TECHNICAL GUIDELINES

Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future in Residential Construction Sector in Indonesia

UN environment programme

International Resource Panel

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GLOSSARY

Term	Acronym, units	Description
Building Information Modelling	**BIM**	Modelling a building project in a three-dimensional environment through collaboration with architects, engineers, contractors, and suppliers.
Circular economy	**CE**	An economy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized.
Compound Annual Growth Rate	**CAGR**	CAGR represents a constant rate of return over a period of time.
Construction & demolition waste	**C&DW**	Waste generated during the construction, renovation, or demolition of a building or infrastructure.
Dynamic Sector Map	**DSM**	A dynamic sector map represents the sector dynamics consisting of various stakeholders and the relationships and interdependencies among them.
Energy intensity	**EI. MJ/m^{2}a or MJ/km.**	Energy demand per unit (and year).
End-of-life recovery rate improvement	**EoL**	ME strategy concerned with improving the recovery and recycling of materials from products no longer in use and discarded, to increase the amount of secondary materials available.
Fabrication yield improvement	**FYI**	ME strategy which reduces the amount of material scrap in the fabrication process, thereby lessening the demand for primary materials.
The Group of Twenty	**G20**	The Group of Twenty is the premier forum for international economic cooperation. It comprises 19 countries (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Türkiye, United Kingdom and United States) and the European Union.
Greenhouse gas emissions	**GHG, kg or Gt CO_2e**	Emissions of gases that cause the greenhouse effect. Reported in units of potency equivalent to that of a kilogram, ton, or gigaton of carbon dioxide.
Gross Domestic Product	**GDP**	Gross Domestic Product measures the monetary value of final goods and services produced in a country in a given period of time.
Gross National Income	**GNI**	Gross National Income measures the GDP plus income received from abroad in a given period of time.

Term	Acronym, units	Description
International Resource Panel	**IRP**	The International Resource Panel was launched by the United Nations Environment Programme in 2007 to build and share the knowledge needed to improve our use of resources worldwide.
Life-cycle emissions		The emissions associated with the entire life cycle of a product, including material production, construction, operations, and disposal. Includes credit for replacing primary materials when recycling at the end-of-life of a product, and for the storage of carbon in wood. Also labelled as 'systemswide' emissions. Here, they refer to the system-wide emissions associated with the production, operations, and disposal of the entire modelled product stock.
Low Energy Demand (scenario)	**LED**	A scenario aiming to limit global average temperature rise to 1.5°C through the implementation of radical energy demand reduction efforts and with renewable energy, without using CO2 capture and storage.
Lifetime extension	**LTE**	ME strategy to increase the lifetime of products through better design, increased repair and enhanced secondary markets.
Per capita floor area	**m^2/cap**	The average residential floor area available per person.
Material Efficiency	**ME**	The pursuit of technical strategies, business models, consumer preferences and policy instruments that would lead to a substantial reduction in the production of high-volume, energy-intensive materials required to deliver human well-being; expressed as a ratio of the amount of product or service obtained by unit of material use.
Material Efficiency strategy	**ME strategy**	A unique approach to improve material efficiency. In this report, a range of strategies is modelled and their implementation through policy is investigated.
Multi-family home	**MFH**	A type of housing where multiple housing units are contained within one or several buildings within a complex (e.g., apartments).
Material intensity	**MI, kg/m^2**	Amount of material content per unit or product.
Material substitution	**MSu**	ME strategy in which materials in products are replaced by other materials (e.g., wood replacing cement and steel in buildings).
Nationally Determined Contributions	**NDC**	Nationally Determined Contributions constitute the efforts each country takes to reduce national emissions and adapt to the impacts of climate change.
Open dynamic material systems model	**ODYM**	An open model for Material Flow Analysis developed by Pauliuk and Heeren (2019).

Term	Acronym, units	Description
Open dynamic material systems model for the resource efficiency and climate change mitigation project	**ODYM-RECC**	A modular depiction of product stocks in major end-use sectors and the associated material cycles of climate-relevant bulk materials.
Participatory Systems Mapping	**PSM**	Participatory Systems Mapping is a participatory modelling methodology in which a group of stakeholders collaboratively develop a simple causal map of an issue during the course of a workshop.
Resource Efficiency	**RE**	Efficient use resources including materials, water, energy, biodiversity, land and, in the context of climate change, financial resources.
Reduce, reuse, recycle	**3Rs**	Indicates an order of priority for strategies to reduce and manage waste.
Reuse	**ReU**	ME strategy consisting of recovery, remanufacturing, and reuse of components or products displacing the production of spare parts or primary products.
Single-family home	**SFH**	A housing unit with a stand-alone structure and its own lot intended for one family.
Shared Socioeconomic Pathway	**SSP**	Narratives and socioeconomic scenarios used by modellers to develop global energy and GHG emissions scenarios.
Sustainable consumption and production	**SCP**	A framework encompassing any and all issues that seek to improve the way that products and materials are sourced, manufactured and marketed and the way that products are purchased, used, and disposed of at the end of their useful lives.
Using Less Material by Design	**ULD**	ME strategy regarding reducing the size or solid mass of products, which reduces the amount of materials in the product and potentially also the energy required for operation (e.g. using less steel in the bearing structure of buildings).
Zero Energy Building	**ZEB**	A building with a very low energy demand. When equipped with photovoltaics, such buildings produce as much energy as they consume.

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FOREWORD

The predicted increase of global population certainly has a significant impact on the increased use of natural resources or materials. Implementation of resource efficiency strategies can help to reduce the use of limited natural resources on earth and bring additional economic benefits. The modeling conducted by the International Resource Panel (IRP) in 2017 entitled "Resource Efficiency: Potential and Economic Implications" provides an estimate of an economic benefit of approximately US$2 trillion globally and resource savings can be obtained if resource efficiency measures are implemented. Additionally, resource efficiency strategies can also benefit to climate change mitigation. Through the implementation of resource efficiency strategies by businesses and industries, the final product can be more environmentally friendly and the extraction of natural resources, both renewable and non-renewable, can be reduced, so that climate change impacts can be minimized.

The Ministry of Environment and Forestry (KLHK), whose mandate is to manage the environment in a sustainable manner, has an important role in supporting the realization of resource efficiency practices in Indonesia. In line with this, Technical Guidelines "Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low Carbon Future in Residential Construction Sector in Indonesia" was prepared to provide recommendations for stakeholders in order to promote national material efficiency strategies for residential construction sector in Indonesia.

This study is based on the workshop series conducted in December 2022 (online) and March 2023 (offline in Jakarta) involving stakeholders from the public sector, business, industry association, academia, and non-government organisation. The modelling in this study shows that Indonesia has great potential in implementing resource-saving efforts. The modelling found that Indonesia could reduce around 46% of the cumulative material production if material efficiency improvements are implemented in the residential construction sector. This study supports the role of KLHK in promoting national resource efficiency measures which can accelerate decarbonization of residential construction sector in Indonesia by providing analysis of opportunities and challenges for material efficiency as well as roadmap recommendations for stakeholders, including standards and instruments implementers, including government, financial institutions, related experts or professions, building owners, academia, and other related parties.

The implementation of standards related to resource efficiency in Indonesia is one of the Action Menus listed in the 2020-2030 Indonesia Sustainable Consumption and Production Strategy Framework and the Sustainable Consumption and Production Action Guidelines signed by the Minister of Environment and Forestry and the Minister of National Development Planning/Head of BAPPENAS in 2020.

This study also contributes to supporting KLHK in the achievement of Sustainable Development Goal (SDG) 12 Responsible Consumption and Production, particularly for target indicators 12.1, 12.6, 12.7 and 12.8.

This study is part of the international cooperation project Initiative Resource Efficiency and Climate Action or IREK Phase II funded by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and implemented by GIZ. The IREK II project focuses on supporting the implementation of strategies and programs related to resource efficiency and climate protection in the industrial sector.

Finally, we would like to thank all parties who have participated in the preparation of this document since December 2022, especially stakeholders who took active part in the workshop in March 2023 in Jakarta. Hopefully, this document can be beneficial to relevant national stakeholders who would like to support their respective organizations in the efforts to improve resource efficiency in Indonesia.

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1 INTRODUCTION

In its global report "Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future (RECC)" (International Resource Panel 2020), the International Resource Panel (IRP) conducted a rigorous assessment of the contribution of material efficiency to Greenhouse Gas (GHG) abatement strategies. More importantly, the RECC report assessed the reduction potential of GHG emissions resulting from material efficiency strategies applied in residential buildings and light duty vehicles, and reviewed policies that addressed these strategies. The report used the 'Open Dynamic Material Systems for Resource Efficiency and Climate Change' (ODYM-RECC) model to show GHG emissions reduction potential from material efficiency strategies in G7 countries as well as China and India.

The IRP has been recently commissioned to disseminate more strategically its global knowledge products also at regional and national level through its work programme by its member countries. To operationalise this mandate and continue its work on strengthening the knowledge of resource efficiency, the IRP will contextualise the results and key messages of the global RECC report in Argentina, Mexico, and Indonesia according to national contexts. Under the grant, the IRP will support further science-based decision-making opportunities on resource efficient and low carbon future in the aforementioned countries.

The G20 Environment Communiqué acknowledges that resource efficiency and circular economy are important tools to achieve sustainable development and can contribute to sustainable consumption and production, address climate change, reduce biodiversity loss, land degradation and pollution (G20 2021). The G20 Environment Communiqué and the G20 Resource Efficiency Dialogue Roadmap 2021 encourage the provision of financial, technological, and capacity building support to emerging economies and developing countries, making the best use of existing governance frameworks, and working to identify new and innovative solutions.

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OBJECTIVES

2.1 Overall objective

The primary objective of the IRP is to contribute to an improved understanding of sustainable development from the perspective of natural resources, provide science-based policy options while enhancing human well-being. While the Panel provides insights at the global level, it plays a critical role at the national level. As recognized in the theory of change concept of the IRP Work Programme 2022-2025, the IRP uses a systems approach to influence policy by, among others, translating knowledge to the regional and national levels (International Resource Panel 2022).

The objective of this project is to contextualise findings and recommendations of the global RECC report to Argentina, Mexico, and Indonesia, by delving into the specifics of the national priorities and circumstances and highlighting material efficiency strategies with the biggest potential for GHG emissions reduction. The project will leverage on international scientific cooperation and policy engagement that was carried out for the "parent" report while increasing its policy relevance and acceptance to national contexts by: applying the core conceptual framework contained in the RECC report, conducting a stakeholder consultation with key local actors (national level actors, private sector representatives, knowledge institutions, civil society, youth organizations etc.) in Argentina, Mexico, and Indonesia and cooperating with local experts on the development of three national policy documents to be presented as IRP Technical Guideline. The insights gained from the project will support the IRP Work Programme 2022-2025, High Impact Priority Area 2, Sustainable Resource Management for effective action on Climate Change, Biodiversity, and Pollution.

2.2 Specific objectives

This project's specific objectives were to conduct national stakeholder consultations in the form of online and in-person meetings for presentation of the main findings and recommendations of the IRP RECC report and identification of national priorities for material efficiency strategies with GHG emissions reduction potential. These consultations brought together experts of the IRP, IRP Steering Committee members, GIZ, UNEP Regional Offices and key national stakeholders. These stakeholder consultations were used to collect further case studies from Argentina, Mexico and Indonesia to identify national priorities and sensitize national actors, including representatives from national governments on the contribution of material efficiency to GHG abatement strategies.

Following the workshops, the participatory information gathering and mapping, the case studies and knowledge gaps were reviewed and expanded with assistance from the regional experts. The process included refining the maps and establishing three national Priority Action Frameworks, which include a summary of the key challenges, opportunities, along with proposed strategies for policy, process, and practice. Follow up (virtual) consultations were held to review the proposed strategies for the partner countries on the Priority Action Frameworks, to ensure the system mapping, proposed actions, and that the understanding of the policy, process and practices are well founded.

The national policy documents will also leverage the cooperation and engagement for the RECC report. The contextualised national Technical Guidelines are intended to increase policy relevance and acceptance of the IRP RECC report among national stakeholders (including public and private sector, civil society, research institutions). The national policy documents apply the core conceptual frameworks of the RECC report to national priorities and circumstances of Argentina, Mexico and Indonesia and highlight national material efficiency strategies with the biggest potential for GHG emissions reduction and develop science-based policy recommendations. The data and case studies gathered during national stakeholders' consultation have particularly informed these policy documents.

3

BACKGROUND

3.1 Country profile

Indonesia, a Southeast Asian country, is the fourth most populous country in the world after India, China, and the United States (US). In 2021, Indonesia's population was 272.7 million and is growing at the rate of 1.22 per cent per year. In July 2020, Indonesia was grouped among upper-middle income countries by the World Bank, boasting a Gross National Income (GNI) of USD4,050 in 2019, raising from USD3,840 in 2019 (Akhlas 2020). However, due to the pandemic-driven economic downturn, Indonesia went back into being a lower-middle income country in 2021 (Jiao and Sihombing 2021).

Nonetheless, Indonesia has shown its resilience with economic growth of around 5.4 per cent in the first three quarters of 2022, a year-on-year increase from 3.7 per cent in the ending year of the pandemic in 2021 due to a successful vaccination and economic management during the pandemic, although inflation has picked up to 5.7 per cent due to commodity price increase (World Bank 2022b).

Indonesia has more than 100 million aspiring middle class (World Bank 2019). At about Rp17,000 trillion (more than USD1.1 trillion) Gross Domestic Products (GDP) in 2022, Indonesia is a member of G20, the 20 largest economies in the world (Indonesia Central Bureau of Statistics 2022b). By 2045, the 100 years anniversary of its independence, Indonesia thrives to be a member of the G7 — between the fourth and the seventh largest economy in the world — with per capita income of USD19.7 – USD23.2 thousand. Therefore, Indonesia is expected to become a high-income country by sometime between 2038 and 2041 (Ministry of National Development Planning of the Republic of Indonesia 2019).

3.1.1 Building and construction sectors

As a rapidly growing developing country that prioritizes development of infrastructure and housing, Indonesia is undergoing massive construction activities. As such, the Government of Indonesia (GOI) has enacted massive and ambitious housing development. Additionally, to protect the economy and employment from the pandemic-caused downturn, construction sector is a sector in which the government increases its expenditures.

According to Population Census, only 61 per cent of the population had access to affordable houses (Indonesia Central Bureau of Statistics 2020). The GOI has been mandated to provide sufficient housing to the people as stipulated by Law No. 23/2014 on Regional Government and Law No. 1/2011 on Housing and Housing Areas. Based on the law, housing development falls under the authority of the regional government.

The One Million Houses Program is an example to provide housing especially for the lower income group through, as the name suggests, construction of one million houses per year. This will be achieved through the provision of multi-family low-cost rental buildings, special houses, the Independent Housing Development Stimulant (*Bantuan Stimulan Pembangunan Rumah Swadaya, BSPS*), and Public Utility Infrastructure (*Prasarana Sarana Utilitas Umum, PSU*); subsidies for housing financing in the form of Housing Ownership Credits and Housing Financial Liquidity Facility (*Kredit Kepemilikan Rumah Fasilitas Likuiditas Pembiayaan Perumahan, KPR FLPP*); and Subsidy to Assist on Down Payment (*Subsidi Bantuan Uang Muka, SBUM*); and simplification of permitting for the provincial and local governments (Government Regulation No. 64/2016 on Housing Development).

The rapid growth in demands for housing, other buildings, and public infrastructure leads to a rapid growth of the construction sector. In 2022, Indonesia produced about 64 million tons (Mt) of cement. Comparatively, the production volume in 2018 was 75.2 Mt. In 2021, Indonesia used 65.2 million tons of cement (Indonesia Central Bureau of Statistics 2022a). Indonesia is the sixth largest cement producing country in the world.

A large number of Indonesia's cement is exported, and the value is also growing. Prior to the pandemic, from 1.22 Mt valued at USD62.92 million in 2015, exports of cement grew to 7.29 Mt valued at USD283.45 million in 2019. This is a staggering 51.6 per cent and 45.7 per cent increase in export volume and value, respectively. Meanwhile, Indonesia also imports a significant amount of cement from abroad. In 2021, Indonesia imported 6.3 thousand tons of cement, almost half of which was from China, valued in total at USD4 million. This was admittedly much lower than 48.8 thousand tons in 2017 and 33.5 thousand tons in 2018 (Indonesia Central Bureau of Statistics 2022a).

The growth of the sector can also be shown by the growth of the number of construction companies that reached 27.7 per cent in 2022. East Java housed the greatest number of construction companies at 23,752 companies, followed by Central Java at 16,211 companies, while Bangka Belitung housed the smallest number at 807 companies. The amount of the output of the sector increased by 7.3 per cent (Indonesia Central Bureau of Statistics 2022a). However, in 2020, the income of the sector was Rp 1.3 quadrillion (about USD87.4 billion), a slight decrease from Rp 1.6 quadrillion (USD107 billion) in 2019. Of which, material costs constitute half of the income (Indonesia Central Bureau of Statistics 2022b). About Rp 20.6 trillion (about USD1.37 billion) of domestic and Rp 123.2 trillion (about USD8.2 billion) of foreign investments are poured into the construction sector.

In addition to the development of infrastructure and buildings in many parts of the country, the GOI has also devised a massive development of its new capital city, the Nusantara, in East Kalimantan. Construction is already starting, and the first batch of state-official re-settlers will start to live in the new capital city in 2024. The massive construction of infrastructure and building in the new capital is expected to lead a similarly massive growth of the construction sector.

3.1.2 Commitment to Addressing Climate Change

Indonesia has been committed to contributing to addressing climate change globally with the rest of the world. Indonesia has submitted its Nationally Determined Contribution (NDC) that has already been updated twice. The latest one, the 2022 Enhanced NDC, confirms a commitment to a reduction of 32 per cent below its otherwise business as usual (BAU) trajectory using own resources (unconditional) and 43 per cent with international cooperation (conditional) in 2030 (Government of Indonesia 2022).

The enhanced commitment is especially instructive amid the pandemic-driven economic downturn. Indonesia is also committed to turning its forest and other land use sectors as a net sink by 2030 through massive rehabilitation, reforestation, better forest management, and conservation. Meanwhile, Indonesia also commits to reaching economy-wide carbon neutrality ("net zero") in 2060 or earlier (Ministry of National Development Planning of the Republic of Indonesia 2021).

Indonesia expects its total emissions to grow from 1.3 billion (giga-) tons of carbon dioxide emissions equivalent ($GtCO_2e$) in 2010 to 2.9 $GtCO_2e$ in 2030. Energy sector shows the largest absolute amount at 0.45 $GtCO_2e$ per year (about 34 per cent of total) in 2010 to about 1.7 $GtCO_2e$ per year (58.2 per cent of total) in 2030. In the Enhanced NDC, emissions from the energy sector will be limited to about 1.3 $GtCO_2e$ per year and 1.2 $GtCO_2e$, unconditionally and conditionally, respectively, showing a reduction of 12.5 per cent and 15.5 per cent. Emissions from the cement industry is accounted for as emissions from the industrial processes and product use (IPPU), in addition to its energy use that is accounted for in the energy sector. In 2010, it is 36 $GtCO_2e$ per year and is expected grow to 69.6 $GtCO_2e$ per year in 2030. In the conditional emission reduction commitment, IPPU emissions limitations unconditionally and conditionally are to be limited to about 63 and 61 $GtCO_2e$ per year, respectively. That is a reduction of emissions of 0.2 and 0.3 per cent from BAU, respectively (Government of Indonesia 2022).

Existing state policies and regulations affecting residential building constructions in Indonesia are focused on energy performance and therefore indirectly affect the use of materials in buildings. **Table 1** shows the list of policies and regulations governing material and energy use in residential buildings in Indonesia, which mainly target material choice in residential buildings (Nos. 1-4), material procurement (No. 5-6), and material manufacturing (Nos. 7-10).

Table 1: Existing policy mix governing material and energy use in Indonesia — * including, but not limited to, sample regulations at the city level.

No.	Name	Year	Type	Key Features
1	Regulation of the Minister of Public Works and Housing 21/2021 – clause 21 verse 5c, clause 21 verse 6, 23 verse 3e, 25 verse 4e, 28 verse 1d	2021	Regulation	• Air conditioning refrigerant. • Environmentally friendly materials (eco labelling). • Green supply chain. • Selection of materials that reduce solar radiation & conduction. • 1. Material characteristics are included in the OTTV calculation. • 2. Explanation of the basic principles of material selection to reduce cooling loads (User Guide Building Envelope DKI). • 3. Detailed explanations are referred to SNI (Indonesian National Standard) 6389.
2	Bandung Mayor Reg. 1023/2016 – clause 31*	2016	Regulation	• Air conditioning refrigerant. • Selection of materials that reduce solar radiation & conduction.
3	DKI Jakarta Governor Reg. 60/2022 – clause 10*	2022	Regulation	• Selection of materials that reduce solar radiation & conduction.
4	Semarang Mayor Reg. 24/2019 – clause 12*	2019	Regulation	• Selection of materials that reduce solar radiation & conduction.
5	Regulation of the Minister of Environment and Forestry No. 5 / 2019	2019	Regulation	• Procedures for Applying Environmentally Friendly Labels for the Procurement of Environmentally Friendly Goods and Services.
6	Instruction Letter of the Head of LKPP (Goods and Services Procurement Policy Institute) No. 16 / 2020	2020	Policy	• Green Products/Green Industrial Products to Be Used in Sustainable Government Procurement of Goods/Services.
7	Regulation of the Minister of Industry No 26 / 2018	2018	Regulation	• Green Industry Standard for Portland Cement.
8	Regulation of the Minister of Industry No 12 / 2019	2019	Regulation	• Green Industry Standard for Ceramic Tiles.
9	Regulation of the Minister of Industry No 38 / 2019	2019	Regulation	• Green Industry Standard for Water-Based Paints.
10	Regulation of the Minister of Industry No 12 / 2020	2020	Regulation	• Green Industry Standard for Flat Glass.

4

RESEARCH METHODS

These Technical Guidelines build on a literature and policy review, two national consultation workshops and quantitative modelling. Based on desk-based literature and policy review, an online consultation workshop was conducted to map the dynamics of the construction sector. Using the participatory systems mapping tool (PSM), the participants of the workshop identified all stakeholders involved in the residential construction industry and their relationships with one another. A Dynamic Sector Map was created and shared with all the participants for their additional and continued inputs. Based on the dynamic sector map, the project team consulted with key stakeholders to explore the opportunities and barriers for achieving material efficiency in the construction sector in Indonesia. The dynamic sector map is attached in **Annex II: Dynamic Sector Map**.

Based on the information produced in the 1st online national workshop and subsequent stakeholder consultations, a 2nd in-person national workshop was conducted in Indonesia. The in-person workshop was designed as a full-day event with presentation from the ministry representative, presentations from the IRP expert team, panel discussion with local experts, and two roundtable discussions with national stakeholders from Indonesia. The workshop was planned to build on the dynamic sector map and deliberate over key actions to be prioritised in Indonesia. A list of key actions (see **Annex I: Detailed Action Framework**) was compiled based on RECC report (International Resource Panel 2020), Roadmap for Energy-Efficient Buildings and Construction in ASEAN (International Energy Agency 2022), Roadmap for an Energy Efficient, Low-carbon Buildings and Construction Sector in Indonesia (Svendsen and Cordova Schultz 2022) and Building Materials and the Climate: Status and Solutions (United Nations Environment Programme 2023).

The format of the roundtable discussions allowed participants to deliberate over key focused areas. Each roundtable comprised of 5-7 participants representing different sectors to facilitate cross-sectoral deliberations. Participants were asked to deliberate on one of the five proposed goals to achieve material efficiency. In the 1st roundtable discussion, the participants were asked to discuss key opportunities and barriers in undertaking priority actions to achieve the proposed goals. The participants then discussed solutions to fulfil the opportunities and removing the barriers to achieve material efficiency in Indonesia. After the first round of discussions, the participants were asked to comment on two additional goals deliberated on by other groups. The commenting rounds were useful in getting feedback from more than one group. In the 2nd roundtable, participants discussed the tentative timeframes required to fulfil key priority actions and the reasons for the expected timeframe. Later, the participants recommended actions to accelerate the net-zero transition in Indonesia.

The IRP team then analysed the findings from the 1st and the 2nd national workshops, in conjunction with the literature and policy review, to propose key recommendations for Indonesia. Lastly, a 3rd national review workshop was conducted to receive feedback from the national stakeholders to verify the feasibility of proposed recommendations and disseminate the findings of the research. **Figure 1** shows the process followed during the research and **Table 2** shows the number of participants involved throughout the research process.

Figure 1: Research process guiding the project.

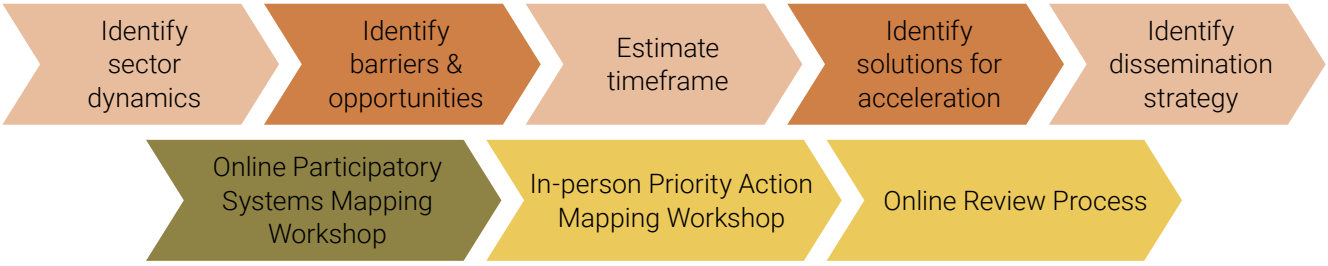

Table 2: Number of participants attending the workshops.

Stakeholders	**Number of expert participants**	
	1st Online Systems Mapping Workshop	2nd In-Person Priority Action Mapping Workshop
Government	9	15
Private Sector	2	5
Civil Society	5	9
Academia	0	2
Total	**16 [7 females, 9 males]**	**31 [10 females, 21 males]**

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MODEL ANALYSIS

5.1 Modelling the residential sector

While emissions caused by the operation of buildings and measures for improving energy efficiency have increasingly gained recognition, environmental impacts related to the materials requirements for the construction of residential buildings are not identified in emission statistics. This section assesses the potential reductions in life-cycle greenhouse gas (GHG) emissions of materials in the residential buildings sector and analyses the environmental benefits of the implementation of policies to regulate the use of materials for construction.

Within the context of numerical modelling, regulatory policies are implemented as Material Efficiency (ME) strategies, namely initiatives that aim to optimise the use of materials to reduce material footprints and promote sustainable development. Understanding the implications of such strategies necessitates an in-depth analysis of material flows across the various phases of buildings' life cycle. This includes demand for new constructions, waste management and primary resource extraction to secure adequate primary production. The effectiveness of ME strategies is evaluated by comparing a baseline scenario, in which the set of variables describing the system does not change beyond the projected future state of economic and societal development, to scenarios in which the dynamics of the system changes in response to initiatives aimed at using materials more efficiently.

The scenario modelling addresses the production and consumption of primary and secondary materials, the material content of buildings, their manufacturing and use phase and their End-of-Life management. For each of these life-cycle steps, material balance and emissions are evaluated based on data derived from engineering calculations, empirical observations, case studies from the literature and statistics.

The time horizon for the scenario modelling is set at 2060. The selected narrative projects a continued growth in driving forces such as population and the economy and the implementation of ME strategies reflects an optimistic view of the future with favourable conditions to facilitate climate change mitigation.

5.2 Material Flows Accounting and GHG

This section outlines an overview of the application of the modelling framework to the residential building sector and the materials accounting approach is outlined. The modelling results have been informed by the ODYM-RECC model (Open Dynamic Material System Model for Resource Efficiency and Climate Change) developed by Pauliuk et al. (2021) which combines the analysis of material flows with life-cycle assessment thinking and engineering calculations (Pauliuk and Heeren 2020).

5.2.1 Buildings demand

Floor area per capita is the main driver of building demand. As the population grows, living conditions improve and old buildings are demolished, new buildings are needed. The scenario for future floor space per capita is based on the value of 25m^2 in 2020 (International Energy Agency 2017), its past dynamics and the general trend of increasing floor space with growing GDP. It is assumed that this trend continues and therefore the floor area per capita in 2060 is set to 40m^2.

5.2.2 Existing building stocks and archetypes

The building stock of Indonesia is described using archetypes of residential buildings. Archetypes are representative models of buildings that share similar occupancy patterns, geometry and material composition. The most commonly used materials in building construction were derived from the analysis of the literature and case studies of Indonesia's architecture. The model utilises four basic archetypes, which are summarised in **Table 3**.

Table 3: Archetype characteristics.

Parameter	Single-Family House	Multi-Purpose Building	Vernacular House	Vernacular Masonry
Floor area	180 m^2	78 m^2 per unit, 1872 m^2 total	50 m^2	90 m^2
Footprint and height	8.5 m by 10.5 m, two-storeys, 3.5 m floor to floor	22 m by 40 m, three-storeys, 3.5 m floor to floor	7.5 m by 7.5 m, one-storey, 3-8 m high (pitched roof/ ceiling)	7.5 m by 12.5 m, one-storey, 3-8 m high (pitched roof/ ceiling)
Additional floor area	80 m^2	1350 m^2 corridors plus under roof space	—	—
Perimeter length	43.2 m	136 m	30 m	40 m
Gross exterior wall area	302.4 m^2	3148 m^2	90 m^2	140 m^2

Single-landed houses are the most common type of housing in Indonesia (Utama A. and Gheewala S. H. 2008) and their size and material composition differ depending on the affluence. Low-Income Vernacular houses (47.1 per cent) are modelled as self-built vernacular houses made of natural materials, and 11.4 per cent of the building stock is modelled as Luxury Vernacular masonry. The remaining 41.4 per cent of the stock is modelled as Multi-Purpose Buildings located in cities, for commercial use on the ground floor and residential use on the upper storeys. In future scenarios, the introduction of modern and planned Single-Family Houses because of the replacement of natural materials with concrete as a fire safety measure is considered. The material intensity of archetypes depends on the selected ME strategies scenario, and the standard design derived from the analysis of literature is compared in **Table 4** to alternative designs derived from architectural investigation. The approach for these Technical Guidelines focuses on strategies tightly linked to main bulk materials: concrete, cement, bricks, steel, and timber.

5.2.3 From waste recovery to primary production and emissions

Quantifying the future availability of secondary materials requires modelling the stock of buildings currently in use and its age structure. At the End-of-Life of buildings, recycling rates of construction materials determine the quantity of demolition waste that can be converted into secondary material. It is estimated that over half of the building stock was built after the year 2000. This has significant implications for the potential availability of secondary material, as a large number of materials would be available in the form of waste to be recycled or reused in the second half of this century. Once the availability of the secondary material is estimated, the production of primary materials is calculated to meet the remaining demand. Finally, the production processes of materials are converted to environmental impacts through emission factors.

5.3 Modelling Material Efficiency strategies for buildings

There are significant opportunities to achieve reductions of emissions in the residential building sector if ME strategies are put in place. Material efficiency primarily aims to reduce emissions associated with the life cycle of construction materials, by reducing the demand of primary production. A range of strategies is analysed in a what-if counterfactual framework. This assessment comprises different scenarios, each presenting a potential future with its development pathways and underlying assumptions, which determine the material cycles and resulting GHG emissions until 2060. The benefits of the implementation of ME strategies are calculated as the difference in GHG emissions with a baseline scenario without the adoption of the strategies.

5.3.1 Reducing waste and recycling

Reducing waste benefits GHG emissions savings by conserving resources. Indirect reduction of emissions related to the production of materials can be achieved by increasing the recycling rates of materials at the end of life of buildings and reusing construction components. Recycling steel from structures with a recovery rate of more than 90 per cent was considered in the baseline scenario (Pauliuk et al. 2013). Case studies suggest that up to 29 per cent of the steel components (Milford et al. 2013) and up to 27 per cent of the concrete (Shanks et al. 2019) can be reused without requiring crushing, shredding, and/or remelting. Additionally, improving fabrication yields in the production phase of materials can reduce the amount of material scrap generated during production, thereby lessening the demand for material inputs for the manufacturing sector. In a high waste reduction scenario, it is assumed that yields in cement and bricks production could be increased by 1.5 percentage points (Shanks et al. 2019). Integrating higher material recovery and reuse rates into waste streams, alongside improvements in fabrication yields, could save 9 per cent of the cumulative emissions linked to primary production of materials for residential buildings by 2060 by reducing the production of primary material by 5 per cent. In total, almost 11 per cent of demolition waste to be disposed could be saved.

5.3.2 Materials substitution

Opportunities for GHG savings rise when buildings are designed with materials with low carbon emissions during their life cycle. The material substitution scenario replaces the building envelope, internal walls, and structural elements with sustainably harvested wooden constructions. To ensure that the alternative design does not compromise the functionality of buildings or worsen energy efficiency, additional layers of insulation are added within the envelope's construction to match the same thermal resistance of the traditional design. In this scenario, by 2060 35 per cent of new buildings would use low-carbon materials. The resulting material footprints of buildings are reported in **Table 4**. By using materials with low life-cycle emissions in buildings, 2 per cent of cumulative emissions up to 2060 could be reduced, as well as 7 per cent of bulk materials. Structures made of timber have a two-fold effect, given their capability of replacing high carbon-intensive concrete and their capacity to store carbon. In Indonesia, the potential of material substitution is limited by the already employment of natural materials such as bamboo.

5.3.3 Use less material by design

Planning construction can help optimise the design of buildings and prevent using redundant materials. In a scenario with material efficient design, it is assumed that the amount of brick and reinforced concrete in external and internal walls and roofs can be reduced by 20 per cent, in internal floors by 8 per cent and the amount of construction grade steel in beams by 36 per cent. In this scenario, by 2060 70 per cent of new buildings would use optimised design. The resulting material footprints of buildings are reported in **Table 4**. An optimised design approach to building constructions could result in a reduction of cumulative emissions up to 2060, achieving savings of 10 per cent. Moreover, the adoption of such an approach would also yield a corresponding reduction in total material demand of 6 per cent, because of lower material requirements in building construction.

Table 4: Material footprints of building archetypes. Values are expressed in kg/m^2.

Housing type	Concrete	Cement	Steel	Wood products	Bricks	Other
Single-Family House						
Standard design	693.4	96.4	66.7	1.9	788.1	105.3
Material-substitution	445.6	77.6	124.8	234.8	19.3	104.3
Optimised design	685.6	77.6	54.2	1.9	635.5	104.7
Multi-Purpose Building						
Standard design	1002.9	107.3	75.9	1.9	849.4	88.3
Material-substitution	879.1	88.1	124.0	240.7	15.8	87.5
Optimised design	932.9	88.1	61.5	1.9	682.8	87.8
Vernacular House						
Standard design	1115.2	90.1	104.6	170.9	52.5	67.9
Material-substitution	1020.0	90.1	238.6	234.3	52.5	67.9
Optimised design	1115.2	90.1	91.7	170.9	52.5	67.9
Vernacular Masonry						
Standard design	1375.2	111.3	104.1	0.6	986.6	71.2
Material-substitution	1360.0	99.3	301.3	216.7	43.0	67.2
Optimised design	1370.2	99.3	91.3	0.6	806.3	68.0

5.3.4 User behaviour

Reducing demand for new buildings is the most direct way to reduce emissions related to material production, by the construction of smaller houses, reduction of vacant buildings or more effective use of floor space. In this scenario, it is assumed that the target for the floor area per capita in 2060 would be 10 per cent less than the baseline scenario. Additionally, extending the lifetime of buildings before demolition, by repurposing of the space or by increased refurbishment, would also contribute to a reduction in new constructions. It is assumed that the lifetime of buildings could be extended by 90 per cent of the standard lifetime. More intensive use of building space has the highest reduction potential. Materials demand could be directly reduced by 37 per cent. Together with the extension of lifetime to reduce new construction demand and manufacturing, 35 per cent of emissions could be saved. Repurposing allows significant savings in terms of waste prevented from buildings demolition, achieving savings of 52 per cent.

5.4 Conclusions of model analysis

5.4.1 Implementation of all ME strategies

The simultaneous implementation of all the examined ME strategies would result in a 46 per cent reduction of the cumulative system wide GHG emissions related to the construction and disposal of residential buildings by the year 2060. In this scenario, the total savings do not correspond to all the savings explored in the previous scenarios because of the interaction of different ME strategies. For example, directly reducing the material demand by optimising the building design also jointly reduces the secondary availability in the future, hence limiting the effectiveness of waste reducing scenarios. The modelling results indicate that material cycle improvements could reduce the cumulative production of materials for the construction of residential buildings in Indonesia by 46 per cent. Notably, the reduction of emissions could be achieved without requiring the development of new technologies.

5.4.2 Decarbonisation of production systems

Beyond the implementation of ME strategies, a further scenario is explored to investigate the maximum decarbonisation potential of material cycles. Together with the simultaneous implementation of all the ME strategies, production processes can be also decarbonised. The energy required for material production processes in Indonesia is sourced from the national electricity mix. Shifting to cleaner energy sources would result in a direct reduction of emissions during the production phase of materials. Currently, in Indonesia only 14 per cent of electricity is generated from renewable sources. In the clean energy scenario, it is assumed that by 2060 electricity production in Indonesia from renewable sources would increase up to 40 per cent, more than the 23 per cent target set by 2025 (International Energy Agency 2021). The increased employment of energy produced from renewable sources in the production phase of materials would lead up to 52 per cent reduction of cumulative emissions for the materials cycle, almost halving the total environmental pressure of materials in the residential buildings sector.

5.4.3 Modelling discussion

Since building lifetimes are longer compared to other durable products, some of the ME strategies may not fully realise their potential within the relatively short modelling horizon until 2060. This highlights the critical need for the implementation of impactful strategies aimed at mitigating GHG emissions within the residential building sector.

Some of the ME strategies rely on improvements in recycling and reuse patterns. Nonetheless, in some cases, the bulky and heavy nature of construction materials may lead to substantial environmental consequences during transportation which is not captured in the model. Additionally, recycling concrete may require larger amounts of additional cement, which is responsible for most of the impact of concrete.

The material substitution scenario relies on the availability of timber or similar wood products. However, the assessment is not linked to any forestry model, and sustainable management of forests should be ensured with proper regulations.

Users' behaviour strategies contrast with the ongoing improvement of living conditions in Indonesia and rely on the population's resilience toward sustainable development. Nevertheless, smaller heating and cooling spaces also reduce energy demand and emissions related to the operational phase of buildings, providing a crucial synergy between material and energy use reduction.

Table 5: Material efficiency strategies summary.

	Scenario					
	Reducing waste	Material substitution	Optimised design	User behaviour	All ME strategies	Production decarbonisation
ME strategies	**ME strategies implemented in the scenario**					
Improvement of recovery rates Improve recycling rates and availability of secondary materials to replace primary production.	x				x	x
Reuse of components Replacement of the production of spare parts or even primary products.	x				x	x
Improved fabrication yields Reduction of production of scrap in material production by improving fabrication yields.	x				x	x
Material substitution Use of construction materials with lower life-cycle emissions.		x			x	x
Using less material by design Use less material by optimised design of buildings without loss in functionality.			x		x	x
More intensive use Reduction of space demand by more effective use of existing space.				x	x	x
Lifetime extension Repurposing of existing buildings to extend their lifespan before demolition.				x	x	x
Energy supply decarbonisation Increased share of renewable energy sources in production processes.						x
	Saving potentials compared to baseline					
Waste generation	-11%			-52%	-57%	-57%
Material production	-5%	-7%	-6%	-37%	-46%	-46%
GHG emissions	-9%	-2%	-10%	-35%	-46%	-52%

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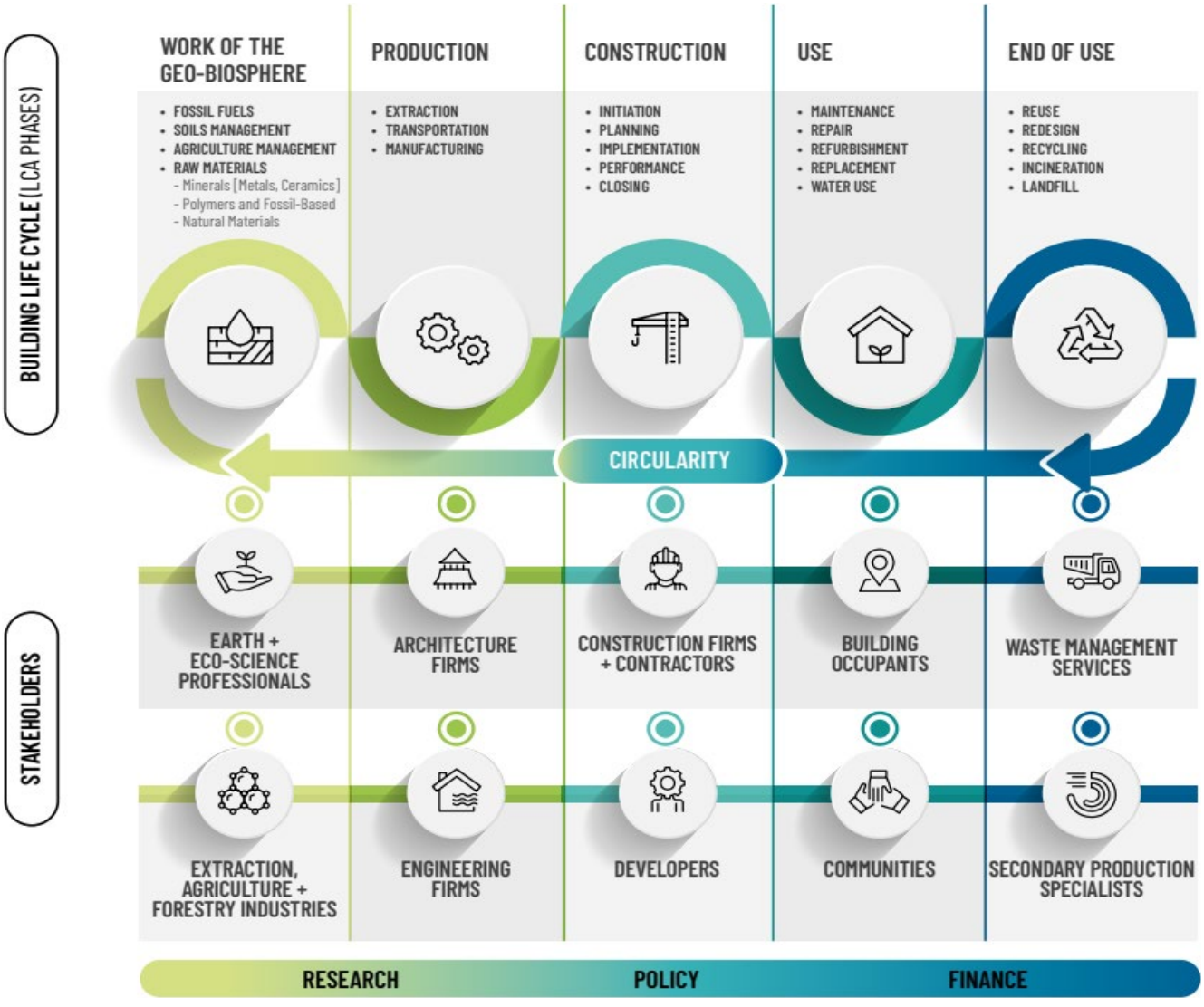
6

SECTOR DYNAMICS

The residential building construction sector in Indonesia consists of a wide range of actors that relate to one another as per market dynamics. The market dynamics of the residential building construction sector can be linked to the building's whole life cycle. Residential building life cycle includes four stages:
1) Production of materials, 2) Construction of buildings, 3) Use of buildings, 4) End of use (United Nations Environment Programme 2023). To decarbonise the residential building construction sector, actions must be taken in all four stages of building life cycle to achieve maximum material efficiency. **Figure 2** explains the four stages of the residential building life cycle.

The whole life cycle of materials used in residential buildings is predominantly dependent on the materials market, the housing market, and the financial market. These primary markets further depend on market dynamics within the transportation industry, energy production and supply, and land markets. Presently, Indonesia's state institutions regulate different markets through various fiscal and non-fiscal policies. Moreover, financial institutions, such as banks, provide monetary support to the residential building construction sector – including the material manufacturing industry – operating within the state regulations. To facilitate the analysis of various actors, their roles and responsibilities, and relations to one another, the residential building construction sector is divided into five sub-sectors, namely: (1) Governance and Planning, (2) Financial Regulation, (3) Material Supply Chain, (4) Construction and Design, (5) Civil Society and Academia.

Figure 2: Key stakeholders whose participation is critical to the decarbonization of buildings at different life phases (United Nations Environment Programme 2023).



Scientific report on resource efficiency and climate change suggests that all actors have a role to play in reducing the GHG emissions along the entire life cycle of the residential building stock. As the participants of the national consultations in Indonesia also proposed, a collaborative and collective effort will accelerate the efforts to achieving a net-zero future in Indonesia's residential building sector. To this effect, the rest of this section articulates some of the roles and responsibilities of various actors. The actors currently engaged in the residential building construction sector in Indonesia are indicated in **Table 6**.

It is crucial to note that labour participation across the entire life cycle of the residential building construction is highly differentiated across various sub-sectors and dependent on the prevailing socio-cultural dynamics. In such a context, women currently only represent 3% of the total workers in Indonesia's construction industry. Female construction workers have reported that women receive lower pay rates than men, they lack access to technologies and training, and experience worksite insecurity and discrimination (Asian Development Bank 2014; Rostiyanti et al. 2020). In a study exploring motivational factors for women participating in the construction industry, Hansen et al. (2020) suggest that working conditions such as work performance appreciation, maternity leave entitlement, hygienic sanitation facilities for women, and work mobilisation; good interpersonal relationships in the work environment; gender equality through recognition of women's work and equal availability of resources; good and proper management; and security during construction work are factors that motivate women to participate in the construction sector in Indonesia.

In sectors such as forestry, women have played a critical leadership role in resource management and biodiversity conservation practices globally (Shiva 1992; Kiptot and Franzel 2012). In Indonesia, women have also recently played an active role in protecting forests against extractive industry through projects such as the REDD+ (Reducing Emission from Deforestation and forest Degradation), despite the patriarchal pushback from the local villagers (Yang and Rieger 2023). Critical to women's participation in projects such REDD+ was support from local NGO *HAkA*. Drawing on lessons from positive experiences such as REDD+, Arwida et al. (2016) suggest prioritizing gender analysis in various projects through collection of gender-disaggregated data, mainstreaming gender concerns, and working with relevant stakeholders at subnational levels to improve the lives of women and men. Ensuring women's increased participation in local and national decision-making and planning bodies throughout the lifecycle of residential buildings will advance gender equality (United Nations Development Programme 2021). Embedding equity considerations across all sectors, and national and subnational institutions listed in the following sections would be key to enabling gender equality in the country.

Table 6: Identified actors involved in the residential building construction sector in Indonesia

Governance and Planning	Financial Regulation	Material Supply Chain	Construction and Design	Civil Society and Academia
■ Ministry of Environment and Forestry ■ Ministry of Public Works and Housing ■ Ministry of Energy and Mineral Resources ■ Ministry of Industry ■ Ministry of National Development Planning ■ National Standards Agency ■ National Research and Innovation Agency (BRIN) ■ Governor DKI Jakarta ■ Spatial Planning Agencies	■ Bank Indonesia ■ Banks committed to sustainable finance (e.g., Bank Mandiri, Bank BRI, BNI, BCA, BRI Syariah, Bank Muamalat, Bank Artha Graha, Bank BJB) ■ International banks (e.g., Asian Development Bank, Bank Central Asia)	■ Cement producers (e.g., Semen Indonesia) ■ Steel producers (e.g., PT-Krakatau Steel) ■ Other material producers (e.g., Toto Indonesia, Asahimas, Phillips, ICI paint, Dusaspun) ■ Material wholesalers ■ Material retailers ■ Transport companies	■ Private Developers (e.g., PT Intiland Development Tbk, PT Ciputra Development Tbk, Sinar Mas Land, PT Summarecon Agung Tbk, PT Agung Podomoro Land Tbk, Springhill) ■ Architects ■ Engineers (Civil, HVAC, Electrical) ■ Consultants ■ Contractors ■ Demolition companies	■ Green Building Council Indonesia (GBCI) ■ Indonesian Institute of Architects (IAI) ■ Indonesian Landscape Expert Association – (IALI) ■ Association of Indonesian Planning Experts (IAP) ■ Association of Indonesian Urban Design Experts (IARKI)

6.1 Governance and planning

The governance and planning sector involves various state institutions and actors – including ministries, national institutes, subnational governments, and local municipalities. The main role of the governance and planning sector is to regulate and monitor the entire supply chain of materials used in residential buildings. This includes regulating the extraction of resources, production and manufacturing of building materials, transportation and procurement by construction industry, management during the building use, and recycling, reuse, and safe destruction of materials at the end of life. The following actors are currently involved in regulating and monitoring the residential building constructions in Indonesia and can potentially take up the role of regulating and monitoring a net-zero transition in the residential building sector.

The Ministry of Environment and Forestry (KLHK) administers government affairs in the environmental and forestry sector by formulating and implementing policies related to sustainability, natural resources and their ecosystems, waste management and climate change control among others. The ministry also coordinates and synchronises the implementation of sustainable environmental management and manages state property. The Ministry of Energy and Mineral Resources (ESDM) formulates and implements policies in the field of development, control and supervision of oil and gas, electricity, minerals and coal, new energy, renewable energy, energy conservation and geology. The ministry also conducts research and development in the field of energy and mineral resources. Furthermore, Ministry of Industry (Kemenperin) aims to support a competitive, advanced, and green industry by developing a natural resource-based industries, controlling export of raw materials and energy sources, increasing mastery of technology and quality of industrial human resources, develop industrial facilities and infrastructure, increasing the use of domestic products and engage in international cooperation. Together, the KLHK, ESDM and Kemenperin can take up policy development and implementation regarding decarbonising the material production and manufacturing processes – such as sustainable forestry for provision of bio-based materials, fuel switching for cement and steel production, or recycling of building materials at the End of Life of buildings.

The Ministry of Public Works and Housing (PUPR) supports the implementation of Strategic Plan to achieve national development targets, including accelerating the development of water sovereignty, food sovereignty, energy sovereignty, road infrastructure, settlement infrastructure, and public housing. The Ministry of National Development Planning (BAPPENAS) aims to conduct high quality and credible national development planning, by developing macroeconomic goals, prioritising development projects, preparing infrastructure plans, supporting the coordination of financial allocations and investments, assisting and controlling development, developing an interagency innovative development policy, synchronizing and synergising national strategic policies and activities across agencies, increasing partnerships and the role of non-state agencies, and developing innovative and visionary plans. Jointly, PUPR and BAPPENAS can support in policy development and implementation in relation to construction techniques, planning policy development and infrastructure development.

Indonesia's National Standards Agency (BSN) has a key role to play in setting labelling standards for material efficiency in residential building constructions. As a governmental body, BSN works towards strengthening a productive, independent, and competitive economic structure through management of standardization and conformity assessment. Some of its current tasks include developing and implementing standards, managing the accreditation system, national standard unit of measure, human resources in the field of standardisation and conformity assessment and implementing BSN bureaucratic reforms. BSN's mandate and the mission make it ideally suited to support the development and implementation material labelling standards.

Finally, the various city administrations, such as Provincial Government of DKI Jakarta, have already taken up initiatives towards sustainability and residential building constructions. City-level administrative bodies can support in local-level policy development, implementation, and demonstration of best practices through pilot projects.

6.2 Financial regulation

The financial sector directly or indirectly influences residential building constructions in Indonesia. The financial sector involves actors such as international, national, as well as private banks, investment companies, pension providers, and insurance companies. Currently there is a lack of direct involvement by financial institutions in funding material efficiency and decarbonisation processes. However, their already existing links with the material manufacturing as well as building construction sectors can be leveraged to support the material efficiency agenda.

Although there is lack of financing for material decarbonisation, the financial sector in Indonesia has begun to invest towards NDCs more broadly speaking. To this effect, the International Information Hub of Indonesia's Financial Services Authority has issued a Sustainable Finance roadmap for 2015-2019 (Phase 1) and 2021–2025 (Phase 2). In seeking to keep up with the increased NDCs published in 2022, the phase 2 of the Sustainable Finance roadmap proposed to undertake following actions: (1) Development of a green taxonomy to classify sustainable financing and investment activities in Indonesia; (2) Implementation of environmental, social and governance aspects; (3) Real programme development to present success stories; (4) Innovation in sustainable financial products and services; and (5) a national campaign for sustainable finance.

To date, eight banks have committed to standing as Pioneers in Sustainable Banking in Indonesia, namely: Bank Mandiri, Bank BRI, BNI, BCA, BRI Syariah, Bank Muamalat, Bank Artha Graha, Bank BJB (Ruhiyat and Murwaningsari 2019). Parallelly, a non-bank private financial institution Indonesia Infrastructure Finance (IIF) issued their first Sustainability Bond for sustainable infrastructure with the help of the World Bank in 2022 (World Bank 2022a). The banking and non-banking financial sector thrust to support green initiatives must be leveraged towards ME strategies for accelerated progress towards low-carbon futures.

6.3 Material supply chain

The material supply chain includes actors ranging from material production and manufacturing companies to wholesale and resale traders, and demolition and recycling agencies. Actors involved in the material supply chain can support material efficiency by reducing the embodied carbon content of materials. The material supply chain actors can support decarbonisation by reducing the energy used in producing, manufacturing, transporting, and recycling the building materials. Among the various building materials, decarbonising the most carbon-intensive materials – namely, cement and steel – must be prioritised. While there are several wholesale and retail traders in the country, there is scope for increasing the number of recycling agencies to increase material lifespan.

Indonesia's largest cement producer is a state-owned enterprise Semen Indonesia Group. Founded in 1991, Semen Indonesia represents about 53% of Indonesia's domestic cement sales. The company produces about 51 million tonnes per annum and exports to various countries in Asia. The company has cement plants across Indonesia and undertakes coal, limestone and clay mining, cement sack manufacturing, ready-mix concrete manufacturing among other activities. Indonesia's largest steel producer is also a state-owned enterprise PT Krakatau Steel established since the 1970s. The company produced about 2 million metric tons of iron and steel and aims to increase the production to 10 million metric tons by 2027 in partnership with South Korean company Posco. With an aim to become Southeast Asia's leader in providing innovative and sustainable industrial services, PT Krakatau Steel also aims to support the growth and sustainability of the national industry and infrastructure. Given the scale of material production and sale, implementing ME strategies within the production and distribution processes of Semen Indonesia Group and PT Krakatau Steel would generate high impact on GHG reduction. As state-owned enterprises, these companies could also set the precedence for other private manufacturing companies.

6.4 Construction and design sector

The construction and design sector also has a critical role to play in achieving material efficiency in the residential building constructions. The embodied carbon of buildings include carbon used during the construction of buildings. Therefore, by reducing the energy used during constructions, such as by reducing the materials used for scaffolding and framing, reducing transportation and material waste, or designing buildings for longer lifespans would reduce the embodied carbon of buildings and achieve material efficiency.

The actors involved in the construction and design sector include developers, contractors, construction workers, designers such as architects, civil engineers, HVAC consultants, landscape and interior designers, building operators, and demolition companies. With increasing number of architectural and engineering faculties in Indonesia, there are numerous designers and consultants across the country. Similarly, there are both formal and informal contractors involved in Indonesia's residential building construction. Indonesian Institute of Architects (IAI), Indonesian Landscape Expert Association – (IALI), Association of Indonesian Planning Experts (IAP), Association of Indonesian Urban Design Experts (IARKI) are some of the organisational entities who can take up the role of developing professional codes, policies, best practice repositories, training and knowledge dissemination among various designers, consultants, and contractors.

6.5 Informal housing sector

Informal housing used to be a large portion of housing situation in Indonesia. They have usually lacked access to various urban facilities such as electricity, running water, and healthy and decent sewages. In 2007, Law No. 17/2007 on the National Long-Term Development Plan 2005–2025 was established, including a target of zero slums in 2015. In 2011, Law No. 1/2011 on Housing and Settlements was enacted with a stipulation that "every Indonesian citizen should live in a decent and affordable settlement within a healthy, safe, harmonious, organized, integrated, and sustainable environment" (Roberts et al. 2019). In 2011, it was estimated that more than 27 million people in more than 7 million households live in more than 57,000 ha of slum areas in Indonesia (Sucahyono 2019). Consequently, programs such as Kampung (Neighbourhood) Improvement Program, Neighbourhood Development, Urban Slum Upgrading, Low-Cost Rental Apartment, and Traditional Settlements Revitalization were commenced (Sucahyono 2019).

Started several decades ago in 1969, Kampung Improvement Program (KIP), possibly among the oldest program of its kind, has been deemed as among the largest in the world at its time and possibly the most successful approached to the housing needs of the urban poor. It is entirely funded by the provincial government of Jakarta. The World Bank contributed to the success with concessional loans while Aga Khan Foundation awarded the program with a generous award in 1980 (Devas 1981). Less and less people now live in slums in Indonesia, although in 2019, about 19 per cent of Indonesians still lived in urban slums (World Bank 2023).

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7 PRIORITY ACTION FRAMEWORK

Achieving material efficiency in the residential building construction sector requires a multipronged and whole life cycle approach. Since residential building constructions are dependent on a variety of actors throughout the lifespan of the building, decarbonising the sector requires involvement from all the involved stakeholders. This section outlines the roles and responsibilities of various stakeholders involved in the residential building construction in Indonesia.

Considering the four stages of the building life cycle, five goals and respective actions are proposed for material efficiency in the residential building sector in Indonesia. All the proposed goals and detailed actions to decarbonise construction materials are elaborated in the **ANNEX 1: Detailed Action Framework**. The five proposed goals significantly overlap with the ME strategies presented in **Section 5**. While ME strategies presented in **Section 5** were guided by modelling considerations, the five goals presented in this section were designed to facilitate effective roundtable discussions during stakeholder consultations. More specifically, the tables included in this section elaborate on key actions that need to be prioritised for effective and accelerated implementation of the net-zero agenda. In the following tables, actions for each stakeholder are elaborated in detail. The tables also explain the current opportunities that exist for each stakeholder to fulfil the respective action along with barriers that are currently impeding the stakeholders in utilising the opportunities. Finally, the tables also elaborate on the solutions that can be implemented to reduce the barriers and fulfil the opportunities for effective implementation of the goals. The five proposed goals are as follows:

GOAL 1: Use Low-Carbon Materials

To achieve material efficiency, low-carbon materials must be widely produced and used in residential buildings. This goal relates to the first two stages of the building life cycle, namely 1) Production of materials and 2) Construction of buildings. A successful implementation of this goal depends on providing incentives for material manufacturers to produce low-carbon materials and for private developers, building owners, and users to use them during construction. In keeping with Indonesia's nationally determined contributions, government institutions and manufacturing industries are expected to commit to lowering embodied carbon emissions of materials. Financial support will be required to encourage and fulfil the commitments towards lowering embodied carbon emissions of materials. To make production and use of low-carbon materials widespread across the country, pilot projects and public procurement are deemed the most effective means. The new capital city of Indonesia can effectively act as a pilot project. Lastly, to make the goal most widespread, all stakeholders must be made aware of appropriate and available materials and technologies.

GOAL 2: Use Less Material by Design

Material efficiency can be achieved by using less material by design during the second phase of the building life cycle, namely 2) Construction of buildings. Using less material in buildings will reduce the demand on raw and processed materials – effectively reducing the embodied carbon of buildings. To achieve this goal, designers such as architects, civil engineers, interior designers, HVAC consultants need to incorporate strategies to use less material while designing residential buildings. This includes using minimum required standards for steel and concrete for structurally sound and disaster resilient constructions or using least material in building envelops while achieving optimum indoor comfort. Moreover, using less material also means designing for long building lifespans – without compromising disaster and hazard resilience of building constructions. Here, designs must be adaptable for changing uses and structures must be designed to sustain wear and tear for long periods of time. Simultaneously, high quality and improved decarbonisation methods such as optimising construction management for reducing material waste need to be incorporated into all housing constructions. Lastly, the construction techniques themselves must be optimised for minimum use of materials – including efficient use of materials for framing and scaffolding, using prefabricated and modular materials to reduce on-site use of casting materials, or using building information modelling. With most efficient use of materials, design processes can significantly reduce the embodied carbon in buildings.

GOAL 3: Material Decarbonisation and Substitution

Cement and steel contribute to the GHG emissions the most among the building materials used globally. Cement and steel also do not have perfect substitutes within building construction sector. Therefore, it is imperative that cement and steel sectors are decarbonised at an accelerated rate along all stages of their life cycle. This includes taking steps to decarbonise material extraction, manufacturing, transportation, assembly, as well as recycling and reuse of materials. As cement and steel require high levels of energy for production, fuel substitution will substantially reduce the embodied carbon of cement and steel. Similar steps can be undertaken to reduce the carbon footprint of building material processing such as aluminium or plastics. Alongside decarbonising material processing, minimizing material downcycling will also increase the lifespan of materials thereby reducing the carbon emissions. Lastly, high-carbon materials such as concrete and steel must be substituted with low-carbon materials. Low-carbon materials include bio-based materials such as wood produced from sustainable forestry and bamboo, and earth-based materials such as clay or rammed earth. While most of the bio-based and earth-based materials do not permit the construction of high-rise and heavy-weight constructions, new and hybrid material technologies such as processed bamboo or reinforced rammed earth can be further developed and used to minimise the use of high-carbon materials such as concrete and steel.

GOAL 4: Decarbonisation of Manufacturing Processes

Manufacturing processes contribute to the embodied carbon in the building materials. Therefore, decarbonising the material manufacturing processes are key to achieving material efficiency in the residential building sector. To this effect, manufacturers need to be trained in most efficient low-carbon technologies for material manufacturing. However, the bigger challenge is that low-carbon manufacturing technologies are currently not available. Therefore, investments in innovation and R&D must be increased. Some of the known decarbonisation processes include using higher clinker ratio or using less carbon in producing steel to the required strength. Similarly, significant potential lies in switching high GHG emission fuels to sustainable forms of energies, as well as using fuels more efficiently in the manufacturing of the construction materials. Lastly, these efforts could be streamlined with clear policies for material decarbonisation.

GOAL 5: Reduce Waste and Increase Reuse and Recycling

A significant, yet currently neglected, dimension of material efficiency is material reuse and recycling. Residential buildings are currently not designed to be dismantlable and produce high amount of material waste upon end of use. Often buildings are demolished in a manner that does not permit the reuse of materials. Therefore, for the purposes of material efficiency, it is imperative that buildings are designed and constructed in a manner that reduces waste and allows for the reuse and recycling of the used materials. To this effect, building renovations and repurposing must be encouraged to expand the lifespan of buildings. Buildings must be designed in a manner that permits dismantling at the end of use and enable reuse and repurposing of materials – by using materials such as precast concrete panels. To facilitate the effective reuse of materials, recycling companies must be incentivised and brought into the supply chain of materials for building construction.

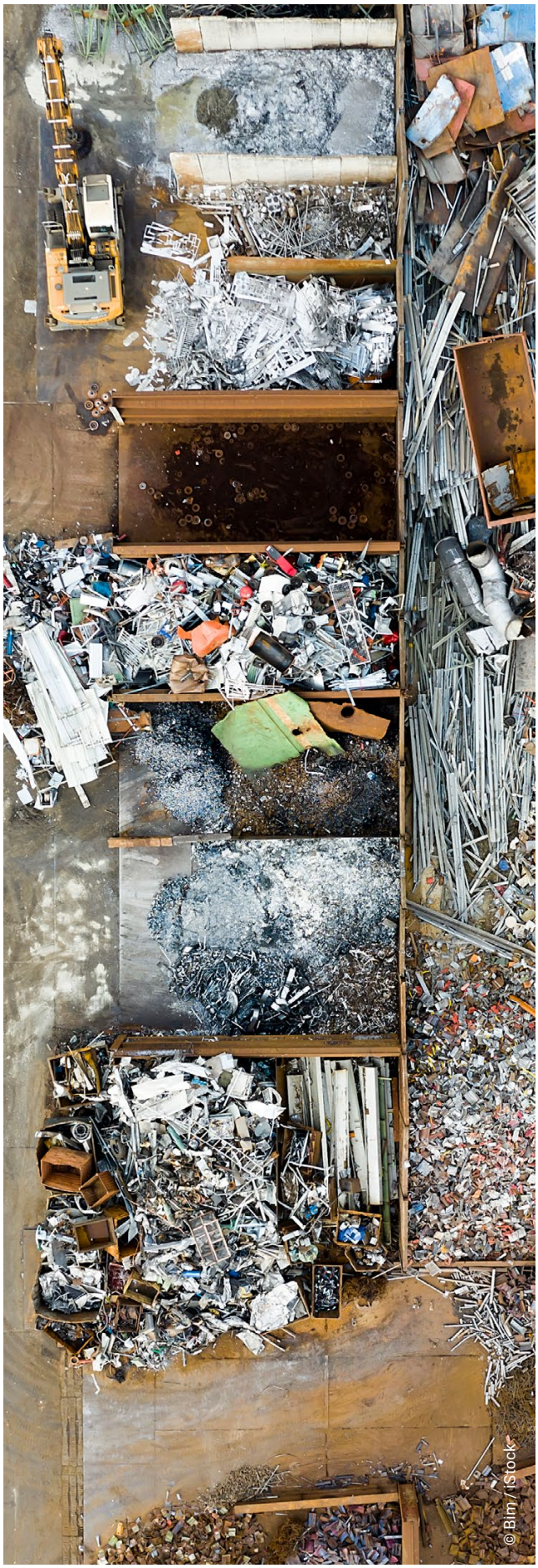

Table 7: Priority Action Framework for Goal 1

GOAL 1: USE LOW-CARBON MATERIALS				
	Priority Actions	**Opportunities**	**Barriers**	**Solutions**
A: National, Subnational and Local Governments	1.1 Provide incentives for high material efficiency	• Incentives for renewable energy/local material are available.	• Database of green products is not yet available. • Product advertising is lacking.	• Develop a national Life Cycle Inventory (LCI) for construction materials.
	1.2 Make commitments to lowering embodied carbon emissions of materials	• New Capital City is available as a pilot project.	• Green labelling/standard is not yet available for all sustainable materials.	• Make local material use mandatory. • Improve green building standards. • Develop carbon footprint standards. • Enforce legal requirements for carbon reduction commitment. • Collect data related to low-carbon materials.
	1.4 Raise awareness of benefits of low embodied carbon construction	• Environmental-friendly housing is being developed in the New Capital City as a pilot project.	• State-led projects are currently underutilised for demonstrating the potentials of net-zero transitions.	• Embed the development of environmentally friendly housing in all new projects.
B: Financial Institutions	1.1 Provide incentives for high material efficiency 1.2 Make commitments to lowering embodied carbon emissions of materials	• Green finance is available.	• Information about green products is lacking or not available for decision makers.	• Develop a national LCI database for building/housing material.
C: Manufacturers, Retailers and Suppliers	1.2 Make commitments to lowering embodied carbon emissions of materials	• Fly ash and bottom ash (FABA) – waste from coal-fired power plant – is allowed to be used in cement industries.	• Obtaining low carbon materials is difficult. • Using newly developed low-carbon materials is financially risky.	• Provide incentives for producing low-carbon materials.
D: Private Developers and Contractors	1.2 Make commitments to lowering embodied carbon emissions of materials	• Demand for sustainable construction is growing.	• Obtaining low carbon materials is difficult. • Using newly developed low-carbon materials is financially risky.	• Provide incentives for efficient utilisation of low-carbon materials.
H: Academia and Research Institutes	1.2 Make commitments to lowering embodied carbon emissions of materials	• Capacities to engage in research and development exists.	• Lack of data regarding low-carbon materials and their utilisation.	• Collect data regarding low-carbon materials and their utilisation.
I: Civil Society	1.2 Make commitments to lowering embodied carbon emissions of materials	• Many civil society organisations are already committed to sustainable development.	• Behaviour change is difficult.	• Increase awareness among citizens regarding low-carbon materials.

Table 8: Priority Action Framework for Goal 2

GOAL 2: USE LESS MATERIAL BY DESIGN				
	Priority Actions	**Opportunities**	**Barriers**	**Solutions**
A: National, Subnational and Local Governments	2.2 Adopt design policies to promote long building lifespans	• Construction industry will become sustainable. • Potential benefit in terms of money and reputation.	• Difficult to encourage contractors to comply with regulations. • Assessment of structures and buildings is often subjective. • Many disaster-prone areas. • Lack of retrofit regulations.	• Develop and enforce regulations. • Provide education and training. • Provide free capacity building to architects, designers, and consultants. • Put in place objective methods for building and structural assessment.
B: Financial Institutions	2.2 Adopt design policies to promote long building lifespans	• Government budget efficiency.	• Lack of available budget.	• Engage with a third party to ensure that green housing assessment leads to loan access. • Assessment results shall be proposed to the government to issue recommendation letter.
C: Manufacturers, Retailers and Suppliers	2.1 Boost capacity of designers	• Increase product availability which had low carbon emissions. • Use less materials.	• Less knowledge of product design and market demand.	• Regulations. • Education and Training.
	2.5. Optimise construction techniques	• New technology for material use optimisation.	• Lack of knowledge, time, and budget.	• Invent new technology and construction methods. • Initiate green development strategy.
D: Private Developers and Contractors	2.5 Optimise construction techniques	• New technology for material use optimisation.	• Lack of knowledge, time, and budget.	• Invent new technology and construction methods. • Initiate green development concept and strategy.
E: Architects, Designers, and Consultants	2.1 Boost capacity of designers	• More green designers.	• Designers are not paying enough attention to green products. • High cost and timelines for implementation. • Low awareness.	• Regulation enforcement. • Allow and incentivise green design certification. • Provide free capacity building.
	2.2 Adopt design policies to promote long building lifespans	• Applicable in the field. • Appropriate use. • Low long-term costs.	• Lack of skilled and knowledgeable professionals.	• Improve skills and knowledge. • Capacity building on policy implementation.
H: Academia and Research Institutes	2.3 Make high quality and improved decarbonisation methods available	• Research and development are available but needs to be improved.	• It is not yet implemented since people are not sure whether it is competitive enough.	• Develop pilot projects, i.e., new capital city.
	2.5 Optimise construction techniques	• New technology for material use optimisation.	• Lack of knowledge, time, and budget.	• Invent new technology and construction methods. • Develop green concepts and strategy.

Table 9: Priority Action Framework for Goal 3

GOAL 3: MATERIAL DECARBONISATION AND SUBSTITUTION				
	Priority Actions	**Opportunities**	**Barriers**	**Solutions**
A: National, Subnational and Local Governments	3.1 Accelerate multiple pathways to decarbonisation in the cement sector / 3.4 Promote the adoption of bio-based materials	• Regulation of the use of hazardous material.	• Lack of incentives. • Utilisation of hazardous materials for feedstock.	• Incentivise low carbon factories. • Enforce regulations on PPC cement use. • Phase out of OPC cement. • Give tax incentive to cover for the increasing production cost because of carbon efficiency. • Periodic scheduling and control of product and delivery. • Include specification of decarbonised material in green building specification. • Support for research, funding, promotion, pilot project of bamboo housing design and technology.
B: Financial Institutions	3.1 Accelerate multiple pathways to decarbonisation in the cement sector / 3.4 Promote the adoption of bio-based materials	• Financial institutions can provide loan for cement and steel producer with low interest when they implement carbon efficiency in their production process. • Regulation of the use of hazardous materials. • Financial support for supply chain.	• Project "bankability" (how to ensure that the project is feasible to get funding) is low.	• Capacity building and coaching for low-carbon building project until proposal approval. • Tax holiday for green energy in iron and steel factories.
C: Manufacturers, Retailers and Suppliers	3.1 Accelerate multiple pathways to decarbonisation in the cement sector / 3.2 Reduce the carbon footprint of the steel-making sector	• Localisation of cement factories to reduce emissions from transportation. • Product improvement. • CCUS implementation. • Raw material modification.	• Lack of law enforcement for low-carbon technology for steel and cement production. • High cost of low-carbon cement and steel production. • Unregulated production. • Few cement factories use low-carbon material such as fly ash, bottom ash, or limestone clay. • High production cost of CCUS.	• CCUS retrofitting. • Embed energy efficiency along whole life cycle. • Develop policies to support environmental-friendly material use. • Leverage on international financial support for green energy project. • Manufacture green materials.
D: Private Developers and Contractors	3.4 Promote the adoption of bio-based materials	• Greater demand for low-carbon cement and bio-based materials.	• Many contractors are still reluctant to use environmental-friendly cement.	• Include specification of decarbonised material in green building specification.
E: Architects, Designers, and Consultants	3.1 Accelerate multiple pathways to decarbonisation in the cement sector / 3.2 Reduce the carbon footprint of the steel-making sector	• Promotion of low-carbon material use though consent and consultation with house owner. • The value of buildings that use environmentally friendly materials is high.	• Many contractors are still reluctant to use environmentally friendly cement.	• Promote the use of environmentally friendly materials among contractors and users.
	3.4 Promote the adoption of bio-based materials	• Use of biomaterials for buildings.	• The ecosystem for the use of bio-based materials is not available. • Lack of database inventory or carbon footprint of materials.	• Provide green design support.

GOAL 3: MATERIAL DECARBONISATION AND SUBSTITUTION				
	Priority Actions	**Opportunities**	**Barriers**	**Solutions**
F: Demolition and Recycling Companies	3.1 Accelerate multiple pathways to decarbonisation in the cement sector	• Old building retrofitting.	• Lack of regulations and incentives. • Lack of spatial planning.	• Building inspection.
G: Building Owners, Tenants or Occupiers	3.1 Accelerate multiple pathways to decarbonisation in the cement sector	• Increase the selling price and building value of buildings that use environmental -friendly materials.	• Increase the selling price and building value of buildings that use environmental -friendly materials. • Building material maintenance (corrosion prevention).	• Tax incentive in order not to increase selling price.
	3.4 Promote the adoption of bio-based materials	• Availability of many material sources such as bamboo; rice husk; 3D printing made from bio-based materials or deconstruction waste.	• Bamboo building is often considered as "house for the poor" and unsafe. • Timber materials for structural frames could be more expensive than concrete. • Timber structures might need AC to keep low humidity levels to prevent shrinkage and swelling. • Termite attack on some wood products even after being treated.	• Include specification of decarbonised material in green building specification.
H: Academia and Research Institutes	3.1 Accelerate multiple pathways to decarbonisation in the cement sector / 3.2 Reduce the carbon footprint of the steel-making sector / 3.4 Promote the adoption of bio-based materials	• R&D on environmentally friendly raw materials in cement. • R&D for CCUS. • Research on energy conservation in steel industry. • R&D on bamboo for building material.	• Gap between research and higher education curriculums.	• Research about material decarbonisation & substitution to be internalised in higher education curriculum.

Table 10: Priority Action Framework for Goal 4

GOAL 4: DECARBONISATION OF MANUFACTURING PROCESSES				
	Priority Actions	**Opportunities**	**Barriers**	**Solutions**
A: National, Subnational and Local Governments	4.1 Boost capacity of manufacturers	• Capacity building for relevant industries + construction industries (steel, cement, glass, ceramic). • Development of module of GHG emissions reduction.	• Not yet a priority, budget is limited. • Human resources are limited.	• Need funding from outside of state budget. • Blended/creative financing. • Provide incentives to manufacturers.
	4.3 Promote fuel switching and higher efficiencies in manufacturing of construction materials	• Decarbonisation plan is already included in RUPTL (electricity supply business plan). • Government already has emissions reduction plan.	• Not yet internalised at the subnational level.	• Intensify socialisation for industries and institutions at subnational level.
C: Manufacturers, Retailers and Suppliers	4.1 Boost capacity of manufacturers	• Added value for companies. • Green financing.	• High investment cost. • Lack of awareness. • Business as usual.	• Access investment funding from banks. • Use new technology in old and new factories. • Encourage the production of local products with low carbon principles. • Increase TKDN (domestic component level) for the material production of certain products. • Use more recycled materials.
	4.3 Promote fuel switching and higher efficiencies in manufacturing of construction materials	• Increase added value and competitiveness. • Reduce energy cost (energy use). • Initiate cooperation with other countries that has implemented decarbonisation. • Utilise carbon pricing regulation. • Produce environmental-friendly material (decree letter is available).	• Investment for additional equipment is relatively high. • Availability of reliable alternative fuel. • Obtain the permit for several alternative energy material is relatively difficult. • Regulation on carbon tax for manufacturers is not yet available.	• Increase the use of alternative energy in industries. • Blended financing. • Government incentive for industries to comply.
D: Private Developers and Contractors	4.3 Promote fuel switching and higher efficiencies in manufacturing of construction materials	• Green industry standards are available for certain commodities in the construction sector. • Good cooperation between producer and user in using environmental-friendly material.	• Tight competition between local and import products.	• Prioritise certified products in procurement. • Strict supervision from the government on material that has complied with national standards (SNI).
H: Academia and Research Institutes	4.1 Boost capacity of manufacturers	• Vocation school is available. • Relevant study unit can be found in universities. • Cooperation with universities and research institutes.	• Decarbonisation topic is not part of the curriculum yet. • Industry needs and research institution is not matched yet. • Not all industries can conduct training.	• Include decarbonisation in education curriculum. • Socialisation from the government to industries. • Funding from cooperation.
	4.3 Promote fuel switching and higher efficiencies in manufacturing of construction materials	• Plenty studies on decarbonisation. • Low carbon from manufacturing industries.	• Funding mechanism in conducting the research.	• Increase the budget for research from the government. • Research cooperation with manufacturing industries. • Matching between industries and universities/research institutes. • Cooperation between government and private sector in terms of alternative energy supply.

Table 11: Priority Action Framework for Goal 5

GOAL 5: REDUCE WASTE AND INCREASE REUSE AND RECYCLING				
	Priority Actions	**Opportunities**	**Barriers**	**Solutions**
A: National, Subnational and Local Governments	5.1 Incentivise renovation and repurposing of buildings to expand lifetime	• Awareness among people about green housing (recycling and reusing of materials). • Have rating tools for assessment.	• No information & socialization of green housing (EDGE & GBCI).	• Make user-friendly rating tools for green housing. • Policy for renovation and repurposing about incentives.
B: Financial Institutions	5.1 Incentivise renovation and repurposing of buildings to expand lifetime	• Added value for housing when it will set (more comfortable and greener). • Continue to reduce GHG emissions.	• No incentive for rebuilding and repurposing houses.	• Housing credit with low interest (4%). • Free consultation (Penyusunan programme) about renovation and repurposing with recycling materials.
E: Architects, Designers, and Consultants	5.1 Incentivise renovation and repurposing of buildings to expand lifetime	• New business opportunity for consultants. • New job and business opportunity for green material production and demolition waste.	• Higher cost for consultation. • Limited architect's capacity in determining green housing criteria (when choosing material from reuse and recycling).	• Capacity building for architects in Indonesia on eco-friendly products or demolition products. • Concept "construct to destruct" -> people need to think about the deconstruction phase from early on (the design phase).
	5.3 Improve deconstruction processes to enable reuse and repurposing	• Availability of modular materials.	• Architect's design is difficult to be demolished/ deconstructed.	• Incorporate modular designs.
F: Demolition and Recycling Companies	5.3 Improve deconstruction processes to enable reuse and repurposing	• Existing knowledge of deconstruction processes among self-built houses. • Modular constructions are increasingly being used.	• Few contractor companies focusing on demolition. • High demolition cost. • Few companies treating/managing demolition waste.	• Leverage knowledge of deconstruction from self-built sector. • Partner with modular construction companies to develop deconstruction processes.
G: Building Owners, Tenants or Occupiers	5.1 Incentivise renovation and repurposing of buildings to expand lifetime	• Houses will be more comfortable, more modern, greener, contributing to GHG emissions reduction.	• Lack of funding. • Lack of knowledge. • Lack of eco-friendly products. • Difficulties in apply for IMB (building permit) and RTB (demolition technical plan) which requires technical drawings, etc.	• Policies on Demolition Technical Plan. • Socialisation on eco-friendly housing for consultants & communities. • Database of eco-friendly products.
H: Academia and Research Institutes	5.3 Improve deconstruction processes to enable reuse and repurposing	• Many universities and institutions work on sustainability.	• Limited research on eco-friendly housing and demolition processes applicable in Indonesia.	• Support technical and managerial development of deconstruction processes.

8

ACTIONS TO ACCELERATE DECARBONISATION OF MATERIALS

The priority action framework produced through participatory workshops with national stakeholders in Indonesia show that all stakeholders need to take up actions so that existing opportunities towards achieving material efficiency can be leveraged and barriers can be removed. However, given the fast rate at which climate change is progressing, it is imperative to act towards accelerating the net-zero agenda in residential building construction sector in Indonesia. To this end, the following tables indicate towards precise actions that need to be undertaken to accelerate each of the priority actions elaborated in the previous sections. The actions elaborated in the following sections are derived from 2nd national workshop through a separate roundtable discussion with national stakeholders.

Against each priority action in the following tables, participants predicted the required years to make the action widespread across Indonesia. Further, key reasons for the current timeframe and actions required to accelerate the process of decarbonisation are stipulated against each priority action. To accelerate the process of decarbonisation within 5 years, participants suggested collecting data, providing financial support, providing technical support for standards development, as well as undertake research and provide training. Somewhat long-term actions (between 5–10 years) include achieving key performance indicators, institutionalise carbon taxation, increase stakeholder consultation, and decarbonise heavy industry. These actions are expected to help decarbonise Indonesia's residential building construction sector within 10 years.

Table 12: Roadmap for accelerating the decarbonisation process.

Priority Actions	< 5 years	5-10 years
GOAL 1: USE LOW-CARBON MATERIALS		
G.1.1 Provide incentives for high material efficiency	• Mandatory data collection and reporting on low-carbon materials. • Provide financial support. • Provide technical support for policy & standards development. • Research on low-carbon materials (type, use, and model project).	• Achieve Key Performance Indicators (KPI) for smart city development by 2045.
G.1.2 Make commitments to lowering embodied carbon emissions of materials	• Research on low-carbon materials (type, use, and model project). • Facilitate the sector in reducing embodied carbon content of materials. • Generate more accurate data.	
GOAL 2: USE LESS MATERIAL BY DESIGN		
G.2.1 Boost capacity of designers	**Education at academic level** • Integrate sustainability curriculum in universities. • Training of lecturers, academicians, and trainers. • Develop programmes for manufacturers and designers.	**Regulation** • Increase stakeholder consultation.
G.2.2 Adopt design policies to promote long building lifespans	• Follow national long-term development planning (KLHS = strategic environmental assessment). • Develop standardisation and Technical Guidance. • Socialise the private sector.	
G.2.5 Optimise construction techniques	• Technology is developing fast. • Public awareness of sustainability is raising. • Research and Development will accelerate the process.	
GOAL 3: USE LOW-CARBON MATERIALS to MATERIAL DECARBONISATION AND SUBSTITUTION		
G.3.1 Accelerate multiple pathways to decarbonisation in the cement sector	• Develop implementation and technical guidance. • Support governments to prioritize. • Encourage the use of new technology such as CCUS. • Provide financial support. • Develop material recycling.	
G.3.3 Invest in the radical transformation of building material processing and minimise downcycling	• Governments should involve all stakeholders before making regulations. • Industries need to adopt technologies and regulations.	

Priority Actions	< 5 years	5-10 years
GOAL 4: DECARBONISATION OF MANUFACTURING PROCESSES		
G.4.1 Boost capacities of manufacturers	• Capacity building for trainers in manufacturing and academia. • Regulations for eco-labelling (Ministry of Manpower and Ministry of Industry). • Financial support for green industries.	
G.4.3 Promote fuel switching and higher efficiencies in manufacturing of construction materials	• Technological support. • Knowledge transfer for capacity building. • Soft loans for efficiency or renewable energy programmes. • Policies/regulations for green project finance in heavy industry. • Coaching/mentoring/socialisation for financial institutions. • Implement carbon taxation policy.	
GOAL 5: REDUCE WASTE AND INCREASE REUSE AND RECYCLING		
G.5.1 Incentivise renovation and repurposing of buildings rather to expand lifetime	• Coordination between relevant stakeholders (academics, researchers, NGOs, GBCI). • Develop technical guidance and standard operating procedures prior to stakeholder consultation. • President instructions to be issued to generate implementation. • Discuss with users/building owners regarding their wishes and problems on renovation and repurposing. • Provide free consultation to formulate recommendations on housing credits, examples of drawings of green material concepts recommendations of greener renovation, re-purposing, and demolition. • Provide direct appointment/award.	

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9

ROADMAP RECOMMENDATIONS

Based on the barriers and opportunities faced by various actors in the residential building construction sector, and stakeholder suggestions for accelerating the agenda for net-zero future, following recommendations are proposed:

1) Use ongoing large-scale projects, such as the New Capital City, as pilot to test and promote ME strategies and low carbon technologies.

2) Collect and maintain accurate data regarding low-carbon materials and their utilisation to inform evidence-based implementation of ME strategies, development of policies, design practices, and prioritisation of actions.

3) Provide technical and financial support for policy development through consultative processes between academia, industry actors, financial institutions, and policymakers.

4) Provide technical and financial support for the enforcement of ME strategies by providing capacity building to architects, engineers, consultants, contractors, as well as policymakers.

5) Invest in R&D for new low carbon technologies and materials by collaborating with academic and research institutes as well as industry professionals.

6) Increase stakeholder consultation among academia, industry actors, financial institutions, policymakers, building users and civil society to obtain citizen views and generate public awareness regarding material efficiency in the building sector.

7) Institutionalise and support gender equality by providing equitable access to resources and facilities, equitable participation in decision-making processes, and equal benefit sharing among women and men, to generate a more sustained and widespread uptake of ME strategies.

8) Incorporate building deconstruction and material reuse and recycling into policy frameworks, construction management, and university curriculums and support the integration of demolition companies into material supply chain.

10

FURTHER CONSIDERATIONS

These Technical Guidelines identified key priority actions to support decarbonisation of the residential building construction sector in Indonesia through modelling, policy analysis, dynamic systems mapping, and stakeholder consultations. Based on the results from these Guidelines, following considerations can be taken forward:

- Indonesia's updated NDCs provide an instructive mandate for reducing 32 per cent GHG emissions below its otherwise business as usual scenario, which supports the goals for material efficiency proposed in these Technical Guidelines.
- With growing GNI and housing demand, the demand for construction materials is going to increase in the future. Therefore, decarbonising Indonesia's construction sector has significant potential for achieving national GHG emission reduction target.
- The assumptions underlying in the ME implementation are ambitious and will require significant and collaborative effort to enforce.
- The demolition and recycling companies are not well integrated into the material supply chain and construction management. Integrating building deconstruction, recycling and reuse of materials has significant potential in reducing material demand.
- Current state policies are focused on energy efficiency of buildings and therefore indirectly affect the demand for low-carbon materials. Developing ME focused policies will effect change at a rapid pace.
- Financial sector has begun to commit itself towards providing green finance in Indonesia led by eight banks, and other non-bank institutions. This momentum must be leveraged by private and public actors and sustained through national and international support.
- Indonesia's construction material manufacturing industry is dominated by large state-owned cement and steel companies. Decarbonising these companies will produce large impact on GHG emission reduction and set precedence for smaller companies.
- The informal housing sector has a significant, yet under-documented, potential for contributing towards GHG emission reduction. Largely, informal housing already implements many ME strategies such as using less material by design and recycling and reuse of materials. These strategies must be recognised as contributing towards fulfilling the national GHG emissions reduction targets.
- Procedurally, these Guidelines relied on participatory systems mapping and priority action mapping workshops and the results are derived based on the perspectives of workshop participants, quantitative modelling, and literature and policy review. The process can be repeated to monitor the progress towards low-carbon futures and update the actions based on changed circumstances.
- During the participatory sessions, the national stakeholders appeared enthused and optimistic about implementing the ME strategies within the period of 5-10 years in Indonesia. Participants' views were conditional on the effective implementation of the proposed actions and support from all relevant actors.

ANNEXES

Annex I: Detailed Action Framework

1	GOAL 1: USE LOW-CARBON MATERIALS	
1.1	**Provide incentives for high material efficiency**	• Reduce demand for high carbon materials. • Incentivise low carbon materials. • Encourage reliance on recycled and repurposed materials.
1.2	**Make commitments to lowering embodied carbon emissions of materials**	• Require embodied carbon emissions assessments or LCAs for new major and public investments. • Require public bodies to disclose information on portfolio and/or asset-level embodied carbon emissions. • Provide financial incentives for low-carbon products and business models. • Support the use of preferential loans or mortgages to stimulate a market for low-carbon materials.
1.3	**Promote low embodied carbon emissions through public procurement and pilots**	• Develop network of green material providers. • Incorporate concerns related to embodied carbon emissions in planning and building regulations. • Mandate disclosure on new construction and large renovation projects. • Initiate pilot projects using low-carbon materials and provide incentives to developers. • Include requirements in public tendered contracts to use low-carbon materials for public procurement.
1.4	**Raise awareness of benefits of low embodied carbon construction**	• Provide information and raise awareness. • Promote tools, training and capacity building regarding low-carbon materials and technologies. • Conduct and commission research and case studies into low-carbon materials and approaches. • Provide training to government agencies regarding data collection on embodied carbon emissions of materials and building project, and regarding creation of an integrated policy portfolio. • Provide training on how to develop information and assessment tools for project developers, designers, and consumers such as embodied carbon emissions disclosure, LCA, labelling and EPDs.

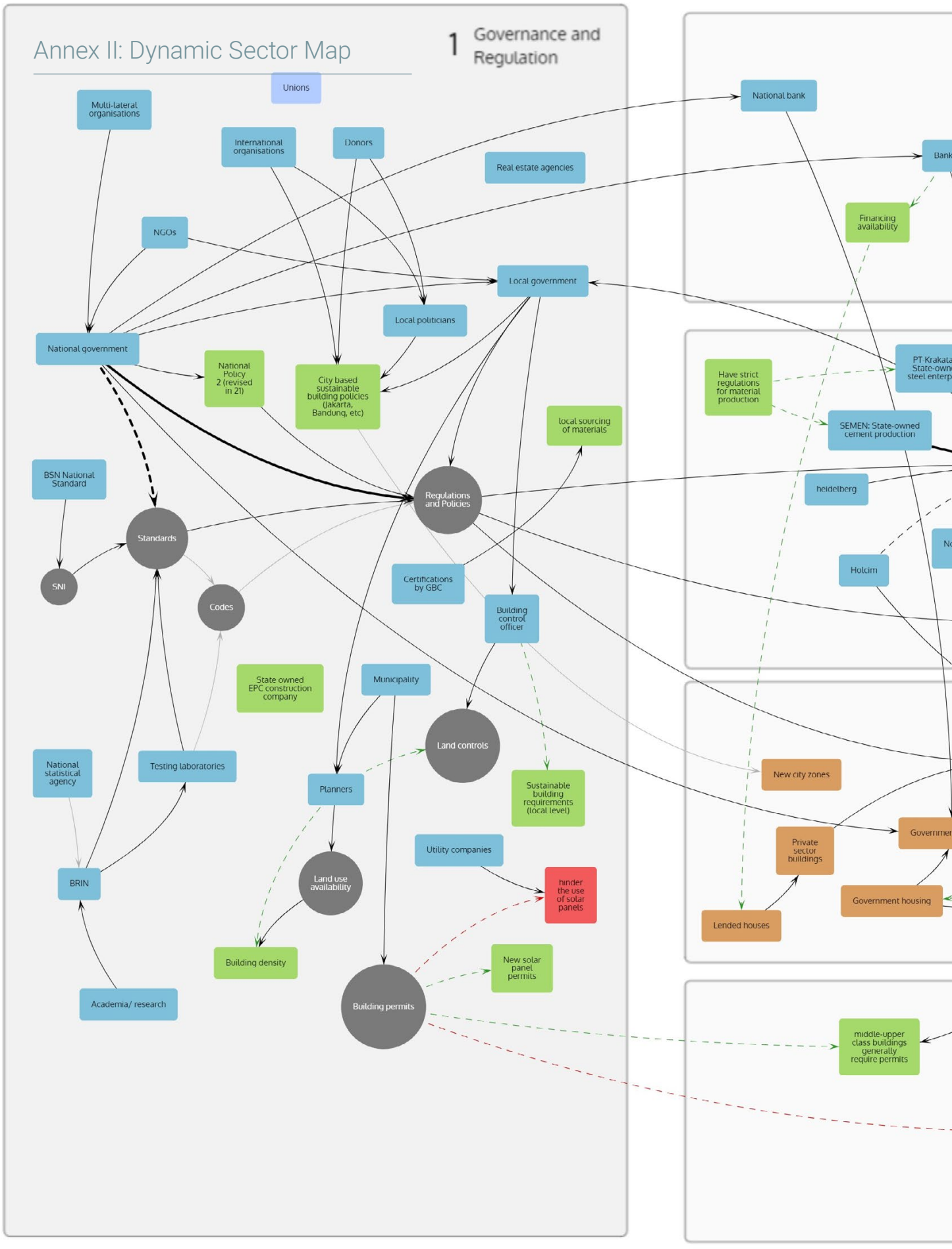
2	GOAL 2: USE LESS MATERIAL BY DESIGN	
2.1	**Boost capacity of designers**	• Training of professionals (architects, engineers, contractors etc.) • Training to comply with policies such as labelling. • Develop accreditation systems for professionals with material efficient design skills.
2.2	**Adopt design policies to promote long building lifespans**	• Incentivise appropriate design, more durable materials, modularity and renovation/upgrading.
2.3	**Make high quality and improved decarbonisation methods available**	• Promote evidence-based material selection. • Utilise whole life carbon assessments to inform decarbonization decisions.
2.4	**Build regulations for disaster and hazard resilient constructions**	• Ensure that buildings can withstand extreme events. • Post-disaster reconstruction for durability.
2.5	**Optimise construction techniques**	• Optimise framing and scaffolding. • Optimise steel reinforcement in concrete buildings. • Use advanced framing techniques – reduce redundancies in framing. • Use building information modelling (BIM). • Use prefabrication and modular building components.

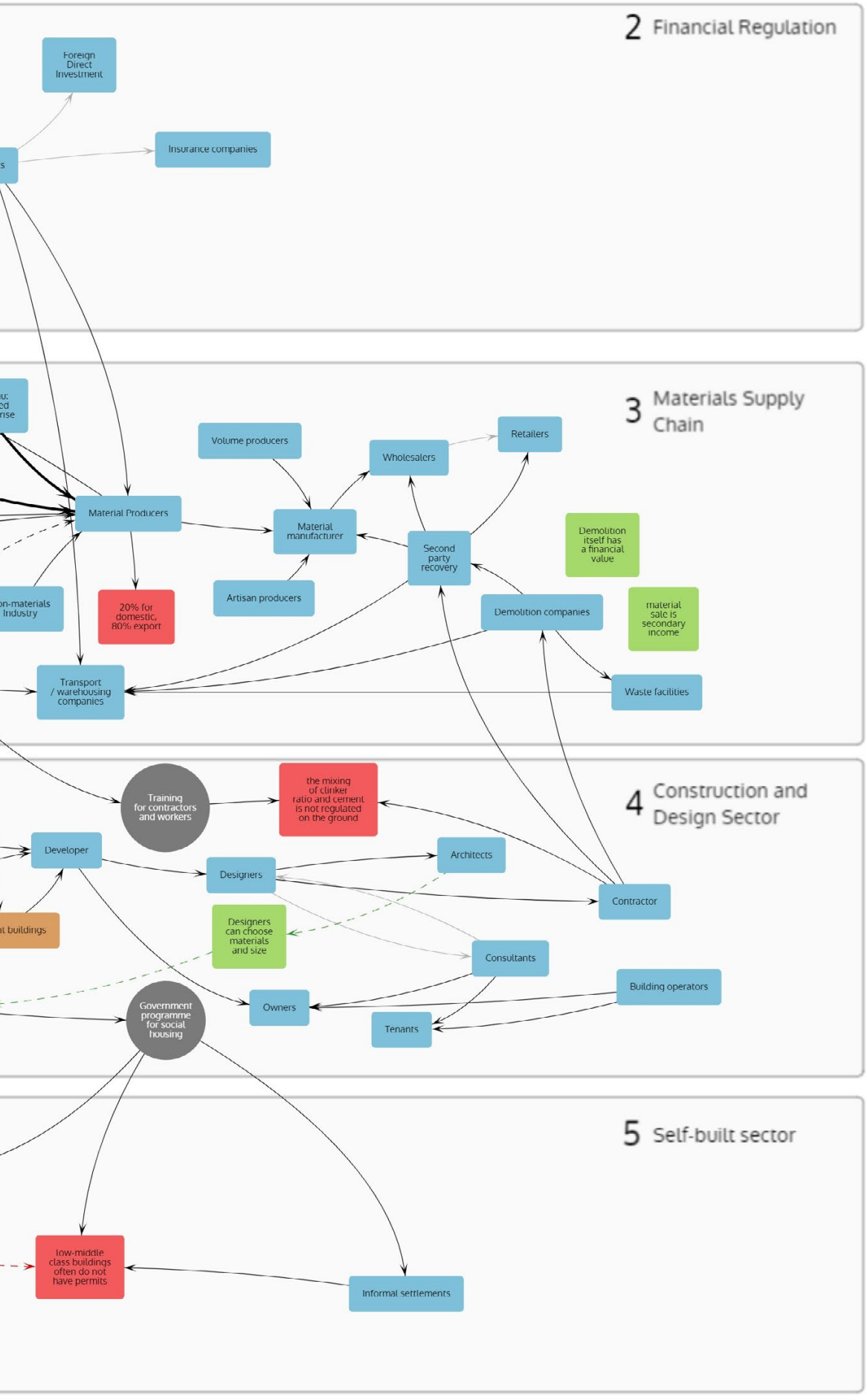
3	GOAL 3: MATERIAL DECARBONISATION AND SUBSTITUTION	
3.1	**Accelerate multiple pathways to decarbonisation in the cement sector**	• Increase funding for public-private partnerships to accelerate the development, demonstration, and commercialization of concrete decarbonization technologies and techniques. • Invest in materials science capacity in concrete technology and practice.
3.2	**Reduce the carbon footprint of the steel-making sector**	• Encourage upgrades of existing plants to best available technology in steelmaking. • Provide financial and structural support into R&D on early-stage low emission technologies. • Incentivize material efficiency strategies across the steel life cycle to increase steel's circularity and reduce its embodied carbon.
3.3	**Invest in the radical transformation of building material processing (e.g. aluminium) and minimize downcycling**	• Improve collection and grade-specific sortation at end-of-life to maximise the use of scrap in future material production without the risk of downcycling to low-value applications. • Invest in and enable the transition of digitized off-site manufacturing methods to greatly cut down on inefficient material waste and air quality emissions from antiquated, inefficient on-site construction techniques.
3.4	**Promote the adoption of bio-based materials**	• Facilitate the adoption of localized, low-carbon building materials by facilitating intensive brick-making practices with compressed soils; replacing cementitious material and mortar; and using waste by-products such as fly-ash in coal industries. • Use sustainably produced timber. • Promote awareness among building professionals by partnering with industry associations.

4	GOAL 4: DECARBONISATION OF MANUFACTURING PROCESSES	
4.1	**Boost capacity of manufacturers**	• Provide training on reducing embodied carbon emissions of materials, increasing efficiency in manufacturing processes and circular design principles. • Provide training on compliance to policies such as labelling. • Provide capacity building on the topics of light weighting structures, achieving high-density developments without relying on tall structures (i.e., reduce reliance on steel and concrete), use appropriate LCA tools and methodologies.
4.2	**Increase investment in innovation and R&D**	• Develop measures to support applied research into low-carbon, bio-based and locally sourced materials, and solutions. • Develop strategies for decarbonising hard-to-abate sectors. • Implement policies that enable improved design and purchasing decisions based for on embodied carbon emissions and energy.
4.3	**Promote fuel switching and higher efficiencies in manufacturing of construction materials**	• Develop measures to speed up the implementation of decarbonisation in industries manufacturing construction materials. • Include building material manufacturing industries as part of demand-side management efforts. • Promote energy management by developing best practice guides. • Support establishment/engagement of material development/training facilities/laboratories through innovative academic and private sector actors and engaging official product and material certification bodies.
4.4	**Have clear policies on material decarbonisation**	• Promote clear and consistent standards for carbon labelling. • Ensure a fair playing field for low carbon building materials through international and multilateral engagement.

5	GOAL 5: REDUCE WASTE AND INCREASE REUSE AND RECYCLING	
5.1	**Incentivise renovation and repurposing of buildings to expand lifetime**	• Designers able to design for repurposing buildings use. • Modular designs and materials to enable repurposing to new uses. • Have building and planning policies that enable and ease repurposing.
5.2	**Reuse and recycle building waste at the end of buildings' lifetimes**	• Mandate plans and systems for collection and reuse/recycling of construction and demolition of waste. • Incentivize building designs and a marketplace for material reuse and develop standards to ensure the quality and efficacy for their use.
5.3	**Improve deconstruction processes to enable reuse and repurposing**	• Develop guidelines or protocols for deconstruction. • Promote selective sorting of materials and waste from site. • Promote and standardise material recovery and storage facilities. • Facilitate stakeholder engagement among designers and recyclers to identify chokepoints and supply quality problems.
5.4	**Target economic incentives to increase overall recycling volumes**	• Incentivize efficient collection and sorting to create competitive secondary markets. • Put premiums on the cleanliness of recycling streams to minimize downcycling. • Invest in new equipment for collecting, sorting, and converting waste at the time of building demolition so that it can be efficiently repurposed into a new life cycle. • Put market (recycled content) and regulatory (collection targets) incentives into place that ensure the diversion of collected CRD polymers from landfills and towards recycling.

Annex II: Dynamic Sector Map




2 Financial Regulation
Foreign Direct Investment
Insurance companies
3 Materials Supply Chain
Volume producers
Wholesalers
Retailers
Material Producers
Material manufacturer
Second party recovery
Demolition itself has a financial value
Artisan producers
20% for domestic, 80% export
Demolition companies
material sale is secondary income
Transport / warehousing companies
Waste facilities
4 Construction and Design Sector
Training for contractors and workers
the mixing of clinker ratio and cement is not regulated on the ground
Developer
Architects
Designers
Contractor
Designers can choose materials and size
Consultants
Building operators
Owners
Government programme for social housing
Tenants
5 Self-built sector
low-middle class buildings often do not have permits
Informal settlements

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ABOUT THE INTERNATIONAL RESOURCE PANEL

Aim of the Panel

The International Resource Panel was established to provide independent, coherent and authoritative scientific assessments on the use of natural resources and their environmental impacts over the full life cycle. The Panel aims to contribute to a better understanding of how to decouple economic growth from environmental degradation while enhancing well-being.

Benefiting from the broad support of governments and scientific communities, the Panel is constituted of eminent scientists and experts from all parts of the world, bringing their multidisciplinary expertise to address resource management issues.

The information contained in the International Resource Panel's reports is intended to:
- be evidence based and policy relevant,
- inform policy framing and development, and
- support evaluation and monitoring of policy effectiveness.

Outputs of the Panel

Since the International Resource Panel's launch in 2007, more than 33 assessments have been published. The assessments of the Panel to date demonstrate the numerous opportunities for governments, businesses and wider society to work together to create and implement policies that ultimately lead to sustainable resource management, including through better planning, technological innovation and strategic incentives and investments.

Following its establishment, the Panel first devoted much of its research to issues related to the use, stocks and scarcities of individual resources, as well as to the development and application of the perspective of 'decoupling' economic growth from natural resource use and environmental degradation. These reports include resource-specific studies on biofuels, water and the use and recycling of metal stocks in society.

Building upon this knowledge base, the Panel moved into examining systematic approaches to resource use. These include looking into the direct and indirect impacts of trade on natural resource use; connections between resources and human mobility; issues of sustainable land and food system management; priority economic sectors and materials for sustainable resource management; benefits, risks and trade-offs of low-carbon technologies; city-level decoupling; and the untapped potential for decoupling resource use and related environmental impacts from economic growth.

Upcoming work

In the forthcoming months, the International Resource Panel will focus on status, trends, outlook, and solutions for sustainable resource management, the socioeconomic implications of resource efficiency and the circular economy, the connections between finance and sustainable resource use and circular economy in consumer electronic products, among others.

More information about the Panel and its research can be found at:
Website: www.resourcepanel.org
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