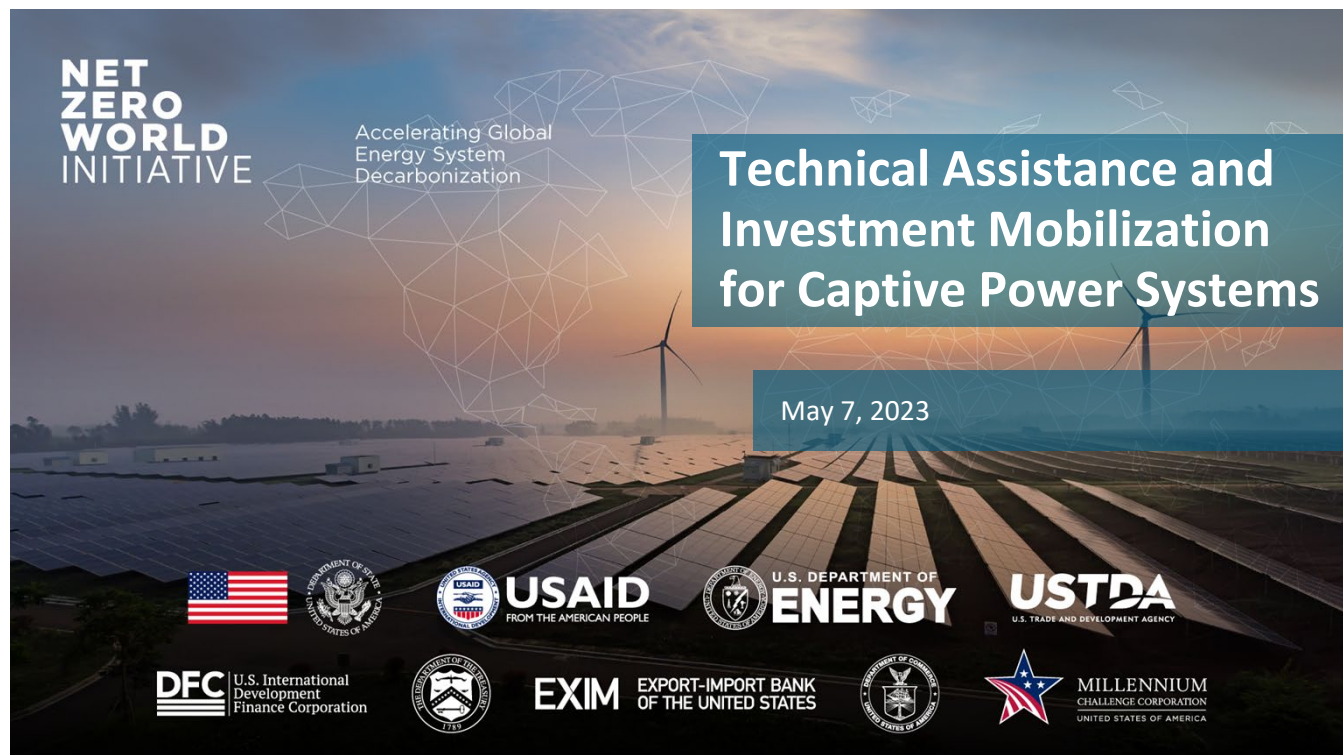
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ANNEX B

Captive Power System Assistance



The Net Zero World Initiative Harnesses USG and Laboratory Capabilities in Partnership with Countries and Philanthropies

Work is designed to:

- Address country priorities
- Tackle hard to decarbonize energy services
- Mobilize investment
- Accelerate decarbonization actions

Early action in Indonesia includes:

- Reducing implementation risk for electrification initiatives at 5 remote island sites in 3 provinces

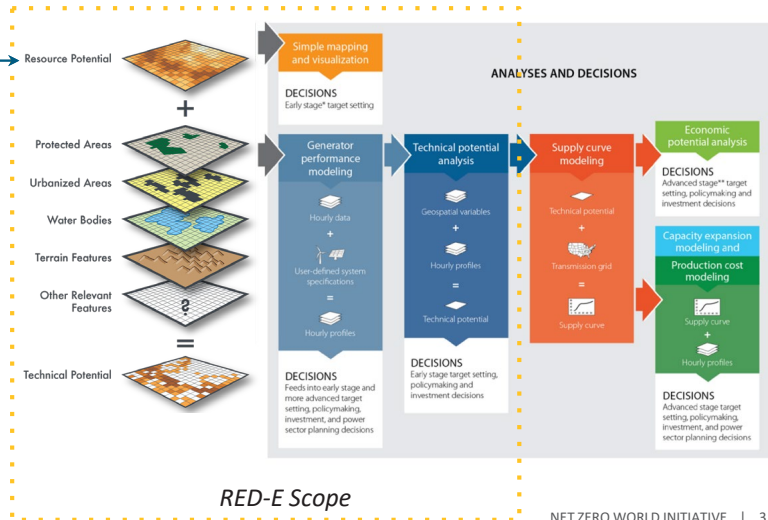
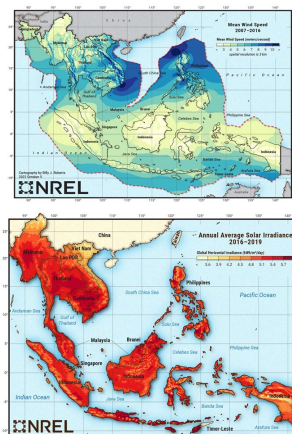
KEY ENERGY SECTORS AND TOPICS AND INITIAL LAB TEAM



RE Data Explorer to Support Project Identification

RE Data Explorer is an innovative and intuitive web platform that enables users to easily access **high-quality renewable energy data** and **applied analytics** to assess potential RE projects

High Resolution
Regional Wind
and Solar
Resource Data



Site Specific Scoping for Industrial Operators



Data Collection

- Site-specific information on targeted industrial sites
- Industry types and number of facilities at sites
- Energy and fuels costs
- Current and projected energy requirements
- Capacity and annual production by facility
- Raw materials (types, quantities)

Analyses

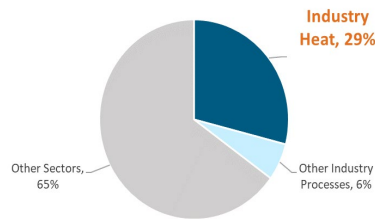
- Current and projected **electricity demand** by facility
- Current and projected **heat demand** for processes at each facility

Evaluation

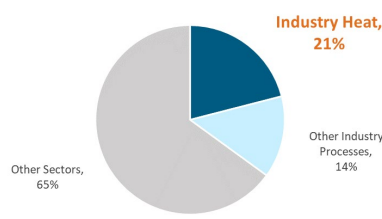
- Potential for fuel substitution
- Potential for electrification of certain processes
- Potential for energy efficiency improvements
- Potential for process improvements

Decarbonizing Industrial Heat

Global Final Energy Demand



Global CO₂ Emissions



Contribution of Industrial Heat to Global Final Energy Demand and CO₂ Emissions in 2018
Sources: BloombergNEF and WBCSD, 2021; Lovins, 2021; Rissman et al. 2020; Thiel and Stark, 2021.

Technologies to decarbonize low-to-medium process heat exist but face barriers.

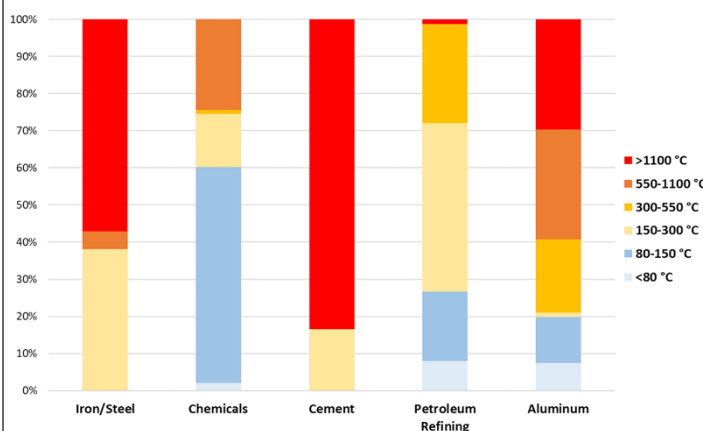
Technologies to decarbonize high temperature process heat requires investment in R&D and demonstration.

Sources: Rightor et al., 2020; EECA 2001; Deason et al., 2018; Jadun, et al., 2017.

Technology	Maturity	Cost	Industry applications
Electric boiler	Commercial	Low-Medium	Many industries, with steam demand
Hybrid boiler	Commercial	Medium	Many industries, with steam demand
Heat pump	<100C: commercial 100-150C: emerging >150C: R&D	Low-Medium-High	Many industries, with corresponding temperature needs
Infrared drying	Commercial	Low-Medium	Industries with drying, evaporation, melting, reacting, processing, mold forming needs
Resistance heating	Commercial	Low-Medium	Industries with metal, plastics, chemical processing needs
Extrusion porosification	Commercial	Low-Medium	Industries with melting, reacting, and processing needs
Induction heating	Commercial	High	Industries with melting, reacting, and processing needs
Friction heating	Commercial	High	Industries with melting, reacting, and processing needs
Ohmic drying	Emerging	Medium	Industries with drying, evaporation, melting, reacting, processing, heat treating needs
Microwave, radiofrequency	Emerging	High	Industries with drying, evaporation, melting, reacting, processing, and sterilization needs
Pulsed electric field	Emerging	High	Industries with sterilization, melting, reacting, and processing needs
Ultrasound	Emerging	High	Industries with enhanced drying, sterilization needs
Pulsed light	Emerging	High	Industries with sterilization needs
Ultraviolet	Emerging	High	Industries with sterilization and curing needs
Electroslag, vacuum, plasma	Emerging	High NET	Industries with higher temperature needs

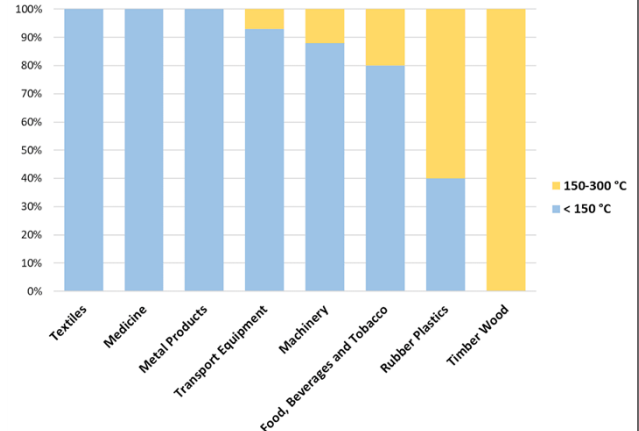
Decarbonizing Industrial Heat

Industrial Heat Temperature Requirements by Heavy Industry



Energy-intensive industries require relatively high-temp process heat. But low-temperature process heat needs exist.

Industrial Heat Temperature Requirements by Light Industry



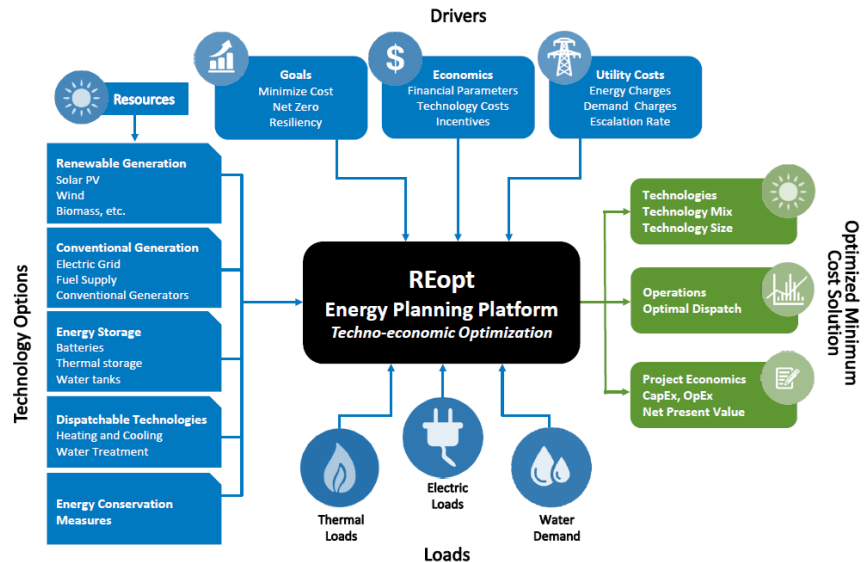
More efforts are needed to increase electrification in light industry, e.g., food, beverages, and textiles.

NET ZERO WORLD INITIATIVE | 6

Energy Flow Modeling and Techno-economic Analysis

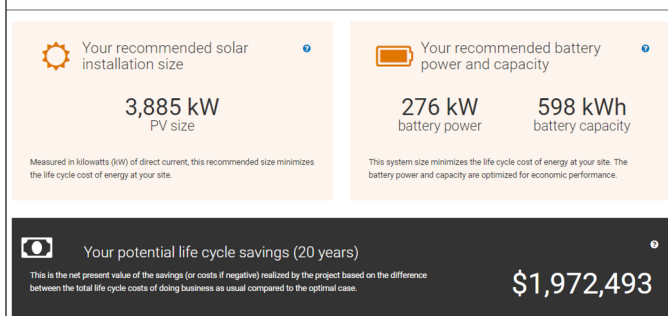
Energy modeling capabilities:

- Co-generation (combined heat & power) plants
- Thermal demand of industrial systems
- Electricity demand of industrial systems
- Identify and calculate energy, cost of energy, and environmental impacts

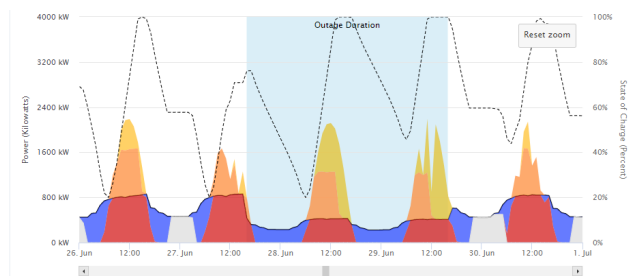


NET ZERO WORLD INITIATIVE | 7

Analytic Outputs for Operators



System Sizing and NPV for Energy Technologies



Hourly Dispatch and Resilience

	Business As Usual	Financial	Difference
System Size, Energy Production, and System Cost			
PV Size	0 kW	113 kW	113 kW
Annualized PV Energy Production	0 kWh	132,000 kWh	132,000 kWh
Battery Power	0 kW	0 kW	0 kW
Battery Capacity	0 kWh	0 kWh	0 kWh
Net CAPEX + Replacement + O&M	\$0	\$133,318	\$133,318
Energy Supplied From Grid in Year 1	132,000 kWh	65,384 kWh	66,616 kWh
Year 1 Utility Cost — Before Tax			
Utility Energy Cost	\$18,112	-\$404	\$18,515
Utility Demand Cost	\$0	\$0	\$0
Utility Fixed Cost	\$0	\$0	\$0
Utility Minimum Cost Adder	\$0	\$0	\$0

Detailed Financial Outputs including Pro-Forma Cash Flow

Multi-criteria Evaluation of Power Alternatives

Multi-criteria comparison and evaluation of alternatives to coal-power on a range of stakeholder criteria



Cross-industry focus including bauxite refining, aluminum smelting, cement, iron and steel, paper and pulp, textiles, chemicals, and other heavy industries

Energy efficiency

Costs

Impacts on local economy

Time to develop & deploy

Multi-criteria Analysis

Resilience and security

Land-use considerations

Supply chain risks

Local air pollution

NET ZERO WORLD INITIATIVE | 9

Investment Mobilization for Pilot Projects

Island Energy Transition pilot project anticipates \$1.3M U.S. Trade and Development Agency grant for feasibility studies at 5 sites and plan to mobilize up to \$1.3B for 500 MW of clean energy mini-grids

Techno-Economic Assessment

Action: (a) multi-criteria evaluation and financial analysis for optimum clean energy alternative(s) for two pilot captive power sites (2GW).

Output: (b) results of multi-criteria evaluation and financial analysis, (c) implementation roadmap for two pilot sites, and (d) input into \$20B JETP Policy and Investment Plan.

Replication and Scale-Up

Action: (a) national roadmap for clean energy alternatives to captive coal.

Output: (b) additional capital mobilized from the \$20B JETP commitment (or other sources) for clean energy alternatives to captive coal.

Feasibility Study and Engineering Designs

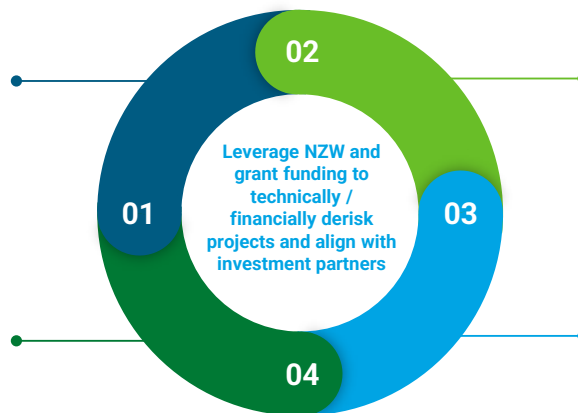
Action: (a) feasibility and engineering designs for clean energy alternatives for two pilot sites.

Output: all documentation to support: (b) issuance of requests for proposals (RFP) by pilot site owners, and (c) issuance of capital by financial institutions for completion of engineering work for two pilot sites.

Investment Mobilization for Project Execution

Action: (a) support for issuance of capital for two pilot sites. Potential sources: GFANZ, local banks, DFC, MDBs, etc.

Output: (b) \$2B mobilized and 2GW clean power deployed for two pilot sites.



Technical Assistance and Investment Mobilization Partners

Stakeholder	Potential Role
Government Agencies and National Laboratories	Deep collaboration to develop technical and investment plans, support implementation, and build technical capacity — U.S. Department of Energy (DOE), U.S. Department of State, U.S. Agency for International Development (USAID), and U.S. DOE national laboratories
Private Industry	Provide technologies or services for project feasibility, engineering design, and execution
Global Financial Alliance for Net Zero (GFANZ) / Local Banks	Provide credit risk assessment, debt (e.g., Bank of America, Citi, Deutsche Bank, HSBC, Macquarie, MUFG, Standard Chartered, and local financial institutions)
Multilateral Development Banks	Provide financial assistance and advisory services to address systemic barriers to clean energy (e.g., concessional financing, risk sharing facilities (RSF), loan loss reserves)
US Trade and Development Agency (USTDA)	Provide funding for feasibility studies; demonstration projects; technical assistance
U.S. International Development Finance Corporation (DFC)	Provide debt, equity, guarantees, support for feasibility studies, investment funds, political risk insurance, and project pipeline creation
Millennium Challenge Corporation (MCC)	Provide large-scale grants to fund country-led solutions. New \$698 million Indonesian Compact II focus on blended finance mechanisms.
Export-Import Bank of the United States (EXIM)	Provide direct loans, loan guarantees, insurance, working capital and supply chain guarantees to U.S. exporters, commercial banks, and foreign buyers



NET ZERO WORLD INITIATIVE | 11

Potential Collaboration with Net Zero World

NZW provides customized assistance that responds to country priorities with the goal of achieving just net zero energy transitions together

For additional information, please contact:

NZW Indonesia Country Coordinator

Bruce Hamilton bhamilton@anl.gov +1.312.261.0653

NZW Indonesia Investment Lead

Carolyn Szum ccszum@lbl.gov

NZW Indonesia Captive Power System POCs

Investment	Jon Anda	anda@anl.gov
Energy Management	Vestal Tutterow	vtutterow@lbl.gov
Power Systems	Todd Levin	tlevin@anl.gov
RE Data Explorer	Akhilesh Magal	akhilesh.magal@nrel.gov

NET ZERO WORLD INITIATIVE | 12

Analysis of Possible Demand and Supply Developments for Class I Nickel

Prepared by Matthew Riddle, David Gohlke and Qiang Dai (Argonne National Laboratory)
for Net Zero World: Indonesia

June 16, 2023

Introduction

As electric vehicle (EV) sales surge, the demand for lithium-ion battery materials has grown accordingly, leading to concerns about the ability of supply for these materials to keep up with growing demand. One key material that has been gaining attention is class I nickel, which is used in the cathodes of most lithium-ion batteries. Class I nickel is largely produced from sulphide ores, but can also be produced from the more abundant laterite ores using processes such as high pressure acid leaching (HPAL). This study explores the current status and expected future developments in the supply and demand for class I nickel, and the implications for efforts to generate class I nickel from laterite ores in Indonesia.

Nickel demand projections

Demand for nickel has been projected to grow rapidly as EVs become more widely adopted, but the rate of growth depends on several factors, the two most important being the rate of adoption of EVs and the battery chemistries used. Figure 1 shows one set of projections, developed by Argonne, from the recently released draft update to DOE's critical materials strategy (U.S. DOE, 2023). Four separate trajectories are modeled, which include high and low scenarios for the adoption of EVs and grid storage, and high and low scenarios for material intensity.

The trajectory of demand varies greatly depending on the scenario assumptions, however even in the lowest demand scenario (trajectory A), nickel

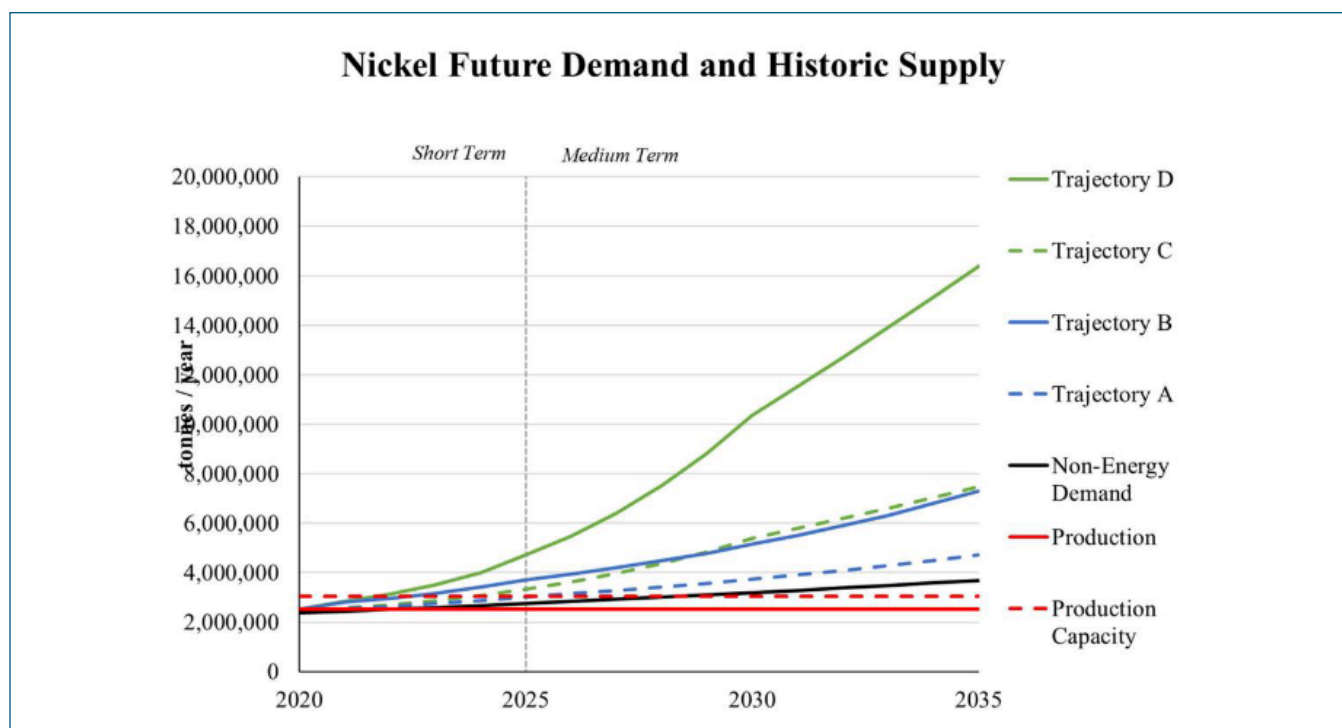


Figure 1. Nickel demand trajectories, current production, and production capacity.

demand still grows beyond current production capacity levels. In the highest scenario (trajectory D) it surges to almost five times current production capacity by 2035.

The high EV adoption scenarios are based on the International Energy Agency's (IEA) net zero by 2050 scenario (NZE), while the low EV adoption scenarios are based on IEA's stated policies scenario (STEPS). The differences in the material intensity scenarios are driven largely by the rate of adoption of lithium iron phosphate (LFP) batteries, which do not require any nickel. The scenarios used in this study, based on Xu et al. (2020), considered two possible extremes, one which reached 60% LFP by 2035, with the balance nickel manganese cobalt (NMC) or nickel cobalt aluminum oxide (NCA); the other scenario reached 97% NMC + NCA by 2035.

Several more recent projections for market shares of different battery chemistries fall within the range used in this study. For example, Fastmarkets projects that LFP will account for 35% of the global EV market by 2029 (Yang et al., 2023), and UBS projects it to be 40% by 2030 (S&P Global, 2022). Avicenne estimates that LFP will account for 41% of the global cathode active material market for all Li-ion battery applications (not just EVs) in 2030 (Sanders and Noel, 2022).

Tradeoffs between NMC and LFP

LFP and NMC batteries each have distinct advantages, which will likely lead to continued use of both types of batteries. NMC and NCA batteries have higher energy density than LFP, which allows vehicles to have longer ranges for a given amount of battery weight and volume. They also perform better at low temperatures, and thus may be more attractive for car buyers who live in cold climates. LFP batteries, on the other hand, require fewer expensive materials, have longer cycle life allowing them to maintain their full level of charge for longer, and have lower risk of fires. As a result, LFP and NMC batteries have tended to be used in different segments of the market. LFP batteries have been used more in Asia and in lower-cost EVs, while NMC batteries have been used more in the U.S. and Europe and in vehicles with longer driving ranges.

Both LFP and NMC technologies continue to develop. One important industry trend has been toward NMC chemistries with higher nickel contents relative to cobalt and manganese, such as NMC622, NMC811, and NMC955. As the nickel content increases, the energy densities also increase, but the manufacturing process also becomes more challenging (Greenwood et al, 2021). As manufacturing techniques for these more advanced NMC batteries improve, this could increase the energy density advantage of NMC over LFP, while also increasing the nickel content per battery.

Stationary grid storage may also be an important use of lithium-ion batteries, but projected demand is lower than for EVs, and nickel-based batteries are less likely to be used to satisfy this demand. The energy-dense, but more volatile and relatively expensive NMC or NCA lithium-ion batteries are less likely to be considered for stationary storage, and so LFP and non-lithium-ion battery technologies likely will have greater market share than in the automotive sector.

New North American battery cell manufacturing announcements

This section reviews new battery manufacturing project announcements in North America, a key source of demand for class I nickel worldwide. Over the next decade, over 1,000 gigawatt hours per year of manufacturing capacity for batteries cells has been announced by companies across North America. This has been rapidly increasing, with 90% of the total capacity announced since 2021. Combined, since 2021, these companies have announced commitments for over \$70 billion. The largest driver of these increased investments has been the forecast growth of EVs, however other uses such as stationary storage and electronics will receive a portion of these batteries as well. The announced growth in manufacturing capacity is shown in Figure 2.

The vast majority of EVs manufactured in the United States today are using some blend of nickel, cobalt, manganese, and aluminum as the metals in the cathode active material (Gohlke et al, 2021). In recent years, technical improvements in battery capacity have led to lithium iron phosphate (LFP),

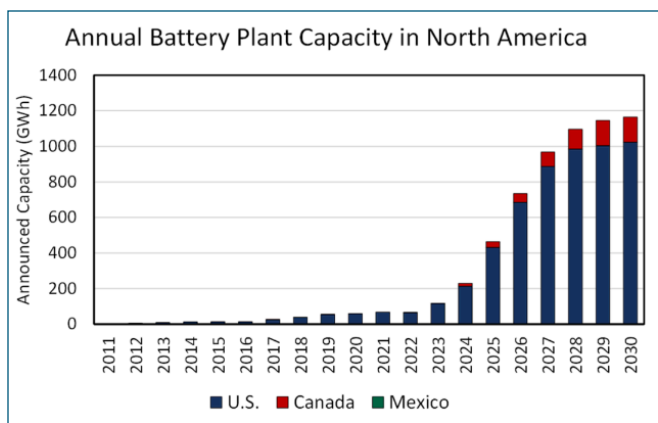


Figure 2. Announced North American battery plant capacity.

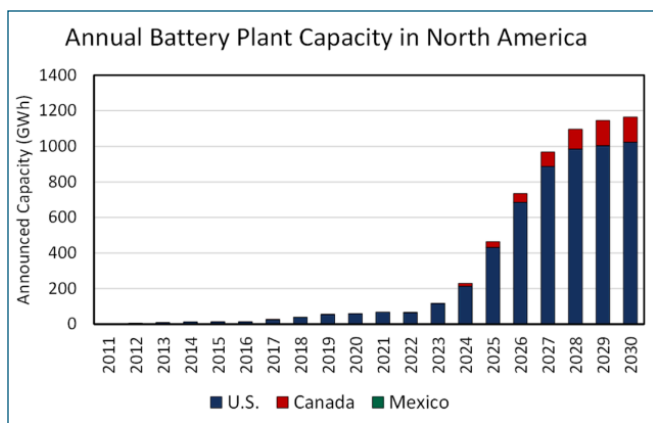


Figure 3. Announced North American LFP battery plant capacity.

which had previously been used primarily in Asia, being considered a viable option by U.S. vehicle manufacturers (Ford, 2023; Tesla, 2023). As a subset of Figure 2, Figure 3 shows the announced growth in LFP lithium-ion batteries. This is not necessarily exhaustive as many lithium-ion announcements do not explicitly state their plans with regards to cathode chemistry. However, it is reasonable to assume that NMC and NCA chemistries will maintain a strong role in the U.S. EV battery ecosystem. Ford's February 2023 announcement that it plans to build an LFP plant in the U.S. indicates that it would be the country's first automaker-backed LFP battery plant in the U.S., suggesting that most U.S. battery plants will still be producing NMC or NCA cells (Ford, 2023). Figure 3. Announced North American LFP battery plant capacity.

Sources of supply

The other side of the equation is the supply of class I nickel. Sulphide ores are generally the most economical source of class I nickel, but laterite ores are more abundant, with about 60% of world nickel resources being in the form of laterites (USGS, 2023). Most high-grade sulphide ore deposits have already been developed, but there are projects underway to develop new, often lower-grade sulphide ores, including the Crawford, Dumont, and Baptiste deposits in Canada, Tamarack in the United States, and Kabanga in Tanzania, among others. Estimating the total amount of expected production from these resources requires more research. If there is sufficient lower-cost class I nickel

available from processing sulphide ores to meet demand, it may be more difficult for HPAL projects to find buyers. However, the lower-grade sulphide ores being developed may not have as much of a cost advantage over HPAL projects as higher-grade sulphide mines. Recycling can also recover battery-grade nickel materials from end-of-life batteries and help bridge the gap between nickel supply and demand. However, due to the rapid expected growth in global EV sales through 2030, and the long life span of EV batteries, the amount of nickel recoverable from end-of-life batteries will fall far short of nickel demand for EVs in any given year over the next two decades. One study co-authored by Argonne estimated that even assuming 100% collection of end-of-life EV batteries and 98% recovery efficiency for critical minerals, recycling could only meet 2-4% of the global Ni demand for EVs through 2029, and 15-26% of the demand through 2039 (Xu et al, 2020).

Summary

The market trajectory for class I nickel is difficult to predict with great confidence, as there are many factors that could affect the supply and demand of nickel. The rate of adoption of new EVs, trends in adoption of different battery chemistries, and the amount of development of new sulphide ores all could have significant impacts on future demand and supply trajectories. However, signs point to likely rapid increases in demand for nickel, making it challenging for traditional sulphide mining and processing to meet this rising demand. EV adoption

rates are expected to continue to increase and NMC batteries are likely to continue to be a significant part of the battery market moving forward. New sulphide mines will be able to meet some of this new demand, but this may require developing lower-grade deposits, and it is not clear if there is sufficient

supply to meet the growing demand. Recycling is not able to make up much of the gap due to delays in the availability of end-of-life batteries in a rapidly growing market. As a result, it is likely that class I nickel will remain a desired commodity for the foreseeable future.

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Life-Cycle Environmental Analysis of Nickel Production in Indonesia

Prepared by Jarod Kelly and Rakesh Iyer (Argonne National Laboratory) for Net Zero World: Indonesia

May 31, 2023

Executive Summary

Nickel (Ni) has become an increasingly important mineral globally due to decarbonization efforts of the transportation sector through battery electric vehicles (BEVs), which require batteries with high specific energy. The popular automotive NMC cathode chemistry consists of lithium, nickel, manganese, and cobalt, and often uses nomenclatures of “111,” “532,” and “811,” which represent the stoichiometric ratio of nickel to manganese and cobalt. As Ni content increases in these cathodes, so does their specific energy. Thus, more Ni is needed in these types of batteries to meet the increasing range demands of BEVs, and that increased demand has led to increased extraction from previously dormant assets. One such asset is the laterite ore-based Ni found in Indonesia. While Indonesia has long been a player within the Ni market (tied with Australia for the most Ni resources globally), they have expanded production as lateritic Ni has become cost competitive with sulfidic Ni. However, the Indonesian government also has restricted the export of Ni ore and instead requires mineral upgrades to be conducted domestically (i.e., production of refined Ni in some form within the country). This has led to full-scale Ni production projects in Indonesia that extract the ore and process it via high-pressure acid leaching (HPAL) to generate a final product of Class I Ni.

This study examined a hypothetical HPAL-based Ni operation in Indonesia, considering numerous energy input pathways as alternatives to the currently proposed method of providing electricity via a captive-coal facility. This study intends to focus on the environmental implications of each such pathway. Our baseline modeling suggests that the drying stages of Ni production typically utilize natural gas significantly more than electricity,

but the proposed projects in Indonesia may be able to leverage electricity to generate the high temperatures and pressures necessary in HPAL processing. As such, we investigated scenarios in which the ratio of natural gas to electricity varies between the baseline (~90% natural gas) to 50% natural gas to 0% natural gas, with the remainder being electricity, except for a small invariable amount of diesel energy needed for mobile and other equipment. We also considered dramatic reductions in total energy input from the baseline condition since that is a conservative estimate from the literature. Finally, we evaluated electricity generation conditions that were either captive-coal, solar photovoltaic, enhanced geothermal systems (EGS), or hydropower.

Our results first present the environmental burdens associated with the different literature models of HPAL-based Ni, and then consider the abovementioned scenarios. We observe a dramatic improvement in all energy and emissions profiles when converting from captive coal to any of the other mentioned forms of electricity (inclusive of the infrastructure burden for each source). The burden reduction is greater than 50% for all metrics except water, and in many cases, the reductions are upwards of 75% on a life cycle basis. Practical issues related to PV deployment are the necessity of some complementary electricity source or storage solution for grid balancing, while geothermal and hydroelectric facilities have site-specific requirements that may not be suitable for all locations.

Background/Introduction

Increasing calls for decarbonization are expected to increase the use of lithium-ion batteries (LIBs), leading to a significant jump in global nickel (Ni) demand (Zhang et al. 2023). This has accelerated

the shift in global Ni production from relatively high-grade sulfide ores to low-grade laterite ores (> 50% at present) (Pandey et al. 2023). With its vast laterite reserves, Indonesia has emerged as the largest global Ni producer (USGS 2022; Pandey et al. 2023), especially after the Indonesian government mandated domestic Ni processing instead of ore exports (IEA 2022). Environmentally, laterite-based Ni production is reportedly highly energy- and carbon-intensive due to its large material and energy input needs compared to its sulfidic-ore counterpart (Mudd 2010; Norgate and Jahanshahi 2011). This is because sulfidic-ore Ni is processed exothermically, while laterite ores have historically required high heat consumption for drying operations (Mudd 2010; Norgate and Jahanshahi 2011). Compounding this environmental challenge, Indonesian plants are being designed to use captive coal-based electricity to produce lateritic Ni (NPR 2023;

Castillo et al. 2023), which is counterproductive to the decarbonization of both Ni and LIB production and presents local criteria air pollutants (CAPs) challenges.

Here, we analyze Indonesia’s lateritic Ni produced using HPAL — the predominant production technology in that nation — for its energy, GHG, and CAP intensity. We provide a brief literature review on the process and the data available for material and energy flows. Next, we discuss the details of our analysis, including the aim of this study, the material and energy flows used for a baseline HPAL-based Ni production process from literature, and our key assumptions and environmental metrics covered in this analysis. We also describe additional scenarios used to evaluate the prospects for GHGs and CAPs reduction by switching from captive coal to renewable energy (RE) sources. Subsequently, we describe the key results from this study as well as important limitations that must be considered in tandem with our results. Finally, we summarize the key findings and highlights of this analysis. Our analysis is conducted using Argonne’s GREET® (Greenhouse gases, Regulated Emissions, and Energy use in Technologies) 2022rev1 model (Lee et al. 2023) — a world-leading tool for life cycle analysis of materials and technologies.

Literature Review

HPAL: A Brief Overview

Ni production is typically conducted from either sulfidic ores (via pyrometallurgy) or laterite ores (via hydrometallurgy). Several hydrometallurgical routes exist at present, including heap leaching (HL), atmospheric acid leaching (AL), high-pressure acid leaching (HPAL), the Caron process, and the direct Ni (DNI) process (Pandey et al. 2023). Of these, HPAL is a widely used technology because of its several advantages, including low acid consumption and high metal recovery rates ($\geq 95\%$) from even low-grade laterite ores (Pandey et al. 2023). Figure 1 shows a schematic of Ni production via a generalized HPAL process (Pandey et al. 2023): note that the intermediate product from the HPAL process is mixed hydroxide precipitate (MHP), which is further processed to produce Class I Ni metal.

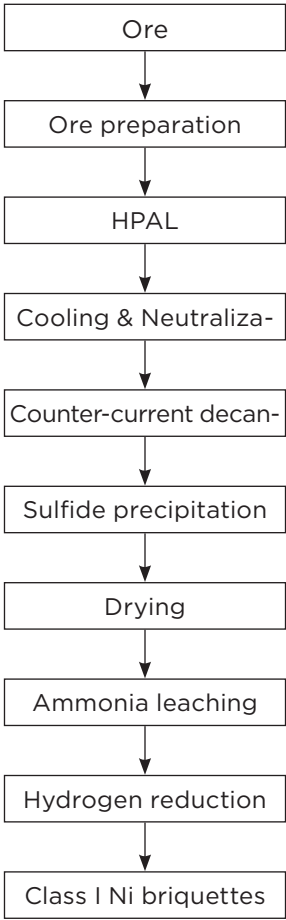


Figure 1. Schematic of Ni production from laterite ores via HPAL route (based on [Pandey et al.

Briefly, laterite ore is washed, comminuted, and leached with sulfuric acid at high pressure (30-50 bar) and temperature (240-270 °C) in an autoclave (Figure 1) (Pandey et al. 2023). The leached ore is neutralized using limestone, then separated using counter-current decantation to separate iron (Pandey et al. 2023). MHP is produced after removing manganese (Mn) and cobalt (Co) using lime. MHP is used to either produce nickel sulfate (NiSO₄) or processed further to produce Class I Ni metal (Pandey et al. 2023). At present, HPAL is commercially used in many laterite-based Ni production plants, such as Moa Bay, Cuba; Murrin Murrin, Australia; Goro, New Caledonia; and Ramu River, Papua New Guinea (Pandey et al. 2023).

HPAL: Life Cycle Inventory (LCI) Review

HPAL has been in commercial use for several years, thus some details are available about the various reagents and energy sources used for lateritic Ni production via this route. However, unlike the extensive work on life-cycle inventories (LCIs) — or the exact quantities of these materials and energy forms — for sulfidic Ni production in literature (Khoo

et al. 2017), only three studies provide the LCIs for lateritic Ni production via HPAL (Northey and Haque 2013; Northey et al. 2014; Khoo et al. 2017). Two of these studies are published by the same authors (Northey and Haque 2013; Northey et al. 2014), while the third study (Khoo et al. 2017) uses LCI data from previous works published by one or more of these authors (Norgate and Haque 2010; Northey and Haque 2013). Table 1 summarizes the LCIs from these studies. There is also prior work on this subject focusing on the embodied energy use and greenhouse gas (GHG) emissions of lateritic Ni production but it does not provide any LCI details, and is thus unable to directly inform the present analysis (Norgate and Haque 2010; Norgate and Jahanshahi 2011).

The studies listed in Table 1 each have their limitations. Only one of the three studies (Northey and Haque 2013) provides disaggregated LCIs for all the individual processes involved in HPAL Ni production from laterite ores. The other two studies (Northey et al. 2014; Khoo et al. 2017) only provide a combined LCI encompassing all the Ni production processes without any process-level disaggregation.

GREET Baseline Inputs	(Northey et al. 2014)	(Northey and Haque 2013)	(Khoo et al. 2017)
Material inputs (US ton/US ton Ni)			
Ammonium nitrate	0.053	0.88	
Lime	20		
Limestone		19.4	15.76
Sulfur			13.19
Ammonia	0.637	0.7	0.074
Sulfuric acid	25	23.08	
Hydrogen	0.07	0.07	
Energy inputs (mmBtu/US ton Ni)			
Diesel	5.487	3.962	6.101
Natural gas	567.501	533.187	25.440
Electricity	16.991	25.227	30.931

Table 1. LCIs for lateritic Ni production via HPAL routes in literature.

Also, our literature review did not yield any studies that investigate (or could be used to investigate) the variation in material and energy inputs for lateritic Ni production as a function of ore grade. This is an important issue, as the rapid expansion in Ni mining to meet demand has caused a significant decline in Ni ore grade (Mudd 2010), which can increase the quantity of material and energy inputs for Ni production, and thereby, influence environmental impacts. All three studies in Table 1 consider a single ore grade (1.3%) for analysis (Northey and Haque 2013; Northey et al. 2014; Khoo et al. 2017).

An important concern with the LCIs in Table 1 is the wide variation in energy inputs between the studies. Two studies consider a large input of natural gas for HPAL Ni production (likely for autoclave heating) (Northey and Haque 2013; Northey et al. 2014). In contrast, the third study (Khoo et al. 2017) reports much lower natural gas use by referencing earlier studies from the authors of the former two studies (Norgate and Haque 2010; Northey and Haque 2013), even though this natural gas use data is either not reported or is different from that mentioned in the referenced work.

Interestingly and importantly, the first two studies report different reagents for the neutralization step – lime (Northey et al. 2014) versus limestone (Northey and Haque 2013) — which is confusing as both studies have the same authors. We are uncertain if the authors simply made a typographical error in their reporting. It is unclear if this difference can have a significant bearing on the GHG footprint of lateritic HPAL Ni production. While limestone production is less GHG-intensive than lime production (Wang et al. 2022; Lee et al. 2023), limestone's reaction with other chemicals typically produces process CO₂ emissions. Lastly, none of the studies highlight the exact chemical reactions and/or process emissions (GHGs and/or CAPs) generated during each of the steps.

Life-Cycle Analysis (LCA) of Lateritic Ni Production

Our goal is to analyze the GHG, water, and CAP footprint of lateritic Ni production in Indonesia via HPAL technology. Our system boundary includes all stages of Class I Ni production (Figure 1), beginning with ore mining and beneficiation and culminating in the production of Ni briquettes, inclusive of the

HPAL process (Pandey et al. 2023). In terms of scope, this analysis is confined to the environmental impacts and embedded energy consumption of lateritic Ni production at a generic level, without focusing on any site-specific details for different Ni plants in Indonesia. The environmental metrics considered in this analysis include GHGs, water consumption, and CAPs (sulfur oxides or SOX, particulate matter or PM₁₀, and nitrogen oxides or NOX). Our analysis is conducted using Argonne's GREET® 2022rev1 model (Lee et al. 2023). Note that the GREET 2022rev1 model (Iyer and Kelly 2022; Lee et al. 2023) contains an HPAL-based lateritic Ni production route (Northey and Haque 2013) since it represents the most conservative LCI among those listed in Table 1 from a resource use and environmental perspective (i.e., will lead to the highest energy use and emission impacts among all the studies listed in Table 1).

Given the limitations associated with LCIs for lateritic Ni production (noted above), we consider multiple scenarios related to Ni production in this analysis. We use the GREET model to determine the energy and environmental metrics of lateritic Ni production for all the LCIs listed in Table 1, as this provides a range of values for these metrics for existing literature. Additionally, we consider three inputs associated with Ni production to vary in this analysis. These are (a) the nature of the electric grid mix; (b) the total process energy used; and (c) the share of electricity and other energy sources within the total process energy. Table 2 provides the reasons for considering these input-related scenarios and additional details. We also made several adjustments to the original GREET model for this analysis based on specific assumptions, which are listed in Tables 2 and 3.

Across all these scenarios, we focus solely on energy and environmental metrics for analysis. We do not focus on Ni production costs under these scenarios or on LCIs obtained from literature, as this is beyond the scope of our work. Our analysis also does not focus on any site-specific LCIs for Ni production within different parts of Indonesia or on the variation in Ni ore grade with time and its effects on these metrics, mainly due to a lack of data on these parameters. Finally, this analysis does not include or comment on issues such as water effluents, resource depletion, human toxicity exposures, or labor practices.

Input variable	Scenario details and assumptions	Reasons for choosing this scenario
Nature of electric grid mix	Baseline assumes the electric grid mix for Ni production as GREET 2022rev1 (Lee et al. 2023). Captive coal-based electricity for lateritic Ni production, in line with HPAL plans in Indonesia. Alternative scenarios consider the use of RE sources (solar photovoltaic, EGS, and hydro).	Given the plans for Indonesian HPAL plants to have electricity supplied by captive coal-based electricity, these scenarios help determine the GHG and CAP impacts of switching from coal to alternative energy sources for Ni production (inclusive of electric plant infrastructure).
Total process energy used	Baseline assumes the same process energy use for Ni production as GREET 2022rev1 (Lee et al. 2023). Other scenarios consider 50% and 10% of the baseline value for process energy.	Baseline scenario provides a conservative scenario, while the mid- and low scenarios illustrate the importance of energy (process energy in the low scenario is similar to [Khoo et al. 2017]).
Share (%) of electricity and other energy sources in total process energy	Two alternative scenarios are considered that assume the same absolute amount of diesel as the baseline scenario. One alternative considers the rest of the process energy to be supplied only by electricity (assuming a 1:1 replacement between natural gas and electricity, i.e., all the natural gas- related energy in the baseline scenario is replaced by an equal amount of electricity-based energy). The other alternative scenario assumes an equal energy split between natural gas and electricity, similar to (Khoo et al. 2017).	These scenarios help evaluate the effects of switching from direct natural gas use to electricity on energy use and emissions of Ni production, especially when coupled with the total process energy-related scenarios.

Table 2. Scenarios considered for LCA analyses in this work.

Parameter	Assumption
Types of coal used	For captive coal-based electricity, both bituminous and sub-bituminous coal are assumed to be used in a 50:50 share, based on IEA data (IEA 2023). Bituminous has a higher heat content and thus lower GHG emissions per megajoule than sub-bituminous (~20% lower).
Transmission and distribution (T&D) losses	Since the HPAL plants in Indonesia plan to utilize captive coal-based electricity (NPR 2023; Castillo et al. 2023), we consider a T&D loss of 0% for coal-based electricity scenarios. We extend this T&D loss figure (0%) to all renewable energy scenarios, assuming the associated power plants to be captive for our analysis.

Table 3. Other key assumptions in this study.

Results & Discussion

Our first analysis examines the life cycle environment burdens associated with Ni production from laterite ore using HPAL processes based on the literature. For this, we utilized the inventory data presented in Table 1 within GREET to conduct calculations. However, we also added one scenario that considered the possibility that Northey et al. (2014), which is the GREET baseline, made a typographic mistake in their inventory. To do this, we replaced the 20 tons of lime/ton of Ni with 20 tons of limestone/ton of Ni. The results of our analysis are presented in Figure 2. In this figure, the three studies and our counterfactual are grouped within the reported environmental burden categories and presented against each other as percentages of the maximum value from within that category across the study. We also provide the value of that maximum above each category for context. We can see that the Northey et al. (2014) analysis has the highest energy and water consumption and the highest GHG, NOx, and PM10 emissions. However, we see that the Khoo et al. (2017) study has the highest SOx emissions. Furthermore, we observe that by substituting limestone for lime in the Northey et al. (2014) paper,

a substantial decrease can be seen across all burden categories, most notably water consumption, GHG emissions, and PM10 emissions.

For the remainder of our analyses, we leverage the Northey et al. (2014) inventory data as our baseline for both material and energy inputs since that study is the basis for lateritic Ni production in GREET. As noted in Table 2, we conducted numerous scenario analyses based on different assumptions about the source of electricity into the system (coal, PV, EGS, and hydro), the quantity of energy into the system (baseline, 50% of baseline, and 10% of baseline), and the share of energy that is natural gas versus electricity (baseline, 100% natural gas/0% electricity, and 50% natural gas/50% electricity). Figures 2(a-c) and 3(a-c) show the results for life cycle energy consumption, GHG emissions, water consumption, and SOx, PM10, and NOx emissions, respectively.

The general arc of results is consistent with expectations. Under the baseline natural gas to electricity share, the source of electricity has a minimal impact on the overall results. This is because that baseline condition only consumes 2.9% of its energy as electricity; thus, there is little opportunity for electricity decarbonization

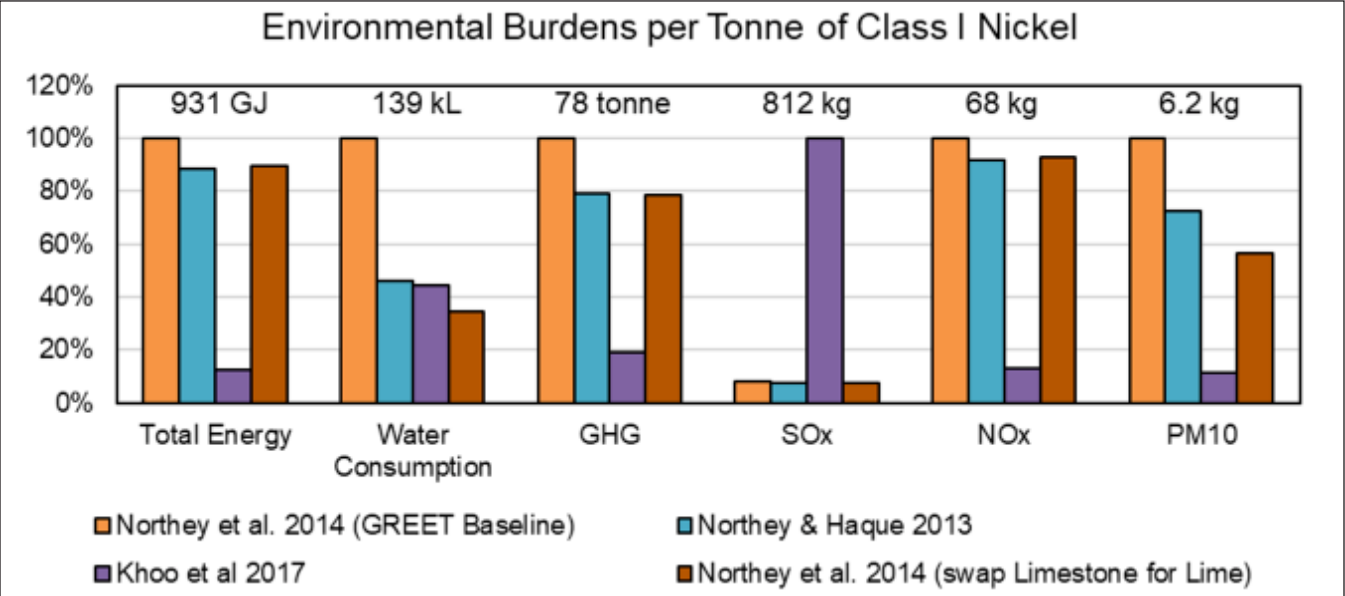


Figure 2. Life cycle analysis comparison of literature studies, inclusive of our revision of the Northey et al. (2014) study to replace lime with limestone.

options to make an impact. However, we see that if 100% of the non-diesel energy can be converted to electricity (recall that we assume diesel to be invariable), then the variance between the electricity sources is much more impactful. We will focus discussion here on the All NG to Electric and Baseline Energy scenarios while noting that the 50/50 NG to Electric and 50% Baseline Energy and 10% Baseline Energy scenarios follow the same trends (just with reduced absolute values). We see that the captive coal scenario consumes over twice as much life cycle energy as the alternative energy scenarios while emitting roughly five- to six times the GHG, PM10, and NOx emissions, and over three times the SOx emissions. However, while it consumes more water than the PV and geothermal scenarios, it consumes ~85% less water than the hydropower scenario.

Overall, the substantial decrease in energy use and emissions (GHG and CAP) of lateritic Ni produced using RE over that produced via coal-based electricity highlights the benefits of producing Ni using alternative energy sources from both local and global viewpoints (Figure 3). The decrease is independent of the actual RE source (solar PV/hydro/geothermal) used as a replacement for captive coal, with relatively small differences in energy use and emissions of different RE technologies. The reductions in energy use and emissions are further magnified by an increase in the share of electricity in total process energy for Ni production (Figures 2-3). Together, these results indicate the importance of shifting from captive coal to RE power plants and from fossil fuels to renewables-based electricity for decarbonizing Ni production, regardless of the actual RE source.

Among the different RE sources, Ni produced using hydropower consumes the least amount of energy and emits the lowest amount of GHGs, while consuming the highest amount of water among all energy sources (including coal) (Figure 3). The assumption in the GREET model that water is consumed to produce hydroelectricity explains its highest water use among all sources of electricity generation. Note that this water may be available for use for other needs (agricultural, residential, and/or industrial) post-electricity generation.

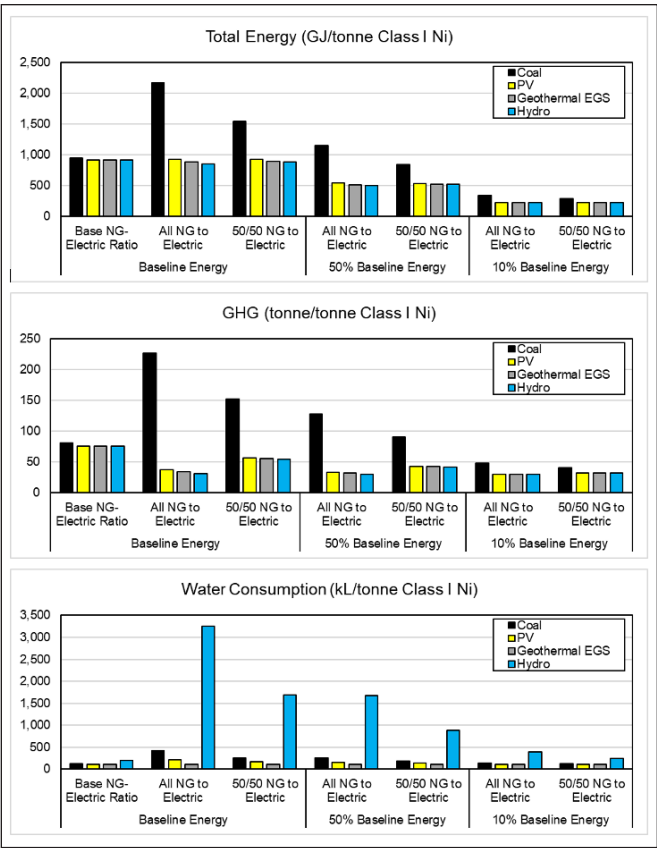


Figure 2(a-c). (a) Life cycle energy consumption, (b) GHG emissions, and (c) water consumption results of scenarios described in Table 2, highlighting the impact of an electricity source and the ratio of electricity to natural gas in providing system energy

Note that while the broader conclusions of this analysis are robust, there are specific limitations on the actual use of each aforementioned RE technology for lateritic Ni production. For instance, solar PV is an intermittent source of electricity and will have to be coupled with other sources of energy to ensure stability in the energy supply. This source can be either an energy storage platform (such as batteries or pumped storage hydro), other RE sources with more stability (such as hydro and geothermal energy), or even coal. Hydropower and geothermal energy can only be generated at specific sites, and hydropower can also exhibit seasonal variations that may need to be complemented with energy from other sources (such as batteries or coal). Thus, while

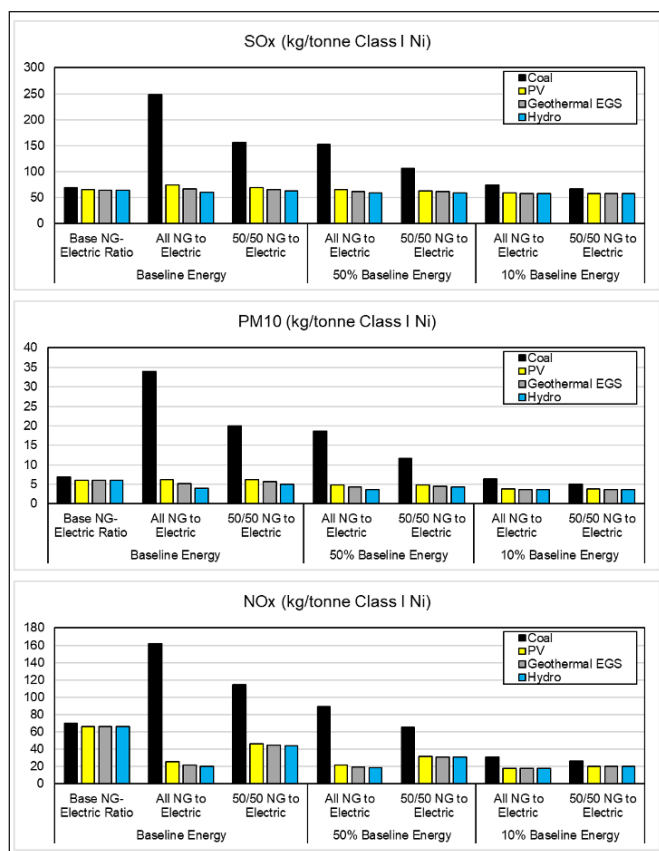


Figure 3(a-c). (a) Life cycle SOx, (b) PM10, and (c) NOx emissions results of scenarios described in Table 2, highlighting the impact of an electricity source and the ratio of electricity to natural gas in providing system energy.

RE is important from the viewpoint of reducing the environmental footprint of lateritic Ni, it is not a panacea to the challenges posed by the use of captive coal to produce this metal. In other words, the environmental impacts of lateritic Ni production under captive coal and RE scenarios represent the maximum and minimum values of these impacts, respectively. Any shift towards RE for this purpose, even if at a partial level, will yield reductions in GHG and CAP emissions.

Summary

A major increase in Ni demand is expected due to the expanded use of LIBs across multiple sectors for their decarbonization potential, necessitating its extraction from both sulfide and laterite ores. While the presence of laterite ore has made Indonesia the largest Ni producer in the world, the use of captive coal-based electricity to produce the metal has raised concerns about its harmful local and global environmental impacts. Using Argonne's GREET model and data from the literature, we determine the life-cycle energy use, emissions (GHGs and CAPs), and water footprint of Ni production from laterite ores across multiple scenarios. Our analysis shows improvement in life cycle energy use and environmental metrics for lateritic Ni production via lower process energy, a higher share of electricity in this process energy, and a shift from coal to RE to generate this electricity. This highlights the benefits of changing these inputs from the perspective of decarbonizing Ni production, independent of the actual RE source used as an alternative to captive coal. However, since the renewables considered here typically generate electricity intermittently on a daily and/or seasonal basis, these will likely need to be coupled with other electricity sources to provide supply stability, such as batteries, other RE sources, or even fossil fuels like coal. Nevertheless, our results indicate the environmental benefits of even a partial transition from coal to RE for Ni production.

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ANNEX E

Workshop Summary

Summary Report: U.S. – Indonesia Joint Workshop on Decarbonization of the Building Sector

Prepared for Lawrence Berkeley National Laboratory

22-24 February 2023



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Lead Author

Mark Lister, co-Chief Executive Officer, Asia Clean Energy Partners

Contributors

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Dr Ronnen Levinson, Net Zero World (NZW) Building Sector Coordinator, Lawrence Berkeley National Lab

Dr Nan Zhou, NZW Technical Program Manager, Lawrence Berkeley National Lab

Marc LaFrance, NZW Buildings Lead, U.S. DOE Building Technologies Office

Bruce Hamilton, NZW Indonesia Country Coordinator

Jon Respati, Chairman, Masyarakat Konservasi dan Efisiensi Energi Indonesia (MASKEEI)

Adeviyanti Halim, Founder and Director, Damia Convex

Tiara Hasibuan, Project Manager, Damia Convex

Bonnie Cobiseno, Administrator, Lawrence Berkeley National Laboratory

Bayu Wisnu Aji, Business Development Senior Manager, MAXpower Group

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Abbreviations

A/C	air conditioning
AC	alternating current
ANSI	American National Standards Institute
APS	Announced Pledges Scenario
ASEAN	Association of Southeast Asian Nations
ASTM	American Society for Testing and Materials
BGH	Bangunan Gedung Hijau (building certification)
BMS	building management system
BTO	Building Technologies Office
COP	coefficient of performance
CCS	carbon capture and storage
CO	carbon monoxide
CO ₂	carbon dioxide
DC	direct current
DOAS	dedicated outdoor air system
DOE	United States Department of Energy
EBTKE	Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi = the Indonesian Directorate General of New Renewable Energy and Energy Conservation
EC	energy conservation
EE	energy efficiency
EnMS	energy management system
EPD	environmental product declaration
ESCO	energy services company
ESDM	Kementerian Energi dan Sumber Daya Mineral = Indonesian Ministry of Energy and Mineral Resources
EUI	energy use intensity
EV	electric vehicle
GBCI	Green Building Council Indonesia (and Green Building Certification Initiative)
GHG	greenhouse gases
GW	gigawatt
HCHO	formaldehyde
HVAC	heating, ventilation and air conditioning
IAQ	indoor air quality
IEA	International Energy Agency
IFC	International Finance Corporation
ISO	International Standards Organization
kW	kilowatt
kWh	kilowatt-hour
kWp	kilowatt peak
LBNL	Lawrence Berkeley National Laboratory
LCA	life cycle assessment
LEAP	Low Emissions Analysis Platform
LEDS	Low Emission Development Strategies
LEED	Leadership in Energy and Environmental Design
LGUs	local government units
m ²	square meter
M&V	measurement and verification

MASKEEI	Masyarakat Konservasi dan Efisiensi Energi Indonesia = Indonesian Conservation and Energy Efficiency Society
ME	monitoring and evaluation
MEMR	Indonesian Ministry of Energy and Mineral Resources
MEPS	minimum energy performance standards
MRT	Mean Radiant Temperature
MWh	megawatt-hour
NDC	Nationally Determined Contribution (under the Paris Agreement)
NGO	non-government organization
NZE	net zero energy
NZW	Net Zero World
NZWI	Net Zero World Initiative
OJK	Otoritas Jasa Keuangan (the Indonesian banking regulator)
OSS	online single submission
PCM	phase change material
PM2.5	the amount of solid or liquid particulate matter 2.5 microns and less in aerodynamic diameter suspended in the atmosphere or in a sample of ambient air
PM10	the amount of solid or liquid particulate matter 10 microns and less in aerodynamic diameter suspended in the atmosphere or in a sample of ambient air
PP	Peraturan Pemerintah (government regulations)
PUPR	Kementerian Pekerjaan Umum dan Perumahan Rakyat = Indonesian Ministry of Public Works and Housing
PV	photovoltaic
R&D	research and development
RE	renewable energy
RH	relative humidity
RT	refrigeration tons
SCS	solar cooling system
SIMBG	Sistem Informasi Manajemen Bangunan Gedung
SKK	Sertifikat Kompetensi Kerja
SLE	Super Low Energy
SLF	Sertifikat Laik Fungsi
SNI	Standar Nasional Indonesia
SR	Solar reflectance
T	temperature
TE	thermal emittance
TIMES	The Integrated MARKAL-EFOM System
TOE	tons of oil equivalent
TREC	Tropical Renewable Energy Center
UPI	University Pendidikan Indonesia
U.S.	United States
VOC	volatile organic compounds
VSD	variable speed drive
ZCB	zero carbon building

1. Background to the NZWI Initiative and its engagement with the Indonesian building sector

The Net Zero World Initiative

The Net Zero World Initiative (NZWI) is a multi-agency United States (U.S.) Government initiative that leverages expertise across government agencies and U.S. Department of Energy (DOE) national laboratories, in partnership with other governments and philanthropies, to accelerate the decarbonization of global energy systems. The NZWI supports countries committed to raising their climate ambitions and enables country partners to harness the power and technical expertise of U.S. and international industry, think tanks, and universities. In its initial phase, the NZWI is developing both energy system-wide and specific decarbonization approaches for sectors including buildings, transport, power, industry, storage, nuclear, carbon capture and geologic storage, and energy use in agriculture.

The broad strategic objectives of the NZWI are to:

- **Develop and support ambitious technical, market, and investment strategies for clean energy transformation** – collaborating with partners to develop country-specific technical and investment plans detailing the crosscutting planning and deployment strategies needed at national, regional, and local levels.
- **Deliver holistic support for immediate and sustained transformative projects that maximize overall impact for the region** - the Initiative supports, for example, the development of cross-sector project pipelines and infrastructure modernization plans for partnering with the private sector and developing robust research, development, demonstration, and deployment partnerships to quickly advance technologies from research to implementation.
- **Foster exchanges between U.S. leaders and among countries to support peer-to-peer learning and confidence building**—The initiative supports exchanges between U.S. states and cities, business leaders, and across countries to inform technical and investment plans and key design and implementation measures to enable peer-to-peer learning, tailored replication of successes, and confidence building. The initiative also provides implementation support for workforce development programs, with particular emphasis on gender equity and the inclusion of underrepresented groups.

Initial partner countries include Argentina, Chile, Egypt, Indonesia, Nigeria, Singapore, Thailand, and Ukraine. By joining the Net Zero World Initiative, partner governments and local institutions gain access to:

- **expert technical, deployment, and investment analysis and facilitation** from the U.S. Government, including the U.S. DOE's world-class national laboratories
- **targeted support for in-country technical institutions** to build long-term, self-sustaining technical capacity
- **deep collaboration to develop technical and investment plans and support implementation** for technology project design and testing, infrastructure modernization, enabling policies and measures, investment analysis and facilitation,

capacity building and workforce development, and other critical actions needed to achieve near- and long-term energy system decarbonization.

NZWI and the Indonesian Building Sector

The COVID-19 pandemic recovery, recent energy price volatility, geopolitical conflicts and climate events have significantly impacted the global economy, disrupted global supply chains, and dramatically increased the energy cost for global citizens. The built environment can help mitigate the effects of these multiple shocks, given its interconnection with energy systems and circular materials-based construction, and its purpose to provide resilience and wellness-inducing living spaces. The built environment offers deep and rapid opportunities for decarbonization and energy security for governments, companies, and citizens through low embodied carbon materials, closed-loop technologies, and demand-side energy management solutions.

In 2020, buildings in the Association of Southeast Asian Nations (ASEAN) region accounted for almost a quarter of total final energy consumption and process-related direct and indirect CO₂ emissions. Over 40% of final energy consumption in buildings is used in the form of electricity, generated mostly from fossil fuels. By 2040, the region's population is expected to grow by over 100 million people. The rate of urbanization will reach approximately 60%, adding 120 million urban dwellers. At the same time, the floor area of buildings is expected to increase by 60% from 2017 levels (International Energy Agency, 2019).

Indonesia is the largest energy consumer in the region, comprising a third of ASEAN's energy demand. Buildings account for a quarter of energy demand already, and are the fastest growing energy end use, projected to grow 56% from 2015 to 2025. It is projected that an additional ~78 GW in power generation will need to be added by 2026 to keep up with household demand and increasing electrification (McNeil, 2018).

To meet its net-zero goals, Indonesia faces the challenge of building a low-carbon electric grid while simultaneously addressing rapid load growth in the buildings, industry, and transportation sectors. The analysis for Indonesia indicates ways for early demand-side and electrification actions to help make this challenge more achievable and affordable. Mobilizing investments in cost-effective energy efficiency, developing building codes and practices that reduce fast growing cooling loads, and facilitating load shifting, particularly for electric vehicle charging, are early investments that can make a net-zero electricity supply more achievable and affordable by mid-century.

Key macro-challenges facing the built environment include unprecedented climate change, rapid urbanization, rising energy demand from a burgeoning middle class, excessive resource use, and social inequalities. Additionally, the local nature of buildings (weather, culture, and construction diversity) and a fragmented industry (architects, engineers, builders, owners, operators, tenants, utilities etc.) make actionability complex. Decarbonization hinges on government and private sector stakeholders leading with clear market signals by investing in research and development, adopting clean and digital technologies, promoting investments and incentives, and hastening the transition to clean energy through human capital development and public information campaigns, and multi-sectoral partnering with industry to co-create policy and regulations towards net-zero built environments.

In early discussions under the NZWI, the Indonesian Ministry of Mines and Energy (ESDM) identified technical collaboration areas for application of Net Zero World Initiative analysis and capacity building assistance, in energy system-wide decarbonization assessments. Based on these discussions with the ESDM, the NZWI team applied LEAP and TIMES¹ models to create a two-model framework that supports ESDM's use of LEAP, and benefits from robust price/cost-based pathway modeling capabilities provided by the TIMES optimization modeling engine. Three core scenarios were modeled: the No New Carbon Policies scenario, the Carbon Price Only scenario, and the Net Zero 2060 scenario. All three scenarios use population, gross domestic product (GDP), and energy service demand projections consistent with the International Energy Agency's Announced Pledges Scenario (IEA's APS).

In the modeled scenarios, achievement of net-zero objectives hinge on full electrification of the buildings sector, an accelerated phaseout of fossil fuels in industry along with a scale-up of renewables, electrification of most of the transportation sector, and carbon capture and storage (CCS) to mitigate the remaining emissions. Moving toward net zero will accelerate the electrification of various end-use sectors and supercharge the already strong growth in national electricity demand, particularly in later years—making it even more important to limit new infrastructure requirements by pursuing building efficiency measures that can significantly reduce buildings sector electricity consumption, lower system peak load, and decrease grid-scale storage needs.

2. NZWI Workshop objectives

Buildings have the potential to transition from consuming fossil fuels to net zero energy, unlocking the potential for dynamic energy efficiency and flexibility within the energy system. This can deliver significant cost and environmental savings given new technologies, business models, and enabling policy, human capacity, and investments. To meet net zero goals, a priority is on adaptive reuse—i.e., deep renovation where the urbanization is already high such as in Jakarta, and leapfrog approaches in areas of new construction such as in Nusantara, to limit land and energy use, build resilience, and strengthen the built environment and national economy. To this end, the following approaches are critical at the intersection of private and public sector efforts towards net zero energy buildings, and form the basis of potential areas for building sector collaboration between the U.S. and Indonesia under the Net Zero World Initiative, to be explored in this Workshop:

1. Research and Development

Prioritized, rigorous, clean energy transition pathway modeling and development at the national and sub-national level. This can be supported by the U.S. research national labs who have decades of technical experience in third-party neutral studies, modeling, and analyses to create techno-economic frameworks.

¹ LEAP, the *Low Emissions Analysis Platform*, is a widely-used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute and is a de facto standard for countries undertaking integrated resource planning, greenhouse gas (GHG) mitigation assessments, and Low Emission Development Strategies (LEDS) especially in the developing world. TIMES is *The Integrated MARKAL-EFOM System*, a bottom-up model generator that uses linear-programming to produce a least-cost energy system, optimized according to a number of user constraints, over medium to long-term time horizons. The referred report is available at no cost from the Net Zero World Initiative at https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-33619.pdf.

2. Transformative policy and regulations

While the private sector is responsible for designing, building, operating and retrofitting significant portions of many nations' building stock, buildings are governed by local permitting, regulatory requirements and national standard setting. Hence governments can take a lead role in formulating stretch goals and putting in place a portfolio of policies, projects, and partnerships that will coordinate efforts by all stakeholders. Codes and standards can greatly boost building energy efficiency and resilience at scale; developing "stretch building codes" and further guiding buildings to achieve net zero energy performance. Energy data are crucial for existing buildings to conduct benchmarking and energy performance analytics. Cooling is one of the largest building energy demands in tropic climate regions such as ASEAN and Indonesia. Sustainable and green cooling solutions and policy are needed to integrate both passive and active cooling technologies. International experience has found that labeling and certification programs for both buildings and equipment are extremely useful to leverage market opportunities.

3. Technology frameworks for selection and commercialization of innovative technology solutions for net zero carbon buildings and system resilience

Collaboration on piloting and testing of innovative technologies, and incubation of new business models and climate tech entrepreneurship suitable for Indonesia's ethos. Promising technologies include low embodied carbon construction, especially affordable housing, institutional buildings, and commercial buildings; climate resilient construction; electrification of end-uses so they will decarbonize automatically as the power sector becomes carbon neutral; smart sensors, monitors, and control systems to optimize building energy management; energy storage; and clean energy generation.

4. Financing and incentives programs to fund zero energy building development

Investments are key through cooperation on creating investment pathways for national and subnational levels. The NZWI can work with financing institutions in Indonesia and Asia to develop zero energy and green building financing opportunities. To fulfill these activities, capacity building and providing training to local Indonesian stakeholders on aspects of financing for net zero buildings will be crucial. It is also important to engage the private sector, especially small and medium enterprises, to participate in financing zero-energy building development in Indonesia.

5. Human Capital: Upskilling and reskilling with capacity development

Assistance with workforce development and other capacity building programs including co-funding for technical institutes in Indonesia to conduct NZW activities in cooperation with the Government of Indonesia, U.S. agencies, and DOE national laboratories.

Indonesia has the potential to lead Southeast Asia with net zero energy building skills and project demonstrations, gaining the benefits of cost-effective planning and optimized supply chains, energy efficiency, flexible load management, reducing peak electricity demand, energy costs reduction and revenue generation, as well as the critical economic, environmental, and social impacts of innovation, employment, energy resilience, and energy equity for underserved communities.

In summary, a net zero building sector could potentially be a true leapfrog opportunity to achieve macro-benefits of decarbonization and energy security by providing resilient energy infrastructure while improving economic competitiveness of communities, cities, and regions. The U.S.-Indonesia Joint Workshop on Decarbonizing the Building Sector, held in Tangerang on 22-24 February 2023, was convened to further explore these areas towards a concrete plan or Roadmap for decarbonization of the buildings sector in Indonesia. The event was supported by the U.S. Department of Energy (DOE), Lawrence Berkeley National Laboratory, the Indonesian Ministry of Energy and Mineral Resources (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, abbreviated ESDM), and the Indonesian Conservation and Energy Efficiency Society (Masyarakat Konservasi dan Efisiensi Energi Indonesia, abbreviated MASKEEI), and attracted over 150 building industry participants to discuss pathways for collaboration in achieving a net zero energy building sector in the country. The program also included a study tour to some leading green buildings in the “BSD City” complex in South Tangerang (Greater Jakarta).

The following sections provide detail of the Workshop proceedings, including a summary of all discussions. Subsequent Annexes are attached to provide the Workshop agenda, participants and feedback from the event.

3. Summary of Workshop proceedings

Session 1: Introduction to workshop

Moderator: Nan Zhou, Lawrence Berkeley National Laboratory (LBNL)

Dr Zhou briefly introduced the Workshop, the importance of the building sector to zero-carbon goals, and the objective to explore collaboration between Indonesia and the U.S. She noted that there were over 150 registered participants, with a number of international visitors.

Welcome and introduction to Day 1 program

Dadan Kusdiana, Director General of New, Renewable Energy, and Energy Conservation, Kementerian Energi dan Sumber Daya Mineral (ESDM)², Indonesia

Key presentation points

- Director Kusdiana greeted dignitaries and welcomed participants to the Workshop.
- He emphasized the need to meet energy demand while reducing greenhouse gases (GHG). In 2022 Indonesia succeeded reducing 91.5 million tons CO₂ from energy efficiency and energy conservation. Their target is to reduce a further 340-380 million tons by 2025, or a reduction of 1% per year compared to business as usual.
- Most of the electricity in Indonesia comes from coal power plants. Thus, energy efficiency is important to reduce CO₂ emissions. The building sector is considered to be important in Indonesia, and many studies have pointed to its greater potential.
- Went through some of the policies in place and essential programs that needs to be implemented, including energy management system, standards, and training.
- Within the framework of NZWI, ESDM is firmly behind this workshop to help try to identify solutions.

Net Zero World (NZW) partnership

Maria DiGiulian, Senior Policy Advisor, U.S. Department of Energy (DOE) International Affairs Office

Key presentation points

- Ms DiGiulian's office oversees the entire NZWI, across all sectors. The NZWI is a top priority of U.S. energy secretary Jennifer Grandholm.
- Ms DiGiulian thanked colleagues at the State Department, DOE and LBNL for organizing the workshop and making it happen, including Bruce Hamilton, Nan Zhou and Ronnen Levinson, and also acknowledged local support from ESDM, the Indonesian Ministry of Public Works and Housing (Kementerian Pekerjaan Umum dan Perumahan Rakyat, abbreviated PUPR) and MASKEEI.
- This is the first NZWI event in Indonesia, and satisfaction was expressed that the first event is on the built environment, given building are so important to everyday life. 40%

² Kementerian Energi dan Sumber Daya Mineral = Ministry of Energy & Mineral Resources (MEMR, or ESDM)

of energy is used in buildings, we spend a lot of time in buildings, and the sector is important to NZWI's objectives.

- The workshop will take a deeper dive into some of the technologies, policies, and techniques for creating zero-carbon buildings, and hopes for some practical outcomes. U.S. representation is eager to see Indonesia's representation achieve its goals, share experience in the sector from other countries, and examine issues across sectors to provide assistance.

U.S. perspectives on Net Zero World opportunities

Marc LaFrance, NZW Buildings Lead, U.S. DOE Building Technologies Office (BTO)

Key presentation points

- The U.S. is pursuing ambitious climate goals – and the transition needs to be people-centred, efficient and clean.
- The buildings sector is core to achieving a net zero world, through considerations of how to improve construction industry practices, low-carbon building materials, and lower energy consumption. Upgrade of existing buildings will be essential to success.
- Transforming the construction industry is a key first step – to create the right conditions for new building construction. Locally manufactured materials and technologies will be key to zero-carbon building (ZCB) goals, as they will help to increase low carbon-footprint investments in Indonesia, and increase cost efficiency.
- Also, the performance of energy using equipment will influence the overall performance of buildings. Improved product durability leads to lower materials use in the long term.
- Systems integration – the building has to interact and work well in the context of the energy sector – moving towards grid-interactive buildings, with improved energy management.
- Disconnecting macroeconomic growth drivers from energy consumption was discussed, as well as potential collaborations on policy assessment.
- A few suggested areas were raised where the U.S. and Indonesia might work together: there are five U.S. national labs focused on buildings. Indonesia will have access to the best science to support its roadmap activities, and workforce development objectives.

Session 2: Energy conservation and green buildings in Indonesia

Moderator: Jon Respati, Chairman, Masyarakat Konservasi dan Efisiensi Energi Indonesia (MASKEEI)³

Improving energy conservation in Indonesia's building sector

Hendro Gunawan, Deputy Director of Energy Conservation, ESDM, Indonesia

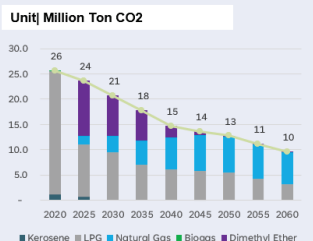
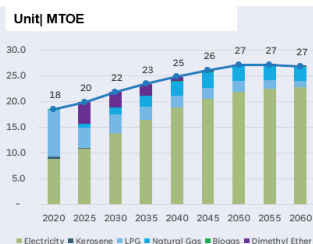
Key presentation points

- The Indonesian Government has multiple commitments to reducing GHG, including the 29% by 2030 target in its Nationally Determined Contribution (NDC) under the Paris Agreement, and a 41% conditional target. Its economy-wide roadmap targets net zero by 2060.
- In 2022, Indonesia has succeeded in reducing GHG emissions from the energy sector by 91.5 million tons of CO₂e using energy efficiency (EE). EE conservation targets are for 17% by 2030, and 39% by 2050, compared to a business-as-usual baseline. The biggest areas are transportation and industry, but buildings are also important.
- Indonesia's public sector EE programs are founded in energy management, through ISO 50001. ESDM itself has more than 16 buildings with appointed energy managers, and is assisting regional and local governments to get involved in supporting central government with good practice in their own buildings.
- On top of that, ESDM is implementing standards and labelling, energy services company (ESCO) sector support, awareness raising activities, and awards (such as the Subroto award) for buildings and other sectors (including some of the sites to be visited on Friday). Minimum energy performance standards (MEPS) were also emphasized as being an important part of building sector decarbonization activities.
- PUPR⁴ has carriage over the regulation of green buildings, as well as national standards (Standar Nasional Indonesia, abbreviated SNI), to encourage energy management in public and commercial buildings, applying smart system, passive design, and the use of Renewable Energy.
- In the building sector, ESDM has a 2030 target to apply energy management in buildings in all sectors, to reach the reduction of 1% per year CO₂ emissions and 17% final energy consumption reduction in 2030. ESDM believe the targets will be achieved, and progress is tracking ahead of schedule.
- ESDM is currently promoting electric vehicles (EVs) and electric bikes, as well as induction stoves, to accelerate electrification, and progressing on multiple fronts including coal phaseout and other measures.

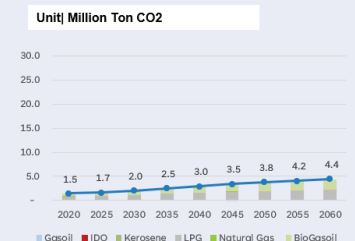
STRATEGIC STEPS IN COMMERCIAL AND RESIDENTIAL BUILDING



RESIDENTIAL SECTOR



COMMERCIAL SECTOR



Policy and Strategy

1. Implementation of **Energy Management and or Green Building** in public and commercial building
2. Implementation of Minimum Energy Performance Standard (MEPS) to encourage the use **high energy efficient technologies appliances in building**
3. Using **smart system** to manage energy usage
4. Implementation of **passive design** in buildings
5. Encouragement to use **Renewable Energy** in buildings toward **Net Zero Energy Buildings (NZE)**

Note:

- There is a gradual phase-in potential of MEPS (AC), the stocks will reach the Best Available Technology (BAT) by 2060, estimated to be 40% from the current level;
- The equipment is assuming MEPS that leads to an average unit consumption at the current BAT level by 2060, estimated to be at 60% of the current level;

Questions and Discussion

What are the measures that ESDM takes to ensure that mandatory requirements are upheld?

- Soon there will be a replacement for the Peraturan Pemerintah (PP)70 regulation, which will include new sectors mandated for EE. The revised PP70 will reduce the consumption threshold for obligated sites from 6000 tonnes to 4000 tonnes per annum, and include more industries; the threshold will be 500 TOE per annum for buildings.

What is the process for increasing the stringency of MEPS?

What are ideas for collaborating with the U.S.?

- These questions were not answered due to time constraints.

Green buildings and building codes in Indonesia

Mochammad Sulton Sahara, Deputy Director of Settlement and Housing Engineering, Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR)

Key presentation points

- Mr Sulton Sahara gave apologies for Ibu Dian Iwarati, for not being able to attend.
- Importance must be placed not just on having building codes and regulations, but on enforcing the system, such that building standards and quality are upheld. National government creates the umbrella regulation, while the implementation is conducted at municipality level (except national defense buildings).
- Indonesia is a big and diffuse country, with 34 provinces. It is in the 'Pacific Ring of Fire' and prone to volcanic eruptions and earthquakes; this must be kept in mind for building sector structural requirements. green building certification cannot be separated from the certificate of occupancy (Sertifikat Laik Fungsi, abbreviated SLF) as a result.

- ‘Green Buildings’ are defined in the *16/2021 Government Regulation concerning Implementation of Building Law Regulations*, and to some extent in PP 15/2021 regarding architecture.
- The Job Creation Act for the construction sector sets out certifications for workers in the industry. Work competence certificates (Sertifikat Kompetensi Kerja, abbreviated SKK), building permits, and certificates of occupancy are all instruments to promote green building principles, in that green buildings must be planned and built by experts, and meet permitting and occupancy requirements that can specify green building parameters and standards. This can apply across the building cycle: from planning, construction, and utilization to demolition.
- The presentation ran through different professional roles in building implementation, and the building permitting system, including PUPR’s Building Information System database: Indonesia has a new information system of OSS (online single submission) for buildings known as Sistem Informasi Manajemen Bangunan Gedung (SIMBG), that can be applied at a decentralized regional/municipality level.
- PUPR also undertakes coaching for local government units (LGUs) and the building sector on the permitting and buildings approvals process.

Questions and Discussion

How can adjustments in national regulations be made at the local level?

- Govt Regulation PP16/2021 stipulate the minimum standards, but regional standards can be set higher.

How can this be integrated with green building rating tool systems, such as Bangunan Gedung Hijau (BGH)?

- Govt Regulation no.6 sits across construction and construction services. These are performance assessments, rather than ratings tools. The authority to undertake ratings assignments lies with the building owner, not with PUPR.

Are there any incentives to meet greener building requirements, including for retrofitting existing buildings?

- Housing ministry has regulations regarding retrofitting, and it is instructive to refer to the Otoritas Jasa Keuangan (OJK) Green Taxonomy also.

Green tropical building solutions for net zero energy

Iwan Prijanto, Chairman, Green Building Council Indonesia (GBCI)

Key presentation points

- GBCI is a part of the World Green Building Council.
- Indonesia’s energy transition plan is heavily based on the supply side. Demand side activity is more difficult, but very important. Need to have a more concerted discussion about energy demand in buildings.
- Overall emissions footprint of Indonesia’s building sector per capita is low, but increasing rapidly. The highest emissions for the building sector in Indonesia are from the residential sector (based on electricity use); as much as 80% of residential emissions come from the R1 (low income residential) building category.

- There are different profiles of electricity usage between low-income, middle-income, and middle-high-income households. The highest demand for low income comes from small electrical appliances; that for middle income and middle high comes from air conditioning (A/C).
- Cooling becomes the dominant share of electricity use in households as income increases. Need to promote non-mechanical cooling and passive solutions such as natural ventilation to achieve adaptive thermal comfort. These points were given a lot of emphasis in the presentation, and their interaction with indoor air quality was also noted.
- The GREENSHIP framework developed by GBCI towards net zero buildings sets out the need for passive design, followed by energy efficiency (EE), followed by renewable energy (RE). There is some integration between the GREENSHIP rating and the building code requirements.
- A couple of examples of net zero buildings in Indonesia were presented, including the TK Pahoa School, and Bedawang Nala, Jimbaran Hijau, Bali.

Questions and Discussion

EE is important in affordable residential settings – is there an awareness program for this? What is government doing about EE in affordable housing?

- Different strategies are needed for different market segments. We should not see the low-income sector as being inefficient, it is just that they cannot respond to the drivers, even where awareness exists. Research on this topic (green building techniques for low-income housing) has largely shown it's not economically viable; it's not easy to tackle this sector, but it remains a priority.
- When income increases, A/C demand increases – this is a lifestyle choice, and we need awareness for people about the impact of their actions.
- PUPR is running monitoring efforts on lower-income households, including rating tools for 1A Class buildings, that will help to define energy performance.

Session 3: Introduction to net zero energy buildings

Moderator: Mark Lister, Asia Clean Energy Partners

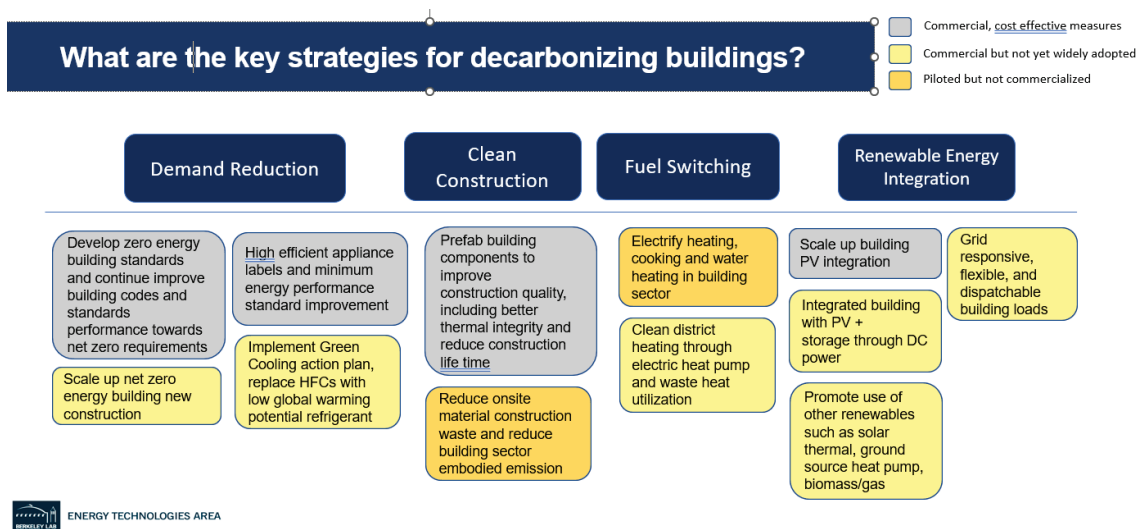
Zero energy building concept and policies

Dr Nan Zhou, NZW Technical Program Manager, Lawrence Berkeley National Lab (LBNL)

Key presentation points

- Indonesia's policy settings for buildings are largely in place, including for specific technologies, building design and so on. How do we scale up adoption of technologies and practices towards net zero buildings? This is currently too slow, in the context of Indonesia's pledge to reach net zero by 2060, across all sectors. Indonesia plans an additional 56 Gigawatts (GW) generation capacity by 2027 (mostly thermal); however, LBNL modeling has indicated that 20 GW of this could be avoided through EE policy alone.
- Strategies for accelerating net zero buildings were discussed, including demand reduction, clean construction, fuel switching, and renewable energy integration.

- The U.S. has applied aggressive building codes, and enabled both rooftop photovoltaic (PV) and residential/commercial retrofits.
- The presentation covered policies, updated codes and standards as useful tools towards net zero, and the use of technologies across passive technology (advanced envelope, natural ventilation, skylights) and active technology (energy efficient lighting, AC controls, efficient appliances).
- A case study from China was presented, with Energy Use Intensity (EUI) of 35 kWh/m², solar PV, and natural ventilation.



Questions and Discussion

Residential sector is the biggest emission—how can zero-carbon concepts and strategies be implemented at the scale of residential buildings?

- Residential is more challenging than commercial; however, many policies and initiatives can still be followed, including target setting, government setting, implement building codes, using passive design, natural ventilation, active designs, or installing solar PV to cover load. A phased approach will be needed for the residential sector, including providing incentives and raising awareness.

Developing the net zero building concept in Indonesia

Totok Sulistiyanto, Low Carbon Building Working Group, MASKEEI

Key presentation points

- Indonesia's emissions are dominated by transportation and industry; however, the building sector has the best opportunities for least-cost for CO₂ emission reduction.
- Many buildings in Jakarta cannot be considered green buildings. Energy used per square meter is increasing in Indonesia, at 2.5% per annum.
- RE can deliver 75% of required emission reductions: first phase to 2030 is to discontinue coal power plan and reduce diesel generation, and RE will generate as much as 57% of requirements by 2035.

- ‘Net zero ready’ buildings need to meet some criteria, including having 10% RE in the building. EE should be expected to deliver on a large share of the requirement.
- Pertamina Tower was discussed as Indonesia’s highest performing green building, and was planned to use geothermal heat for cooling instead of electricity. However, the project was not completed.

Questions and Discussion

What is ‘net zero ready’?

- The spirit is going to 100% net zero building, but the sub-requirements can differ among countries. For example, in Japan net zero buildings must achieve a 70% reduction in energy used.
- Building EUI should certainly be lowered first, to at most 85 kilowatt-hours per square meter (kW/m²) with a percentage of on-site RE.

Does hydrogen as a component have a role in fuel switching for buildings?

- The technology is applicable for transportation right now, but in future will be more competitive for distributed power generation.

Best practices for tropical / retrofitted / green buildings in Indonesia

Kafi’uddin MT, ASHRAE/Buildings EE Working Group, MASKEEI

Key presentation points

- There is a huge potential for energy efficiency in existing buildings – this should demand ~98% of our attention.
- Based on life cycle costs, the construction cost is only about 21% and the remainder is in operation costs. The composition will differ when the buildings use smarter systems, and construction will become a larger component.
- Decarbonizing the Indonesian building sector requires a multi-pronged approach. The main cause of inefficiency in existing buildings are poor design, poor installation, and poor operation and maintenance. The EUI of Indonesian buildings is very high, compared to nearby countries with similar climate such as Singapore.
- Pathways to action are available, but the main obstacle is the mindset of the building management and the top management of the company that owns the buildings. Awareness of energy efficiency needs to be increased, as well as the capacity building from the building management.
- Digitalization and automated software should be maximized to plan the operation and maintenance, including scheduling maintenance to prevent potential losses in performance.

Energy Inefficiency Factors In Building Caused :



Questions and Discussion

How can green building be made more attractive to building owners? Based on experience, when it comes to giving suggestions to client, even where there is a good return on investment (ROI) when it comes to investment, proposals are often not favorably received.

- It is indeed a challenge to convince the client. The most important thing is finding the right person: not only the building owner, but also the engineer, so the potential of energy efficiency can be understood by all personnel.

Is there any experiences in retrofitting passive design, and resultant cost saving?

- Little cost detail was quoted. Grand Indonesia achieved cost savings of up to 20% with passive measures, though this figure includes installing solar PV on building roofs.

Session 4: Fostering clean technology construction investment in Indonesia with advanced technologies and materials

Moderator: Marc LaFrance, U.S. DOE

Cool roofs and walls

Beta Paramita, Research Fellow, Universitas Pendidikan Indonesia (UPI)⁵

Key presentation points and discussion

- The Cool Roofs Indonesia initiative has many projects across the country, and has been active since starting from Tangerang in 2019, with a grant from the Clean Cooling Collaborative.
- 'Cool Roof' is already registered national brand, and is aiming to promote affordable products that can reduce 5-10 °C indoor temperature. Cool walls can further reduce indoor temperature by 2 °C.
- A key limitation is that products cannot be tested/certified in Indonesia, and this must be done in other countries such as the U.S.

Window shading & films

Bipin Shah, President, WinBuild Inc.

Key presentation points and discussion

- Cooling loads are heavily influenced (as much as half) by the quality and design of windows. Heat transfer, solar heat gain, and visibility are key criteria when considering window shading and films.
- Modelling simulations of window performance can be very helpful. Modelling must be suitable for the country, and international models may not apply. In India, these technologies can create a 30-40% energy saving.

⁵ Universitas Pendidikan Indonesia = Indonesia University of Education

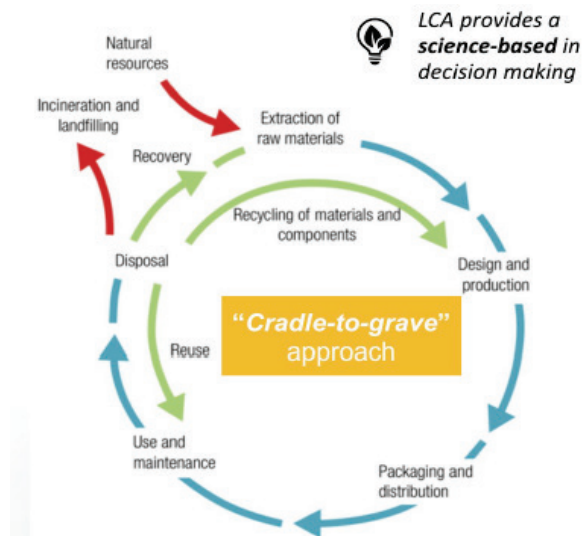
- High performance windows and related products are already manufactured in Indonesia by a limited number of suppliers, but are not affordable (price is 2-3x regular windows), leading to subsequent low demand. Additionally, transportation of glass is not easy – so creating demand for low-E windows will create new business and job opportunities in Indonesia.

Low-embodied-carbon construction materials

Jessica Hanafi, Director, Life Cycle Assessment Indonesia

Key presentation points and discussion

- The construction industry is a major contributor to global carbon emissions, and reducing embodied carbon in construction materials is crucial to achieving a low-carbon economy and constructing low-carbon buildings. However, stakeholders often struggle to measure their carbon footprint and embodied carbon.
- To address this challenge, life cycle assessment (LCA) provides a scientific and comprehensive approach to measuring the embodied carbon of materials and buildings. The approach is quite new in implementation in Indonesia (for the building sector), though more common in the cement industry and for exported steel.
- As building construction involves many materials, information on the embodied carbon of each material is crucial. Conducting a baseline measurement of the embodied carbon through LCA allows manufacturers to understand the embodied carbon in the construction materials and the building.
- The ultimate information is in the form of environmental labelling type III, which presented the result of an LCA into an environmental product declaration (EPD). The EPD provides comparable and verified information, preventing misinformation and enabling individuals to make informed decisions about the carbon footprint of the materials they use.
- LCA also enables the development of a roadmap for reducing embodied carbon and achieving low embodied carbon construction materials. Efforts such as using recycled and locally sourced materials can reduce embodied carbon, but their environmental impact may not always be measured. LCA and EPDs remain important tools for measuring and reducing embodied carbon.



Phase-change material for tropical buildings

Ardiyansyah Yatim, Senior Researcher, University of Indonesia

Key presentation points and discussion

- Air conditioning systems consume around 60% of electric energy in building in tropical regions. The implementation of phase-change material (PCM) in buildings can reduce the energy consumption of air conditioning through either passive or active systems.

- PCM can be incorporated into building materials in walls and roofs to reduce cooling load by increasing the building's thermal inertia. In active system, PCM can store cooling during low-demand period and release it during high-demand (daytime) period, hence reducing power consumption during peak load.
- PCM implementation can save 19-30 kWh/m²/year and contribute toward the decarbonization of the building sector in Indonesia. This will need support from government/regulators, including standardization of requirements in codes and green building ratings.

Session 5: Energy management technology in buildings and its application to Indonesia

Moderator: Muhammad Ali, Public Relations Officer, Building Engineers Association (Banten Chapter)

Air conditioning cooling load calculation

Pulkit Agarwal, General Manager, Carrier Indonesia

Key presentation points and discussion

- Carrier estimates that less than 20% of buildings in Jakarta are using a building management system (BMS), and less than 5% are deploying energy management systems (EnMS). A big challenge in Indonesia is getting the data.
- Carrier has software to help in calculating carbon emission in each city in Indonesia, which can help to inform building designs.
- It is hoped that the insights they can provide can be used to collaborate with academics on certification and other software development.

Control systems / building automation

Dedi Mintaraja, Building Automation Systems Specialist, Schneider Electric Indonesia

Key presentation points and discussion

- The presentation ran through the example of Kallang Pulse, Schneider Electric's new home to 1,200 staff in Singapore.
- Extensive EnMS technology was implemented in the building, across grid-interactive smart devices, sensors, and solar panels. The building is real-time monitoring 5,000 data points from all electrical devices including the use of water and cooling system.
- This allows Schneider to perform analytic services and do predictive maintenance. It not only enables energy efficiency, but also operation & maintenance efficiency
- Schneider has estimated savings in the building of 45% of electricity consumption, equating to 1,253 tons of CO₂ per annum.

Up-to-date lighting technology

Wibawa Jati Kusuma, Director Chief Commercial Operation, Signify Indonesia

Key presentation points and discussion

- Signify claims to be able to improve lighting efficiency by 70% in most existing building applications, using both efficient technologies and centralized management techniques.
- The technology can be remotely controlled in a command center, and can be integrated with multisite buildings.
- Business models offered by Signify include an umbrella contract or ESCO model.
- It remains a challenge to undertake space management and maximize natural light.

Leveraging DC power in buildings for dramatic embodied and operational carbon savings

Derek Cowburn, Founder and CEO, LumenCache

Key presentation points and discussion

- Listened to all the Workshop presentations – summarized the needs he has heard so far as
 - Low income rollout and high growth challenges
 - Disaster recovery, response, safety, and resilience
 - Collaboration of unique needs of 500+ jurisdictions
 - Measured results and lightweight data collection
 - Public awareness, training, collaboration, business
 - Focus on Indonesian solutions for Indonesia
- Introduced his platform LumenCache as an enabler for direct current (DC) systems in households. The biggest challenge remains in training people, who may be reluctant to invest in BMS/EnMS technologies.

Smart buildings and energy management

Yonathan Pangaribuan, Country Head Indonesia, UL Solutions

Key presentation points and discussion

- ‘Smart’ building has no single definition. Different bodies will have different definitions, and there are a range of intangible factors to consider, including for example how safe and comfortable the tenants feel inside the building.
- Created a system to calculate, measure, monetize smart buildings to help increase demand for BMS/EnMS. The aim was for collaboration with U.S. government to promote adoption of technology (but still keeping the technology affordable).
- The implementation can be done in stages—e.g., starting from smart lighting, replacing windows, add rooftop PV, towards overall achievement of net zero energy buildings.

Session 6: Roadmap to net zero buildings in Indonesia

Moderator: Daud Tjondrorahardja, Architect, Green Building and Management Consultant, and Representative, Green Building Council Indonesia

Implementing a national green building code in Indonesia

Muhammad Nur Fajri Alfata, Associate Engineer, Directorate of Housing and Settlement Engineering, PUPR, Indonesia

Key presentation points

- The 'Green Building Code' is listed as part of the NDC Implementation Strategy. There is a process in place to implement it, in the context of Indonesia's overall NDC commitments (greenhouse gas reduction of 31.9% unconditional, 43.2% conditional, by 2030).
- PUPR has developed 8 climate zones across the country that will be used as a foundation to determine standard levels, e.g. for localized passive cooling requirements in the code.
- A broadscale project is underway with PUPR for developing low-carbon apartments, across a range of human and technical factors, and creating standardization of approaches (standard adaptive thermal comfort and standard weather data) for low carbon housing.
- There will be a clear focus on low carbon buildings in the process of moving Indonesia's capital city to Nusantara. The aim is to provide 100% energy sources from RE, 60% energy saving through the building sector, and reaching net zero in 2045 in the new capital.

Need for a Building Energy Research Centre, including testing and certification programs

Beta Paramita, Research Fellow, Universitas Pendidikan Indonesia (UPI)

Key presentation points

- Made an appeal to researchers and other stakeholders about the need for a consolidated buildings research and data agency. UPI is part of building simulation initiatives globally.
- There's already a comprehensive Roadmap for Buildings and Construction Indonesia, 2022 (Ministry of Public Works and Housing).
- Materials use is very significant, if coming at the issues from the point of view of net zero/life cycle/overall decarbonization. There's no real database about materials and their properties, or building data, to inform decisions. A research centre for these low carbon materials can meet this need.
- Certification and testing for materials can also be performed by such a research centre. Also training and competence certification, linked to the regulations PP 16/2021 and PP 14/2021 overseen by PUPR.
- Can also do testing and simulation for a range of products—e.g., solar water heating, PV/diesel hybrids.
- The Center could be formed as an open collaboration with between associations, non-government organizations (NGOs), industry, academia, and government.

Development of U.S.-Indonesia work plan for net zero buildings

Ronnen Levinson, NZW Building Sector Coordinator, LBNL

Key presentation points

- The Net Zero World (NZW) Initiative seeks transformation, affordability, and new capacity in the building sector for Indonesia. Modeling predicts that energy-efficient technologies and designs can lower annual building energy use in Indonesia by 45-50%.
- The Initiative seeks to mobilize the network of 70 National laboratories in the U.S. Lawrence Berkeley National Lab alone employs over 4,000 people, including researchers and their supporting teams.
- The NZWI work program for collaboration with Indonesia responds to Indonesian priorities and was jointly developed with the Indonesian Directorate General of New Renewable Energy and Energy Conservation (Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi, abbreviated EBTKE) and other units of ESDM. At a high level, the work program supports Indonesia through the following ideas and principles:
 - Leveraging resources and building on existing initiatives
 - Convening NZW Building Working Groups to conduct approved collaboration and joint work, including:
 - EE and RE technologies for residential buildings
 - Policy development
 - Building Design
 - NZE building standards and construction guidelines that promote both decarbonization and resilience
 - Pilot net zero energy buildings for government housing
 - Workforce development

Group discussion of work plan

How was the National Laboratories network in the U.S. established, and how is it funded?

- The National Labs structure in the U.S. is very extensive, and setting up something that supports a scientific approach in Indonesia would be welcome.
- There are many ways that funding makes its way to the national labs. From the national labs perspective, there's a competitive process where labs submit tenders and compete. From the DOE perspective, national labs have enormous capability but labour rates are high, and they don't want to fund things that would be best done by the private sector. Private organizations can also fund research by the national labs.

How ready is Indonesia to deliver on a Net Zero Buildings Roadmap?

- Indonesian regulations are complex and overlapping. Many people just try to follow what is mandatory, rather than going further than that. There is little incentive to pursue non-obligatory activities. Business is thinking in terms of both emissions reduction, but also cost reduction.
- A research centre and database would help business to make informed decisions, and tradeoffs. The Ministry of Education has provided a grant to Cool Roofs to map energy consumption.

- University of Bandung has a lot of relevant facilities, and capacity for testing building materials etc, and providing quality assurance.
- University to University collaborations, and also collaboration with the private sector / manufacturers, could be valuable. Need to increase interactions between practitioners to speed knowledge exchange.
- Collaboration with other countries such as India to share what has been researched would be valuable. We don't have to recreate the research; learning from each other can achieve a better and quicker result.
- Any Roadmap should interact with the other existing 'Roadmaps' – by International Energy Agency (IEA) and government ministries, related to overall decarbonization. The Jababeka Net Zero Cluster was also mentioned.

How much will the roadmap take into account socio-economic disparities?

- One of the foundations of NZW is the “just transition”.
- There are similar activity patterns among the majority of Indonesians—can we cluster activities together by energy use? This could then take disparity and social justice into consideration in the roadmap. Different area will have different appropriate approaches, and mapping of the energy consumption patterns of different residential groupings in Indonesia would be valuable.

How is the funding for any Roadmap under NZWI going to work? How can Indonesia get research funding?

- It's difficult to make proposals to the government and get research funding at present.
- Two successful projects in India and South Africa were mentioned as potential models, that were established as private labs and subsequently got significant government funding.

Session 7: Final thoughts about Day 1

Hendro Gunawan, Deputy Director of Energy Conservation, ESDM

Jon Respati, Chairman, Masyarakat Konservasi dan Efisiensi Energi Indonesia (MASKEEI)

Key presentation points

- It is clear that an institutional set-up is needed - defining a committee to take this initiative forward, and better define the Roadmap. This should be our aim for the end of tomorrow's session.
- Residential buildings are important to Indonesia's decarbonization goals, which will only increase with time.
- Concrete actions are needed, and everyone's input to the Workshop's recommendations is encouraged.

Networking reception sponsored by BeCool

Day 2

Session 8: Energy management

Moderator: Herlin Herlianika, Past President, ASHRAE Indonesia Chapter

Energy management aspects in developing high performance buildings

Ignesjz Kemalawarta, Director, PT Sinar Mas Land Group

Key presentation points

- Mr Kemalawarta ran through the high-performance building practices of PT Sinar Mas across microclimate and site optimization, green design and construction, green operational systems, and energy management.
- Green buildings were claimed to be 4-5% more expensive to build, but there are savings as well, across energy consumption, healthier living, thermal comfort, natural light, reduced pollution, and reduced noise.
- Green construction is based on green design, construction supervision and waste management, while green operations were a combination of passive efforts, active technologies, and maintenance operations.
- PT Sinar Mas has achieved 52.4% total energy saving in its Green Office Park 9 building.
- Common mistakes include improper installation, poor maintenance, and improper operation.
- The company has also developed a comprehensive ‘Green Habit’ program to raise occupant awareness on the importance of energy saving behavior.

Best practices in energy management

Slamet Ristono, Building Energy Manager, Grand Indonesia Mall and BCA Tower

Key presentation points

- Grand Indonesia operates according to International Standards Organization (ISO) 50001 – based on the ‘Plan-Do-Check-Act’ framework. Planning and reviewing energy performance indicators can be difficult in Indonesia without data/benchmarks of building performance.
- To be successful, EnMS must be integrated and initiated by management, and led by a designated person internally, who can communicate at all levels.
- They estimate that building energy use is 61% building facilities/owner driven, and 39% tenant driven.
- Regulation should enforce that buildings should have an energy manager as the leader of a ‘green team’, and conduct mandatory energy audits by certified energy auditors. However, there is a distinct lack of energy managers and energy auditors, to implement any regulations.

Smart buildings and energy management

Yonathan Pangaribuan, Country Head Indonesia, UL Solutions

Key presentation points

- UL develops product standards, while UL Solutions carries out inspections for compliance.
- Energy management and the ability to forecast future demand is a complex issue, with multiple variables that need to be considered, such as weather, occupancy, utility rates, maintenance process, consumer awareness, and supply constraints. The linkage between smart buildings, smart communities and smart cities was also discussed.
- Outlined 6 key strategies to improve EE:
 - Improve energy efficiency in buildings
 - Integrate energy management and facility management
 - Increase use of RE
 - Incorporate demand of EV
 - Implement virtual power plants and demand response programs
 - Intensify education and community engagement
- The UL SPIRE program is a world's first comprehensive smart building assessment and rating program, to not only achieve net zero, but also improve the building over time and create value for different stakeholder groups.

Making energy management mandatory

Gigih Udi Atmo, Director of Energy Conservation, Directorate of Energy Conservation, ESDM

Key presentation points

- Reiterated Indonesia's commitments to decarbonization
- Revision of PP70/2009 was focused upon, and the components of the revision. The presentation highlighted the threshold EnMS regulatory requirements placed on sites using >4000 tons of oil equivalent (TOE) annually, which would be set at >500 TOE annually for individual buildings. This requirement on buildings would impact an additional 679 buildings across Indonesia, and reduce an estimated 767,000 tons of annual emissions.

GOVERNMENT REG. DRAFT ON ENERGY CONSERVATION

(Revision on PP 70/2009)

Directions	
1. Energy conservation implementation:	
• energy supply side (MEMR sector)	
• energy use side (transportation, industry, building and household sector)	
2. The obligation for implementing energy conservation through energy management for Energy User consuming energy $\geq$ the set mandatory threshold	
3. Energy conservation implementation by Ministries/Institutions and Regional Government	
4. Minimum Energy Performance Standard (MEPS) and Energy Efficient Labeling on energy use devices	
5. Development and supervision	
6. Incentives and disincentives	
7. Energy Service Company (ESCO)	
8. Funding	
9. Human Resources capacity improvement	
10. Data and information	

4000 TOE/annum	INDUSTRIAL SECTOR
Energy Saving Potential (TOE/Annum)	3,5 Million
Energy Saving Potential (Trilyun Rp/Annum)	42,69
CO2 Emission Reduction (Ton/Annum)	35,03 Million

4000 TOE/annum	TRANSPORTATION SECTOR
Energy Saving Potential (TOE/ Annum)	1,1 Million
Energy Saving Potential (Trilyun Rp/Annum)	11,86
CO2 Emission Reduction (Ton/Annum)	2,5 Million

500 TOE/annum	BUILDING SECTOR
Energy Saving Potential (TOE/Annum)	77,7 Thou.
Energy Saving Potential (Trilyun Rp/Annum)	0,94
CO2 Emission Reduction (Ton/Annum)	767 Thou.

- Quoted the Indonesian National Standards (SNI) for Energy Conservation (EC) in buildings – for lighting (6197:2020), AC systems (6390:2020), and building envelopes (6389:2020), and the Roadmap on appliances MEPS 2021-2024.

Questions and Discussion

How do we get existing buildings/retrofits more engaged with green building practices?

- Participants have heard how EnMS are already mandated for certain size buildings, as well as the benefits from good EnMS practices, including on health, productivity, and property values.
- New buildings are much more on board with green building certifications, compared to existing buildings which have not embraced ratings and green initiatives to the same degree. This hasn't changed all that much over the years. The "illness" is with existing buildings, but new buildings are taking the medicine!
- Before any focus on certification, we need capacity building to develop retrofit projects. Need to engage with building owners to do this, to build awareness. It's difficult to move forward with retrofits where the building doesn't have an energy manager. Important to have capacity building and energy managers, as well as a mandate to do audits.
- Can work to develop a green taxonomy with the banking sector (in collaboration with the banking regulator, OJK) so that the banking sector can also understand the benefits of EE to finance retrofits. Would be good to join efforts on this.
- Need incentives for existing housing/residential; most of the EE approaches are in new buildings. Developers want to see market value from their efforts, on existing buildings. It's not clear how they will benefit at present.

How many buildings in Indonesia are constructed and immediately sold upon completion?

Working in U.S. on early warning sensors and predictive monitoring of performance – are these technologies coming to Indonesia?

How is performance maintained over time, with degradation of systems?

- These questions were raised, but not fully addressed in the discussion.

Session 9: Passive technologies for energy-efficient, resilient, and healthy buildings

Moderator: Tiyyok Prasetyo Adi, International and Government Relations Director, Green Building Council Indonesia

Adaptive thermal comfort in tropical buildings

M. Donny Koerniawan, Professor, Bandung Institute of Technology, Indonesia

Key presentation points

- Ran through findings of studies related to thermal comfort in tropical settings.
- In tropical environments, people are able to adapt to higher temperatures and still be comfortable, and are less sensitive to humidity. So dehumidification technologies are not as important as expected. However, air velocity and overall temperature are more significant. 24 °C was quoted as a comfortable temperature for people in the tropics.
- Comfort affects both reactions and concentration levels, and can evoke adaptation behaviors as well as physiological and psychological response.
- Complex activities are performed better at low temperatures.

Fenestration testing, certification, and ratings

Bipin Shah, President, Winbuild Inc.

Key presentation points

- Window attachments represent a wide range of products that are commonly attached to windows in a house. These products are outdoor-mounted louvered shutters, roller shutters and awnings.
- For the most part, indoor-mounted coverings and window fashions are used more for aesthetic reasons, privacy, and glare control. Dynamic shades also can be applied to the windows. Such attachments can also provide substantial energy savings, but this is not as well understood because their energy impact can be orientation and climate dependent.
- Lawrence Berkeley National Laboratory, supported by the Department of Energy, has significantly expanded the modeling capabilities of energy performance assessment tools. Simulation methods for window attachments now cover a large range of products.
- Fair, accurate, and unbiased product ratings are important for window products, and help to define the characteristics of good energy systems as well as durability. The process broadly stated is to simulate, test, validate, inspect, and label/certify before introducing products to the market.
- While not all approaches used in the U.S. are relevant, there are significant opportunities for Indonesia to learn from U.S. experience in establishing window rating systems. For example, Energy Star and LBNL work on simulation tools that provide consistency and reliability regarding window performance for different products.

The need to strengthen regulations on indoor air quality in buildings

Ahmad Gamal, Director of SMART CITY

Key presentation points

- Poor Indoor Air Quality (IAQ) for buildings is a driver for airborne disease, and came more into focus due to COVID-19. 7 million deaths are caused by air pollution annually. There are 3 main sources of air pollution: physical (T, RH, PM10/PM2.5)⁶, chemical (CO, HCHO, VOC)⁷, and biological (fungi, bacteria, virus, germs).
- We want buildings to be green and energy-efficient, but also to create and provide healthy environments. Regulation and focus on IAQ is a little bit lax in Indonesia.
- The biggest challenge to deploy IAQ standards is actually passive EE measures, and introduction of ventilation and outside air. For areas that are mechanically cooled, it would be better to seal off areas for EE, rather than allow air flows...so this becomes a competing objective.
- There are no safeguards on public buildings in Indonesia, in terms of IAQ. PUPR Regulation 16/2021 doesn't talk about the IAQ levels, only relative humidity. Ministry of Health has some parameters, but these don't integrate well with the energy requirements. There is a legal vacuum in this space, which needs to be addressed.

Cool roof and wall measurement and certification

Ronnen Levinson, NZW Building Sector Coordinator, LBNL

Key presentation points

- Solar-reflective “cool” roofs and walls can provide many benefits to building occupants, communities, power utilities, and the planet. The presentation ran through why materials for cool roofs and walls are effective, including their ability to reflect near-infrared wavelengths of sunlight. Reflective surfaces are not all white; there can be different colors of cool material.
- Cool roofs can lower inside temperatures and reduce heating, ventilation and air conditioning (HVAC) energy that leads to cost savings, as well as minimize the effect of urban heat islands.

Solar-reflective “cool” roofs and walls can provide **many benefits** to building occupants, communities, power utilities, and the planet



HVAC energy and \$ savings



Comfort, health, and safety in heat waves



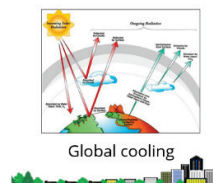
Heat island mitigation



Smog abatement



Peak power demand reduction



Global cooling

⁶ T = temperature; RH = relative humidity ; PM10/PM2.5 = the amount of solid or liquid particulate matter 10/2.5 microns and less in aerodynamic diameter suspended in the atmosphere or in a sample of ambient air.

⁷ CO = carbon monoxide; HCHO = formaldehyde; VOC = volatile organic compounds

- Ratings for building envelopes cover both the ability of a roof or wall to reflect sunlight (“solar reflectance”) and radiate heat (“thermal emittance”), which can be measured as a basis for product ratings. In the United States, solar reflectance and thermal emittance are measured before and after 3 years of natural exposure.
- Solar reflectance (SR) can be measured with a reflectometer, albedometer, or bench spectrophotometer, while thermal emittance (TE) can be measured with an emissometer. The ‘Cool Roof Time Machine’ (American Society for Testing and Materials [ASTM] D7897) can predict 3-year-aged SR and TE in <3 days.
- The Cool Roof Rating Council (<https://coolroofs.org>) is a U.S. organization that maintains an American National Standards Institute (ANSI) standard for rating roofs (ANSI/CRRC S100) and a manual for rating walls (CRRC-2).

Questions and discussion

How can we best address the legal vacuum related to IAQ?

- The IAQ issue is a wakeup call to those considering net zero energy (NZE) buildings - need to advocate for this issue to the government, as Dr Gamal’s organization and ability to give representation for the issue is quite small.
- Writing a letter/paper to PUPR was encouraged by participants.

Have they studied cool roofs in Indonesia? How does the impact of cool roofs compare to the impact of insulation?

- Both insulation and cool roofs and walls are important. A white roof might be cooler by 20 – 30 °C than a black roof on a sunny afternoon.

There are biases in thermal comfort studies, based on the acclimatization of respondents – has this been accounted for?

- This was noted, though the index used has differences for tropical and subtropical peoples.

On windows and higher window ratings, the finance aspect is important – what incentives are there?

- U.S. gives incentives for installing better windows.
- In India, cool roofs have also improved expansion/contraction of buildings and prevented problems like cracking.
- In South Africa, there are examples of where reflective walls reduced the need for public/streetlighting, providing further benefits.

Should application of the IFC EDGE tool be discussed in this Workshop?

- The International Finance Corporation (IFC) EDGE tool was mentioned, and contact is ongoing with IFC, though they were not represented in this meeting.

Mean Radiant Temperature (MRT) is important in defining thermal comfort – what is the approach used in the study?

- MRT had a low impact on the research results. The outside of the buildings will be affected by the MRT, but it was not controlled/measured in the thermal chambers.

Green roofs and roof gardens – is there energy data related to the impacts of this?

- These have been studied in detail; in summary, it's good to look at any roof covering that is not hot, dry and dark!

Session 10: Active technologies for energy-efficient, resilient, and healthy buildings

Moderator: John Budi H. Listijono, Member, MASKEEI Board of Experts

Opportunities and challenges of implementing solar cooling systems in buildings

Arnas Lubis, Researcher, University of Indonesia

Key presentation points

- Universitas Indonesia, collaborating with Kawasaki Thermal Engineering and Waseda University, has installed the first 238 kilowatt (kW) solar cooling system (SCS) for building application in Indonesia, at the university's Manufacturing Center.
- This system uses a single-double-effect absorption chiller; this means that the system can run in single-effect mode when there is enough heat from solar, and run in double-effect mode when there is not enough heat from solar and combined with gas. They also plan to add variable speed drives (VSD) to the system.
- From the typical field test data, the solar cooling system can reduce the primary energy consumption between 11 and 48% compared conventional system with a coefficient of performance (COP) of 3.1. When not use, there is a radiator to release the heat.
- In addition, this study predicts the performance of this system in the six big cities in Indonesia; the total average in one month is 24.2 MWh of electricity energy reduction and 16.6 tons of CO₂ reduction. The system remains expensive, at about 3x the cost of a typical system.

Implementation of various hybrid system technologies for buildings and residential areas

Novagia Adita, Researcher, Tropical Energy Centre, University of Indonesia

Key presentation points

- The Tropical Renewable Energy Center (TREC) is undertaking experiments with grid-connected building technologies.
- The Center has built a nanogrid for a single building or load using electricity from solar PV, battery, or small diesel generation.
- The facility runs as 220 V alternating current (AC) and/or 230 V DC (dual power nanogrid technology). DC voltage has been found to be more efficient and stable for appliances.
- A 3 kilowatt (peak) (kWp) PV array, 5 kW fuel-cell and 19.2 kWh battery can be switched automatically or manually.
- Could be implemented in a residential building as the capacity is small.

Integrating passive and active building technologies

M. Donny Koerniawan, Professor, Bandung Institute of Technology, Indonesia

Key presentation points

- Reiterated the importance of being clear about ‘net zero building’ definitions, quoting the U.S. DOE definition.
- Made the claim that an inefficient building, or one that is uncomfortably warm for example, cannot be designated as net zero. It needs to be efficient first, and in compliance with comfort, health and safety standards.
- Building performance in Indonesia is still difficult to standardize, and there remains no clear definition of NZE buildings between stakeholders, especially regulators (PUPR, ESDM, etc).

Modular DC power and control benefits across all economic strata

Derek Cowburn, Founder and CEO, LumenCache

Key presentation points

- LumenCache is focused on DC lighting for homes – which is easier to install, removes the cost of copper wire and the need for AC wiring, and reduces the cost of componentry/transformers. The company also has a platform for energy management at the household level.
- Other advantages include that DC lighting and components are much less expensive, and use much less materials, as well as a range of other factors around longevity of equipment, integration of solar PV, and the ability to incorporate sensor systems.
- This approach is nascent in Indonesia, though the potential is huge.

Questions and discussion

Has LumenCache considered energy storage connected to the solar collectors? Is equipment all in DC or some in AC?

- All loads, especially small devices are using DC. Power factor is a big loss in buildings, which is an artefact of AC power, and automatic power factor correction is another benefit of using DC.
- One of the last holdouts of conversion to DC is ceiling fans. Cost of DC controllers has come down significantly.

Indonesia needs to further explore ideas like cogeneration. What were some of the additional considerations for solar cooling? Can waste-to-energy be used alongside solar for cooling – e.g., at Gardens by the Bay in Singapore?

- There’s a lack of detailed knowledge about such systems in Indonesia.
- To address humidity, can combine liquid dehumidification with fan coil units to reduce air moisture content. Another solution is a dedicated outdoor air system (DOAS), to control combining a convention A/C and passive system.
- Usually there is limited area for solar collectors to support such a system. Can potentially use phase change materials for thermal storage.

Session 11: Net zero energy building policies

Moderator: Muhammad Ery Wijaya, Indonesia Country Manager, Global Buildings Performance Network

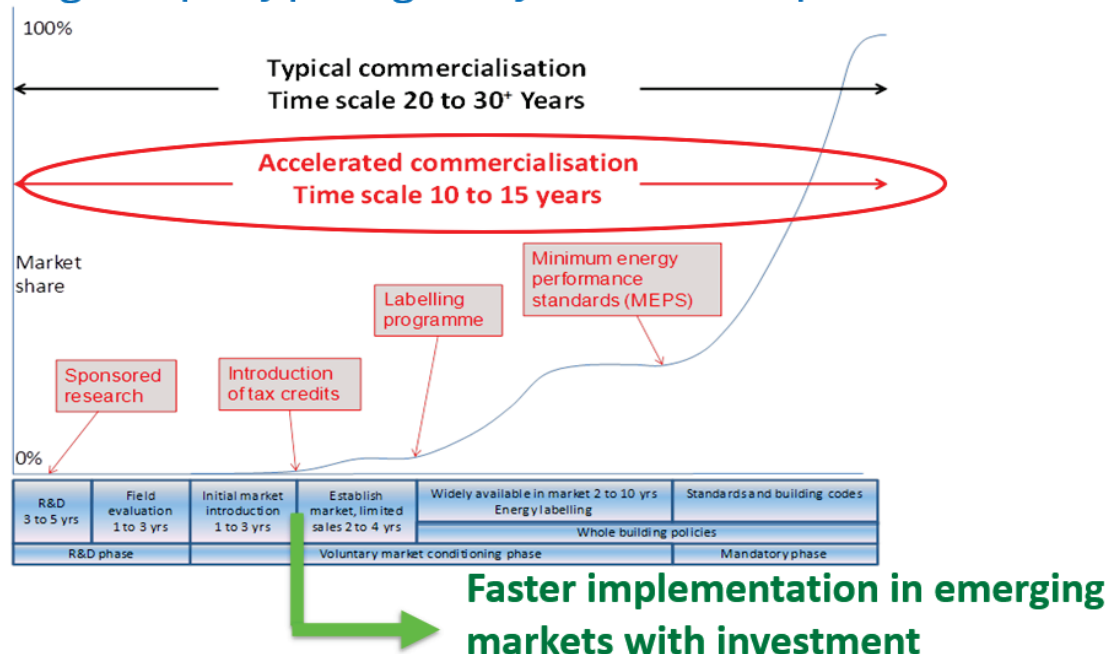
Overview of net zero energy building policies

Marc LaFrance, NZW Buildings Lead, U.S. DOE Building Technologies Office (BTO)

Key presentation points

- This talk presented the macro context of the major policy mechanisms that will help move the building sector towards zero energy buildings, and put in context the various policy mechanism such as research and development (R&D), voluntary and mandatory, while showing how investing in voluntary programs can increase the likelihood for impactful, effective mandatory building codes and minimum energy performance standards (MEPS).
- The entire process from R&D to implementation could take 20-30 years, but it is the role of policy to incentivize actions and compress this timeline. As an example, constant MEPS updates have reduced energy consumption up to 75% in the last 50 years in the U.S. Having mandatory programs can encourage innovation in industries.
- Product labeling programs were discussed along with examples of the U.S. MEPS program success, and the need to have high quality ratings and labels to ensure that products meet the intended performance.
- It is critical to have a long term goal for building materials manufacturing, to be maximized locally.

Integrated policy packages – systems and components



Whole-building rating and certification programs

Ashu Dehadani / Nagesh Gupta, Associate Director - Technical Development / Sr. Manager - Technical Solutions, Green Business Certification Inc. (GBCI) India

Key presentation points

- The presentation focused on the role of certification systems in accelerating low carbon building development, and discussed the relevance, robustness, and flexibility of the rating systems in ensuring structured engagement with the projects on their net zero journey.
- Certification programs contribute three major planks to acceleration of net zero buildings: (1) providing a robust and comprehensive framework for action; (2) providing an educational and capacity building framework; and (3) a scalable and dynamic framework to allow comparisons over places and over time.
- Examples driving market transformation from different parts of the world were presented, including types of LEED (Leadership in Energy and Environmental Design) certified buildings, communities, and cities that have deployed certification systems.
- LEED has 21 adaptations; the 'LEED Zero' program (Zero Carbon, Zero Energy, Zero Water, Zero Waste) is a relevant tool to achieve net zero carbon balance by projects.

Minimum efficiency performance standards for buildings and equipment

Ronnen Levinson, NZW Building Sector Coordinator, LBNL

Key presentation points

- Minimum efficiency performance standards (MEPS) will typically cover household appliances, commercial and industrial products, and also lighting and are important drivers of building energy performance.
- Indonesia issued MEPS for lighting and air conditioning (A/C) in 2011-15, 2021 for refrigerators, 2022 for other appliances.
- Local manufacture of energy efficient A/C is less prevalent than in other ASEAN countries.
- There are potential savings of 20 GW by 2030 through electrical efficiency with the biggest demand reduction by far coming from more efficient air conditioners.
- There is room for improvement to increase the manufacturing of energy efficient A/C with lower prices, and to continue harmonizing with ASEAN MEPS, at increasing stringency.

Net zero energy building financing

Yosef Lim, Senior Regional Manager, G-Energy Global Pte Ltd, Singapore

Key presentation points

- G-Energy is an accredited ESCO company that has achieved savings of over \$450 million for its clients.
- Cooling systems can consume 60% of energy consumptions in tropical buildings.
- Singapore has a direction on Super Low Energy (SLE) Buildings. SLE is defined as at least 60% energy savings. By 2030, 80% of buildings must be green buildings, meaning that 80% of new developments must be SLE, and achieve an 80% improvement in energy efficiency. Singapore requires also an energy audit every 3 years.

- A challenge in Singapore is the space to install onsite or offsite RE; there is a strong imperative to reduce energy/undertake energy efficiency before RE.
- A case study from Singapore was presented, with the focus area being chiller plant, air handling units, solar PV and lighting. Savings to overall energy consumption totaled \$15 million over 20 years, including 9% from chiller and air handling, 4% from lighting, and 57% from solar PV.

Questions and Discussion

Do green building certifications calculate embodied emissions in building materials and the construction process? How is this measured in certifications?

- There is a systematic process to calculate the carbon emission in building materials. Information should be provided from the manufacturers of the building materials, including analysis on hazardous materials.

Which centralized air handling system is the best to achieve net zero?

- A chiller system is most applicable if the cooling load is 400 refrigeration tons (RT) and above. The Singapore Government's recommendation is that if the building cooling load <500 RT, a decentralized system should be used. A water cooled chiller system is more efficient than an air cooled chiller system.

Session 12: Technical and workforce development opportunity and gap analysis

Moderator: Ronnen Levinson, LBNL

Group discussion of technical and workforce development opportunities and gaps

The Workshop concluded with an open discussion to identify a number of areas in which the U.S. and Indonesia might productively take collaboration forward under the Net Zero World Initiative, including training and capacity building; pilot projects for low-income housing; support for rating and certification schemes; and the possibility of establishing a building research centre for knowledge exchange, information databases and performing product testing, bolstered by access to the expertise of the U.S. National Laboratories network.

Each table was asked to briefly discuss and present its ideas for technical and workforce development opportunities, based on a list of suggested collaboration areas. The summary of ideas contributed by each table was as follows:

Table 1

- Most important aspect is ensuring implementation. Regulation and standards are already in place; government must continue to make it mandatory, and also strengthen monitoring systems.

Table 2

- Policy development for the ESCO business model, as ESCO regulation was established in 2016 but lapsed in 2019, and activity remains nascent.

- There is a market failure of ESCOs in Indonesia. Better understanding and training on project risks, project monitoring, financing and implementation of ESCO projects in Indonesia is necessary.

Table 3

- Need better disaggregated data on residential electricity consumption, as it is the highest demand of building sector electricity. There is very minimal residential consumption profiling data, which could be a focus for a building research center, along with a building performance database.

Table 4

- Concentrate on one type of buildings (such as low-income residential buildings) and make good examples/pilots of net zero performance.

Table 5

- Priorities are for training and capacity building, pilot projects for low income housing and existing buildings, and innovative financing models.

Table 6

- Create an oversight board to control the progress of collaboration of net zero energy building activities and initiatives.
- Improve collaboration with universities and research centers.

Table 7

- Make a collaboration to close knowledge gaps, focused on a database of energy consumption and future opportunities for performance improvement.

Table 8

- Green procurement:
 - (1) Green building is expensive, material is not available in Indonesia; there is a large impact and carbon footprint of logistics.
 - (2) Suppliers in green materials are limited, and local companies could contribute further.

Table 9

- Create agents of change in the education system at the college level, and upgrade curricula.
- Establish a department for new low-carbon housing development.
- Create an (open source) database for building data and R&D.

Table 10

- Follow the workshop by establishing an institutional structure and working groups.

Table 11

- Create incentives, licensing, educational curricula, and freely available building tools and information.

Session 13: Final thoughts about Day 2

Day 2 closing remarks

Jon Respati, Chairman, Masyarakat Konservasi dan Efisiensi Energi Indonesia (MASKEEI)

Hendro Gunawan, Deputy Director of Energy Conservation, ESDM, Indonesia

In closing the Workshop, ESDM and MASKEEI thanked all participants for their enthusiastic contributions over both days, and underscored the importance of stakeholder engagement to any collaboration arising with the U.S. Government under the Net Zero World Initiative.

4. Conclusions: Potential areas of building sector collaboration between the U.S. and Indonesia under the NZWI

From the foregoing discussions, stakeholder feedback and input from both U.S. and Indonesian counterparts, the Workshop concluded with recommendations that could be taken forward under the Net Zero World Initiative. These can be summarized as follows.

1. **Establishing a Road Map for Net Zero Buildings 2024 – 2030 (and 2031 – 2060)**, as an overarching direction for the building sector in the context of economy wide commitments to climate and net zero action through nationally determined contributions (NDCs) under the Paris Agreement on Climate Change, and other national strategies.
2. **Establishing a national, collaborative Research Center** for buildings-related technology and best practices, with a workplan incorporating
 - Improved knowledge sharing and exchange
 - Product information database and studies on low carbon materials
 - Technology impact modeling (for building construction)
 - Benchmarking and retrofit opportunity identification (through studies and surveys)
3. **Training and capacity building** programs – both training and “train the trainer” (teacher training) programs related to:
 - Codes and standards for Net Zero Energy Buildings
 - Certified green/net zero energy building professionals
 - Energy auditors (with a focus on Investment Grade Auditors)
 - Certified measurement and verification (M&V) professionals
 - Program monitoring and evaluation (ME) professionals
4. **Innovative financing** for net zero energy buildings, including assistance in ESCO industry development with a focus on workable financing models to be implemented for state-owned assets
5. Net zero and passive design **pilot projects for low-income residential buildings**
6. **Green procurement** programs (e.g. Buy-Clean for low carbon materials)
7. Strengthening Indonesia’s **product testing capabilities**
8. **Certification and ratings** development and support, for alignment of product and building certifications and ratings with international best practice, and provision of tools and resources.

A clear recommendation sitting behind these activities was identifying the need for an ongoing Working Group or institutional arrangement to take the recommendations forward. Establishment of such a Group can be pursued by the Net Zero World Initiative as a first priority and outcome of this Workshop.

Annex A – Workshop Agenda

Day 1 (Wed 22 Feb): General Presentations, Panel Discussions, & Roadmapping

Time	Topic	Presenter	Role & Organization
8:15 - 8:45	Registration		
Session 1: Introduction to workshop			
Moderator: Nan Zhou, Lawrence Berkeley National Laboratory (LBNL)			
8:45 - 8:50	Moderator’s overview [5 min]		
8:50 - 9:00	Welcome and introduction to Day 1 program [10 min]	Dadan Kusdiana (by video link)	Director General of New, Renewable Energy, and Energy Conservation, Kementerian Energi dan Sumber Daya Mineral (ESDM), Indonesia
9:00 - 9:10	Net Zero World (NZW) partnership [10 min]	Maria DiGiulian	Senior Policy Advisor, U.S. Department of Energy (DOE) International Affairs Office
9:10 - 9:20	U.S. perspectives on Net Zero World opportunities [10 min]	Marc LaFrance	NZW Buildings Lead, U.S. DOE Building Technologies Office (BTO)
Session 2: Energy conservation and green buildings in Indonesia			
Moderator: Jon Respati, Chairman, Masyarakat Konservasi dan Efisiensi Energi Indonesia (MASKEEI)			
9:20 - 9:25	Moderator’s overview [5 min]		
9:25 - 9:45	Improving energy conservation in Indonesia’s building sector [15-min presentation + 5-min Q&A]	Hendro Gunawan	Deputy Director of Energy Conservation, ESDM, Indonesia
9:45 - 10:05	Green buildings and building codes in Indonesia [15-min presentation + 5-min Q&A]	Mochammad Sulton Sahara	Deputy Director of Settlement and Housing Engineering, Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR)

Time	Topic	Presenter	Role & Organization
10:05 - 10:25	Green tropical building solutions for net zero energy [15-min presentation + 5-min Q&A]	Iwan Prijanto	Chairman, Green Building Council Indonesia
10:25 - 10:40	Morning break		
Session 3: Introduction to net zero energy buildings			
Moderator: Mark Lister, Asia Clean Energy Partners			
10:40 - 10:45	Moderator's overview [5 min]		
10:45 - 11:05	Zero energy building concept and policies [15-min presentation + 5-min Q&A]	Nan Zhou	NZW Technical Program Manager, Lawrence Berkeley National Lab (LBNL)
11:05 - 11:25	Developing the net zero building concept in Indonesia [15-min presentation + 5-min Q&A]	Totok Sulistiyanto	Low Carbon Building Working Group, MASKEEI
11:25 - 11:45	Best practices for tropical / retrofitted / green buildings in Indonesia [15-min presentation + 5-min Q&A]	Kafi'uddin MT	ASHRAE/Buildings EE Working Group, MASKEEI
11:45 - 11:50	Recap of morning program	Mark Lister	Co-CEO, CFO, and COO, Asia Clean Energy Partners
11:50 - 13:00	Working lunch		
Session 4: Fostering clean technology construction investment in Indonesia with advanced technologies and materials (panel discussion)			
Moderator: Marc LaFrance, U.S. DOE			
13:00 - 13:05	Moderator's overview [5 min]		
13:05 - 13:20	Cool roofs and walls [3 min]	Beta Paramita	Research Fellow, Universitas Pendidikan Indonesia (UPI)
	Window shading & films [3 min]	Bipin Shah	President, WinBuild Inc.
	Low-embodied-carbon construction materials [3 min]	Jessica Hanafi	Director, Life Cycle Assessment Indonesia
	Phase change material for tropical buildings [3 min]	Ardiyansyah Yatim	Senior Researcher, University of Indonesia
13:20 - 13:50	Panel discussion [30 min]		

Time	Topic	Presenter	Role & Organization
Session 5: Energy management technology in buildings and its application to Indonesia (panel discussion)			
Moderator: Muhammad Ali, Public Relations Officer, Building Engineers Association (Banten Chapter)			
13:50 - 13:55	Moderator's overview [5 min]		
13:55 - 14:10	Air conditioning cooling load calculation [3 min]	Pulkit Agarwal	General Manager, Carrier Indonesia
	Control systems / building automation [3 min]	Dedi Mintaraja	Building Automation Systems Specialist, Schneider Electric Indonesia
	Up-to-date lighting technology [3 min]	Wibawa Jati Kusuma	Director Chief Commercial Operation, Signify Indonesia
	Leveraging DC power in buildings for dramatic embodied and operational carbon savings [3 min]	Derek Cowburn	Founder and CEO, LumenCache
	Smart buildings and energy management [3 min]	Yonathan Pangaribuan	Country Head Indonesia, UL Solutions
14:10 - 14:40	Panel discussion [30 min]		
14:40 - 14:55	Afternoon break		
Session 6: Roadmap to net zero buildings in Indonesia (group discussion)			
Moderator: Daud Tjondrorahardja, Architect, Green Building and Management Consultant, and Representative, Green Building Council Indonesia			
14:55 - 15:00	Moderator's overview [5 min]		
15:00 - 15:10	Implementing a national green building code in Indonesia [10 min]	Muhammad Nur Fajri Alfata	Associate Engineer, Directorate of Housing and Settlement Engineering, PUPR, Indonesia
15:10 - 15:20	Need for Building Energy Research Centre, including testing and certification programs [10 min]	Beta Paramita	Research Fellow, UPI
15:20 - 15:30	Group discussion of both topics [10 min]		
15:30 - 15:40	Development of U.S.-Indonesia work plan for net zero buildings [10 min]	Ronnen Levinson	NZW Building Sector Coordinator, LBNL

Time	Topic	Presenter	Role & Organization
15:40 - 16:20	Group discussion of work plan [40 min]		
Session 7: Final thoughts about Day 1			
16:20 – 16:30	Day 1 closing remarks [10 min]	Hendro Gunawan	Deputy Director of Energy Conservation, ESDM
16:30 - 18:00	Networking reception sponsored by BeCool		

Day 2 (Thu 23 Feb): Technical Program Focusing on Building Energy Technology and Workforce Development

Time	Topic	Presenter	Organization
8:15 - 8:45	Registration		
8:45 - 8:55	Overview of Day 2 program	Nan Zhou	NZW Technical Program Manager, LBNL
Session 8: Energy management			
Moderator: Herlin Herlianika, Past President, ASHRAE Indonesia Chapter			
8:55 - 9:00	Moderator's overview [5 min]		
9:00 - 9:15	Making energy management mandatory [15 min]	Gigih Udi Atmo	Director of Energy Conservation, Directorate of Energy Conservation, ESDM
9:15 - 9:30	Energy management aspects in developing high performance buildings [15 min]	Ignesjz Kemalawarta	Director, PT Sinar Mas Land Group
9:30 - 9:45	Best practices in energy management [15 min]	Slamet Ristono	Building Energy Manager, Grand Indonesia Mall and BCA Tower
9:45 - 10:00	Smart buildings and energy management [15 min]	Yonathan Pangaribuan	Country Head Indonesia, UL Solutions
10:00 - 10:15	Q&A [15 min]		
10:25 - 10:40	Morning break		
Session 9: Passive technologies for energy-efficient, resilient, and healthy buildings			
Moderator: Tiyyok Prasetyo Adi, International and Government Relations Director, Green Building Council Indonesia			
10:40 - 10:45	Moderator's overview [5 min]		

Time	Topic	Presenter	Organization
10:45 - 11:00	Adaptive thermal comfort in tropical buildings [15 min]	M. Donny Koerniawan	Professor, Bandung Institute of Technology, Indonesia
11:00 - 11:15	Fenestration testing, certification, and ratings [15 min]	Bipin Shah	President, Winbuild Inc.
11:15 – 11:30	The need to strengthen regulations on indoor air quality in buildings [15 min]	Dr Ahmad Gamal	Director of SMART CITY
11:30 - 11:45	Cool roof and wall measurement and certification [15 min]	Ronnen Levinson	NZW Building Sector Coordinator, LBNL
11:45 - 12:00	Q&A [15 min]		
12:00 - 13:00	Working Lunch		
Session 10: Active technologies for energy-efficient, resilient, and healthy buildings			
Moderator: John Budi H. Listijono, Member, MASKEEI Board of Experts			
13:00 - 13:05	Moderator’s overview [5 min]		
13:05 - 13:20	Opportunities and challenges of implementing solar cooling systems in buildings [15 min]	Arnas Lubis	Researcher, University of Indonesia
13:20 - 13:35	Implementation of various hybrid system technologies for buildings and residential areas [15 min]	Novagia Adita	Researcher, Tropical Energy Centre, University of Indonesia
13:35 - 13:50	Integrating passive and active building technologies [15 min]	M. Donny Koerniawan	Member, High Performance Buildings and Cities Working Group, MASKEEI
13:50 - 14:05	Modular DC power and control benefits across all economic strata [15 min]	Derek Cowburn	Founder and CEO, LumenCache
14:05 - 14:20	Q&A [15 min]		
14:20 - 14:35	Afternoon break		
Session 11: Net zero energy building policies			
Moderator: Muhammad Ery Wijaya, Indonesia Country Manager, Global Buildings Performance Network			
14:35 - 14:40	Moderator’s overview [5 min]		

Time	Topic	Presenter	Organization
14:40 - 14:55	Overview of net zero energy building policies [15 min]	Marc LaFrance	NZW Buildings Lead, U.S. DOE BTO
14:55 - 15:10	Whole-building rating and certification programs [15 min]	Ashu Dehadani / Nagesh Gupta	Associate Director - Technical Development / Sr. Manager - Technical Solutions, Green Business Certification Inc. (GBCI) India
15:10 - 15:25	Minimum efficiency performance standards for buildings and equipment [15 min]	Ronnen Levinson	NZW Building Sector Coordinator, LBNL
15:25 - 15:40	Net zero energy building financing [15 min]	Yosef Lim	Senior Regional Manager, G-Energy Global Pte Ltd, Singapore
15:40 - 15:55	Q&A [15 min]		
Session 12: Technical and workforce development opportunity and gap analysis			
Moderator: Ronnen Levinson, LBNL			
15:55 - 16:00	Moderator's overview [5 min]		
16:00 - 16:15	Group discussion of technical opportunities and gaps [15 min]		
16:15 - 16:30	Group discussion of workforce development opportunities and gaps [15 min]		
Session 13: Final thoughts about Day 2			
16:30 - 16:40	Day 2 closing remarks [10 min]	Hendro Gunawan / Jon Respati	Deputy Director of Energy Conservation, ESDM / Chairman, MASKEI

Day 3 (Fri 24 Feb): Visit low-energy, high-performance buildings

BSD CITY, South Tangerang, Banten, Indonesia

Bumi Serpong Damai Urban Center (BSD City), South Tangerang (25 km southwest of Jakarta) in the Province of Banten, is one of the most ambitious urban planning developments in Indonesia. The project encompasses modern housing, business and commercial properties with a total area of approximately 6,000 hectares which has been developed over more than 30 years by Sinar Mas Group, one of the leading developers in South East Asia. The currently developed area represents around 50% of the total planned area, and the development continues at high speed applying the latest technology and a vision for sustainability.

BSD City is designed around the people who will live, work and play here. The Project has led to a significant growth of population in South Tangerang and it has brought high economic growth in Banten Province, which was one of the least developed areas in Indonesia until the beginning of this century.

There are many buildings and facilities in BSD City that are of interest to visitors, but due to the limited time available we will only visit two to three sites as outlined below.

Sinar Mas Land Plaza BSD City



BSD Green Office Park is Indonesia's first green office in a district encompassing a total area of approximately 25 hectares. The district offers a park-like ambience and is intended to be the location of 11 multi-storey buildings. It is also the home location to Sinar Mas Land Headquarters.

Currently Sinar Mas Land owns 5 Green Mark Certified buildings, of which Sinar Mas Land Plaza is one. The buildings received the Subroto Energy Efficiency Award (2021) and the ASEAN Energy Award (2021).

Grha Unilever – the Head Office of PT Unilever Tbk, the largest consumer goods producer in Indonesia.



Grha Unilever is a 5-storey office building located in the Green Office Park BSD complex. This building was built combining Unilever's image as a global company with Indonesian cultural richness. The high-tech design applies sustainable principles with comprehensive active and passive features. This building was built in 2015 and completed in 2017 and is used as the Head Office of PT. Unilever Indonesia. Grha Unilever has successfully achieved Platinum Certification under the New Building category from the Green Building Council Indonesia, and is also a recipient of the SUBROTO Energy Efficiency Award (2019) and the ASEAN Energy Award (2022).

Multimedia Nusantara University – A Leading National University in ICT and Entrepreneurship



The Multimedia Nusantara University (UMN) building won the 1st Runner Up Energy Efficient Building award for the Tropical Building category at the ASEAN Energy Award in Bangkok, Thailand (2019) and the Subroto Energy Efficiency Award (2018) in the New Building category given by the Ministry of Energy and Mineral Resources of the Republic of Indonesia.

Proposed Schedule of Visits

08.00 – 08.15	Participants assemble in the Hotel lobby, JHL Solitaire
08.20 – 08.50	Depart by bus from Hotel to Green Office Park, Sinar Mas Land Arrive at the Marketing Office Sinar Mas Land Building
08.55 - 09 .35	Tour Green Building Offices, Sinar Mas Land (SML)
09.35 – 09.45	Leave Sinar Mas Land Building for adjacent Grha Unilever (walking)
09.45 – 10.30	Tour Grha Unilever Building
10.35 – 11.05	Leave Grha Unilever for Multimedia Nusantara University (MNU)
11.05 – 11.35	Tour the MNU Building
11.40 – 11.50	Leave MNU returning to JHL Solitaire Arrive at the Hotel—end of the tour

Link for Maps from JHL Solitaire to Site Visit Objects: <https://bit.ly/3Y2MU6S>

Annex B – List of Workshop Registrants

Name	Job Title	Organization Name	Sector	Email Address	Country
Bipin Shah	President	WinBuild Inc	Consultant	winbuild.usa@gmail.com	United States
Marc LaFrance	Building Technology Office International Lead	U.S. Department of Energy	Government	marc.lafrance@ee.doe.gov	United States
Derek Cowburn	CEO	LumenCache	Industry	dcowburn@lumencache.com	United States
Ronnen Levinson	Staff Scientist	Lawrence Berkeley National Laboratory	National Laboratory	RMLevinson@LBL.gov	United States
Nan Zhou	NZW Technical Program Manager	Lawrence Berkeley National Lab	National Laboratory	NZHOU@lbl.gov	United States
Rowena Uday Rawte	Global Head of Sustainability	HY M&E Consultancy Services Pte Ltd	Green Building Organization	rowena@hy-me.com.sg	Singapore
Janu Sah	Student	Pulchowk engineering campus	Academia	sahjaanu111@gmail.com	Nepal
Hamidah Rosidanti Susilatun	Lecturer	Politeknik STIA LAN Jakarta	Academia	hamidah.susilatun@gmail.com	Indonesia
Haipan Salam	Lecturer	Universitas Pendidikan Indonesia	Academia	haipan@upi.edu	Indonesia
Herlin Hertianika	President Elect	ASHRAE	Association	hherlianika@gmail.com	Indonesia
Theresia Astrid Wulaningsari	Architect	IAI JAKARTA	Building Architect/Engineer	theresia.astrid.w@gmail.com	Indonesia
Jessica Agusna	Green Initiative Department	Sinarmasland	Building Architect/Engineer	jessica.agusna@sinarmasland.com	Indonesia
Budi Pratikno	Engineer	Unilever	Building Architect/Engineer	budi.pratikno@unilever.com	Indonesia
Widhi Atmaka	Researcher	BRIN	Government	widhiatmaka33@gmail.com	Indonesia
Danika Akiko	Rating Development	Green Building Council Indonesia	Green Building Organization	akiko@gbcindonesia.org	Indonesia
Wibawa Kusuma	Director Chief Commercial Operation	PT. SIGNIFY COMMERCIAL INDONESIA	Industry	youlanda.kenyo.prima@signify.com	Indonesia
Fernando S	owner	PT. BKS	Contractor	fernandoacr2017@gmail.com	Indonesia
Bayu Wisnu Aji	Business Development	MASKEEI	Non-Governmental Organization (NGO)	bayuwaji@yahoo.com	Indonesia
Yaseri D Apritasari	Researcher & Lecturer	Podomoro University	Academia	yaseri.apritasari@podomorouniversity.ac.id	Indonesia
Try Ramadhan	Lecturer	Universitas Pendidikan Indonesia	Academia	tryramadhan@upi.edu	Indonesia
TITUS KURNIAWAN	Lecturer	Universitas Pembangunan Jaya	Academia	titus.kurniawan@upj.ac.id	Indonesia

Name	Job Title	Organization Name	Sector	Email Address	Country
Surya Gunanta Tarigan	Lecturer	Universitas Pembangunan Jaya	Academia	surya.gunanta@upj.ac.id	Indonesia
SUGINI SUGINI	PROFESSOR OF ARCHITECTURE DEPARTMENT	UNIVERSITAS ISLAM INDONESIA	Academia	sugini@uii.ac.id	Indonesia
Rizki Siregar	Lecturer	Universitas Multimedia Nusantara	Academia	siregar.rizki@gmail.com	Indonesia
Ratna Safitri	Lecturer	Universitas Pembangunan Jaya	Academia	ratna.safitri@upj.ac.id	Indonesia
Rahmi Andarini	Lecturer	Universitas Multimedia Nusantara	Academia	rahmi.andarini@lecturer.umn.ac.id	Indonesia
Rahma Purisari	Lecturer	Universitas Pembangunan Jaya	Academia	rahma.purisari@upj.ac.id	Indonesia
Prabang Setyono	Head Department of Environmental Study	Universitas Sebelas Maret	Academia	prabangsetyono@gmail.com	Indonesia
Muhammad Idrus Alhamid	Lecture and researcher	Universitas Indonesia	Academia	mamak@eng.ui.ac.id	Indonesia
Mochamad Donny	Lecturer/Researcher	Department of Architecture ITB Bandung, Indonesia	Academia	donnykoer@gmail.com	Indonesia
Maria Prihandrijanti	Lecturer & Researcher	Universitas Agung Podomoro	Academia	maria.prihandrijanti@podomoro.university.ac.id	Indonesia
Khalid Abdul Mannan	Lecturer	Universitas Pembangunan Jaya	Academia	khalid.abdul@upj.ac.id	Indonesia
Issa Tafriidj	Lecturer	Universitas Pembangunan Jaya	Academia	issa.samichat@upj.ac.id	Indonesia
Ferry Firmawan	Lecturer	USM	Academia	doktorfirmawan@gmail.com	Indonesia
Farhan Hidayat	Fresh Graduate	University of Indonesia	Academia	appang100@gmail.com	Indonesia
Beta Paramita	Asst Professor	Universitas Pendidikan Indonesia (UPI)	Academia	betaparamita@upi.edu	Indonesia
Astrid Hapsari Rahardjo	Academic lecturer in architecture	Universitas Tanri Abeng	Academia	astrid.rahardjo@tau.ac.id	Indonesia
Arnas Lubis	Lecturer and Researcher	Universitas Indonesia	Academia	arnas@eng.ui.ac.id	Indonesia
Ardiansyah Yatim	Professor	Universitas Indonesia	Academia	ardiansyah@eng.ui.ac.id	Indonesia
Apri Wiyono	Lecturer	Universitas Pendidikan Indonesia	Academia	apri.wiyono@upi.edu	Indonesia
Usep Surahman	Researcher	Universitas Pendidikan Indonesia	Building Architect/Engineer	usep@upi.edu	Indonesia
Tasqya Syamsina	Staff Copywriter	Tia	Building Architect/Engineer	tasqyasamsina05@gmail.com	Indonesia
Slamet Ristono	General Manager Engineering & Maintenance	PT. Grand Indonesia	Building Architect/Engineer	slamet.ristono@grand-indonesia.com	Indonesia
Satrio Prakoso	Founder & Director	Sustainahaus	Building Architect/Engineer	satrio.prakoso@sustainahaus.com	Indonesia
Ryan Surya Abdi	Architect Staff	PT. Bina Karya (Persero)	Building Architect/Engineer	ryansuryaabdi@gmail.com	Indonesia
Rio Pambudi	Coordinator Power Plant	PT. Grand Indonesia	Building Architect/Engineer	rio.pambudi@grand-indonesia.com	Indonesia
Rana Yusuf Nasir	Vice Chairman of MASKEE Board of Experts	MASKEE (Indonesia Society for Conservation & Efficiency Energy)	Building Architect/Engineer	ranayusuf.nasir@gmail.com	Indonesia
Rana Nafisa Nurdina	Student	University College London	Building Architect/Engineer	ranafisa@live.com	Indonesia
Muhammad Hendrananta	ARCHITECT	SAN STUDIO	Building Architect/Engineer	nanta.hendra@gmail.com	Indonesia
Muh. Fahem Al-Rasyid	Electrical Engineer	Universitas Indonesia	Building Architect/Engineer	alrasyidfahem@gmail.com	Indonesia

Name	Job Title	Organization Name	Sector	Email Address	Country
Melania Lidwina Pandliangan	Lecturer/Architect	Universitas Pembangunan Jaya	Building Architect/Engineer	melania.lidwina@upj.ac.id	Indonesia
Irene Mellina Panggabean	Assistant Chief Engineer	Jones Lang Lasalle	Building Architect/Engineer	irene.panggabean@jll.com	Indonesia
Heruanda Barabah	Sustainability Consultant	PT Mantra Bali	Building Architect/Engineer	heru@eco-mantra.com	Indonesia
Herman Sbastian	Student	Mercu Buana University	Building Architect/Engineer	sbastian1978online@gmail.com	Indonesia
Hendra Muliana	GM Design & Planning	PT. MNC Land Tbk	Building Architect/Engineer	hendra.muliana@mncgroup.com	Indonesia
Farhan Darsa	Environment Practices	Sinarmas Land	Building Architect/Engineer	darsafarhan@gmail.com	Indonesia
Aulia Rahma Nastiti	Architect - BIM Engineer	PT Cakra Manggilingan Jaya	Building Architect/Engineer	nastiti.aularahma@gmail.com	Indonesia
Ario Nugroho	Environment	Sinar Mas Land	Building Architect/Engineer	ario.nugroho@sinarmasland.com	Indonesia
Andy Citawarman	Water Sector Leader	Mott MacDonald	Building Architect/Engineer	andy.citawarman@gmail.com	Indonesia
Alfarabi Habil Muhammad	Green Building Engineer	Narama Mandiri	Building Architect/Engineer	alfarabihabil4@gmail.com	Indonesia
Sastra Anugraha	Regional Technical, Senior Manager	PT. Maha Kimia Indonesia	Building Chemical Distributor	sastra@mahachem.com	Indonesia
Eka Marlina	Southeast Asia SHE Head	Ecolab	Chemical specialty	eka.marlina@gmail.com	Indonesia
Balqis Affiah	Green Building Compliance	Sinarmas Land	Developer	balqis.affiah@sinarmasland.com	Indonesia
Dean Reardon	Director	PT Eco Sistem Indonesia	Eco Systems Transportation	dean@ecosystemsasia.com	Indonesia
Hendra Wijaya	Sales Manager	Pelita Promo Internusa	Exhibition Services	hendra.pelitapromo@gmail.com	Indonesia
Vetri Nurtiyanti	Researcher	BRIN	Government	vetri.nurtiyanti@brin.go.id	Indonesia
Rosabelle Purnama	Energy and Mineral Resources Specialist	U.S. Embassy	Government	purnamar@state.gov	Indonesia
Putri Rosanti	Energy Conservation Spv	Ministry of Energy and Mineral Resources	Government	putri.anggraeni@esdm.go.id	Indonesia
Muhammad Arga Karunia	Architectural Expert	PT Bina Karya (Persero)	Government	karuniarga@gmail.com	Indonesia
Michael Quigley	Energy Officer	U.S. Embassy Jakarta	Government	QuigleyMJ@state.gov	Indonesia
Mesi Shinta Dewi	Head Section of Environmental Law Enforcement and Compliance	Environmental Agency, Tangerang Municipality	Government	mesi1701@yahoo.com	Indonesia
Marliana Marlina	Staff of Sub Directorate of Investment & Coordination for Geothermal	Directorate of Geothermal, DGNREEC, MEMR	Government	Lyamarbun87@gmail.com	Indonesia
Hendro Gunawan	Coordinator of technical guidance and cooperation	Ministry of Energy and Mineral Resources	Government	hendro@esdm.go.id	Indonesia
Gigih Udi Atmo	Director of Energy Conservation	Directorate of Energy Conservation	Government	gigih.atmo@esdm.go.id	Indonesia
FF Hendro Gunawan	Policy Analyst	Kementerian ESDM	Government	hendro@esdm.go.id	Indonesia

Name	Job Title	Organization Name	Sector	Email Address	Country
Endang Widayati	Energy Auditor	KEBTKE	Government	endangwidayati4@gmail.com	Indonesia
Arief Heru Kuncoro	Peneliti	National Research and Innovation Agency (Badan Riset dan Inovasi Nasional, BRIN)	Government	arie054@brin.go.id	Indonesia
Arga Febriantoni	Energy Researcher	National Research and Innovation Agency (BRIN)	Government	arga.febriantoni@brin.go.id	Indonesia
Vita Ristiyana	Project Officer	PT Yodaya Hijau Bestari	Green Building Organization	ristivanavita@gmail.com	Indonesia
Totok Sulistiyanto Wardoyo	Vice Chair / Director	MASKEEI / PT. Narama Mandiri	Green Building Organization	totok.sulis@naramamandiri.net	Indonesia
Savitra Perdana	Green Building Rating Development & Certification Manager	Green Building Council Indonesia	Green Building Organization	deny@gbciindonesia.org	Indonesia
Rahman Wirajaya	MarComm Manager	AP Buildings	Green Building Organization	info@apbuildings.co.id	Indonesia
Iwan Prijanto	Chairperson	Green Building Council Indonesia	Green Building Organization	iwan.prijanto@gmail.com	Indonesia
Ferdian Lo	Senior Project Manager	PPI	Green Building Organization	ferdian@peltapromo.com	Indonesia
Daud Tjondrorahardja	Representative	GBCI	Green Building Organization	yogyakarta@gbciindonesia.org	Indonesia
Dany Watanabe	Business & Operations Manager	G-Energy Indonesia	Green Building Organization	dany.watanabe@genergy.com.sg	Indonesia
Chandra Hertiasning	Bandung Representative	Green Building Council Indonesia	Green Building Organization	chandra@cakralinjaya.co.id	Indonesia
Bradley Jason Teguh	Business Development Executive	G-Energy	Green Building Organization	bradley.jason.teguh@gmail.com	Indonesia
Novega Arlinka	Business Lead	MUSA Green	Green Tech Startup	novega@musagreen.com	Indonesia
Yudhi Anggoro	Building Manager	PT JLL Indonesia	Industry	yudhi.anggoro@jll.com	Indonesia
Yana Yoga Pratama	Direktur	PT Mitra Indonesia Bersahaja	Industry	yanayogapratama@gmail.com	Indonesia
Vina Sitorus	Shareholder	Eco Regions Pte Ltd	Industry	vina.anggi99@gmail.com	Indonesia
Rofik Hartanto	RnD, QC, & Sustainability Director	Saint-Gobain Indonesia	Industry	rofik.hartanto@saint-gobain.com	Indonesia
Rismin Yapto	Assistant Project Manager	PPI	Industry	rismin@peltapromo.com	Indonesia
Ricky Sitorus	Design Lead	Gema Projects	Industry	brsitorus@gmail.com	Indonesia
Rea Alfina	Marketing	PT Pelita Promo Internusa	Industry	marcomm@peltapromo.com	Indonesia
Ramadhani Santoso	director of advanced engineering	energia Indonesia	Industry	ramadhani@energiaindonesia.com	Indonesia
Parlindungan Yonathan Pangaribuan	Country Head	UL Solutions	Industry	yonathan.parlindungan@ul.com	Indonesia
Narendra Afian Pradipto	Sustainability	PT Lippo Karawaci Tbk	Industry	narendra.afian@lippokarawaci.co.id	Indonesia
Myta Noviani	Business Ecosystem Development	PT Jababeka Infrastruktur	Industry	myta.noviani@jababeka.com	Indonesia
Muhammad Kismurtono	Senior Researcher and Senior Executive Professional Engineer	PT. SWASTISIDDHI AMARGA BIOENERGI	Industry	muhammadkismurtono@gmail.com	Indonesia
Mohammad Naufal	Founder & CEO	Carbon Addons	Industry	mohammad.noval21@gmail.com	Indonesia

Name	Job Title	Organization Name	Sector	Email Address	Country
Lydia Rudtio	business development manager	BMI (PT. Monier)	Industry	lydia-caroline.rutio@bmigroup.com	Indonesia
Linda Widiachristy	Sustainability Development Coordinator	Saint-Gobain Indonesia	Industry	linda.widiachristy@saint-gobain.com	Indonesia
Kaswanto Wanto	Supervisor	PT TESSO TETRA CHEMIKA	Industry	kaswanto@tesso.com	Indonesia
Iman Firmansyah	Senior Manager Business Development	PT. Jababeka Infrastruktur	Industry	iman.firmansyah@jababekainfra.com	Indonesia
Furmans Nurgafi	Head of Key Account Manager	PT. Signify Commercial Indonesia	Industry	firmans.nurgafi@signify.com	Indonesia
Edward Edward	Director	PT. Indojaya Mitra Sarana	Industry	edward@ims-automation.com	Indonesia
Dewi Galih	HR Legal GA	PT Tesso Tetra Chemika	Industry	dewi@tesso.com	Indonesia
Daniel Janthinus Kristianto	R&D - Bus. Dev	PT. Dharma Precision Parts	Industry	daniel.kristianto@dac.dharmap.com	Indonesia
Andhang Rakhmat Trihamdani	Senior Engineer	YKKAP R&D Center Indonesia	Industry	andhang-rt@ykkap.co.id	Indonesia
Amalia Nurjannah	Research Engineer	YKKAP R&D Center (Indonesia)	Industry	amalia-n@ykkap.co.id	Indonesia
Aldyan Rosika Hartanto	Sr. Spv HSSE	PT Pertamina Patra Niaga	Industry	aldyanrosika@pertamina.com	Indonesia
Agung Wicaksono	Managing Director	PT. Jababeka Infrastruktur	Industry	agung.wicaksono@jababekainfra.com	Indonesia
AG Priyambodo	CSR & Green Initiatives Support	PT Bumi Serpong Damai, Tbk	Industry	adhityo.priyambodo@sinarmasland.com	Indonesia
Riski Riyadi	Research & Business Relation Development	PT Jababeka Infrastruktur	Infrastructure	riski.riyadi@jababekainfra.com	Indonesia
Henrikus Rico Adhi Iswara	Business Development	PT. Jababeka Infrastruktur	Infrastructure	henrikus.rico@jababekainfra.com	Indonesia
Rio Jon Piter Silitonga	Research Analyst	ASEAN Centre for Energy	Intergovernmental Organisation	riosilitonga@aseanenergy.org	Indonesia
Fina Nurzariasari	Key Account Manager	Signify	Lighting Vendor	fina.nurzariasari@signify.com	Indonesia
Buyung Hartono Sunaryo	Director	PT Imeco Inter Sarana	Manufacturers Agent	buyung@imeco.co.id	Indonesia
Charles Hutapea	Project Manager	PT. Agape Pratama Indonesia	MEP Contractor	agape_pratama@yahoo.co.id	Indonesia
Rimlas Sigalingging	Freelance	NGO	NGO	rimlas.s05@gmail.com	Indonesia
Rifqi Dewanto	Research Officer (Renewable Energy and Emission Reduction Cluster)	Resilience Development Initiative	NGO	rifqi.hakim@di.or.id	Indonesia
Raphael Anindito	Program Manager	Global Buildings Performance Network (GBPN)	NGO	raphael.anindito@gbpn.org	Indonesia
Nanik Rahmawati	Program Manager	CLASP	NGO	nrahmawati75@gmail.com	Indonesia
Kynan Tjandaputra	Associate	CLASP	NGO	ktjandaputra@clasp.ngo	Indonesia
Haris Setianindar	Deputy secretariat Maskeel	MASKEEI	NGO	haris.setianindar@gmail.com	Indonesia
Fathin Sabbiha Wismadi	Researcher	IESR	NGO	fathin@iesr.or.id	Indonesia

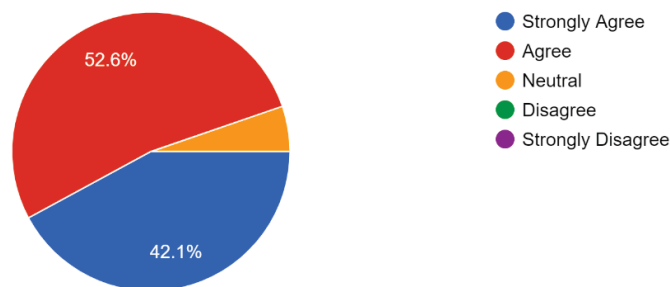
Name	Job Title	Organization Name	Sector	Email Address	Country
Ery Wijaya	Country Manager	Green Buildings Performance Network (GBPN)	NGO	ery.wijaya@gbpn.org	Indonesia
Erwin Kasim	Secretary	MASKEEI	NGO	erwinkasimchevron@gmail.com	Indonesia
Dwi Cahyo Husodo	Coordinator in Energy Efficiency and Sustainable Building	(IESR)	NGO	dwi@iesr.or.id	Indonesia
Ananggadhipa Sedyanto Putro	Secretariat MASKEEI	MASKEEI	NGO	ananggadhipa.sp@gmail.com	Indonesia
Aldrich Suryawan	Grant Manager and Researcher	Resilience Development Initiative	NGO	aldrichsuryawan@gmail.com	Indonesia
SOEDJONO (JON) Respati	Chairman	MASKEEI, Indonesian Energy Conservation And Efficiency Society	Non-Profit	jonespati756@gmail.com	Indonesia
Rurin Sitoresmi	Program Development, Event, and Rating Development	GBC Indonesia	Non-Profit	rurin@gbcindonesia.org	Indonesia
Febryan Paramitha	YEA Chair	ASHRAE Indonesia Chapter	Non-Profit	febryanparamitha@gmail.com	Indonesia
Amalia Bendang	Staff	MASKEEI	Non-Profit	amaliabendang@gmail.com	Indonesia
Albert Iskandar	Kepala Bagian Umum	Rumah Sakit Immanuel	Non-Profit	albert22042000@gmail.com	Indonesia
Sri Wulandari	Assistant Manager Workplace and Travel	PT Unilever Indonesia. Tbk	Office/Building Management	sri.wulandari@unilever.com	Indonesia
Dick Bernadi	Head of Project Management	CBRE	Project Management Consultant	dick.bernardi@cbre.com	Indonesia
Ignesjz Kemalawarta	Advisor	Sinar Mas Land	Property	ignesjz.kemalawarta@sinarmasland.com	Indonesia
Prisca Winata	Energy & Sustainability Lead	Jones Lang LaSalle	Real Estate	prisca.winata@jll.com	Indonesia
Faradila Septiani	Business Secretary	MUSA Green	Technology	admin@musagreen.com	Indonesia
Khushal Matai	Assistant Professor	School of Planning and Architecture New Delhi	Government	arkushal@live.com	India
Rohith Ravula	Associate Director - Market Development	Green Business Certification Institute Private Limited	Green Building Organization	rravula@gbci.org	India
Nagesh Gupta	Sr Manager - technical solutions	Green Business Certification Inc	Green Building Organization	ngupta@gbci.org	India
Ashu Dehadani	Associate Director (Technical Development)	Green Business Certification Inc.	Green Building Organization	adehadani@gbci.org	India
Feiyu Li	China Office Manager	LUMENCACHE	Industry	echo@lumencache.com	China
Mark Lister	co-CEO and Chief Financial Officer	Asia Clean Energy Partners Limited	Consultant	mark.lister@asiacleanenergypartners.com	Australia

Annex C – Participant Feedback and Evaluation

A feedback and evaluation form was circulated at the end of Day 1 (38 responses) and the end of Day 2 (32 responses). Raw feedback received on the questions is consolidated and summarized below. Some responses are translated from Bahasa Indonesia, for ease of reference.

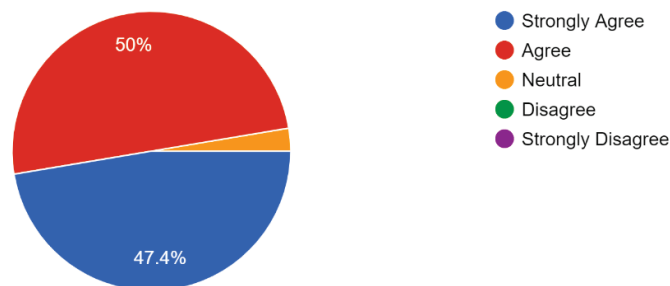
I learned something useful from Session 1: Introduction to workshop

38 responses



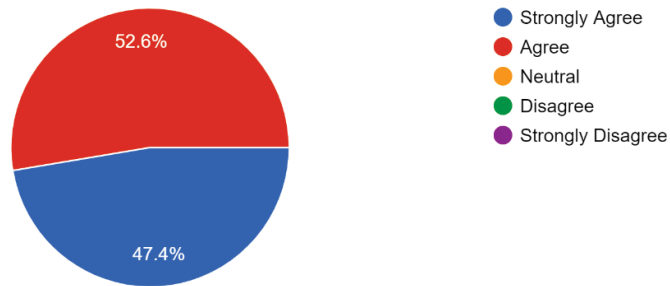
I learned something useful from Session 2: Energy conservation and green buildings in Indonesia

38 responses



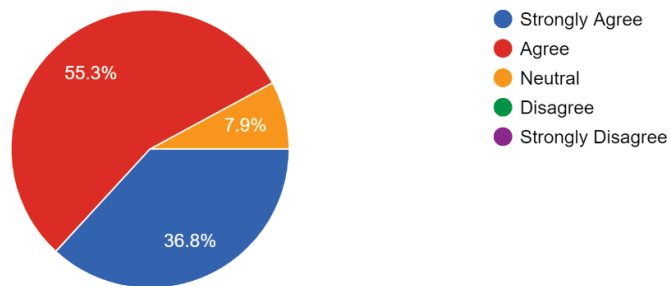
I learned something useful from Session 3: Introduction to net zero energy buildings

38 responses



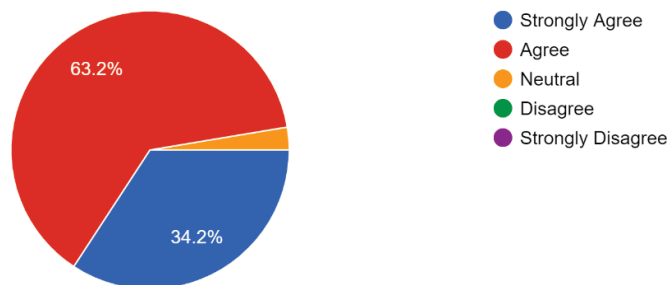
I learned something useful from Session 4: Fostering clean technology construction investment in Indonesia with advanced technologies and materials (panel discussion)

38 responses



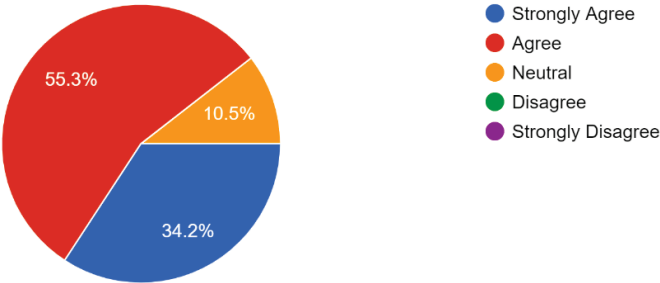
I learned something useful from Session 5: Energy management technology in buildings and its application to Indonesia (panel discussion)

38 responses



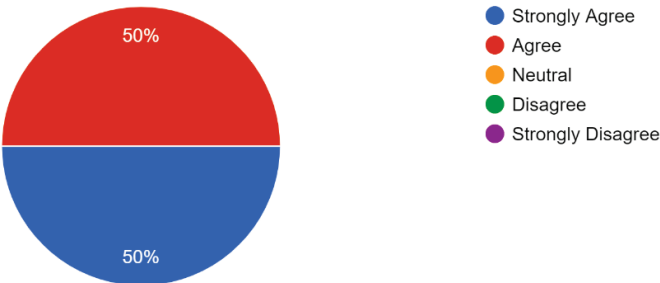
I learned something useful from Session 6: Roadmap to net zero buildings in Indonesia (group discussion)

38 responses



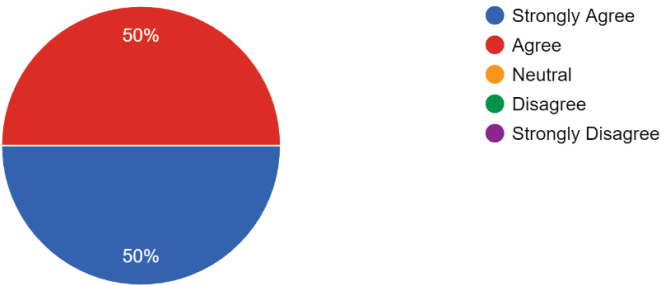
I learned something useful from Session 8: Energy management

32 responses



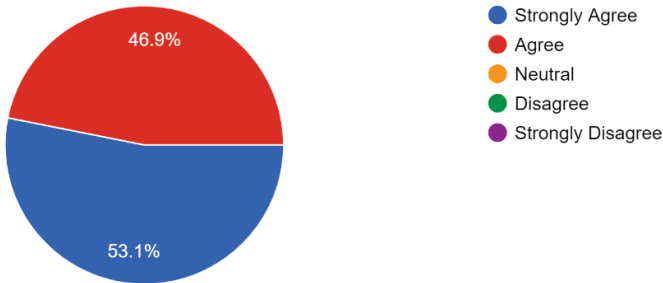
I learned something useful from Session 9: Passive technologies for energy-efficient, resilient, and healthy buildings

32 responses



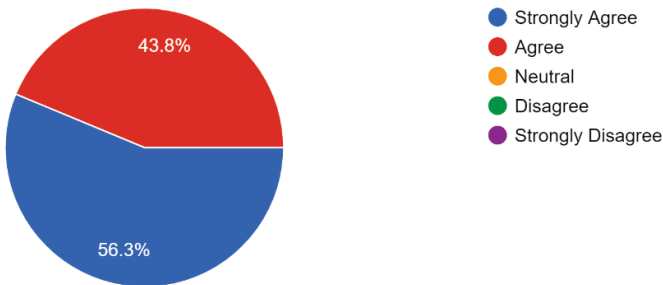
I learned something useful from Session 10: Active technologies for energy-efficient, resilient, and healthy buildings

32 responses



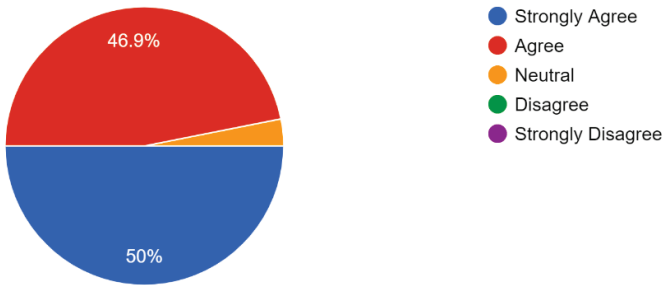
I learned something useful from Session 11: Net zero energy building policies

32 responses



I learned something useful from Session 12: Technical and workforce development opportunity and gap analysis

32 responses



What are the 3 most important things you learned?

- Sessions 2,3,6
- (1) NZ should become mandatory in couple years. we must take action now. (2) Although challenging, the commitment requires a lot of stakeholders to work together as a team. (3) Regulations can become the major enforcement to achieve the NZ goals. as well as funding/incentive scenario for NZ buildings
- Policy, new technology, action plan
- Energy technology, smart building, green building
- Regulation about Green Building
- Net zero roadmap, awareness, stakeholders
- Energy efficiency, net zero buildings, renewable energy
- Strategies towards energy conservation and limiting emission, types of materials, methods, and devices for actions, and decarbonization management as related to architecture and LCA
- Problem and strategy approaches
- Networking, new information about companies and organization related to the decarbonizing the building sector topic and knowledge about solutions to decarbonize the building sector in Indonesia
- Net zero carbon road map, EE regulation, clean energy
- session 4; session 5; session 6
- Road map and Government regulation to increase awareness of Energy Efficiency
- energy conservation zero energy building concept and policies net zero building concept
- Current status of net zero in building sector
- How to reduce energy consumption, passive and active design help reduce energy, new standard
- Net Zero Practices, policies , cool roof and walls,
- Roadmap carbonizing in Indonesia is clear.
- Definitions, software's, guidelines
- Connection, Collaboration, also Coherent work from multisector will be benefit for achieving Decarbonizing Building Energy 2. Private sector able to be the main actor 3. Private sector - driving market - legal aspect
- Roadmap to NZEB
- That existing building has to be the biggest concern for the building decarbonisation issue in Indonesia
- 1. How Roadmap to net zero buildings in Indonesia. 2. How Energy management technology in buildings and its application to Indonesia. 3. How Energy conservation and green buildings in Indonesia
- participation of government, industry and planner
- The step of Decarbonizing Building, Mandatory plan for ISO50001, Building Decarbonization Roadmap
- Common understanding and common goals to achieve net zero building in Indonesia; Building materials for residential building to achieve net zero buildings especially for middle-low income residential buildings in tropical climate; The possibility of collaboration and roadmap to net zero buildings in Indonesia in collaboration with the U.S. National Laboratory;
- Carbon Emissions Index

- 1, green building is not always easy to implement, 2, there are different definition / understanding of green building
- Capacity Building, Green Roof, Update technology
- technological advancement in green architecture, national plan for net zero, that there is a lack of emphasis being place on social justice
- Green Building, Rating Tools, Strategi Implementation
- The Important of Decarbonization Building in Indonesia
- regulations, roadmap, technologies
- Insight, technical competence, networking
- Data is important to reach NZE, but in Indonesia data is not sufficient.
- Yes I learned something that is right and true so number one is efficiency, effective and good building. All of them are Green building.
- 1. The energy consumption from household sector 2. Progress of green building & energy efficiency in Existing building 3. Updates on government regulations regarding green building & EE
- Target NZE 2060 should be achieved with roadmap, the important for reduction carbon, building should more efficient energy
- About adaptive thermal comfort There are a lot of regulations that overlapped New technologies regarding to active design in building
- Collaboration, stakeholders
- Energy management & Indoor Quality Index
- Adaptive thermal, Passive design, cool roof
- Smart System
- Road map zero Energy
- net zero building policies
- Building materials and renewable energy
- Thermal comfort measurement, IEQ evaluation, DC lighting
- Energy Building, Zero Emission, Green Building
- -
- New passive technology, resilient and healthy building, and policies
- Policies, Key definitions, certifications
- Rating tool important, commitment owner to NZE building, technology can support energy efficiency
- Passive technology, active technology, policies
- Updated technology on pathway yo net zero
- Education, rethinking about Existing Building & make a new Culture for Indonesia society.
- Gap in testing capabilities, gap in data as baseline, big room for improvement
- Efficient, Green Technology of building, Renewable Energy
- The concept of thermal comfort in building, various standards and certification in green building, also smart energy management
- How to implement strategies of NZE in Buildings
- Collaboration, research and campaign of net zero building
- Energy efficiency, Environmental Management, less waste
- Active and passive design strategy to get ZEB, Roadmap towards ZEB, Collaboration between stakeholders to achieve ZEB
- Policies, Certification, definitions

- Need clear Regulation for incentive and disincentive, applying consequences for not implementing Energy Efficiency programs
- The role of government in implementing green building
- 1. We need to start now. 2. we need to walk the talk. 3. Follow up the collaboration
- NZEB possible to achieve, the definition of NZEB,
- Retrofitting Existing building is important to reach NZE
- Net zero energy building policies
- 1. Human factors in the buildings should also be considered when discussing energy-efficient buildings with zero emissions 2. There are many ways to achieve decarbonization, and one of them is through solid research facilitation, which should be open to all. Research opportunities should be made more widely available 3. Education on climate change, decarbonization, and efficiency in energy should be provided heavily to people in the lower economy layer and children of school age

What are the 3 most important actions for Indonesia to take to decarbonize its building sector?

- Regulator, data base, networking
- (1) Accelerating the Regulations for Energy Audit and Managements to enforce the action start. (2) Aged building must set baseline first by energy audit and start retrofiting their diminishing system. (3) Regulations around renewable /clean energy options has to be escalated to encourage RE use.
- Set the target, fill the research/knowledge gap, set action plan.
- Study, analyse, implementation
- Engage all buildings to achieve energy efficiency
- Training, assessment
- Change our habit, awareness and action to make some innovation to decarbonization
- Spread awareness in the lower layers of economic pyramids, reward those who take actions i.e. through tax breaks, make the policy readily available socially to be implemented inclusively
- Generating and implementing regulations related to Indonesian climate characteristics, Generating innovations on material technology, and Influencing the concept on all stakeholder in all phases.
- Collaboration, capacity building and financial support
- socialization of net zero carbon road map & clean energy, simple EE implementation,
- regulation and commitment, human capital, budget
- Capacity Building of Building operator / owner
- Building materials. Government policies and regulations. Behavior of building users
- Regulation, market or costumer driver, investor demand
- Energy efficiency, government, price for energy
- Setting regulation, creation of green market trend, providing incentives for decarbonized buildings.
- Science Tech, regulation (Government) and incentive
- Implement regulations, more interactions with consultants and stakeholders, implement innovative technologies
- Integrated regulations - not overlap 2. Incentive and disincentive 3. Society "punishment" - people are not going to use building which is energy inefficient

- Lowering energy consumption, regulations, and standards
- Awareness raising and better incentive and support from the government for GB implementation
- 1. Regulation 2. Commitment from every stake holder to take action now. 3. Start from simple things
- mandatory building codes and campaign or education to the society
- Holistic approach by collaboration of all stakeholders, acceleration of the regulation, clear investment advantage of the green material
- -establish common understanding, -develop regulations, plans, roadmap, and steps to achieve the goals; - collaborate among stakeholders in gradually achieving the goals
- prioritized green building
- Capacity Building, Gap Qualification in planning and operation, More Workshop
- map the most needy sector, plan how to democratise decarbonisation, ensure the process and implementation are just and egalitarian
- Regulation, Public Policy, Awareness
- Carrying out capacity building for all stakeholders involved in the building construction industry, providing incentives and convenience in terms of policies/regulations, clear road maps and actions for the process towards decarbonization
- Make a good system, decide on the prioritized strategy, prepare the infrastructure
- Raw material choice, Energy efficiency, less waste
- Raised the public awareness because they are the major housing constructor in Indonesia, more than 70% houses in Indonesia are build by the owner, informally (with out building permit)
- It is action in Indonesia. Number one Renewable Energy especially wind Energy, Sun Energy and hydrogen energy.
- 1. Identify baseline data 2. Make achievable targets 3. Support green building & EE
- Implementation green building, use material good for environment, and making new code for green building
- The collaboration between stakeholders The regulations that convinced all parties to reach the goals Increasing knowledge about new technologies
- Research, educate, action
- Energy efficiency, green procurement, and net zero energy
- Collaboration with stakeholder,
- Networking and operate human resources
- Capacity building, audit for Building should mandatory
- strong commitment government and stakeholders
- Building Code, EE Regulation, NZE Roadmap
- Education, database, open access
- Env Law Enforcement, Public Policy, Tools Assessment
- Set up a specific target about Net Zero, Regulate energy audit for existing building regularly, Provide incentive
- Policy creation, enforcement of green regulations, certifications
- Commitment from owner, commitment with policy, research technology for increase energy efficiency
- Get stakeholders to collaborate properly, invest in research and development, formalise regulation
- Regulation, technology adaption, capacity building

- Education, make a new benchmark for net zero and make a new strategy for Net Zero Road Map in Indonesia based on Data.
- Act to align regulations and policy, conduct more and more training, fund research and provide incentive to create net zero economy.
- Efficient dynamics, Effective and Renewable Energy.
- Increasing green procurement, building comprehensive testing mechanism, and mainstreaming green and net zero building
- In financial sector, democratize the green technology, green affordable housing
- Action of all stakeholders
- Rethinking less emission, Standard Operation Procedure Decarbonized Building (SNI) and Academic Curriculum of Decarbonized Building
- Supporting regulations, capacity building, availability of adequate measurement facilities and infrastructure.
- Implementation of policies, govt to drive the decarbonization movement, all stakeholders to be equally responsible to drive the change
- Develop clear regulatory incentive and disincentive, apply law enforcement, allocate enough budget for socialization, training and provide workforce, and provide and support financing with low interest and longer tenor for ESCOs
- Building commitment among regional government leaders in implementing green building
- 1. Collaboration. 2. Pilot project. 3. Advocacy by the real implementation
- fixed regulation, education, willingness
- Energy Efficiency, Renewable Energy, and Low Carbon Material.
- awareness raising and clear incentives for green building procurement
- 1. Make funded research available widely and openly 2. Implementation through practice and policy management 3. Education on this topic should take place through K-12 and college level curriculum to raise awareness and inspire ideas and drive actions throughout all society layers

Who are the 3 most important stakeholders to make this happen?

- Government, private sector, academic sector
- building owners, regulators/government, technology vendors/innovations
- Manufacturer, manufacturer, government
- Government, company, owner
- Building, government, and professional organization
- Government, architect, developer
- ESDM, U.S. energy institution
- The government (as the leader to set examples), the practitioners and educators to help spread awareness, and researchers in the related industry
- Government, Building Owners (in all stages, planning to operation and maintenance), Construction Services (designer, contractor, construction management consultant, vendors etc)
- Ministries related to the topic (policy makers), building owners and universities
- Government, private sector, academia
- government, building owner, consultant
- Regulator (centre and local), Expert and Building operator

- Energy, material, Government
- Government, investor, customer
- Government, owner
- Government, Academia, and Private Sector
- Government, PEMDA n associations
- Govt, Owners, FM companies
- Academia; Private sector; Government
- PUPR, ESDM, President
- ESDM, PUPR, building developer
- 1. us (academic) or researcher 2. Government 3. Industry
- government, industry and planner
- Government (regulator), real estate developer, material industries
- Government, private sectors/ NGO, academia/researchers.
- authority, building owner, material supplier
- Related Engineer Association (Planner & Operation), Governments, GB Association
- government, academia, industry
- DJBK, DJCK, Local Government
- Government, Developer, Consultant (Architect, MEP, Structure)
- government, industry, society
- Contractor building, academic society, government
- Local Media, Teachers,
- PT. SWASTISIDDHI AMARGA BIOENERGI, PT. CİSADANE SAWIT RAYA dan PTPN V, Bandung.
- 1. Government 2. Private sector 3 financial institutions
- Government, educational, and industries
- Ministries that related to the sector, Communities and Ourself
- Government, education institution
- Regulation, building capacity, awareness
- Government, Academic, practitioner
- Government, private, education
- Regulator, expert & building management / operator
- government, human capital center, construction stakeholder
- MEMR, MOPWH, Ministry of Environment
- Government, education institutions, private sector
- DJCK, DJBK dan KESDM
- Government, Practitioner, Finance Institution
- Govt, owners, users
- Government, educational, and industries
- Government of multiple ministries, industries, academia
- Government, investor, customer
- Government, Industry and Manufacture
- Government, Academia, Private sector
- PT. SWASTISIDDHI AMARGA BIOENERGI, PT. CİSADANE SAWIT RAYA and PTPN. V, Tandun
- Government, private sector, and academia
- Government, researcher, private industry
- Researcher, Industry and community

- Academia, Governance, and Private Sector
- Government, Developer, Academia
- Govt, owners, consultants
- Government, Investors, Developer
- Government, business community, university community
- Each stakeholders has important part. But no.1 is architect, because they the one whom previously set the trends, whom deliver the design to the clients, whom creates the demands, whom gather other engineer to collaborate in their building. 2. Government, they need to walk their commitment. 3. Private sector, they whom can support financially the R&D to fulfill the markets demands
- Government, Local government, Association
- MEMR, Public Works, Ministry of Industry
- Ministry of ESDM (MEMR) and PUPR (MoPWH)
- The government as the policy maker and reinforcer, practitioners, researchers/ educators

How would you like to participate in U.S.- Indonesia efforts to decarbonize the Indonesian building sector?

- Research and education
- We know some companies already set NZ targets but very few has taken any actions. Other companies especially locals even haven't had any NZ target or commitment. As a sustainability consultant, I would like to help setting companies' NZ target and roadmap and also ensure they take action of the commitment they've made.
- I am really interested to contribute in filling the research gap.
- Introduce the society about green building and net zero building
- With energy efficiency and implement net zero energy
- It's a nice way to encourage decarbonization in Indonesia
- As a research collaborator and educator in the university level
- As a planning and construction management consultant, I will have my participation in ensuring the achievement of high performance building through construction stage and document reviews and recommendations. However, as my focus on building information modelling, i will also do building simulations and having the building review and analysis on net zero emission compliance on all building elements prior to the construction's action plans.
- I am currently working in the same sector, I would be happy to support this agenda
- Exploring practical energy efficiency research
- energy management in building sector
- Campaign in energy efficiency and conduct cap. Building
- Very supportive
- Group discussion
- Helping owner to retrofit their chiller
- As private sector distributing raw materials for construction industry, I will be actively promoting materials which supports actively the net zero product such and make it easy to access and affordable
- sharing experience, update journal, join a movement

- Open to suggestions on how we can participate
- Would involve and participate actively
- Making a research about NZEB
- For IESR to be a part of the research stage
- First trying to bring this issue on class, to many architecture students to think about designing Green Building and net zero building.
- to share this awareness to our students, who will be involved in the future of building development
- Connecting the industries with the builders
- Keen interest to participate
- yes
- I like to participate because as building engineer planner
- contributing to the social justice side of the policymaking
- Please send the PDF or PPT
- Really want to participate in the next similar activity
- as consultant/expert
- Networking continuous monitoring update
- Join the working group for roadmap discussion, because GBPN in cooperation with MEMR Indonesia is currently developing a roadmap for Net Zero Emission in the Building Sector.
- Yes. I am sure that I like to participate in U.S. - Indonesia. So for that its I got the project decarbonisation from Europe.
- Active is SKK & help ESCO
- Yes
- Open to suggestions
- Increasing my knowledge about the topic and start to change my mindset about the topic
- Educator
- With training
- Exploring research regarding NZEC
- Research
- Great
- training, education, capacity building
- As a consultant
- Very interested
- Spread the information in my subject university
- Sharing good practices and to encourage and assist in the implementation process.
- Yes
- Same answer with the day 1 form
- Discussion group
- I would like to start from make a new perspective in our society because, Net Zero in Indonesia can't happen if a major society are still not aware about that topic. The Impact of Social Media can be option that can help to free educate a new generation about this topic.
- Provide information to clients which most of them are building construction product manufacturer such as paint, mortars. Help them to connect with testing facility when they require to provide data prior launching their product which support net zero program.
- Yes I like to participate in U.S. -Indonesia.
- Conducting further study in green building in Indonesia
- Joint research

- To do some research to earn prototypes of net zero building in Indonesia
- Can Make ISO (International Standard Organization) convert SNI (Standard Nasional Indonesia)
- By participating in research related to the application of active and passive design in Indonesia.
- Attend FGD session and involved in Gov specific EE Projects as advisors
- By inserting this material into my lecture material.
- We plan to build an ecosystem where all stakeholders can be continuously connected, continue discussions, collaborate to produce results in the form of pilot projects, continuously, not just one finished project. We are currently preparing an effective and relevant platform to accommodate the needs of all parties in achieving this common goal.
- yes i Would
- I like to join the discussion and workshops.
- Being a part on the research stage of the project
- Through funded research and education as it is my role as both. I have done informal education on the topics of the climate crisis and global warming mitigation to children of age 7-12 to raise awareness and inspire ideas of action for the future. These activities were done in an educational-fun environment to help children understand the importance of these issues more thoroughly.

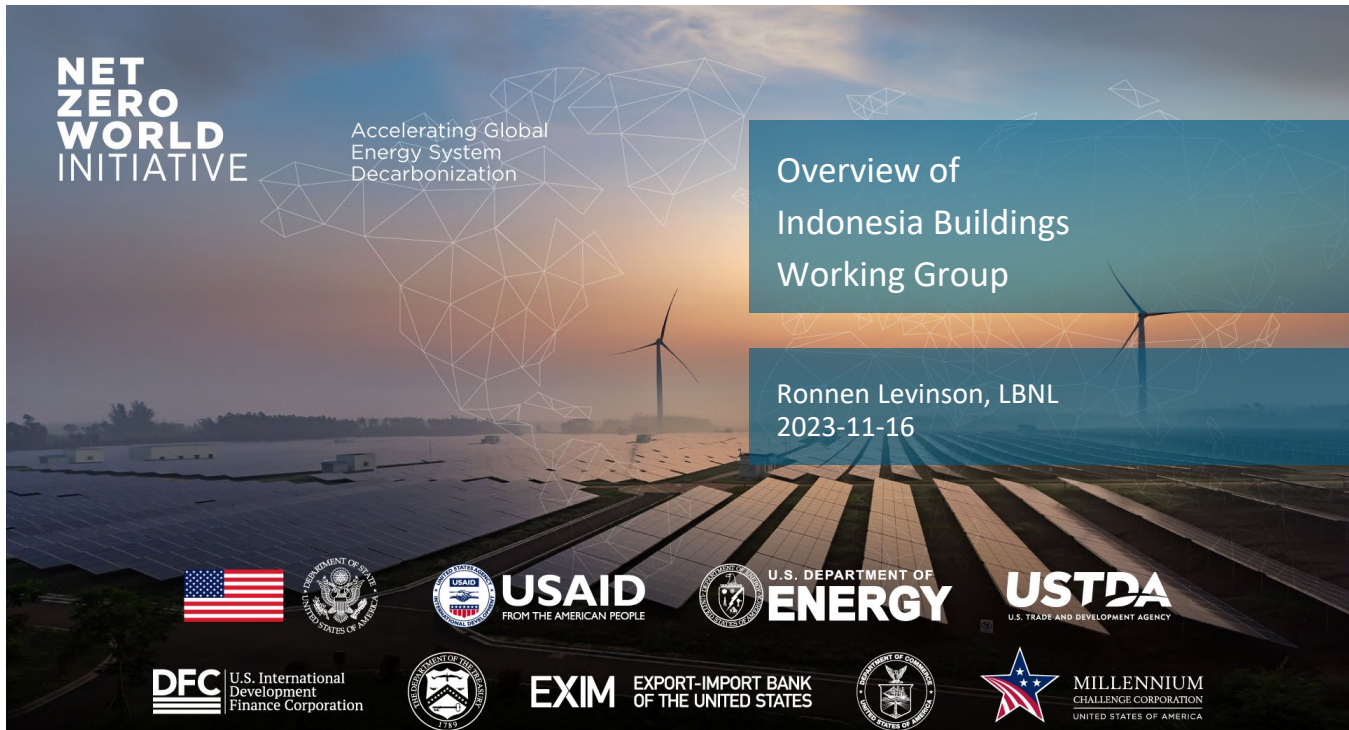
Please share any other comments you have about the Workshop (optional)

- According the need of institution report, we ask the committee to give a e-certificate
- ESDM should prepare better plan for building sector
- Thank you for this workshop. It's make new opportunity for me for increase knowledge and networking.
- I glad to attend this meeting, I hope we can invite again for energy supply topics
- Please issue a certificate of attendance for our reports. Thanks
- Please provide certificate of attendance / observer. Involve the building construction sector to enhance the implementation of theories and strategies in construction phases through related actors.
- Its a great events, thank you for making this happened. One problem is the distance of the venue. I think its better to provide the participants with a transportation vehicle from Jakarta.
- Overall ok
- very good
- Need further action in collaboration 3 stakeholders above and support from U.S. DOE
- Great sessions!
- broaden my views
- Need to gather small group discussion (ex.per table) to hear our next neighbor's opinion about specific topic. Then bring to room discussion
- Good to attend
- Very enjoyed to come in this workshop, so many idea and insight
- no complain, all was good
- I think we should expand the coverage to the other net zero initiatives.
- appreciate if can share the presentation material . Thanks

- NZEP could be achieved if we can apply cogen system and renewable energy such as waste to energy, Not only solar PV
- time is far too limited, and some moderators were not strict enough with the speakers and the audience. We lost a lot of time listening to irrelevant and meandering questions.
- The material provided is very interesting.
- Data on building energy baseline is very important for the roadmap
- That is very good and luck so when it is do this event again. So is not it more slowly .
- Good time management
- Great
- It was a great day and so many new knowledge
- Thank you.
- Overall ok
- Need further action on item that had been summarized
- very good
- Great event and need to be conducted regularly
- Great!
- Moderators were even less strict than yesterday. The seminar was running > 30 mins behind schedule, and the very important group discussion session was cut short. Very disappointing. Moderators should have done better
- I think most important for the road map is to make a new curriculum for Junior & High School in Indonesia to understand more about Sustainability & Impact of climate change, so a new generation can have a new perspective to rethinking the future and net Zero.
- Great event!
- All two days and Travelling to building three locations are great building in Indonesia as the same in Kuala Lumpur, Malaysia
- Thank you for developing such a nice workshop!
- Great workshop and so much opportunities! (e certificate will be appreciated for participants) thank you
- Very pleasant. It would be great to be able to take part in such activities in the future.
- Too many topics and speakers, thus no time enough available for Q&A and discussion with seminar participants
- Excellent event
- I hope to be able to have further discussions with parties who are willing/willing to support the realization of the platform that I talked about earlier. Because without a forum we are only moving on our own without a quick and comprehensive solution to deal with issues that are very urgent to be resolved together.
- Great, I'm waiting another workshop.
- Thank you for facilitating this very interesting workshop
- It was great though the discussions went really fast. I'm hoping to get involved in the next activities/ workshops/ research in the future.

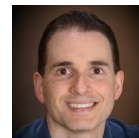
ANNEX F

Working Group Overview



NZWI promotes decarbonization of Indonesia's major economic sectors, including buildings

- Bi-lateral collaboration between the US Department of Energy (DOE) and the Indonesian Ministry of Energy and Mineral Resources (MEMR)
- The **NZWI Indonesia buildings working group** is managed by Lawrence Berkeley National Laboratory (LBNL), the Indonesian Energy Conservation and Efficiency Society (MASKEEI), and MEMR



[Ronnen Levinson](#)
LBNL



[Jon Respati](#)
MASKEEI



[Hendro Gunawan](#)
MEMR

Feb 2023 building decarbonization workshop yielded a working group led by LBNL, MASKEEI, and MEMR with 4 sub-working groups (SWGs)

SWG-A **National Center**

- Whole-building cooling technologies
- Low-carbon buildings materials database
- National road map
- Energy benchmarking
- Community initiatives
- Testing & certification
- More...

[Eddi Santosa](#)
PT DEX Solusi Transit



SWG-B **Capacity Building**

- Train-the-trainer
- Energy M&V training
- Energy audit/management training
- SME ESCO development
- Building simulation university course

[Jimmy Juwana](#)
Green Building Council Indonesia



SWG-C **Analysis & Financing**

- Whole-building cooling cost-benefit analyses
- Building EE market analysis
- Develop innovative financing models for NZB, incl. ESCOs

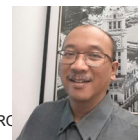
[Ery Wijaya](#)
MASKEEI



SWG-D **Pilot Projects**

- Affordable housing pilot projects w/passive, low-cost, & resilient strategies for LMI communities
- Collaborate w/other infrastructure donors to incorporate NZ EE building designs/stds

[Iwan Prijanto](#)
Green Building Council Indonesia



NET ZERO WORLD INITIATIVE | 3

Buildings working group membership & mission

- **Members**
 - Building professionals, practitioners, and academics
 - Energy/building officials from MEMR, Public Works & Housing (PUPR)
 - Experts from U.S. National Laboratories
- **Mission**
 - Apply up-to-date, inclusive, and sustainable architectural design, low-carbon building materials, and energy-efficient & innovative construction to benefit low-to-moderate income (LMI) Indonesian communities across the archipelago's diverse tropical climate zones while decarbonizing Indonesia's building sector

NET ZERO WORLD INITIATIVE | 4

Criteria for prioritizing working-group activities

- Potential for energy savings and carbon reduction
- Level of challenge to overcome
- Level of potential support from key stakeholders for building up Indonesian industries and market
- Need for financial support (government, industry, others)
- Need for technical support from US National Laboratories
- Ability to leading to development & building of pilot projects that fit the Indonesian context

Cool Solutions to save energy, cool cities, and boost resilience to extreme heat

Rongxin Yin
Handi Chandra Putra, Ph.D.
Ronnen Levinson, Ph.D.

Lawrence Berkeley National Laboratory
Berkeley, California, USA



1

A cool exterior wall reflects sunlight to reduce need for air conditioning—saving energy, money, and carbon

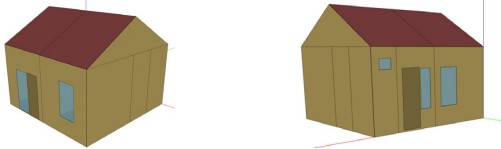
Wall solar reflectance

- Conventional $\approx 25\%$
- Cool color $\approx 40\%$
- Off or dull white $\approx 60\%$
- Bright white $\approx 80\%$



2

Low-middle income residential house model description

Total Floor Area (sq. meters)	36 m ²
Building shape	
Number of Floors	1
Window Fraction (Window-to-Floor Ratio)	23% total (North→26%, South→20%)
Window Locations	Front and Back
Shading Geometry	None
Orientation	Front of the house faces South and (West)
Thermal Zoning	The house is divided into seven thermal zones: 'bath', 'bedroom 1', 'bedroom 1 attic', 'bedroom 2', 'kitchen', 'living room', 'living room attic'
Floor to ceiling height	3.4 meters



3

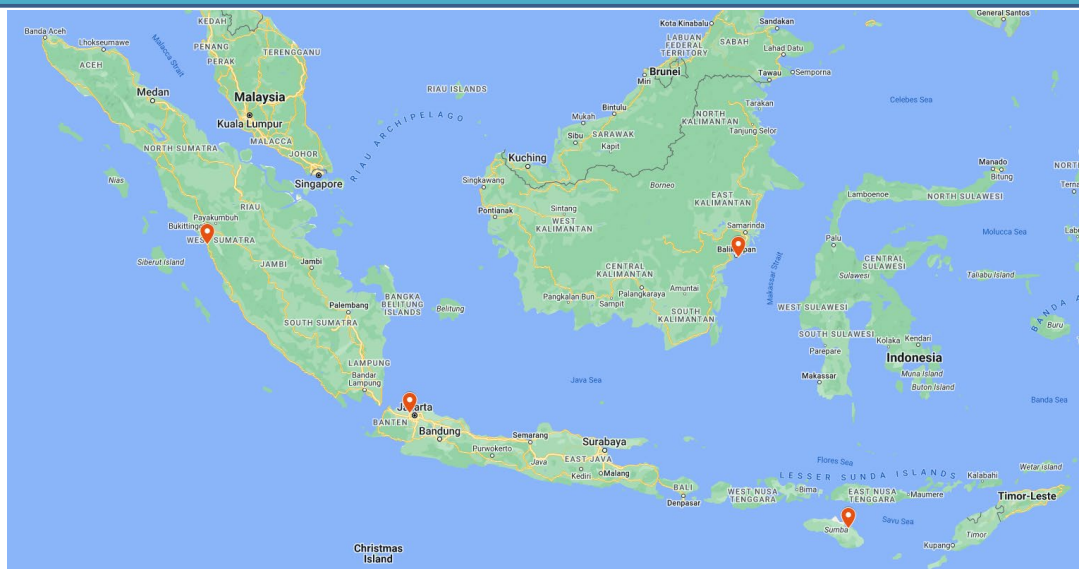
Low-middle income residential house model description cont'd

Category	Component	Description	Value
Envelope	Exterior Wall	100mm brick/plaster board	U-Factor: 3.57 W/m ² K
	Roof	Clay tile/metal decking	U-Factor: 3.48 W/m ² K
	Ceiling	19mm gypsum board	U-Factor: 2.59 W/m ² K
	Partition Wall	Plaster board	U-Factor: 2.58 W/m ² K
	Ground Floor	100mm concrete	U-Factor: 4.67 W/m ² K
	Window	Single pane clear glass	U-Factor: 4.98 W/m ² K SHGC: 0.70 Visible transmittance: 0.70
Infiltration	Air Changes per Hour (ACH)	Bedroom #1	4.8
		Bedroom #2	6.9
		Living room	3.0
		Kitchen/dining	3.0
Internal Loads	People (Number)	Bedroom #1	2
		Bedroom #2	1
		Living room	3
		Kitchen/dining	3
	Lighting Power Density	Bedroom #1 (W/m ²)	3
		Bedroom #2 (W/m ²)	3
		Living room (W/m ²)	5
		Kitchen/dining (W/m ²)	5
	Equipment Power Density	Bedroom #1 (W/m ²)	10
		Bedroom #2 (W/m ²)	5
		Living room (W/m ²)	15
		Kitchen/dining (W)	90
	Gas Range	Kitchen/dining (W)	540
HVAC	Cooling System	Mini split air conditioners	Single speed
	Capacity	Cooling sizing factor	1.15
	Efficiency	Coefficient of performance (COP)	2.5
	Thermostat	Cooling setpoint (°C)	25
Domestic Hot Water	Water Heater	N/A	N/A



4

We evaluated annual energy savings and thermal comfort metrics in four locations



5

We evaluated the following scenarios (a total of 200 cases for each location)

Category	Scenario	Description
Location	1. Balikpapan 2. Jakarta 3. Padang 4. Waingapu	Selected representative cities
Orientation	1. South 2. West	Front house facing direction
Air conditioning	1. Bedroom-Only AC	Two bedrooms, 9pm-5:30am, cooling setpoint 25 deg C
	2. No AC	No AC installed
	3. Whole-House AC	Whole house except the bathroom, 24/7, cooling setpoint 25 deg C
	4. Whole-House AC 12h	Whole house except the bathroom, 6pm-6am, cooling setpoint 25 deg C
Cooling solutions	Building envelope	Cool wall, cool roof, insulated wall, insulated roof
	Glazing	Low-e window, solar-control window film, interior shade, awning on the window
	Ventilation	Ceiling fan, natural ventilation

6

Model parameters of baseline and cooling solutions

Cooling Solutions	Model Parameters	Baseline	Level #1	Level #2
Cool Roof	Solar Reflectance (-)	0.25	0.40	0.60
Cool Wall	Solar Reflectance (-)	0.25	0.40	0.60
Insulated Roof	Additional Layer Thermal Resistance (m ² K/W)	N/A	0.176 (R-1)	2.552 (R-12.3)
	Thermal Emittance (-)	N/A	0.04	0.04
Insulated Wall	Insulation Layer Thickness (m)	N/A	0.075 (R-13)	0.15 (R-25)
Low-e Window	U-value (W/m ² K)	4.98	3.42	2.83
	SHGC	0.70	0.38	0.35
	Visible Transmittance	0.70	0.64	0.61
Solar-control Window Film	U-value (W/m ² K)	4.98	4.98	4.98
	SHGC	0.70	0.49	0.30
	Visible Transmittance	0.70	0.52	0.31
Ceiling Fan	Cooling Thermostat Setpoint (°C)	25.0	26.9	28.0
	Air Speed (m/s)	0.1	0.4	0.8
Awning	Awning Depth (m)	N/A	0.5	0.5
	SHGC	0.70	0.70	0.10
	Visible Transmittance	0.70	0.70	0.09
Interior Shade	Slat Solar Reflectance (-)	N/A	0.1	0.8
NV_DayAndNight	Window Open Area Fraction	0.0	0.5	1.0
NV_NightOnly	Window Open Area Fraction	0.0	0.5	1.0

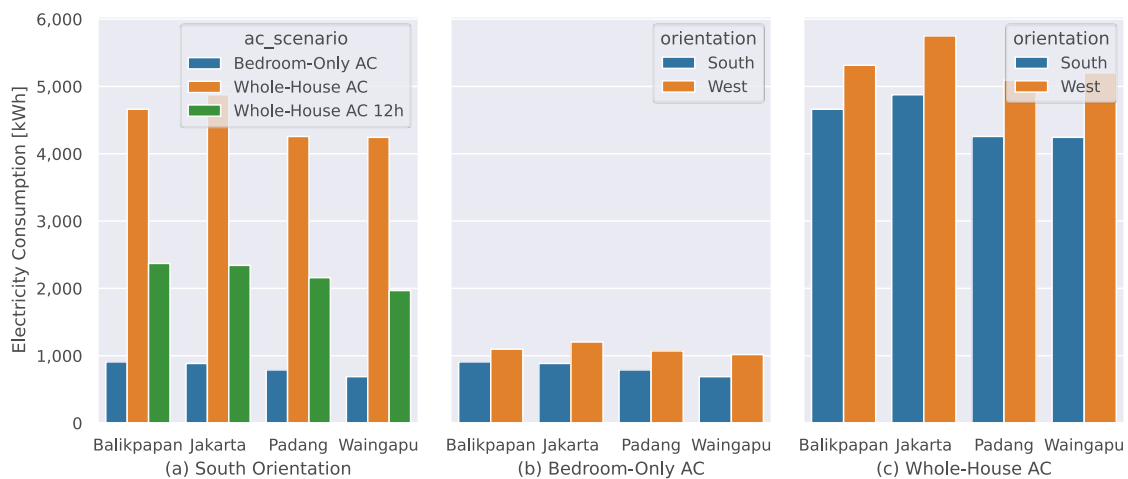
Notes

- Baseline: Clay tile/metal deck, no insulation, no aluminum barrier
- Insulation Roof #1: Baseline + Air Gap + Bubble wrap insulation (R-1, thermal emittance=0.04)
- Insulation Roof #2: Baseline + Foil-Faced Polyiso (3.5" Polyiso R-22, with wood rafter equivalent R-12.27, thermal emittance=0.04)
- NV_DayAndNight: Natural ventilation by opening windows when the outside air temperature is cool
- NV_NightOnly: Scheduled natural ventilation (1 am - 6 am) by opening windows when the outside air temperature is cool

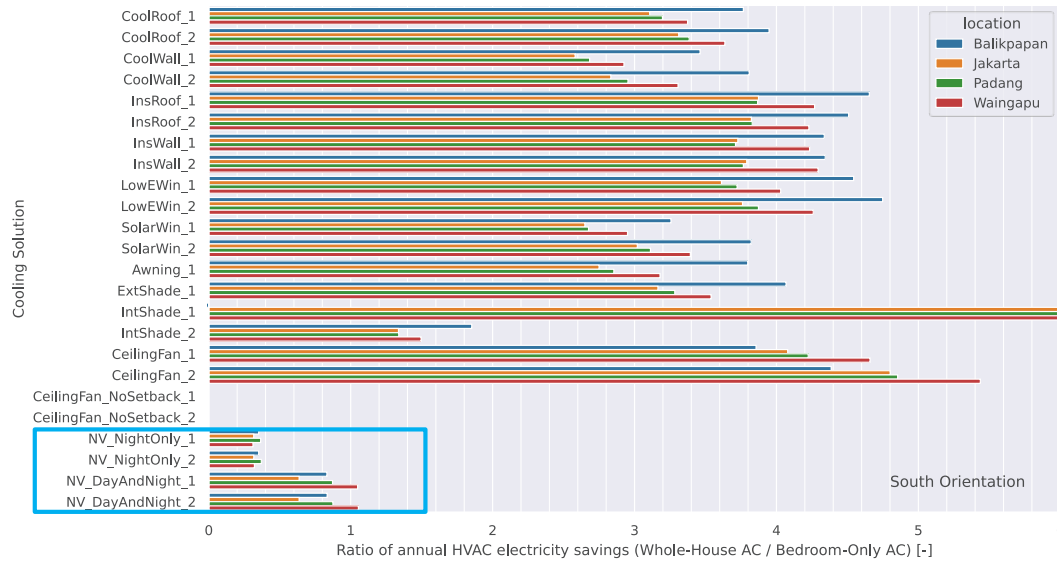


Annual HVAC electricity consumption for whole-house AC (32 m², 24h) are 5X those for bedroom AC (15 m², 9 pm-5:30 am)

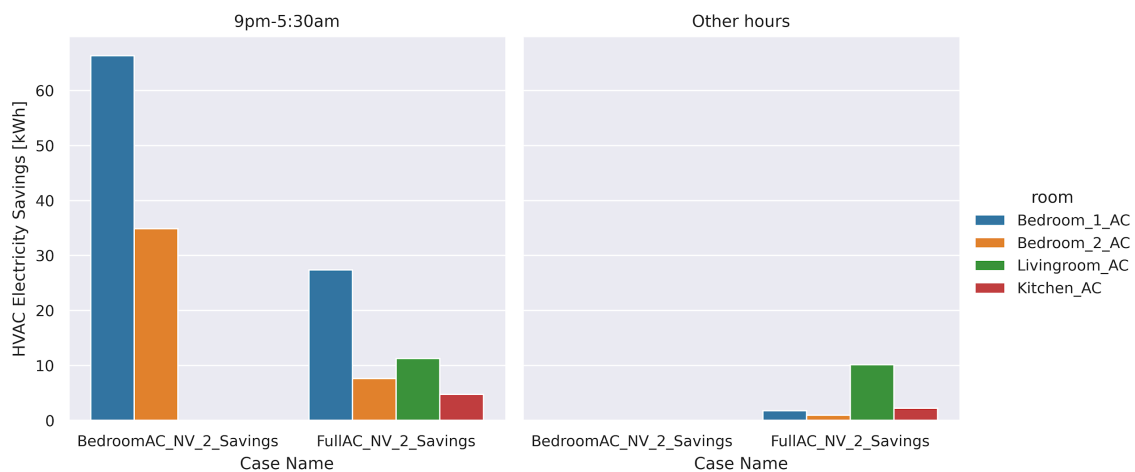
Comparison of Annual HVAC Electricity Consumption between Locations



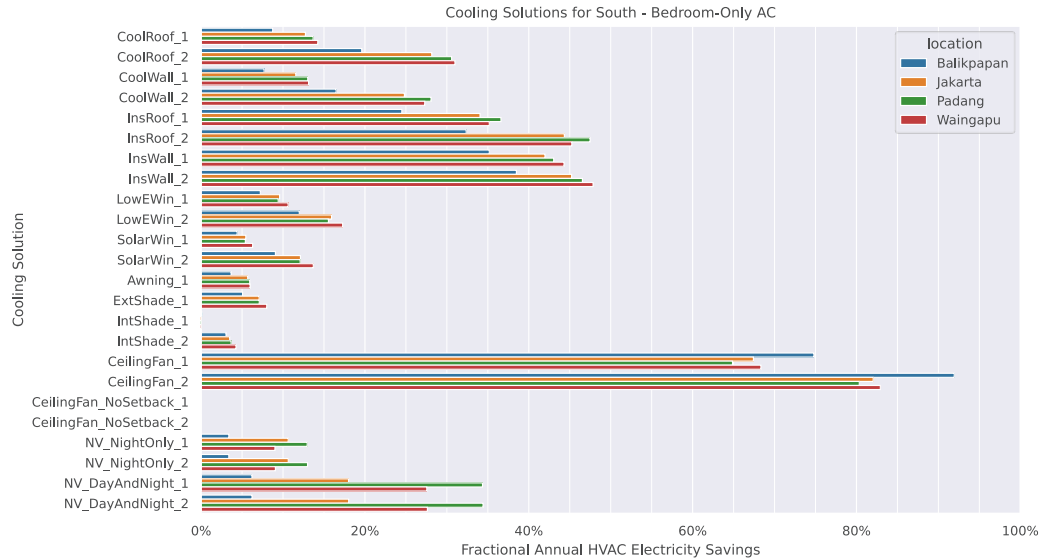
Energy savings for whole-house AC (32 m², 24h) are 5X those for bedroom AC (15 m², 9 pm-5:30 am) [except for opening windows for natural ventilation]



For the baseline operation between 9 pm and 5:30 am, higher HVAC electricity consumption is observed for the bedroom AC only compared to the full-house AC due to warmer bedroom and adjacent space temperatures when AC starts

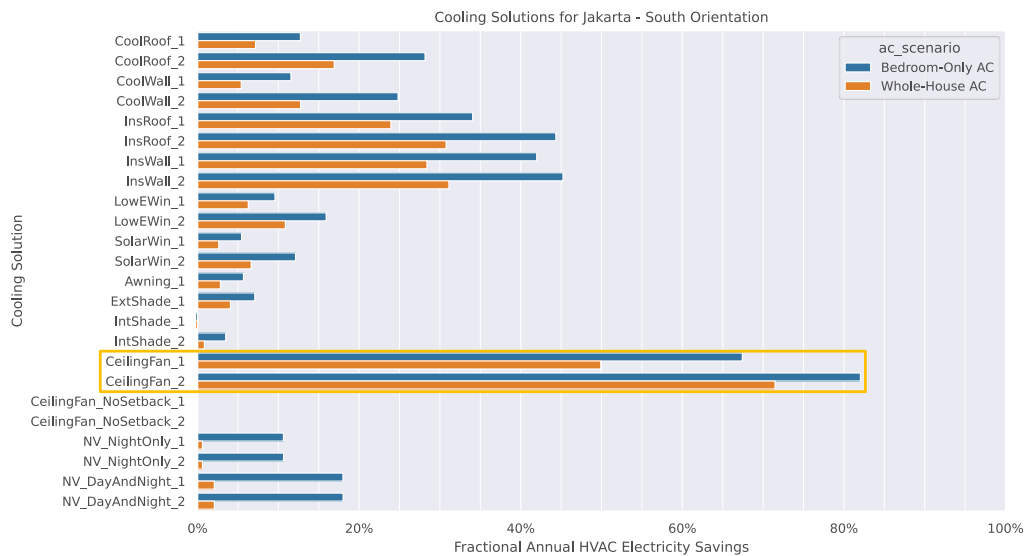


“Natural Ventilation” is more effective in Padang and Waingapu than in Balikpapan and Jakarta, yielding annual HVAC electricity savings of 25-35%



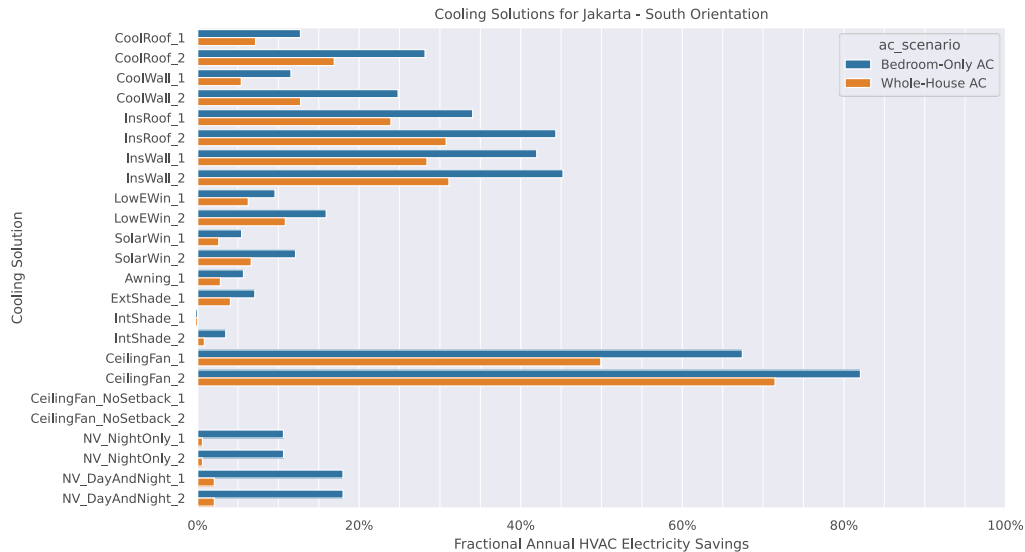
11

Ceiling fan with thermostat setback control achieves the highest HVAC electricity savings compared to all other cooling solutions



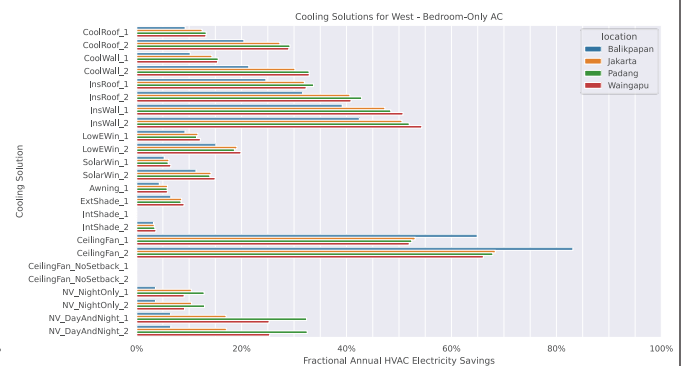
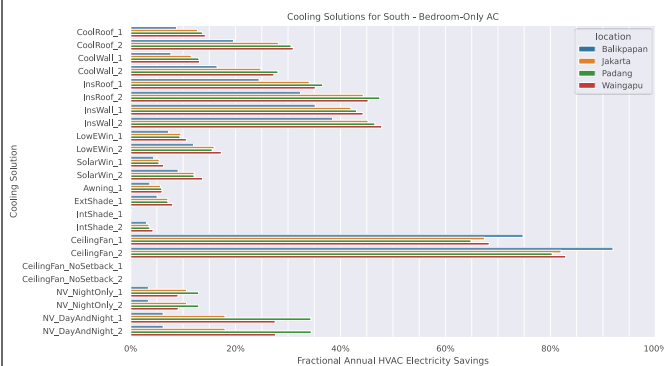
12

Within the building envelope category, insulated wall, insulated Roof, cool wall, cool roof, and low-e window are the top three cooling solutions, capable of yielding annual HVAC electricity savings of 15-45%



13

Low-e window and solar-control window film yield annual HVAC electricity savings of 10-17%, which is about half of opaque surfaces (wall and roof) cooling solutions' performance



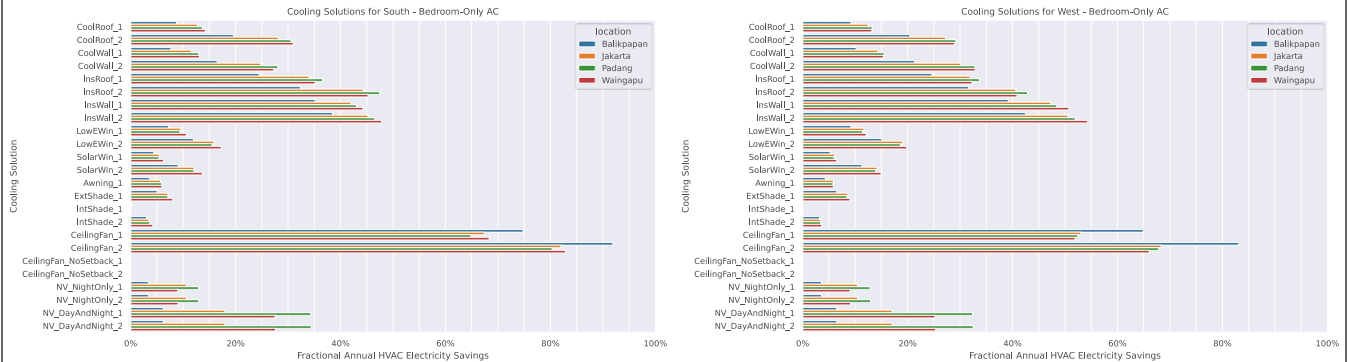
Category	Component	Description	Value	Net Areas (m2)
Envelope	Exterior Wall	100mm brick/plaster board	U-Factor: 3.57 W/m²K	30.64
	Roof	Clay tile/metal decking	U-Factor: 3.48 W/m²K	41.36
	Ceiling	19mm gypsum board	U-Factor: 2.59 W/m²K	36
	Partition Wall	Plaster board	U-Factor: 2.58 W/m²K	50.81
	Ground Floor	100mm concrete	U-Factor: 4.67 W/m²K	36
	Window	Single pane clear glass	U-Factor: 4.98 W/m²K SHGC: 0.70 Visible transmittance: 0.70	8.33

Window Fraction

- 23% total (North→26%, South→20%)

14

Compared with Shade_1, Shade_2 is preferred for both south- and west-facing houses, yielding annual HVAC electricity savings of 5%



Shade 1: "Interior shade with low solar reflectance" , and Shade 2: "Interior shade with high solar reflectance"

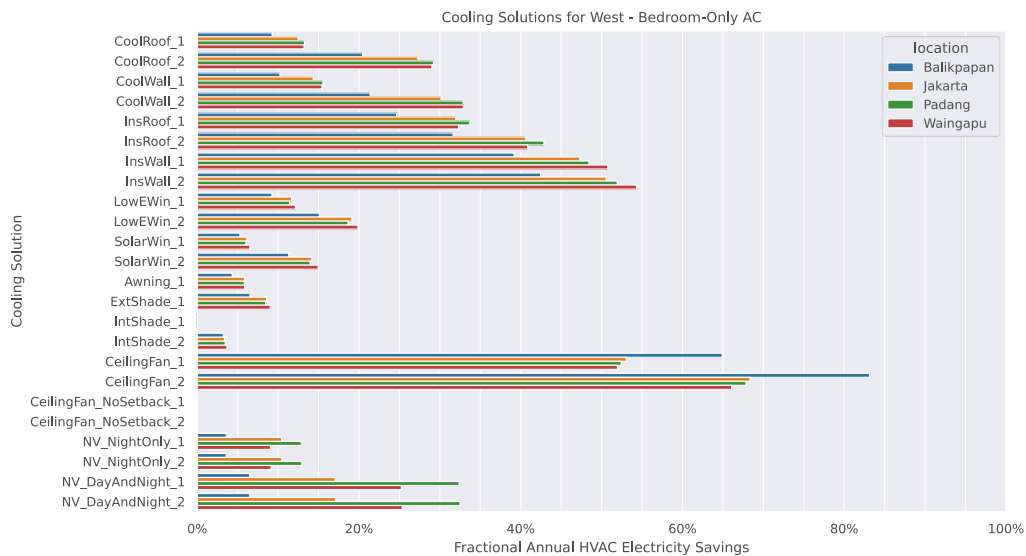
Shade 1 has very poor performance in reducing HVAC electricity consumption and may have a negative effect on west-facing houses.

"Awning on windows" yields similar HVAC electricity savings (5-8%) for both south- and west-facing houses across all locations.



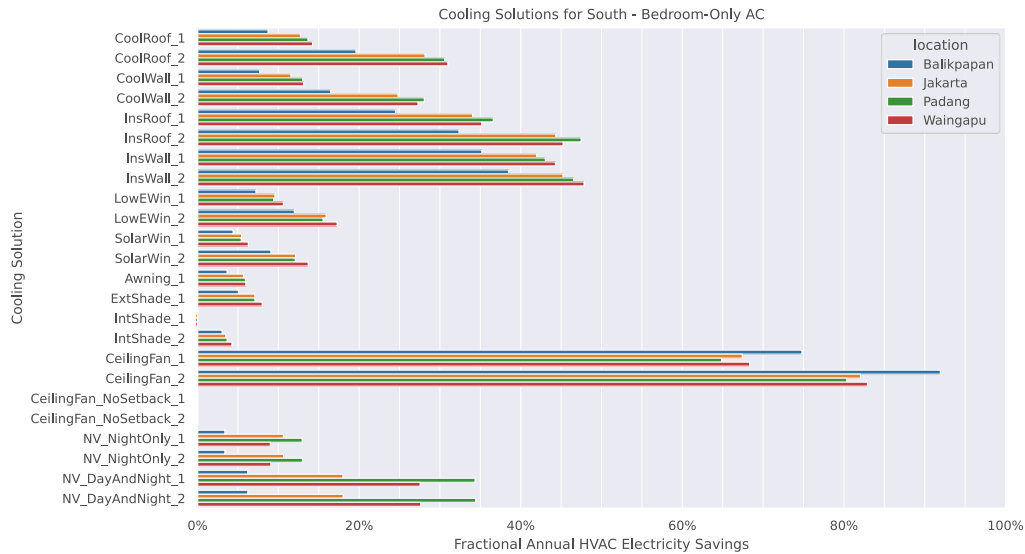
15

Between cool wall and cool roof, cool wall is more effective for west-facing houses due to the cooling load through exterior walls on the east and west sides



16

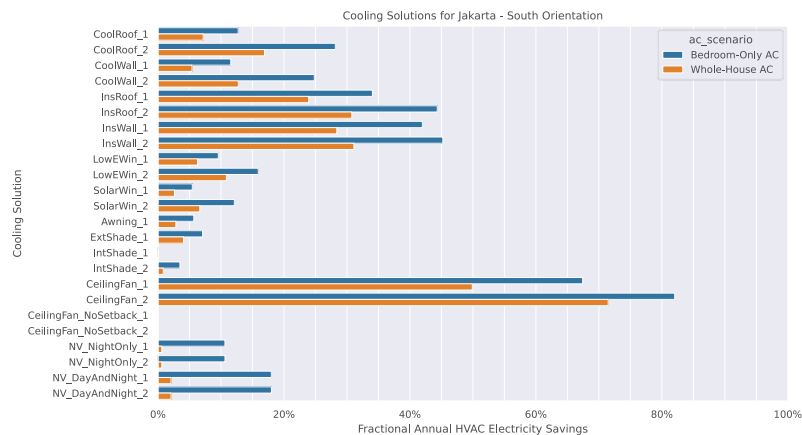
Natural ventilation can be twice as effective when windows are opened based on outside air temperature rather than according to a schedule



17

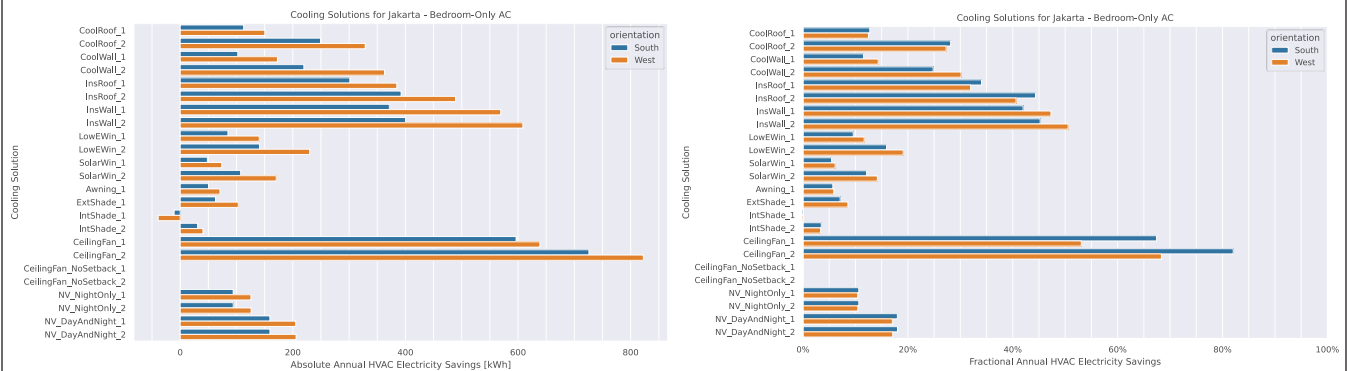
Passive cooling solutions implemented in a portion of the house result in higher fractional HVAC electricity savings in the context of bedroom AC only, when compared to running the full house AC 24 hours

Natural ventilation can potentially save up to 20% of HVAC electricity consumption in the context of bedroom AC usage (from 9 pm to 5:30 am) due to high indoor and adjacent spaces temperatures when the AC unit starts.



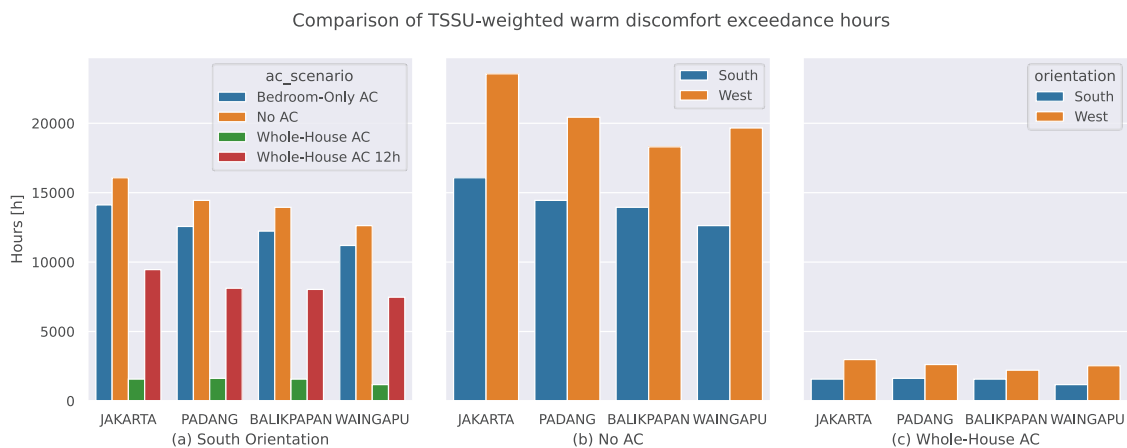
18

While most cooling solutions yield higher absolute HVAC electricity savings in west-facing houses than in south-facing houses, the fractional savings can be lower due to the higher baseline HVAC consumption



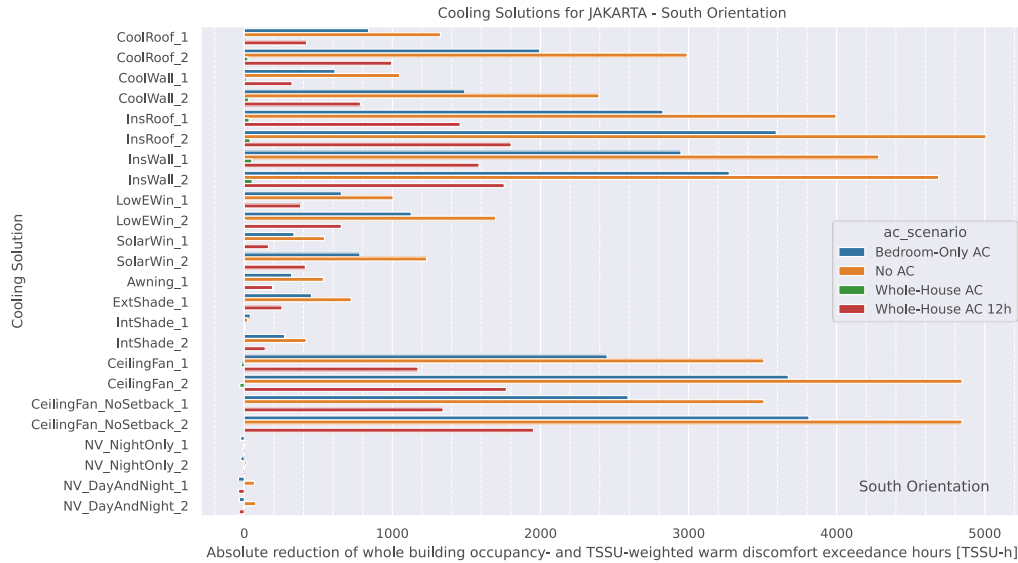
19

A whole-house AC system yields the fewest TSSU-weighted warm discomfort exceedance hours when compared to other AC scenarios, and a south-facing orientation is preferred

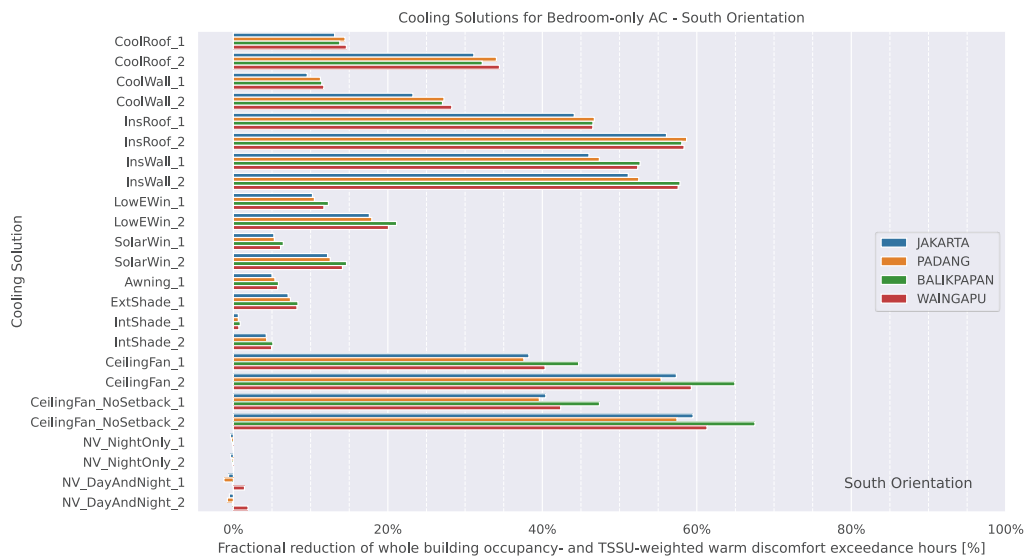


20

Most passive cooling solutions can reduce the occupancy- and TSSU-weighted discomfort exceedance hours while saving HVAC electricity consumption to varying degrees, except for “Natural Ventilation by opening windows”



The performance leaders in the fractional reduction of occupancy- and TSSU-weighted discomfort exceedance hours are ceiling fan, insulated roof, insulated wall, cool roof, cool wall, and low-e window, with reductions ranging between 20% and 60%



Thank you!

Ronnen Levinson, Ph.D.

Staff Scientist and Leader, Heat Island Group
Lawrence Berkeley National Laboratory
Berkeley, California, USA
tel. +1 510-486-7494
RMLevinson@LBL.gov



23



Scoping Indonesia's Building Sector Cost-Benefit Analyses for Cooling Technologies

Prepared for the Net Zero World Initiative's
Indonesia Building Decarbonization Working Group
Subgroup C: Analysis and Financing

October 2023



**NET
ZERO
WORLD
INITIATIVE**

Accelerating Global
Energy System
Decarbonization

Scoping Indonesia's Building Sector Cost-Benefit Analyses for Cooling Technologies

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Scoping Indonesia's Building Sector Cost-Benefit Analyses for Cooling Technologies

1 Introduction

Supported by the New Zero World (NZW) Initiative, this scoping paper sets out the methodological framework of a cost-benefit analysis (CBA) to estimate the consumer, national, and/or industry costs and impacts of adoption of several building sector passive or low-energy cooling solutions at various energy performance levels (e.g., natural ventilation, high-performance windows, and ceiling fans) in Indonesia. Once the scope of the CBA is agreed, performance of the subsequent analysis will support investment decision making by the Indonesia Just Energy Transition Partnership (JETP). Further detail on the objectives of this work, and the organizations progressing it, is provided in the background information below.

1.1 Background on the Net Zero World Initiative

The United States has launched a flagship, whole-of-government partnership to accelerate global energy system decarbonization, in an effort to contribute to global climate change response by sharing and leveraging the U.S. Department of Energy's (DOE) research and knowledge capabilities. The Net Zero World (NZW) Initiative brings together nine U.S. government agencies and 10 U.S. DOE laboratories, to partner with countries to develop tailored, actionable technology road maps and investment strategies, aimed at achievement of net zero, resilient, and inclusive energy transitions.

The NZW Initiative is managed by a cross-lab Net Zero World Action Center (NZW AC) with country, technical, investment, partnership, and operations teams managing the design and implementation of the initiative, in close coordination and with guidance from the U.S. Government agencies. Through an initial focus on bilateral programs in key sectors, with countries that have potential for material impact on global decarbonization, the NZW Initiative will enable country partners to access the resources and technical expertise of U.S. federal agencies, U.S. DOE national laboratories, businesses, think tanks, and universities, in collaboration with global partners and philanthropies, to accelerate action towards net zero emissions.

Indonesia was identified as an initial priority country for the NZW Initiative, with an early focus on action for decarbonization of the buildings sector. In February 2023, the NZW Initiative convened a first workshop for private sector industry, policymakers, academia and research, and other built environment professionals in Indonesia to discuss opportunities, solutions, and policies for advancing net zero goals for Indonesia's buildings.

1.2 Background on the Just Energy Transition Partnership (JETP) in Indonesia

Launched on November 15, 2022 at the G20 Leaders' Summit in Bali, the Just Energy Transition Partnership (JETP) is an agreement to mobilize an initial USD 20 billion in public and private financing to decarbonize Indonesia's energy sector, using a mix of grants, concessional loans, market-rate loans, guarantees, and private investments. The President of Indonesia and a newly-formed International Partners Group (IPG), led by the United States and Japan and including Canada, Denmark, the European Union, France, Germany, Italy, Norway, and the United Kingdom, issued a Joint Statement to formalize this landmark partnership.

Almost three months after the G20 announcement of the JETP for Indonesia, a JETP Secretariat was established on February 16, 2023 within the Government of Indonesia's (GOI) Ministry of Energy and Mineral Resources (ESDM), and tasked with administering the partnership agreement, creating an investment plan within six months, and connecting funders to projects. The JETP Secretariat launch event came during the United States and Japan joint visit of the IPG co-leads, to ensure the success of the envisaged USD 20 billion investment in Indonesia's energy transition. The GOI is eager to identify pilot projects for JETP funding while it is in the process of creating a much larger investment plan, though to do this successfully, there is work to do to lessen perceived investor risk and remove barriers that have previously dissuaded financiers and companies from investing in clean energy projects in Indonesia.

The JETP Secretariat has established four JETP Working Groups (WG) with international organizations serving as leads: (a) Technical – International Energy Agency (IEA), (b) Policy – World Bank, (c) Finance – Asian Development Bank (ADB), (d) Just Transition – United Nations Development Program (UNDP). The JETP Secretariat is also currently drafting the Comprehensive Investment and Policy Plan (CIPP) that will guide JETP financing/investment over the next three to five years. The first phase of the CIPP will be released in mid-October 2023, with an emphasis on required energy sector investment. ADB also indicated that a fifth WG is being discussed for launch in the near term, that would focus on decarbonization of other sectors/industries (including buildings and transport).

1.3 The Need for Cost-Benefit Analyses to inform JETP investment decision making for the buildings sector in Indonesia

The NZW Collaborative Work Program with the Government of Indonesia (GOI) includes technical assistance and investment mobilization facilitation to accelerate deployment of energy efficiency technologies and solutions for the building sector. A key outcome from the February 2023 Workshop was the establishment of a Net Zero World Indonesia Building Decarbonization Working Group (NZW IBDWG) to take forward building sector actions, co-chaired by Lawrence Berkeley National Laboratory (LBNL), The Indonesian Ministry of Energy and Mineral Resources (ESDM), and local industry representative body the Indonesian Energy Conservation and Efficiency Society (Masyarakat Konservasi dan Efisiensi Energi, known as MASKEEI).

Given the strong likelihood that the JETP Secretariat will seek robust analysis to inform financing/investment in the building sector in the second phase¹ of the CIPP, and also invite NZW to participate in a fifth WG with a buildings sector element, NZW is now progressing cost-benefit analyses (CBAs) to estimate the consumer, national, and/or industry costs and impacts² of adoption of several building sector cooling solutions (e.g., inverter air conditioners, natural ventilation, high-performance windows, and ceiling fans). The CBAs will be used to inform JETP investments in policies and programs to advance research, development, deployment, and commercial adoption (RDDCA) of building sector cooling solutions in Indonesia, to address the country's projected 75% increase in energy demand by 2040. According to the IEA, this growth could be limited to under 50% through energy efficiency, with the largest potential savings coming from the buildings sector (38%) through measures such as minimum energy performance standards (MEPS) and improvements in building envelope.³

As noted, mechanical cooling and air-conditioning loom large as the principal driver of increased energy demand in Indonesia. Given the specific issues related with these technologies in their own right, the NZW Initiative intends to progress two strands of cost benefit analysis:

1. one that relates to passive cooling technologies and building materials (that is the subject of the remainder of the CBA scoping in this paper); and
2. an extension/supplement to an existing detailed study from 2020 inverter-driven (variable-speed) air conditioner (AC), to quantify energy equity metrics (e.g., energy burden for households) to inform JETP investments⁴. This prior study found that AC sales in Indonesia are forecasted to increase by 7.5% each year, which suggests that the peak power demand could increase by over 20 gigawatt (GW) by 2035⁵. Large-scale deployment of highly efficient and increasingly affordable inverter-driven (variable-speed) ACs could reduce Indonesia's AC electricity use by 30–50%, and is the principal technological solution for whole-building cooling efficiency in Indonesia. In this context, a team of lab researchers assessed consumer, national, and manufacturer costs and impacts associated with adoption of highly efficient inverter-driven ACs at various minimum energy performance standards (MEPS), evaluating consumer lifecycle cost savings (LCC), consumer payback period, national energy savings and carbon dioxide (CO₂) mitigation by 2035, consumer net present value (NPV), manufacturer NPV, total manufacturing investment required, and several other metrics. NZWI will now build upon the 2020 study to collect additional data as required, identify and add several energy equity impacts to the study, and develop and deliver briefing material on results of the analysis that will help inform JETP investments. These include employment, imports, exports, energy burdens for low-to-moderate income (LMI) consumers, and/or gross domestic product (GDP).

¹ Discussions held between NZW and ADB in June 2023 have indicated that the first phase of the CIPP will *not* include guidance for JETP financing/investment for the buildings sector, although the ADB will work to “tee-up” building sector financing/investment for a second phase of the CIPP, which is anticipated to launch late in 2023 (after the first CIPP is complete).

² Such as life-cycle cost (LCC) and payback period (PBP) impacts to consumers likely to result directly from adoption of high-performance building sector cooling solutions, or the aggregate impacts at the national level of adoption of high-performance cooling solutions, as measured by the net present value (NPV) to all consumers.

³ IEA. 2023. “E4 Country Profile: Energy Efficiency Indonesia: Energy Efficiency in Emerging Economies (E4) programme findings and work.” Accessed August 1st, 2023 at <https://www.iea.org/articles/e4-country-profile-energy-efficiency-indonesia>

⁴ Letschert, Virginie, et al. (2020), *Accelerating the Transition to More Energy Efficient Air Conditioners in Indonesia*, Lawrence Berkeley National Laboratory

⁵ McNeil, M et al (2019), *Forecasting Indonesia's electricity load through 2030 and peak demand reductions from appliance and lighting efficiency*, Lawrence Berkeley National Laboratory

The initial planning for the first of these two CBA activities establishes adoption of building sector **passive or low-energy cooling solutions** at various energy performance levels (e.g., natural ventilation, high-performance windows, and ceiling fans) as a principal focus for building sector decarbonization activity. As the incomes of Indonesia's middle classes rise and access to electricity improves, along with rising global temperatures, a clear trend is towards an increasing demand for energy used for cooling. International Energy Agency (IEA) predictions of air-conditioner (AC) adoption (2019) have the number of AC units in the ASEAN region rising from 40 million in 2017 to 300 million in 2040; half of these are expected to be in Indonesia. Large-scale adoption of mechanical cooling solutions gives rise to concerns about the incompatibility of increased building electricity loads and national decarbonization objectives; this will be explored further in the second proposed CBA. Greater emphasis on increasing building envelope performance, passive or hybrid cooling strategies, incorporation of thermal storage technologies, effective energy management and operations, smart controls, tenant education, and raising the awareness of the impacts of consumer behavior are therefore critical actions to reduce cooling loads and emissions.

Under the NZW IBDWG Subgroup C (SGC): *Analysis and Financing*, this paper establish a CBA framework to estimate the consumer, national, and/or industry costs and impacts of adoption of several building sector passive or low-energy cooling solutions at various energy performance levels (e.g., natural ventilation, high-performance windows, and ceiling fans). The CBA will be used to inform JETP investments in policies and programs to advance research, development and deployment of building sector cooling solutions in Indonesia.

2 Cost-Benefit Analysis Methodology

Cost Benefit Analysis (CBA) is a standard appraisal tool for governments in both developed and developing economies. CBA aims to quantify, in monetary terms, the costs and benefits of a proposal, including items for which the market may not provide a satisfactory measure of economic value. CBA offers the possibility of capturing impacts of a project beyond financial returns, which is particularly relevant when assessing the merits of a public sector investment, by providing a measure of total economic value of the environmental and social changes caused by a project, to be weighed alongside any financial benefits in the investment decision.

CBA therefore offers a methodical approach to decision-making, enabling stakeholders to make well-informed choices by assessing advantages and disadvantages under a data-driven and evidence-based approach. The purpose of this section (and this scoping paper) is to set out a structured framework for cost-benefit analysis as it relates to cooling solutions in Indonesia, supplemented by sensitivity analysis techniques designed to address uncertainties that often underpin complex choices.

CBA is typically applied at the project level, to determine the overall viability of a proposed investment. JETP is receptive to considering broadly based investments into building cooling improvement ‘scenarios’, as a part of its efforts to accelerate decarbonization in Indonesia. These scenarios may be made up of one or more technology solutions to be applied, and are not applied in isolation of other socio-economic factors that may also need to be considered.

Conduct of the CBA is proposed in three broad stages:

1. Defining the scope of project and level of ambition, in terms of the building type and cooling technologies, and level of efficiency to be pursued, to construct a set of priority impact ‘scenarios’ that can be considered as a basis for decisions on investment. In coordinated support of these scenarios, the NZW IBDWG Subgroup A is simultaneously working to:
 - select approximately 10 cooling solutions for the tropical climates of Indonesia, and one building space type, for annual energy savings potential / thermal comfort improvement analyses. These 10 solutions will be made up of one or more technologies or techniques, and will serve as the basis of the CBA to be performed.
 - establish the performance of a baseline building that does not employ any of the solutions would be established, before assessing the merits of deployment of each individual solution at 3-5 levels of efficiency—e.g., ‘good’, ‘better’, and ‘best’ window technologies. Time and effort permitting, some packages of solutions (e.g., baseline buildings + multiple solutions) may also be considered.
 - decide on the timeframe over which the costs and benefits will be measured, and apply discount rates to future costs and payoffs.
2. The CBA will then be developed to consider the chosen ‘scenarios’, based on application of one or more of these solutions, and extrapolating to national-level impacts by further applying other assumptions that encompass overall energy use trends, cultural issues and practices, government policy settings, and planned speed and ease of implementation. The broader costs and benefits of each of the priority impact scenarios must be established and estimated as accurately as possible, including assigning monetary values and conducting research to obtain reliable data. It also requires a determination for whom costs and benefits will be counted, and which outcomes will be emphasized (e.g. consumer life cycle cost (LCC) and payback period

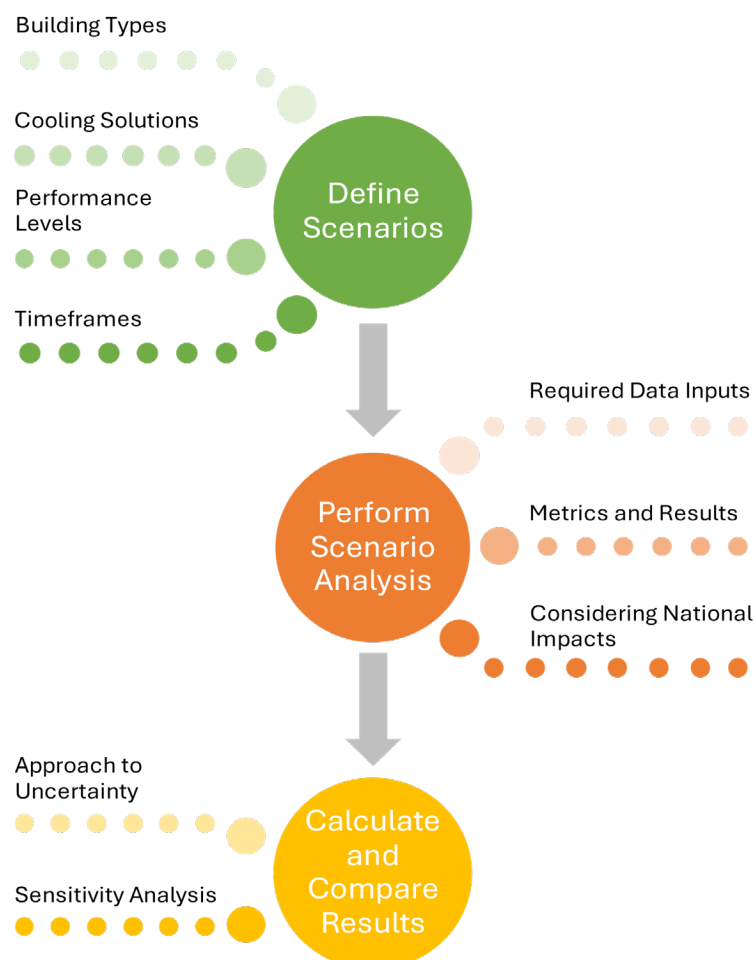
(PBP) analyses, energy burden analysis for low-to-moderate income (LMI) consumers, and national net present value (NPV) analysis).

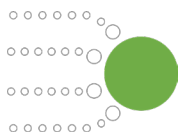
3. The priority impact scenarios can then be compared against the baseline and against each other, based on data availability, and outcomes against overall JETP goals. Calculations must be performed so that conclusions can be drawn from the analysis, and the merits of the various scenarios considered. This includes accounting for uncertainty, and considering some sensitivity analysis on which to draw conclusions about the different scenarios.

3 Components of the Proposed CBA Framework

In broad terms, the framework proposed for CBA of different building cooling solutions under the NZW initiative set out above is presented schematically in Figure 1, and each section expanded upon below. This Framework can be used to guide the reader through the remaining scoping considerations presented by this paper.

Figure 1. Proposed Scope and Framework for Cost Benefit Analysis on whole-of-building cooling solutions for Indonesia's building sector





3.1 Define Scenarios

As its departure point the CBA will draw upon work completed by NZW IBDWG Subgroup A to identify cooling solutions, as outlined in Part 2.1. This work will yield a range of useful data about energy savings and thermal comfort impact from a range of cooling solutions, as well as cost data.

To effect the CBA, the proposed interventions need to be better defined into a set of ‘scenarios’ that can serve as the basis for overall cost and benefit considerations. The scenarios will be described as a series of actions and interventions that can be compared against a baseline, that will allow for consistent comparisons. Having made an assessment of the merits of various courses of action at the individual building/end user level, extrapolation to economy-wide impacts from the rollout of a broader program can be considered, introducing other parameters which will need to feature into the calculation. The components of scenario definition are broadly outlined in the section that follows below.



3.1.1 Building types

Both desktop research and consultations in Indonesia have made it clear that this CBA should focus on measures to be applied in the residential sector, with a focus on low and middle income (LMI) residences. According to various analyses and reports including ESDM’s own *Roadmap for an Energy Efficient, Low-Carbon Buildings and Construction Sector In Indonesia* (2021), the residential sector accounts for as much as 89% of total building floorspace in the country, and is the fastest growing sector in terms of both energy use and new dwelling construction. Residential buildings for LMI Indonesians is also the subsector that needs the most support in the way of financing for transition technologies and design measures.

To perform the analysis, a prototype Indonesian residential building will need to be established to create a baseline. The U.S. has substantial data to draw upon in considering different building categories, in terms of their size, type (e.g., single-family home or apartment building), total conditioned floor area, window-to-wall ratio (WWR), thermal properties of building materials used, rating and prevalence of existing cooling appliances, and so on⁶.

Subgroup A is developing advanced modelling to develop a home ‘prototype’ which can be analyzed under four different climate conditions pertaining to Indonesia. This prototype building and the assumptions applied to it can then be used to simulate baseline energy performance. Assumptions must also be made based on building location and climate zone, age, orientation, construction

⁶ See for instance Levinson et al (2021), *Methodology to assess performance of resilient cooling technologies*, Lawrence Berkeley National Laboratory and Center for the Built Environment, University of California, Berkeley

composition, and the degree of thermal discomfort experienced by occupants under normal conditions.

In performing the CBA, it is further recommended that the analytical team collaborate with Subgroup D of the NZW IBDWG, which is identifying pilot projects, in terms of selecting building types and technologies.



3.1.2 Cooling solutions

Most Indonesians live in areas in which average daily temperatures exceed 25 °C. Even when and where temperatures are lower, high humidity levels increase perceived temperatures. Space cooling needs in Indonesia are among the highest in the world, with an average of over 1 500 cooling degree days per year. Comfort provided by air conditioners is available to only a fraction of the population today, with one-in-ten households having an air conditioner. Fans are much more common at an average of 1.5 units per household. With increasing income, purchasing an air conditioner is high on the list of priorities for many households and businesses.

Given the intended coverage and separate detailed treatment given by a second CBA on priority efficient AC technologies, planned CBA scope of works outlined in this paper relates to the most appropriate passive cooling solutions for tropical buildings, including building materials, design, building envelope, and non-energy (nature-based) technologies that displace mechanical and electrical cooling.

The solutions to be included in the CBA that supplements this AC analysis will therefore be selected from the following: phase change material; displacement cooling; cool surfaces (roof and wall); louver shading; adaptive façade; low-e windows; solar control window film; radiant cooling; green roof and wall; breathable wall; combination of perforated block and evaporative cooling; building integrated photovoltaic (BIPV) roof and façade; ceiling fan; curtain - window treatment; waste to facade insulation material; insulated roof and wall; organic and natural insulation material (bamboo, wood, leaves); shading devices for windows; night cooling; roof ventilation (ventilation shaft); cross ventilation; and dehumidification desiccant. A separate paper is being developed and will be tabled to further inform JETP's deliberations about these technologies and their applicability in Indonesia.

As noted, approximately ten of these solutions will be analyzed by NZW IBDWG Subgroup A as inputs to the CBA. The baseline or prototype building is being modelled with different degrees of application of passive technologies, both in isolation and in combination, to determine the most cost-effective and readily applicable cooling technologies to inform JETP investment.



3.1.3 Performance Levels

For all solutions embedded in each scenario for the CBA, it will be necessary to define the desired level of ambition in each case for the level of efficiency performance to be achieved. For example, IEA (2021) has found that appliances and equipment sold in Indonesia today are on average 30 - 50% less efficient than the most efficient technologies available on its domestic market. The best available air-conditioner in Indonesia is more than twice as efficient as the market average, and the best available technologies globally are around three-times more efficient.

The US has considerable data on the performance and cost of passive cooling technologies, and this data may be leveraged for the purposes of the CBA⁷. Indeed the work of NZW IBDWG Subgroup A will pursue this in its parallel study of the performance of chosen technologies, which will form a core input. While it would be ideal to consider the costs and benefits of each technology applied at multiple levels of ambition – e.g. ‘good’, ‘better’ and ‘best’ technologies – the lack of available data on market performance of various technologies in Indonesia, especially non-electrical technologies, may prove a challenge. Moreover, this will also give rise to a large number of scenarios that may be unmanageable for comparative purposes. For the CBA, and consideration of overall results, it is therefore suggested to consider the prototype building performance against a limited number of efficiency setpoints for each technology – for example, a ‘best available’ or ‘maximum ambition’ installation, with the associated costs and benefits, along with an assumed ‘mid-level’ installation, that will achieve half of the energy savings of the best available technology, with changed cost and benefit parameters.



3.1.4 Timeframes

The timeframe applied in the CBA calculations is important as it helps to account for the time value of money, i.e. the concept that a sum of money today is worth more than the same sum of money in the future, and so future financial benefits need to be ‘discounted’. A discount rate allows future costs and benefits under the CBA to be converted into present value equivalents.

The discount rate is used to calculate the Net Present Value (NPV) of a project. The choice of discount rate can reflect the level of risk associated with a project, with a higher discount rate typically applied to riskier or more uncertain projects. On the other hand, it can also reflect societal preferences and policy goals, such as long-term environmental benefits or social welfare implications. Additionally, discount rates can also be influenced by physical factors such as the underlying useful life of a technology or project over which benefits might be accrued, or underlying rates of inflation or cost of capital.

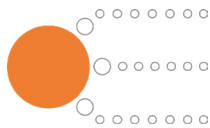
⁷ See for instance the approach taken in Section 10 of Levinson et al (2021), *Methodology to assess performance of resilient cooling technologies*, Lawrence Berkeley National Laboratory and Center for the Built Environment, University of California, Berkeley

In the envisaged CBA, benefits will likely accrue over a long period from any cooling technology interventions. It will be important to match achievement of any results with the time horizon for JETP investments, which are not specifically defined, especially as it relates to energy efficiency technologies or actions. At present, JETP time horizons are listed as

...to define pathways to achieve new and accelerated targets by:

- *Peaking total power sector emissions by 2030, shifting the projected emissions peak forward;*
- *Capping power sector emissions at 290 MT of CO₂ in 2030, down from the baseline value of 357 MT CO₂;*
- *Establishing a goal to reach net zero emissions in the power sector by 2050, bringing forward Indonesia's net zero power sector emissions target by ten years; and*
- *Accelerating the deployment of renewable energy so that renewable energy generation comprises at least 34 percent of all power generation by 2030, roughly doubling total renewables deployment over this decade compared to current plans.*

Under these statements, it is clear that 2030 is a touchstone year for any JETP investments; analysis should therefore present a picture of costs and benefits by 2030, as well as over the whole life cycle.



3.2 Perform Scenario Analysis

Having (under Part 3.1) reached an agreed definition of the reference building type, cooling technologies and performance levels that make up each scenario, and the timeframe for the analysis, the analysis can then focus on acquiring the data needed to understand performance of each scenario relative to each other (Part 3.2.1), and the merits of each approach according to agreed metrics and output results (Part 3.2.2).

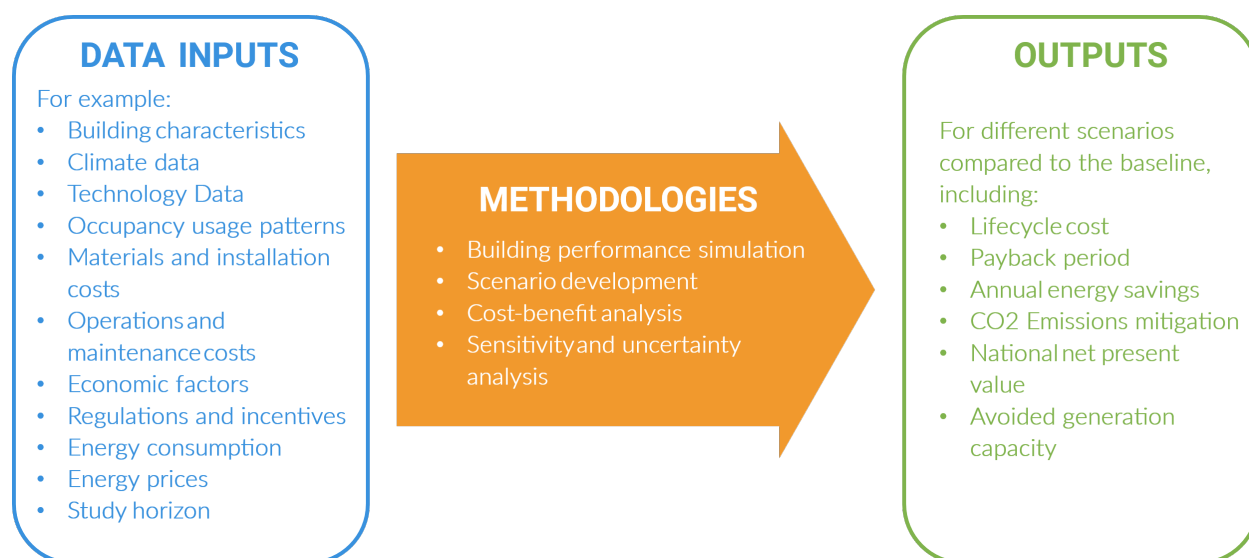
To comprehensively evaluate the performance of various building solutions, and their attractiveness as an investment proposition, it is imperative to start by constructing and analyzing alternative scenarios for the same base building. It is essential to start with a **Baseline Scenario** that encompasses the existing systems, technologies, and energy sources present in the building at the time of conducting the analysis. Constructing alternative scenarios by selecting and applying a combination of cooling technologies will provide a nuanced understanding of their respective performance against the baseline, and enable investment decisions by considering both the costs of, and benefits from, such measures.

This micro- or single-building level view of each scenario must then be scaled up to consider national-level impacts of any broader programmatic investment, targeting a number of buildings to which the technology measures of each scenario are applied. This will require more than a simple

multiplication of impacts at an individual building level, supplementing the analysis with broader parameters of the investment's costs and benefits, including e.g. impacts on the national energy grid, jobs, economic livelihoods, and national greenhouse gas emissions (Part 3.2.3). This will allow the scenarios to be more broadly expressed in terms of national impacts and JETP objectives, and to consider the outcomes that would be achieved both with and without JETP investment, which is the principal purpose of the CBA.

Cost-benefit analysis (CBA) for implementing cooling solutions for buildings requires consideration of various data points specific to the local context related to both a) technology specifications and overall energy performance; and b) economic and cost parameters, both for individual measures and broader economic factors, that will ultimately dictate investment decision making. An overall framework of data flows for the cost-benefit analysis is presented in Figure 2. The framework structures coherent stages for the CBA of data requirements, methodologies, and expected output that will serve to formulate insights and conclusions for the cost-benefit analysis.

Figure 2: Data flow framework for the CBA



3.2.1 Required Data Inputs

Across the categories outlined in Figure 2, there is no doubt that data limitations will restrict the accuracy of the CBA study. The expert U.S. and Indonesia teams working under NZW IBDWG Subgroup A have substantial background and U.S. data to draw upon in modelling the performance of different passive cooling technologies in buildings with given characteristics, and this will be drawn upon heavily to establish building prototypes and baseline energy performance in Indonesia's climate. There are also numerous case studies and analyses performed as a once-off local investigation into the efficacy of passive cooling strategies, that may serve as useful further

references for the CBA: see for instance the work of Nugroho (2022) and Chen et al (2020)⁸. Note that the lack of a national data set on building performance is also a possible objective to be addressed under NZWI, with the formation of a national Building Research Center in Indonesia.

Beyond assumed individual building characteristics and technology performance data, there is a range of data required to both effectively develop scenarios and perform cost benefit analysis, some of which are listed above and described in more detail below:

- **Upfront Materials Costs:** Refers to the initial expenses incurred when starting a project. These costs are associated with getting the project completed before revenues/savings or benefits are realized, and may differ quite widely in terms of access, availability and cost between locations.
- **Design and Construction:** These are cost components associated with planning, designing, building, and installing cooling solutions. These costs can represent a significant portion of the initial investment required for the project and can be driven by items such as engineering site works and labor for installation. There may also be costs with conducting land surveys, obtaining necessary permits, licenses, and approvals from regulatory authorities, and complying with legal and regulatory requirements before initiating a project. Kementerian Pekerjaan Umum dan Perumahan Rakyat, or the Ministry of Public Works and Housing (Kemen PUPR), is Indonesia's governing body issuing these permits.
- **Operations and Maintenance Costs:** These costs are part of the annual recurring cost needed to keep the installed technology of the project operational and functioning. The costs of electricity and other utilities are examples of variable costs, while fixed costs may include equipment parts replacement and maintenance regimes.
- **Economic Factors:** Metrics that affect the timing and value of future costs and benefits impact on the analysis, affecting the present value of future cash flows and therefore the real value of costs and benefits over time. Economic factors affecting the outcome include inflation and interest rates, as well as any policy incentives in effect or impositions on industry that may change the overall cost equation, as well as energy tariffs or carbon prices. Another factor to consider is whether project climate change impacts could be considered in the CBA, given a relatively long time horizon for calculations.
- **External Costs and Benefits:** These are indirect costs unaccounted for by the direct energy impact or financial accounts of the project, such as impacts on overall required levels of energy supply infrastructure, employment impacts, or consideration of the health, wellbeing and productivity levels of building occupants.

The following tabulated parameters and data sources are suggested potential starting points for the establishment of a usable data set, and conduct of the CBA for cooling solutions in Indonesia:

⁸ See for instance Nugroho, A.M. (2022), *Passive cooling performance on Indonesia contemporary tropical facade in producing the present comfortable space* IOP Conf. Ser.: Earth Environment Science 1007 012005; and Chen, Y. et al (2020), *Performance of Passive Design Strategies in Hot and Humid Regions. Case study: Tangerang, Indonesia*, Journal of Asian Architecture and Building Engineering 20(11).

Table 1: Data Requirements and Sources for CBA

Input Parameter	Data Requirement	Source	Link
Capital Cost			
Upfront Material Cost	Passive Solutions	Institut Teknologi Bandung Building Technology Research Group	ITB BTRG
	Active Solutions	Can be obtained from market retail surveys	
Design & Construction	Design & Engineering	Arcadis Construction Cost	Arcadis
Surveys & Permits	Permitting Costs	Ministry of Public Works and Housing	Kemen PUPR
Annual Operations and Maintenance Costs			
Variable Costs	Electricity prices	Persusahan Listrik Negara	PLN
	Labor Cost	Lembaga Pengembangan Jasa Konstruksi Nasional/ National Construction Services Development Board	LPJK
	Repairs & Maintenance		
Fixed Costs	Depreciation cost		
	Retrofit materials		
Economic factors			
Macroeconomic Indicators	Inflation Rate	Bank Indonesia Economic and Financial Statistics	SEKI
	Interest Rate		
Policy Incentives	Rebates	Persusahan Listrik Negara	PLN
	Incentives	Indonesia Ministry of Finance	Kementerian Keuangan
		Indonesia Ministry of Energy and Mineral Resources	ESDM
Externalities			
Emission Costs	Carbon Pricing	OECD Effective Carbon Rates	OECD



3.2.2 Metrics and Results

The calculations to be performed for each scenario will allow a common basis for comparison and decision on the benefits of different measures. The data output may take the form of a table that will set out different metrics for each scenario, including:

- Payback Period
- Consumer Lifecycle Cost
- Energy burden analysis for low-to-moderate income (LMI) consumers

Method for calculating each of these metrics is provided below.

Note that this data output will be for impacts at the individual building level; further consideration is given to national level analysis in Part 3.2.3 below.

Payback Period (PBP)

Payback period is a financial metric used to determine the amount of time it takes for an investment to generate enough cash flows to recover its initial cost. It provides insight into how quickly an investment will recoup its initial outlay from the cash flows it generates. The simple payback period is calculated by dividing the initial investment by the annual cash flows generated by the investment, while the discounted payback period considers the time value of money by discounting future cash flows to their present value before calculating the payback period. PBP is a basic and straightforward method, but it may not provide a complete picture of an investment's profitability over its entire lifecycle.

In its simplest form, the calculation process consists of dividing the cost of the initial investment by the annual cash flows.

Payback Period = Initial Investment ÷ Cash Flow Per Year

Consumer Lifecycle Cost (LCC)

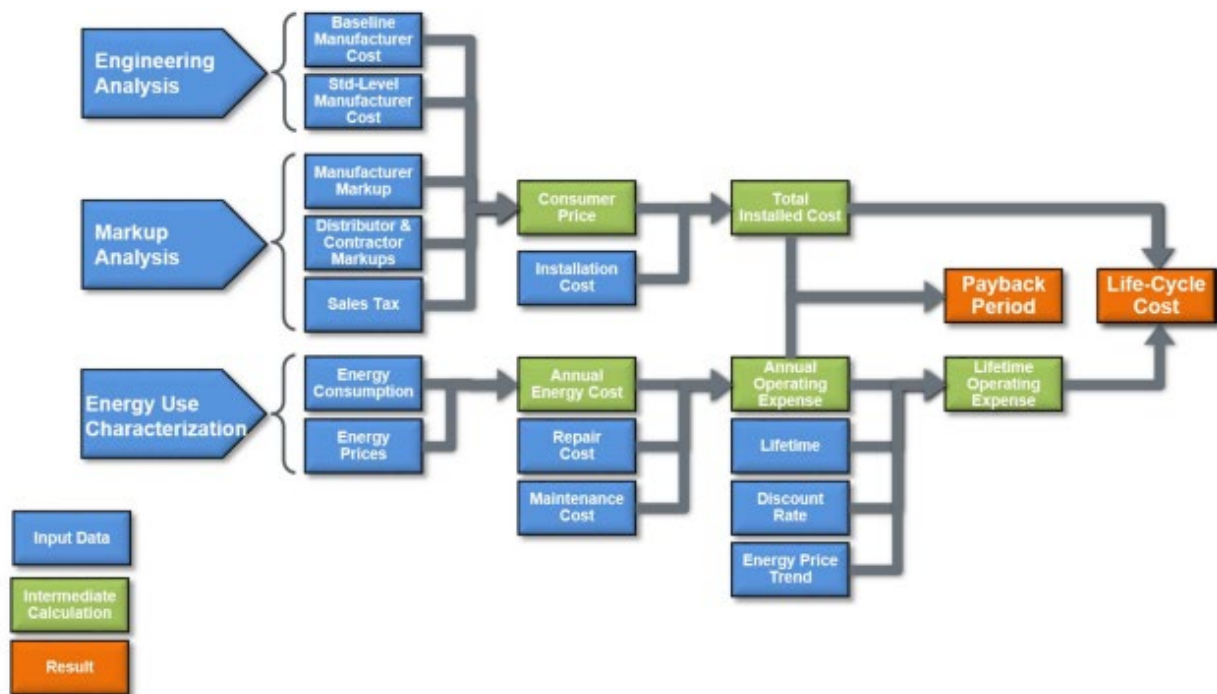
A Consumer Lifecycle Cost (LCC) analysis determines the total cost of owning, operating, and maintaining a project, asset, or system over its entire lifespan, aiming to take into account all costs associated with the asset, including not only the initial acquisition cost but also the ongoing operational and maintenance costs, as well as potential end-of-life disposal or replacement costs. Key components of a LCC analysis typically include acquisition costs, operating and maintenance costs (encompassing energy costs, labor costs, maintenance and repair costs, insurance and other operational expenses), discount rates across the estimated duration for which the asset will be operational and relevant, and end-of-life costs associated with decommissioning, disposing of, or replacing the asset at the end of its useful life.

In terms of discount rates to be applied in the LCC, a reasonable estimate of most asset's operation life is 20 years, while prevailing interest rates in Indonesia have averaged approximately 5-6% over the past 10 years (Trading Economics, 2023). It would be prudent, therefore, to use a discount rate of at least 6% in determining the value of future financial costs and benefits in the CBA, however it is more important to ensure that the same discount rate is used by all the SGCs.

The basic formula for calculating life cycle cost is **Capital cost + Operating Costs + Maintenance Costs + Replacement Costs – residual value**.

In relation to calculation method for both of these metrics, Letschert (2020) has provided a helpful flow diagram of how to derive each result, presented in Figure 3:

Figure 3: Data input requirements for PBP and LCCA



For the purposes of this CBA, it may be difficult to establish every aspect of the required input data to inform calculations, especially for passive or non-electrical technologies. However, intermediate data such as product prices and estimated displacement of energy use may be available, with which to derive the key inputs of installed cost and annual/lifetime operating expense.

Energy burden analysis for low-to-moderate income (LMI) consumers

Energy burden analysis for low-to-moderate income (LMI) consumers refers to the assessment of the proportion of a household's income that is spent on energy-related expenses. This analysis aims to understand the impact of energy costs on households with limited financial resources and to identify potential challenges and solutions to alleviate the energy burden faced by these consumers.

LMI households often dedicate a larger portion of their income to essential expenses like housing, food and healthcare, leaving them more vulnerable to fluctuations in energy prices. High energy costs can create financial stress and lead to difficult choices between paying energy bills, buying necessities, or covering other important expenses.

Energy burden analysis can therefore be derived from a general understanding and assumptions related to average income levels across low- and middle-income households. Energy burden is defined as the **average annual housing energy costs** divided by the **average annual household income**.



3.2.3 *Considering National Impacts*

A comprehensive national net present value (NPV) analysis entails a systematic assessment that transcends individual building-level considerations and extends to large-scale scenarios across Indonesia within the context of large JETP investment. This national NPV analysis would move beyond consumer-centric cost-benefit evaluations, energy displacement, and CO₂ reduction metrics to incorporate a holistic and broader system-level perspective. These considerations might include:

1. **Energy System Investment Impact:** This aspect involves evaluating the influence of the investment on energy system costs and performance. It encompasses reductions in network expenditure, alleviation of peak load stress, and related factors that impact the efficiency of and cost-effectiveness of the energy system.
2. **Economic Impact:** This considers a comprehensive examination of the investment's direct and indirect economic effects, including factors such as employment generation, contribution to GDP growth, tax revenue augmentation, and other macroeconomic indicators reflecting the investment's influence on the broader economy.
3. **Emission Cost Evaluation:** This study will also build on the methodological framework for quantifying emissions-related benefits and assigning monetary values to emission reductions, which are contingent on the carbon intensity of the electricity supply. It also considers the social costs and benefits associated with emission reductions borne by the public.
4. **Opportunity Costs:** Explores the potential alternative investment avenues to assess whether the allocated resources could be more optimally employed elsewhere. This involves recalculating the NPV under different investment scenarios to identify the most beneficial utilization of funds.
5. **Distributional Impacts:** Examines how the costs and benefits are distributed among various segments of the population or sectors of the economy. This analysis ensures that the investment fosters equitable outcomes, considering location-based factors (e.g. climate variations and income difference levels).
6. **Policy Alignment:** This ensures that the investment alignment with national goals, strategies, and policies is evaluated to gauge its contribution to broader national objectives, such as economic development, environmental sustainability, and social equity.
7. **Discount Rate and Analysis Duration:** Appropriate discount rate is crucial to account for the time value for money. This rate reflects the opportunity cost of allocating funds elsewhere and transforms future cash flows into their present value. The analysis also defines the time horizon, which can vary based on the products' total useful life, spanning a few years to several decades. Inflation adjustments ensure accurate estimates of costs and benefits over time, which is especially pertinent for long-term projects.

For each scenario, consideration and costing of these wider impacts with or without JETP investments, and calibration with broader JETP objectives for impact across all its dimensions, will ultimately be the key arbiter of deciding on the shape of JETP investment programs for building cooling solutions.

Further to the above national-level considerations, input-output analysis is a quantitative economic method used to model the interdependencies between different sectors in an economy, and may also be applicable. Output is often represented as a matrix where each row and column correspond to a specific economic sector. The entries in the matrix represent the monetary value of transactions between sectors, including inputs (such as raw materials, labor, and capital) and outputs (goods and services). It helps in understanding the economic impact of exogenous changes, such as changes in consumer demand, government spending, or technology advancement. Additionally, input-output analysis can be extended to study dynamic systems, incorporating time lags, investment, and technological progress, providing a more nuanced understanding of economic interactions over time. Another consideration in terms of national benefits is in the fact that, for the baseline scenario, many buildings in Indonesia may have a pre-existing un-met cooling demand, or a cooling deficit – any measures to reduce this deficit will therefore have additional impacts on productivity, comfort and health that may otherwise not be calculated.



3.3 Calculate and Compare Results

A table allowing comparison of different metrics and results for each scenario at the individual building level could then be presented, with an example given in Figure 4 below. This approach mirrors the results presented in the study completed by Letschert et al (2020) related to the impact of more efficient air conditioning in Indonesia.

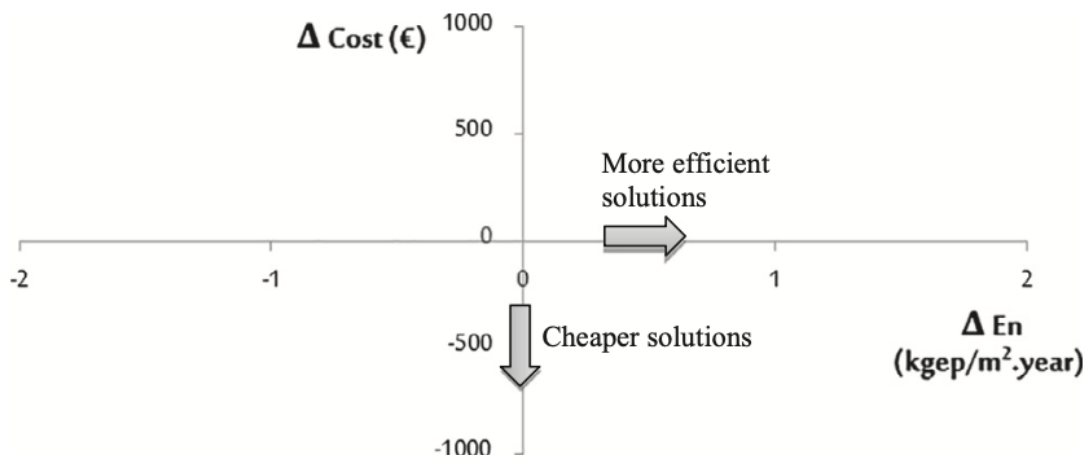
Figure 4: Example Tabulation of CBA Results

Comparison to Baseline:	Scenario 1 (mid-level performance, range x of technologies)	Scenario 2 (mid-level performance, range y of technologies)	Scenario 3 (mid-level performance, range x of technologies)	Scenario 4 (mid-level performance, range y of technologies)
Investment Required (USDm)				
Payback Period (years)				
Lifecycle Cost/Benefit (USDm)				
Energy Burden Analysis (change in average energy cost/average household income, %)				
National Net Present Value (USDm)				
Annual Energy Savings by 2030 (GWh)				
Annual Energy Savings by 2050 (GWh)				

CO₂ Emissions Mitigation (MT)				
Avoided Generation Capacity by 2030 (MW)				
Avoided Generation Capacity by 2050 (MW)				

At the level of individual measures, more detail could be provided by the visualization technique devised by (Araujo et al., 2016) for contrasting different building alternatives, which employs a two-dimensional graphical framework (Figure 4). In this depiction, the vertical axis signifies the fluctuation in costs, while the horizontal axis corresponds to the variance in energy performance. Each alternative solution is denoted as a distinct point on the graph, with the reference solution consistently mapped to the point (0, 0). Solutions characterized by lower expenses are situated towards the lower section of the graph, while those boasting superior energy performance are positioned towards the graph's rightmost region.

Figure 4: Graphical representation of the CBA by (Araujo et al., 2016)



The difference in life cycle energy performance is related to the difference in the building energy needs of each alternative solution when compared to the reference (baseline) solution:

$$\Delta En = En_{ref} - En_j$$

The difference in life cycle cost is related to the cost associated with the alternative solution relative to the reference (baseline) solution:

$$\Delta Cost = Cost_j - Cost_{ref}$$

This means that if the ΔEn value is positive, the solution is better than the reference solution as it consumes less energy. On the other hand, if the ΔEn value is negative, the solution consumes more

energy, which means that it is worse than the reference solution. Moreover, if $\Delta Cost$ has a positive value, it means that the solution j is worse as it is more expensive than the reference solution.



3.3.1 Approach to Uncertainty

Addressing uncertainty and variability in a systematic and transparent manner helps to make the CBA more comprehensive and robust, so that decision-makers can understand the potential range of outcomes and make informed choices that evaluate both upside possibility and downside risk. Uncertainty arises due to a wide range of factors including fluctuating economic conditions, regulatory change, changing market trends, geopolitical shifts, technological advancement, and other external shocks or unforeseen events.

Uncertainty can be reporting upon through the CBA by using a range of techniques, including

- **Probability Analysis:** Instead of using single-point estimates for costs and benefits, using probability distributions to represent the uncertainty associated with each estimate can allow calculation of the expected value of costs and benefits along with measures of uncertainty, such as confidence intervals or risk profiles.
- **Value of Information Analysis:** evaluating whether further data collection or research could reduce uncertainty, and if the potential benefit of obtaining more precise estimates justifies the cost of collecting additional information.
- **Expert Judgment:** In cases where data is limited, rely on expert opinions and insights to inform your estimates. Expert judgment can provide valuable qualitative information that complements quantitative analysis.
- **Risk Mitigation Assessment:** Consider incorporating risk mitigation strategies into the analysis. Identify potential risks and explore how different strategies could reduce the impact of negative outcomes.
- **Threshold Analysis:** Determine the level of uncertainty that would make the project economically unviable. This threshold can guide decision-makers in assessing whether the project's potential benefits outweigh the risks.
- **Update and Review:** As the project progresses and new information becomes available, update the CBA to account for changing conditions and refine estimates. Regularly review and adjust the analysis as necessary.

Given the overall resources available for performing the CBA, it's likely that not all of these techniques will be able to be deployed; it is also likely (and methodologically valid) that outputs may be expressed as distributions, rather than single numbers. It will be important to clearly communicate the uncertainty associated with the analysis findings to JETP decision-makers, to set expectations and inform the decision-making process.



3.3.2 Sensitivity Analysis

Perform sensitivity analysis to account for uncertainties and variations in key assumptions. Test how changes in variables like discount rate, cash flows, and economic conditions affect the NPV outcome.

A sensitivity analysis should be conducted to test and understand the robustness of the outcomes from the study and its response under varying conditions. A sensitivity analysis should also be developed when CBA is performed with at least two different rates.

Key parameters to be tested are the discount rate and the energy price, which have inverse impacts: an increase in the discount rate will decrease the value of money. Therefore, solutions with low energy performance or high operational costs will be more advantageous as money will have a lower value. However, the exact solutions will become less advantageous with an increase in the energy price.

ANNEX I

Cooling Cost-Benefit Analysis Results



Agenda

- 1 Overview of Net Zero World
- 2 Cost Benefit Analysis (CBA) Study
- 3 CBA: Data Collection
- 4 CBA: Metrics
- 5 Conclusions
- 6 Potential Further Analysis

Overview of Net Zero World

**NET
ZERO
WORLD
INITIATIVE**

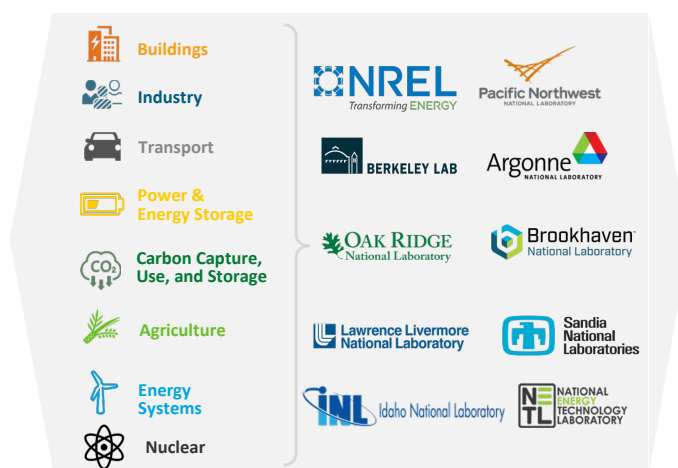
Accelerating Global
Energy System
Decarbonization

Net Zero World

A whole-of-government program that provides:

- Immediate and sustained access to expert technical, deployment, and investment analysis and facilitation to help countries
- Targeted support for in-country technical institutions to build long-term, self-sustaining technical capacity.
- Deep collaboration to develop technical and investment plans and support implementation

Key Energy Sectors, Topics, and Whole-of-Government Team



NET ZERO WORLD INITIATIVE | 4

Current Partner Countries



Cost Benefit Analysis (CBA) Study

Whole-Building Passive Cooling Solutions for Indonesia's Building Sector

**NET
ZERO
WORLD
INITIATIVE**

Accelerating Global
Energy System
Decarbonization

A February 2023 NZW Building Decarbonization Workshop Yielded a U.S. - Indonesia Working Group With 4 Sub-working Groups (SWGs)

SWG-A National Center

- Whole-building cooling technologies
- Low-carbon buildings materials database
- National road map
- Energy benchmarking
- Community initiatives
- Testing & certification
- More...

Eddi Santosa

PT DEX Solusi Transit



SWG-B Capacity Building

- Train-the-trainer
- Energy M&V training
- Energy audit/management training
- SME ESCO development
- Building simulation university course

Jimmy Juwana

Green Building Council Indonesia



SWG-C Analysis & Financing

- Whole-building cooling cost-benefit analyses
- Building EE market analysis
- Develop innovative financing models for NZB, incl. ESCOs

Ery Wijaya

MASKEE



SWG-D Pilot Projects

- Affordable housing pilot projects w/passive, low-cost, & resilient strategies for LMI communities
- Collaborate w/other infrastructure donors to incorporate NZ EE building designs/stds

Iwan Prijanto

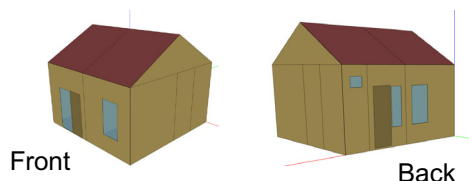
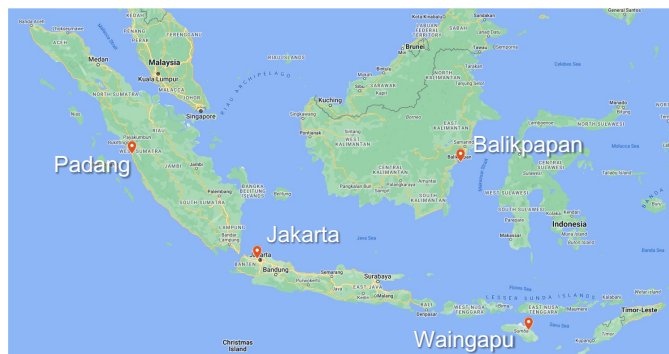
Green Building Council Indonesia



NET ZERO WORLD INITIATIVE | 7

Technical Analysis of Whole-building Cooling Solutions for Tropical Climates of Indonesia [SWG-A]

NZW Activity: Quantify energy savings, carbon reductions, and comfort improvements offered by 12 passive or low-energy cooling strategies, such as natural ventilation, high-performance windows, and ceiling fans, by simulating the annual hourly performance of 1 prototype home in 4 Indonesian climates, with and w/o AC.



- 36 m² low-to-moderate income (LMI) rowhouse
- Living room, kitchen, bathroom, 2 bedrooms, attic
- Brick walls, clay tile roof, single-pane windows, concrete foundation, unitary single-speed direct expansion AC
- Minimally insulated

NET ZERO WORLD INITIATIVE | 8

Indonesia Cost-Benefit Analysis to Support Efficient Cooling of the Buildings Sector [SWG-C]

NZW Activity: Leveraging the results from SWG-A, assess the consumer and national costs and impacts associated with the 12 whole-building cooling solutions. This evaluation involves estimating:

- life cycle costs (LCC), payback period (PBP), and net present values (NPV);
- annual electricity burden change for low-to-moderate income (LMI) stakeholders; and
- reduced national annual power-sector generation need by 2030, 2040, 2050, and 2060 due to the implementation of select passive and low-energy cooling solutions.

Target Impact: Guide Indonesia JETP investments in policies and programs to advance research, development, deployment, and commercial adoption (RDDCA) of efficient residential building sector cooling technologies and solutions in Indonesia.

Asian Development Bank (ADB): Holding discussions with ADB (Head of JETP Finance Working Group (WG)) to determine path for integration of building investment in the Indonesia Comprehensive Investment and Policy Plan (CIPP).



Results Report

SWG-C: CBA

Data Collection

By employing a distribution of the Indonesian household population and its orientations, the proportions of the total Indonesian household population represented by four cities and their orientations were determined, as illustrated in the table below.

City	Climate Zone	Orientation Fraction	
	Fraction	South	West
Jakarta	65%	67%	33%
Balikpapan	12%	50%	50%
Padang	15%	50%	50%
Waingapu	5%	50%	50%

Table. Fraction of Indonesian Households Represented by Different Climate Zones

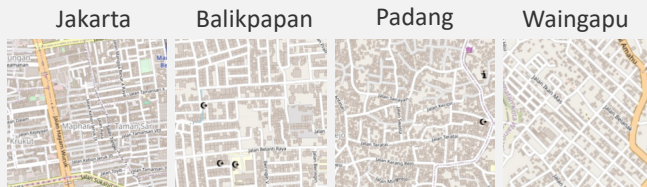


Fig. Street Map Views of Four Cities

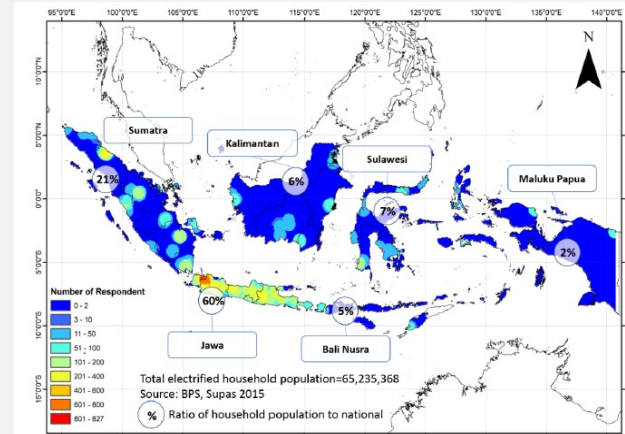


Fig. Distribution of Household Population

DATA INPUTS

Population and Household Orientations

NET ZERO WORLD INITIATIVE | 11

Average household electricity use and savings for each energy conservation measure (ECM) are found from weighted average of model results according to location and orientation.

Bedroom Only Energy		
ECM	Annual AC Electricity (kWh)	Annual Savings (kWh)
Baseline	945.9	0.0
CeilingFan_1	360.2	585.8
CeilingFan_2	215.4	730.5
CeilingFan_NoSetback_1	945.9	0.0
CeilingFan_NoSetback_2	945.9	0.0
CoolRoof_1	829.2	116.7
CoolRoof_2	688.6	257.4
CoolWall_1	827.1	118.9
CoolWall_2	693.3	252.6
ExtAwning_1	893.3	52.6
ExtShade_1	874.8	71.2
InsRoof_1	639.7	306.3
InsRoof_2	551.0	394.9
InsWall_1	532.2	413.7
InsWall_2	500.9	445.1
IntShade_1	963.3	-17.3
IntShade_2	913.4	32.5
LowEWin_1	849.2	96.7
LowEWin_2	786.6	159.4
NV_DayAndNight_1	767.4	178.5
NV_DayAndNight_2	767.0	178.9
NV_NightOnly_1	851.9	94.0
NV_NightOnly_2	851.7	94.2
SolarWin_1	892.5	53.5
SolarWin_2	825.7	120.2

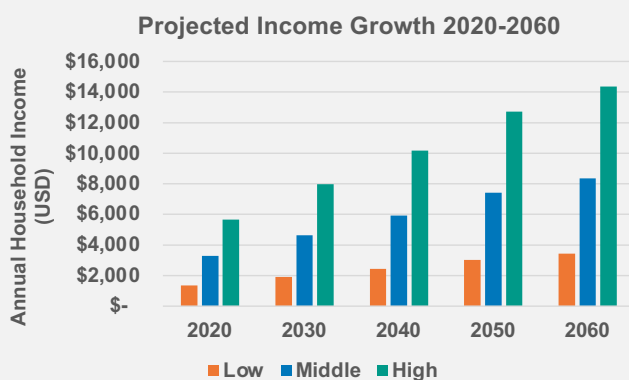
Whole Home AC Energy		
ECM	Annual AC Electricity (kWh)	Annual Savings (kWh)
Baseline	4892.8	0.0
CeilingFan_1	2525.0	2367.9
CeilingFan_2	1492.0	3400.9
CeilingFan_NoSetback_1	4892.8	0.0
CeilingFan_NoSetback_2	4892.8	0.0
CoolRoof_1	4559.2	333.6
CoolRoof_2	4106.4	786.4
CoolWall_1	4607.7	285.1
CoolWall_2	4219.2	673.7
ExtAwning_1	4753.9	139.0
ExtShade_1	4685.8	207.0
InsRoof_1	3797.3	1095.5
InsRoof_2	3483.9	1409.0
InsWall_1	3452.6	1440.2
InsWall_2	3314.9	1577.9
IntShade_1	4986.3	93.4
IntShade_2	4852.3	40.5
LowEWin_1	4575.5	317.3
LowEWin_2	4346.8	546.1
NV_DayAndNight_1	4758.1	134.7
NV_DayAndNight_2	4757.7	135.2
NV_NightOnly_1	4860.2	32.7
NV_NightOnly_2	4860.0	32.9
SolarWin_1	4761.4	131.4
SolarWin_2	4557.4	335.4

DATA INPUTS

Average Household Electricity Use and Savings

NET ZERO WORLD INITIATIVE | 12

Substantial nationwide income growth is expected from 2020 to 2060.



Indonesian Annual Household Income 2023		
Income Group	Income (USD/year)	Pop. Frac.
Low	\$ 1,475	20%
Middle	\$ 3,599	63%
High	\$ 6,184	17%

Source: Bank Indonesia. (2023, September). Monthly Consumer Expectation Survey. Bank Indonesia. <https://www.bankindonesia.go.id/>

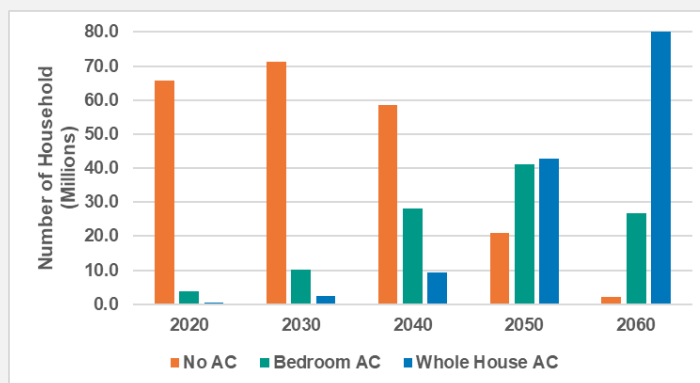
Source: International Energy Agency. (2020). An Energy Sector Roadmap to Net Zero Emissions in Indonesia. <https://www.iea.org/>

DATA INPUTS

National Income Growth

NET ZERO WORLD INITIATIVE | 13

Growing income will spur a huge growth in number of single-family housing and an increase in the fraction of homes with any type of air conditioning (AC).



Sources: • Park, W., Shah, N., Letschert, V., & Blake, P. (2021). Harmonizing Energy-Efficiency Standards for Room Air Conditioners in Southeast Asia.
• CLASP. (2020). Indonesia Residential Energy Use Survey. CLASP. <https://www.clasp.ngo/>
• International Energy Agency. (2020). An Energy Sector Roadmap to Net Zero Emissions in Indonesia. <https://www.iea.org/>

DATA INPUTS

National Expansion of Air Conditioning Adoption

NET ZERO WORLD INITIATIVE | 14

Average AC minimum equipment performance standards (MEPS) will need to be increased to be able to reach net zero by 2050/2060.

Fractions of Standard, Med and High Performance vs. Time						
Inverter Type	2019	2020	2030	2040	2050	2060
Inverter High Perf	3%	4%	10%	20%	30%	40%
Inverter Med Perf	12%	13%	20%	30%	40%	50%
Total Inverter AC	15%	17%	30%	50%	70%	90%
Non-Inverter AC	85%	83%	70%	50%	30%	10%

Table. Fractions of Standard, Medium, and High-Performance AC in the future

Cooling Seasonal Performance Factor (CSPF)						
Inverter Type	2019	2020	2030	2040	2050	2060
Inverter High Perf	6	6.1	6.8	8	9	10
Inverter Med Perf	4	4.1	4.8	5.75	6.5	7
Standard	2.5	2.5	3	4	5	5
CSPF Weighted Avg High MEPS	2.785	2.852	3.74	5.325	6.8	8

Table. Cooling Seasonal Performance Factor Increase based on MEPS

Sources:

- Park, W., Shah, N., Letschert, V., & Blake, P. (2021). Harmonizing Energy-Efficiency Standards for Room Air Conditioners in Southeast Asia.
- International Energy Agency. (2020). An Energy Sector Roadmap to Net Zero Emissions in Indonesia. <https://www.iea.org/>
- SMEs for change in inverter stock in time such that CSPF grows according to IEA projections

DATA INPUTS

Minimum Equipment Performance Standards (MEPS)

NET ZERO WORLD INITIATIVE | 15

Using the fractions of standard, medium, and high-performance AC and its efficiency improvements detailed in the preceding slide, relative energy scale factors are assumed for future years in relation to the baseline of 2020, set at a factor of 1. The CBA analysis assumes these increasing MEPS to project the scaling of heating, ventilating, and air conditioning (HVAC) electricity consumption in the future.

HVAC Energy Scale Factor	2020	2030	2040	2050	2060
High MEPS Scenario	1	0.76	0.54	0.42	0.36

Table. Fractions of Standard, Medium, and High-Performance AC in the future

Sources:

- Park, W., Shah, N., Letschert, V., & Blake, P. (2021). Harmonizing Energy-Efficiency Standards for Room Air Conditioners in Southeast Asia.
- International Energy Agency. (2020). An Energy Sector Roadmap to Net Zero Emissions in Indonesia. <https://www.iea.org/>
- SMEs for change in inverter stock in time such that CSPF grows according to IEA projections

DATA INPUTS

Minimum Equipment Performance Standards (MEPS)

NET ZERO WORLD INITIATIVE | 16

ECMs have install costs, replacement costs, maintenance costs, and lifetimes in addition to energy savings. Some ECMs, like cool walls and low-E windows, are only incremental costs over expected household maintenance costs like painting roofs and walls and replacing windows.

ECM	New Install (\$)	Incremental Install (\$)	Replacement (\$)	Incremental Replacement	Maintenance (\$)	Lifetime (Yrs)
CeilingFan_1	\$ 100.00	\$ 100.00	\$ 75.00	\$ 75.00	\$ 2.00	10.00
CeilingFan_2	\$ 100.00	\$ 100.00	\$ 75.00	\$ 75.00	\$ 2.00	10.00
CeilingFan_NoSetback_1	\$ 100.00	\$ 100.00	\$ 75.00	\$ 75.00	\$ 2.00	100.00
CeilingFan_NoSetback_2	\$ 100.00	\$ 100.00	\$ 75.00	\$ 75.00	\$ 2.00	100.00
CoolRoof_1	\$ 516.25	\$ 351.05	\$ 516.25	\$ 351.05	\$ 2.00	15.00
CoolRoof_2	\$ 516.25	\$ 351.05	\$ 516.25	\$ 351.05	\$ 2.00	15.00
CoolWall_1	\$ 241.74	\$ 20.50	\$ 241.74	\$ 20.50	\$ 2.00	10.00
CoolWall_2	\$ 241.74	\$ 20.50	\$ 241.74	\$ 20.50	\$ 2.00	10.00
ExtAwning_1	\$ 112.00	\$ 112.00	\$ 112.00	\$ 112.00	\$ 1.00	20.00
ExtShade_1	\$ 164.00	\$ 164.00	\$ 164.00	\$ 164.00	\$ 1.00	15.00
InsRoof_1	\$ 82.60	\$ 82.60	\$ 82.60	\$ 82.60	\$ -	100.00
InsRoof_2	\$ 826.00	\$ 826.00	\$ 826.00	\$ 826.00	\$ -	100.00
InsWall_1	\$ 612.00	\$ 612.00	\$ 612.00	\$ 612.00	\$ -	100.00
InsWall_2	\$ 703.80	\$ 703.80	\$ 703.80	\$ 703.80	\$ -	100.00
IntShade_1	\$ 384.00	\$ 384.00	\$ 384.00	\$ 384.00	\$ 2.00	20.00
IntShade_2	\$ 384.00	\$ 384.00	\$ 384.00	\$ 384.00	\$ 2.00	20.00
LowEWin_1	\$ 2,209.88	\$ 353.58	\$ 2,209.88	\$ 353.58	\$ -	50.00
LowEWin_2	\$ 2,209.88	\$ 353.58	\$ 2,209.88	\$ 353.58	\$ -	50.00
NV_DayAndNight_1	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 1.00	100.00
NV_DayAndNight_2	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 1.00	100.00
NV_NightOnly_1	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 1.00	100.00
NV_NightOnly_2	\$ 0.01	\$ 0.01	\$ 0.01	\$ 0.01	\$ 1.00	100.00
SolarWin_1	\$ 473.93	\$ 473.93	\$ 473.93	\$ 473.93	\$ -	15.00
SolarWin_2	\$ 473.93	\$ 473.93	\$ 473.93	\$ 473.93	\$ -	15.00

DATA INPUTS

Energy Conservation Measures (ECM) Cost Data

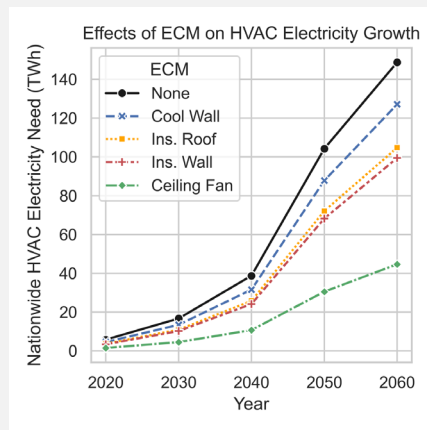
NET ZERO WORLD INITIATIVE | 17

SWG-C: CBA

Metrics

METRICS

Nationwide electricity demand for AC is expected to rise exponentially through 2060 and so ECMs are necessary to curb the growth. Ceiling fan with AC temp. setback (28.1 °C from 25 °C) is the most effective, followed by insulated walls, insulated roofs, and cool walls/roofs.



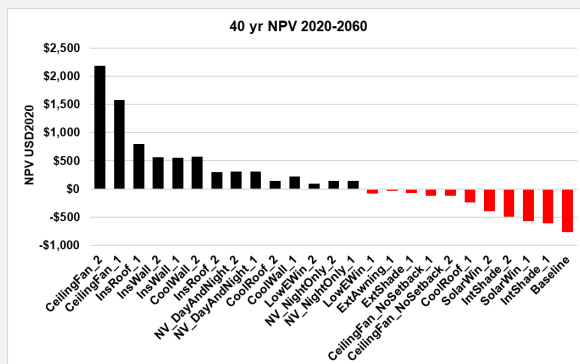
Nationwide AC Electricity Demand (TWh)					
ECM	2020	2030	2040	2050	2060
Baseline	5.8	16.7	38.8	104.2	148.8
CeilingFan_1	2.5	7.6	18.1	51.6	75.5
CeilingFan_2	1.5	4.5	10.7	30.5	44.7
CeilingFan_NoSetback_1	5.8	16.7	38.8	104.2	148.8
CeilingFan_NoSetback_2	5.8	16.7	38.8	104.2	148.8
CoolRoof_1	5.2	15.1	35.3	96.2	138.1
CoolRoof_2	4.5	13.2	30.9	85.7	123.8
CoolWall_1	5.2	15.2	35.5	97.1	139.5
CoolWall_2	4.5	13.4	31.6	87.8	127.1
ExtAwning_1	5.5	16.0	37.3	100.8	144.3
ExtShade_1	5.4	15.7	36.6	99.3	142.2
InsRoof_1	4.1	12.2	28.7	79.3	114.5
InsRoof_2	3.7	10.9	25.8	72.1	104.7
InsWall_1	3.6	10.7	25.3	71.2	103.7
InsWall_2	3.4	10.2	24.2	68.2	99.4
IntShade_1	5.9	17.0	39.5	106.2	151.6
IntShade_2	5.7	16.3	38.1	103.0	147.3
LowEWin_1	5.3	15.3	35.7	96.9	138.8
LowEWin_2	4.9	14.4	33.6	91.7	131.6
NV_DayAndNight_1	5.1	15.0	35.4	98.7	143.2
NV_DayAndNight_2	5.1	15.0	35.4	98.7	143.2
NV_NightOnly_1	5.4	15.9	37.2	102.0	146.9
NV_NightOnly_2	5.4	15.9	37.2	102.0	146.9
SolarWin_1	5.5	16.0	37.3	101.0	144.5
SolarWin_2	5.2	15.1	35.3	96.1	138.0

METRICS

National Electricity Demand

NET ZERO WORLD INITIATIVE | 19

Net present value (NPV) considers costs and savings including the time value of money. For this analysis, we used a discount rate of 5% for consistency with Indonesian whole sector analysis. Ceiling fans with temp. setback have the best NPV for all ranges of analysis years.



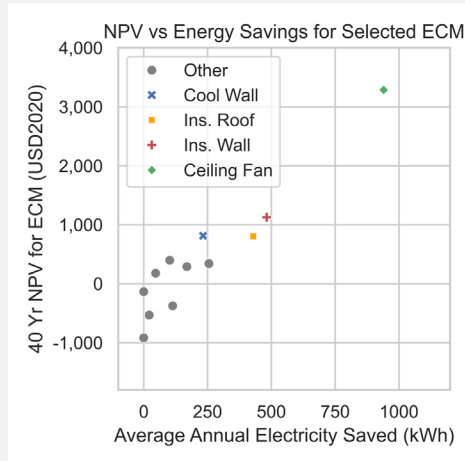
ECM	2020 NPV	2030 NPV	2040 NPV	2050 NPV	2060 NPV
Baseline	\$ (410.00)	\$ (510.38)	\$ (764.42)	\$ (894.80)	\$ (918.03)
CeilingFan_1	\$ (27.71)	\$ 813.50	\$ 1,577.08	\$ 2,034.53	\$ 2,356.61
CeilingFan_2	\$ (5.30)	\$ 1,131.99	\$ 2,183.53	\$ 2,823.61	\$ 3,284.13
CeilingFan_NoSetback_1	\$ (100.00)	\$ (115.44)	\$ (124.92)	\$ (130.74)	\$ (134.32)
CeilingFan_NoSetback_2	\$ (100.00)	\$ (115.44)	\$ (124.92)	\$ (130.74)	\$ (134.32)
CoolRoof_1	\$ (338.05)	\$ (196.16)	\$ (242.58)	\$ (253.57)	\$ (207.20)
CoolRoof_2	\$ (321.87)	\$ 17.94	\$ 140.89	\$ 228.61	\$ 341.43
CoolWall_1	\$ (7.82)	\$ 115.49	\$ 221.65	\$ 280.76	\$ 318.38
CoolWall_2	\$ 7.14	\$ 311.78	\$ 570.37	\$ 717.54	\$ 813.16
ExtAwning_1	\$ (106.26)	\$ (44.90)	\$ (34.67)	\$ (4.92)	\$ (1.51)
ExtShade_1	\$ (156.04)	\$ (67.23)	\$ (69.70)	\$ (63.66)	\$ (34.55)
InsRoof_1	\$ (46.25)	\$ 402.52	\$ 792.89	\$ 1,023.87	\$ 1,182.11
InsRoof_2	\$ (779.17)	\$ (201.08)	\$ 301.55	\$ 598.87	\$ 802.46
InsWall_1	\$ (563.31)	\$ 36.43	\$ 555.77	\$ 862.12	\$ 1,070.97
InsWall_2	\$ (651.13)	\$ (1.29)	\$ 563.14	\$ 896.78	\$ 1,124.99
IntShade_1	\$ (386.38)	\$ (432.34)	\$ (614.95)	\$ (638.32)	\$ (709.28)
IntShade_2	\$ (380.91)	\$ (361.07)	\$ (489.08)	\$ (481.16)	\$ (531.85)
LowEWin_1	\$ (342.39)	\$ (205.33)	\$ (87.81)	\$ (18.95)	\$ 27.49
LowEWin_2	\$ (334.91)	\$ (105.32)	\$ 92.97	\$ 209.74	\$ 289.11
NV_DayAndNight_1	\$ 16.05	\$ 187.79	\$ 309.40	\$ 369.28	\$ 397.48
NV_DayAndNight_2	\$ 16.09	\$ 188.27	\$ 310.20	\$ 370.25	\$ 398.54
NV_NightOnly_1	\$ 8.06	\$ 88.60	\$ 142.70	\$ 167.39	\$ 176.67
NV_NightOnly_2	\$ 8.08	\$ 88.83	\$ 143.08	\$ 167.86	\$ 177.17
SolarWin_1	\$ (468.19)	\$ (399.58)	\$ (571.41)	\$ (649.27)	\$ (629.04)
SolarWin_2	\$ (460.62)	\$ (299.86)	\$ (393.58)	\$ (426.05)	\$ (375.62)

METRICS

Net Present Value (NPV)

NET ZERO WORLD INITIATIVE | 20

An ECM with a high average household energy savings and a high NPV is good for both the nation and individual households. The four ECMS that gave the best nationwide impact also have high NPV, so they are win-win ECMS.



METRICS

Net Present Value (NPV)

NET ZERO WORLD INITIATIVE | 21

Those ECM with higher install costs but longer lifetimes and better energy savings rank higher when NPV is evaluated at 2060 vs 2040 where the extra energy savings and reduced install costs finally catch up.

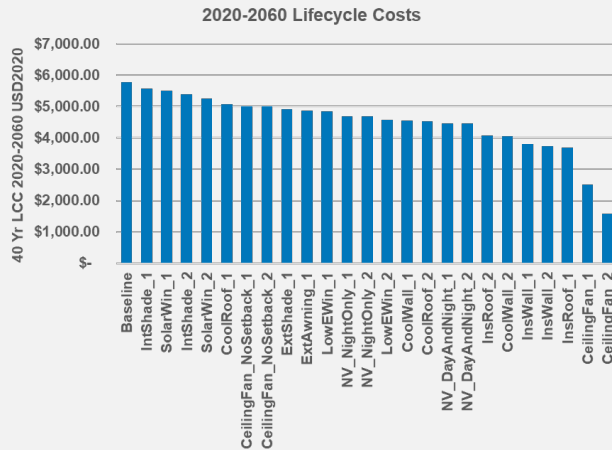
NPVs sorted by 2040 NPV Value			NPVs sorted by 2060 NPV Values		
ECM	2040 NPV	2060 NPV	ECM	2040 NPV	2060 NPV
CeilingFan_2	\$ 2,183.53	\$ 3,284.13	CeilingFan_2	\$ 2,183.53	\$ 3,284.13
CeilingFan_1	\$ 1,577.08	\$ 2,356.61	CeilingFan_1	\$ 1,577.08	\$ 2,356.61
InsRoof_1	\$ 792.89	\$ 1,182.11	InsRoof_1	\$ 792.89	\$ 1,182.11
CoolWall_2	\$ 570.37	\$ 813.16	InsWall_2	\$ 563.14	\$ 1,124.99
InsWall_2	\$ 563.14	\$ 1,124.99	InsWall_1	\$ 555.77	\$ 1,070.97
InsWall_1	\$ 555.77	\$ 1,070.97	CoolWall_2	\$ 570.37	\$ 813.16
NV_DayAndNight_2	\$ 310.20	\$ 398.54	InsRoof_2	\$ 301.55	\$ 802.46
NV_DayAndNight_1	\$ 309.40	\$ 397.48	NV_DayAndNight_2	\$ 310.20	\$ 398.54
InsRoof_2	\$ 301.55	\$ 802.46	NV_DayAndNight_1	\$ 309.40	\$ 397.48
CoolWall_1	\$ 221.65	\$ 318.38	CoolRoof_2	\$ 140.69	\$ 341.43
NV_NightOnly_2	\$ 143.08	\$ 177.17	CoolWall_1	\$ 221.65	\$ 318.38
NV_NightOnly_1	\$ 142.70	\$ 176.67	LowEWin_2	\$ 92.97	\$ 289.11
CoolRoof_2	\$ 140.69	\$ 341.43	NV_NightOnly_2	\$ 143.08	\$ 177.17
LowEWin_2	\$ 92.97	\$ 289.11	NV_NightOnly_1	\$ 142.70	\$ 176.67
ExtAwning_1	\$ (34.67)	\$ (1.51)	LowEWin_1	\$ (87.81)	\$ 27.49
ExtShade_1	\$ (69.70)	\$ (34.55)	ExtAwning_1	\$ (34.67)	\$ (1.51)
LowEWin_1	\$ (87.81)	\$ 27.49	ExtShade_1	\$ (69.70)	\$ (34.55)
CeilingFan_NoSetback_1	\$ (124.92)	\$ (134.32)	CeilingFan_NoSetback_1	\$ (124.92)	\$ (134.32)
CeilingFan_NoSetback_2	\$ (124.92)	\$ (134.32)	CeilingFan_NoSetback_2	\$ (124.92)	\$ (134.32)
CoolRoof_1	\$ (242.58)	\$ (207.20)	CoolRoof_1	\$ (242.58)	\$ (207.20)
SolarWin_2	\$ (393.58)	\$ (375.62)	SolarWin_2	\$ (393.58)	\$ (375.62)
IntShade_2	\$ (489.06)	\$ (531.85)	IntShade_2	\$ (489.06)	\$ (531.85)
SolarWin_1	\$ (571.41)	\$ (629.04)	SolarWin_1	\$ (571.41)	\$ (629.04)
IntShade_1	\$ (614.95)	\$ (709.28)	IntShade_1	\$ (614.95)	\$ (709.28)
Baseline	\$ (764.42)	\$ (918.03)	Baseline	\$ (764.42)	\$ (918.03)

METRICS

Net Present Value (NPV)

NET ZERO WORLD INITIATIVE | 22

Lifecycle costs (LCC) follow NPV. Through 2060, the ECMs with the lowest LCCs are ceiling fans with temp. setback followed by insulated roof with R-3.0, insulated walls, cool wall with solar reflectance of 0.6, and insulated roof with R-2.3.



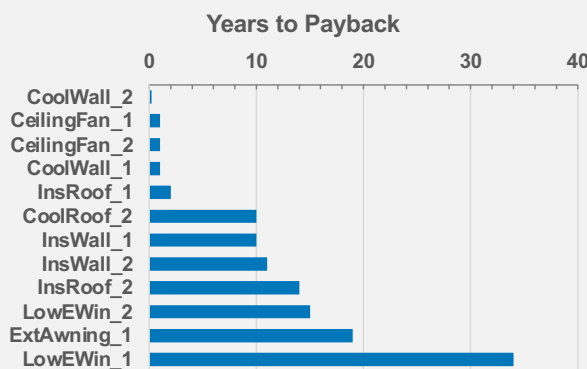
ECM	LCC	
	2060	
Baseline	\$	5,790.03
IntShade_1	\$	5,581.28
SolarWin_1	\$	5,501.04
IntShade_2	\$	5,403.85
SolarWin_2	\$	5,247.62
CoolRoof_1	\$	5,079.20
CeilingFan_NoSetback_1	\$	5,006.32
CeilingFan_NoSetback_2	\$	5,006.32
ExtShade_1	\$	4,906.55
ExtAwning_1	\$	4,873.51
LowEWin_1	\$	4,844.51
NV_NightOnly_1	\$	4,695.33
NV_NightOnly_2	\$	4,694.83
LowEWin_2	\$	4,582.89
CoolWall_1	\$	4,553.62
CoolRoof_2	\$	4,530.57
NV_DayAndNight_1	\$	4,474.52
NV_DayAndNight_2	\$	4,473.46
InsRoof_2	\$	4,069.54
CoolWall_2	\$	4,058.84
InsWall_1	\$	3,801.03
InsWall_2	\$	3,747.01
InsRoof_1	\$	3,689.89
CeilingFan_1	\$	2,515.39
CeilingFan_2	\$	1,587.87

METRICS

Life Cycle Cost (LCC)

NET ZERO WORLD INITIATIVE | 23

While the payback period is predominantly influenced by the initial installation costs, the four key technologies highlighted in terms of LCC and NPV – ceiling fans with temp. setback, insulated walls and roof, and cool walls – are consistently ranked as having shorter payback periods.



ECM	Years to Payback
CoolWall_2	0
CeilingFan_1	1
CeilingFan_2	1
CoolWall_1	1
InsRoof_1	2
CoolRoof_2	10
InsWall_1	10
InsWall_2	11
InsRoof_2	14
LowEWin_2	15
ExtAwning_1	19
LowEWin_1	34

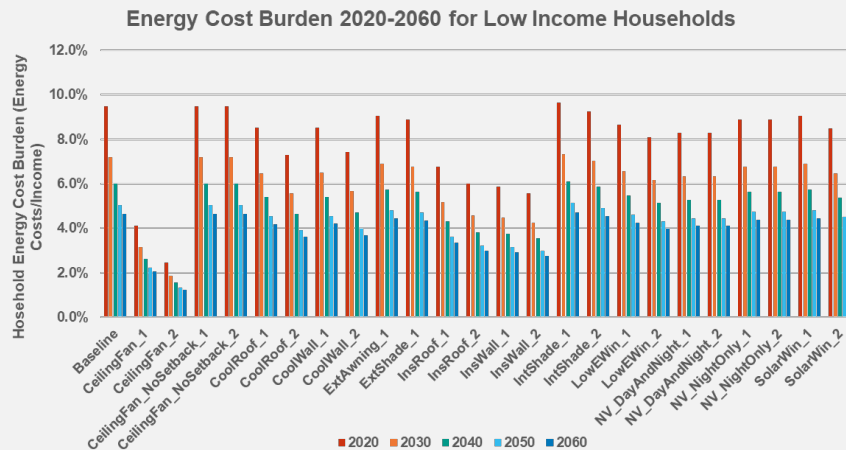
ECMs not shown had payback times in excess of 40 years or never reach payback.

METRICS

Payback Period

NET ZERO WORLD INITIATIVE | 24

The energy cost burden (ECB) for low-income households with AC is nearly 10% today with no ECMs, but with rising income and AC efficiency, that will drop to 4.6% by 2060. Implementing the ceiling fan with temp. setback, the ECB drops to 2.4% now and 1.2% in 2060.



METRICS

Energy Cost Burden (ECB)

NET ZERO WORLD INITIATIVE | 25

Conclusions

- Based on LCC, NPV, and payback period, four technologies are identified as more efficient and economically sound – ceiling fan with temp. setback (28.1 °C from 25 °C), insulated wall, insulated roof, and cool wall with high solar reflectance.
- Presently, the energy cost burden for low-income households with AC in Indonesia is approximately 10%. However, by installing a ceiling fan with temp. setback, this burden could decrease to 2.4% today and further reduce to 1.2% by the year 2060.
- The payback time of a ceiling fan with temp. setback is one year, exhibiting the lowest LCC and NPV among 12 ECMs considered.

NET ZERO WORLD INITIATIVE | 26

Potential Further Analysis

- Assessment of the combined impact of ECMs.
- Evaluation of ECM effects in multifamily housing.
- Conducting sensitivity and uncertainty analyses to gauge the national impact, incorporating additional data on future projections of energy costs and policies.
- Just Energy Transition Plan (JETP) metrics associated with investments in building sector ECMs, such as:
 - Avoided power sector infrastructure investments
 - Domestic job creation
 - Domestic manufacturing job creation
 - Gross domestic product (GDP) growth

NET ZERO WORLD INITIATIVE | 27

Thank you!

NZW Technical Team

Ralph T. Muehleisen, Ph.D., P. E.
Chief Building Scientist
Buildings and Industrial Technology Group
Leader, Argonne National Lab (ANL)
rmuehleisen@anl.gov

H. Clarisse Kim, Ph.D.
Principal Scientist, ANL
Technical Team Co-Lead for NZW
zeng.z@anl.gov

NZW Management Team

Bruce Hamilton
NZW Indonesia Country Coordinator
bhamilton@anl.gov

Ji-Hyun (Jeannie) Kim, Ph.D.
Building Scientist, Buildings and
Industrial Technology Group, ANL
jeannie.kim@anl.gov

Zhaoyun Zeng, Ph.D.
Postdoctoral Appointee, Buildings
and Industrial Technology Group, ANL
zengz@anl.gov

Carolyn Szum
NZW Indonesia Investment Lead
ccszum@lbl.gov

Ronnen Levinson
NZW Buildings Technical Coordinator
rmlevinson@lbl.gov

Proposed Capacity Building in NZWI Related Technology, Process and Policy, Particularly on Retrofitting Existing Buildings

Every course consists of 3 Levels/ Modules and Micro Teaching (Training of Trainers)—The proposed courses are: (1) *Energy Management*; (2) *Energy Audit*; (3) *Building Carbon Footprint Calculation*, (4) *Integrated Design Approach*, (5) *Energy Efficiency Projects Monitoring and Verification (M&V)*, and (6) *NZB Development Program Monitoring and Evaluation for National scale (M&E)*.

Due to the limited space, we only present samples of the proposed training modules

Training of Teachers / MICRO TEACHING- Module 2

Course Description:

The Micro Teaching for Teacher Trainers course is designed to provide trainers of teachers with the skills and knowledge needed to effectively teach, assess, and provide feedback to aspiring teachers through micro-teaching sessions. This course focuses on the principles and techniques of micro teaching, classroom management, and constructive feedback to enhance the teaching abilities of future educators.

Module 2: Classroom Management in Micro Teaching and Facilitating Micro Teaching Sessions

- Establishing a positive and inclusive classroom environment
- Managing time effectively during micro teaching sessions
- Handling challenging situations and disruptions
- Using technology and multimedia resources in micro teaching
- Creating a safe and respectful learning space
- Conducting role-play and simulations for classroom management
- Demonstrating strategies for effective teaching
- Providing clear instructions and guidelines
- Encouraging student participation and active learning
- Understanding the teacher of trainers role as an observer and facilitator
- Collecting data and evidence during micro teaching sessions
- Addressing common teaching challenges and misconceptions

Assessment Methods:

- Micro teaching session facilitation and assessment
- Lesson plan development and presentation
- Classroom management simulation exercises
- Peer and self-assessment activities
- Final reflective portfolio

- Course Materials:
- Micro teaching handbooks and resources
- Lesson planning templates and curriculum guidelines
- Classroom management tools and strategies
- Assessment rubrics and feedback models
- Technology and multimedia resources for teaching

By the end of this Micro Teaching for Teachers of Trainers course, participants will have acquired the skills and knowledge necessary to effectively facilitate micro teaching sessions, provide constructive feedback, and prepare aspiring teachers for success in the classroom. They will be prepared to support the growth and development of future educators.

ENERGY MANAGEMENT – Module 3 – Level: Elementary

This proposed course is an enhancement of the currently existing available course.

Course Description:

This course is designed to provide a good understanding of the principles and practices of energy management. Participants will gain a comprehensive understanding of various energy sources, energy consumption patterns related to productivity and energy costs, efficiency and conservation techniques, and sustainability principles. Through lectures, discussions, hands-on exercises, and projects, participants will gain the knowledge and skills necessary to make informed decisions about energy use in their daily works and responsibilities and in the broader context of society.

Module 3: Sustainable Energy Practices and Energy Management in the Future

- Sustainable energy systems
- Carbon footprint and greenhouse gas emissions
- Renewable energy integration
- Energy and transportation
- Circular economy and energy recycling
- Sustainability at works and in daily life
- Emerging energy technologies and trends
- Career opportunities in energy management
- Preparing for next level coursework in energy management

Assessment Methods:

- Quizzes and assignments
- Group project presentation
- Final exam
- Class participation and engagement

Course Materials:

- Textbook on energy management principles
- Research articles and case studies
- Energy monitoring tools and software
- Multimedia resources (videos, documentaries)

By the end of this course, participants should have a solid foundation in energy management principles and be capable of making informed decisions about energy use in their work and personal lives and contribute to the society's sustainability efforts.

ENERGY MANAGEMENT – Module 2 – Level: Advanced**Energy Systems Analysis, Sustainable Energy and Corporate Responsibility**

- Integrated energy systems modeling
- Techno-economic analysis of energy systems
- Life cycle assessment (LCA) of energy technologies
- Energy scenario planning and optimization
- Energy system resilience and reliability
- Case studies of energy system transformations
- Sustainable energy transitions
- Corporate sustainability strategies
- Sustainability reporting and disclosure
- Environmental, Social, and Governance (ESG) criteria in energy management
- Circular economy principles in the energy sector
- Clean Energy (EE+RE) and carbon offset strategies

Assessment Methods:

- Capstone energy project and presentation
- Final exam assessing comprehensive knowledge
- Participation in class discussions, case studies, and group activities
- Evaluation of leadership and communication skills

Course Materials:

- Advanced textbooks on energy policy, economics, and leadership
- Research papers and policy documents
- Energy modeling and analysis software
- Case studies of successful energy management projects

By the end of this course, participants should have a deep understanding of energy policy, economics, and systems analysis, as well as the leadership and communication skills necessary for successful careers in the energy sector. They will be prepared to tackle complex energy challenges, drive sustainability initiatives, and make significant contributions to the field.

ENERGY AUDIT FOR BUILDINGS – Module 2 – Level: Advanced

This proposed course is an enhancement of the currently available course in Energy Audit.

Course Description:

This advanced-level energy building audit course is designed to provide participants with advanced knowledge and skills in conducting comprehensive energy audits for various types of buildings. Emphasis is placed on hands-on experience, data analysis, and the development of actionable recommendations. The course also covers advanced topics such as building automation, commissioning, and advanced energy modeling.

Module 2: Energy Modeling and Simulation, and Commissioning and Retro-Commissioning

- Advanced building energy modeling software (e.g., EnergyPlus)
- Simulation of building energy performance for complex buildings
- Sensitivity analysis and scenario testing for large-scale projects
- Interpreting simulation results for multifaceted buildings
- Calibration of models with real-world data
- Using modeling for energy optimization and retrofit planning in complex buildings
- Commissioning process for large and complex buildings
- Retro-commissioning in existing buildings with intricate systems

- Measurement and verification (M&V) procedures for complex facilities
- Hands-on commissioning exercises for multifaceted systems
- Case studies of successful commissioning projects in complex buildings

Assessment Methods:

- Quizzes and building energy audit assignments
- Group project presentation and comprehensive report for large and complex buildings
- Final exam assessing overall course knowledge
- Class participation and engagement

Course Materials:

- Advanced textbooks on building energy auditing, sustainability, and complex building systems
- Research papers and case studies on advanced energy-efficient buildings, especially those with complex systems
- Building energy modeling software and simulation tools for multifaceted buildings
- Advanced energy auditing equipment and tools for large and complex facilities

By the end of this advanced-level course, participants should have an advanced understanding of building energy auditing principles and techniques for large, complex buildings. They will be prepared to lead and conduct complex energy audits, analyze data, and develop comprehensive recommendations for improving energy efficiency in multifaceted environments.

BUILDING CARBON PRINT CALCULATION – Module 3 – Level: Intermediate

This proposed course is based on the newly developed modules to enhance the energy auditors' skill related to buildings carbon print calculation.

Course Description:

The intermediate-level Carbon Calculation and Footprint course builds upon the foundational knowledge from the previous level course and delves deeper into the complex aspects of carbon emissions, accounting, and mitigation. Students will gain a comprehensive understanding of carbon footprint assessment methods and explore advanced topics related to carbon reduction strategies.

Module 3: Carbon Reduction Policies and Regulations, Carbon Reduction Project Development, and Future Trends in Carbon Reduction

- International climate agreements (e.g., Paris Agreement)
- National and regional carbon reduction policies
- Environmental, Social, and Governance (ESG) criteria in investing
- Carbon disclosure and transparency requirements
- Carbon credits and trading mechanisms

Carbon pricing and its role in decarbonization

- Group projects on advanced carbon reduction initiatives
- Proposal development and project planning
- Implementation of carbon reduction projects
- Measurement and verification of carbon reductions
- Project presentations and lessons learned
- Emerging technologies and innovations in carbon reduction
- Carbon-negative technologies and practices
- Preparing for advanced studies and careers in carbon management

Assessment Methods:

- Quizzes and assignments
- Group project presentation and report on advanced carbon reduction initiatives
- Final exam assessing overall course knowledge
- Class participation and engagement

Course Materials:

- Advanced textbooks on carbon accounting, climate policy, and carbon reduction strategies
- Research papers and case studies on advanced carbon footprint assessment and reduction
- Carbon calculation software and advanced online tools
- Carbon data sets and emission factors for practical exercises

By the end of this intermediate-level course, participants should have an advanced understanding of carbon emissions, carbon footprint assessment, and cutting-edge carbon reduction strategies. They will be prepared to contribute to organizations' efforts to reduce their carbon footprints and make informed decisions regarding climate change mitigation and adaptation.

BUILDING ENERGY PERFORMANCE MONITORING & VERIFICATION (M&V)

This proposed course is based on newly developed modules to provide energy auditors and managers with skills needed to perform technical M&V on energy efficiency projects.

Module 1 – Level: Introduction

Module 2: Energy Performance Monitoring and Verification Tools, Data Analysis and Energy Management

- Energy monitoring systems and technology
- Real-time data collection and analysis
- Integration of energy efficiency and on-site renewable energy application

- Advanced building energy management systems (BEMS)
- IoT in energy monitoring and control
- Hands-on experience with advanced energy monitoring equipment
- Statistical analysis of energy data
- Advanced data visualization techniques
- Identifying energy-saving opportunities
- Energy benchmarking and industry standards
- Energy management strategies for different sub-sectors (residential, commercial, industrial buildings)
- Using data to optimize energy performances

Assessment Methods:

- Quizzes and assignments
- Group project presentation and report on complex energy audits
- Final exam assessing overall course knowledge
- Class participation and engagement

Course Materials:

- Textbooks on advanced energy evaluation, monitoring, and energy management
- Research papers and case studies on complex energy evaluation projects
- Advanced energy monitoring equipment and software
- Building blueprints and energy data sets for practical exercises

By the end of this intermediate-level course, participants should have a deeper understanding of energy performance monitoring and verification techniques, including energy audits procedures and data analysis. They will be prepared to conduct in-depth assessments, analyze energy data, and report on M&V results.

ENERGY PROJECT'S MONITORING AND EVALUATION (M&E) – Module 1 – Level: Introduction

This course is based on newly developed modules to provide knowledge and skill to perform monitoring and evaluation on larger scale capacity building program — e.g., program at national or regional level.

Course Description:

The Energy Monitoring and Evaluation course is focusing on energy assessment and performance monitoring and evaluation. Participants will gain basic understanding of energy evaluation knowledge, techniques, procedures, monitoring method and technologies, and data analysis. This course emphasizes using practical experience, data-driven decision-making, and leadership in energy management.

Module 1: Introduction to Evaluation in the Energy Sector, Building Subsector in the Context of Decarbonizing the Building Sector

- The definitions, principles and theoretical concepts of evaluation
- The fundamental evaluation aspects:
 - Objectives, purposes, tasks, intended use of evaluation report
 - Perspective (ex-ante vs. ex-post) evaluation
 - Assessment and evaluation criteria
 - Modality for evaluation (internal, external)
- The motives and purpose of evaluation in the society and in the economic efficiency context
- Standards, Quality Criteria for Credible Evaluation (meta-evaluation)
- Code of Conduct in Evaluation Practices
- The object of Evaluation in the Energy Sector (for decarbonizing building sector), e.g.: (i) Policy & Strategy; (ii) Program and Project, (iii) Technology and Innovation; (iv) Organization/ Institution/ Enterprise; and (v) Community approach/ model
- Examples of evaluation in the energy sector (for decarbonizing the sector)

Assessment Methods:

- Quizzes and assignments
- Group project presentation on monitoring & evaluation framework, planning monitoring & evaluation framework
- Assessment on overall course materials knowledge
- Observing participants' active engagement during the course

Course Materials:

- Textbooks, papers, and practical guidelines on energy monitoring and evaluation, and energy management
- Case studies on energy evaluation projects

By the end of this course, participants should be well-prepared to take on leadership roles in energy evaluation and monitoring, conduct complex assessments, analyze large datasets, and make strategic energy management decisions. They will be equipped to drive significant energy efficiency improvements in various sectors and contribute to a sustainable energy future.

10/16/2023

ANNEX K

Pilot Projects

Sub-working groupD of the Net Zero World Initiative: Decarbonizing the Indonesian Building Sector, Pilot Project Development

Proposed Strategic Direction of NetZero Building Development in Indonesia

The followings are components of the proposed general strategic direction for the development of net zero buildings in Indonesia in the context of Indonesia's current conditions and strategic challenges:

1. Develop and apply technologies and methods that are best suited to (which, to some extent, are varying) Indonesia's tropical climate zones, by using low or carbon free building materials; addressing individual buildings' cooling needs and urban cooling issues suited to Indonesian unique circumstances.
2. Promote and develop the most effective and affordable solutions to reduce carbon emissions while maintaining building's health and living comfort.
3. Improve the adaptive capacity of buildings and settlements, especially those at the bottom of the social economic pyramid, to make them more resilient to the global climate change impacts.
4. Develop, facilitate, and encourage innovations in mitigating carbon emission (in the net zero building perspective), adaptative built environment, and restoration of the natural environment, responding to varied contextual challenges in the Indonesian archipelago.
5. Strive to achieve the highest possible growth in the value creation of the net-zero development initiatives in Indonesia, leading to as many as possible green job opportunities for Indonesia's skilled green working force.

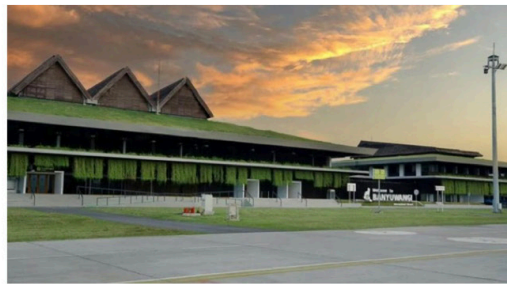
	Project Name	Category	Size	Current Projects' Status	Key Stakeholders	Emission reduction potential
1	Mother & Child Building of Persahabatan Hospital in Jakarta	New Building	30,000 m ²	Under construction & about to be GB & Net Zero certified	Persahabatan Hospital funded from IDB Loan	EUI 30-50 % below conventional building, minimum 5-10% RE appl.
2	Net Zero Public Schools owned by Education Agency of Jakarta	New Building	5000 sqm – 10.000 m ²	Under POE, Under design development process	Education Agency of Provincial Government of Jakarta, supported by GBCI	EUI 50% below conventional building, minimum 10 % RE appl
3	Civil Servant Echelon 3 Housing in IKN (New capital City	New Building	10,000 m ² / 8-story building, 210 apartment units	Under procurement process	WIKI Buildings SBU A major SOE supported by GBCI	EUI 50% below conventional building, minimum 15% RE appl
4	A NetZero Certified designed for a Typical Affordable Small house in Jakarta	New Buildings Design Manual	60-120 m ² land parcel	To be proposed to the Spatial & Housing Development Provincial Government of Jakarta	Spatial & Housing Development Provincial Government of Jakarta & Green Building	EUI 50% below conventional building, minimum 10 % RE appl

5	Existing Office Buildings owned by major SOE's in Indonesia	Retrofit Existing Buildings	TBD	To be proposed to the SOE top Mgt /Asset & Realty Director	Bldngs'owners:' PLN, SIG, WIKA, PERTAMINA, Krakatau Steel	EUI 30-50 % below conventional building, minimum 10-15% RE application
6	Net Zero Healthy Village in Bandung, W Java	Redevelopment & Improvement	~ 5 ha	Under R&D and Community Development process	Urban Village Communities' Parahyangan Catholic University & Green Building Council Indonesia	EUI 30-50 % below conventional building, minimum 10-15% RE application
7	NZ Office Buildings	New/ Retrofit Buildings	TBD	Proposed Proj. ideas envisioned for future development	NZW Indonesia Team	EUI 50% below conventional building, minimum 15% RE appl

Below are some examples of net zero and prospective net zero buildings in Indonesia that have received GreenSHIP Net Zero Certification from the Green Building Council Indonesia:



Bedawang Nala-Jimbaran - Bali



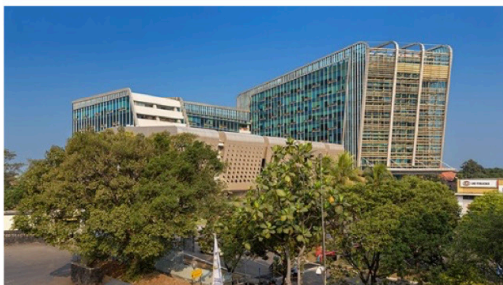
Banyuwangi Airport - East Java



Pahoa Kindergarten - Tangerang



Four Public School - Jakarta



Office United Tractor - Jakarta



Office Kamojang Geothermal



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9700 South Cass Avenue
Lemont, IL 60439

www.anl.gov

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