

Developing SCBA Frameworks for Healthcare Energy Transitions in Emerging Economies

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Abstract

The healthcare sector contributes approximately 4.4% of global greenhouse gas emissions, with projections suggesting these could triple by 2050 without decisive mitigation. In emerging economies, transitioning healthcare facilities to renewable energy is constrained by limited finance, inadequate infrastructure, and the absence of appraisal tools that capture economic and social returns. Conventional cost-benefit analysis (CBA) inadequately captures the social, environmental, and health dimensions relevant to sustainable healthcare transitions in resource-constrained settings. This paper develops an SCBA framework for evaluating renewable energy transitions in Puskesmas, Indonesia, integrating established SCBA approaches with evidence from healthcare sustainability and energy transition research. The framework incorporates stakeholder engagement principles and adaptations for limited-resource contexts, enabling monetisation of financial, social, environmental, and health dimensions within a unified analytical structure.

The principal contribution is a replicable SCBA method incorporating distributional equity and health service continuity, providing policymakers and health system planners in emerging economies with a structured, evidence-based appraisal tool. Subsequent work will refine the framework through detailed monetisation of its constituent components and validate it against Indonesian primary healthcare conditions, drawing on established approaches to wider economic benefits and externality quantification.

Keywords

Social Cost-Benefit Analysis, Healthcare Sustainability, Renewable Energy Transition, Puskesmas, Emerging Economies

1. Introduction

The transition to low-carbon healthcare systems is increasingly urgent, as the sector contributes approximately 4.4% of global greenhouse gas emissions (Karliner et al., 2019). Without targeted mitigation, these emissions are projected to grow substantially (Manyari, 2024). Healthcare emissions matter because they directly undermine the sector's core mission to protect and improve population health, driving climate change and associated health risks such as heat stress, vector-borne diseases, and extreme weather events (Smith et al., 2020). Evidence shows that healthcare systems are among the highest institutional emitters in several countries, with hospitals, pharmaceuticals, and medical supply chains responsible for a large share of environmental impacts (Tennison et al., 2021). The GHG emission sources also generate air pollutants and resource depletion, further exacerbating morbidity and mortality (Watts et al., 2021). As climate change intensifies, the resulting health burdens increase demand for healthcare services, creating a feedback loop in which the sector's environmental impact contributes to the very conditions it must treat (Romanello et al., 2022). Reducing healthcare emissions is therefore essential not only for meeting national and global climate targets but also for safeguarding long-term health system resilience, service continuity, and public health outcomes.

Emerging economies face substantial barriers to achieving net-zero emissions because of a combination of financial, structural, and institutional constraints. Clean energy projects are significantly more expensive to finance in emerging economies, where high capital costs, limited access to affordable credit, and elevated political and structural risks deter investment (IEA, 2021). Despite renewables maintaining their cost advantage globally, emerging economies encounter challenges in adoption because of financial constraints and infrastructure limitations (IRENA & CPI, 2023; Pereira et al., 2025). Emerging markets outside China must also more than double their annual energy transition investment to align with net-zero pathways by 2050 (Cuming, 2024). Weak regulatory frameworks, insufficient technological capacity, and the absence of tailored net-zero strategies further complicate decarbonisation efforts in emerging economies (Okeke, 2025). Energy transition in emerging markets requires adequate socio-technical capacity and meaningful community engagement (Winanti & Mas'udi, 2022). Healthcare facilities in these settings face the same persistent barriers, including limited capital, unreliable infrastructure, and insufficient analytical tools to guide investment decisions (Lamba & Chandrakar, 2025; Sahoo et al., 2025).

Conventional cost-benefit analysis (CBA) remains widely used for energy investment appraisal (Samson, 2021), yet its narrow financial focus overlooks critical environmental, social, and health co-benefits that are central to sustainable healthcare planning (Ekins & Zenghelis, 2021). CBA is poorly suited to valuing intangible or non-market outcomes such as environmental quality, social equity, and health benefits, leading to systematic underestimation of impacts that cannot be easily priced (Ackerman & Heinzlerling, 2004). It also embeds subjectivity in the selection and weighting of impacts, often neglects distributional effects, and overlooks equity considerations that are central to public sector decision-making (Treasury, 2026). These limitations create a methodological gap for contexts such as healthcare energy transitions in emerging economies, where social, environmental, and health co-benefits are significant but not captured by financial metrics alone. As a result, conventional CBA provides an incomplete evidence base for policymakers, reinforcing short-term financial decision-making and obscuring broader societal value.

Social Cost-Benefit Analysis (SCBA) offers a more comprehensive alternative by systematically quantifying the full spectrum of societal costs and benefits (De Wit & Over, 2024). Unlike conventional CBA, SCBA explicitly evaluates non-financial dimensions such as distributional effects, equity considerations, and the broader social value of climate actions, ensuring that resource allocation reflects both efficiency and fairness (Boardman et al., 2018). This holistic perspective is important for sectors such as healthcare, where interventions generate wide-ranging co-benefits — improved health outcomes, reduced pollution, and enhanced community resilience — that are not captured by market prices. SCBA has been applied across various public infrastructure domains, including transport, energy, and urban

development (Machaira, 2016; Misal, 2021; Pienaar, 2018). It is actively promoted by government guidelines, including those of the Australian Government and the NSW Government. They emphasise comprehensive valuation, equity considerations, and transparent appraisal as foundations for evidence-based public investment (Australian Centre for Evaluation (ACE), 2025; NSW Government Health, 2018). By integrating social, environmental, and economic factors, SCBA provides a more robust foundation for selecting projects that maximise long-term societal welfare and support climate-resilient development pathways (Misal, 2021).

Indonesia provides a highly relevant empirical context for this work, as it faces rapid growth in healthcare demand alongside persistent energy reliability challenges, particularly in remote and island regions. *Puskesmas* (community health centres), as the backbone of primary healthcare delivery, operate in diverse and often resource-constrained environments (Aisyah et al., 2025). Unstable electricity supply directly affects service continuity, cold chain management, and emergency care. Many remote facilities in eastern Indonesia, including those in Manado and Gorontalo, rely on diesel generators with high average generation cost (Danish Energy Agency (DEA) & Ea Energy Analyses, 2019). It makes *Puskesmas* in small islands disproportionately vulnerable to climate and diesel supply disruptions (Wijaya & Mecca, 2020). These conditions create a critical need for decision-support tools that capture the social, environmental, and health implications of clean energy investments, making the Indonesian *Puskesmas* network a high-impact setting for developing and validating a contextually grounded SCBA framework.

This research addresses the methodological gap identified above by developing an SCBA framework tailored to healthcare facilities in resource-constrained settings, with an empirical grounding in Indonesian *Puskesmas* and hospitals. By integrating evidence from the Global South, incorporating stakeholder engagement principles, and adapting established SCBA approaches to local conditions, the project provides a more comprehensive basis for evaluating renewable energy transitions (Pereira et al., 2025). The remainder of the article is structured as follows. Section 2 describes the research methods. Section 3 presents a structured literature review that synthesises evidence on healthcare energy use, sustainability transitions, and economic appraisal methods, identifying gaps in existing evaluation approaches and clarifying the conceptual foundations of the proposed framework. Section 4 presents the SCBA framework and its constituent components. Section 5 concludes with recommendations for future research.

1.1 Aim, Objectives, and Contribution

This study constitutes the financial analysis component of a broader research project on net-zero transition in healthcare. The project aims to develop an equity-sensitive, evidence-based decision-support tool that captures the full societal value of clean energy investments in resource-constrained healthcare systems across emerging economies. The financial analysis component pursues three objectives: (1) to review the limitations of conventional energy appraisal methods in healthcare settings; (2) to construct a contextually adapted SCBA framework integrating financial, social, environmental, and health dimensions; and (3) to validate the framework against Indonesian primary healthcare conditions.

This paper addresses Objective 2 by constructing an SCBA framework for evaluating renewable energy transitions in resource-constrained healthcare facilities. The framework responds to a recognised limitation of conventional appraisal methods, which typically cannot account for the social, environmental, and health dimensions of energy interventions in public healthcare settings. The principal contribution is an SCBA framework suitable for appraising energy interventions in *Puskesmas*, providing policymakers and health system planners in emerging economies with a structured, contextually appropriate analytical tool. By extending conventional cost-benefit analysis to incorporate distributional equity and health service continuity, the framework offers a replicable method for evaluating clean energy investments where resources are constrained and social returns are substantial.

2. Methods

An initial review of seminal books was conducted to identify and analyse existing SCBA concepts. The literature on SCBA applicable for emerging economies is anchored by three foundational methodological texts (Dasgupta et al., 1972; Little & Mirrlees, 1968; Squire & Van der Tak, 1975). They have been supplemented by (Brent, 1998; Curry & Weiss, 2023; Kirkpatrick & Weiss, 1996; Potts, 2002).

After the initial review, the applications of SCBA to energy intervention were reviewed. The objectives of the follow-on literature review are to identify, to synthesise, and to evaluate literature on the application of SCBA to renewable energy and energy efficiency transitions. A topic search was conducted in the *Web of Science* core collection using

the following search string: (“social cost benefit analysis” OR “SCBA”) AND (“decarbonisation” OR “renewable energy” OR “energy efficiency”). The number of results was 19. Of these, 8 were excluded by screening against the following inclusion and exclusion criteria. The final synthesis includes 11 studies evaluating the application of SCBA to energy interventions.

Inclusion criteria:

- Studies focusing on “Social Cost-Benefit Analysis”,
- Articles discussing “decarbonisation”,
- English-language publications.

Exclusion criteria:

- Studies not related to “Social Cost-Benefit Analysis” (7),
- Non-English publications (1).

3. Results and Discussion

This section presents the results of the literature review informing the development of the SCBA framework. Section 3.1 examines foundational social appraisal methodologies which provide the theoretical basis for shadow pricing, distributional weighting, and social discount rates in emerging economy contexts. Section 3.2 reviews contemporary SCBA applications in energy and infrastructure projects, identifying the components employed for economic, environmental, and social impacts. These bodies of literature inform the construction of the SCBA framework presented in Section 4.

3.1. Initial Review Results

A methodology for evaluating industrial projects from the perspective of society as a whole, rather than from a private organisation’s viewpoint, was provided by Little and Mirrlees (1968). The central concept is the use of shadow prices (accounting prices) to revalue inputs and outputs to reflect their true social scarcity and utility. The method adapts the Discounted Cash Flow (DCF) approach, converting private costs and benefits into social costs and benefits by adjusting for taxes, subsidies, and external effects. This revaluation covers the shadow pricing of traded and non-traded goods, labour, and foreign exchange, alongside social discount rates appropriate to emerging-economy contexts.

Two key parameters define this framework. The Shadow Wage Rate (SWR) represents the real cost to society of employing an additional worker, which often differs significantly from the market wage. The Accounting Rate of Interest (ARI) is the discount rate used to reduce future social profits to their present value; unlike a commercial interest rate, it reflects the social productivity of investment — how much an additional unit of investment adds to a country’s future welfare. Together, the SWR and ARI connect market prices to the real social value of resources in an emerging economy.

Little and Mirrlees (1968) measure all project values in terms of foreign exchange, using world prices as the common standard. For traded goods, this is straightforward: exports are valued at the border price received and imports at the border price paid. These border prices are preferred because domestic prices in emerging economies are typically distorted by taxes, subsidies, and trade restrictions. For non-traded goods — such as local construction or domestic transport — no border price exists directly. Little and Mirrlees address this by decomposing non-traded goods into their constituent parts until traded goods and basic labour inputs are reached, at which point border prices can be applied. This distinction between traded and non-traded goods determines how every project input and output is valued.

The Squire and van der Tak (1975) method is broadly consistent with Little and Mirrlees (1968) but is structured as a step-by-step procedure, making it more accessible. Its principal contribution is the integration of savings and distributional objectives into a single appraisal framework. Beginning with a standard financial analysis, the method progressively adjusts project costs and benefits to reflect true economic costs — replacing distorted market prices with shadow prices and applying a standard conversion factor for non-traded goods. It further recognises that in capital-scarce emerging economies, savings that are reinvested are more valuable than income that is consumed and applies a premium accordingly. Greater social value is assigned to income received by poorer households, embedding an equity objective directly into the appraisal. A project is approved if the sum of its adjusted benefits exceeds its adjusted costs when discounted at the social rate of interest.

The UNIDO method, developed by Dasgupta et al. (1972), is a five-stage framework for assessing whether a project genuinely benefits an emerging economy's population. Beginning with a standard financial analysis, the method progressively adjusts project values by replacing market prices with shadow prices, including an explicit shadow price for foreign exchange. It recognises that scarce savings and investment are more valuable than immediate consumption and applies a premium accordingly. Distributional concerns are addressed by assigning greater social value to income received by poorer households. The framework also accommodates merit goods — goods and services whose social value exceeds individuals' willingness to pay — alongside broader social objectives outside conventional economic measurement. The principal distinction from Little and Mirrlees (1968) lies in the choice of numéraire: UNIDO measures all values in terms of domestic consumption rather than foreign exchange, though the two frameworks yield equivalent results when applied consistently.

3.2. SCBA Applications in Energy Projects

Ürge-Vorsatz et al. (2014) reviewed the systematic monetisation of economic, environmental, and social co-impacts for integration into decision support tools, including SCBA. Economic impacts are monetised using market prices, avoided costs, and marginal abatement cost curves. Environmental impacts — air pollution reductions, ecosystem effects, and avoided climate damages — are valued using dose–response functions, damage cost estimates, and the social cost of carbon. Social impacts, including health improvements, productivity gains, and energy access benefits, are monetised through willingness-to-pay studies, cost-of-illness methods, and hedonic valuation. The review recommends integrating monetised co-impacts through SCBA, multicriteria analysis, or integrated assessment models, demonstrating that including co-benefits can substantially alter the economic case for mitigation options.

Jamasb and Nepal (2010) apply a standard SCBA combining engineering-based cost functions with monetised environmental impacts. Private costs are estimated using facility-specific investment and operating cost curves derived from European waste treatment plants, annualised over 20 years at an 8% discount rate. Benefits are quantified through gate fee revenues, electricity and heat generation, and recovered materials sales. External costs and benefits are monetised using damage cost estimates for air pollutants, carbon price scenarios for CO₂ and CH₄ emissions, and standard dis-amenity values, all expressed on a per-tonne-of-waste basis.

Islam and Jashimuddin (2017) monetise economic, environmental, and social impacts to evaluate a waste-to-energy (WtE) strategy for Chittagong. Economic impacts — capital and operating costs, electricity sales, and carbon credit revenues — are valued using market prices and national electricity tariffs. Environmental impacts are monetised by assigning damage cost values to methane emissions from landfills and valuing avoided CO₂ emissions when WtE displaces coal-fired power. Social impacts, including reduced land use pressure, improved sanitation, and avoided public health risks from open dumping, are incorporated through external cost factors, with non-monetisable effects acknowledged qualitatively.

Medina-Mijangos and Seguí-Amórtégui (2021) monetise economic, environmental, and social impacts to assess a municipal solid waste energy recovery facility. Economic impacts — labour, maintenance, gate fees, and revenues from electricity, steam, and recovered materials — are valued using market prices and audited financial accounts on a per-tonne basis. Environmental impacts are monetised through avoided landfill taxes, avoided fossil fuel use, and published damage cost estimates for air pollutants. Social impacts, including public health risks and dis-amenities such as odour, noise, and visual intrusion, are quantified using established external cost factors, with unquantifiable effects acknowledged qualitatively.

Al Irsyad and Nepal (2016) monetise the economic, environmental, and social impacts of energy efficiency improvements in Indonesia's street lighting systems. Economic impacts — electricity savings, reduced subsidy payments, and avoided investment in new generation capacity — are monetised using energy audit data, national tariff structures, and subsidy rates. Environmental impacts are valued by converting electricity savings into avoided CO₂ emissions and applying standard carbon cost estimates. Social impacts, including reduced peak load pressure and improved public lighting reliability, are incorporated through monetised indicators such as avoided blackout-related costs.

Rai et al. (2024) apply a structured SCBA to hydropower development in Bhutan, monetising economic, environmental, and social impacts. Economic benefits are quantified by multiplying annual electricity generation by the prevailing export tariff. Costs are annualised through a capital recovery factor at an assumed social discount rate of 8%. Environmental impacts — loss of forest, grassland, and cropland because of dam and transmission line

construction — are monetised using per-hectare ecosystem service values from a global valuation database, converting ecological degradation into annualised monetary losses. This approach integrates biophysical land use change with economic performance metrics, enabling the comparison of financial gains against ecosystem service losses.

Venhovens et al. (2024) conducted a SCBA to evaluate the socioeconomic impact of a community-owned solar park in the Netherlands. Economic effects — construction costs, land acquisition, agricultural opportunity costs, electricity revenues, subsidies, and maintenance — are expressed as annual monetary values using market prices and project-specific data. Environmental impacts, including emission savings and biodiversity effects, are monetised where possible using published emission reduction values and land use compensation estimates; non-market ecological effects are identified qualitatively. Social impacts are monetised through stakeholder-specific parameters such as recreational value, landowner compensation, and changes in local welfare. Effects that cannot be reliably monetised — visual intrusion, community acceptance, and social cohesion — are documented qualitatively and excluded from the NPV calculation.

Ishaq et al. (2026) apply a hybrid SCBA to assess economic, environmental, and social impacts. Economic values — capital expenditure, operation and maintenance costs, feed-in tariff revenues, and electricity sales — are converted into annual cash flows and assessed through NPV at a 2.5% discount rate. Environmental impacts are monetised using the US EPA's social cost of carbon and Taiwanese estimates of avoided health damages per kWh of displaced fossil fuel electricity. Social impacts, including fishery disruption and ecological disturbance, are translated into monetary terms using government compensation formulas and sector-specific expenditure surveys. Non-monetisable impacts, such as visual intrusion and community opposition, are documented qualitatively but excluded from the NPV calculation.

Siddiqui et al. (2024) monetise economic, environmental, and social impacts across the full life cycle of each bus type. Economic impacts — purchase costs, fuel or electricity costs, maintenance, and fare revenues — are discounted to NPV. Environmental impacts are monetised using standard emission damage factors for avoided pollutants and greenhouse gases across solar, electric, and hydrogen buses, with external pollution costs assigned to diesel buses. Social impacts — employment generation, reduced private vehicle expenses, and lower noise pollution — are translated into monetary terms using wage-based valuation, transport cost savings, and published noise damage coefficients.

Jayasena et al. (2022) monetise economic, environmental, and social impacts across the full life cycle of passive and net-zero houses. Economic impacts — capital investment, construction labour, maintenance, electricity costs, and rental value — are converted into annual cash flows and assessed using NPV, cost-benefit ratios, and internal rates of return. Environmental impacts are monetised using life cycle energy consumption, greenhouse gas emission factors, carbon credit values, and avoided emissions relative to a conventional dwelling. Social impacts, including improved indoor air quality, reduced hospitalisation risk, productivity gains, and job creation, are translated into monetary terms using published health cost factors and wage-based valuation. Non-monetisable benefits such as comfort and wellbeing are acknowledged qualitatively.

Abdou et al. (2026) compare SCBA and Social Return on Investment (SROI) to assess how private firms, community enterprises, and non-profits contribute to employment in Amsterdam's energy sector. Their findings show that private programmes emphasise technical skills and career pathways, whilst community and non-profit initiatives generate additional environmental and social value through sustainability renovations and public awareness activities. By combining SCBA and SROI, the study proposes a hybrid framework that captures wider co-benefits, offering a useful parallel for research seeking to account for non-market and decarbonisation-related impacts in public sector evaluation.

Across the reviewed studies, economic, environmental, and social impacts are monetised through market-based valuation, standardised externality pricing, and benefit transfer. Economic impacts are quantified using observed market prices for capital expenditure, operation and maintenance, land acquisition, electricity revenues, and avoided fuel purchases, with upfront investments annualised through capital recovery factors. Environmental impacts are monetised by applying established external cost coefficients — most commonly the social cost of carbon, pollutant-specific damage factors, or avoided landfill fees — to physical indicators such as tonnes of CO₂ abated or waste diverted. Social impacts are translated into monetary terms using compensation formulas, willingness-to-pay estimates, avoided healthcare costs, and labour market metrics. Where primary valuation data are unavailable, studies

rely on benefit transfer, drawing ecosystem service values or health damage coefficients from comparable contexts. Studies on renewable energy interventions identify multiple co-benefits — reduced air pollutants, improved health outcomes, enhanced resilience, and greater equity in service access — yet these are often described qualitatively rather than monetised. A methodological gap persists in integrating co-benefits into appraisal frameworks, particularly in contexts where vulnerable populations rely heavily on primary care facilities.

4. SCBA Framework

Based on the findings of the literature review, an SCBA framework is proposed as shown in Figure 1. The framework integrates the monetisation of environmental and social impacts, and the application of a social discount rate to derive a net present social value for the project under evaluation. It is structured to reflect the three principal dimensions of social value: financial efficiency, environmental impact, and social equity.

5. Conclusions

The reviewed studies demonstrate SCBA has been applied across a range of energy and infrastructure contexts, with economic, environmental, and social impacts monetised through market-based valuation, standardised externality pricing, and benefit transfer. Economic impacts are quantified using observed market prices and annualised capital costs; environmental impacts through carbon pricing and pollutant damage factors; and social impacts via willingness-to-pay estimates, avoided healthcare costs, and labour market metrics. Where primary valuation data are unavailable, benefit transfer is employed. Whilst renewable energy interventions consistently generate co-benefits — including reduced air pollutants, improved health outcomes, and greater equity in service access — these are frequently described qualitatively rather than monetised. A methodological gap therefore persists in integrating co-benefits into appraisal frameworks, particularly where vulnerable populations depend on primary healthcare facilities and social returns may substantially alter the economic case for investment.

This paper has addressed that gap by developing an SCBA framework for evaluating renewable energy transitions in resource-constrained healthcare facilities. By integrating financial, social, environmental, and health dimensions into a unified analytical structure, the framework enables a more comprehensive assessment of the societal value of clean energy investments than conventional appraisal methods permit. The principal contribution is a replicable SCBA methodology that incorporates distributional equity and health service continuity, providing policymakers and health system planners in emerging economies with a structured appraisal tool suited to contexts where social returns are substantial but conventional financial metrics alone do not justify investment.

Subsequent work will empirically ground the framework in the Indonesian Puskesmas context through verification and validation. The framework will be refined via detailed monetisation of its constituent components, drawing on established approaches to the quantification of externalities and wider economic effects. Validation against Indonesian primary healthcare conditions is expected to confirm that the framework is both contextually appropriate and operationally tractable under resource constraints typical of emerging economy health systems. Together, these steps advance the broader project objective of developing an equity-sensitive, evidence-based decision-support tool for net-zero transitions in healthcare (Table 1 and Figure 1).

Table 1. Costs and benefits considered in the selected literature.

Reference	Technology	Location	Financial		Environmental		Social	
			Costs	Benefits	Costs	Benefits	Costs	Benefits
Ürge-Vorsatz et al. (2014)	Co-Benefits	WW	Discusses transaction costs; policy costs	Co-benefits of integrated mitigation	Risks; adverse side effects; double-counting issues	Air quality; ecosystem gains	Distributional impacts; trade-offs	Health; equity; productivity co-benefits
Jamasb & Nepal (2010)	WtE	GB	CAPEX; O&M; tipping fees; land; planning delays; alternative options	Gate fees; electricity and heat sales; metal recovery; residuals; avoided landfill	Air emissions (NO _x , SO ₂ , particulates, dioxins); GHG; leachate impacts	Avoided methane; avoided fossil-fuel electricity; reduced GHG; waste diversion	Local disamenities (odour, noise, congestion); perceived health risks; visual impacts	Improved waste management; reduced landfill reliance; energy security; compatibility with recycling; potential CHP benefits
Islam & Jashimuddin (2017)	WtE	BD	CAPEX; O&M; waste collection; infrastructure	Electricity sales; carbon credits	Landfill emissions; leachate; air pollution	Avoided methane; avoided coal use; renewable energy	Odour; health risks	Improved waste management; reduced landfill burden
Medina-Mijangos & Seguí-Amórtégui (2021)	WtE	ES	CAPEX; O&M; labour; depreciation; provision of services	Electricity; steam; materials; gate fees	Air emissions; dioxins	Avoided: landfill, methane, fossil-fuel use	Disamenities; Odour; noise; health risks	Education; worker skills; improved waste management
al Irsyad & Nepal (2016)	Lighting	ID	Meter installation; lamp replacement; smart controls; maintenance	Electricity savings; subsidy savings; reduced peak load	Lamp disposal; manufacturing impacts	Reduced emissions from lower electricity demand	Safety concerns during transition	Improved lighting quality; reduced public expenditure
Rai et al. (2024)	Hydropower	BT	CAPEX; O&M; transmission infrastructure	Hydropower generation revenue	Forest loss; agricultural land loss; biodiversity impacts	Renewable energy; avoided fossil-fuel emissions	Loss of ecosystem services; land-use conflict	National development; energy security
Venhovens et al. (2024)	Solar Park	NL	Land acquisition; construction;	Electricity sales; subsidy;	Land-use change; biodiversity disturbance	Renewable generation;	Visual intrusion;	Social cohesion; community

Reference	Technology	Location	Financial		Environmental		Social	
			Costs	Benefits	Costs	Benefits	Costs	Benefits
			maintenance; grid upgrades	cooperative revenue		avoided emissions	local opposition	participation; recreation/education
Ishaq et al. (2026)	Offshore Wind	TW	CAPEX; O&M; grid connection; fishery compensation	Electricity sales; avoided fossil-fuel imports	Marine disturbance; bird mortality; seabed impacts	GHG reduction; avoided air pollutants	Visual impact; construction noise; fishery disruption	Health improvements from cleaner air
Siddiqui et al. (2024)	Buses	PK	Purchase; shipment; customs; fuel/charging infrastructure; maintenance	Fuel savings; reduced private car use; fare revenue; employment	Diesel emissions; noise pollution	Reduced toxic emissions; cleaner air	Pollution exposure (diesel)	Employment; reduced transport costs; improved air quality
Jayasena et al. (2022)	Passive Houses	CA	Construction; system installation; maintenance	Energy savings; reduced electricity bills; rental value	Embodied emissions; material use	GHG savings; reduced resource use	Construction- phase IAQ issues	Improved health; comfort; productivity; job creation
(Abdou et al., 2026)	Training	NL	Delivery costs; training provision; staffing; coaching; certification; administrative overhead; opportunity cost of participation	Increased employability; higher wages; reduced welfare dependence; productivity gains; value creation for employers; improved matching jobseekers & energy-sector vacancies	Minimal direct environmental costs (training- focused); resource use for training facilities	Indirect environmental gains via workforce supporting renewable-energy transition; sustainability renovations completed by trainees	Accessibility barriers for vulnerable jobseekers; risk of exclusion from private-sector programs; uneven government support; potential mismatch between training & labour-market needs	Sustainable employment; skills; certifications; social inclusion; capacity-building; strengthened networks; sensitisation to sustainability; contributions to SDGs; scalable innovations from non-profit initiatives

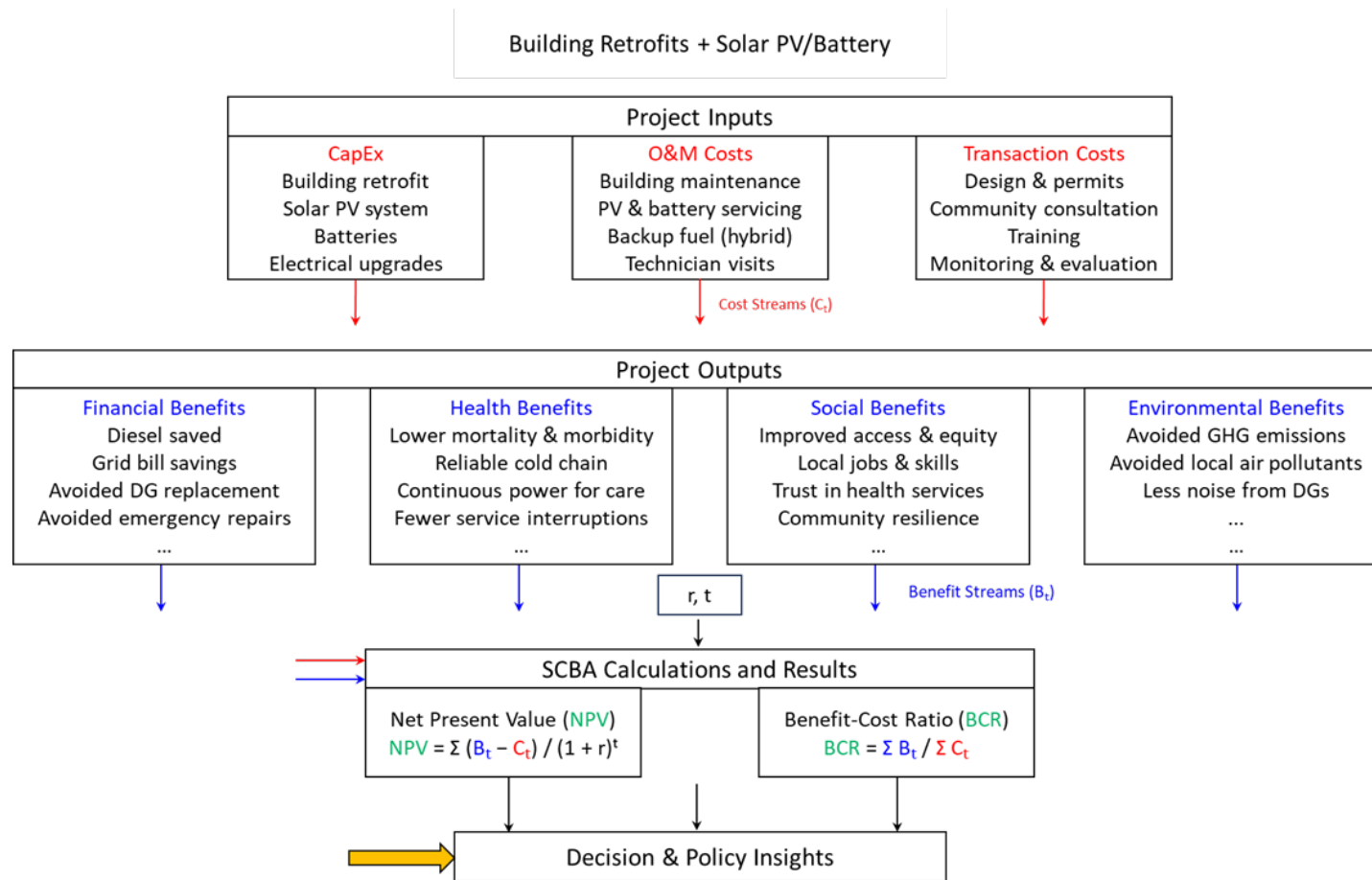


Figure 1. SCBA Framework for energy interventions

CRedit authorship contribution statement

Sri Astuti Thamrin: Funding acquisition, Methodology, Supervision, Writing – review & editing. **Christoffel M. O. Mintardjo:** Funding acquisition, Writing – review & editing. **Prince Charles Heston Runtuwu:** Validation Writing – review & editing. **Lu Aye:** Conceptualisation, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualisation, Writing – original draft, Writing – review & editing.

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Data availability

The data that support the findings of this work are available from the corresponding author (LA) upon reasonable request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

AI Usage Statement

A large language model was used to support language refinement and structural editing during manuscript preparation. The authors retain full responsibility for the manuscript’s content, and all analyses, interpretations, and conclusions were developed and independently verified by the authors. AI assistance was limited strictly to improve clarity and readability.

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