TECHNICAL GUIDELINES

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

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/m²a 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.

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 CO_2 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).

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 efficiency of the management of resources in attendance to climate change is a key issue for the articulation of climate agendas, sustainable production and consumption, industrial environmental regulation and initiatives to improve the performance of cities and promotion of sustainable buildings from a circular economy approach.

Technical Guidelines represent Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low Carbon Future in Construction Sector in Mexico, provide guiding elements to advance more decisively and synergistic towards the consolidation of a comprehensive environmental policy facing the global and local challenges of development, by influencing several sustainable development objectives adopted by Mexico and where the construction and building sector, together with the cement and steel industry, have a key role in helping to decouple economic growth from environmental degradation, increase resource efficiency and promote sustainable lifestyles.

It should be noted that these national Technical Guidelines are contextualized within the framework of the Special Climate Change Program, which identify as a strategic line of action, "Promoting the efficient use of resources in the residential and commercial sectors that contributes to the development of inclusive Human Settlements and climate resilient". To reinforce these commitments, the 2022 update of the Nationally Determined Contribution, Mexico establishes an increase in ambition with new commitments to mitigate greenhouse gases, through actions throughout the national economy, including the household sector.

The environmental promotion and regulation instruments aimed at caring for natural resources and conserving ecosystems represent a challenge that requires redoubling efforts, focusing actions, and consolidating the necessary social agreement, inter-institutional coordination, and international cooperation in order to transform the complex environmental reality at local and global level.

For SEMARNAT, the national technical guideline represents the product of a valuable group discussion among the different actors involved in the value chain, on the findings, opportunities, and barriers to achieve material efficiency in the residential sector in our country.

Through the agreements reached regarding the modeling, the mapping of actors, the proposals for actions to accelerate the decarbonization of materials and the recommendations for the road map, the Technical Guidelines provide updated information that will allow aligning efforts around goals in common. Such as the case of the sectoral agendas supported by the agreements that SEMARNAT has been working with key actors like the National Chamber of Cement (CANACEM) and the National Chamber of the Iron and Steel Industry (CANACERO).

Finally, the role of cooperation and climate financing are recognized as tools that allow accelerating the implementation of its commitments and the interest in the cooperative approaches established by the International Cooperation Program "Resource Efficiency and Climate Action Initiative" is manifested in Article 6 of the Paris Agreement, for increasing ambition level.

"Facing complexity in a shared way, we will be able to advance in more effective mechanisms to address climate challenges".

Alonso Jiménez Reyes
Undersecretary of Environment Regulations
Secretary of Environment and Natural Resources

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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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2 OBJECTIVES

2.1 Overall objectives

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 and 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.


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3 BACKGROUND

3.1 Country profile

According to Mexico's National Institute of Statistics and Geography (INEGI), Mexico had 126 million inhabitants in 2020; while Mexico's National Population Council (CONAPO) estimates that Mexico's population will be 148.2 million by 2050 (Mexico National Population Council [CONAPO] 2018). Consequently, there will be 22.2 million additional people who will demand a large amount of resources for their development and well-being.

Mexico is among the 15 largest economies in the world and the second largest economies in Latin America, with 3.6 CO_2 metric tons per capita while the world has a media of 4.6 (World Bank 2023). The current national vision of development contemplates a transition towards productive models with a social focus, increasing the environmental commitments established at the international level, with a series of cross-cutting and sectorial agendas to meet the different challenges and objectives proposed, some of which are represented in the recent Nationally Determined Contributions (NDC) (Mexico Secretariat of Environment and Natural Resources (SEMARNAT) 2022) submitted to the United Nations Framework Convention on Climate Change (UNFCCC).

From the federal perspective, there are some instruments that consider the most efficient use of resources, such as the National Vision towards Sustainable Management: Zero Waste, in line with the vision of the 2030 Agenda in Mexico and the initiative of the Circular Economy Law. In the financial sector, the recent Sustainable Taxonomy of Mexico seems to lay the groundwork for directing financing to projects aligned with the Sustainable Development Goals (SDGs).

Regarding the construction sector and particularly in the universe of social housing, Mexico has mechanisms and programmes on a national scale that consider sustainability aspects in design, construction, equipment, performance and financing, both in the National Housing Programme 2019-2024 (*Secretaría de Desarrollo Agrario, Territorial y Urbano* (SEDATU)) and in the sectoral programmes of the National Housing Agencies (*Organismos Nacionales de Vivienda* (ONAVIS)), such as the Institute of the National Housing Fund for Workers (*Instituto del Fondo Nacional de la Vivienda para los Trabajadores* (INFONAVIT)), National Housing Commission (*Comisión Nacional de Vivienda* (CONAVI)), and the Federal Mortgage Society (*Sociedad Hipotecaria Federal* (SHF)).

Table 1: General programmes and initiatives related with sustainable buildings in Mexico.

No.	National Initiative	Institution	Reference
1	Agenda 2030 for Mexico	SEMARNAT	Link
2	NDCs 2022	SEMARNAT	Link
3	Visión Nacional Cero Residuos	SEMARNAT	Link
4	Iniciativa de Ley General de Economía Circular	Senado de la República	Link
5	Programa Nacional de Vivienda	SEDATU	Link
6	Taxonomía Sostenible de México	SHCP	Link
7	Programa Transversal de Edificaciones	SENER-CONUEE	Link
8	Autoproducción de Vivienda Adecuada en México	SEDATU	Link

3.1.1 Construction practices in residential sector in Mexico

The housing construction industry in Mexico plays an important role in the country's economy, accounting for 5.7 per cent of GDP (National Institute of Statistics and Geography Mexico 2022). According to the National Housing Survey, there are 35.3 million inhabited private homes, of which 92.4 per cent have walls of brick, block, quarry or cement; 78.4 per cent have a concrete slab roof or joists with vaulting; 97.7 per cent have a cement or solid floor, wood or other covering; 89.2 per cent have a room for cooking; 97.6 per cent have sanitary facilities; 76.9 per cent have piped water inside the dwelling; 1.2 per cent acoustic insulation, and 6.0 per cent thermal insulation, with a housing backlog of 8.2 million dwellings (National Institute of Statistics and Geography Mexico 2021), revealing opportunities to establish guidelines and strategies to meet the objectives established in the present and future approach to social housing policy and those related to the 2030 Agenda.

Table 2: National social housing programmes with sustainable criteria in Mexico.

No.	National Programme	Institution	Reference
1	Ecocasa	SHF	Link
2	Programa de vivienda social	CONAVI	Link
3	Línea II – Adquisición de vivienda o terreno	INFONAVIT	Link
4	Línea III – Construcción o autoproducción	INFONAVIT	Link
5	Línea IV – Reparación, Ampliación o Mejoramiento	INFONAVIT	Link
6	Mejoravit	INFONAVIT	Link
7	Mejoramiento Integral Sustentable	FIDE – CONAVI	Link

In the last 30 years, several programmes have been developed that include sustainability elements in the planning, equipment and design of social housing, for which valuable tools, pilot projects, studies and sources of information for the sector have been developed; although perhaps some of the most important results have been the lessons learned, the updating of housing regulations, the growth of the green market for materials and technologies, as well as the awareness and professionalization of the sector in terms of energy efficiency and sustainability.

One of the emblematic and current programmes today is Ecocasa (SHF), since its conception uses a financing fund with a preferential rate, aimed at managing housing projects that meet standards higher than 20 per cent in energy and environmental efficiency, compared to conventional housing. In this programme, 4 tools are used to evaluate different aspects of housing, such as Energy (DEEVi), Water (SAAVi), Environment (HEEVi) and the Carbon Footprint of materials considering the Life Cycle Analysis (Huella de carbono ACV), the last one being of great importance for the transition towards decarbonization in construction materials.

Self-driven housing production is a reality in Mexico, 57.3 per cent of the houses are self-produced. In the context of self-production, Mexico developed the National Self-production Strategy, through the Decide y Construye platform, contemplates the promotion of regional materials in the different intervention modalities (retrofit, expansion and new self-produced housing), where the "Por mi Rumbo" tool has been developed to guide beneficiaries on the materials and ecotechnologies available in their neighbourhood, which means support for MSMEs of the construction sector, and possible reductions in the carbon footprint due to the immediate accessibility of materials.

Table 3: Tools, apps, and information sources for sustainable housing in Mexico.

No.	Tools and Information sources	Type	Institution	Reference
1	Ecocasa – ACV Materiales	Tool	SHF	Link
2	Decide y Construye	Information source	SEDATU	Link
3	Por mi rumbo	App	SEDATU	Link
4	Mi PyME Eficiente	Training and Information source	ALENER – GIZ	Link
5	Kit de herramientas y Aplicaciones	Apps and Tools	CONUEE	Link
6	ENCEVI	Information source	INEGI	Link
7	SIESCO	Apps and Information source	CONAVI	Link

3.1.2 Parallel initiatives

The government of Mexico City (CDMX) recently approved the Circular Economy Law (Government of Mexico City 2023). Mexico City also has the Integral Recycling Centre for Construction Waste (CIREC) with a capacity to process 1,200 tons/day of mixed construction waste and with a capacity to manufacture 640 m^3/day of hydraulic concrete with recycled aggregate. With these initiatives, along with the environmental standard NACDMX-007 establishing the obligation to use recycled material, the CDMX becomes the first state in Mexico to implement a circular economy law and put into practice a vision of zero waste.

Environmental certification systems for buildings have been one of the main promoters for strengthening the sustainable construction market in Mexico; the EDGE building certification system has certified around 30,000 homes. In addition, the Organismo Nacional de Normalización para la Construcción y la Certificación de la Edificación, A.C. (ONNCCE) has an Environmental Product Declarations (EPD) programme aimed at individuals and organizations that wish to communicate the environmental aspects of their construction products and services.

In terms of academia, some lines of research and design of certification systems and Life Cycle Analysis of construction materials have been developed by diverse institutions. The Engineering Institute of the UNAM, together with SHF, developed the LCA tool to determine the carbon footprint of some construction materials for the Ecocasa programme; while the Universidad Iberoamericana is currently designing a tool for the environmental evaluation of buildings, focusing on life cycle analysis.

Presently, the material usage and energy usage in residential buildings is regulated through codes, policies, and standards as listed in Table 1. Among these, many standards affect the use of energy (nos. 1, 5-7), thermal comfort (nos. 8-9, 11), and building materials (nos. 3, 4). More directly related to building materials, the standard NMX-AA-164-SCFI-2013 recommends that forest-based materials must be locally procured, 30 per cent of materials must be recycled for rehabilitation of buildings, new/rehabilitated buildings must use modular design to reduce waste up to 10 per cent and must have waste management system in place.

Table 4: Existing policy mix governing material and energy use in Mexico.

No.	Name	Year	Type	Key Features
1	Energy Conservation Code in Buildings (IECC Mexico)	2016	Code	• Energy efficiency in buildings regulations, design, and operations. • Voluntary.
2	National Housing Code	2017	Code	• Sustainable housing section. • Voluntary, social housing.
3	National Housing Plan (current policy)	2019-2022	Policy	• Sustainable criteria for social housing. • Sustainable materials and green technologies for social housing.
4	NOM 008 ENER 2001	2001	Standard	• Energy Efficiency in non-residential building envelope.
5	NMX C 460 ONNCCE 2009	2009	Standard	• Thermal insulation. U-Value to housing envelope by thermal zone in Mexico.
6	NMX-AA-164-SCFI-2013	2013	Standard	• Sustainable buildings criteria and environmental requirements.
7	NOM 020 ENER 2011	2011	Standard	• Energy Efficiency in residential building envelope.
8	NOM 018 ENER 2011	2011	Standard	• Thermal insulation materials for buildings.
9	NOM 024 ENER 2012	2012	Standard	• Thermal insulation materials for buildings. Optical and thermal characteristics of glasses and glazing systems certification.
10	NOM 009 ENER 2014	2014	Standard	• Energy Efficiency in thermal insulation systems in industry.
11	NMX-AA-171-SCFI-2014	2014	Standard	• Requirements and specifications for environmental performance in hospitality buildings.
12	NMX-C-506-ONNCCE-2015	2015	Standard	• Buildings Commissioning
13	NMX-U-125-SCFI-2016	2016	Standard	• Roof coatings with high solar reflectance index. Specifications and test methods.
14	NMX-C-527-1-ONNCCE-2017	2017	Standard	• Building Information Modelling

No.	Name	Year	Type	Key Features
15	NMX-C-7730-ONNCCE-2018	2018	Standard	• Ergonomics of the thermal environment • Analytical determination and interpretation of thermal comfort by calculating VME and PEI indices and local thermal comfort criteria.
16	NMX-C-21930-ONNCCE-2019	2019	Standard	• EPD (Environment Product Declaration) • Sustainability in Buildings and Civil Engineering Works • Basic Rules for Environmental Product Declarations (EPD) for Construction Products and Services.
17	NMX-C-10140-1-ONNCCE-2020	2020	Standard	• Measurement of Acoustic Insulation of Construction Elements • Application Rules for Specific Products

3.1.3 Opportunities for Low Carbon Future in Materials for housing in Mexico

Although Mexico has a great track record in the formulation of policies, programmes, instruments and mechanisms for housing sustainability, there is still a long way to cover. The important gap in the automated generation of data and access to information specific to the housing sector, the lack of monitoring, reporting and verification schemes and the formulation of an inter-institutional vision in the different levels of government and aligned to the 2030 Agenda. This vision should provide an enabling framework that encourages and recognizes good practices, with financial and non-financial incentives, where the corresponding regulations are applied and where valuable collaborations can be established between the different actors that compose the value chain of the construction and housing sector.

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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 Mexico. 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 Mexico. 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 Mexico. The workshop was planned to build on the dynamic sector map and deliberate over key actions to be prioritised in Mexico. 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) 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 Mexico. 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 Mexico.

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 Mexico. Lastly, a national review process 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.

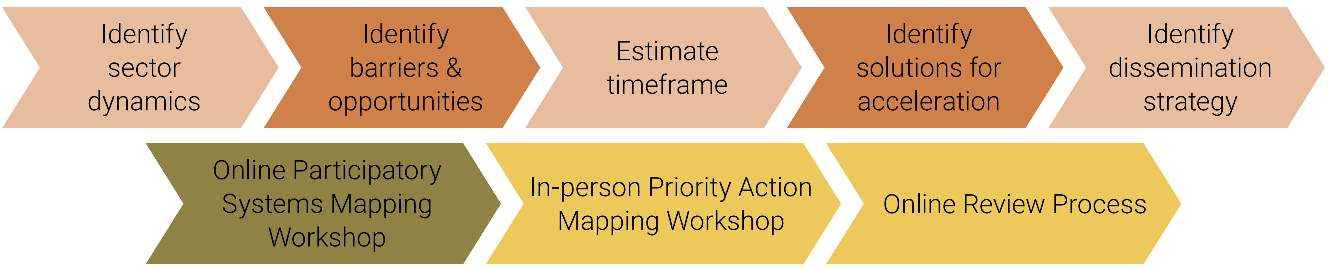

Table 5: Number of participants attending the workshops.

Stakeholders	**Number of participants**	
	1st Online Systems Mapping Workshop	2nd In-Person Priority Action Mapping Workshop
Government	5	6
Private Sector	5	5
Civil Society	0	9
Academia	1	2
Total	**11 [7 females, 5 males]**	**22 [10 females, 12 males]**

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5 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 30m^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 Mexico 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 Mexico's architecture. The model utilises three basic archetypes, which are summarised in **Table 6**.

Table 6: Archetypes characteristics.

Parameter	Single-Family Home	Multi-Family Home	Informal housing
Floor area	93.5 m^2	80 m^2 per unit, 1615 m^2 total	57 m^2
Footprint and height	7.2 m by 10 m, two-storeys, 3 m floor to floor	10.5 m by 60 m, eight-storeys, 3.8 m floor to floor	7 m by 10 m, one-storey, 3 m floor to floor
Additional floor area	—	160 m^2 on ground floor	—
Perimeter length	34.4 m	75 m	34.4 m
Gross exterior wall area	184.2 m^2	2100 m^2	103.2 m^2

The wealth distribution in Mexico indicates that half of the population lives in poverty, 45 per cent at mid-level, and 5 per cent in wealthy conditions. Such composition affects the division of the residential building types. 94.6 per cent of the current stock is modelled by single unit houses, of which 50 per cent built with the limited professional planning (Informal housing). The remaining 44.6 per cent is modelled as Single-Family Homes with leaner design. Apartment blocks, modelled as Multi-Family Homes, represent 5.4 per cent of the total stock. Since in Mexico just over half of the population (53.7 per cent) resides in temperate climates, the predominant materials used for building construction are masonry. Buildings' envelopes and structures are made of brick or concrete blocks, regardless of the type, size, and prosperity status of the owner. Self-built houses are more likely to make use of secondary material and reuse concrete blocks. The material intensity of archetypes depends on the selected ME strategy, and the standard design is compared to alternative designs in **Table 7** to alternative designs derived from architectural investigation. The approach for these Technical Guidelines focus 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 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. The 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 12 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 8 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 7**. 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 10 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 Mexico, the potential of material substitution is limited by the social stigmatisation of natural materials, perceived as low-income materials choice.

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 7**. 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 7: Material footprints of building archetypes. Values are expressed in kg/m^2.

Housing type	Concrete	Cement	Steel	Wood products	Bricks	Other
Single-Family Home						
Standard design	1288.7	106.8	83.0	5.9	582.1	16.1
Material-substitution	715.8	18.0	180.0	159.3	10.4	37.4
Optimized design	1241.6	106.	70.3	5.9	470.4	15.4
Multi-Family Home						
Standard design	1276.1	81.0	78.4	3.5	404.7	5.7
Material-substitution	605.0	40.7	59.3	162.5	2.1	27.4
Optimized design	1242.3	81.0	65.4	3.5	330.1	5.3
Informal housing						
Standard design	2006.4	72.5	112.8	5.1	374.0	23.0
Material-substitution	1648.0	72.5	314.1	91.9	17.0	43.8
Optimized design	1929.6	72.5	99.8	5.1	302.6	23.0

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 42 per cent. Together with the extension of lifetime to reduce new construction demand and manufacturing, 40 per cent of emissions could be saved. Repurposing allows significant savings in terms of waste prevented from buildings demolition, achieving savings of 55 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 51 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 Mexico by 52 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 Mexico 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 Mexico only 15 per cent of electricity is generated from renewable sources. In addition to the COP27 climate summit pledge to double up the renewable energy capacity by 2030, in the clean energy scenarios it is assumed that by 2060 electricity production in Mexico from renewable sources would increase by 30 per cent more. The increased employment of energy produced from renewable sources in the production phase of materials would lead up to 57 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 Mexico 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 8: 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	-8%			-55%	-59%	-59%
Material production	-5%	-10%	-6%	-42%	-52%	-52%
GHG emissions	-12%	-2%	-10%	-40%	-51%	-57%

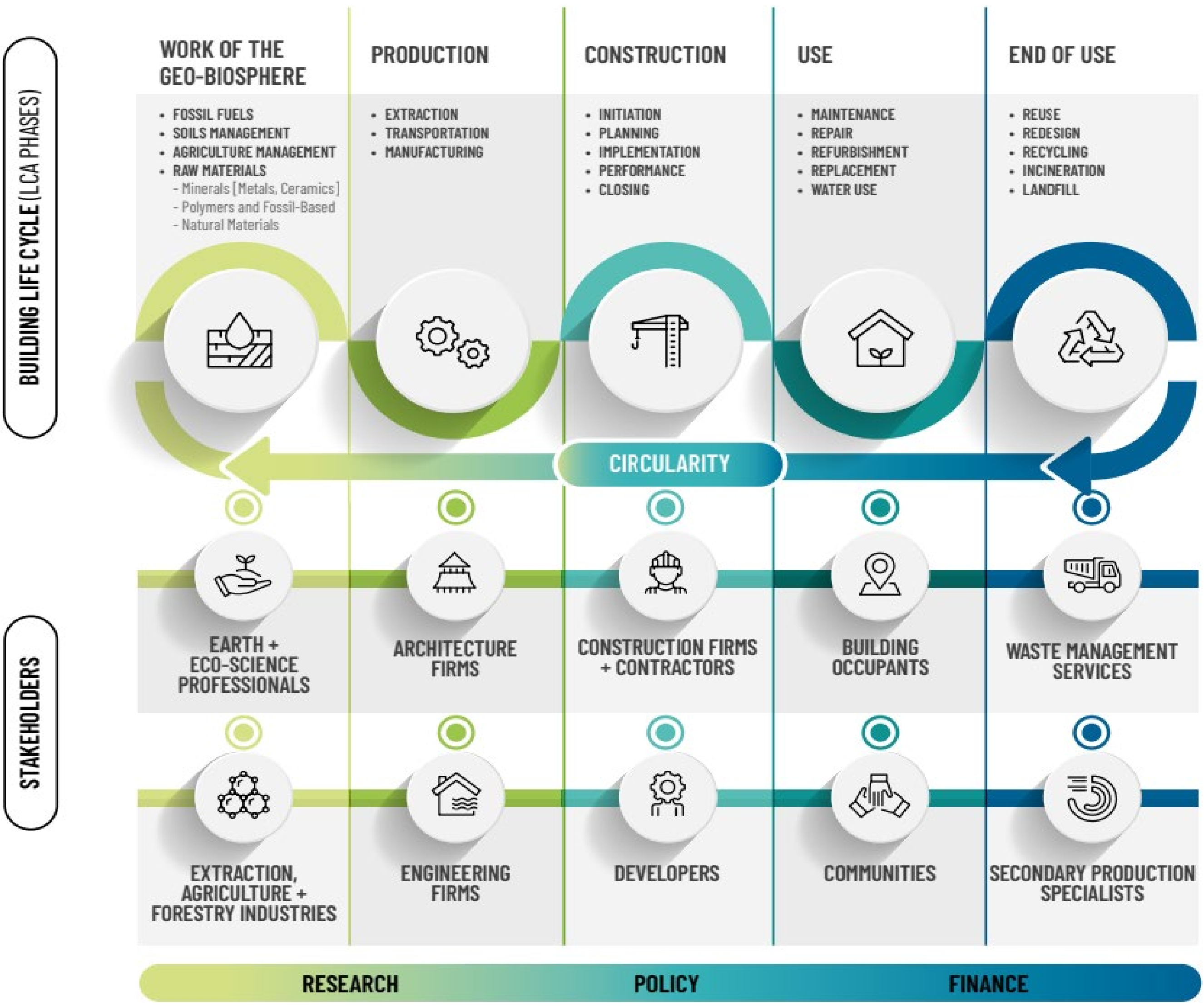
6

SECTOR DYNAMICS

The residential building construction sector in Mexico 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, Mexico'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, p.13).



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 Mexico also proposed, a collaborative and collective effort will accelerate the process towards achieving a low carbon future in Mexico's residential building sector. To this effect, the rest of this section articulates some of the roles and responsivities of various actors. The actors currently engaged in residential building construction sector in Mexico are indicated in **Table 6**.

It is crucial to note that labour participation across the entire life cycle of the residential building construction process is highly differentiated across various sub-sectors and dependent on the prevailing socio-cultural dynamics. In such a context, women are currently underrepresented in Mexico's residential building construction industry (5.47% in 2022) (Government of Mexico 2022). Women's share in Mexico's construction, transport, mining, and electricity is particularly lower than in other sectors, while women have equal or higher representation in manufacturing, wholesale, and retail sectors (The World Bank 2019). Though female labour force participation has increased with economic activity, there remains critical issues related to gender pay gaps, traditional gender norms, lack of access to finance, and gender-based violence, among others (The World Bank 2019). Despite these challenges, women's participation in sectors such as agroforestry have been recognised in literature (Shiva 1992; Kiptot and Franzel 2012; Buechler 2016). Incorporating women's knowledges and experiences in policies and programmes provides an effective avenue for achieving gender equal practices.

Research has also shown that climate change affects men and women differently (Mujer y Medio Ambiente 2010). Yet, the effects of climate change on the ability to choose and access low-carbon materials for residential building constructions has not been explored. Consequently, there is need for further data collection and analysis on the gendered effects of climate change on the use and access of low-carbon materials, as well as generating more gender-equal labour force in various sectors of the residential building construction industry. To this effect, the National Program for Equality between Women and Men (Proigualdad) 2020-2024 provides an overarching roadmap by establishing commitments and policies to generate necessary conditions for the participation of women in all spheres of life. In particular, Proigualdad promotes (1) economic autonomy, (2) conditions for recognition, reduction and redistribution of domestic and care work, (3) improved access to well-being and health, (4) combating gender-based violence, (5) equal participation of women in the decision-making in the political, social, community and private spheres, and (6) building safe and peaceful environments for women and girls. Linking the efforts undertaken under Proigualdad 2020-2024 with various sub-sectors along the life cycle of residential building constructions would advance the agenda towards gender equality. Consequently, 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 9: Actors involved in residential building construction sector in Mexico

Governance and Planning	Financial Regulation	Material Supply Chain	Construction and Design	Civil Society and Academia
▪ Ministry of Environment and Natural Resources (SEMARNAT) ▪ Ministry of Agrarian, Territorial and Urban Development (SEDATU) ▪ Ministry of the Environment (SEDEMA) ▪ National Housing Commission (CONAVI) ▪ National Institute for Federalism and Municipal Development (INAFED) ▪ National Institute of Sustainable Land (INSUS) ▪ The National Commission for the Efficient Use of Energy (CONUEE) ▪ Municipalities	▪ Bank of Mexico ▪ National Bank of Public Works and Services (BANOBRAS) ▪ National Housing Fund for Workers (INFONAVIT) ▪ Housing Fund of the Institute of Security and Social Services for State Workers (FOVISSSTE) ▪ Real Estate Investment Trusts (FIBRAs) ▪ Green Finance Advisory Council (CCFV) ▪ Federal Mortgage Company (SHF)	▪ The Mexican Association of the Ready-Mix Concrete Industry (AMIC) ▪ National Chamber of the Iron and Steel Industry (CANACERO) ▪ The Alliance for Energy Efficiency (ALENER) ▪ Cement producers ▪ Steel producers ▪ Material wholesalers ▪ Material retailers ▪ Transport companies	▪ The Mexican Chamber of the Construction Industry (CMIC) ▪ Mexican Association of Recycling of Construction and Demolition Waste (AMRCD) ▪ The Federation of Architects Association of the Mexican Republic AC (FCARM) ▪ The Federation of Colleges of Mechanical Engineers, Electricians, Electronics and Related Branches, AC of the Mexican Republic AC (FECIME)	▪ The National Organization for Standardization and Certification and Building (ONNCCE) ▪ The National Academy of Architecture ▪ The Academy of Engineers Mexico ▪ Mexican Institute of Cement and Concrete A.C.

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 Mexico and can potentially take up the role of regulating and monitoring transitions towards low carbon future in the residential building sector.

The Ministry of Environment and Natural Resources (SEMARNAT) aims to ensure the optimal protection, conservation, and use of the country's natural resources to generate comprehensive and inclusive environmental policy for sustainable development. The ministry works on four priority aspects, namely: (1) The conservation and sustainable use of ecosystems and their biodiversity; (2) Pollution prevention and control; (3) The integral management of water resources; (4) The fight against climate change. The Ministry of Environment (SEDEMA) works for the protection of the environment and to promote sustainable development of the environment. The ministry has five priority areas including (1) Air Quality and Climate Change, (2) Land Conservation and Biodiversity, (3) Green Urban Infrastructure, (3) Water Supply and Quality, (5) Environmental Education and Communication. Likewise, The National Commission for the Efficient Use of Energy (CONUEE) is a decentralized administrative body of the Ministry of Energy which promotes energy efficiency and act as a technical body in the field of sustainable energy. Together, supporting the goals to decarbonisation of material manufacturing sector, production of sustainable bio-based and earth-based materials, and reducing the use of fuels generating high GHG emissions falls within the remits of SEMARNAT, SEDEMA, and CONUEE.

The Ministry of Agrarian, Territorial and Urban Development (SEDATU) has as its mission to promote sustainable and inclusive territorial development through design, coordination and implementation of territorial planning and urban development and adequate housing policies. SEDATU aims to establish an integrated, orderly, inclusive, sustainable, and secure territorial systems; promote affordable, resilient, and sustainable habitat, advance in the construction of living spaces, and guarantee the right to adequate housing for all people. SEDATU has previously engaged in energy projects as coordinators and mediators. The National Housing Commission (CONAVI) provides housing support for those in need. CONAVI provides subsidies through programmes such as (1) National Reconstruction Programme, (2) Social Housing Programme; or (3) Emerging Housing Project. National Institute for Federalism and Municipal Development (INAFED) is a decentralised administrative body of the Ministry of the Interior has its aim to strengthen the institutional capacities of municipal governments based on the current legal framework. Regulating the use of materials through housing policies, building regulations, and construction management can be taken up jointly by SEDATU, CONAVI and INAFED.

The National Organization for Standardization and Certification of Construction and Building, SC (ONNCCE) is dedicated to developing standardization, certification and inspection activities established since 1994. Since 2000s, ONNCCE acts as a Quality Systems Certification Body (accredited by EMA), Inspection Unit of the NMX-AA-164-SCFI and Programme Administrator under the Mexican Standard NMX-SAA-14025-IMNC-2008 and ISO/TS 14027:2017. ONNCCE develops Product Category Rules (PCR) and publishes Declarations Environmental (EPD) Type III on construction products. ONNCCE has the responsibility of incorporating new research into standards and undertake certification and inspection activities to ensure effective compliance to standards.

6.2 Financial regulation

The financial sector directly or indirectly influences residential building constructions in Mexico. This 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, besides the recent Mexican sustainable taxonomy issued by the Ministry of Finance and Public Credit Ministry (SHCP), to identify activities, assets or Investment projects with positive environmental and social impacts.

The financial institutions in Mexico, including banks and insurance companies, provide financial capital for building construction through loans and insurance schemes. Government has actively provided housing subsidies for the construction of social housing. The government's focus on subsidising developers has shifted towards setting up financial instruments such as loans. While the Institute for the National Housing Fund for Workers (INFONAVIT) established in 1972 was an important source of housing subsidies, the institute now operates on voluntary basis since the policy changes in 1990s. Since 2010, green mortgages became compulsory for new housing developments and optional for individual open market.

The Housing Fund of the Institute of Security and Social Services for State Workers (FOVISSSTE) is in charge of granting housing loans to state workers. FOVISSSTE is now a globally competitive financial institution which aims to provide and operate financial schemes so that the beneficiaries can acquire decent housing and sustainable retirement. The Federal Mortgage Society (SHF) is a state development bank dedicated to promoting development of primary and secondary housing markets through guarantees or financial instruments. The SHF is moving towards a sustainable and intelligent urban development model to reduce the housing gap in Mexico. The National

Bank of Public Works and Services (BANOBRAS) is a leading development banking institution in Mexico with an aim to strengthen the institutional capacities of state and municipal governments. Banobras works towards sustainable development of the country and the well-being of Mexicans. It promotes greater access to credit for infrastructure projects for marginalised regions through credit and guarantees. Banobras also promotes the participation of commercial banks and other private sector agents in infrastructure financing.

A representative body of the Mexican financial sector titled, Green Finance Advisory Council (CCFV), was created in 2016 in response to the growing national need for the creation of a sustainable and resilient financial market. CCFV's main objectives are to promote dialogue on financing assets and projects with environmental impacts; address new risks and financial challenges; propose incentives and mechanisms for favourable changes in market practices; collaborate with various stakeholders to promote public policies supporting the development of a sustainable financial market, and carry strategies alliances with multilateral agencies to promote laudable capacity building through the exchange of best practices and targeted financial education. CCFV is made up of financial associations, institutional investors, development banking, commercial and multilateral banking, independent consultants, ratings, and corporations, among others. CCFV already recognises the residential construction sector as an eligible sector for green bonds as per Green Bonds Initiative.

Additionally, FIBRAs (Fedeicomiso de Infraestructura en Bienes Racíces) or REITs (Real Estate Investment Trusts) have come up in Mexico since 2004 as an investment vehicle – supported by Mexican tax laws and regulations, operating and trading regulations, and Mexican pension funds. Both public and private financial support for green technologies and constructions provide favourable conditions in Mexico to accelerate the ME strategies for a low-carbon future.

6.3 Material supply chain

The material supply chain sector 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.

The Mexican Association of the Ready-Mixed Concrete Industry (AMIC) was established in 1958 to bring together the ready-mix concrete companies. AMIC promotes and professionalises the ready-mix concrete industry, connect producers to suppliers, and represent the industry in promoting environmental and safety standards. Currently, AMIC offers technical support, training, and dissemination of small and large industry events. The National Chamber of the Iron and Steel Industry (CANACERO) was established in 1949 as official advocates of the Mexican steel industry, who have proposed the design of policies that foster sustainable growth and sector development. CANACERO is an independent body which also acts as National Standards Body (ONN) establishing the technical specifications of steel products made in Mexico. The presence of AMIC and CANACERO would help facilitate participation of the cement and steel manufacturers in implementing the ME strategies – through training, capacity building, policy development and enforcement.

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 Mexican Chamber of the Construction Industry (CMIC) coordinates with various government organisations to influence development in Mexico by representing the interests of construction companies, providing excellent services, promoting competitive, cutting-edge, socially responsible, and technologically innovative industry. The Mexican Association of Recycling of Construction and Demolition Waste (AMRCD) encourages and promotes recycling by disseminating knowledge about different uses of recycled aggregates, establishing, and promoting links between various stakeholders, and participating in research and development related to recycling of construction and demolition waste. CMIC and AMRCD have an important role to play in integrating the demolition and recycling agencies into the mainstream supply chain of materials in the building construction sector.

6.5 Civil Society and Academia

Academic institutions can play a significant role in engaging with research and development of new low-carbon materials, technologies, and design and construction techniques. Likewise, civil society organisations can support in knowledge dissemination and capacity building. The National Academy of Architecture is a relevant non-profit organisation in Mexico whose aim is to promote architecture's role in transforming cities towards equitable and sustainable conditions. Likewise, the Academy of Engineering of Mexico is a non-profit association with a purpose of promoting and disseminating the vocation, education, professional practice, research, and innovation in engineering. AEM seeks to encourage participation and collaboration among engineers and related professionals in Mexico and abroad to contribute to equitable, growing, and sustainable development of Mexico.

The Federation of Architects Association of the Mexican Republic AC (FCARM) promotes architecture and professional activities. Likewise, The Federation of Colleges of Mechanical Engineers, Electricians, Electronics and Related Branches, AC of the Mexican Republic AC (FECIME), acts as a representative and coordination body to unite, support and strengthen the various colleges of engineering. ACARM and FECIME are examples of professional bodies which can leverage their networks to train and educate designers on low-carbon technologies and design practices, as well as encourage best practice.

Established in 1923, the Mexican Institute of Cement and Concrete AC (IMCYC) is a non-profit association dedicated to the investigation, teaching and dissemination of cement and concrete application techniques. It aims to promote the optimal use of cement and concrete to meet market needs and improve professional performance. Aiming to be the leading institution in Latin America, IMCYC promotes and trains on the global best practice, disseminate scientific, and technological knowledge through teaching and consulting.

6.6 Self-produced housing

Out of the total housing stock in Mexico, 57.3 per cent has been self-produced – admeasuring to about 20.2 million constructions. The self-produced housing sector contributes to up to 46.3 per cent of the Gross Domestic Product of housing sector. Most importantly, self-produced housing fulfils the current housing deficit of 8.5 million households in Mexico. Self-built housing is predominantly constructed using concrete blocks, bricks, wood and aluminium sheets, and other readily available materials. Houses are self-produced throughout the urban and rural areas, measuring up to 64.3 per cent and 35.7 per cent of the housing stock respectively. Acknowledging the importance of self-produced housing, SEDATU has prepared an online platform titled Por mi Rumbo to facilitate the implementation of various government housing programmes and subsidies. Citizens can access subsidies and loans from this platform.

Self-produced houses are typically constructed with the help of contractors and workers simultaneously employed in the formal/informal construction industry in Mexico. This formal/informal crossover allows contractors and workers to transfer knowledge of sustainable construction materials and techniques to self-produced houses. Many households also obtain information about new sustainable construction materials and techniques through expatriates living in the United States. These transnational flows of information are a significant asset to generating material efficiency and low carbon futures in Mexico's self-built housing sector. Many materials are also recycled within the self-built sector.

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 Mexico.

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 Mexico. All the proposed goals and detailed actions to decarbonise construction materials are detailed in the **Annex I: 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 Mexico'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 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. 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 by design has significant potential to 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 10: 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	• Previous experiences of creating regulatory norms. • Government authority and obligation to regulate low carbon materials. • Internationally adopted commitments. • Government subsidies for constructions with low-carbon materials.	• Lack of single regulatory body. • No focus on circular economy. • Lack of resources for subsidies.	• Establish multilevel governance framework. • Develop better regulations based on life cycle assessment. • Develop policies to ensure fulfilment of international commitments.
C: Manufacturers, Retailers and Suppliers	1.1 Provide incentives for high material efficiency	• Markets are flexible and can be changed to accommodate material efficiency. • Certification system already exists.	• Existing market for low-carbon materials is not profitable. • Lack of access to affordable and quality materials. • Lack of recognition of certifications at an international level.	• Make operation regulations congruent with low carbon materials. • Report point-based standards based on certifications. • Generate incentives that demonstrate clear benefits to companies.
H: Academia and Research Institutes	1.1 Provide incentives for high material efficiency	• Accumulated knowledge through tools and methodologies. • Projects that develop low-carbon materials.	• Difficulty in practicing with sustainability focus. • Lack of development and access to low-carbon materials.	• Generate alliance between private sector, public sector, and academia. • Introduce new and accessible materials with technologies that reduce GHG emissions.

Table 11: 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	• Knowledge base to create norms exists. • Use voluntary certifications and regulations. • Valuators consider regulations.	• Lack of enforcement of legislations. • Imperfect legislations. • Lack of punitive actions.	• Strengthen systems for verification and include them in construction regulations. • Make existing low-carbon materials widely available.
D: Private Developers, Contractors, and Self Builders	2.2 Adopt design policies to promote long building lifespans	• Knowledge base to create norms exists. • Use voluntary certifications and regulations. • Valuators consider regulations.	• Lack of incentives. • Lack of planning and access to technical assistance (self-builders).	• Participate in the improvement of regulations.
E: Architects, Designers, and Consultants	2.1 Boost capacity of designers	• Interest in sustainable building constructions is growing.	• Lack of information. • Lack of capacity building regarding low-carbon and recycled materials for masons. • Lack of access to technical assistance by developers (self-builders).	• Train masons to use low-carbon and recycled materials.
H: Academia and Research Institutes	2.1 Boost capacity of designers	• There is a lot of academic and public talent. • Courses and degrees relating to sustainability and low-carbon construction exist in Mexico and Latin America that can be incorporated into university degrees.	• Lack of contextualised information.	• Participate in generating a database of low-carbon materials.

Table 12: 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	• Monitor the quality of constructions. • Existence of benchmarking tools and EPDs for cement. • Develop a roadmap for cement industry's decarbonisation process. • Certifications and financing processes that generate capital gains.	• Lack of regulations for cement with low carbon footprint. • Lack of financial support for normalising the low-carbon cement industry.	• Establish incentives to use low carbon cement. • Study the cost benefits and feasibility for sector transformation. • Support public recognition through labelling. • Incorporate norms and standards into existing regulations and monitor its enforcement. • Provide incentives. • Provide more support to producers.
	3.4 Promote the adoption of bio-based materials	• Knowledge of bio-based materials exists.	• Lack of availability of bio-based materials.	• Plant sustainable forests.
B: Financial Institutions	3.1 Accelerate multiple pathways to decarbonisation in the cement sector	• Certifications and financing processes that generate capital gains. • Develop financial products that favour low carbon footprint for cement.	• Lack of financial support for normalising the low-carbon cement industry.	• Strengthen institutional capacities for preparing robust regulations. • Provide more support to producers.
C: Manufacturers, Retailers and Suppliers	3.1 Accelerate multiple pathways to decarbonisation in the cement sector	• Certifications and financing processes that generate capital gains. • Adopt Environmental, Social and Governance (ESG) principles.	• Lack of incentives to decarbonise the cement sector.	• Leverage on international financial support for green energy project. • Develop policies to support environmental-friendly material use.
	3.4 Promote the adoption of bio-based materials	• Creation of new products for low-income sectors.	• Bio-based materials require long time to be adopted. • Market competition increase the price of bio-based materials.	• Disseminate information about characteristics of bio-based materials.
D: Private Developers, Contractors, and Self Builders	3.4 Promote the adoption of bio-based materials	• Construct affordable, quality, and resilient buildings.	• Lack of demand for bio-based materials.	• Incorporate and promote bio-based materials to the users.
E: Architects, Designers, and Consultants	3.4 Promote the adoption of bio-based materials	• Incorporate bio-based materials in designs. • Maintain evidence-based practice.	• Lack of clear definitions. • Lack of knowledge that materials contribute to decarbonisation. • Lack of clear regulations for the use of bio-based materials.	• Keep up-to-date knowledge about low-carbon materials and their use in constructions. • Generate clear definitions and policies for the use of bio-based materials.
H: Academia and Research Institutes	3.4 Promote the adoption of bio-based materials	• Develop laboratory tests to certify and evaluate materials.	• Lack of clear definitions. • Lack of finance for R&D in new construction systems.	• Create funds with shared risks to incentivise R&D.
I: Civil Society	3.4 Promote the adoption of bio-based materials	• Available expertise in self-built houses which are constructed with bio-based materials.	• Traditional construction techniques are stigmatized.	• Develop and disseminate information from academia to developers and civil society. • Generate aspirations for the use of natural materials.

Table 13: 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	• Law of Circular Economy CDMX, Environmental norm 007 CDMX, EDOMEX, QRO, NL, COAH.	• Lack of platforms to boost manufacturer capacities.	• Design a capacity building programme with local government support for manufacturers. • Provide financial support to manufacturers. • Disseminate information through courses and programmes.
	4.4 Have clear policies on material decarbonisation	• Mexico has updated National Determined Contributions. • Taxonomy for building finances is available.	• Local legislations are not updated. • Lack of trained personnel. • Opposition from mining unions and actors.	• More traceability and vigilance of the use of low-carbon materials. • Provide restrictions to companies that do not comply with regulations. • Design fiscal and financial incentives • Labelling certification.
C: Manufacturers, Retailers and Suppliers	4.1 Boost capacity of manufacturers	• Many online training platforms are available. • Training in energy efficiency and economy.	• Lack of training regarding decarbonisation of materials and circular economy.	• Develop specific courses and tools around life cycle of materials. • More traceability and vigilance of the use of materials. • Incentivise best practices.
F: Demolition and Recycling Companies	4.1 Boost capacity of manufacturers	• Sustainable taxonomy is available in Mexico.	• Cultural resistance to use recycled materials. • High costs.	• More traceability and vigilance of the use of low-carbon materials. • Implement best practices.
	4.4 Have clear policies on material decarbonisation	• Some states have policies and initiatives that focus on circular economy.	• High financial costs to develop new policies.	• Utilise existing and developed templates for circular economy.

Table 14: 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	• Generation of policies to incentivise innovation.	• Difficult to change administration.	• Do property regulation campaign to effect widespread change in the administration.
	5.3	Improve deconstruction processes to enable reuse and repurposing	• Updated NDCs. • Mexico City's Circular Economy Law. • Sustainability taxonomy.	• Lack of regulations for circular economy. • Lack of municipal and subnational laws.	• Tax the extraction of materials that generate high levels of waste.
B: Financial Institutions	5.1	Incentivise renovation and repurposing of buildings to expand lifetime	• Buildings are low-risk assets. • Renovation and repurposing provide high returns on investment. • Opportunity to invest in a new portfolio.	• Lack of finance to access green technologies. • Lack of data and information about projects and 3rd party verified assets. • Illegality of the property is a barrier to providing finance.	• Create financial products and services to support renovation and repurposing of buildings. • Tax the extraction of materials that generate high levels of waste.
D: Private Developers, Contractors, and Self Builders	5.3	Improve deconstruction processes to enable reuse and repurposing	• Opening new product lines will increase sale. • Reduce costs. • Generate new companies and employment.	• Lack of methodological or procedural guides for deconstruction.	• Provide better interest rates and tax relief.
F: Demolition and Recycling Companies	5.3	Improve deconstruction processes to enable reuse and repurposing	• Opening new product lines will increase sale. • Reduce costs. • Generate new companies and employment.	• Lack of methodological or procedural guides for deconstruction.	• Provide better interest rates and tax relief.
H: Academia and Research Institutes	5.3	Improve deconstruction processes to enable reuse and repurposing	• Generate research and institutional capacities.	• Lack of existing research on deconstruction techniques and processes.	• Conduct research on deconstruction. • Provide continued education on the topic.

ACTIONS TO ACCELERATE DECARBONISATION OF MATERIALS

The priority action framework produced through participatory workshops with national stakeholders in Mexico 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 Mexico. 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 Mexico. 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 10-20 years) include achieving key performance indicators, institutionalise carbon taxation, increase stakeholder consultation, and decarbonise heavy industry. These actions shall help decarbonise the residential building construction sector within 20 years.

Table 15: Roadmap for accelerating the decarbonisation process.

Priority Actions	< 5 years	10-20 years
GOAL 1: USE LOW-CARBON MATERIALS		
G.1.1 Provide incentives for high material efficiency	• Develop measurement tools with academia. • Disseminate knowledge and build capacities. • Effective communication regarding benefits of low-carbon materials. • Develop evaluation methods to avoid green washing. • Provide international support. • Make tools and instruments congruent. • Phase out sectoral implementation. • Cross-sectoral coordination. • Update local regulations.	
GOAL 2: USE LESS MATERIAL BY DESIGN		
G.2.1 Boost capacity of designers	• Obtain international finance. • Collaboration between academia, public, sector, private sector, civil society, and associations. • Obtain technical information from various countries.	
G.2.2 Adopt design policies to promote long building lifespans	• Technical lobbying. • Make receptive legislations. • Generate political will. • Produce dynamic and contextualised energy modelling.	
GOAL 3: MATERIAL DECARBONISATION AND SUBSTITUTION		
G.3.1 Accelerate multiple pathways to decarbonisation in the cement sector	• Publish previous investigations. • Governments should push for decarbonisation. • Manufacturing companies should share information. • Develop a common standard for all manufacturers. • Increase coordination and collaboration among various actors. • Increase in technological investigations.	(continues)
G.3.4 Promote the adoption of bio-based materials	• Identify and publish bio-based materials and their classification. • Improve quality of materials produced to make them attractive for high-end customers. • Provide monetary incentives to whoever demonstrates high percentage GHG reduction. • Develop exemplary projects to demonstrate the benefits of thermal comfort. • Provide incentives for measurable practices of decarbonisation. • Produce user-manuals of bio-based materials and disseminate them publicly.	(continues)

Priority Actions	< 5 years	10-20 years
GOAL 4: DECARBONISATION OF MANUFACTURING PROCESSES		
G.4.1 Boost capacities of manufacturers	• Provide capacity building sessions through collaboration between academia, government, and manufacturers. • Involve the financial sector to establish green credit programmes such as tax incentives. • Dissemination campaigns.	
G.4.4 Have clear policies on material decarbonisation	• Establish a fund guarantee for preferential financing (incentives). • Propose fiscal incentives to be included in the Circular Economy Law. • Propose national plan for standardization of certificates.	
GOAL 5: REDUCE WASTE AND INCREASE REUSE AND RECYCLING		
G.5.1 Incentivise renovation and repurposing of buildings rather to expand lifetime	• Do a property regulation campaign. • Create financial products and services to support renovation and repurposing of buildings. • Sensitize various actors through working groups, public-private partnerships, and Memorandum of Understanding with clear commitments.	
G.5.3 Improve deconstruction processes to enable reuse and repurposing	• Generate working groups, national forums, and platforms to provide status update on deconstruction processes. • Provide financial sponsorships. • Collaborate to share information and research outcomes between organisations, demolition and recycling companies, contractors, and private developers.	

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 low-carbon future, following recommendations are proposed:

1) 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.

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

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

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

5) 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.

6) Link the efforts undertaken under Proigualdad 2020-2024 across the various sub-sectors of the residential building constructions to advance gender equality in the sector and for more sustained and widespread uptake of ME strategies.

7) Leverage the public and private financial mechanisms, including REITs, to support green initiatives across the whole life cycle of building materials. This includes, but is not limited to, the decarbonisation of manufacturing processes, implementation of low carbon design and construction processes, or promotion of ME strategies through pilot projects.

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.

9) Promote and support subnational initiatives related to the circular economy and decarbonization of the construction sector, as well as disseminate and exchange good practices from pioneering cities and regions.

10) Take advantage of the natural inertia of the growing market for sustainable construction to generate incentives (monetary and non-monetary) that promote greater participation by the private sector and improve the supply and demand relationship.

11) Link the current public mechanisms with the building certification systems of the private initiative to strengthen the discourse and compliance with the climate change goals and the national vision of sustainable development.

12) Gradually increase the number of subnational and local construction laws and regulations updated and harmonized with current national development initiatives and instruments.

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FURTHER CONSIDERATIONS

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

- Mexico's updated NDCs provide an instructive mandate, which supports the goals for material efficiency proposed in these Guidelines.
- Mexico has a great track record in the formulation of policies, programmes, instruments, and mechanisms for housing sustainability. However, such initiatives must be supplemented by effective enforcement, monitoring, and reporting.
- Mexico has an open framework towards the decarbonization of the construction sector and it is in the road. Nevertheless, it is important to promote institutional leadership that allows coordinating collaboration needs and directing initiatives and implementation mechanisms across the board.
- Although there are tools, information sources, training and awareness platforms that deal with ME or sustainable and low-carbon construction, it is important to promote its use among designers, builders, financial institutions, and end users.
- The assumptions underlying in the ME implementation are ambitious and will require significant and collaborative effort to enforce.
- The demolition and recycling companies can be better integrated into the material supply chain through already existing platforms such as AMRCD. Integrating building deconstruction, recycling and reuse of materials has significant potential in reducing material demand.
- Although there are green financing products for construction materials recycling companies, these are mainly oriented towards large projects, living a niche opportunity in financing SMEs.
- Though majority of the existing standards are focused on energy efficiency of buildings, material efficiency standards and policies have been formulated and need to be further enforced.
- The self-built housing sector has a significant, yet under-documented, potential for contributing towards GHG emission reduction. While the state now recognised the role of self-built housing, specific evidence-based policies need to be developed in relation to implementing ME strategies in the self-built sector.
- It is relevant that there is an institution that provides constant monitoring, review, and feedback of the mechanisms for the implementation of ME in Mexico.
- 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 most ME in less than 5 years, expect for material decarbonisation and substitution (GOAL 3) which is expected to take up to 20 years to realise. 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. • Integrate considerations of embodied carbon emissions in planning and building regulations. • Require disclosure for all new construction and for large renovation projects. • Initiate low-carbon materials pilot projects and provide development incentives to project 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.

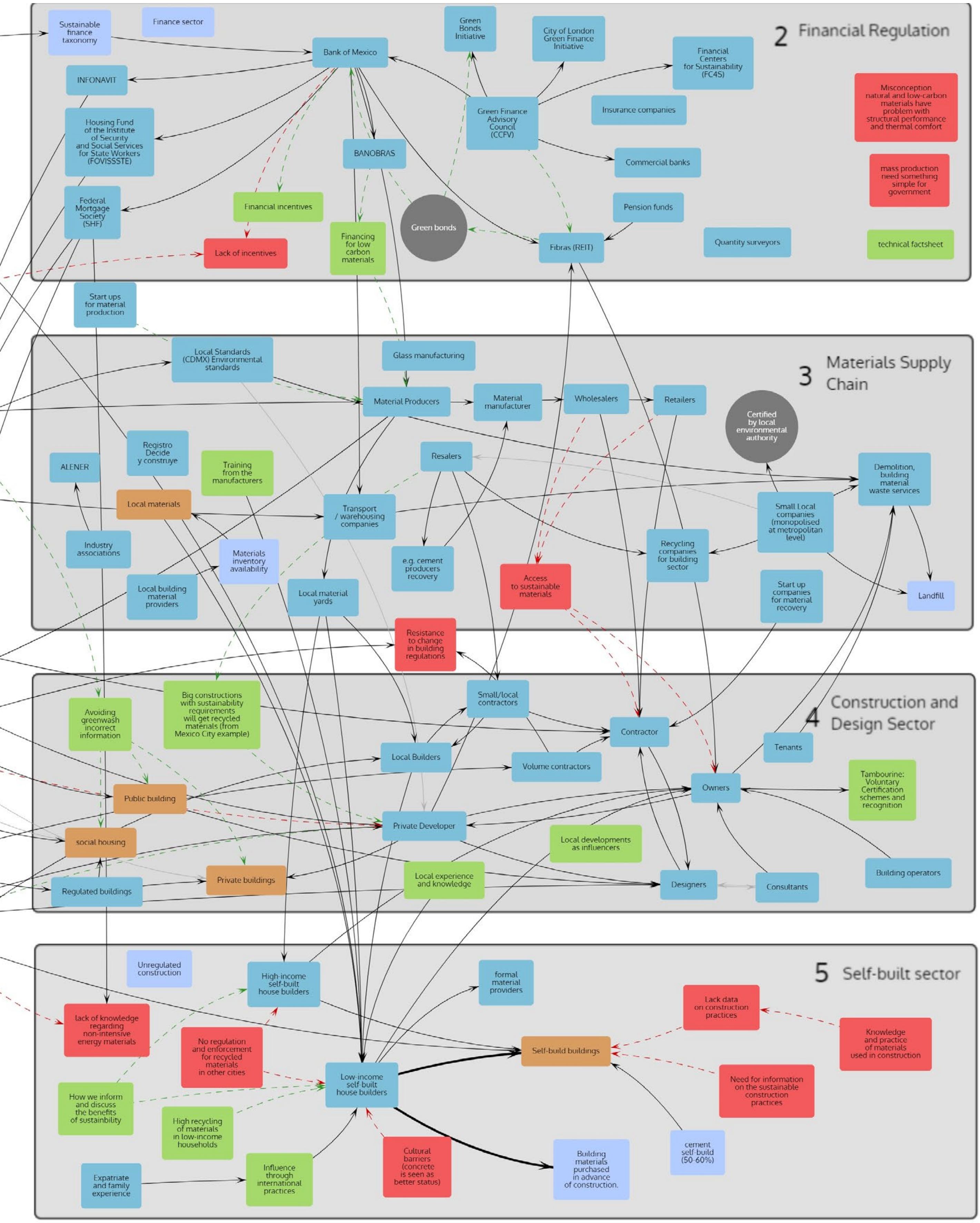
2	GOAL 2: USE LESS MATERIAL BY DESIGN	
2.1	**Boost capacity of designers**	• Training of professionals (architects, engineers, contractors etc.) • Training to comply with policies such as labelling. • Develop accreditation systems for professionals with material efficient design skills.
2.2	**Adopt design 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 availabl**	• 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 choke-points 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
Sustainable finance taxonomy
Finance sector
Green Bonds Initiative
City of London Green Finance Initiative
Bank of Mexico
Financial Centers for Sustainability (FC4S)
INFONAVIT
Green Finance Advisory Council (CCFV)
Insurance companies
Misconception natural and low-carbon materials have problem with structural performance and thermal comfort
Housing Fund of the Institute of Security and Social Services for State Workers (FOVISSSTE)
BANOBRAS
Commercial banks
mass production need something simple for government
Federal Mortgage Society (SHF)
Financial incentives
Pension funds
Green bonds
Financing for low carbon materials
Lack of incentives
Fibras (REIT)
Quantity surveyors
technical factsheet
Start ups for material production
3 Materials Supply Chain
Local Standards (CDMX) Environmental standards
Glass manufacturing
Material Producers
Material manufacturer
Wholesalers
Retailers
Certified by local environmental authority
Registro Decide y construye
ALENER
Training from the manufacturers
Resalers
Demolition, building material waste services
Local materials
Transport / warehousing companies
Small Local companies (monopolised at metropolitan level)
Industry associations
Materials inventory availability
e.g. cement producers recovery
Recycling companies for building sector
Local building material providers
Local material yards
Access to sustainable materials
Start up companies for material recovery
Landfill
Resistance to change in building regulations
4 Construction and Design Sector
Avoiding greenwash incorrect information
Big constructions with sustainability requirements will get recycled materials (from Mexico City example)
Small/local contractors
Contractor
Tenants
Local Builders
Volume contractors
Owners
Tambourine: Voluntary Certification schemes and recognition
Public building
Private Developer
social housing
Local developments as influencers
Private buildings
Local experience and knowledge
Designers
Consultants
Building operators
Regulated buildings
5 Self-built sector
Unregulated construction
High-income self-built house builders
formal material providers
lack of knowledge regarding non-intensive energy materials
Lack data on construction practices
No regulation and enforcement for recycled materials in other cities
Self-build buildings
Knowledge and practice of materials used in construction
Low-income self-built house builders
Need for information on the sustainable construction practices
How we inform and discuss the benefits of sustainbility
High recycling of materials in low-income households
Cultural barriers (concrete is seen as better status)
Building materials purchased in advance of construction.
cement self-build (50-60%)
Expatriate and family experience
Influence through international practices

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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:
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