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Accelerating Global Energy System Decarbonization

Cost-Benefit Analysis For Indonesia Building Sector

Whole-Building Cooling Solutions

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List of Abbreviations

AC	Air-Conditioner
ADB	Asian Development Bank
APS	Announced Pledges Scenario
CBA	Cost-Benefit Analysis
CIPP	Comprehensive Investment and Policy Plan
CSPF	Cooling Seasonal Performance Factor
ECB	Energy Cost Burden
ECM	Energy Conservation Measure
ESDM	Kementerian Energy Dan Sumber Daya Mineral, Indonesian Ministry of Energy and Mineral Resources
EU	European Union
GDP	Gross Domestic Product
GFANZ	Glasgow Financial Alliance of Net Zero
GoI	Government of Indonesia
HVAC	Heating, Ventilation, and Air-Conditioning
IEA	International Energy Agency
IPG	International Partners Group
JETP	Just Energy Transition Partnership
LCC	Life-Cycle Cost
LMI	Low-to-Moderate Income
MASKEEI	Masyarakat Konservasi dan Efisiensi Energi, Indonesian Energy Conservation and Efficiency Society
MEMR	Ministry of Energy and Mineral Resources
MEPS	Minimum Equipment Performance Standards
NPV	Net Present Value
NZW	Net Zero World
NZW AC	Net Zero World Action Center
NZW IBDWG	Net Zero World Indonesia Building Decarbonization Working Group
PBP	Payback Period
RDDCA	Research, Development, Deployment, and Commercial Adoption
SEER	Seasonal Energy Efficiency Ratio
SHGC	Solar Heat Gain Coefficient
SME	Subject Matter Expert
SWG	Sub-Working Group
U.S. DOE	United States Department of Energy
UNDP	United Nations Development Program
US	United States
USD	United States Dollars
VT	Visible Transmittance
WG	Working Group

Executive Summary

The Net Zero World (NZW) Initiative 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 February 2023 U.S.–Indonesia Joint Workshop on Decarbonizing the Building Sector yielded a NZW Indonesia Building Decarbonization Working Group (NZW IBDWG) with four sub-working groups (SWG): SWG-A National Center, SWG-B Capacity Building, SWG-C Investment and Financing, and SWG-D Pilot Projects.

Technical analysis of whole-building cooling solutions for tropical climates of Indonesia was conducted by SWG-A to quantify energy savings, carbon dioxide reductions, and comfort improvements offered by 12 passive or low-energy cooling strategies: ceiling fans with and without thermostat setbacks; cool roofs; cool walls; exterior awnings; exterior shades; interior shades; insulated roofs; insulated walls; low-e windows; solar window films; and natural ventilation. Leveraging the results from SWG-A, cost-benefit analysis (CBA) was conducted by SWG-C to assess the consumer and national costs and impacts associated with these 12 cooling solutions. The evaluation involved estimating life-cycle costs (LCC), payback period (PBP), net present values (NPV), annual electricity burden change for low-income households, and reduced national annual power-sector generation demand by 2030, 2040, 2050, and 2060. This evaluation can help guide Indonesia's Just Energy Transition Partnership (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.

Four key energy conservation measures (ECM) have been identified to reduce air-conditioning (AC) energy demand in single-family housing in Indonesia: ceiling fan with temperature setback (to 28.1 °Celcius from 25 °C); insulated walls; insulated roof; and cool roof. This study found that low-income households with AC installations in Indonesia currently face a high energy cost burden of approximately 10%. However, by implementing a ceiling fan with temperature setback, this burden could decrease to 2.5% today and further reduce to 1.3% by the year 2060. The PBP for a ceiling fan with temperature setback is one year, indicating one of the lowest LCC and best NPV.

In the planned upcoming phase of CBA, a series of building cooling improvement scenarios can be further defined, incorporating more than one ECM in combination with socio-economic factors evaluated in the initial CBA phase. Additionally, the analysis of ECM effects in multifamily housing can be expanded. This broader national analysis aims to encompass a holistic and comprehensive system-level perspective, including factors such as avoided power sector infrastructure investments, domestic job creation, domestic manufacturing job creation, and gross domestic product (GDP) growth.

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1. Introduction

Supported by the Net Zero World (NZW) Initiative, this report provides the methodologies and outputs of the initial phase of cost-benefit analysis (CBA) to estimate the consumer and national costs and impacts of adoption of twelve building sector passive or low-energy cooling solutions at various energy performance levels in Indonesia. This analysis is intended to support investment decision making by the Indonesia Just Energy Transition Partnership (JETP) Secretariat in policies and programs to advance research, development, deployment, and commercial adoption (RDDCA) of efficient residential building sector cooling technologies and solutions.

1.1. Background on the NZW 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 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 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. A February 2023 U.S.–Indonesia Joint Workshop on Decarbonizing the Building Sector in Indonesia convened a first meeting 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. The workshop yielded a NZW Indonesia Building Decarbonization Working Group (NZW IBDWG) with four sub-working groups (SWG): SWG-A National Center, SWG-B Capacity Building, SWG-C Investment and Financing, and SWG-D Pilot Projects. The NZW IBDWG is co-chaired by Lawrence Berkeley National Laboratory, the Indonesian Ministry of Energy and Mineral Resources (MEMR), and local industry representative body Indonesian Energy Conservation and Efficiency Society (Masyarakat Konservasi dan Efisiensi Energi, known as MASKEEI).

1.2. Background on the Indonesia JETP

Indonesia's JETP was launched on November 15, 2022 by the President of the Republic of Indonesia, together with the U.S. President, the Japanese Prime Minister, and other world leaders, at the G20 Leaders' Summit in Bali, Indonesia. The JETP is a collaboration between (i) the Government of Indonesia (GoI); (ii) the International Partners Group (IPG), consisting of the governments of Canada, Denmark, France, Germany, Italy, Japan, Norway, the United Kingdom, the United States, and the European Union (EU); and (iii) the Glasgow Financial Alliance for Net Zero (GFANZ). The United States and Japan co-lead the IPG for the JETP. The partnership aims to support Indonesia's accelerated and socially just energy transition, including the accelerated deployment of renewable energy, and a phase-down of on-grid and off-grid coal-fired electricity generation, a more climate-resilient society, and ultimately, net-zero economy-wide emissions.

In accordance with the Joint Statement issued by GoI and IPG, a Secretariat has been established to serve as a body to support the technical work, coordination, and operationalization of JETP. The Secretariat is hosted by the Ministry of Energy and Mineral Resources and receives guidance from the GoI National Energy Transition Task Force with institutional support and implementation capacity from Asian Development Bank (ADB). The Secretariat plays an important planning and project/program identification role, coordinating the mobilization and deployment of an initial 20 billion US dollars (USD) in public and private financing support from the IPG and GFANZ over a three-to-five-year period.

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 – ADB, (d) Just Transition – United Nations Development Program. One of the key deliverables of the Secretariat is the Comprehensive Investment and Policy Plan (CIPP) that focuses on on-grid power. The first CIPP published in November 2023 supports the achievement of JETP targets for the power sector. The CIPP is a "living document" that will require regular updates to reflect recent market and technology developments as well as near-term priorities. The CIPP includes the following sections:

- Decarbonization vision of Indonesia and energy transition pathways
- Portfolio of JETP programs across investment focus areas
- Policy, financing, and just transition enablers required to accelerate the transition
- Implementation plan and governance

Furthermore, as outlined in the first CIPP, a fifth working group dedicated to energy efficiency and electrification (E^3WG) of the buildings, industry, and transportation sectors will be introduced in the second version of the CIPP in 2024. The objectives of this addition are to recommend a comprehensive technical and financing/investment pathway to the JETP Secretariat to improve energy efficiency and expand electrification in Indonesia. It is anticipated that the results of this CBA, and any subsequent phases to this work, will inform the second version of the CIPP.

1.3. The need for CBA of Passive or Low-Energy Cooling Solutions

As the incomes of Indonesia's middle class rise and access to electricity improves, along with increasing global temperatures, there is a clear trend towards rising demand for energy used for cooling. IEA predictions of air-conditioner (AC) adoption (IEA, 2022) have the number of AC units in the Association of Southeast Asian Nations 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 has been explored by projecting the energy consumption in the building sector with more AC adoption and increased minimum equipment performance standards (MEPS) in the future years.

Given these trends, NZW IBDWG established 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 under NZW.

Under the NZW IBDWG-A: National Center, technical analysis of whole-building cooling solutions for tropical climates of Indonesia was conducted to quantify energy savings, carbon reductions, and comfort improvements offered by 12 passive or low-energy cooling strategies: cool roofs; cool walls; insulated roofs; insulated walls; low-emissivity windows; solar-control window film; ceiling fans with temperature setback; ceiling fans without temperature setback; exterior window shades; interior window shades; natural ventilation based on schedule and outside air temperature; and natural ventilation based only on outside air temperature.

Under the NZW IBDWG SWG-C: Investment and Financing, the results from SWG-A were utilized to perform a CBA estimating of the consumer and national costs and impacts of adoption of these 12 building-sector passive or low-energy cooling solutions at various energy performance levels in Indonesia. For several solutions that yielded high electricity savings at low cost, SWG-C evaluated: (i) life-cycle costs (USD), payback period (years), and net present value (USD); (ii) annual electricity burden change (%) for low-income stakeholders; (iii) reduced annual power-sector generation need by 2030, 2040, 2050, and 2060 (terawatt hours [TWh]); and (iv) reduced annual household electricity consumption by 2030, 2040, 2050, and 2060 (kWh) as a result of implementing select passive and low-energy cooling solutions.

This report describes the methodology and results of the CBA and is intended to inform the E³WG and the second JETP CIPP in 2024.

2. Framework

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. It provides a measure of the 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 framework for CBA of different building cooling solutions under the NZW Initiative presented above is illustrated in Figure 1. Leveraging the building-level energy analysis results from the NZW IBDWG SWG-A, SWG-C assessed the consumer and national costs and impacts associated with the 12 whole-building cooling solutions. Using the evaluated metrics from CBA, cooling solutions were compared against the baseline and each other to identify the most promising measures. Three key stages are expanded in Table 1.

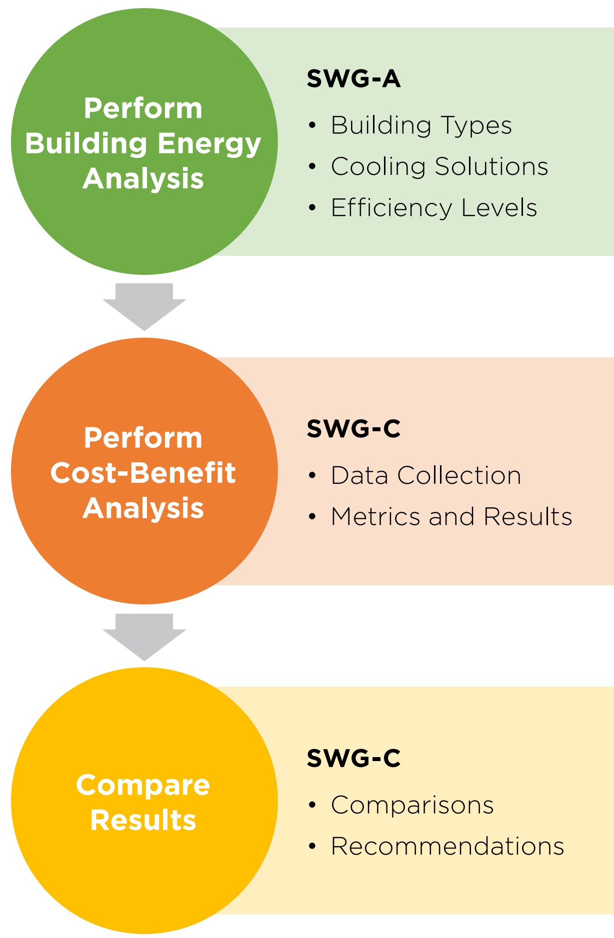


Figure 1. Framework for CBA on Whole-Building Cooling Solutions for Indonesia's Building Sector

Table 1. Framework for CBA and its Work Scopes

Stages	Work Scope
Perform Building Energy Analysis (SWG-A)	The scope of project was established, which involves determining the building type and cooling technologies, and desired efficiency levels. SWG-A selected twelve passive or low-energy cooling solutions tailored for the tropical climates of Indonesia such as natural ventilation, solar-control windows, and ceiling fans. One building type was simulated in four climates to analyze annual energy savings potential. These twelve solutions served as the basis of the CBA. SWG-A also evaluated the performance of a baseline building that does not employ any of the solutions. This baseline assessment preceded the evaluation of each solution's merits at varying efficiency levels.
Perform Cost-Benefit Analysis (SWG-C)	The CBA was then developed to assess the impact of individual cooling solutions on both consumer and national levels, spanning from the present to the year 2060. Data Collection: To project future impacts, reliable data must be acquired to make informed assumptions and quantify uncertainties. The initial phase involved comprehensive data collection, incorporating factors such as national-level energy use trends, future income growth, air-conditioning system trends, minimum equipment performance standards scenarios, and other crucial elements. Determination of Metrics: The broader costs and benefits of each cooling solution were estimated by employing life-cycle cost (LCC), payback period (PBP) analysis, net present value (NPV), and energy burden analysis for low-income consumers.
Compare Results (SWG-C)	Metrics of each cooling solution were compared against the baseline and each other. The goal was to identify the most promising energy conservation measures aligned with the objectives of the JETP. This comparison aids in suggesting optimal strategies for achieving energy efficiency and decarbonization goals.

3. Cost Benefit Analysis Components

Following upon the CBA framework outlined in Part 2, the subsequent chapters provide in-depth outcomes of each stage covering (3.1) Building Energy Analysis outcomes with examined building types, construction specifics, and cooling solutions (i.e., energy conservation measures, ECM) and their efficiency levels, (3.2) Cost-Benefit Analysis outcomes with introduction of the collected data, definitions of metrics employed in the analysis, and presentation of the analysis results, and (3.3) Comparisons and Recommendations with the top four ECMs based on cost-benefit considerations and insights to guide investment decisions for the JETP.

3.1. Building Energy Analysis (SWG-A)

As its departure point, the SWG-A conducted building energy performance simulation with 12 passive or low-energy cooling strategies that include the following:

1. Ceiling Fan with thermostat setback
   - Thermostat setback from 25˚C to 27˚C with air speed of 0.4 m/s
   - Thermostat setback from 25˚C to 28˚C with air speed of 0.8 m/s
2. Ceiling Fan without thermostat setback
   - No setback with air speed of 0.4 m/s
   - No setback with air speed of 0.8 m/s
3. Cool Roof
   - Solar reflectance of 0.40
   - Solar reflectance of 0.60
4. Cool Wall
   - Solar reflectance of 0.40
   - Solar reflectance of 0.60
5. Insulated Roof
   - R-value of 0.18 $m^2 \cdot K/W$
   - R-value of 2.55 $m^2 \cdot K/W$
6. Insulated Wall
   - R-value of 0.88 $m^2 \cdot K/W$
   - R-value of 2.29 $m^2 \cdot K/W$
7. Exterior Awning
   - Solar Heat Gain Coefficient (SHGC) of 0.7 and Visible Transmittance (VT) of 0.7
8. Exterior Shading
   - SHGC of 0.1 and VT of 0.09
9. Interior Shading
   - Solar reflectance of 0.10
   - Solar reflectance of 0.80
10. Low-E Window
    - U-value of 3.41 $W/m^2 \cdot K$, SHGC of 0.3, and VT of 0.48
    - U-value of 2.27 $W/m^2 \cdot K$, SHGC of 0.2, and VT of 0.40
11. Solar Window Film
    - SHGC of 0.49 and VT of 0.52
    - SHGC of 0.30 and VT of 0.31
12. Natural Ventilation
    - Day and night with window opening fraction of 0.5
    - Day and night with window opening fraction of 1.0
    - Night only with window opening fraction of 0.5
    - Night only with window opening fraction of 1.0

A prototype building (Figure 2) representing low-to-moderate income (LMI) single-family housing in Indonesia was chosen. This structure comprises a living room, kitchen, bathroom, two bedrooms, and an attic, with minimal insulation in the envelope. The study (Yin et al., 2023) encompassed four locations in Indonesia—Padang, Jakarta, Waingapu, and Balikpapan—where four orientations (north-, south-, east-, and west-facing) were examined. The analysis included scenarios both with and without the individual cooling solutions mentioned above.

The following CBA draw upon work completed by SWG-A that includes cooling system energy consumption of buildings in combination of the building's location, orientation, cooling solutions implemented, and whether active air-conditioning systems are utilized or not.

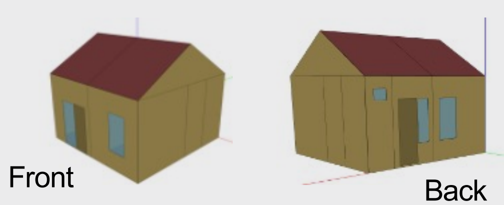
3.2. Cost Benefit Analysis (SWG-C)

Having all energy consumption data (Chapter 3.1), the analysis then focused on acquiring the data needed to understand performance of each scenario relative to each other, and the merits of each approach according to agreed metrics and output results (Chapter 3.2.2).

This single building-level view of each scenario was 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. To enhance the analysis, it was necessary to go beyond a mere multiplication of impacts at the level of individual buildings. This involved incorporating broader parameters of the investment's costs and benefits, such as the national cooling system energy demand (Chapter 3.2.1). By doing so, the scenarios could be expressed more broadly in terms of national impacts and JETP objectives. This approach allowed for consideration of the outcomes that would arise with and without JETP investment, which is the primary aim of the CBA.

Four cities selected to reflect various climate conditions in Indonesia

Building Geometry



Baseline Characteristics

36 m² low-to-moderate income (LMI) single-story rowhouse

Living room, kitchen, bathroom, two bedrooms, attic

Brick walls, clay tile roof, single-pane windows, concrete foundation, unitary single-speed direct expansion AC

Figure 2. Overview of Prototype Building and Locations in Building Energy Analysis

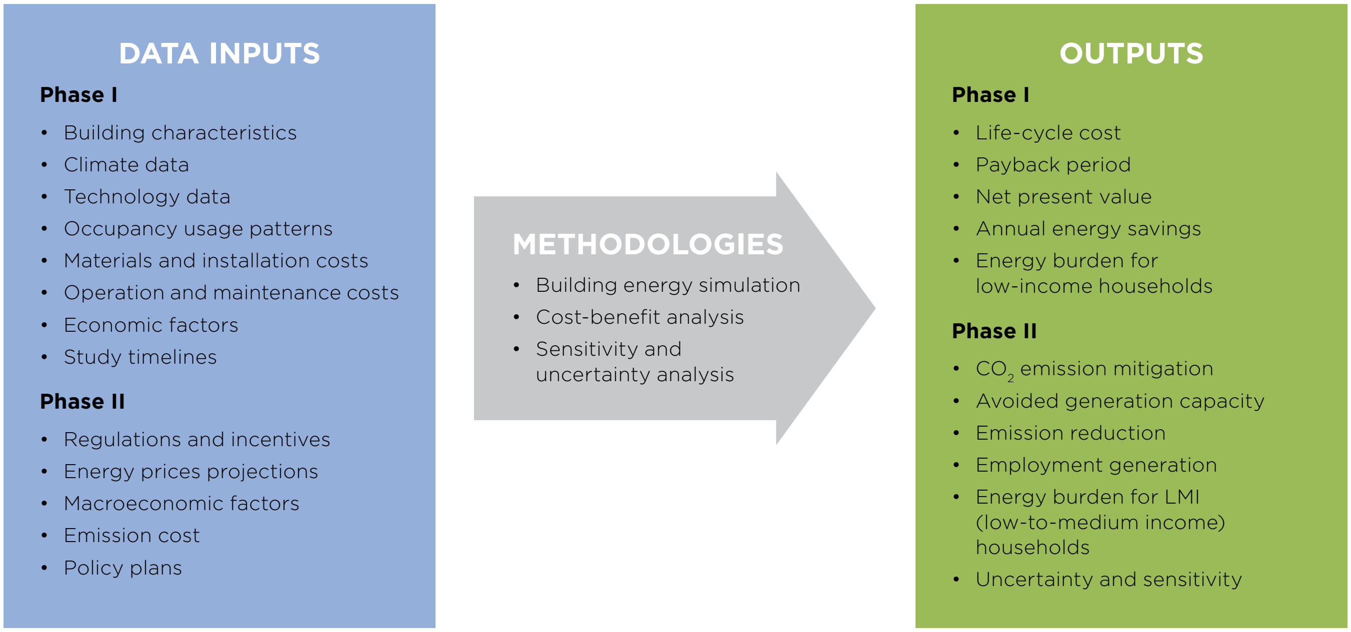


Figure 3. Overall Data Flow Framework for the CBA

CBA for implementing cooling solutions for buildings requires consideration of various data points specific to the local context related to (a) technology specifications and overall energy performance; and (b) economic and cost parameters, both for individual measures and broader economic factors, that will ultimately support investment decision making. An overall framework of data flows for the cost-benefit analysis is presented in Figure 3. In the initial phase of the CBA, our analysis was hindered by data limitations, restricting us to conducting only a partial examination within the framework. More information on the outputs of Phase 1 and future steps are explained in details in Chapters 3.2.2 and 4.

3.2.1. Data Collection

Two significant projections are essential for the CBA: projecting building-level energy performance to the national level and projecting current energy performance into future years. These projections require the acquisition of reliable data to make informed assumptions and quantify uncertainties. The initial phase involved thorough data collection, encompassing factors such as national-level energy use trends, future income growth, trends in air-conditioning systems, and scenarios for minimum equipment performance standards. General methodologies for projection using the collected data are provided in subsequent chapters, with further details of calculations available in Appendices A and B.

Population and House Orientations. To extrapolate the household-level findings to a national scale, we first determined the proportion that each climate zone represents in Indonesia using a population survey (CLASP, 2020). This survey covered 34 provinces in Indonesia, including only the electrified household population (Figure 4). Using this data, we categorized the 34 provinces into four climate regions explored in energy simulations (Jakarta, Balikpapan, Padang, and Waingapu) based on climate conditions and distance, as shown in Table 2, Climate Zone Fraction. The next step was to divide these household populations according to orientations by comparing city street orientations using street map views (Figure 5). In Jakarta, a predominant orientation of houses (North-South) was observed, and we assumed higher fractions in South- and North-facing houses. In other cities, we assumed an equal 25% fraction for each orientation due to irregularities in street orientations (Table 2). By employing a distribution of the Indonesian household population and its

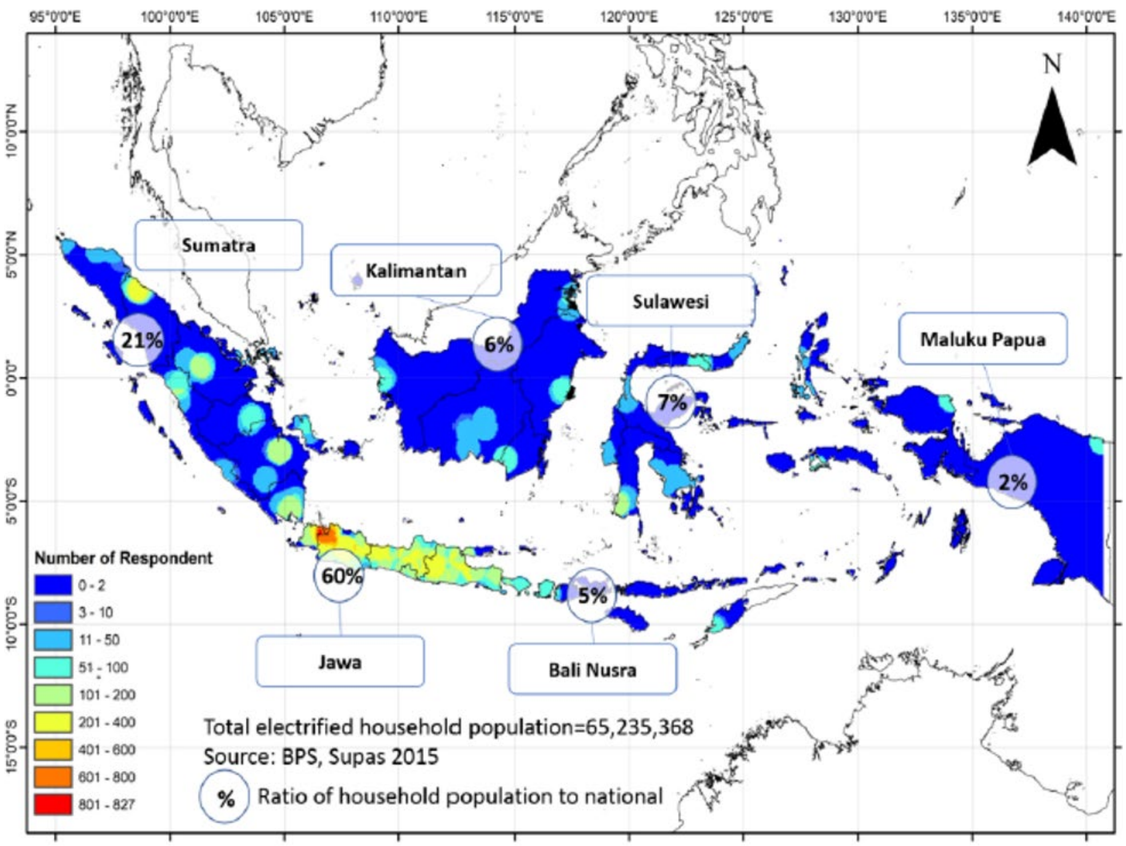


Figure 4. Distribution of Indonesian Household Population with Access to Electricity (Inter-Census Survey 2015, Budan Pusat Statistik BPS Indonesia) Used to Calculate Population Fractions

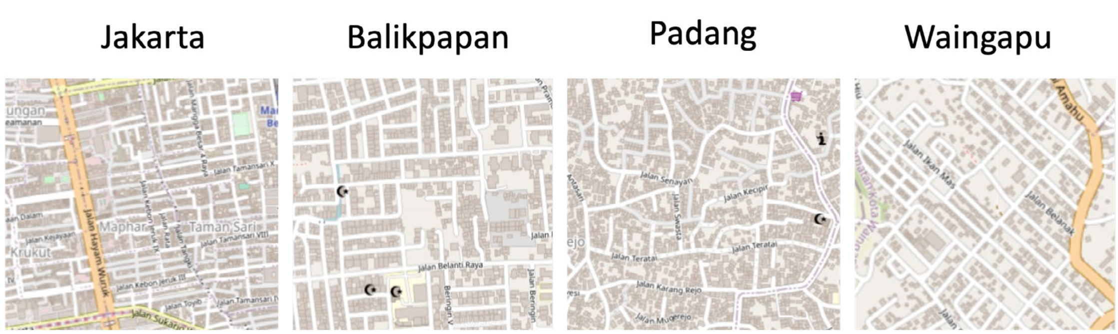


Figure 5. Street Map Views of Four Indonesian Cities Used to Calculate Housing Orientation Fractions

Table 2. Fraction of Indonesian Households Represented by Different Climate Zones

City	Climate Zone Fraction	Orientation Fraction South	West	North	East
Jakarta	65%	40%	15%	30%	15%
Balikpapan	12%	25%	25%	25%	25%
Padang	15%	25%	25%	25%	25%
Waingapu	5%	25%	25%	25%	25%

Table 3. Weighted Average of Model Results Per Household According to Location and Orientation

Bedroom-Only AC Energy			Whole-House AC Energy		
ECM	Annual AC Electricity Use (kWh)	Annual AC Electricity Savings (kWh)	ECM	Annual AC Electricity Use (kWh)	Annual AC Electricity Savings (kWh)
Baseline	949.0	0.0	Baseline	4900.2	0.0
CeilingFan_1	365.3	583.7	CeilingFan_1	2528.7	2371.5
CeilingFan_2	221.6	727.4	CeilingFan_2	1496.8	3403.4
CeilingFan_NoSetback_1	949.0	0.0	CeilingFan_NoSetback_1	4900.2	0.0
CeilingFan_NoSetback_2	949.0	0.0	CeilingFan_NoSetback_2	4900.2	0.0
CoolRoof_1	831.2	117.8	CoolRoof_1	4563.0	337.2
CoolRoof_2	688.2	260.8	CoolRoof_2	4105.5	794.7
CoolWall_1	828.1	120.9	CoolWall_1	4615.5	284.7
CoolWall_2	691.4	257.6	CoolWall_2	4227.5	672.7
ExtExtAwning_1	895.9	53.1	ExtExtAwning_1	4762.5	137.7
ExtShade_1	877.2	71.8	ExtShade_1	4694.5	205.7
InsRoof_1	638.2	310.8	InsRoof_1	3794.5	1105.7
InsRoof_2	548.3	400.6	InsRoof_2	3478.5	1421.7
InsWall_1	529.5	419.5	InsWall_1	3464.0	1436.2
InsWall_2	498.3	450.7	InsWall_2	3326.3	1573.8
IntShade_1	967.4	-18.4	IntShade_1	4991.2	-91.0
IntShade_2	916.7	32.3	IntShade_2	4858.9	41.3
LowEWin_1	851.5	97.5	LowEWin_1	4584.7	315.5
LowEWin_2	788.2	160.8	LowEWin_2	4357.2	543.0
NV_DayAndNight_1	767.4	181.5	NV_DayAndNight_1	4764.6	135.6
NV_DayAndNight_2	767.0	181.9	NV_DayAndNight_2	4764.1	136.1
NV_NightOnly_1	852.9	96.0	NV_NightOnly_1	4867.2	33.0
NV_NightOnly_2	852.8	96.2	NV_NightOnly_2	4867.0	33.2
SolarWin_1	895.3	53.7	SolarWin_1	4768.8	131.4
SolarWin_2	827.7	121.3	SolarWin_2	4565.8	334.3

orientations, the proportions of the total Indonesian household population represented by four cities were determined. Using the fractions, we calculated the national average household electricity use and savings for each energy conservation measure (ECM) by weighting model results based on its location and orientation (Table 3).

Future Nationwide Income Growth. In projecting future scenarios, it is crucial to appropriately assume the expected income growth. This is essential for gaining insights into the prospective energy cost burdens across various income brackets and for forecasting the number of households likely to adopt AC systems in the future. Leveraging data from the Indonesian household income survey in 2023 (Bank Indonesia, 2023; Table 4), we applied the gross domestic product (GDP) per household growth projections from IEA (IEA, 2022) to estimate the income growth in the low-, middle-, and high-income groups in Indonesia from 2020 to 2060 (Figure 6). Anticipated income growth in the coming years is expected to drive significant increases in the number of homes and a rise in the proportion of homes equipped with some form of air-conditioning. By considering future air conditioner stock from various sources (Park et al., 2021; IPSOS, 2020; IEA, 2022), we projected the numbers of households without air-conditioning, those with bedroom air-conditioning, and those with whole-house air-conditioning, as illustrated in Figure 7.

Table 4. Indonesian Annual Household Income in 2023

Indonesian Household Income		
Income Group	Average Annual Income (USD/year)	Fraction of Population
Low	1,475	20%
Middle	3,598	63%
High	6,184	17%

Future Minimum Equipment Performance Standards (MEPS). As the adoption of air-conditioning systems rises, it becomes imperative to raise the average MEPS for air conditioners to achieve a net-zero target by 2050. The subsequent CBA incorporates an analysis of these escalating MEPS to extrapolate the scale of HVAC electricity usage in the future. The fractions of standard-, mid-, and high-performance AC installations (Table 5) are assumed based on projections outlined in IEA (2022) and the Indonesia residential end use survey (CLASP, 2020). Based on the survey data in 2019, we assumed that from 2030 to 2060, both high and medium-performance inverters would increase by 10% each decade. This projection would lead to the total market share of inverter ACs reaching 90% by 2060, consistent with the IEA's Announced Pledges Scenario (APS) for Indonesia. Similarly, the expected increases in the Cooling Seasonal Performance Factor (CSPF, Table 6) are assumed per decade to reach CSPF 8 in 2060 when the high MEPS is applied, aligning with the IEA's Announced Pledges Scenario (APS) for Indonesia. Lastly, by comparing the weighted average of CSPF in Table 6, the scale factor of AC electricity use per decade is determined (Table 7). For example, in 2030, the AC electricity use is projected to decrease by 24% (with a scale factor of 0.76) compared to the year 2020 (with a scale factor of 1).

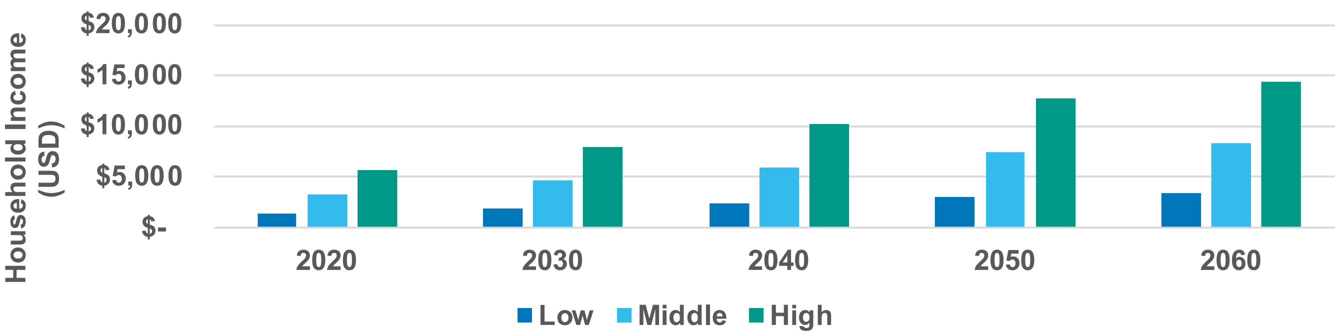


Figure 6. Projected Income Growth in Indonesia, 2020-2060

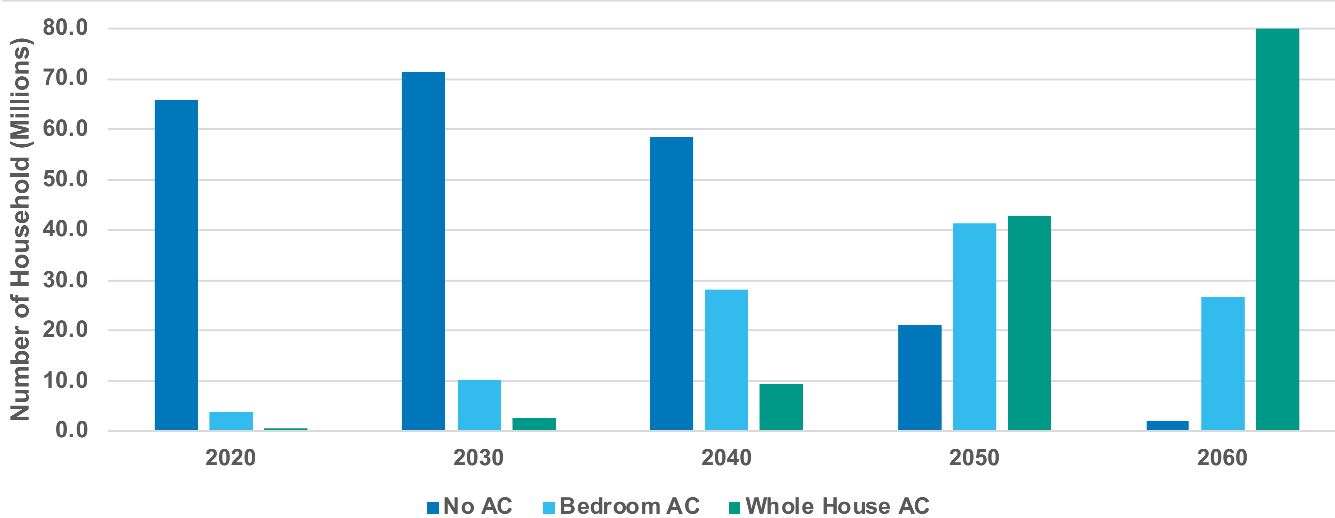


Figure 7. Projected Number of Indonesian Households with Any Type of Air-Conditioning, 2020-2060

Table 5. Fractions of Standard-, Mid-, and High-Performance AC Installations, 2020-2060

Fractions of Standard, Med and High Perform 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 6. Cooling Seasonal Performance Factor, 2020-2060

CSPF	**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 7. Air-Conditioning Electricity Scale Factor, 2020-2060

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

3.2.2. Output Metrics

The calculations performed for each ECM provide a common basis for comparison and decision on the benefits of different measures. The data output for each scenario includes:

- Net Present Value
- Payback Period
- Life-Cycle Cost
- Energy burden analysis for low-to-medium income consumers

The metrics are explained below, with detailed calculations provided in Appendix A.

Net Present Value (NPV). Net present value evaluates the profitability of an investment by calculating the present value of anticipated future cash flows. This involves adjusting these cash flows for the time value of money, considering a specified discount rate. NPV helps determine the current value of a series of cash inflows and outflows over time. The formula involves summing the present values of expected cash flows (i.e., energy cost savings) and subtracting the initial investment cost and annual maintenance expenses (i.e., equipment cost), providing insight into whether the investment is likely to generate positive or negative value. This is a crucial metric in financial analysis, aiding in the evaluation of the economic viability of investments.

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 determined by identifying the year when the NPV (cumulative cash flow) turns positive. While PBP is a basic and straightforward method, it primarily concentrates on the duration required to recover initial costs, rather than offering a comprehensive view of an investment's profitability over its entire lifecycle.

Life-Cycle Cost (LCC). A consumer life-cycle cost 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.

Considering that prevailing interest rates in Indonesia have averaged approximately 5-6% over the past 10 years (Trading Economics, 2023), this study used a 5% discount rate in determining the value of future financial costs and benefits in the CBA.

Energy burden analysis for low-to-medium income consumers. Energy burden analysis for 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. 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 among 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. CBA Results

Nationwide Electricity Demand. Initially, the electricity demand for air-conditioning across the nation is projected up to the year 2060 for each ECM, utilizing the data and assumptions outlined in Chapter 3.2.1. The projection indicates an exponential increase in nationwide electricity demand for AC through 2060, underscoring the imperative for ECMs to mitigate this growth. Notably, ceiling fans with AC temperature setback emerge as the most effective solution, followed by insulated walls, insulated roofs, and cool roofs (Figure 8.)

ECM	2020	2030	2040	2050	2060
	Nationwide AC Electricity Demand (TWh)				
Baseline	5.8	16.6	37.6	107.2	144.3
CeilingFan_1	2.5	7.6	17.4	53.2	73.3
CeilingFan_2	1.5	4.5	10.4	31.6	43.5
CeilingFan_NoSetback_1	5.8	16.6	37.6	107.2	144.3
CeilingFan_NoSetback_2	5.8	16.6	37.6	107.2	144.3
CoolRoof_1	5.2	15.1	34.2	98.9	133.9
CoolRoof_2	4.5	13.1	29.8	88.0	119.9
CoolWall_1	5.2	15.1	34.4	99.8	135.3
CoolWall_2	4.5	13.4	30.4	90.3	123.3
ExtAwning_1	5.5	15.9	36.1	103.7	140.0
ExtShade_1	4.8	13.9	31.5	92.3	125.3
InsRoof_1	4.1	12.1	27.6	81.4	110.9
InsRoof_2	3.7	10.8	24.7	74.0	101.3
InsWall_1	4.1	12.1	27.5	81.8	111.8
InsWall_2	3.5	10.5	24.0	72.5	99.5
IntShade_1	5.9	16.9	38.3	109.2	147.0
IntShade_2	5.7	16.3	36.9	105.9	142.9
LowEWin_1	5.1	14.7	33.3	96.4	130.6
LowEWin_2	4.9	14.2	32.2	93.5	126.8
NV_DayAndNight_1	5.1	15.0	34.1	101.6	138.9
NV_DayAndNight_2	5.1	15.0	34.1	101.6	138.9
NV_NightOnly_1	5.4	15.8	35.9	105.0	142.5
NV_NightOnly_2	5.4	15.8	35.9	104.9	142.5
SolarWin_1	5.5	16.0	36.1	103.8	140.2
SolarWin_2	5.2	15.0	34.1	98.9	134.0

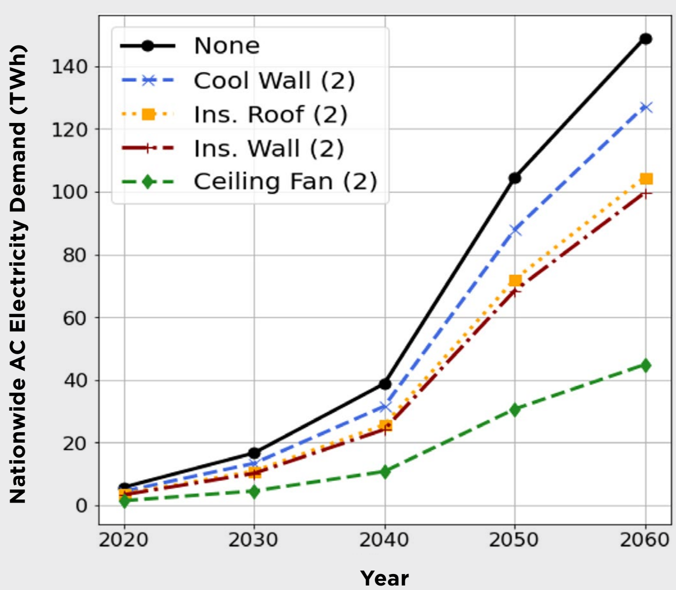


Figure 8. Effects of ECM on HVAC Electricity Growth

NPV, LCC, and PBP. For the cost-benefit analysis of ECMs, data on installation costs, replacement costs, maintenance costs, and lifetimes of individual ECMs are gathered, as shown in Table 8. The costs of equipment, materials and labor are primarily obtained from cost data and reports from Indonesia (Arcadis, 2019; Arcadis, 2023; Park et al., 2021; and Turner & Townsend, 2023) including online marketplaces. Calculations are conducted on an annual basis, with two different retrofit scenarios: 1) a moderate retrofit scenario, referred to as the "best case scenario," where minimal effort and additional cost is needed to install the suggested ECM such as when equipment naturally needs replacement, and 2) an aggressive retrofit, referred to as the "worst case scenario," where major retrofit at a high cost is needed to install the ECM with higher premium such as prematurely replacing a roof or rebuilding walls with insulation. Further details on scenarios and costs of each ECM are illustrated in Appendix C.

Using the collected cost data, NPV, LCC, and PBP are calculated following the formulas outlined in Appendix A. NPV and LCC account for costs and savings, considering the time value of money with a 5% discount rate in this CBA. Ceiling fan installation with temperature setbacks, insulated walls and roof are notably exhibit the best NPV across all analysis years for both retrofit scenarios (Figure 9 and Figure 10).

Table 8. Cost Data and Lifetime for Individual ECMs

	Cost (USD 2020)				Lifetime (Yrs)		
ECM	**New Install**	**Replacement**	**Aggressive Retrofit**	**Maintenance**	**New Install**	**Replacement**	**Aggressive Retrofit**
CeilingFan_1	0	0	0	2	20	20	20
CeilingFan_2	0	0	0	2	20	20	20
CeilingFan_NoSetback_1	0	0	0	2	20	20	20
CeilingFan_NoSetback_2	0	0	0	2	20	20	20
CoolRoof_1	0	0	487	2	50	50	15
CoolRoof_2	0	0	487	2	50	50	15
CoolWall_1	0	0	309	2	15	15	15
CoolWall_2	0	0	309	2	15	15	15
ExtAwning_1	206	206	206	2	20	20	20
ExtShade_1	160	160	160	2	15	15	15
InsRoof_1	88	0	114	0	100	100	100
InsRoof_2	1039	0	1064	0	100	100	100
InsWall_1	35	0	401	0	100	100	100
InsWall_2	110	0	476	0	100	100	100
IntShade_1	58	58	58	2	20	20	20
IntShade_2	58	58	58	2	20	20	20
LowEWin_1	396	396	1106	0	40	40	40
LowEWin_2	535	535	1247	0	40	40	40
NV_DayAndNight_1	0	0	0	0	100	100	100
NV_DayAndNight_2	0	0	0	0	100	100	100
NV_NightOnly_1	0	0	0	0	100	100	100
NV_NightOnly_2	0	0	0	0	100	100	100
SolarWin_1	478	478	478	0	15	15	15
SolarWin_2	478	478	478	0	15	15	15

Scenario 1: Moderate Retrofit					
ECM	NPV (USD) 2020	2030	2040	2050	2060
CeilingFan_1	72.15	983.06	1,656.21	2,105.17	2,426.48
CeilingFan_2	94.47	1,313.51	2,221.08	2,843.95	3,299.25
CeilingFan_NoSetback_1	-	(15.44)	(24.92)	(30.74)	(34.32)
CeilingFan_NoSetback_2	-	(15.44)	(24.92)	(30.74)	(34.32)
CoolRoof_1	13.12	159.34	266.67	333.07	378.02
CoolRoof_2	29.54	380.68	636.98	797.73	907.40
CoolWall_1	12.84	152.34	253.65	313.46	352.29
CoolWall_2	28.04	354.58	590.98	734.16	828.90
ExtAwning_1	(200.63)	(145.72)	(203.92)	(226.91)	(210.32)
ExtShade_1	(137.54)	131.12	327.76	451.44	536.10
InsRoof_1	(51.18)	414.02	754.26	974.70	1,128.77
InsRoof_2	(991.57)	(392.54)	45.51	329.18	527.34
InsWall_1	2.78	475.17	818.97	1,037.60	1,188.09
InsWall_2	(59.68)	573.62	994.46	1,291.88	1,482.94
IntShade_1	(60.44)	(108.00)	(163.27)	(185.68)	(209.69)
IntShade_2	(54.92)	(35.18)	(20.20)	(13.29)	(17.96)
LowEWin_1	(379.75)	(177.34)	(30.29)	62.60	69.92
LowEWin_2	(514.86)	(262.41)	(78.49)	38.94	120.04
NV_DayAndNight_1	16.32	196.89	320.08	378.28	406.78
NV_DayAndNight_2	16.36	197.36	320.84	379.20	407.79
NV_NightOnly_1	8.24	96.85	156.28	181.72	192.13
NV_NightOnly_2	8.26	97.07	156.64	182.15	192.59
SolarWin_1	(472.32)	(402.56)	(582.54)	(663.31)	(643.87)
SolarWin_2	(464.70)	(300.48)	(412.04)	(450.06)	(401.64)

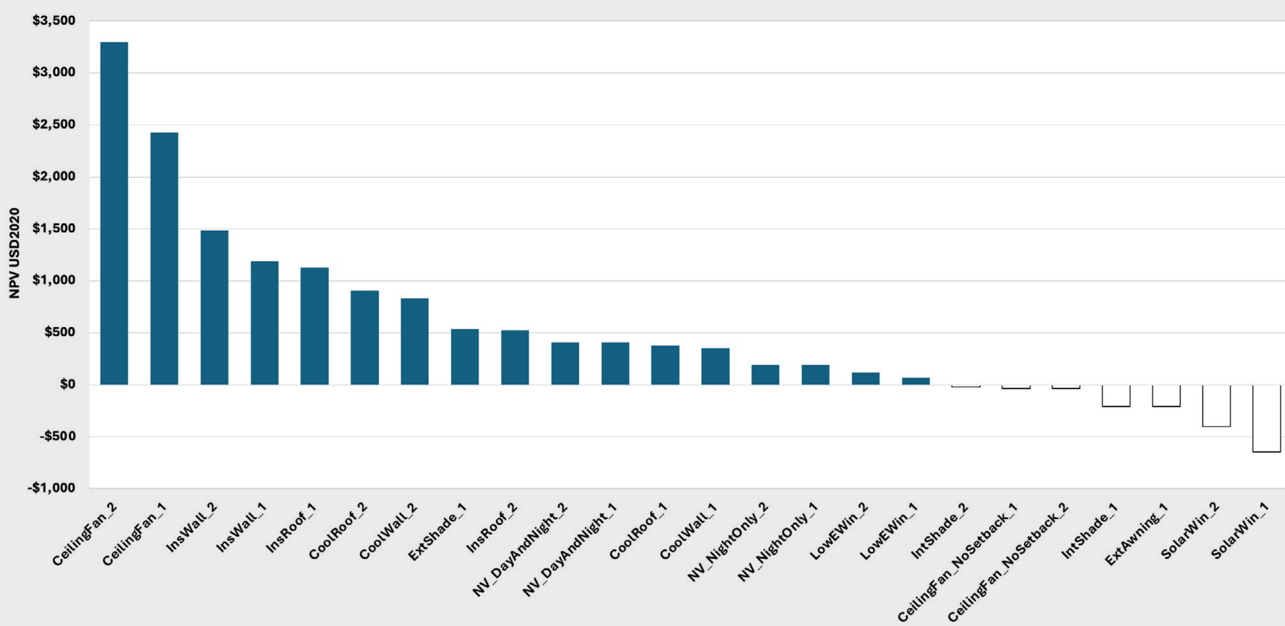


Figure 9. Scenario 1: Moderate Retrofit 40-year NPV (2020-2060) for Individual ECMs

Scenario 2: Aggressive Retrofit					
ECM	NPV (USD) 2020	2030	2040	2050	2060
CeilingFan_1	72.15	983.06	1,656.21	2,105.17	2,426.48
CeilingFan_2	94.47	1,313.51	2,221.08	2,843.95	3,299.25
CeilingFan_NoSetback_1	-	(15.44)	(24.92)	(30.74)	(34.32)
CeilingFan_NoSetback_2	-	(15.44)	(24.92)	(30.74)	(34.32)
CoolRoof_1	(474.29)	(328.07)	(220.74)	(154.34)	(109.39)
CoolRoof_2	(457.86)	(106.73)	(84.87)	(36.90)	72.77
CoolWall_1	(296.06)	(156.56)	(203.84)	(215.51)	(176.67)
CoolWall_2	(280.87)	45.68	165.65	308.83	359.70
ExtAwning_1	(200.63)	(145.72)	(203.92)	(226.91)	(210.32)
ExtShade_1	(137.54)	131.12	327.76	451.44	536.10
InsRoof_1	(77.18)	388.02	728.26	948.70	1,102.77
InsRoof_2	(1,016.57)	(417.54)	20.51	304.18	502.34
InsWall_1	(363.22)	109.17	452.97	671.60	822.09
InsWall_2	(425.68)	207.62	490.52	787.94	927.01
IntShade_1	(60.44)	(108.00)	(163.27)	(185.68)	(209.69)
IntShade_2	(54.92)	(35.18)	(20.20)	(13.29)	(17.96)
LowEWin_1	(1,089.75)	(887.34)	(740.29)	(647.40)	(740.94)
LowEWin_2	(1,226.86)	(974.41)	(790.49)	(673.06)	(591.96)
NV_DayAndNight_1	16.32	196.89	320.08	378.28	406.78
NV_DayAndNight_2	16.36	197.36	320.84	379.20	407.79
NV_NightOnly_1	8.24	96.85	156.28	181.72	192.13
NV_NightOnly_2	8.26	97.07	156.64	182.15	192.59
SolarWin_1	(472.32)	(402.56)	(582.54)	(663.31)	(643.87)
SolarWin_2	(464.70)	(300.48)	(412.04)	(450.06)	(401.64)

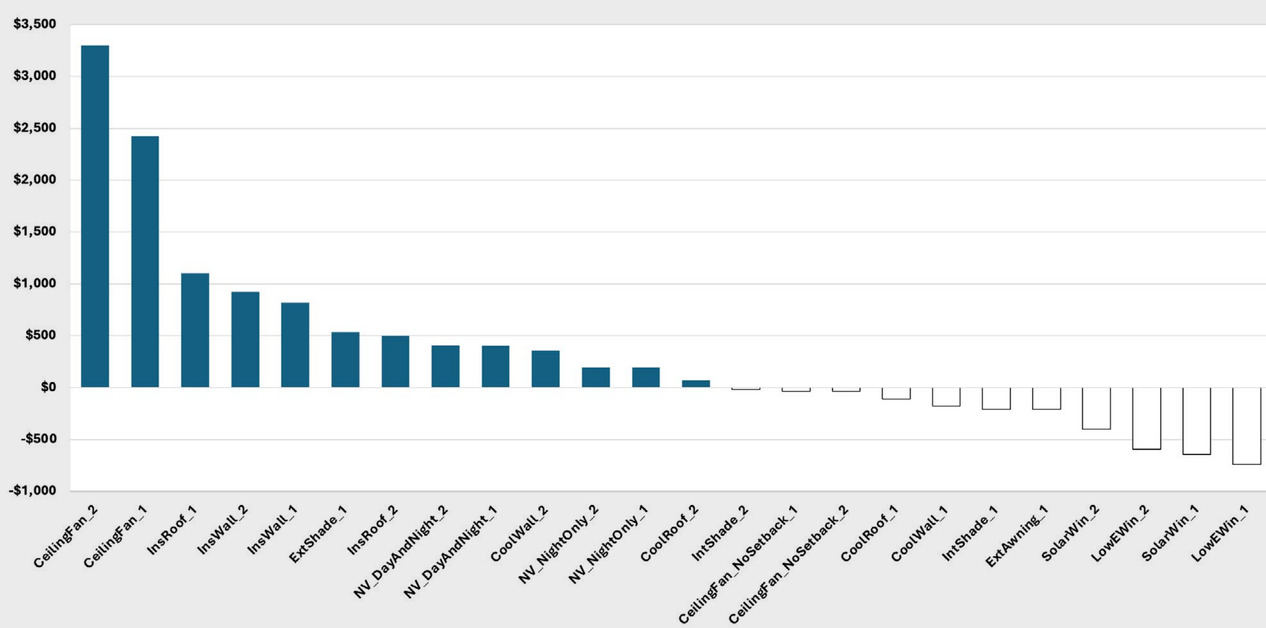


Figure 10. Scenario 2: Aggressive Retrofit 40-year NPV (2020-2060) for Individual ECMs

When comparing the retrofit scenarios between moderate and aggressive, some ECMs show notable changes in ranks based on NPV due to installation costs (Figure 11). This indicates that these ECMs require careful consideration based on the status of current and new housing. For instance, implementing a cool wall and roof with reflective paint is an effective energy efficiency measure, yielding significant energy savings by 2060. However, if major repainting is required for homes with darker exterior surfaces, the NPV of this measure diminishes. To maintain its value in such cases, the solar reflectance of the paint must be greater than 0.6.

Scenario 1: Moderate Retrofit

ECM	2060 NPV (USD)
CeilingFan_2	3,299.25
CeilingFan_1	2,426.48
InsWall_2	1,482.94
InsWall_1	1,188.09
InsRoof_1	1,128.77
CoolRoof_2	907.40
CoolWall_2	828.90
ExtShade_1	536.10
InsRoof_2	527.34
NV_DayAndNight_2	407.79
NV_DayAndNight_1	406.78
CoolRoof_1	378.02
CoolWall_1	352.29
NV_NightOnly_2	192.59
NV_NightOnly_1	192.13
LowEWin_2	120.04
LowEWin_1	69.92
IntShade_2	(17.96)
CeilingFan_NoSetback_1	(34.32)
CeilingFan_NoSetback_2	(34.32)
IntShade_1	(209.69)
ExtAwning_1	(210.32)
SolarWin_2	(401.64)
SolarWin_1	(643.87)

Scenario 2: Aggressive Retrofit

ECM	2060 NPV (USD)
CeilingFan_2	3,299.25
CeilingFan_1	2,426.48
InsRoof_1	1,102.77
InsWall_2	927.01
InsWall_1	822.09
ExtShade_1	536.10
InsRoof_2	502.34
NV_DayAndNight_2	407.79
NV_DayAndNight_1	406.78
CoolWall_2	359.70
NV_NightOnly_2	192.59
NV_NightOnly_1	192.13
CoolRoof_2	72.77
IntShade_2	(17.96)
CeilingFan_NoSetback_1	(34.32)
CeilingFan_NoSetback_2	(34.32)
CoolRoof_1	(109.39)
CoolWall_1	(176.67)
IntShade_1	(209.69)
ExtAwning_1	(210.32)
SolarWin_2	(401.64)
LowEWin_2	(591.96)
SolarWin_1	(643.87)
LowEWin_1	(740.94)

Figure 11. NPV Comparisons Between Moderate and Aggressive Retrofit Scenarios

Life-cycle costs align with NPV trends (Figure 12 an Figure 13). Through 2060 for both retrofit scenarios, ECMs with the lowest life-cycle costs are ceiling fans and insulated wall and roof. It's important to note that the payback time does not directly align with LCC and NPV, as payback time is heavily influenced by initial installation costs (Figure 14 and Figure 15).

Scenario 1: Moderate Retrofit LCC	
ECM	**2060 (USD)**
CeilingFan_2	1,323.83
CeilingFan_1	2,196.59
InsWall_2	3,140.13
InsWall_1	3,434.99
InsRoof_1	3,494.31
CoolRoof_2	3,715.67
CoolWall_2	3,794.17
ExtShade_1	4,086.97
InsRoof_2	4,095.73
NV_DayAndNight_2	4,215.29
NV_DayAndNight_1	4,216.29
CoolRoof_1	4,245.06
CoolWall_1	4,270.78
NV_NightOnly_2	4,430.48
NV_NightOnly_1	4,430.95
LowEWin_2	4,503.03
LowEWin_1	4,553.16
Baseline	4,623.08
IntShade_2	4,641.04
CeilingFan_NoSetback_1	4,657.39
CeilingFan_NoSetback_2	4,657.39
IntShade_1	4,832.76
ExtAwning_1	4,833.40
SolarWin_2	5,024.72
SolarWin_1	5,266.95

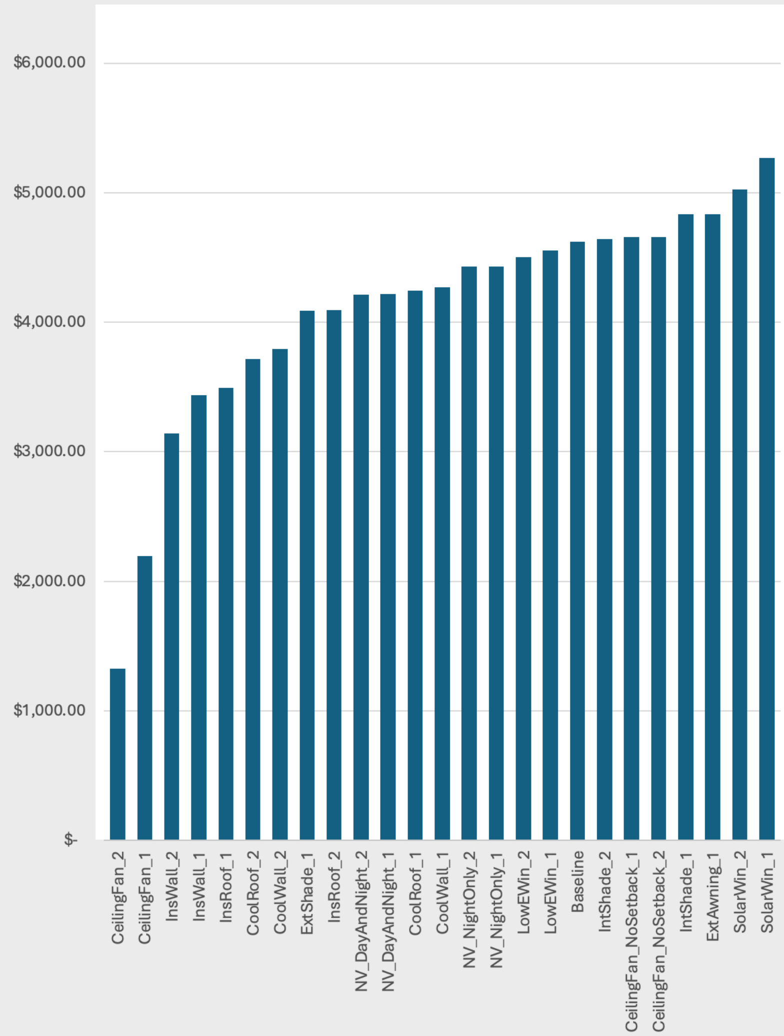


Figure 12. Scenario 1: Moderate Retrofit LCC (2020-2060) for individual ECMs

Scenario 2: Aggressive Retrofit LCC	
ECM	2060 (USD)
CeilingFan_2	1,323.83
CeilingFan_1	2,196.59
InsRoof_1	3,520.31
InsWall_2	3,696.06
InsWall_1	3,800.99
ExtShade_1	4,086.97
InsRoof_2	4,120.73
NV_DayAndNight_2	4,215.29
NV_DayAndNight_1	4,216.29
CoolWall_2	4,263.38
NV_NightOnly_2	4,430.48
NV_NightOnly_1	4,430.95
CoolRoof_2	4,550.31
Baseline	4,623.08
IntShade_2	4,641.04
CeilingFan_NoSetback_1	4,657.39
CeilingFan_NoSetback_2	4,657.39
CoolRoof_1	4,732.46
CoolWall_1	4,799.75
IntShade_1	4,832.76
ExtAwning_1	4,833.40
SolarWin_2	5,024.72
LowEWin_2	5,215.03
SolarWin_1	5,266.95
LowEWin_1	5,364.01

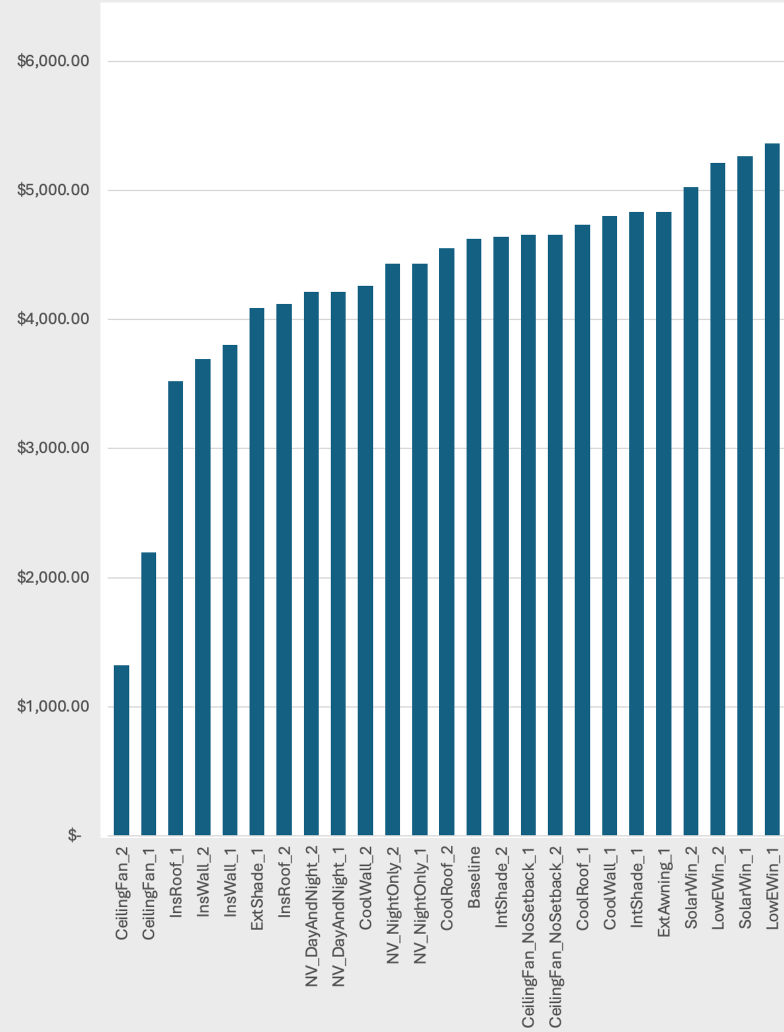


Figure 13. Scenario 2: Aggressive Retrofit LCC (2020-2060) for individual ECMs

Scenario 1: Moderate Retrofit	
ECM	**Years to Payback**
CeilingFan_1	0
CeilingFan_2	0
CoolRoof_1	0
CoolRoof_2	0
CoolWall_1	0
CoolWall_2	0
InsWall_1	0
NV_DayAndNight_1	0
NV_DayAndNight_2	0
NV_NightOnly_1	0
NV_NightOnly_2	0
InsRoof_1	2
InsWall_2	2
ExtShade_1	6
InsRoof_2	19
LowEWin_1	23
LowEWin_2	27

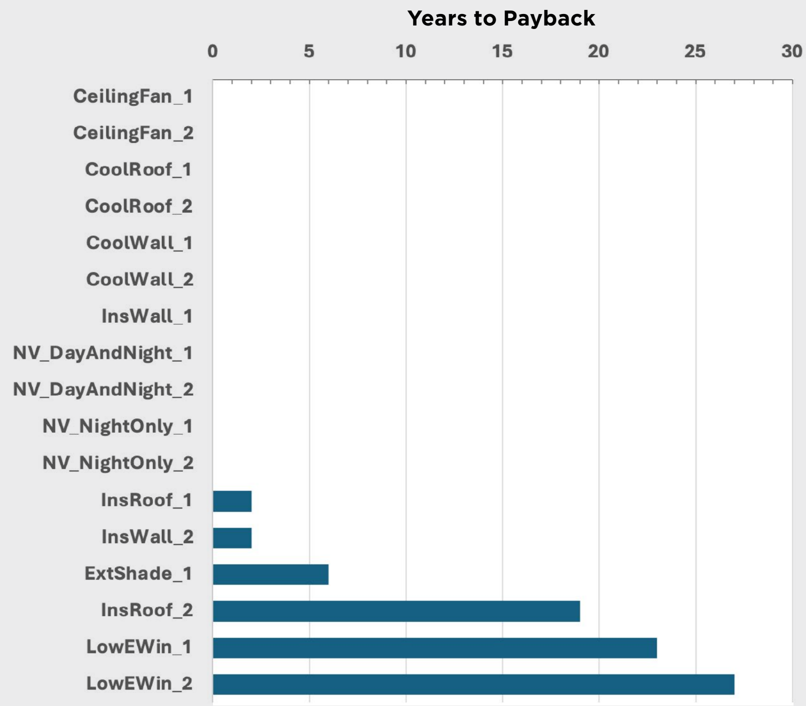


Figure 14. Scenario 1: Moderate Retrofit Years to Payback for individual ECMs

Scenario 2: Aggressive Retrofit	
ECM	**Years to Payback**
CeilingFan_1	0
CeilingFan_2	0
NV_DayAndNight_1	0
NV_DayAndNight_2	0
NV_NightOnly_1	0
NV_NightOnly_2	0
InsRoof_1	2
ExtShade_1	6
InsWall_2	7
InsWall_1	8
CoolWall_2	9
CoolRoof_2	14
InsRoof_2	20

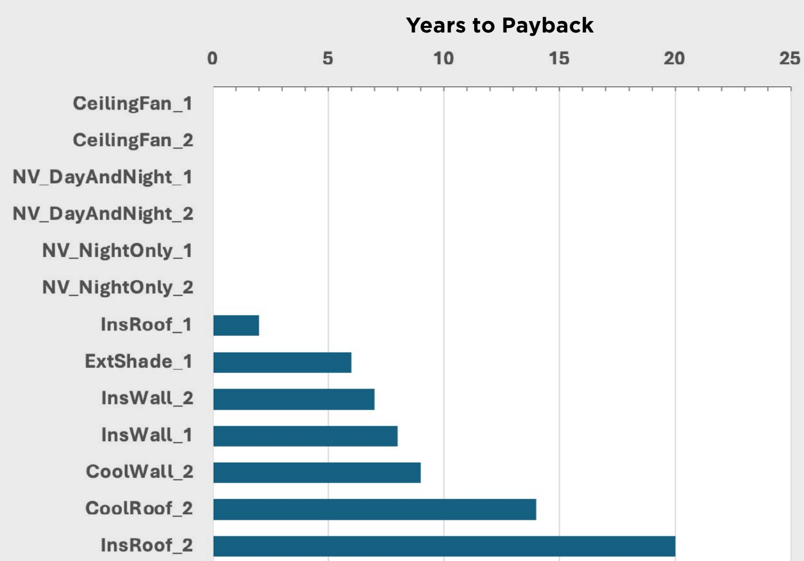


Figure 15. Scenario 1: Moderate Retrofit Years to Payback for individual ECMs

Energy Cost Burden for Low-Income Households. Finally, the energy cost burden (ECB) for low-income households with air-conditioning (AC) is determined by dividing energy costs by income. Presently, the baseline energy expenditure without ECMs comprises nearly 10% of the income for low-income Indonesian households (Baseline; Figure 16). However, projections indicate that as incomes increase and AC efficiency improves over the years, this proportion is expected to decline to 4.9% by 2060 under the baseline scenario without ECM implementation.

In contrast, the adoption of ceiling fans demonstrates a notable impact, significantly reducing the ECB to 2.5% in the current year. This reduction is projected to further diminish to 1.3% by 2060. Such findings underscore the substantial influence of ceiling fan implementation in mitigating the energy cost burden for low-income households in the near future.

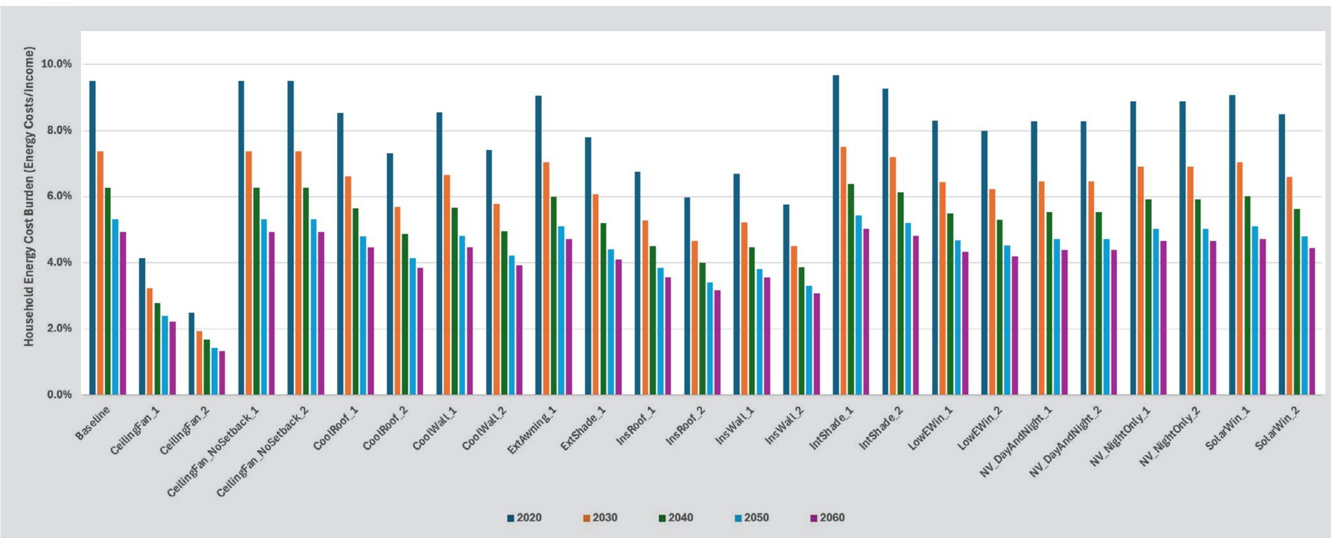


Figure 16. Energy Cost Burden for Low-Income Households 2020-2060

Table 9. Summary of CBA Results for Best ECMs (Based on Scenario 1: Moderate Retrofit)

Comparison to Baseline:	**Ceiling Fan (2)** (with thermostat setback to 28°C and air speed of 0.4 m/s)	**Insulation Wall (2)** (with R-value of 2.29 $m^2 \cdot K/W$)	**Insulation Roof (1)** (with R-value of 0.18 $m^2 \cdot K/W$)	**Cool Roof (2)** (with solar reflectance of 0.60)
Individual Household Investment Required (USD)	0.00	110.00	88.00	0.00
Individual Household Payback Period (years)	1	2	2	1
Individual Household Life-Cycle Cost (USD)	1,323.83	3,140.13	3 ,494.31	3,715.67
Energy Burden Analysis 2020 (average energy cost/average household income, %)	2.5%	5.8%	6.8%	7.3%
Energy Burden Analysis 2030 (average energy cost/average household income, %)	1.9%	4.5%	5.3%	5.7%
Energy Burden Analysis 2040 (average energy cost/average household income, %)	1.7%	3.9%	4.5%	4.9%
Energy Burden Analysis 2050 (average energy cost/average household income, %)	1.4%	3.3%	3.8%	4.2%
Energy Burden Analysis 2060 (average energy cost/average household income, %)	1.3%	3.1%	3.6%	3.9%
Individual Household Net Present Value (USD)	3,299.25	1,482.94	1,128.77	907.40
Individual Household Annual Energy Savings by 2030 (KWh)	11,166.21	5,754.59	4,225.15	3,336.89
Individual Household Annual Energy Savings by 2040 (KWh)	19,171.95	9,789.70	7,194.86	5,656.58
Individual Household Annual Energy Savings by 2050 (KWh)	27,576.68	13,753.72	13,334.20	7,873.68
Individual Household Annual Energy Savings by 2060 (KWh)	37,025.33	18,005.41	13,303.58	10,202.05

4. Conclusions and Future Work

In the first phase of the cost-benefit analysis, the energy system investment impact and distributional impacts are initially accessed by having both national- and household-level electricity demand for air-conditioning systems. This evaluation incorporates net present values, life-cycle costs, and energy cost burdens for low-income households. The results of these calculations are presented in Chapter 3.

Four key ECMs have been identified to reduce AC energy demand in single-family housing in Indonesia: ceiling fan with temperature setback; insulated walls; insulated roof; and cool roof. This study found that low-income households with AC installations in Indonesia currently face a high energy cost burden of approximately 10%. However, by implementing a ceiling fan with temperature setback, this burden could decrease to 2.5% today and further reduce to 1.3% by the year 2060. The PBP for a ceiling fan with temperature setback is immediate, highlighting its lowest LCC and highest NPV.

In the upcoming phase of CBA, a series of building cooling improvement scenarios can be further defined, incorporating more than one ECM in combination with socio-economic factors evaluated in the initial CBA phase. Additionally, the analysis of ECM effects in multifamily housing can be expanded. This further national analysis would incorporate a holistic system-level perspective. These considerations might further include:

1. **Economic Impact:** 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.

2. **Emission Cost Evaluation:** Builds 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.

3. **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.

4. **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).

5. **Policy Alignment:** 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.

6. **Uncertainty and Sensitivity Analysis:** Addresses uncertainty and variability in a systematic and transparent manner, helping 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.

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Appendix A: Methodology

Average household and Nationwide HVAC Energy Demand

The average household HVAC energy demand is estimated from the simulations of the homes with HVAC systems and ECMs. The HVAC energy use for a single home in given home orientation, climate zone, HVAC location, and ECM were simulated by SWG-A. As described in Section 3.2.1, the fractions of buildings with a given orientation in each climate zone, fractions of buildings in each climate zone, and fraction of buildings with HVAC with whole home HVAC or bedroom only HVAC, and the year-by-year HVAC energy scaling from increasing energy MEPS were estimated and are given in Tables 2-7 and Figures 4-7. The average household HVAC energy consumption for a given ECM l in a given year y, $E_{l,y}$, is given by

$$\overline{E_{l,y}} = \sum_{i=1}^{2}\sum_{j=1}^{4}\sum_{k=1}^{4} L_{i,y}\, C_j\, O_{j,k}\, E_{i,j,k,l}\, S_y \qquad (1)$$

where

i denotes the HVAC location (Whole House or Bedroom Only),

j denotes the climate zone (Jakarta, Balikpapan, Padang, and Waingapu)

k denotes the orientation (North, South, East, West),

l denotes the ECM scenario (see Section 3.1),

y denotes the year (2020 – 2060),

$L_{i,y}$ is the nationwide fraction of buildings with HVAC in location I in year y (from linear interpolation data from Figure 4),

C_j is the nationwide fraction of buildings located in climate zone j (see Table 2),

$O_{j,k}$ is the fraction of buildings with orientation k in climate zone j (see Table 2),

$E_{i,j,k,l}$ is the annual HVAC home energy consumption for HVAC location i, in climate zone j, with orientation k and ECM l, and $S_y = CSPF_y / CSPF_{2020}$ is the yearly energy scaling factor from increasing equipment efficiency and $CSPF_y$ is the weighted cooling season performance factor in year y (see Table 6 and 7).

Net Present Value (NPV)

The Net present value is the difference between the present value of cash inflows and preset value of cash outflows over the period of analysis. For this analysis, the analysis is broken into N periods of one year and the annual energy cost savings are considered as cash inflows and annual investments, maintenance, and repair or replacement costs are cash outflows. The NPV over N years can then be written as

$$NPV_N = \sum_{i=1}^{N} S_i P_j DF_i - \sum_{i=1}^{N} M_i IF_j DF_i - Initial\ Investment \quad (2)$$

where

i denotes the year of analysis,

S_i denotes the energy savings in year i,

P_i denotes the energy price in year i,

M_i denotes the maintenance and repair costs in year i,

IF_i denotes the inflation scale factor in year i,

DF_i denotes the discount factor in year i, and

$Initial\ Investment$ denotes the cost to initially purchase and install the ECM

The discount factor in year i, DF_i, accounts for the time value of money and is given by

$$DF_i = \prod_{j=0}^{i} \frac{1}{(1 + DR_j)} \quad (3)$$

where i, and j are years and DR_j is the discount rate in year j. When the discount rate is assumed to be constant DR, Eq (3) reduces to

$$DF_i = (1 + DR)^{-j} \quad (4)$$

The inflation factor in year i, IF_i, accounts for price inflation and is given by

$$IF_i = \prod_{j=0}^{i} (1 + IR_j) \quad (5)$$

where i, and j are years and IR_j is the inflation rate in year j.

When both IR_j and DR_j are constant over time, as in this analysis, inflation and discount factors can be combined into a nominal discount factor computed using a nominal discount rate that combines both inflation and discount effects and Eq. (4). In this analysis we assume a constant nominal discount rate of $DR_j = 5\%$ as discussed in Section 3.2.2 and costs as shown in Table 8.

Notice that the energy savings portion of Eq. (2) does not include an inflation factor because the energy price P_i already accounts for inflation. If a nominal discount rate factor is used, the effects of inflation should be removed from the estimates of energy price P_i.

Payback Period (PBP)

The payback period is the number of years required before the savings of an ECM exceeds the cost of the ECM which is the sum of the install costs and any ongoing maintenance and repair or replacement costs. A review Eq. (2) shows that PBP can be found by finding the year at which NPV becomes positive. If NPV never becomes positive, then the ECM can never pay back.

Life-Cycle Cost (LCC)

The life-cycle cost is the total cost of ownership of the ECM over the timeframe of the analysis.
A review of Eq. (2) shows that LCC is simply the righthand side of the equation and thus

$$LCC_N = \sum_{i=1}^{N} M_i IF_j DF_i + Initial\ Investment \quad (6)$$

where the terms of the Eq. (6) are defined the same as in Eq. (2).

HVAC Energy Cost Burden

The HVAC energy cost burden is the ratio of HVAC energy costs in a given year to the household income in that same year. $\overline{E_{l,y}}$

$$Energy\ Cost\ Burden_{l,y} = \frac{E_{l,y} P_y}{IN_y} \quad (7)$$

where $E_{l,y}$ is the average household energy use in year y for HVAC with ECM l, P_y is the price of energy in year y, and IN_y is the household income in year y. Data for the HVAC energy use and prices are the same as discussed above and the yearly household income comes from linear interpolation of income as shown in Fig. 6.

Appendix B: 40 Year Projections

This appendix provides additional details on the 40-year projections of income, housing, air conditioning stock, and efficiencies of air conditioning equipment.

For consistency with past and future Net Zero analysis, projections were taken where possible from the IEA Net Zero Energy Roadmap (IEANZER; IEA, 2023). Subject matter experts (SMEs) believe the IEANZER early growth projection in air conditioner were too high but that the value given in 2060 is more accurate because of the expected roll-off in AC growth because by that time nearly every home will have AC and of those, more will have whole house AC than bedroom only.

Total Number of Household Projections

The growth in the number of households was taken directly from IEANZER. These growth projections were consistent with those of several other studies reviewed.

Air Conditioning Stock Projection

The air-conditioning stock projections were performed by Argonne SMEs who combined starting data from the CLASP 2020 Indonesia Residential End Use Survey (REUS; IPSOS and CLAST, 2020) and the LBNL reports (Letschert et al., 2020; Park et al., 2021) along with growth models from the Lawrence Berkeley National Laboratory (LBNL) report. REUS was used to estimate the fraction of homes with any AC and the fraction of homes with inverter and non-inverter AC, and the fraction of homes with one AC unit, two AC units, and three AC units in 2020. The homes with two and three AC units are combined to make the fraction of homes with "whole house AC". The growth AC ownership per household is assumed to be exponential as per the LBNL report (Letschert et al., 2020) and expected growth from 2020-2030 from the same report. The exponential growth model was then used to estimate AC ownership through 2050. The change in fractions of homes with one, two and three AC units as estimated by the SMEs, consistent with the growth in overall AC units.

HVAC Energy Factor Projection

The Cooling Seasonal Performance Factor (CSPF) was taken to be an estimate of the average seasonal efficiency of AC units and the overall average CSPF in 2020 was estimated from the fraction of inverter and non-inverter AC units from the previous AC unit analysis, and high performance, medium performance and standard performance CSPF data from the LBNL reports. The CSPF of equipment was expected to rise with time as projected in the LBNL report assuming an aggressive rise in Minimum Equipment Performance Standards (the "HIGH MEPS" scenario in the LBNL report) and SME experience based on 40+ years of US household AC Seasonal Energy Efficiency Ratio (SEER) rise. From the rise in CSPF, the HVAC energy scale factor (relative average AC unit energy in a future year compared to an average year 2020 for same load) was computed.

Residential Energy Price Projection

The residential energy cost projections were estimated by assuming that residential electricity price changes would track wholesale electricity price changes. The average residential energy price in Indonesia in 2020 was taken from GlobalPetrolPrices.com. The wholesale electricity price rise was estimated by taking the Net Zero 2060 scenario from the Times runs (Loulou et al., 2005) and a scaling factor is developed by looking at the wholesale price in any year compared to the wholesale price in 2020. The residential electricity prices in any given year are then found by applying the yearly scaling factors to the residential electricity price in the year 2020.

Household Income Projection

Household income growth was assumed to track GDP per household growth. The 2020 values of low, middle and high income were obtained from the Bank Indonesia Monthly Consumer Expectation Survey (Bank Indonesia, 2023) with the low-income bracket assumed to be the lowest 20% of income, the middle-income bracket being the middle 54% and the upper-income bracket being the upper 16%. In each bracket, a scaling factor was found by taking the ratio of GDP per household in any given year to the GDP per household in 2020. The household income in any given year is then found by scaling the income in the year 2020 by the scaling factor.

Projection Summary

A summary of the projections for each decade are given below.

Year	2020	2030	2040	2050	2060
GDP/household 1000 USD	48.8	69	88	110	124
Total Households (millions)	70.0	84	96	105	109
Air conditioner Stock (millions)	4.9	16	50	148	223
HVAC Energy Scale Factor	1	0.77	0.54	0.42	0.36
Residential Electricity Prices (USD 2020/kWh)	0.092	0.221	0.258	0.261	0.284
Low Income Bracket Mean Yearly Income (USD 2020)	1,347	1,904	2,428	3,035	3,422

Appendix C: ECM Cost Details

This appendix provides details on cost estimates for the ECMs. All costs and wages were researched from August through November of 2023. Many costs and wages were obtained in Indonesian Rupiah (IDR) and converted to US Dollar (USD) using the same conversion rate used throughout this analysis.

Currency conversion rate (2023-11-15)

Currency Rate	Data Source
1,000,000 IDR = 64 USD	https://www.exchange-rates.org/exchange-rate-history/idr-usd-2023-11-15

Indonesian Labor Rates (2023-11-15)

Cost	IDR/hr	USD/hr	Data Source
Drywall	80000	5.12	https://www.salaryexpert.com/salary/job/drywaller/indonesia
Paint	100000	6.4	https://www.salaryexpert.com/salary/job/painter/indonesia
Framer	100000	6.4	https://www.salaryexpert.com/salary/job/framer-carpenter/indonesia
Insulation Installer	72000	4.61	https://www.salaryexpert.com/salary/job/insulation-installer/indonesia
Window Installer	110000	7.04	https://www.salaryexpert.com/salary/job/window-installer/indonesia
Handyman	92500	5.92	https://ownpropertyabroad.com/indonesia/property-maintenance-repair-costs-overview/
Homeowner	–	2	A time value of a homeowner is assumed to be about 1/3 of a handyman

ECM Costs

Cool Wall

A cool wall is assumed to be a standard wall painted white or similar highly reflecting color with a higher quality standard wall paint. In Indonesia, one common higher quality wall paint is Dulux Exterior Weathershield which has a 10-15 year warranty depending on the exact. The assumed lifetime is thus 15 years.

Because this is just standard high quality exterior paint, there is no cost premium for installing this ECM when installed during construction or at end-of-life replacement. In an accelerated retrofit scenario, the walls would be painted prematurely and thus there is an extra cost.

To maintain the performance of the cool wall, the wall should be regularly washed to remove dirt and dust. For this analysis we assume that the homeowner spends one additional hour per year above and beyond what they would for a typical wall and thus the maintenance cost per year is assumed to be 2 USD 2020.

Aggressive Retrofit Cost	Assume prep, 1 coat primer, 2 coats paint					
Standard High Quality Paint	**IDR**	**Size**	**Coverage**	**Coats**	**IDR/m²**	**USD/m²**
Dulux Exterior Weathershield[1]	1650000	20 L	10 m2/L	2	16500	1.06
Dulux Primer/Sealer[2]	1580000	20 L	10 m2/L	1	7900	0.51
Labor Prep, Prime, and 2 coats Paint Wall[3,4]	100000/hr	1 hr	3 m2/h	4	–	9.22
					Total /m²	**10.09**
Wall Area = 30.6 m2 from boundary element method (BEM) Model					**Total USD**	**309**

Data Sources:

[1] Paint Cost: https://www.tokopedia.com/tokocatduluxdecorative/cat-eksterior-dulux-weathershield-brilliant-white-2290-20-lt

[2] Primer Cost: https://www.tokopedia.com/luxuryliving/dulux-weathershield-primer-cat-dasar-exterior-alkali-20l-pail

[3] Labor Rate: https://www.salaryexpert.com/salary/job/painter/indonesia

[4] Labor Time: 20 min to prep, prime or paint 1 coat 1 m^2 as per SME. So 3 m^2/hr per coat.

Cool Roof

Most roofs in the single-family home in Indonesia are either metal or clay tile. For a cool roof, the ECM is assumed to be choosing a highly reflective white or other light color at install, thus there is no cost premium for choosing a cool roof for a new house or in a standard roof retrofit. In an aggressive retrofit, the rooftop is assumed to not be highly reflective and is thus painted with a high-quality exterior paint of the same type used for cool walls. The assumed lifetime of a metal or clay rooftop is 50 years and is thus never replaced in our analysis. Because an aggressive retrofit is painting, the assumed lifetime of an aggressive retrofit is 15 years, the same as for the wall.

To maintain the performance of the cool roof, the roof should be regularly washed to remove dirt and dust. For this analysis we assume that the homeowner spends one additional hour per year above and beyond what they would for a typical roof and thus the maintenance cost per year is assumed to be 2 USD 2020.

Aggressive Retrofit Cost	Assume prep, 1 coat primer, 2 coats paint					
Standard High Quality Paint	**IDR**	**Size**	**Coverage**	**Coats**	**IDR/m²**	**USD/m²**
Dulux Exterior Weathershield[1]	1650000	20 L	10 m²/L	2	16500	1.06
Dulux Primer / Sealer[2]	1580000	20 L	10 m²/L	1	7900	0.51
Labor Prep, Prime, and 2 coats Paint Wall[3,4]	100000/hr	1 hr	2.5 m²/h	4		11.02
					Total /m²	**11.80**
Wall Area = 41.3 m² from BEM Model					**Total USD**	**487**

Data Sources:

[1] https://www.tokopedia.com/tokocatduluxdecorative/cat-eksterior-dulux-weathershield-brilliant-white-2290-20-lt

[2] https://www.tokopedia.com/luxuryliving/dulux-weathershield-primer-cat-dasar-exterior-alkali-20l-pail

[3] Labor Rate: https://www.salaryexpert.com/salary/job/painter/indonesia

[4] Labor Time: 24 min to prep, prime or paint 1 coat 1 m2 as per SME. Slightly slower than for painting wall. So 2.5 m2 / hr per coat.

Ceiling Fan

Ceiling fans are a standard piece of equipment to be installed in each room in a home. We assume that even when an air conditioner is installed in a new home, a ceiling fan would also be installed for times when the temperature is "not too hot" or in case the air conditioner was broken. Therefore, there is no cost premium whatsoever for a ceiling fan. There is no "Aggressive retrofit" scenario because all homes are assumed to have ceiling fans. We will, however, assume that a homeowner who is using a ceiling fan to reduce energy costs will be more careful to provide regular maintenance and thus we assign one hour of extra yearly maintenance per home for maintaining the ceiling fan performance with a total cost of 2 USD 2020.

Roof Insulation

This ECM is putting insulation in the attic under the roof. There is a cost for both material and insulation installation. Installing insulation is a "once in a building lifetime" activity. There are no ongoing maintenance costs. In an Aggressive retrofit, where the building has already been constructed, the SME estimates a 25% increase in time to install. ECM 1 is 8mm of foil backed bubble pack insulation. The foil backing acts as a radiant barrier. ECM 2 is 75mm of foil backed polyisocyanurate insulation.

Roof Insulation Costs	**New Construction**		**Aggressive Retrofit**	
Item	**USD/m²**	**USD**	**USD/m²**	**USD**
8mm bubble insulation[1]	1.17	49	1.17	49
Install Labor[3]	0.92	39	1.54	65
Total	**2.09**	**88**	**2.71**	**114**
Item	**USD/m²**	**USD**	**USD/m²**	**USD**
75mm polyisocyanurate insulation[2]	23.81	1000	23.81	1000
Install Labor[3]	0.92	39	1.54	65
Total	**24.73**	**1039**	**25.34**	**1064**

Data Sources: (IDR to USD conversion at rates given above.)

[1] https://www.tokopedia.com/hollayeppo/aluminium-foil-bubble-double-peredam-panas-insulasi-atap-tebal-8mm

[2] https://www.tokopedia.com/rokindojayamandiri/insulation-sandwich-panel-pir-polysocyanurate-tebal-75-mm

[3] SME estimates an install rate of 5 m2/hr for new construction and a rate of 3 m2/hr for retrofit installations.

Wall Insulation

This ECM is insulation in the walls of the house. This assumes that while the exterior walls are brick or concrete, the interior does have a cavity wall with drywall. During new construction, adding insulation is a very small incremental cost, but as a retrofit, it involves removing drywall, adding insulation, reinstalling drywall and thus is a much higher cost for aggressive retrofit. Since "walls" do not wear out, there is no end-of-life replacement scenario – just new construction and retrofits. There is no maintenance cost associated with this ECM.

Wall Insulation Costs	New Construction		Aggressive Retrofit	
Item	**USD/m²**	**USD**	**USD/m²**	**USD**
25mm Rockwool insulation[1]	0.62	19	0.62	19
Install Insulation Only[3,4]	0.52	16	12.48	382
Total	**1.15**	**35**	**13.10**	**401**
Item	**USD/m²**	**USD**	**USD/m²**	**USD**
75 mm Rockwool insulation[2]	3.08	94	3.08	94
Install Insulation Only[3,4]	0.52	16	12.48	382
Total	**3.61**	**110**	**15.56**	**476**

Data Sources:

[1] https://www.tokopedia.com/zclod2/garden-rockwool-25mm-x-600-x-1200mm

[2] https://www.tokopedia.com/berkahmandirimart/rockwool-board-75mm-x-600-x-1200mm

[3] Install costs estimate 8.75 m2/hr of insulation for new construction: https://www.homewyse.com/services/cost_to_insulate_basement_walls.html

[4] Install costs for aggressive retrofit costs are to remove drywall or add frames, install insulation, drywall and paint. https://www.tokopedia.com/samatua-jaya/pemasangan-partisi-gypsum-2-sisi-rockwool-peredam-suara-density-40?extParam=ivf%3Dfalse&src=topads

Windows

This ECM is an upgrade from standard single glaze windows to low-e double glaze or low-e triple glaze windows. For new windows and replacement retrofits, the cost is simply the price premium of upgrading from single glaze to low-e double glaze or low-e triple glaze windows. Typically, simple sliding windows are installed, but low-e double glaze and especially low-e triple glaze are more commonly found in the European style “tilt-and-turn” windows. So, all windows selected are” tilt-and-turn”. Because windows are generally custom fit for install, pricing windows is more problematic than other equipment. Companies give quotes for installed windows of exact dimensions. For this ECM, the bulk price of core window units per m^2 were estimated from an import site (Alibaba), window installer salary was taken from salaryexpert.com, and the install time was taken from homewyse.com. There is no special maintenance and therefore no maintenance cost for this ECM.

Window Costs	New Construction		Aggressive Retrofit	
Item	**USD/ m2**	**USD**	**USD/ m2**	**USD**
Low E Double Glaze Window Premium1,2	48	396	105	872
Remove old Windows, Install New 4	0	0	28	234
Total	**48**	**396**	**13.10**	**1106**
Item	**USD/ m2**	**USD**	**USD/ m2**	**USD**
Low E, Triple Glaze Window Premium 1,3	64	535	122	1013
Remove old Windows, Install New 4	0	0	28	234
Total	**64**	**535**	**150**	**1247**

Data Sources:

[1] https://www.alibaba.com/product-detail/Aluminum-Tilt-And-Turn-Aluminum-Sound_1601018213558.html

[2] https://www.alibaba.com/product-detail/Doorwin-new-design-hot-sale-window_1600685559683.html

[3] https://www.alibaba.com/product-detail/European-style-high-quality-energy-efficient_62460598163.html

[4] For new construction, no cost premium to install high performance windows. For aggressive retrofit, cost is based on 1.2 hrs/m2 to remove old windows, 2.8 hrs /m2 to install new windows. https://www.homewyse.com/services/cost_to_install_replacement_windows.html

Solar Film

This ECM involves installation of a solar reflecting film on the window interiors. The two levels of ECM are reached by choosing different tint levels. There is no cost penalty for choosing a darker film. These are not standard installs on homes and the costs are the same for new construction, replacement, and aggressive retrofit. There is no special maintenance for this ECM and therefore no maintenance cost.

Solar Reflectance Film	Cost	m^2	IDR	USD/m^2	USD
3m Prestige[1]	800000	1	800000	51.2	425
Install[2]		1	100000	6.4	53
			Total	**57.6**	**478**
Window area = 8.3 m^2 from BEM Model					

Data Sources:

[1] https://www.tokopedia.com/fproxjualmeteran/kaca-film-rumah-dan-gedung-3m-prestige

[2] Install cost as per IDN SME

Awning

This ECM involves installation of a semi-transparent awning over each window. The two ECM have different levels of tinting resulting in different SHGC and VT. There is no cost difference between the two. Each ECM consists of installing two awnings: one on the front of the house and one on the back. These are not standard home installs so the cost is the same for new construction, replacement, or aggressive retrofit.

Awning New and Retrofit Costs	USD/Unit	Units	USD
Awning[1]	98.00	2	196
Install Labor[2]	5.20	2	10.4
		Total	**206**

Data Sources:

[1] https://www.ubuy.co.id/en/product/240JW8NK-window-awning-door-canopy-outdoor-polycarbonate-cover-outdoor-front-door-patio-canopy-uv-rain-snow-s

[2] Install estimate of 1 hr as per SME. For new install that time is prep and install, for replacement, time is to remove old awning and install new one.

Exterior Shade

This ECM involves installation of a non-motorized exterior roller shade. These are not standard home installs so the cost is the same for new construction, replacement, or aggressive retrofit.

Exterior Shade New and Retrofit Costs	USD/Unit	Units	USD
Exterior Shade 6x10 ft[1]	75.00	2	150
Install Labor[2]	5.20	2	10.4
		Total	**160**

Data Sources:

[1] https://www.ruparupa.com/acestore/p/arai-150x200-cm-gorden-roller-blinds-exterior-abu-abu.html

[2] Install estimate of 1 hr as per SME. For new install that time is prep and install, for replacement, time is to remove old awning and install new one.

Interior Shade

This ECM involves installation of a sun blocking interior shade. Low-cost venetian blinds are a standard installation within a new home. There is no cost premium to install a sun blocking shade. The two ECM have different levels of tinting resulting in different SHGC and VT. There is no cost difference between the two. Each ECM consists of installing two awnings: one on the front of the house and one on the back. These are not standard home installs, so the cost is the same for new construction, replacement, or aggressive retrofit.

Interior Shade New and Retrofit Costs	USD/Unit	Units	USD
Sun blocking interior shade[1,2]	29.00	2	58
Install Labor	0	2	0
		Total	**58**

Data Sources:

[1] https://www.ruparupa.com/acestore/p/kris-venetian-blinds-25mm-120x220cm-putih.html

[2] https://www.ruparupa.com/acestore/p/arai-120x250-cm-gorden-roller-blind-dimout-putih.html

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