
# RESOURCE EFFICIENCY AND CLIMATE CHANGE

## Material Efficiency Strategies for a Low-Carbon Future

### Summary for Policymakers

# Acknowledgements

**Lead authors:** Edgar Hertwich, Reid Lifset, Stefan Pauliuk, and Niko Heeren.

**Contributing authors:** Saleem Ali, Qingshi Tu, Fulvio Ardente, Peter Berrill, Tomer Fishman, Koichi Kanaoka, Joanna Kulczycka, Tamar Makov, Eric Masanet, Paul Wolfram.

**Research assistance, feedback, data:** Elvis Acheampong, Elisabeth Beardsley, Tzruya Calvão Chebach, Kimberly Cochran, Luca Ciacci, Martin Clifford, Matthew Eckelman, Seiji Hashimoto, Stephanie Hsiung, Beijia Huang, Aishwarya Iyer, Finnegan Kallmyer, Joanna Kul, Nauman Khursid, Stefanie Klose, Douglas Mainhart, Kamila Michalowska, Rupert Myers, Farnaz Nojavan Asghari, Elsa Olivetti, Sarah Pamenter, Jason Pearson Adam Stocker, Laurent Vandepaer, Shubhra Verma , Paula Vollmer, Eric Williams, Jeff Zabel, Sola Zheng and Bing Zhu. This report was written under the auspices of the International Resource Panel (IRP) of the United Nations Environment Programme (UNEP). We thank Janez Potocnik and Izabella Teixeira, the co-chairs of the IRP, and the members of the IRP and its Steering Committee.

The authors are thankful to the Review Editor, IRP member Anders Wijkman and Panel member Ester van der Voet for their leadership and support in the external review process. They are also grateful for the External Expert Review provided by Andreas Frömelt, Shinichiro Nakamura, Wenji Zhou; and other anonymous expert reviewers.

They thank the Secretariat of the International Resource Panel hosted by the United Nations Environment Programme, in particular Maria Jose Baptista, for the coordination and technical support provided for the preparation of this report. They are also grateful to Julia Okatz, Systemiq, for the support provided to the IRP Secretariat.

**Recommended citation:** IRP (2020). Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future. Hertwich, E., Lifset, R., Pauliuk, S., Heeren, N. A report of the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya.

Design and layout: Marie Moncet and Yi-Ann Chen
Icons made by Freepik from www.flaticon.com
Printed by: UNESCO
Photo cover: Colors of Humanity Series - Marthadavies, iStock / Getty Images

---



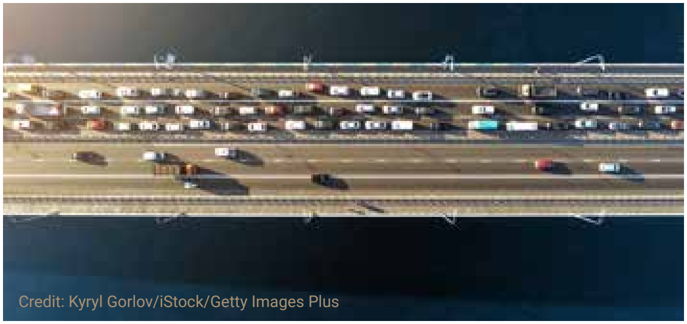
Job No: DTI/2269/PA

ISBN: 978-92-807-3771-4

DOI: 10.5281/zenodo.3542680

UN environment programme

International Resource Panel


Credit: Kyryl Gorlov/iStock/Getty Images Plus


Credit: Pixabay photo/Alexander Koch


Credit: Marcel Wojcik/iStock/Getty Images Plus

Summary for Policymakers

# Resource Efficiency and Climate Change

## Material Efficiency Strategies for a Low-Carbon Future

Prepared by the International Resource Panel

This Document highlights key findings from the full report of the same title and should be read in conjunction with it. References to research and reviews on which this report is based are listed in the full report. The full report can be downloaded at:

https://www.resourcepanel.org/reports/resource-efficiency-and-climate-change

# Foreword

This year, the UN Environment Programme (UNEP) published the tenth edition of its Emissions Gap Report, which revealed that the world must immediately begin delivering deeper and faster greenhouse gas emission cuts to keep global temperature rise to 1.5°C. To achieve this goal, we will need to use the full range of emission reduction options, including the implementation of material efficiency strategies.

The International Resource Panel (IRP) has been providing insights into how humanity can better manage its resources since 2007. Its research shows that natural resource extraction and processing account for more than 90 per cent of global biodiversity loss and water stress and approximately half of global greenhouse gas emissions. This new IRP report, Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future, commissioned by the Group of 7, points to exciting new opportunities to reduce these impacts through material efficiencies in homes and cars.

Climate mitigation efforts have traditionally focused on enhancing energy efficiency and accelerating the transition to renewables. While this is still key, this report shows that material efficiency can also deliver big gains. According to IRP modelling, emissions from the material cycle of residential buildings in the G7 and China could be reduced by at least 80 per cent in 2050 through a series of material efficiency strategies. A more intensive use of homes, design with less materials, and improved recycling of construction materials are among the most promising strategies.

Likewise, material efficiency could deliver significant emission reductions in the production, use and disposal of cars. Specifically, material efficiency strategies could reduce emissions from the material cycle of passenger cars in 2050 by up to 70 per cent in G7 countries and 50 to 60 per cent in China and India. The largest savings would come from a change in patterns of vehicle use (ride-sharing and car-sharing) and a shift towards more intensive use and trip-appropriate smaller cars.

This report makes it clear that natural resources are vital for our well-being, our housing, our transportation and our food. Their efficient use is central to a future with universal access to sustainable and affordable energy sources, emissions-neutral infrastructure and buildings, zero-emission transport systems, energy-efficient industries and low-waste societies. The strategies highlighted in this report can play a big part in making this future a reality.

**Inger Andersen,**
Executive Director
United Nations Environment Programme

# Preface

We are living in a crisis of global heating, which poses a great threat to the wellbeing of the global population that will exceed 9 billion people by mid-century. At the same time, there is a great opportunity to reshape our production and consumption systems in ways that respect planetary boundaries and support societal wellbeing. Material-efficiency strategies will play an essential role in this endeavor, for example, by providing low-carbon housing and mobility services.

The International Resource Panel (IRP) was launched in 2007 to provide independent, authoritative and policy relevant scientific assessments on the status, trends and future state of natural resources. In 28 reports, the Panel has advanced knowledge as to how society can decouple economic development and wellbeing from environmental degradation and resource use.

The attention of policy-making to natural resources has increased in the last decade under frameworks such as the Circular Economy, Sustainable Materials Management, and a Sound Materials-Cycle Society. Yet, as shown by this report, policies related to material use still largely focus on waste management rather than reduction of greenhouse gas emissions. Policies and research on natural resources must be better aligned to the urgent need of mitigating and adapting to climate change.

The IRP is a proud knowledge provider to the Group of 7 on sustainable resource management. Back in 2017 the IRP published a report commissioned by the G7 entitled "Resource Efficiency: Potential and Economic Implications". This report provided scientific evidence showing that increased resource efficiency is not only practically attainable but also contributes to economic growth, job creation and climate change strategies. As a follow-up to this work, the G7 asked the IRP to zoom into the contributions of resource efficiency to greenhouse gas emission reductions.

Consequently, this new report, *Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future*, examines the mitigation opportunities presented by higher material efficiency in the production and use of residential buildings and light-duty vehicles.

The unprecedented integrated bottom-up modeling of the report shows, for example, that in 2060, these strategies could reduce a significant amount of GHG emissions associated with the material cycle of residential buildings. More concretely, the modeling tells us that within this sector, we would have 350 million tons less of GHG emissions in China; 270 million tons less in India, and 170 million tons less in G7 countries, between 2016 and 2060. Opportunities are as significant for material efficiency strategies applied to cars. Even better news, material-efficiency strategies are based on proven technologies available today and therefore provide tangible options for moving towards a 1.5°C target.

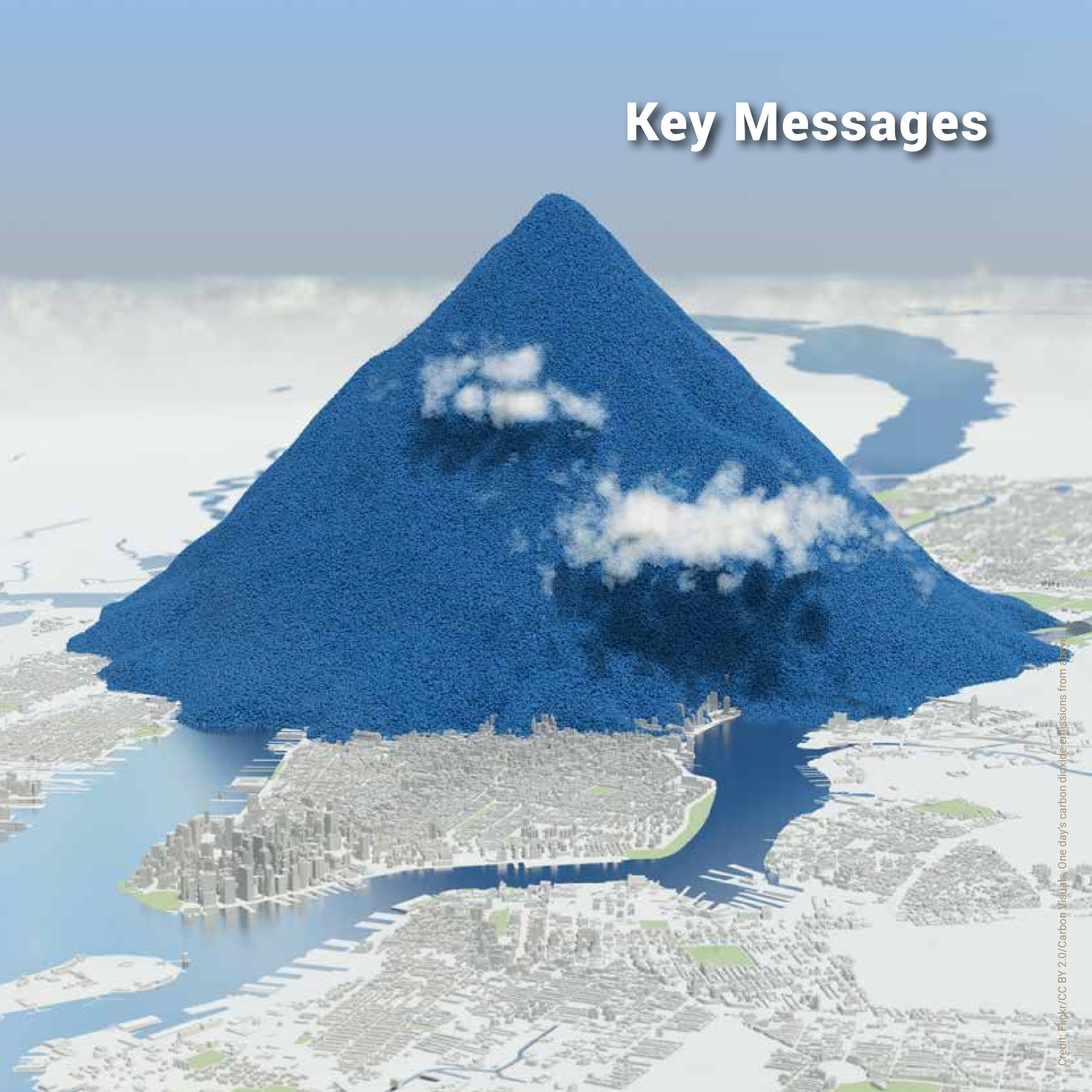
The report finds that policy intervention from different angles is required to achieve these savings. Policies can influence how people live, which materials they use, and how they use them. Instruments such as taxation, zoning and land use regulation play a role, but so do consumer preferences and behavior.

We are grateful to Edgar Hertwich and his team for their dedicated efforts to produce new insights into the material-climate nexus. Material efficiency is an important piece in the climate puzzle, particularly at a moment when more ambitious, fast-paced and impact-driven action is so urgently needed to ensure a prosperous future for all.

**Janez Potočnik**
Co-Chair,
International Resource Panel

**Izabella Teixeira**
Co-Chair,
International Resource Panel

# Key Messages



Credit: Flickr/CC BY 2.0/Carbon Visuals, One day's carbon dioxide emissions from above

## 1. Increasing material efficiency is a key opportunity to move towards the 1.5° C goal set by the Paris agreement

Policymakers must make more ambitious commitments to emission reductions if they are serious about achieving the aspirations of the Paris Agreement. According to the total carbon budget proposed by the IPCC, the G7 would need to limit their remaining $CO_2$ emissions to 50 gigatons (Gt) for temperature increases to be confined to 1.5° C (if emissions are distributed evenly across the global population). Reducing emissions from the production, use, consumption, and disposal of materials can help countries stay within that carbon budget.

Emissions from the production of materials as a share of global GHGs increased from 15% in 1995 to 23% in 2015. This corresponds to the share of GHG emissions from agriculture, forestry, and land use change combined, yet they have received much less attention. An estimated 80% of emissions from material production were associated with material use in construction and manufactured goods. Here, materials are understood as solid materials including metals, wood, construction minerals, and plastics. Fuel, food, or chemicals are not included.

Reducing the GHG emissions for materials required for homes and cars, the most important products of the construction and manufacturing sectors, can cut cumulative life cycle $CO_2e$ emissions in the period of 2016-2060 by up to 25 Gt in G7 countries. The technologies to increase material efficiency are available today.

## 2. There are significant opportunities to reduce GHG emissions associated with residential buildings

In G7 countries, material efficiency strategies, including the use of recycled materials, could reduce **GHG emissions in the material cycle of residential buildings** by 80%–100% in 2050. Potential reductions in China could amount to 80-100%; and to 50-70% in India in 2050.

Strategies with significant potential include more intensive use of homes (up to 70% reduction in 2050 in the G7), designing buildings using less material (8–10% in 2050 in the G7), and use of sustainably harvested timber (1–8% in 2050 in the G7). Improved recycling could reduce GHGs by 14-18% in 2050 in the G7. Overall, cumulative savings in the period 2016-2050 from these strategies in the G7 would amount to 5–7 Gt $CO_2e$.

Material efficiency strategies can also affect **other stages of the life-cycle of residential buildings**, leading to synergistic reductions of energy use. Looking at the whole building life-cycle, material efficiency strategies could reduce emissions in 2050 from the construction, operations, and dismantling of homes by 35-40% in the G7. Analogous savings could be up to 50-70% in China and India.

## 3. There are significant opportunities to reduce GHG emissions associated with passenger cars

Material efficiency could deliver significant reductions of GHG emissions in addition to those reductions expected from a shift towards clean energy and gradual adoption of electric and hydrogen-fuelled vehicles. Material efficiency strategies could **reduce GHG emissions from the material cycle of passenger** cars in 2050 by 57%–70% in G7 countries; 29-62% in China and 39-53% in India.

Material efficiency strategies can also reduce **GHG emissions from operational energy use**. Material efficiency strategies could reduce total GHG emissions for the manufacturing, operations, and end-of-life management of cars in the G7 by 30–40% in 2050. Savings in China and India would be 20-35%.

The largest reductions of life-cycle emissions could be attained by changing patterns of vehicle use (ride-sharing, car-sharing) and shifting towards trip-appropriate smaller vehicles. This is mainly because they reduce not only the demand for materials but also the energy use during the operation of the vehicles.

## 4. Policy intervention is required if material efficiency benefits are to be achieved

Current policies overly focus on landfill diversion and on mass rather than life cycle GHG reduction. The design of houses and vehicles determines how much material they use, the energy used in their manufacturing and operations, their durability, and their ease of reuse and recycling. Building codes and standards connect building design to policy. They can encourage or constrain material efficiency.

Cross-cutting policies are likely to have significant impacts on material efficiency, but quantitative estimates are largely unavailable. Such policies include revision of building standards and codes, use of building certification systems by governments, green public procurement, virgin material taxation, removal of virgin resource subsidies, and recycled content mandates.

## 5. Policy paths to changes in material efficiency are multiple and can be indirect

Increased intensity of use shifts the focus of policy from choice and use of materials to how people live. Policy instruments such as taxation, zoning and land use regulation play a role, but so do consumer preferences and behavior.

Material efficiency is vulnerable to rebound effects because monetary savings can lead to an increase in consumption—savings from use of peer-to-peer lodging (e.g., AirBnb) can lead to more travel and GHG emissions. Policy instruments that directly or indirectly raise the cost of production or consumption, e.g., taxes or cap-and-trade systems, can reduce rebound effects.

Another potential policy path could be the integration of material efficiency considerations into existing Nationally Determined Contributions (NDCs) of the Paris agreement.

NDCs currently include limited commitments to material efficiency. Resource efficiency, resources management, material efficiency, circular economy or consumption side instruments are scarcely mentioned therein, appearing as explicit mitigation measures only in the (I)NDCs of Japan, India, China, and Turkey. Waste management commitments (which partially overlap with material efficiency strategies), have a modest presence in NDCs and building energy efficiency codes, a form of resource policy with strong connections, and perhaps, precedents, for material efficiency policy, have a larger role in NDCs. Material efficiency can be advanced not only by broadening the scope of targets in the NDCs but also by increasing the mitigation ambition.

## 6. Policies should be evaluated on a life cycle basis to reveal burden shifting and synergies across life cycle stages and industrial sectors.

Monitoring and indicator systems alone will not indicate whether a policy is effective. Little systematic quantitative research exists on the effect on GHG emissions of policies targeting efficient material use, product reuse, and refurbishment, and recycling. More rigorous, comprehensive analysis of policies could drive successful policy development.

## **Box 1.** A Note on Terminology and Scope of this Report

Material efficiency, the circular economy, the 3R perspective (reduce, reuse, recycle), and sustainable materials management refer, in varying degrees, to the way in which resources should be used by society to reduce the demand for primary materials while enabling prosperity. There are, however, some nuances.

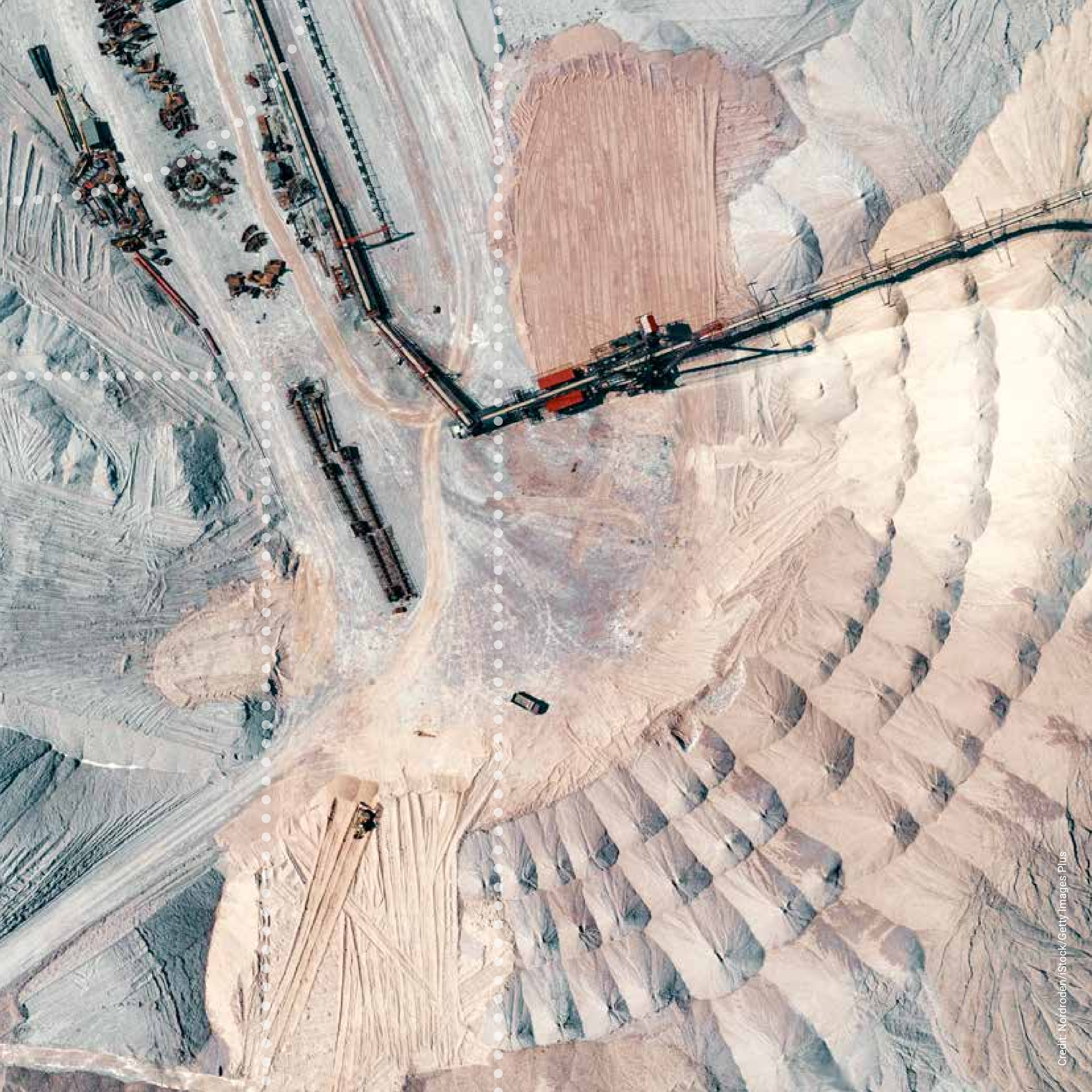
The following are the main definitions used in the report:

- **Material Efficiency** means using less materials to provide the same level of well-being. It is measured by the amount of service obtained per unit of material use. Materials include biomass, cement, fossil fuels, metals, non-metallic minerals, plastics, wood, among others.
- **Resource Efficiency** encompasses material efficiency, but is a broader term which includes materials, water, energy, and land. The Global Resources Outlook 2019 of the International Resource Panel defines it as *achieving higher outputs with lower inputs and can be reflected by indicators such as resource productivity (including GDP/resource consumption).* Therefore, a resource efficient economy will include optimized systems of production and consumption from a natural resource perspective. The term encompasses strategies of dematerialization (savings, reduction of material and energy use) and re-materialization (reuse, remanufacturing and recycling) in a systems-wide approach to a circular economy.
- **Sustainable materials management (SMM)** an approach to serving human needs by using/reusing resources most productively and sustainably throughout their life cycles, generally minimizing the amount of materials involved and all the associated impacts (US EPA, 2015).
- **Circular Economy** refers to 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.
- **The 3R concept (reduce, reuse, recycle)** encompasses similar strategies included in the concepts described above. While originating in waste management policy, the "Rs" affect and are affected by what happens at the production and use stages of the life cycle of products.

In the Communique of the G7 Environment Ministers' Meeting in Bologna, the IRP was requested to *further assess the potential GHG reductions of resource efficiency policies with the aim of pursuing co-benefits by identifying the most promising resource efficient measures in regard to their GHG abatement potential.* In response to this request, the authors developed emissions scenarios that quantify the potential reductions of GHG emissions from increased material efficiency in homes and cars of the G7, with results also shown for China and India. They also reviewed policies aimed at encouraging or mandating material efficiency strategies in those sectors. Homes and cars are particularly relevant as construction and manufacturing each account for 40% of global GHG emissions coming from the use of materials. The specificity and somewhat homogenous nature of these two product categories were required in order to develop a solid bottom-up model.

The G7 request also asked the IRP to consider low-carbon technologies relevant to the implementation of several resource-related frameworks (Resource Efficiency; Circular Economy; Reduce, Reuse, Recycle; Sustainable Materials Management). In the scenario modeling done for this report, the authors considered changes in the background energy mix and associated GHG emissions, as well as the increasing penetration of low-carbon technologies in the two selected sectors (homes and cars) such as passive houses and electric vehicles.

Credit: Iam Anupong/iStock/Getty Images Plus



Credit: Nordroden/iStock/Getty Images Plus

# 1. Introduction

## 1.1 The Materials Climate Change Nexus

As shown in previous IRP assessments, the way the global economy manages natural resources deeply influences the Earth's climate. How we extract these resources and how much we make use of them determines GHG emissions. Without significant improvements in resource efficiency, it will be nearly impossible and substantially more expensive to keep global warming below 1.5-2° Celsius.

The production and use of materials and climate change interact in several ways. The production of materials causes greenhouse gas emissions, which are the cause of anthropogenic climate change. The mitigation of GHG emissions and adaptation to climate change, in turn, affect the demand for materials. More concretely:

- Mitigation efforts may require more and rarer materials. Low-carbon electricity generation through photovoltaics, wind power, nuclear power, and fossil fuel combustion with carbon dioxide capture and storage (CCS), employ materials that are either used in larger amounts or less common, compared to conventional fossil power generation.
- Adaptation options could drive higher demand for materials. Options such as the construction of seawalls and coastal protection structures; modification of transport and road infrastructure; or resilience in the built environment including insulation and cooling, could increase extraction and use of materials and associated GHG emissions.

## 1.2 Growing Material Demand and GHG emissions

Greenhouse gas emissions from the production of materials have more than doubled from 5 Gt CO2e in 1995 to more than 11 Gt CO2e in 2015, given the rise in virgin material production. Material efficiency strategies could reduce the demand for energy-intensive virgin materials without compromising well-being. Resource efficiency and the circular economy may become effective policy frameworks to transform our use of materials.

The share of material production in global greenhouse gas emissions increased from 15% to 23% in the period 1995-2015 (Figure 1). Over half of the carbon footprints of materials are direct emissions from material production processes. Energy supply for the entire value chain accounted for 35% of emissions, mining for 2%, and other economic processes for 9%. The most important materials in terms of GHG emissions were iron and steel (32%), cement, lime, and plaster (25%), rubber and plastics (13%) and other non-metallic minerals (13%) (Figure 2). Construction

**Figure 1.** Emissions caused by material production as a share of total global emissions 1995 vrs. 2015

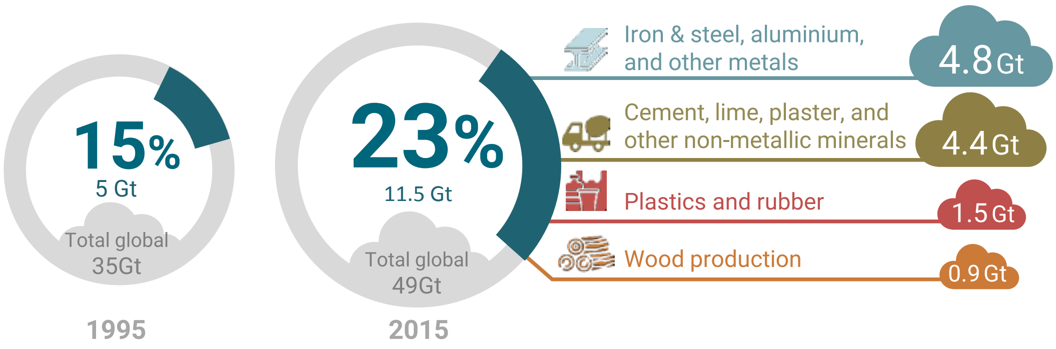
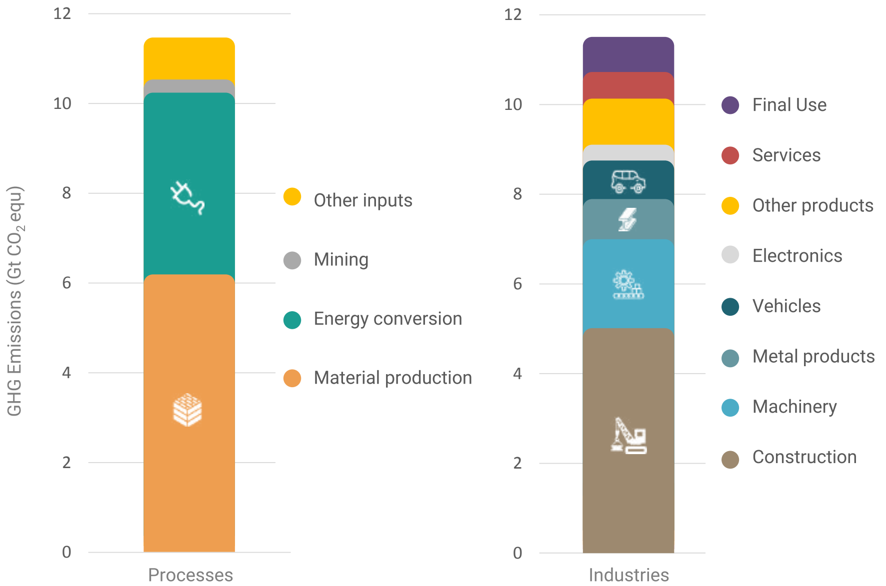



**Figure 2.** Global carbon footprint of materials in 2015:
(A) by emitting process, (B) by first use of materials by downstream production processes.




Source: Hertwich, E.G., Ali, S., Ciacci, L., Fishman, T., Heeren, N., Masanet, E., Asghari, F.N., Olivetti, E., Pauliuk, S., Tu, Q., Wolfram, P., 2019. Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics—a review. Environ. Res. Lett. 14, 043004. https://doi.org/10.1088/1748-9326/ab0fe3 and manufacturing accounted for 40% each of the GHG emissions from first use of materials. Residential buildings were the most important product of construction, cars the most important product of manufacturing.

Most materials are used to produce capital goods. The dynamics of material use are driven by the build-up of capital, such as buildings and infrastructure, which happens mostly in emerging economies. As a result, emerging economies contribute more to global material use than global energy use. The material-related GHG emissions in G7 countries have hence remained fairly stable around 2 Gt CO2e since 1995. G7 countries are net importers of products and services that rely on materials produced in non-OECD countries. The strongest growth of production and consumption has occurred in the BRICS countries (Brazil, Russia, India, China, South Africa).

Credit: Kerkez/iStock/Getty Images Plus

## 1.3 Material Efficiency Strategies: New Opportunities to Reduce GHG emissions

Historically, decarbonization efforts related to materials have focused primarily on reducing process-level energy use and GHG emissions in material production. These production-oriented strategies include energy efficiency, fuel and feedstock switching, process-related $CO_2$ emission reductions, and carbon capture and storage (CCS). However, substantial further reductions of GHG emissions using these strategies tend to be expensive and difficult to implement.

GHG emissions from the production and use of materials can also be mitigated through demand-side strategies (see Material Efficiency Strategies in Box 2). For instance, through material efficient design, the choice of low-carbon and light-weight materials, yield improvements both in manufacturing and recovery, and more intensive use of buildings and vehicles.

Reducing the demand for primary materials through material efficiency can help lower the overall financial and environmental costs associated with decarbonizing industrial production and increase the speed with which such a decarbonization can be attained.

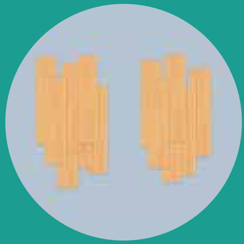
The modelling presented in this report points to significant opportunities for the reduction of GHG emissions from materials through demand-side material efficiency strategies. It also identifies synergies between material efficiency and operational energy use. Material efficiency would reduce emissions far beyond the reductions attained through a decarbonization of electricity supply, an electrification of home energy use, and a shift towards electric and hybrid vehicles.

## Box 2. Material Efficiency Strategies for Climate Action

The following material efficiency strategies were considered in the report:

### Using less material by design

Designing lighter and smaller products that deliver the same service, reduces the amount of materials incorporated in the product and often the energy required to operate the product as well. In this report, we address both the construction of lighter structures (less steel and concrete in the bearing structure of multifamily buildings) and the downsizing of vehicles, i.e., the shift from large vehicles (light trucks, sports utility vehicles) to smaller ones (passenger cars, minicars).

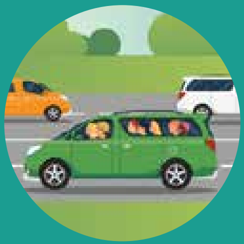


### Material substitution

Replacing cement and steel with wood in buildings and steel with aluminium in cars can reduce life cycle emissions. The mechanisms of emission reductions vary. While wooden structures require less carbon in the construction and even store carbon, aluminium in cars causes an increase in material-related emissions but reduces operational energy use, resulting in a reduction of life cycle emissions.

### Fabrication yield improvements

Reducing material scrap used in the fabrication and manufacturing process can decrease the demand for material input. For example, reduction of trimmings or amount of machining needed in car manufacturing.



**More intensive use**

It implies that less product is required to provide the same service. In the case of vehicles, ride sharing (car-pooling) and car sharing imply that fewer vehicles are used more intensively to provide transport services to a given population. For buildings, both higher utilization rates, e.g., through peer-to-peer lodging, smaller, more efficiently designed residential units, and increased household size/cohabitation can achieve a reduction of building space required.

**Enhanced end-of-life recovery and recycling of materials**

This increases the amount or quality of secondary materials available, which can reduce the amount of primary materials used to produce the same or another product. More of the materials in homes and cars can be recycled but it may require more dismantling/deconstruction to avoid contamination of the different material flows.

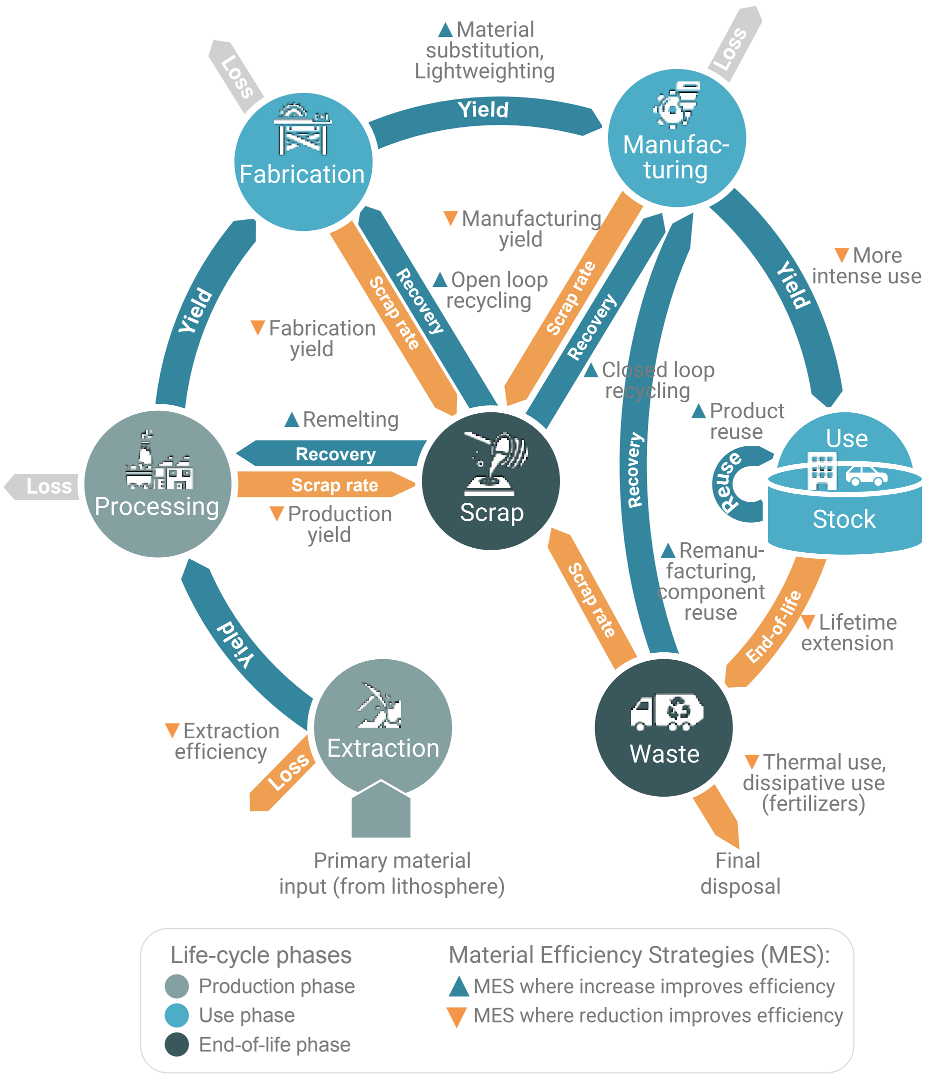
**Recovery, remanufacturing, and reuse of components**

Replacing production of spare parts or even primary products. For example, I-beams of buildings can be reused.

**Product lifetime extension**

Through better design, increasing repair, and enhancing secondary markets. For example, the lifetime of buildings can be enhanced through flexible design which makes it easier to modify interior walls, thus accommodating changing use patterns.

**Figure 3.** Material efficiency strategies in the product life cycle



To seize the mitigation opportunities described above, policies must stimulate the adoption of material efficiency strategies. Those strategies must reduce material use, and the reduction of the use of materials must, in turn, lead to lowered emissions. Measuring the material efficiency gains from policy will require the use of life cycle assessment to reveal synergies and trade-offs across the product life cycle.

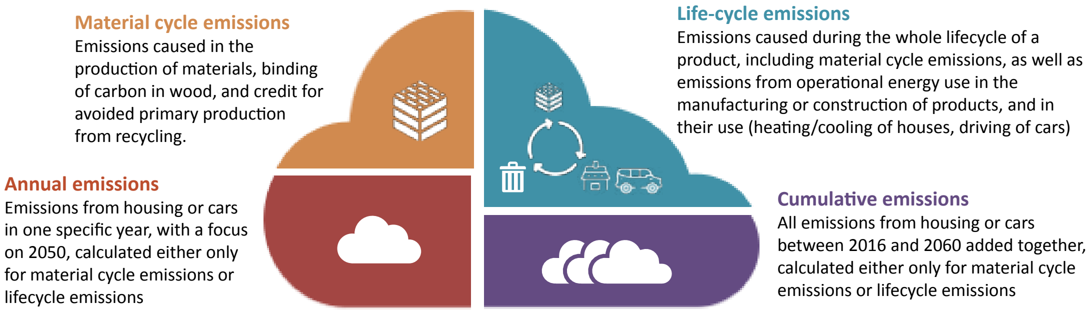
In today's policy landscape, most material efficiency policies miss a climate mitigation perspective, and most climate policies miss a material efficiency perspective. Material efficiency policies typically have emerged as part of efforts to improve the environmental and resource dimensions of waste management with limited linkages to climate change mitigation. Climate change policies have focused mostly on energy efficiency rather than materials efficiency as a central strategy to reduce GHG emissions. Material efficiency as a driver of GHG reductions should be designed in. Clarity of purpose and intentional policy change are crucial to link material efficiency and climate change mitigation.

Tables 1, 2 and 3 of this summary show examples of policy efforts from countries and local governments addressing a diversity of material efficiency strategies.

## **Box 3**. A Note on the Methodology

The impact of material efficiency strategies is quantified by the authors through scenarios developed on the demand for building space and car transport, population and economic projections, and storylines. These are consistent with the Shared Socioeconomic Pathways (SSP) 1 and 2, which are widely used in climate scenario modelling. Two reference scenarios include a decarbonization of the energy mix and shift towards electric vehicles compatible with the target of limiting global warming to 2°C. A third scenario relies extensively on demand reduction, energy and material efficiency, so that decarbonization achieves the 1.5°C. Overall, the model looks at four perspectives of GHG emissions which are essential for integrated decision-making in climate policy.

**Figure 4.** Four perspectives of GHG emissions addressed in this report.




Credit: Mikhail Spaskov/iStock/Getty Images Plus

# 2. Material-Efficient Homes

## 2.1 Understanding the Potential

The material efficiency strategies identified in the report can reduce GHG emissions from the construction, operation, and demolition of residential buildings in the G7 in 2050 by a further 35-40% compared to what would be attained with improved energy efficiency and a low-carbon energy mix. Material efficiency strategies could: (1) reduce the demand for virgin materials for the construction of new buildings; (2) make secondary materials available to other markets, thereby reducing the need to produce virgin materials for these markets; and (3) increase intensity of use reducing the need for heating and cooling, floor space, with corresponding reduction of operational energy use emissions.

Current dominant building methods and **design** result in higher carbon footprints than necessary due to the overuse of carbon-intensive materials such as steel, cement, and glass. Buildings that are lighter and designed closer to technical specifications use less material and can lower associated emissions across the G7 nations by 8-10% in 2050. Savings in China and India could reach 12–20%. To achieve these savings, engineers could calculate recommended dimensions for building components such as load-bearing beams; and architects, could build shapes and use light structures (e.g., trusses over beams).

Emissions from the material-cycle of construction materials can be reduced by 1-8% in the G7 through the **greater use of timber,** considering both reduced emissions and the storage of carbon in wood. Reductions in China and India could reach 5–31%, given larger volumes of new construction and more widespread—and carbon-intensive—use of reinforced concrete. Wood is widely used in the construction of single-family homes in Canada, Japan, the Nordic countries, and the United States, but less commonly used in multi-family buildings or the European G7 countries. Recent advances in construction now allow the use of timber frames in tall buildings, expanding the ability of timber to replace more carbon-intensive construction materials. However, the modelling of land-use competition in many climate change mitigation analyses shows that timber supply is limited, and climate benefits only apply to sustainably source wood products. Moving towards more intensive plantations and improving the management of forests are required to enable this strategy.

**Reducing demand for floor space** by up to 20% compared to the reference scenario would reduce the demand for new construction in the G7. It could lower GHG emissions from the material-cycle of construction materials in residential buildings by up to 73% in 2050 in the G7 (this includes emission savings from recycled building materials used elsewhere in the economy). In China and India, savings would range between 6-59%. More intensive use can be achieved when individuals choose to live in smaller units in multifamily residences rather than single family homes. Further, individuals can be encouraged to share homes and related residential facilities (e.g., co-housing) and to move to smaller residences when families downsize, such as when children move out. More intensive use may also be attractive when it is associated with urban lifestyles and easier access to job markets and public amenities.

In 2016, the recycling of building materials saved 15-20% of the material cycle emissions of residential buildings in the G7. Under optimistic assumptions, improved recycling could save an additional 14-18% in the G7.

More intensive use of residential buildings leads to emission reductions from energy use for heating and cooling. Savings can be proportional to the reduced floor space.

If applied at their full technical potential, the assessed material efficiency strategies together could reduce annual GHG emissions associated with the material cycle of residential buildings in G7 countries and China by 80-100% in 2050, compared to a scenario without material efficiency (including the benefits of use of recycled material). Savings in India would be 50-70% in 2050. This translates to annual GHG savings in 2050 of 130-170 million tons in the G7, 270-350 million tons in China and 110-270 million tons in India. The modelling indicates that reduced floor space also reduces the need for heating and cooling, resulting in estimated emissions savings of 120-130 million tons in the G7 in 2050.

**Figure 5.** Life-cycle emissions from homes with and without Material Efficiency strategies in 2050 in G7 countries, China and India

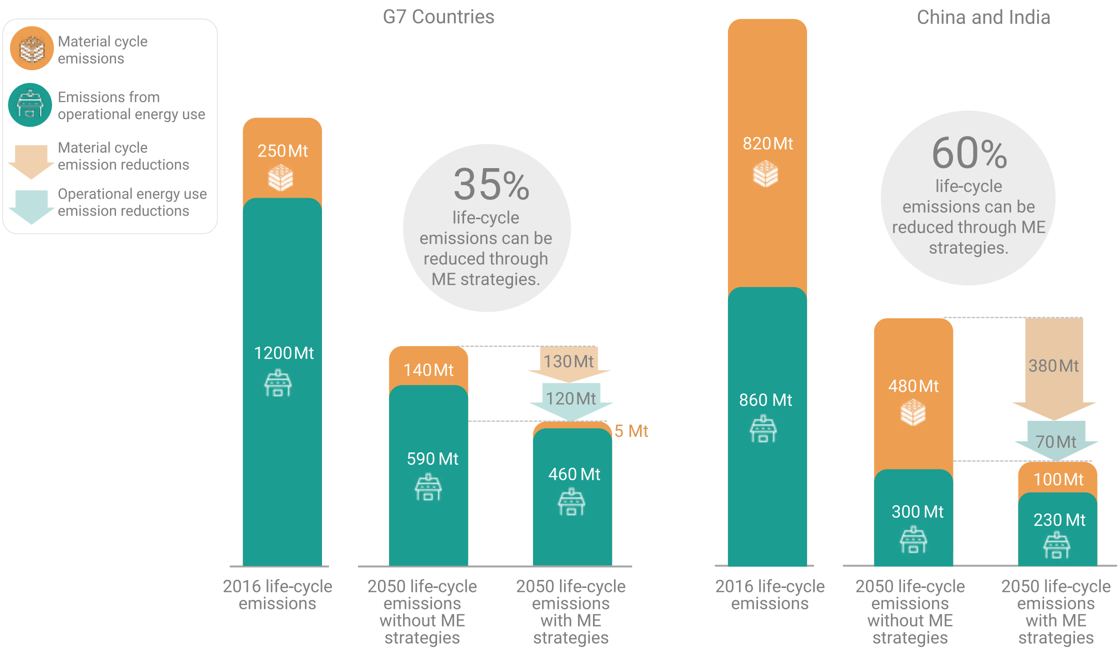
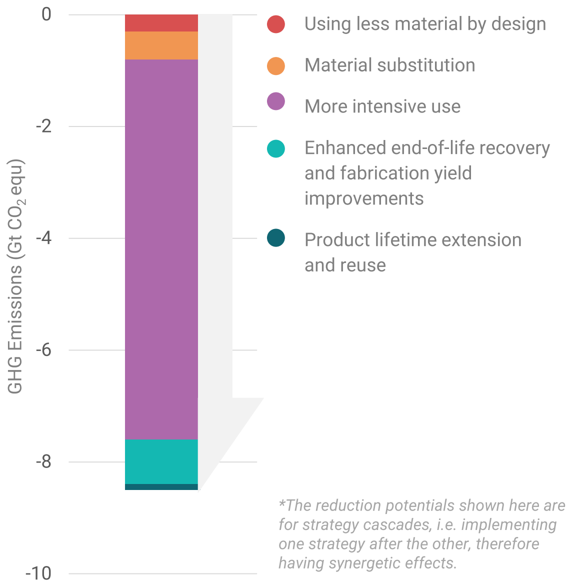


**Figure 6.** Potential GHG savings from material efficiency strategies for homes in G7 (2016-2060)




## 2.2 Policy Considerations

Opportunities for material efficiency in the building and construction sector exist at various levels: materials, components and building. Points of intervention exist in design; material or component production; construction site activities; building use and maintenance; renovation, rehabilitation and reuse of existing buildings; and end-of-life management.

For many material efficiency strategies, design is a crucial point of intervention. Design is shaped by policy indirectly—primarily through building codes. Decisions at the design stage affect material choice, construction techniques, opportunities for increased building lifetimes, and end-of-life strategies including deconstruction, component reuse, and construction and demolition recycling. This suggests the need for careful attention to both the content of building standards and codes and to their diffusion and adoption by public authorities. Performance rather than prescriptive standards can play a key role in removing barriers to innovative material efficiency practices.

Increasing use of building information management (BIM) software and prefabrication can facilitate the adoption of practices and technologies that reduce material use. In some countries, they are mandated for use in construction of primarily larger buildings. Policies for end-of-life management, i.e., reuse and recycling of construction and demolition waste, are widespread, but are often focused on landfill diversion. If material efficiency is to lead to climate change mitigation, policy targets need to shift to, or at least, include, GHG emission reduction goals.

Increased intensity of use of residential buildings through shared and smaller housing is shaped by building codes but also zoning and land use regulation, property, carbon and other taxes, urbanization, demographic trends, and consumer preferences. Shared and smaller housing can be encouraged through changes in regulation and taxation but will also require changes in behavior and lifestyle.

The following table provides a summary of material efficiency strategies for housing, relevant policy instruments and examples, all included in the policy chapter of the report.

**Table 1.** Material Efficiency Strategies for Housing and Policy Options

| Material Efficiency Strategy | Policy Instruments[1] | Description | Regional/Country / local level example[2] |
|---|---|---|---|
| Using less material by design | No policy instruments directly focused on lightweighting identified | | |
| | Mandated prefabrication and modular construction | • Mandating prefabrication and modular construction can facilitate lightweighting | • Singapore Building Control Regulation https://www.bca.gov.sg/emailsender/buildSmart-022018/microsite/<br>• China 30% of new builds being prefab, 13th5-year plan http://www.mohurd.gov.cn/wjfb/201705/W020170504041246.pdf |
| | Mandated use of building information modeling (BIM) | • Use of BIM during design can help to locate areas of medium and low structural loads allowing lightweighting | • British Standards Institute and Department for Business https://www.bsigroup.com/en-GB/Building-Information-Modelling-BIM/ |
| Material substitution | Revision of building and fire codes with respect to mass timber wood framing. | • Compared to concrete and brick, wood construction typically results in fewer life-cycle emissions. Many building codes have limitations on timber construction for historical fire safety reasons.<br>• Provisions for construction of mass timber structures are being updated in some building and fire codes | • International Code Council (ICC) Ad Hoc Committee on Tall Wood Buildings https://www.iccsafe.org/products-and-services/i-codes/code-development/cs/icc-ad-hoc-committee-on-tall-wood-buildings/ |
| | Standards allowing cement with clinker substitutes | • Production of Portland cement causes significant GHG emissions. Alternative binders are currently being researched. | • European Cement Standardization https://shop.bsigroup.com/ProductDetail/?pid=000000000030391002 |
| | Revision of building codes to address embodied impact of materials | • Performance rather than prescription-based standards facilitate use of alternative materials (e.g,. concrete with lower Portland cement content) | • Proposed Low Carbon Concrete Building Code, California https://www.bruce-king.com/building-codes |
| Fabrication Yield Improvement | Mandating prefabrication | • Prefabrication allows for more automation and better planning of production and use of components thus avoiding waste<br>• Prefabrication is sometimes mandated in public and subsidized buildings | • Singapore Building Control Regulation https://www.bca.gov.sg/emailsender/buildSmart-022018/microsite/<br>• China 30% of new builds being prefab, 13th5-year plan http://www.mohurd.gov.cn/wjfb/201705/W020170504041246.pdf |
| | Mandating Building Information Modeling (BIM) | • BIM allows for better collaboration of building planners and a higher degree of digitalization and automation. Both help to identify potential wastage early in planning process and minimize scrap generation through prefabrication and other techniques | • British Standards Institute and Department for Business https://www.bsigroup.com/en-GB/Building-Information-Modelling-BIM/ |
| | | • BIM mostly used for large buildings. No evaluation of material efficiency impacts of mandates identified | |

1- Policy instruments for or related to material efficiency. Some policies which are not intended to encourage material efficiency are included because they have important impacts on material efficiency

2- Laws, regulations and other form of policy in this column are provided as examples, but not necessarily as instances of effective policy. Some are examples of policies that constitute barriers.

| Material Efficiency Strategy | Policy Instruments[1] | Description | Regional/Country / local level example[2] |
|---|---|---|---|
| More Intensive Use | Reduction of transaction costs and taxes on home sales | • Levies on home sales or a taxation of the income from the appreciation of property can limit downsizing after changes in household. | • UK Stamp Land Duty https://www.gov.uk/stamp-duty-land-tax |
| | Relaxation of single-family zoning | • Land use restrictions on minimum site and structure limits, limit construction of multi-family homes and increasing house sizes. | • Minneapolis 2040 plan https://www.brookings.edu/blog/the-avenue/2018/12/12/minneapolis-2040-the-most-wonderful-plan-of-the-year/ <br>• Oregon Chapter 639 https://olis.leg.state.or.us/liz/2019R1/Measures/Overview/HB2001 |
| | Revision of laws restricting accessory dwelling units (ADUs) and infill development | • ADUs and infill development allow for use of land within existing built up areas leading to increased urban density and typically smaller dwellings | • State of Maryland, US, Priority Funding Areas https://doi.org/10.1093/oxfordhb/9780195380620.013.0022 |
| Enhanced end-of-life recovery and recycling of materials | Sorting and processing of construction and demolition waste (C&D) | • Increased sorting allows for better processing and separation of wastes facilitating recycling and the substitution for primary materials. <br>• Mandated sorting helps maintain value of materials and increases likelihood of recycling | • Norway Planning and Building Act rules <br>• Japan Construction Material Recycling Law https://www.env.go.jp/en/laws/recycle/09.pdf |
| | Mandating landfill bans | • Landfill bans are often coupled with supporting policies | • Vermont Agency of Natural Resources Acts 148 and 175 https://cswd.net/recycling-old/construction-demolition-waste/act-175/ |
| Re-Use of Materials and Components | Mandated prefabrication and modular construction Standards guiding design for disassembly/deconstruction | • Prefabricated elements and modular construction facilitate design for disassembly and component reuse. <br>• Design for disassembly can increase separation and reuse of valuable components | • Singapore Building Control Regulation https://www.bca.gov.sg/emailsender/buildSmart-022018/microsite/ <br>• China 30% of new builds being prefab, 13th5-year plan http://www.mohurd.gov.cn/wjfb/201705/W020170504041246.pdf |
| Product Lifetime Extension | No policies for durable construction identified Heritage listings | • Policies to preserve historic buildings that restrict demolition or alteration can limit building energy efficiency. | • US National Historic Preservation Act https://www.nps.gov/history/local-law/nhpa1966.htm <br>• New York City Local Law 97 https://www1.nyc.gov/assets/buildings/local_laws/ll97of2019.pdf |

Credit: sturti/iStock/Getty Images Plus

# 3. Material-efficient cars



## 3.1 Understanding the Potential

The modelling of light duty vehicles assesses the effect of material efficiency measures on material and energy use in vehicle manufacturing, on energy use in vehicle operations, and on the recovery and use of end-of-life materials. It incorporates changes in the vehicle fleet and the timing of the availability of end-of-life vehicles for recycling. Material from end-of-life vehicles that is not used to manufacture new vehicles is mostly downcycled to construction and a corresponding recycling credit is assumed.

Compared to a scenario where no new material efficiency strategies are implemented, the modelled material efficiency strategies can save up to 25 Mt $CO_{2e}$ per year from the G7's materials cycle in 2050. Similar savings of 25-30 Mt each can be attained in China and India. Synergistic emissions reductions associated with reduced operational energy use are 280-430 MtCO2e per year in the G7. In China and India they are 240-270 Mt each.

Materials recovered from end-of-life vehicles are widely recycled in G7 countries. The use of recycled materials can offset half of the GHG emissions associated with the production of materials used in cars. However, secondary steel obtained by car recycling using current technology is contaminated with copper, potentially limiting scrap use as market conditions evolve; Innovative scrap recovery will be needed in the future.

In the G7, **improvements in manufacturing yields, fabrication scrap use, and end-of-life recovery,** can lead to savings of 37% of the GHG emissions from the material cycle of cars in 2050. Savings in China amount to 34% and in India to 26%. Lifetime extension of vehicles and increased reuse of parts in the G7 can lead to additional savings of 5-13% in the G7, 14% in China and 9% in India.

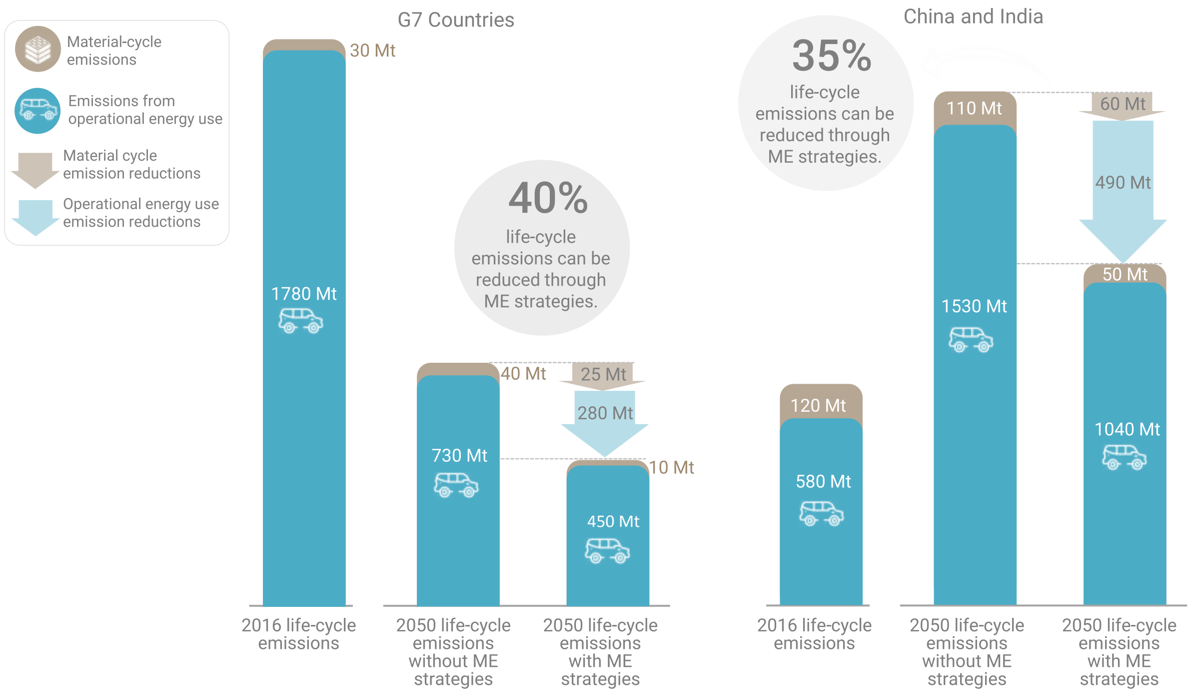
Reducing vehicle weight through **material substitution** leads to fuel savings during vehicle operations. A shift from steel to aluminium in vehicle material composition shows an increase of materials-related GHG emissions during vehicle manufacturing, while the total emissions throughout the vehicle life cycle are reduced. The use of other materials, such as high-strength steel and carbon fibre, exhibit similar trade-offs.

Several material efficiency strategies imply **a change in the patterns of vehicle use:** ride-sharing, car-sharing, and a shift towards smaller vehicles. Both ride and car-sharing have the potential to reduce the total vehicle stock required for meeting the travel demand, leading to a lower material demand for vehicle manufacturing. If up to 25% of the trips in the G7 were conducted as shared rides, material cycle emissions would be reduced by 13-20%. Reductions would be similar in China and India. A partial shift towards smaller vehicles would reduce emissions by 11-14% in the G7, 4% in China and 3% in India.

Taken together, the improvements in material efficiency can reduce material-cycle emissions of cars in 2050 by 57-70% in the G7; 29-62% in China and 39-53% in India. Technical strategies (e.g. reuse of components) and changes in pattern use (e.g. increased ride sharing and use of smaller vehicles) play important roles.

Several material efficiency strategies reduce, simultaneously, energy use for the manufacturing and for the operation of vehicles. The emission savings from operational energy use reductions would be several times larger than those from the material cycle even in scenarios that reflect a gradual shift towards battery-electric and fuel cell vehicles. The investigated material efficiency strategies could reduce total G7 GHG emissions for the manufacturing, operations, and end-of-life management of cars by 30-40%, or 300-450 million tons CO2 equivalent, in 2050. Savings in China and India would be 20-35%. The most important strategies for the reduction in overall life-cycle emissions are ride sharing, car sharing, and a shift towards smaller vehicle sizes.

**Figure 7.** Life-cycle emissions from cars with and without Material Efficiency strategies in 2050 in G7 countries, China and India



## 3.2. Policy Considerations

Material efficiency policies related to cars largely revolve around material choice and end-of-life management. Reduction in materials consumption through light-weight design has been a side-effect of policies aimed at reducing fuel consumption and GHG emissions in vehicle operation, although, in many countries policies have been too weak to counter the trend towards larger, heavier vehicles. Some forms of light-weighting can present trade-offs between increased carbon emissions in production and lessening of emissions during use.

Current policy toward shared mobility in the form of car-sharing, ride-sharing and ride-hailing appropriately focuses on issues of company and driver behavior, impacts on public transit use, and congestion. While emissions from vehicle travel are part of policy discourse, discussions of material use are less common, and incentives are not strong. Ride-hailing tends to increase material use and emissions unless strong incentives for ride-splitting are in place. Policy should steer shared mobility toward the use of under-utilized capacity rather than purchase and use of additional vehicles.

End-of-life management for cars has focused on de-pollution and increasing recycling and recovery rates of non-metallic residues from car shredding. Policy has been less focused on the GHG implications of end-of-life management targets. Adjustment of end-of-life policy to reduce downcycling and address attendant opportunities for GHG reduction warrants attention.

**Figure 8.** Potential GHG savings from material efficiency strategies for cars in G7 (2016-2060)

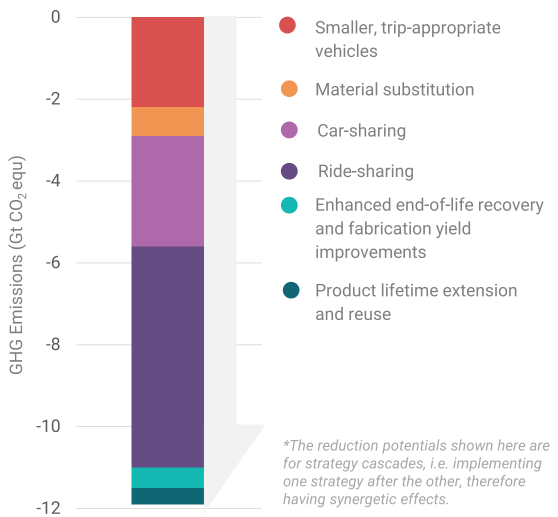


**Table 2.** Material Efficiency Strategies for Cars and Policy Instruments

| Material Efficiency Strategy | Policy Instruments[3] | Description | Regional / Country / local level example[4] |
|---|---|---|---|
| Using less material by design | By product of fuel economy measures | • Fuel economy is widely regulated throughout the G7 resulting in reduced material weight to meet targets. No instances of policy directly focused on lightweighting were identified. | • U.S. Corporate Average Fuel Economy Standards https://www.transportation.gov/mission/sustainability/corporate-average-fuel-economy-cafe-standards<br>• EU regulations on emission performance standards for light duty vehicles https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32007R0715&from=en |
| | Tax on $CO_2$ intensity | • "One-off registration tax" in Norway calculated based CO2 intensity which encourages the choice of higher fuel economy and lighter vehicles | • Norwegian vehicle registration tax |
| Material substitution | By product of fuel economy policy[5] | • Fuel economy is widely regulated throughout the G7 resulting in increased use of aluminum, plastics, and novel materials. No policies directly focused on material composition identified. | • U.S. Corporate Average Fuel Economy Standards https://www.transportation.gov/mission/sustainability/corporate-average-fuel-economy-cafe-standards<br>• EU regulations on emission performance standards for light duty vehicles https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32007R0715&from=en |
| More Intensive Use: | | | |
| Ride Sharing[5] | High occupancy vehicle (HOV) lanes | • Ride-sharing is a practice long encouraged by governments to reduce congestion, energy use and pollution. As with other forms of shared mobility, digital platforms have enhanced its use. | • Metropolitan Transit Authority of Harris County (METRO) HOV lanes (Houston) https://www.ridemetro.org/Pages/HOVHOTLanes.aspx |
| Car sharing[6] | Favorable treatment in parking, zoning and building codes. No policy identified that focuses on material efficiency | • Policies generally encourage car-sharing through relaxation of regulations relating to parking, real estate development and urban planning. | • San Francisco On-Street Shared Vehicle Permit Program https://www.sfmta.com/projects/street-shared-vehicle-parking-permit-program<br>• Vancouver On-Street Car Sharing Parking Policy https://vancouver.ca/streets-transportation/car-sharing-carpooling-and-ride-sharing.aspx |
| Ride Hailing[7] | Permits and fees<br>Driver and vehicle requirements<br>Passenger protections<br>Data reporting | • Most regulations focus on safe and orderly operation of ride-hailing, reduction of congestion, and revenue for local governments and do not explicitly address material efficiency-related impacts. | • New York City Taxi and Limousine Commission Rules, Ride-hailing licenses https://www1.nyc.gov/site/tlc/businesses/high-volume-for-hire-services.page<br>• Chicago ride-hailing tax https://www.chicago.gov/city/en/depts/bacp/provdrs/edu/news/2019/october/Mayor_Lightfoot_Announces_New_Regulations_to_Ease_Traffic.html |
| Enhanced end-of-life recovery and recycling of materials | Extended producer responsibility with recycling & recovery targets | • Policy toward end-of-life vehicles (ELVs) focuses on auto shredder residue (non-metallic materials remaining after shredding of car hulk). Material efficiency could be enhanced if a life cycle approach were employed with greater attention to the end use of recycled metals. | • EU End-of-Life Vehicle Directive https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02000L0053-20130611&qid=1405610569066&from=EN |

3- Policy instruments for or related to material efficiency. Some policies which are not intended to encourage material efficiency but are included because they have important impacts on material efficiency.

4- Laws, regulations and other form of policy in this column are provided as examples, but not necessarily as instances of effective policy. Some are examples of policies that constitute barriers.

5- Called car-pooling in some countries, ride-sharing refers to the sharing of trips where people with same or similar driving destinations travel in the same vehicle. It is different from ride-hailing (e.g., Uber and Lyft), which is a modified taxi service.

6- Car-sharing includes both companies with centralized digital platforms which own vehicles that are rented to members (e.g., Zip Car and Car2Go) and platforms for direct peer-to-peer rental of a vehicle owned by another person or entity.

7- Research suggests that ride-hailing does not currently improve material efficiency and was not modeled.

| Material Efficiency Strategy | Policy Instruments[3] | Description | Regional / Country / local level example[4] |
|---|---|---|---|
| | Regulation of pollution arising from auto recycling | • ELV policy in the US and Canada focus on reduction of risk/pollution arising from ELV management practices without explicit attention to material efficiency. | • US Clean Air Act, for refrigerants<br>• US Clean Water Act, for stormwater management https://www.epa.gov/compliance/clean-water-act-cwa-compliance-monitoring |
| Re-Use and Remanufacturing of Components | Mandating reuse and recycling fee and targets | • Prevention and management of pollution from dismantling and recycling processes.<br>• Remanufacturing of engines and tires extends the life of vehicles and components but is largely limited to heavy-duty vehicles. | • Japanese Automotive Recycling Law https://www.env.go.jp/en/laws/recycle/11.pdf |
| | Standards and definitions for reuse and remanufacturing | • Differing standards and definitions of used and remanufactured goods across industries and countries inhibits trade | • Basel Convention http://www.basel.int/?tabid=4499, EU Waste Framework Directive https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098, US Federal Trade Commission https://www.ftc.gov/enforcement/rules/rulemaking-regulatory-reform-proceedings/rebuilt-reconditioned-other-used |
| Product Lifetime Extension | Regulations mandating access to or quality of repair | • Consumer protection, rather than product lifetime extension, is a common focus of policy on auto repair. Repair may extend product life increasing material efficiency but can keep less fuel-efficient vehicles in service. | • EU regulation (EC) No 715/2007 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02007R0715-20121231&from=EN<br>• U.S. Federal Vehicle Repair Cost Savings Act of 2015 https://www.congress.gov/bill/114th-congress/senate-bill/565 |


Credit: MarioGuti/iStock/Getty Images Plus

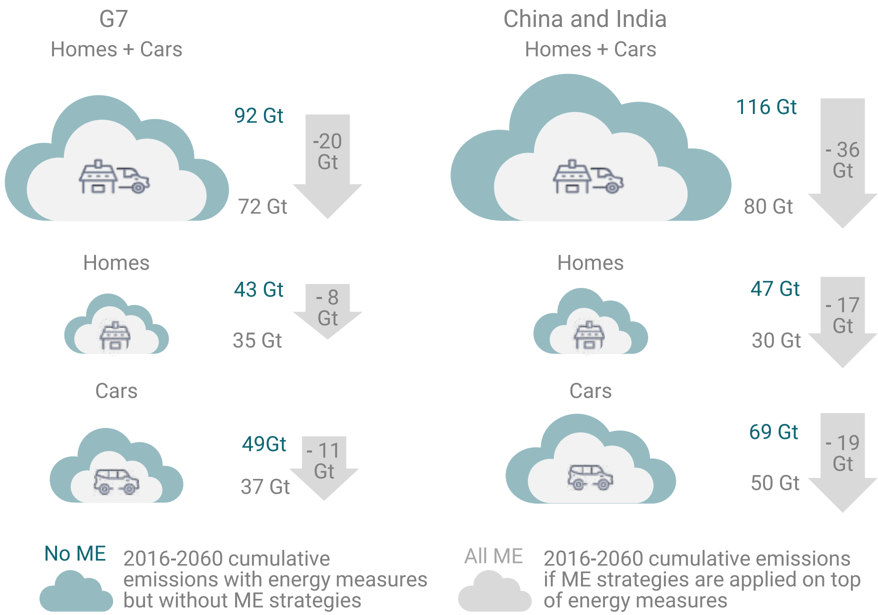

Credit: Federico Rostagno/iStock/Getty Images Plus

# 4. Cumulative Results

## 4.1 Understanding the Potential

In the optimistic scenario developed for this report, the selected material efficiency strategies would reduce cumulative emissions from the production, operation and waste treatment of cars in G7 countries during 2016 - 2060 from 49 Gt to 37 Gt, mostly due to reductions in operational energy use. The cumulative emissions from the construction, operations, and demolition of homes would be reduced from 43 Gt to 35 Gt, mostly due to material savings. The scenario analysis shows that while material efficiency can make a substantial dent into cumulative emissions, additional measures will be required to keep global warming below 1.5 °C. Further options not considered in the report, such as deep-energy retrofits of buildings, a shift from private to public transport, the even faster introduction of electric vehicles and clean energy, and the reduction of GHG emissions in materials production technology will be essential.

**Figure 9.** Savings of Cumulative GHG life cycle emissions for homes and cars in the G7, China and India (2016-2060)




Source: International Resource Panel, 2019

## 4.2 Cross-cutting Policy Considerations

Policies that apply across sectors or that are cross-cutting by nature may have more impact than those focusing specifically on one sector (i.e., homes or cars) or that are unidimensional. These include building certification, green public procurement (GPP), virgin material taxes, recycled content mandates, and removal of virgin material subsidies. Building certification provides potential leverage to increase uptake of many material efficiency strategies related to building design and end-of-life management. GPP is used widely throughout the G7 at many levels of government and thus inclusion of material efficiency would be incremental. The material and GHG benefits of GPP are not routinely assessed but need to be if this policy instrument is to be used effectively. Mandated recycled content is relatively rare but is increasingly discussed in the context of plastic waste management. Virgin materials taxes, as distinct from royalty payments associated with resource extraction, are not widely used, except for modest levies on construction minerals. While politically challenging, reduction of subsidies for virgin resources is likely to provide dual benefits—increased material efficiency and government revenues.


**Table 3.** Cross-cutting Policy Instruments

| Policy Instrument | Description | Relevant Material Efficiency Strategies | Examples |
|---|---|---|---|
| Green Public Procurement (GPP) | Preferential purchasing by public entities of products and materials designed for material efficiency, more intensive use or containing low embodied carbon or recycled materials | • More intensive use<br>• Increased end of life recycling<br>• Recycled content | • Use of local car sharing by Bremen municipality https://clean-fleets.eu/fileadmin/files/documents/Publications/case_studies/Clean_Fleets_case_study_-_Bremen_Car-Sharing_integration.pdf<br>• Dutch system for roads and buildings http://www.oecd.org/gov/ethics/gpp-procurement-Netherlands.pdf<br>• Japanese Law of Green Purchasing https://www.env.go.jp/en/laws/policy/green/index.html |
| Virgin material taxation (VMTs)/ subsidy removal | While resource royalties have a long history, VMTs are not common. | • Change in cost can support all material efficiency strategies | • European taxes and levies on minerals http://www.oecd.org/environment/indicators-modelling-outlooks/policy-instrument-database/ |
| Recycled Content Mandates | Not widely used but increasingly proposed for plastics | • Increased Recycled content | • Japanese Law of Green Purchasing https://www.env.go.jp/en/laws/policy/green/index.html |

| Policy Instrument | Description | Relevant Material Efficiency Strategies | Examples |
|---|---|---|---|
| Revised building standards and codes | Building codes can inhibit or facilitate material efficiency strategies | • Change in material composition<br>• Lightweighting<br>• Reuse of materials and components | • International Code Council (ICC) Ad Hoc Committee on Tall Wood Buildings https://www.iccsafe.org/products-and-services/i-codes/code-development/cs/icc-ad-hoc-committee-on-tall-wood-buildings/<br>• American Concrete Institute standard on Minimum Cementitious Materials Content https://www.ocapa.net/assets/Documents/329.1T-18%20minimum%20cementitious%20materials.pdf<br>• Oregon Chapter 639 https://olis.leg.state.or.us/liz/2019R1/Measures/Overview/HB2001 |
| Use of building certification systems by government | Certification systems can encourage the choice of low-carbon, recycled, or less material by providing points for more material-efficient choices. | • Increased end of life recycling<br>• Recycled content<br>• Change in material composition<br>• Re-Use of Materials and Components | • Adoption, support or promotion of LEED by state and local governments in the US |

Credit: dvoevnore/iStock/Getty Images Plus

# 5. Conclusions

Using residential buildings and light-duty vehicles as examples, this report shows that material efficiency offers an opportunity to significantly reduce GHG emissions through existing technologies. These complement conventional climate strategies to move towards low-carbon energy sources or increase energy efficiency.

Material-related savings can be achieved through better design and engineering. The report also shows that more intensive use and lighter, smaller products can lead to reductions not only in the demand for materials but also in the demand for energy, yielding substantial synergies across mitigation approaches. Similar emission savings are likely to be possible also in commercial buildings, transport systems, and other manufactured products. Further research will be needed to guide policy in these areas.

Social and technological developments can facilitate strategies investigated in this report and create synergies among them. Multifamily homes are smaller, designed more space-efficiently, and offer more opportunities for shared facilities such as guest rooms and playgrounds. Fleets of shared vehicles are more easily used and compelling in more densely populated areas dominated by multifamily residences. Shared fleets and rides are facilitated by smart phones, and new software enables an easier integration of private public transportation systems, providing additional emission reduction opportunities. Changes in social norms and individual preferences may be required to implement a more intensive use, but shared use and compact residences are increasingly popular among the young in urban areas.

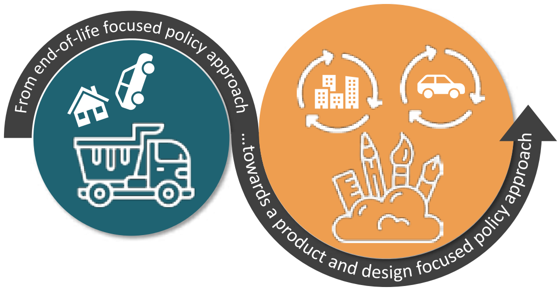
This report has identified policy changes, both cross-cutting and those addressing specific strategies, that can enhance material efficiency of housing and private transport. Material efficiency policies must address key challenges if they are to be effective. Rebound effects, where savings arise from increased efficiency are spent on additional consumption, can counter reductions in GHG emissions. Economic instruments such as taxes and cap-and-trade systems that directly or indirectly raise the cost of production or consumption can mitigate the impact.

Very limited comprehensive research on the efficacy of material efficiency policy was found. Ex post evaluations, experimental studies, and counterfactual analysis can help policymakers evaluate the efficacy of material efficiency policy. The monitoring of outcomes—common in G7 countries indicates if targets have been achieved but does not reveal if the outcome is the result of the policy of interest.

Assessment of outcomes—both reductions in material use and GHG emissions—provides a better basis for policy evaluation than tracking the number of programs or participants. Furthermore, the assessment of emission reduction strategies must be done on a life cycle basis to consider synergies across different sectors, as well as trade-offs. Identification of synergies and trade-offs should feature more prominently in policy guidance. Increasing building lifetimes, for example, is an intriguing strategy but, in many cases, brings down emission reductions only when complemented by a deep-energy retrofit of the buildings in question.

Current material-related policies focus mostly on landfill diversion and mass rather than life cycle GHG reductions. The design of houses and vehicles is a key point of leverage. Design determines how much material they use, the energy used in their manufacturing and operations, their durability, and their ease of reuse and recycling. For example, building codes and standards are policy instruments addressing building design. They can encourage or constrain material efficiency.

Contributions from material efficiency could help countries stay within their carbon budget. There is only a finite amount of $CO_2$ that can be emitted before the atmosphere reaches a concentration at which the global average temperature will rise by 1.5°C above pre-industrial levels. Emissions need to be reduced on a gigaton-scale to stay within the carbon budget proposed by the IPCC. Material efficiency can contribute to such reductions.



For more information, contact:

**Secretariat of the International Resource Panel (IRP)**
Economy Division
United Nations Environment Programme
1 rue Miollis
Building VII
75015 Paris, France
Tel: +33 1 44 37 14 50
Fax: +33 1 44 37 14 74
Email: resourcepanel@unep.org
Website: www.internationalresourcepanel.org

**Resource Efficiency and Climate Change:**
Material Efficiency Strategies for a Low-Carbon Future

Summary for Policymakers

The International Resource Panel (IRP) 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.

The Secretariat is hosted by the United Nations Environment Programme. Since 2017, the IRP has published twenty-eight assessments. These assessments demonstrate the 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.

This report was developed by the IRP in response to a request by leaders of the Group of 7 nations in the context of efforts to promote resource efficiency as a core element of sustainable development. It conducts a rigorous assessment of the contribution of material efficiency to GHG abatement strategies. More concretely, it assesses the reduction potential of GHG emissions from material efficiency strategies applied in residential buildings and light duty vehicles, and reviews policies that address these strategies.

According to the Panel, GHG emissions from the material cycle of residential buildings in the G7 and China could be reduced by at least 80% in 2050 through more intensive use of homes, design with less materials, improved recycling of construction materials, and other strategies.

Significant reductions of GHG emissions could also be achieved in the production, use and disposal of cars. IRP modelling shows that GHG emissions from the material cycle of passenger cars in 2050 could be reduced by up to 70% in G7 countries and 60% in China and India through ride-sharing, car-sharing, and a shift towards trip-appropriate smaller cars, among others.

Increasing material efficiency is a key opportunity to achieve the aspirations of the Paris Agreement. Materials are vital to modern society, but their production is an important source of greenhouse gases. Emissions from material production are now comparable to those from agriculture, forestry, and land use change combined, yet they have received much less attention from the climate policy community. As shown by IRP estimates, it is time to look beyond energy efficiency to reduce global carbon footprint.

**Job No: DTI/2269/PA**
**ISBN: 978-92-807-3771-4**

**For more information, contact:**
**Secretariat of the International Resource Panel (IRP)**
**Economy Division**
**United Nations Environment Programme**
1 rue Miollis - Building VII - 75015 Paris, France
Tel: +33 1 44 37 14 50 - Fax: +33 1 44 37 14 74
Email: **resourcepanel@unep.org**
**Website: www.internationalresourcepanel.org**